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COMMENTS ON TEXT BY TSU TO REVIEWER:
This chapter has been allocated 56 template pages, currently it counts 81 pages (excluding this page and the bibliography), so it is 25 pages over target. Reviewers are kindly asked to indicate where the chapter could be shortened.

Chapter 4: Sustainable Development and Equity

Contents

Executive Summary

Since the first assessment report, the IPCC has considered issues of sustainable development (SD) and equity: acknowledging the importance to climate decision-making, and progressively expanding the scope to include: the co-benefits of climate actions for SD and equity, the importance of advancing broader SD objectives for effective climate response, the relevance of lifestyle and behaviour, the relevance of procedural equity to decision-making, and the relevance of ethical frameworks and equitable burden-sharing in assessing climate responses. In this Assessment Report, we further explore key dimensions of SD and equity, highlighting the significance of disparities across different groups, and the importance of advancing broader SD objectives and equity for an effective climate response.

SD is variably conceived as development that preserves the interests of future generations, that preserves the natural environment and resources, or that harmonizes the co-evolution of three pillars (economic, social, environmental). Weak and strong sustainability require the preservation of capital stocks at different levels of aggregation. Ensuring SD is less ambitious but more consensual than seeking a socially optimal pathway.

Equity permeates the SD literature. First, intergenerational equity underlies the basic notion of sustainability. But intragenerational equity is also relevant on several counts. Development, the elimination of poverty, and the convergence of living standards across the world, can all be framed as equity objectives, and are even sometimes argued to be human rights. While such objectives may generate an apparent tension with sustainability if development strains the Earth system, it appears that efforts to make a transition to sustainable pathways will gather momentum only when equity in burden-sharing and benefit-sharing is manifest. The need for a specific, operational meaning of the concept of equity is repeatedly expressed.

There are multiple policy approaches to SD and equity. Some view economic and technological development as the key driver to SD. Other approaches focus on ecological issues and call for a deeper transformation that provides equitable access to sustainable living standards. Top-down approaches differ from bottom-up approaches, for which regional and gender specific potentials deserve a greater attention.

A number of determinants can be considered as drivers or barriers to SD. Some of these can be framed at either individual or societal levels (i.e. human capital, behaviour), while others can only be understood from the lens of the collective organization of societies (i.e. population, governance, technology, legacy of development) and their biophysical endowments (i.e. natural resources). Population, affluence and technology are considered three key factors that determine the environmental impacts of a given society, and thus can foster or constrain the transition towards SD (high agreement, robust evidence).

The prospects for sustainable development are strongly mediated by human capital, i.e., the capacity of human beings as productive agents to promote increases in income through the acquisition of skills and the accumulation of knowledge. Improvements in human capital are in turn related to nutritional, health and education standards, and all combined contribute to increasing economic returns at individual and societal scales, although both improvement and returns are gender-differentiated (high agreement, robust evidence).

Governing a transition toward a more sustainable development pathway is inevitably challenging because it involves multiple agents that hold vested interests, varying degrees of agency and power, and differential access to authority. It is also challenging because it cuts across several realms of policy, organization and action, from international to local, and individual levels.

The global consumption of goods and services has increased dramatically over the last decades, in both absolute and per capita terms, and is a key driver of environmental degradation, including global warming (high agreement, robust evidence). This trend involves the spread of high-consumption life-styles in some countries and sub-regions, while in other parts of the world large populations continue to live in poverty. There are high disparities in consumption both between and within countries. Mobility, food, and housing are responsible for about three-quarters of consumption-related environmental impacts in industrialized countries (medium agreement, medium evidence).

Sustainable consumption and production studies and real-world initiatives prove the existence of a large unrealized potential for limiting the environmental impact of economic activity. However, how to tap this potential is much less understood, as is the potential for decoupling human well-being from economic growth.

Consumption-based accounting of GHG emissions supports a range of mitigation policy options and actions by identifying the distribution of GHG emissions among different categories of final uses (demand), geographical locations, and household types. This approach already informs actions by citizens, communities, cities and corporations.

How development paths unfold in the future will impact both emissions and mitigative capacity. Yet the link between individual characteristics of the development paths (in particular, GDP growth rate) and emissions is ambiguous (high agreement, robust evidence).

In fact, understanding how development paths impact on emissions and mitigative capacity, and, more generally, how development paths can be made more sustainable and more equitable in the future requires in-depth analysis of the mechanisms that underpin these paths. Of particular importance are the processes that may generate path dependence and lock-ins, notably “increasing returns” but also use of scarce resources, switching costs, negative externalities or complementarities between outcomes.

The study of transitions between pathways is an emerging field of literature, notably in the context of technology transitions. Yet analyzing how to transition between pathways remains a major scientific challenge. To do so, models should simultaneously capture processes relevant for the short- term and for the long-term. And output-wise, models should provide information on the relationships between the economy, society, and the environment, and on the distribution of economic activity, notably across income groups, especially in the perspective of assessing the possible future evolution of well-being.

Whether responding to climate change through mitigation and adaption or working to sustain development, appropriate and adequate response capacity is required to undertake public efforts and guide individual action. Response capacity, the ability to foresee and effectively respond to biophysical and socio-economic feedbacks, is critical to sustainability and the course of climate change. The complexity of this process presents scientific (how well can we predict the effects across temporal and spatial scales of different responses), political (how can we organize to see that the best combination of responses takes place), and financial (who should pay for projects with diverse effects) challenges.

SD and climate change are inextricably linked, insofar as human-induced climate change can be explained by historical and current patterns of socio-economic development and resource use. Addressing climate change should thus consider the distinct implications it may have for socio-economic and biophysical systems. Conversely, making development pathways more sustainable can go a long way towards mitigation, adaptation and mitigative and adaptive capacity.

The conceptual framework provided by Chapters 2 and 3 sheds light on the issues addressed in this Chapter. The analysis of SD can explicitly incorporate uncertainty and risks, and make use of the aggregating power of consequentialist measures of well-being, without neglecting other considerations. Pessimism about the possibility to measure individual well-being and social welfare is receding and several empirical approaches have been developed (capabilities, subjective well-being, equivalent income).

The climate change problem is a classic commons problem, and therefore relies on cooperative action to yield an effective solution. If individual actors make mitigation decisions based on a rational balancing of their own mitigation costs against their own expected benefits from avoided climate impacts, then mitigation action will fall far below the globally optimal level of mitigation (high agreement, robust evidence). Additional complexity arises from several factors: the large differences between actors (including in their contribution and vulnerability to climate change), the intra-generational nature of the problem, and the uncertainties inherent in climate science and in prospects for mitigation and adaptation.

A cooperative solution can distribute the costs of mitigation among actors in many possible ways. Equity, which is considered an important factor in this distribution of burdens (although there are others, such as sovereignty), has been explored extensively by ethicists, climate policy analysts, and representatives of states, and explicitly reflected in international agreements. A relatively small number of core equity principles that are well-grounded in moral philosophy serve as the basis for this discussion.

One core equity principle is responsibility, which in the context of climate generally refers to responsibility for GHG emissions. A second core principle is capacity, reflecting primarily ability to pay, but sometimes other dimensions of capacity. A third core principle, grounded in a human rights context, is a right to sustainable development. A fourth core principle is equality, premised on the assumption that each human being has equal moral worth and thus should have equal rights or, more broadly, equal opportunities for welfare. In one perspective, this moral equality is interpreted to imply an equal right to the natural carbon sinks, as they are a common resource, and thus an equal right to emit. Various quantitative indicators can help illuminate how these various equity principles reflect on the "common but differentiated responsibilities and respective capabilities" of different nations or national groupings, and burden-sharing frameworks – both resource-sharing and burden-sharing – have been developed that draw in various ways on these equity principles.

A key feature of sustainability concerns is that they bear on the long term. Thus, specific indicators of sustainability and SD that have been proposed so far (such as green GDP, genuine savings, the Index of Sustainable Economic Well-being, the ecological footprint, and composite indicators) do not seem to be as relevant to policy-making as a direct assessment of the future risks to the well-being of human populations and natural systems.

This chapter has focused on examining ways in which the broader objectives of equitable and sustainable development are supportive – and perhaps preconditions – of an effective, robust, and long-term response to the climate problem. This is because building both mitigative capacity and adaptive capacity relies to a profound extent on the same factors as those that are integral to equitable and sustainable development (high agreement, medium evidence).

Likewise, mitigate and adaptation measures can strongly affect broader SD and equity objectives, (high agreement, robust evidence) and it is thus necessary to assess their broader implications. Implications of measures can be assessed using alternative frameworks: the three pillars (economic, social, environmental), capital (productive, human, natural, social), and well-being. As risk is a central aspect of sustainability, the analysis of mitigation measures and measures should not stop with central estimates of consequences for SD and equity, but examine likelihood of potential impacts.

4.1 Introduction

4.1.1 Key messages of previous IPCC reports

This chapter seeks to place climate change, and climate change mitigation in particular, in the context of equity and sustainable development. Prior IPCC assessments have sought to do this as well, progressively expanding the scope of assessment to include broader and more insightful reflections on the policy-relevant contributions of academic literature.

The IPCC *First Assessment Report* (FAR) (IPCC, 1990) underscored the fundamental nature of equity and sustainable development to climate policy. While the FAR gave only cursory consideration to broader sustainable development objectives in its evaluation of potential response strategies, focusing primarily on efficiency and effectiveness with respect to mitigation specifically, its more important contribution was to squarely and explicitly place the imminent negotiations on a global climate regime within an equity and sustainable development rubric. Specifically, in response to its mandate to identify "possible elements for inclusion in a framework convention on climate change", the IPCC specifically and prominently put forward the "endorsement and elaboration of the concept of sustainable development" for negotiators to consider as part of the convention's Preamble. It also noted that a key issue would be "how to address equitably the consequences for all" – and in particular, "whether obligations should be equitably differentiated according to countries' respective responsibilities for causing and combating climate change and their level of development". This set the stage for the ensuing negotiations of the UNFCCC, which ultimately included explicit appeals to equity and sustainable development, including in its Preamble, its Principles (Article 2), its Objective (Article 3), and its Commitments (Article 4).

The IPCC *Second Assessment Report* (SAR) (IPCC, 1995), published after the UNFCCC was signed, maintained this focus on equity and sustainable development. As with the FAR, the SAR's assessment of potential response strategies treated broader sustainable development objectives only briefly, although it reflected a growing appreciation for the prospects for sustainable development co-benefits and reiterated the policy relevance of equity and sustainable development. It did this most visibly within a special section of the Summary for Policymakers, which presented "Information Relevant to Interpreting Article 2 of the UN Framework Convention on Climate Change", including "Equity and social considerations" and "Economic development to proceed in a sustainable manner". Notably, the SAR added an emphasis on procedural equity, recognizing that a climate regime cannot be equitable in its structure and implementation if it is not designed through a legitimate process that empowers all actors to effectively participate, and arguing for the need to build capacities and strengthen institutions, particularly in developing countries.

The IPCC *Special Report on Emission Scenarios* (SRES) (Nakicenovic et al., 2000) conveyed important lessons from the academic study of development pathways. The SRES demonstrated that broader sustainable development goals can contribute indirectly, yet substantially, to reducing emissions. This IPCC contribution reflected a change in the scientific literature, which had in recent years expanded its discussion of sustainable development to encompass analyses of lifestyles, culture, and behaviour, complementing its traditional techno-economic analyses. It also reflected a recognition that economic growth (especially as currently measured) is not the sole goal of societies across the globe. The SRES thus provided insights into how policy intervention can decouple economic growth from emissions and well-being from economic growth, showing that both forms of decoupling are important elements of a transition to a world with low greenhouse gas (GHG) emissions.

The IPCC *Third Assessment Report* (TAR) (IPCC, 2001) maintained and deepened the consideration of broader sustainable development objectives in its assessment of potential response strategies. Moreover, and perhaps owing to a growing appreciation for the severity of the climate challenge, the TAR stressed the need for an ambitious and encompassing response, and was thus more attentive to the potential for climate-focused measures to conflict with basic development aspirations. It thus articulated the fundamental equity challenge of climate change to be ensuring "that neither the impact of climate change nor that of mitigation policies exacerbates existing inequities both within and across nations", specifically because "restrictions on emissions will continue to be viewed by many people in developing countries as yet another constraint on the development process". The TAR recognized, in other words, the need to deepen the analysis of equitable burden-sharing as a basis for an equitable climate regime, but even more fundamentally as a means to avoid undermining prospects for sustainable development in developing countries. More generally, the TAR observed that equitable burden-sharing is not solely an ethical matter; even from a rational-actor game-theoretic perspective, an agreement in which the burden is equitably shared is more likely to be signed by a large number of countries, and thus to be more effective and efficient. Equitable burden-sharing would provide the basis by which the developing countries could earnestly engage in a global climate effort.

The IPCC *Fourth Assessment Report* (AR4) (IPCC, 2007) further expanded the consideration of broader sustainable development objectives in its assessment of potential response strategies. It stressed the importance of civil society and other non-government actors in designing climate policy and equitable sustainable development strategies in general. The AR4 focused more strongly than previous assessments on the distributional implications of climate policies, noting that conventional climate policy analysis that is based too narrowly on traditional utilitarian or cost-benefit frameworks will neglect critical equity issues. In particular, it neglects both the distribution of costs and benefits of a given set of policies, and the further distributional inequities that arise when these policies are implemented in a world where the poor have limited scope to influence policy adoption and implementation. This is particularly problematic, the AR4 notes, in integrated assessment model (IAM) analyses of "optimal" mitigation pathways, because climate impacts do not affect the poor exclusively, or even mainly, through changes in real incomes. Nor do these approaches satisfactorily account for uncertainty and risk, which is treated differently by the poor compared with the rich, due to their higher risk aversion and lower access to assets and financial mechanisms, such as insurance, that buffer against shocks.

The AR4 went on to outline alternative ethical frameworks including rights-based and capabilities-based approaches, suggesting how they can inform climate policy decisions. In particular, the AR4 discussed the implications of these different frameworks for equitable international burden-sharing. It is these approaches that have inspired the environmental justice framework and informed its approach to climate policy decisions, both at the national and international levels.

The IPCC *Special Report on Renewable Energy Sources and Climate Change Mitigation* (SRREN) (IPCC, 2011) deepened the consideration of broader sustainable development objectives in assessing renewable energies options, noting particularly that while they can be synergistic (for example, through helping to expand access to energy services, increase energy security, and reduce other environmental pressures), they also pose challenges (such as those relating to increasing pressure on land resources, and affordability) and that trade-offs must be negotiated in a manner that is sensitive to equity considerations.

Building upon the progressively more sophisticated understanding of the sustainable development and equity context of climate change as found in the scientific literature and reflected in the prior IPCC assessments, this Fifth Assessment Report (AR5) elaborates further on key dimensions and expands the treatment in important directions.

4.1.2 The narrative focus and key messages of this chapter

In keeping with the previous IPCC assessments, this chapter considers sustainable development and equity as matters of policy relevance for climate change decision-makers. It recognizes that climate change is in fact inextricably linked with sustainable development and equity. It examines these links with the aim of drawing policy-relevant conclusions regarding promising responses to climate change.

In one direction, the link is self-evident: an effective climate response is necessary for equitable and sustainable development to occur. The disruptions that climate change would cause in the absence of an effective societal response are so severe (AR5 WGI, AR5 WGII) that development would be severely compromised, even taking into account future societies' ability to adapt (Shalizi and Lecocq, 2010). Nor is this development likely to be equitable, as an increasingly inhospitable climate will most seriously undermine the future prospects of those nations, communities, and individuals that are already most in need of development. Without an effective response to climate change, including both timely mitigation and proactive adaptation, development can be neither sustainable nor equitable.

In recent years, the academic community has come increasingly to appreciate the extent to which the converse is true as well: a shift toward more equitable and sustainable modes of development can help society realize an effective climate response. Indeed, without adopting more sustainable and equitable modes of development, it may not be possible to effectively address the climate challenge.

The scientific community is coming to understand that climate change is but one example of how humankind is pressing up against – and transgressing – its planetary boundaries (Rockstrom et al., 2009). Technical measures can certainly help in the near-term to alleviate climate change. However, the comprehensive and durable strategies society needs are those that recognize climate change shares its root causes with other dimensions of the global sustainability crisis, and that without addressing these root causes, robust solutions may not be accessible.

This chapter thus focuses on the ways in which a broader agenda in support of sustainable development and equity will support and enable an effective societal response to the climate challenge, by establishing the basis by which mitigative and adaptive capacity can be built and sustained. In examining this premise, this chapter focuses on several broad themes.

4.1.2.1 Consumption, disparities and well-being

The first theme relates to well-being and consumption. We have long understood the relationship between aggregate levels of consumption and environmental pressures, including GHG emissions. What we are increasingly understanding is the significance of high-consumption lifestyles in particular and consumption disparities (Sec. 4.4). An important part of this literature relates to the methodologies for understanding and calculating the environmental impacts across national boundaries of different modes of consumption, through consumption-based accounting and GHG footprint analysis (Sec. 4.4). Important research is now being undertaken on the relationship between well-being and consumption, and how to moderate consumption and its impacts without sacrificing well-being – and indeed, while enhancing it. More research is now available on the importance of behaviour, lifestyles and culture, and their relationship to over-consumption.

At the same time, there is more data and research available to help understand "under-consumption", i.e., poverty and deprivation, and its impacts on well-being more broadly, and specifically on the means by which it undermines mitigative and adaptive capacity. Energy poverty is one critical example, linked directly to climate change, of under-consumption that is highly correlated with weakening of livelihoods, lack of resilience, and limiting of mitigative and adaptive capacity. Overcoming under-consumption and reversing over-consumption, while maintaining and advancing human well-being, are fundamental dimensions of a transition to a sustainable development pathway, and are equally critical to resolving the climate problem (see Sec. 4.5).

4.1.2.2 Equity at the national and international scales

Given the disparities evident in consumption patterns, the distributional implications of climate response strategies are critically important. As recent history shows, understanding how policies affect different segments of the population is critical to designing and implementing politically acceptable and effective national climate response strategies. A just transition will be necessary, if the required public support is to be gained for the substantial techno-economic, institutional and lifestyle shifts needed to reduce emissions substantially and enable adaptive responses.

At the international level, an equitable regime with fair burden-sharing is likely to be a necessary condition for an effective global response (Sec. 4.3, 4.6). Given the urgency of the climate challenge, a rather rapid transition will be required if the global temperature rise is to be kept below politically agreed targets such as 1.5°C or 2°C over pre-industrial levels, with global emissions peaking by 2020. Particularly in a situation calling for a concerted global effort, the most promising response is a cooperative approach "that would quickly require humanity to think like a society of people, not like a collection of individual states" (Victor 1998).

While scientific assessments cannot define what is equitable and how equity should be interpreted in implementing the Convention and climate policies in general, they can help illuminate the implications of alternative choices and their ethical basis (Sec 4.6, also Chapter 3, Chapter 13).

4.1.2.3 Building institutions and capacity for democratic governance

Charting an effective and viable course through the climate challenge is not merely a technical exercise. It will involve myriad and sequential decisions, among states and civil society actors, supported by the broadest possible constituencies. This is true at the national as well as international levels, where effective governance relating to global common resources, in particular, is not yet mature. Such a process requires the education and empowerment of diverse actors to participate in systems of decision-making that are designed and implemented with procedural equity as a deliberate objective.

This chapter also discusses alternative indicators that can reflect dimensions of sustainable development other than the standard economic dimensions that are partially reflected in the conventional indicators of development, such as GDP (Sec. 4.2 and 4.7). It also reflects on the previous framing chapters, suggesting how incorporating the dimension of risk (Chapter 2) in the analysis of sustainable development is helpful to obtain more relevant tools of evaluation of the hazards confronting future generations, and how the notions of well-being and social welfare function (Chapter 3) provide useful guides for a comprehensive assessment of the multiple dimensions and determinants of sustainable development and the understanding of equity and distributional issues distribution (Sec. 4.7). This chapter also provides some indication of how considerations of sustainable development and equity, with a specific architecture of levels of analysis (from determinants to end results), can help inform assessments of sector-specific climate strategies (Sec. 4.8).

4.2 Approaches and Indicators

This section starts by mapping out the various conceptual approaches to the issues of sustainable development (4.2.1) and equity (4.2.2), concluding with a review of policy approaches (4.2.3).

Sustainable development and equity may or may not be separable, as explained below. For clarity, a first subsection deals with sustainable development, and the specific questions of equity are introduced in a second subsection.

4.2.1 Sustainability and sustainable development

Sustainable development, although a widely used concept in academic and policy circles, has many different meanings and therefore provokes many different responses (Hopwood et al., 2005). The most frequently quoted definition is from *Our Common Future* (World Commission on Environment and Development (WCED), 1987), the Brundtland Report:

Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It contains within it two key concepts:

- *the concept of needs, in particular the essential needs of the world's poor, to which overriding priority should be given; and*
- *the idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs.*

This definition acknowledges a tension between the idea of sustainability and the idea of development (Jabareen, 2006). Sustainability refers to the possibility of preserving a certain state of affairs, and has been used primarily in the ecological context, whereas development refers to the idea of progress, and shifts the focus to social and economic achievements. One of the first definitions of sustainable development (Prescott-Allen, 1980) referred to a process of development that is compatible with the preservation of ecosystems and species.

The Brundtland definition also suggests that a tension may arise between development and the well-being of future generations. A development path is sustainable if its benefits can be preserved indefinitely and enjoyed by all future generations, and is not sustainable if its benefits are only temporary. The development-ecology tension and the development-future generations tension are intimately linked when the degradation of the environment is the vehicle of reduced possibilities for future generations.

A popular conceptualization of sustainable development goes beyond the preservation of the environment and involves three "pillars" or three "bottom-lines" of sustainability: environmental, economic, and social aspects (Elkington, 1998; Flint and Danner, 2001; Pope et al., 2004; Sneddon et al., 2006). Sustainability in the economic sphere has to do with the preservation of a healthy economic and financial system, while sustainability in the social sphere is about avoiding conflicts and social unrest. There is some variation in the articulation of the three spheres, with some arguing for an equal appraisal of their co-evolution and mutual interactions, and others considering that there is a hierarchy and that economic activities are embedded in the social matrix, which is itself grounded in the ecosphere (Fischer et al., 2007).

An important distinction opposes weak sustainability to strong sustainability approaches. The former rely on the assumption that human-made capital can replace natural resources with a high degree of substitutability. The notion of strong sustainability, in contrast, relies on the view that natural stocks must be preserved and cannot be replaced by human-made capital.

The weak sustainability approach is often believed to be inherent to economic modelling and appears embodied in measurement tools that aggregate all forms of capital together, such as genuine savings, introduced in 4.2.2 (Dietz and Neumayer, 2007). But economic models and indicators can, in principle, accommodate any degree of substitutability between different forms of capital. The question of substitutability also arises regarding the various forms of natural capital.

The divide between weak and strong sustainability is therefore different from the question of whether one should evaluate development paths only in terms of human well-being or also take account of natural systems as intrinsically valuable. It can be observed that the ethical arguments against strictly anthropocentric goals and in favour of respecting other animal species are gaining ground in public debates and legal systems. While respecting other species implies a form of strong sustainability, one may however also support strong sustainability by arguing that human flourishing requires a preserved natural environment.

A related notion is vulnerability. The study of the vulnerability of ecosystems has recently been linked to sustainability and to the study of the coupled dynamics of ecological and socio-economic systems (Kates, 2001; WC Clark and Dickson, 2003). A key premise of this new direction of research is that social and biophysical processes are interdependent and co-evolving (Polsky and Eakin, 2011).

The notion of sustainable development can be compared with other criteria for the evaluation of growth paths, and find foundations in the theory of intertemporal ethics introduced in Chapter 3. As it deals with the responsibility of the present generation toward future generations, it is especially linked to intergenerational equity. This connection is discussed in the next subsection on equity. An obvious critical remark is in order here. As a criterion for the evaluation of development paths, the notion of sustainability is arguably quite coarse. A path may be sustainable and nevertheless fail to address the interests of future generations, or the well-being of some members of society. A path may also be sustainable in spite of involving great inefficiency and high levels of destruction. For instance, a path of constantly increasing welfare from now on may involve the present generation wasting resources and suffering from an unduly low level of well-being. In this light, sustainability appears a minimal requirement, not a label of acceptability. The current attraction for the term may therefore reflect a sense of urgency about the ongoing evolution of system Earth.

Indeed, although there is no perfect consensus on the definition of sustainable development, there are internationally agreed principles of sustainable development adopted by heads of states and governments at the 1992 UN Conference on Environment and Development. Sustainable development and equity approaches to guide policy can be found in the Rio Declaration on Environment and Development and Agenda 21 (1992), the Programme for Further Implementation of Agenda 21 and the Commitments to the Rio Declaration principles (1997), and the Johannesburg Plan of Implementation (2002). One guiding principle is: "The right to development must be fulfilled so as to equitably meet developmental and environmental needs of present and future generations" (Principle 3). Another principle is the "common but differentiated responsibilities based on historical responsibility for global environmental degradation" (Rio Principle 7), which is also operationalized in the legally binding UN Framework Convention on Climate Change and its Kyoto Protocol.

4.2.2 Equity in climate policy and in development

Equity is, with sustainability, playing a key role in research and policy debates around climate issues. The various dimensions of the concept, as developed in social ethics, have been introduced in Chapter 3 (see also Section 4.7). At the most general level, it bears on the intergenerational distribution (of which sustainability is a key aspect, as explained in 4.2.1.1), the intra-generational distribution (inequality, poverty, development), as well as on the procedures used for collective decision-making (democracy, inclusion). But it is also very often invoked in specific contexts of allocation of burdens or benefits, such as the attribution of emission rights. The application of equity principles to specific allocation problems is studied in the economic theory of fair allocation (W Thomson, 2011) and is common practice in collective debates and decisions. Equity theory and social welfare theory have been merged in Fleurbaey and Maniquet (2011).

Equity between generations underlies the notion of sustainable development. While the general theory of intergenerational welfare has been reviewed in Chapter 3, the specific connection with sustainable development can be explained here. There has been a recent surge of research on intergenerational equity, motivated by dissatisfaction with the tradition of discounting the utility of future generations in the analysis of growth paths (see, e.g., Asheim (2007), Roemer and Suzumura (2007) for recent syntheses). Though mathematically convenient to obtain a complete comparison of streams of utility over an infinity of periods (Koopmans, 1960), discounting leads to neglecting what happens in the very long run and appears in direct contradiction with the ideal of sustainability, especially when assessing policies with long-term consequences, such as infrastructure policies (Lind, 1982) and climate mitigation policies (Portney and JP Weyant, 1999). The debate on discounting has been reviewed in Chapter 3.

Researchers have therefore sought alternatives to the discounted utilitarian approach. However, despite many attempts (e.g., Dasgupta (1974), Chichilnisky (1996)), it has proved difficult to find robust alternative criteria for comparing streams of utility over time. It is genuinely hard to define criteria which are impartial toward an infinite number of generations and are sensitive to the utility of each generation (Lauwers, 1998, 2010; Basu and Mitra, 2003; Zame, 2007). Such difficulties may, however, be attributed to the classical framework of growth analysis, which involves an infinite horizon. It would be more realistic to consider that the horizon is finite but uncertain. It is often argued that an infinite horizon approximates an uncertain finite horizon, but it may not be a good approximation.

Nevertheless, this literature has delivered original arguments in favour of sustainability. Such arguments do not depend on having an infinite horizon. A first argument assumes that investment for the future is productive, i.e., a sacrifice for the future typically gives more to the future than it costs the present (GB Asheim et al., 2001). Consider an unsustainable path in which a generation t consumes 100 and generation t+1 consumes 95. If generation t reduces its consumption to 95, the productivity of the investment implies that generation t+1 is then able to consume more than 100 – for instance, 102. Any criterion that is impartial between generations should prefer the new allocation, with consumptions 95/102, to the initial allocation, with consumptions 100/95. Generalizing this reasoning, one concludes that, when investment is productive, an optimal path for *any* impartial criterion must necessarily have non-decreasing consumption, as required by sustainability principles. Sustainability, in short, is an immediate implication of impartiality in the context of productive investment.

Another argument in favour of sustainability is that it is easy to justify giving almost absolute priority to the future generations when they are worse off than the present generation and the horizon is far away (GB Asheim et al., 2012). Future generations being worse off than the present is the characteristic of unsustainability, and giving them absolute priority will imply restoring sustainability whenever this is feasible. The justification for an almost absolute priority to future generations when they are worse off is as follows: Consider an unsustainable path in which many future generations are worse off than the present one. Equalizing consumption between these generations and the present one, keeping the total consumption constant, is desirable by virtue of the basic transfer principle of welfare economics, even though it will not give much to the numerous future generations but may cost a lot to the present generation. It is the mere fact that the future contains many generations that implies that even a moderate degree of inequality aversion requires giving high priority to the future when the future generations are worse off. Observe that the future ceases to have priority when future generations are better off than the present one. This is how sustainability is obtained as a requirement.

Equity *within* every generation is often considered an intrinsic component of sustainability in relation to the social pillar. The idea is that social justice is a guarantee of stability for the social system. A cynical observation, however, is that social justice is sufficient for social stability but may not be necessary. But even if the sustainability of social institutions requires only a minimal degree of equity, one may think that at the world level and in most countries, such a minimal degree is far from being achieved. The Brundtland injunction to meet the needs of the present and future populations calls for important changes to the status quo, and even though humanity has let a large fraction of its population starve for many generations, this state of affairs is considered morally unsustainable and, in the long run, politically unsustainable. The Millennium Development Goals (MDGs), adopted in 2000, embody such considerations (United Nations, 2000).

The relation between equity within generations and the preservation of ecosystems is more complex. On the one hand, the convergence of developing countries toward the standard of living of the richest populations is admittedly unsustainable if the consumption and production processes of the rich are universally adopted. On the other hand, the evolution of lifestyles and processes toward sustainability, and the political viability of joint efforts in that direction, may depend on a distribution of costs and resources that is perceived as fair and equitable. Put more bluntly, any attempt to preserve the natural environment by keeping living standards low for a large part of the world population will face strong political resistance, and will almost certainly fail. Global sustainability cannot be achieved by maintaining gross inequities among and within countries. Whether sustainability can be achieved via equity principles is one of the key questions addressed in this chapter.

These issues reverberate in political arenas. In the Rio Declaration, equity is explicitly mentioned in Principle 3 (quoted earlier) and is further set out by Principle 7: "States shall cooperate in a spirit of global partnership to conserve, protect and restore the health and integrity of the Earth's ecosystem. In view of the different contributions to global environmental degradation, States have common but differentiated responsibilities. The developed countries acknowledge the responsibility that they bear in the international pursuit of sustainable development in view of the pressures their societies place on the global environment and of the technologies and financial resources they command." The Rio Declaration principles are part of the international norms for the collective and individual efforts of States in dealing with climate change mitigation and adaptation. They are crystallized in the legally binding Framework Convention on Climate Change that was negotiated in parallel with the Rio Declaration and Agenda 21. Equity under the principle of common but differentiated responsibilities and respective capabilities appears in Preamble paragraph 6, Article 3.1 and Article 4, as well as the Kyoto Protocol. Preamble paragraph 6 also recognizes the need to take into account countries' social and economic conditions.

Research on the issue of equitable access to sustainable development envisaged for Brazil, China, India and South Africa (Winkler, Jayaraman, et al., 2011) concludes that for the resolution of the apparent conflict between equity and sustainability, there is a strong need to fill the gap in defining these criteria and providing a specific, operational meaning to the concept of equity. Overcoming the barriers to the provision and preservation of global public goods, in particular the atmosphere, in an unequal world remains an elusive task.

Another approach that is gaining ground, and which also links sustainable development with equity, is the notion of sustainable development as a human right. In an analysis of the relevance of international human rights obligations in light of the multiple constraints climate change poses to the sustainable development of developing countries, the UNFCCC is seen as particularly suitable to facilitate rights-based cooperation in accordance with the principle of affirmative action and the legal duty of all states to cooperate to realize human rights (Wewerinke and Yu III, 2010). An Expert Group of the Commission on the Status of Women in 2008 recommended that the international climate change negotiation process and climate change policies at the national level must adopt the principles of gender equality at all stages, including research, analysis and design and implementation of mitigation and adaptation strategies.

In the context of climate change negotiations, the concept of equity raises competing visions between various countries and regions of the world according to their national interests and specific circumstances (Heyward, 2007). Equity is also treated differently in top-down approaches, which start from internationally fixed and quantified objectives (emission limitation and reduction targets) and allocate responsibility based on equity principles, versus bottom-up approaches that address climate change that are mainly based upon qualitative actions toward sustainable development. These approaches are in line with the argument that strong linkages between climate change and sustainable development lead to potential benefits, creating greater opportunities and optimal conditions for the implementation of climate policies (B. Metz et al., 2002; Brown and Corbera, 2003; R Swart et al., 2003; KH Olsen, 2007). These issues are reviewed in more detail in Sec. 4.6 and in Chapter 13.

4.2.3 Toward sustainable development and equity

There are many conceptions about how to make our development path sustainable. While most proponents of sustainable development agree with the Brundtland Report's objectives to reconcile social, economic and environmental goals, models of sustainable development have emerged in many different forms and combinations. A common theme is that technology can bring benefits for environmental protection. Von Weizsäcker et al. (1997), for example, argued that technical innovation could cut global resource use in half while doubling wealth, for a four-fold productivity increase; a 2009 follow-up argues that productivity can actually increase by a factor of five through improvements in resource and energy productivity innovation in industry, technical innovation and policy (von Weizsäcker et al., 2009). There is also widespread support for a dramatic increase in energy efficiency and change in energy use from fossil fuels to renewable sources (Flavin and Lenssen, 1994).

Some have supported the idea of separating economic from ecological issues (Gallopín, 2003). One approach argues that sustainable development is predominantly of concern in the developing world (McCormick, 1991) and therefore, the process of implementing sustainable development should be accompanied by a high level of growth benefiting the poor. From the perspective of a *sustainable economic development*, the underlying assumption is that economic well-being is the best way to overcome most of the problems faced by societies (Allaby, 1983). This perspective is in line with the "status quo" approach described in Hopwood et al. (2005), which considers that economic prosperity is "the driver towards sustainability". In the climate change debate, this perspective leads some to argue that instead of investing in mitigation, wealthier countries should make direct transfers to poorer countries to support development, on the assumption that richer future generations in developing countries will be more able to cope with the impacts of (unmitigated) climate change (Schelling, 1995, 2006). The need for change is recognized, but primarily when it focuses on building sustainable economies that provide strategic economic advantages in the global economy.

A contrasting line of thought is that sustainability is primarily about ecological issues – which, from this point of view, should be predominant in the debates about sustainable development. A report by the Economic Commission for Latin America and the Caribbean (Gallopín, 2003) has identified a range of terminologies of sustainable development from an ecological perspective. These range from sustainable development as the development and management of natural resources, to "sustainable society", "ecological sustainable economic development", and environmentally sustainable development.

Beyond the deep connection between meeting human needs and preserving the natural environment, alternative paradigms of sustainable development are considering the idea that sustainable development is a multidimensional process which requires strong interlinkages between economic, environmental, socio-cultural, political and technological factors to be effectively achieved (Hopwood et al., 2005; Udo and Jansson, 2009). Hopwood et al. (2005) suggest a "transformatory approach" which embraces the view that environmental degradation and inequities will persist unless a strong commitment to social equity is achieved in order to promote access to economic opportunities, livelihood and good health. This approach also recognizes environmental justice as a key determinant of social transformation, which may lead to fulfilling human needs and enhancing the quality of life. Other approaches stress the need to embrace a plurality of perspectives on sustainable development, but with a greater emphasis on freedom-oriented development (Gallopín, 2003; Sneddon et al., 2006). This implies recognizing, for instance, the need for innovative approaches relating to people-centred development and right-based approaches to development (NGLS, 2002).

Feminist scholars, meanwhile, have advanced sustainable development approaches that build on women's experiences and aspirations. They have raised the need to take a fuller account of gender relations affecting fertility, childbirth and resource consumption in proposing solutions to environmental and social problems (Arizpe et al., 1994) and called for placing "social reproduction" at the centre of new development perspectives. Di Chiro (2008), paraphrasing Bakker and Gill (2003), defines social reproduction as "the intersecting complex of political-economic, socio-cultural, and material environmental processes required to maintain everyday life and sustain human cultures and communities on a daily basis and inter-generationally".

There is a critical role for governments in the implementation of a pluralistic approach to sustainable development, to inform and take actions to push the notion of sustainable development forward into more fruitful conceptualization (Sneddon et al., 2006). The “Reform approach” mapped out in Hopwood et al. (2005) also recognizes the critical role of governments and takes the view that market-friendly reforms are also crucial prerequisites to sustainable development.

There is growing research on sustainable development approaches that aim to build a “low-carbon economy” or “lowcarbon society” and, in the process, meet the mitigation and adaptation challenges of climate change, including the need for social, economic and technological transitions (Sukla et al., 2008). Studies in China show that controlling emissions without proper policies to counteract the negative effects will have an adverse impact on the country’s economic development, reducing its per capita income and the living standards of both urban and rural residents (Wang Can et al., 2005; Wang Ke, 2008).

Based on past experiences with energy transitions, a successful transition to low carbon energy sources and technologies will need governments to provide protection of a niche market possibly for decades, and a complete transition to a low carbon economy is likely to be very slow (Fouquet, 2010). This has implications for the scale and speed of international cooperation that will in particular support developing countries to make the necessary transitions to sustainable development.

4.3 Determinants, drivers and barriers

This section explores the determinants to sustainable development and equity, emphasizing their relationship with climate change mitigation and adaptation. Determinants are understood as factors that can contribute either positively (i.e. drivers) or negatively (i.e. barriers) towards achieving sustainable development and equity, including population and demography, human capital and education, behaviour, governance systems, technology, legacy of development, natural resources and finance. In what follows, a non-exhaustive review of the most recent literature is conducted to define each of these factors and show existing synergies and trade-offs between them and the realization of sustainable and equitable development.

4.3.1 Population and demography

Population variables, including size, density, growth rate as well as age, sex, education and settlement structures, play a determinant role in countries’ development trajectories. These variables are reciprocally influenced by countries’ development paths, including evolving policies, socio-cultural trends, as well as by changes in the economy (Dyson, 2006). As such, population trends are key to understanding past and future development pathways (Sec. 4.4 and Chapter 6), insofar as they influence our ability to achieve a sustainable and equitable future within and across countries. At present, demographic trends show very different patterns in different parts of the world. While population sizes are already on a declining trajectory in Eastern Europe and Japan, they are set for significant further increase in many developing countries (particularly in Africa and Southwestern Asia) due to a very young population age structure and continued high levels of fertility. As the most recent population projections by the United Nations and by the International Institute for Applied Systems Analysis (IIASA) show, the world’s population is almost certain to increase to between 8 and 10 billion by mid-century. After that period, uncertainty increases significantly, with the future trend in birth rates being the key determinant (Lutz and Samir, 2010; United Nations, 2011a; R Lee, 2011; Scherbov et al., 2011). The population of Sub-Saharan Africa will almost certainly double and could still increase by a factor of three or more depending on the course of fertility over the coming decades, which depends primarily on progress in female education and the availability of reproductive health services (Bongaarts, 2009; Bloom, 2011; Bongaarts and Sinding, 2011).

Declining fertility rates, together with continued increases in life expectancy, result in significant population ageing around the world, with the current low fertility countries being most advanced in this process. For populations that are still in the process of fertility decline, the expected burden of ageing is a more distant prospect, while the declining birth rates are expected to bring some near term benefits. This phase in the universal process of demographic transition, when the ratio of children to adults is already declining and the proportion of elderly has not yet increased, is considered a window of opportunity for economic development (Bloom and Canning, 2000). But populations are not only growing due to currently high fertility rates, but also due to the population growth momentum that results from a high proportion of young people entering the reproductive age groups, which is a result of past high fertility rates.

In this regard, continued high population growth is widely regarded as an obstacle to social and economic development, because it tends to make efforts such as the provision of clean drinking water and agricultural goods and the expansion of health services and school enrolment rates an uphill battle (Dyson, 2006; Potts, 2007; Pimentel and Paoletti, 2009). On the other hand, poverty, poor health, high infant mortality and lack of education are also considered important reasons for continued high fertility, since they tend to inhibit the progress of demographic transition. This has given rise to the fear of a vicious circle of a low level of development leading to high population growth that in turn inhibits the development that would be necessary to bring down fertility (Caole and Hoover, 1958; Ehrlich and J Holdren, 1971; Dasgupta, 1993).

However, history shows that countries can break this vicious circle with the right social policies. Prominent examples are South Korea and Mauritius, which in the 1950s were used as textbook examples of countries trapped in this circle (Meade, 1967). In both cases it was the early emphasis on universal female education and family planning that led to lower fertility, better health, higher female labour force participation and productivity and complemented with the right macro-economic and environmental policies has made them among the most developed nations on their continents. Beyond these two examples, virtually all the countries of East Asia, Southeast Asia and Latin America that in the 1950s had fertility levels around six children per woman and are now around or even well below the replacement level of two surviving children went through comparable phases of social development (Bloom, 2011; United Nations, 2011a).

The discussion regarding population growth and environmental change has been traditionally structured in terms of the so-called I=PAT identity (Ehrlich and J Holdren, 1971; Kaya, 1990) which views environment impact (I) as the product of population size (P), affluence (A=GDP/person) and technology (T= impact per GDP unit). In this conceptualization, population growth by definition leads to greater environmental impact if A and T are constant, and likewise higher income leads to more impact. Some argue that improved health and lower mortality rates worldwide explaining population growth could be jeopardized over the next few decades if global environmental problems persist and the emergent positive correlations between the persistence and expansion of some diseases with changing environmental conditions are confirmed (McMichael, 2002). Other scholars argue that the relationships between population size, technology and resource use intensity – the latter related to affluence – are more subtle, primarily because populations are heterogeneous and impacts cannot be directly associated with individuals (e.g. energy consumption is often at the household level), as well as because these three factors are closely interlinked in the sense that population and economic growth are closely related as are education, fertility, economic growth and technology development (G Sen, 1994; FL MacKellar et al., 1995; BC O'Neill et al., 2001). Additionally, studies demonstrate that informal institutions can play a mediating role in regulating resource use in contexts of rising populations (Mazzucato and Niemeijer, 2002).

With the rise of climate change science, the literature on population and environment has begun to explore more closely people's vulnerability to climate stressors, including variability and extreme events, and to analyze their adaptive capacity and reliance on environmental resources to cope with adversities and adapt to gradual changes and shocks (Bankoff et al., 2004; Adger et al., 2009); see the Working Group II report. It is generally shown that not only the number of people matters, but also their composition by age, gender, place of residence and level of education, as well as the institutional context that influences people's decision-making and development opportunities. People have differential vulnerabilities, a fact that is increasingly considered by impact studies (Lutz, 2009; Wamsler et al., 2012).

The relationship between demographic trends on the one hand and sustainable development and equity on the other is thus complex and controversial. It also makes a difference whether sustainability is only understood to relate to environmental factors or also to social systems; for example, social security and pension systems are frequently labelled as unsustainable in the context of rapid population ageing. While very rapid population growth and rapid shrinking are both broadly seen as unsustainable by governments and scholars alike (see UN review of national population policies) but for different reasons, it is not clear whether moderate population growth or shrinking are necessarily so, if they are associated with continued improvements in quality of life and a diminishing negative impact on the environment. Several prominent international expert committees have recently issued synthesis statements on population and sustainable development, including "The Laxenburg Declaration on Population and Sustainable Development", signed by a global panel of experts, the "People and the Planet" of the UK's Royal Society and the Inter-Academies Panel "Statement on Population and Consumption". They agree that demographic trends must be explicitly taken into consideration when discussing sustainable development and should not be separated from the issue of consumption. As stated by the Inter-Academy Panel:

> *Population and consumption are at the heart of sustainable development and efforts to move the world towards the sustainable use of its natural resources. Both are politically and ethically sensitive, but it is essential that this does not lead to them being neglected by policy makers. The world needs to adopt a rational and evidence-based approach to addressing the issues raised by population growth and unsustainable consumption patterns, one that respects human rights and the legitimate aspirations of people and countries with low-income to improve their living standards and levels of well-being. (Inter-Academies Panel, 2012)*

4.3.2 Human capital and education

Economists define human capital as the capacity of human beings as productive agents to promote increases in income through the acquisition of skills and the accumulation of knowledge (Iyer, 2006). This definition entails a purposive link between the acquisition of skills and knowledge and an individual's contribution to the economic system (i.e. human capital is useful insofar as it can help increasing economic efficiency and growth). Improvements in human capital as defined above are intrinsically related to improved nutritional, health and education standards, and all combined contribute to increasing economic returns at individual and societal scales, although both improvement and returns are gender-differentiated (Schultz 1995). Over the last decades, macro-economic research has shown a strong correlation between low levels of economic development and low levels of human capital and vice versa (Schultz 2003; Iyer 2006), whilst micro-economic studies have also shown a positive relationship between, for example, increases in the quantity and quality of formal education and future earnings (Duflo 2001). Therefore, growth in human capital has to be considered a key explanatory factor beyond the evolution of economic systems, both in terms of growth and constant innovation (Schultz 1961).

Human capital, education and knowledge are associated with economic development, but they also directly contribute to human development in a broader sense. Human capital, in this perspective, can be viewed as a component of human capability, defined as the ability of human beings to lead lives they have reason to value (A Sen, 1997, 2001). This refers to a person's ability to achieve a given list of "functionings", i.e., certain achievements that in turn depend on a range of personal and social factors, including age, gender, health, income, nutritional knowledge and education, environmental condition, among others – see Clark (2009) and Schokkaert (2009) for a review of Sen's capability approach and its critiques. Knowledge and skills, acquired through both formal and informal education, are key means for individuals to maintain or enhance well-being, for example by holding to or accessing a new job, progressing in an organization and increasing income over time, but also by engaging in non-market activities, such as reading, communicating or making choices in a more informed manner, which can also foster their well-being.

In the context of climate, sustainable development, and equity, human capital and knowledge are central to understanding the potential for individual and collective responses to climate mitigation and adaptation, and thus prospects for lowering emissions and achieving equitable and sustainable development (Sec. 4.4 and Chapter 6). Human capital provides the basis for continuous innovation in and diffusion of environment-friendly technologies, for making more informed choices, for changing consumption patterns by individuals and collectives, and for organizing cooperative societal responses to challenges (Sec. 4.3.4 and 4.3.5 below). Thus, from the perspective of sustainable development and equity, the building of human capital can provide the foundation for certain "functionings" such as living more sustainable lives, or pursuing procedural and distributive justice across different spheres of collective action and across a range of development and environment issues, including climate change.

Several studies suggest that knowledge (or lack of) by local populations and individuals on climate change and what to do about it can act as a strong driver or barrier of collective and individual action (Semenza et al., 2008; Sutton and Tobin, 2011). For this reason, researchers have proposed didactical methods to improve the understanding of climate change science and potential responses across higher education curricula (Kagawa and Selby, 2010; Burandt and Barth, 2010), and others have investigated why business communities that do not participate in climate governance initiatives have to date ignored or paid very little attention to the problem, thereby constraining business and employees' reflection and action (Patenaude, 2011).

4.3.3 Behaviours, values, and cultures – tentative title -

[Note from the authors: This section will be developed in the SOD (contributing authors: John Thøgersen, Tim Jackson…)]

The key points this section will address include:

- A review of evidence regarding barriers and opportunities for behavioural change that fosters the transition towards sustainability and equitable human well-being.
- A review of development psychology literature to discuss what drives behavioural change (education, shocks, etc.).
- A review of climate change behaviour literature: exploring barriers to the adoption of individual mitigation and adaptation measures, as well as the cognitive elements that influence people's resilience to stress and shocks.
- A review of the linkages between culture and social/individual behaviour, and the influence of culture on patterns of behaviour regarding consumption, use of natural resources, etc.

4.3.4 Governance: institutions, policies and actors

Governance in the broadest sense refers to a collective effort to decide and agree on a particular goal, for example, sustainable development or mitigating climate change, and to subsequently steer society towards such a goal. Governance goes beyond notions of government (Rosenau, 1990; OR Young, 1999) and integrates actor networks, rule-making systems and formal and informal institutions – incentive structures or "rules of the game" – operating at or across various levels of social organization (Biermann et al., 2009; Chotray and Stoker, 2009). With regard to global governance, two broad categories of meanings have been generally identified: a phenomenological perspective frames it as an emerging new phenomenon of world politics that can be described and analyzed; another, normative perspective frames it as a political program or project that is needed to cope with various problems of modernity or, in contrast, is to be criticized for its flaws and attempts at global domination of weak states by the powerful (Biermann, 2004).

Biermann (ibid., p.8) sees global governance as a phenomenon that goes beyond nation states, and increasingly involves actors that had so far been active mostly at the sub-national level. Additionally, such increase in participation has given rise to new forms of institutions in addition to the traditional system of legally binding documents negotiated by states. As a result, politics are often organized and negotiated in networks and in new forms of public-private and private-private cooperation, as well as between states and private entities. Furthermore, such a system is characterized by an increasing segmentation of different layers and clusters of rule-making and rule-implementing, fragmented both vertically between supranational, international, national and subnational layers of authority and horizontally between different parallel rule-making systems maintained by different groups of actors.

Agents of governance, and global governance in particular, can be multiple, and include public and private actors, groups and individuals: governments, cities, multilateral organizations, non-governmental organizations, corporations, and entrepreneurs of different kinds, among others. These actors can all have different capacities and resources, including political (influence), financial (money), cognitive (information) and moral (legitimacy), that are necessary to steer the behaviour of the collective within and across territorial boundaries (Dingwerth and Pattberg, 2009). This proliferation has promoted multiple resource exchanges among various actors and the multiplication of spheres of authority has inspired “new modes of governance” beyond traditional command and control measures, such as self-governance, enabling, provision and public-private partnerships (Pattberg, 2010; Pattberg, 2012). It has also led scholars to debate the nature of public and private actor relationships, the state-non-state actor divide and the interface of formal and informal arenas of climate change governance (Andonova et al., 2009; Bulkeley, 2010, 2012; Bulkeley and Schroeder, 2011).

A central element of governance is the concept of authority, which can be defined as an instance of power that is associated with at least a minimum of voluntary compliance, making it likely that a command with a specific content will be obeyed by a given collective (M Weber, 1978). Authority then characterizes the extent to which institutions, actors or individuals are able to facilitate and/or constrain the agency of others. Legitimacy to act as an agent of governance means having obtained the acceptance and justifications of authority by the governed, which nonetheless can become a source of controversy and mask or reify unequal power relations (Backstrand 2008). The governed may be electorates, citizens or consumers, or even collectives such as sectors of society, corporations or municipalities. Legitimacy can be derived in different ways, such as through participation and inclusiveness, democratic control and discursive quality (Dingwerth, 2007).

Governance for sustainable development remains a desired yet arduous and elusive task. This is because, as highlighted above (Sec. 4.2), it involves reorganizing or rethinking the way society relates to biophysical systems and human beings relate to one another, within and across generations, which in turn involves reframing or crafting new institutions that can steer human behaviour towards sustaining both equitable human development (i.e. a development path that prioritizes human well-being over economic growth, and adopts recognition, and both procedural and distributive justice as guiding principles) and ecological conservation and preservation to the greatest extent possible (Roberts and Parks, 2007; Adger and Jordan, 2009). Governing such a transition is inevitably challenging because, on the one hand, it involves multiple agents that hold vested interests when it comes to prioritizing between the three pillars of sustainability and to promote equity principles, who in turn hold varying degrees of power and access to authority. On the other hand, it cuts across several realms of policy, organization and action, from international to local, and individual levels. The transition may thus require a “constitutional moment” to bring about the revolutionary institutional reforms needed to address these challenges, which may or may not guarantee success (Biermann et al., 2012).

The governance of climate change mitigation and adaptation is an element of a complex and evolving arena of global environmental governance, which deals with other, and often overlapping issues such as biodiversity loss, desertification, ozone depletion and pollution. Sites of climate change governance and policy-making are indeed multiple and are not confined to the UNFCCC and national rule-making processes (Okereke et al., 2009; Andonova et al., 2009) (see chapters 13-15 of this report, notably figure 13.1 for a visual summary). There are various sorts of governance initiatives emerging alongside the UNFCCC and other intergovernmental agreements: public-private partnerships, private sector governance initiatives, NGO transnational initiatives, and subnational transnational initiatives (see Chapter 13 for details). These initiatives include, for example, transnational networks of cities to help cities mitigate and adapt to climate change (Bulkeley, 2010), global public-private initiatives such as the Global Compact that harnesses the power of business to the goals of key UN treaties and declarations (Newell et al., 2012) and the multitude of processes that are being established to help implement emissions trading markets or the REDD+ mechanism to avoid deforestation in tropical forest countries (Corbera and Schroeder, 2011; Bailey et al., 2011).

Governing for sustainability and climate change opens up a variety of empirical questions that require attention and are relevant for this report. First, as Adger and Jordan suggest (p. 20), there is a need to understand whether there is a real shift "from government to governance", which could illuminate the actual role that formal policy prescriptions adopted by governments at multiple scales play in determining the process and outcomes of a transition towards sustainability or a "climate safe" world. Second, and related to this last point, there is a need to explore if and how different modes of governance translate into positive outcomes across all dimensions of sustainability and draw lessons regarding their effectiveness and distributional implications, or any existing trade-offs. And third, it is critical to pay attention to how these modes of governance are defined in the first place, by whom and for whose benefit, which reminds us of the impossibility of disconnecting sustainability and climate change governance from existing trends in global capitalism and political economy.

Regarding the latter, for example, the prevailing organization of capitalism, around what is usually known as "neoliberalism", provides the context for the sorts of governance practices of climate change that have dominated to date (Newell and Paterson 2010). Paterson argues that global environmental governance has progressively geared towards promoting government-based regulatory frameworks that facilitate capitalist gains under the name of sustainability, such as market-based policy instruments, and towards increased reliance on private-based certification, labelling and auditing schemes (Paterson, 2009). Many of the specific governance initiatives discussed in Chapters 13-15, whether organized by states or among novel configurations of actors, have focused on creating new markets or investment opportunities. This applies, for example, to the emergence of carbon markets (Paterson, 2009; M Betsill and Hoffmann, 2011), voluntary carbon offsetting (Lovell et al., 2009), investor-led governance initiatives such as the Carbon Disclosure Project (Kolk et al., 2008) or partnerships such as the Renewable Energy and Energy Efficiency Partnership (Parthan et al., 2010) to develop specific technologies.

This requirement to accommodate the need for capital accumulation necessarily constrains how the pursuit of sustainability might be carried out, even while it generates opportunities to bring new actors into the process of governing climate change. Furthermore, the "decentralization" that governance per se involves makes it difficult to establish responsibilities, and ensure transparency and accountability in any transition towards sustainability. Nonetheless, it has been argued that states, through conventional command-and-control approaches, including taxation, should still be regarded as key agents in steering such transition (Weale, 2009), yet it is also true that state legislation, particularly in regions such as the EU, is either driven or constrained by decisions made beyond national constituencies.

4.3.5 Technology

Technology has been a central element of human, social, and economic development since ancient times. It influences the way in which humans interact with biophysical systems, design their economic systems and relate to one another (Mokyr, 1992). Drawing on the FAR (IPCC, 1990), we define technology as the practical application of knowledge to achieve particular tasks, employing both technical artefacts, including hardware and equipment, and social information, such as software and know-how for the production and use of such artefacts. Science and technology are regarded as key means to achieve sustainability, particularly if they contribute to maintain economic development whilst using environmental resources more efficiently and enhancing social development (G Atkinson, 2000; J Holdren, 2008). The central chapters of this report explore, among others, the challenges and opportunities of innovation, diffusion and uptake of mitigation and adaptation technological options in different sectors.

For framing purposes, however, it is important to highlight here that the nature of the global science, technology, and innovation (STI) enterprise is such that it does not automatically address sustainable development and equity challenges. Basic health, energy and nutritional needs of large parts of the world's population are still unfulfilled – for example, the World Health Organization (WHO) and the United Nations Children's Fund (UNICEF) estimate that 2.5 billion people suffer from poor sanitation facilities and over 780 million people did not have access to clean water in 2010 (WHO and UNICEF, 2012). The International Energy Agency estimates that 2.7 billion people worldwide relied on traditional highly-polluting biomass cookstoves for household cooking and heating in 2009, and 1.3 billion did not have access to electricity (IEA, 2011). And the Food and Agriculture Organization of the United Nations has estimated that 925 million people worldwide were undernourished in 2010 (FAO, 2011). In the health sphere, and enormous disparities remain – life expectancy at birth in least-developed countries was 59 years in 2010, whereas the average for high-income OECD countries is 80 years (World Development Indicators) , and neglected tropical diseases afflict over 1 billion people (WHO, 2010).

While the STI enterprise has made major contributions in each of these areas over the past decades, it has not been sufficient to fully address these challenges in all parts of the world – in fact, for each of the areas mentioned in the previous paragraph, it is estimated that these numbers will not decline significantly in the near future unless there is a dramatic transformation in our efforts to tackle these issues. The fact is that much of the STI capabilities and resources are concentrated in industrialized countries and, not surprisingly, are directed towards meeting the needs of consumers in these countries (and of the relatively-wealthy consumers in developing countries). This is due, in large part, to the fact that the STI enterprise is organized is a way that the overwhelming majority of the development of technologies and their deployment in the real world is mediated by markets and carried out by private firms since they are better placed to carry out these activities. However, such a market-driven process, while providing abundant incentives for technological innovation, does not necessarily address the needs of those who do not have sufficient market power. While scholars recently have suggested that businesses should focus on the needs of the poor (Prahalad, 2004), given that they together constitute a significant market – and this view has even been taken up in the business discourse to some extent – this has not yet translated into significant successes.

Furthermore, developing and mainstreaming new technologies across relevant social actors and groups (e.g. firms, families, individuals) is not a straightforward process. Innovation and diffusion require skills and knowledge from both developers and users, as well as different combinations of enabling policies, markets, social capital and financial means depending on the type of technology and the application being considered (Bretschger, 2005; Dinica, 2009; Blalock and Gertler, 2009; KU Rao and Kishore, 2010; JP Weyant, 2011; Jänicke, 2012). National income and inequality levels, as well as consumer preferences, also contribute to explain the diffusion and adoption of environmental technologies (Windrum et al., 2009; Vona and Patriarca, 2011). It has been argued, for example, that countries' mitigative capacity is influenced by the interplay between income, abatement cost and opportunity cost, while the effectiveness of government regulation, clear market rules, a skilled work force and public awareness are critical to absorb, adopt and scale-up new technologies (Winkler et al., 2007). Both the SRREN and the *Fourth Assessment Report* highlight that technological change is influenced by government policies and economic growth, insofar both public and private finance is required to level the playing field of renewable energies against the most dominant fossil fuel based technologies (Sathaye et al., 2007; IPCC, 2011).

The case of renewable energy technologies (RETs) offers much evidence, as many recent reviews and evidence confirm, that further uptake of technologies that may offer sustainable development benefits is jeopardized by multiple, sometimes overlapping factors, including: intermittent policy subsidies, governments' changing R&D support, misalignments between policy levels, sectors and institutions, the incompatibility of RETs with current infrastructure systems, and other issues related to legitimacy and the lack of knowledge and skills across all the involved sectors, among others (Jorgensen, 2008; Luo and X Zhang, 2012; Negro et al., 2012). Specific renewable options, such as biomass power or hydrogen-fuelled transport, are compromised by a mismatch between the required economic incentives and governments' adherence to market liberalization principles (Dinica, 2009) and by a lack of public investment in infrastructure (PE Meyer and Winebrake, 2009; Dinica, 2009), respectively. The development of carbon capture and storage technology is constrained by investment costs and low carbon prices (Lohwasser and Madlener, 2012). In the Kyoto Protocol context, in-country human capital and foreign investment have played a key role in determining the level of international or domestic technology transfer through the Clean Development Mechanism (Dechezleprêtre et al., 2009; B Wang, 2010), although some authors argue that such transfer has often involved technology variants that are closer to environmental un-sustainability than to more sustainable renewable technologies (Bodas Freitas et al., 2012). In the context of adaptation, scholars have also shown that adapting to water scarcity though the deployment of supply-side technological options, combined with demand-side policy instruments are often constrained by social institutions and formal regulations (NW Arnell and Charlton, 2009).

However, to further understand the wider implications for sustainability and equity of an increased uptake of RETs and other environmental and mitigation technologies, it is necessary to develop biophysical and socio-economic assessments that capture the trade-offs and synergies between the three dimensions of sustainable development, as well as the impacts over socio-ecological systems across geographical scales. For example, some scholars argue that a massive scale-up of RETs may lead to a global land rush that in some instances may compete with land for food (Scheidel and Sorman, 2012) and land for conservation (ALR Jackson, 2011). The biophysical sustainability of renewable energy infrastructure may be compromised in the long term on the basis of existing stocks of required minerals (García-Olivares et al., 2012).

Additionally, it is well known that the extraction of fossil fuels, as well as of uranium and other minerals required in the development of RETs – and other commodities – result in significant environmental and socio-economic impacts at national and local levels, a dynamic that may worsen with the current expansion of the world's "social metabolism" (Martinez-Alier et al., 2010; Muradian et al., 2012). Resource extraction conflicts arise from an inequitable share of the rents and costs associated with these processes and their uneven consumption across governance scales. There is evidence that resource extractive economies and civil conflict are interlinked (Le Billon, 2001; Janus, 2012). Resource extraction conflicts, however, have multiple manifestations and may or may not include direct contestation at local, regional or national scales, and may or may not result in loss of human lives. Yet these conflicts involve multiple valuation languages, and a diverse portfolio of action-based and discursive strategies that reflect differently upon sustainability and equity issues, including procedural and distributive matters (Veuthey and Gerber, 2010; Urkidi and Walter, 2011)

There is also sound evidence that the deployment of large-scale technological infrastructure for RETs can also translate into negative impacts and conflicts, insofar as it may affect multiple stakeholders in contexts of uneven power relations and distinct degrees of procedural and distributive fairness in decision-making (Gamboa and Munda, 2007; ALR Jackson, 2011). This means that environmental impacts of RETs need to be framed beyond positive greenhouse gas emission reductions and encompass analyses of their impact on landscapes' ecological and social dimensions –accounting for multiple values – and on energy distribution and access from a territorial perspective (Wolsink, 2007; Zografos and Martinez-Alier, 2009). For instance, large-scale RETs involve careful siting and a substantive amount of investment on infrastructure development, thus resulting in very centralized management systems in comparison to small-scale cogeneration or solar photovoltaic technologies. Some argue that the former should be favoured on the basis of reduced costs per unit of energy (Aki et al., 2006) while others argue that decentralized systems have a strong positive effect on consumers' behaviour and reduced energy consumption – for a review, see Keirstead (2008). In particular contexts, small-scale energy provision technologies offer both opportunities and challenges for sustainable development and equity; they can contribute significantly to improving the well-being of the recipients, such as rural communities and community neighbourhoods without access to the electricity grid or to other sources of fuel for water heating, but they can also place a burden on poor people through higher levels of technology maintenance, particularly if appropriate policy incentives and management systems are not in place, therefore resulting in a very expensive and inefficient mitigation pathway (Sharma, 2007; Zerriffi and E Wilson, 2010).

It has been suggested that an innovation system should be assessed not only in terms of the scale of the investments, but also for its allocation among various objectives and options, the efficiency by which inputs are converted into outputs, and how effectively the outputs are utilized for meeting the objectives) (Sagar and JP Holdren, 2002). And, in fact, there have been reports and analyses focused on enhancing investments in innovation for public goods such as clean energy and health (Nemet and Kammen, 2007; AEIC, 2010; Bazilian et al., 2010; WHO, 2012) and also on methodology by which to develop a suitable portfolio of investments (Pugh et al., 2011). In addition, there are novel institutional forms being explored that help overcome this innovation deficit by bringing together existing actors and capabilities in innovative ways and/or strengthening capabilities in developing countries to develop, adapt, and successfully deploy technologies (Wheeler and Berkley, 2001; Moran, 2009; Sagar et al., 2009). It likely will take many steps of these kinds to help direct, reshape, and enhance science and technology activities and capabilities in different parts of the world to leverage the potential of technologies and the implement them at scale to also address sustainable development challenges for the marginalized in the world while tackling the climate challenge.

4.3.6 Legacy of development

After World War II, diverse relations between rich nations and poor nations – security, economic, and humanitarian – were comingled and addressed under the umbrella of "development". These relations, and the differing perspectives on their mixed results, are an important determinant of the prospects for a future transition to sustainable development.

During the 1950s and 1960s, expectations were firmly implanted that poverty in poor nations could and would be reduced dramatically over the next half-century through economic development spurred by aid, both financial and in kind, from rich nations. By the 1970s, however, it was clear that economic development was not on a path to fulfilling expectations, for several reasons: 1) contributions of aid from the rich nations were not at the levels promised; 2) technological and institutional changes were only partially successful, proved inappropriate, or had unpredicted, unfortunate consequences; 3) requests for military aid and the security and economic objectives of rich nations in the context of the Cold War were frequently given priority over poverty reduction and development: and 4) graft, patronage, and the favouring of special interests diverted funds from poverty reduction. As this early legacy of development became documented, diverse efforts were made to improve how development worked, but with only modest success, leaving people in both rich and poor nations concerned about the process (Sachs, 1992; Easterly, 2001, 2007) (to add references).

The process of building expectations of economic development was repeated in the Millennium Development Goals (MDG) to be met by 2015 that were instituted in 2000. There are definitely some success stories with respect to meeting the MDGs (United Nations, 2011b), but the significant improvements are largely in China and India where economic growth accelerated rather independently of the MDG process and broader development cooperation efforts. Excluding these countries, the record is mixed at best and still relatively poor in Africa (Keyzer and Wesenbeeck, 2007; Easterly, 2009).

Layering the goal of environmental sustainability onto the goal of poverty reduction in development further compounded the legacy of unmet expectations. There have been scientific difficulties determining sustainable pathways as well as difficulties in implementing appropriate technologies, monitoring for environmental responses, integrating multiple value-approaches and sources of knowledge, coordinating institutions and, generally speaking, governing for sustainability (Brown, 2009) (see section 4.3.4).

There are multiple perspectives on the resulting legacy of unmet development and sustainability expectations. In rich nations, the evidence from the legacy of development can be interpreted to support the diverse views of fiscal conservatives who oppose aid, libertarians who oppose both humanitarian and environmental interventions, progressives who urge that more needs to be done to reach social and environmental goals, and some environmentalists who urge dematerialization and depopulation as the only solution. In poor nations, the legacy similarly is taken as support for various view, including a distrust of rich nations who have not delivered development and environmental assistance as promised, cynicism toward the intentions when it is provided, and also a wariness of its unpredicted outcomes.

In both developed and developing nations, these various sentiments within the public, policy makers, and climate negotiators contribute to what philosopher Stephen Gardiner refers to as the “perfect moral storm” of climate policy (Gardiner, 2011b) (see also Sec. 4.6).

In the spirit of the UNFCCC that acknowledged differentiated responsibilities based on level of development, most analysts of climate negotiations recognize the legacy of development (Stern and Treasury, 2007). Others, however, argue that humanitarian questions and even the legacy of greenhouse gas emissions so cloud global climate negotiations that the possibility for reaching a global agreement is highly unlikely. It has been argued, for example, that nations should proceed with ad hoc agreements and voluntary efforts (DG Victor, 2004) and that questions of the mechanisms for reducing greenhouse gases and questions of development would be better negotiated separately (Posner and Sunstein, 2007; Posner and Weisbach, 2010). However, given the rich nations record of meeting humanitarian commitments, poor nations may be unwilling to accept separate negotiations (C Stone, 2004).

4.3.7 Natural resources

The location, typologies, existing quantities, long-term availability and the rates of exploitation of fossil fuels, minerals and other natural resources such as fertile land, timber or freshwater contribute to shape the organization of national economies (e.g. in terms of trade balance and rent potential) and their role in global geo-political and trade systems. This configuration evolves over time to reflect changes in global economic trends, in international politics or in consumption patterns. Muradian et al. (2012), for example, argue that we are currently witnessing a shift in the historical trend toward declining the use of natural resource per unit of economic output due to the rise of Asian economies; a growth in the dependency of developed countries on natural resources and embodied materials from developing and emerging economies; a steady increase in the exploitation of natural resources that is likely to continue in the near future under current growth rates; and a reconfiguration of geo-political relations and global commodity chains due to the appearance of new actors from emerging economies, including both public and private actors.

These trends in the global political economy offer both opportunities and threats for resource-rich countries (van der Ploeg, 2011; Muradian et al., 2012). Governments can increase their bargaining power over the conditions for extraction of natural resources, and benefit-sharing can translate into increased national revenues and potential investments in human development, for example in education and health services, particularly if well-functioning institutions and/or policies are in place (Mehlum et al., 2006; Yang, 2010). A recent study of oil-producing countries demonstrates that most of these countries, albeit with some exceptions, are able to maintain political stability through a combination of large-scale rent distribution, high spending on the security apparatus and protection by outsiders (Omgba, 2009; Basedau and Lay, 2009). It has also been suggested that both domestic and international factors, such as robust human capital formation, migration policy and countries' global economic integration, are the keys to explaining whether oil resources result in a key developmental "curse" or a "blessing" (Brunnschweiler and EH Bulte, 2008; Bearce and Hutnick, 2011; Kurtz and Brooks, 2011; Rudra and NM Jensen, 2011). In Chile, for example, adequate fiscal policies and wise investment allowed for positive genuine savings from resource extraction and increased wealth per capita over the period 1985-2004 (Figueroa and Calfucura, 2010).

Those resource-rich countries that characterized by governance problems, however, such as rent-seeking behaviour, corruption and weak judiciary and political institutions, have more limited capacity to distribute resource extraction rents, as well as to increase income per capita (Ross, 1999; Mehlum et al., 2006; Mildner et al., 2011; Pendergast et al., 2011; Bjorvatn et al., 2012). Furthermore, these countries also face risks associated with an over-specialization on agriculture and resource-based exports that can undermine other productive sectors – through increases in exchange rates and with an increasing reliance on importing countries and regions' economic growth trajectories (Muradian et al., 2012). Additionally, some argue that there is a positive relationship between an increase in primary commodity exports and the rise of socio-environmental conflicts due to the advancement of the "extraction frontier", and generally between resource abundance and armed conflict (Martinez-Alier et al., 2010; Muradian et al., 2012). Scholars have also noted the effects that conflict may then trigger on resource exploitation rates, suggesting that such conflict may induce a decrease in the extraction and export rates of oil and minerals but an increase in other resources, such as fisheries (SM Mitchell and Thies, 2012). In contrast, some have contested the link between resource abundance and civil conflict and suggested an inverted relationship, where abundance is associated with a reduced probability of the onset of war (Brunnschweiler and EH Bulte, 2009)

The literature explored above is far from coming up with definitive conclusions on the inter-relationships between resource endowments and use, and in-country development issues, including varying degrees of social welfare and conflict. Recent reviews, for example, remark the need to continue investigating current resource booms and busts and documenting the latter's effect on national economies, policies, and social well-being, and to draw historical comparisons across countries and different institutional contexts (Wick and E Bulte, 2009; Deacon, 2011; van der Ploeg, 2011). Deacon, for instance, highlights the need to provide more nuanced, in-country analyses of countries' response to resource windfall profits built upon "before and after" data, with the aim to inform aid policies and to the need of empirically investigating the mechanisms that make a resource-rich country more or less prone to achieve high levels of human development. Van der Ploeg, in turn, places also emphasis on the urgency of understanding how in-country saving patterns (i.e. investment in international financial capital or in domestic productive capital), as well as the public or private nature of savings' owners may affect economic growth.

Precisely, in the context of this chapter, the issues addressed above indicate the importance of taking into account resource endowments and historical resource use patterns when considering sustainability, equity and climate change issues. The combination of resource abundance, the evolving availability and access conditions of such resources, coupled with both macro- and micro-economic trends, institutional, policy and governance patterns influence the balance between the three pillars of sustainability (Costantini and Salvatore Monni, 2008). Van der Ploeg (2011) shows that many resource-rich countries have negative genuine savings, i.e. they do not fully reinvest their resource rents in foreign assets or productive capital (e.g., buildings, roads, machines, human capital, or health), which in turn impoverishes future generations and undermines both natural capital and human development prospects. If these countries had followed Hartwick's rule, they would currently be less dependent on natural resources exports, although it is also true that countries with positive genuine savings can show decreasing wealth per capita due to ill-targeted investments and high population growth.

The issues discussed also relate to procedural and distributive justice issues. The state and those actors with vested interests in accessing and/or exploiting natural resources would have to ideally ensure that equity principles are met and respected (Banai et al., 2011). This involves working towards a fair sharing of resource extraction revenues and investing in human well-being, and cautiously assessing the rate and extent to which natural resources should be exploited. The Ecuador government's recent choice to keep millions of oil barrels underground in exchange of global contributions for avoided emissions represents an innovative way to secure rents while avoiding the depletion of natural capital (Rival, 2010; Martin, 2011). In fact, economic valuation studies have for a long time noted that systematic valuations of both positive and negative externalities may render the exploitation of land and mineral resources socially unacceptable whilst aiding policy-making in the context of resource use policies (de Groot, 2006; Thampapillai, 2011). Changes in incentives and market structures to increase the recycling of non-renewable metals and induce awareness among final consumers have also been proposed (Jeremy Richards, 2006) and the need to treat both exhaustible and renewable resources as social capital (i.e. urging governments to invest rents in projects that could yield a continuing stream of social returns) has also been emphasized (Mikesell, 1987; R Solow, 1993)

In the context of climate change, resource endowments – and their associated economic, political and institutional structures – are critical elements to consider when examining countries' mitigative and adaptive capacity. For example, a given country with abundant fossil fuel reserves has, in theory, a strong economic interest in exploiting such reserves, and this in avoiding the adoption of policy regulations that could constrain such exploitation. Opportunity costs are only one of the factors influencing countries' mitigative capacity (Winkler et al., 2007) but they stress the importance of finding ways to steadily compensate fossil fuel-rich countries against forgone benefits, and particularly if they are to participate in the globally significant mitigation efforts required to avoid dangerous climate change (Ramanathan and Xu, 2010). Additionally, if this given country faces increased exposure to climate variability and extreme events, the forgone benefits of fossil fuel rents may undermine its ability to respond to increasing adaptation costs. In this regard, a recent analysis of the relationship between countries' adoption of mitigation policies and their vulnerability to climate change confirms that countries which should suffer considerable impacts of climate change in the future, which include many resource-rich developing countries, do not show a strong commitment to either mitigation or adaptation, whilst countries exhibiting strong political commitment and action towards mitigation are also active in promoting adaptation policies. This is an indication that vulnerability is unlikely to prevail over the free-rider problem of mitigation and the development concerns of many developing countries (Tubi et al., 2012).

4.3.8 Finance

[Note from the authors: this section will be substantially rewritten in light of the Chapter 16 FOD. In particular, eliminating some of the details of the existing international financial agreements and instruments, assessing them in the context of other financial flows (e.g., domestic private sector investment and FDI)].

Strengthening the transition towards sustainable development, and ensuring equitable human well-being, requires fundamental improvements of human capital, behavioural changes, and addressing the current challenges that governance and technological systems face to steer such a transition. This transition will involve substantial shifts in the scale and nature of investments, and thus the importance of finance. In this regard, Chapter 16 addresses the financing of climate mitigation and adaption and surveys a range of estimates of the requirements of developing countries to finance the costs of mitigation, adaptation and technology development (Parry et al., 2009; World Bank, 2010a; UNDESA, 2011). Finance and technology transfer are recognized as means of implementation to achieve sustainable development under international agreements, in particular Agenda 21 and the UNFCCC, and reaffirmed in subsequent UN resolutions and programs.

With regard to financing of sustainable development, the June 2012 UN Conference on Sustainable Development produced an outcome document titled “The Future We Want”. Paragraph 252 reads:

> *We reaffirm that the means of implementation identified in Agenda 21, the Programme for the Further Implementation of Agenda 21, the Johannesburg Plan of Implementation, the Monterrey Consensus of the International Conference on Financing for Development and the Doha Declaration on Financing for Development are indispensable for achieving the full and effective translation of sustainable development commitments into tangible sustainable development outcomes. We reiterate that each country has primary responsibility for its own economic and social development and that the role of national policies, domestic resources and development strategies cannot be overemphasized. We reaffirm that developing countries need additional resources for sustainable development. We recognize the need for significant mobilization of resources from a variety of sources and the effective use of financing, in order to promote sustainable development. We acknowledge that good governance and the rule of law at the national and international levels are essential for sustained, inclusive and equitable economic growth, sustainable development and the eradication of poverty and hunger.* (United Nations, 2012)

The summit agreed to establish an intergovernmental process under the auspices of the UN General Assembly that “will assess financing needs, consider the effectiveness, consistency and synergies of existing instruments and frameworks, and evaluate additional initiatives, with a view to preparing a report proposing options on an effective sustainable development financing strategy to facilitate the mobilization of resources and their effective use in achieving sustainable development objectives” (paragraph 255). An intergovernmental committee, comprising 30 experts nominated by regional groups, with equitable geographical representation, will implement this process, concluding its work by 2014. The General Assembly is to then consider the report of the intergovernmental committee and take appropriate action.

In the context of the principle of common but differentiated responsibilities operationalized in the UNFCCC, developed countries and countries with economies in transition (i.e. Annex I Parties to the UNFCCC) have commitments to provide financial resources to developing countries (i.e. non-Annex I Parties). While some developing countries are able to mobilize some domestic financial resources for specific actions, the needs almost always exceed their *ability to finance from domestic sources. The majority of developing countries continue to need means* of implementation from external sources; accordingly, their ability to undertake sustainable development actions in general, and climate change mitigation and adaptation actions in particular, can be severely constrained by lack of finance.

UNFCCC Parties have also established three other funds in the past few years: the Special Climate Change Fund (SCCF), to support mitigation, adaptation and technology transfer to developing countries; the Least Developed Countries Fund (LDCF), to support the preparation of National Adaptation Plans; and the Adaptation Fund, to support adaptation programs and projects in developing countries. The SCCF and LDCF are managed by the Global Environment Facility (GEF), while the Adaptation Fund is governed by a 16-member board representing Parties to the Kyoto Protocol, with the World Bank acting as trustee. Additionally, in 2010, the Green Climate Fund was established at the 16th session of the Conference of the Parties (COP). The fund is an operating entity of the financial mechanism of the UNFCCC under Article 11 and will support projects, programs, policies and other activities in developing country Parties. Currently, the operation of the financial mechanism is partly entrusted to the GEF on an ongoing basis, subject to review every four years by Parties who provide guidance to the GEF. Furthermore, at its 17th session, the COP adopted a decision to undertake a work programme on long-term finance with the aim of contributing to the ongoing efforts to scale up the mobilization of climate change finance after 2012 (UNFCCC, 2011). As such it will analyze options for the mobilization of resources from a wide variety of sources, public and private, bilateral and multilateral, including alternative sources and relevant analytical work on climate-related financing needs of developing countries.

As of June 2012, the Adaptation Fund has approved projects and programs for a total of US$117 million. Meanwhile, GEF funding shows great unevenness in the funding of mitigation and adaptation projects. From its inception in 1991 until June 2011 the GEF Trust Fund has funded 755 mitigation projects costing US$3.39 billion and attracting US$19.9 billion in co-funding, spread across 156 developing countries and economies in transition. On the other hand, the GEF has funded through the LDCF a total of 47 projects for a total of US$178.6 million and another 32 through the SCCF for a total of US$127.74 million. The GEF Strategic Priority on Adaptation (SPA) programme distributed US$50 million between 2004 and 2010, aiming to show how adaptation planning and assessment can be practically translated into full-scale projects.

In addition to the Adaptation Fund and GEF-managed funds, the World Bank has also two Climate Investment Funds (CIFs): the Strategic Climate Fund (SCF) and the Clean Technology Fund (CTN). The SCF has three lines of financing: 1) the Forest Investment Programme (FIP), which provides scaled-up financing to developing countries to start reforms identified in their national REDD+ strategy; 2) the Pilot Programme for Climate Resilience (PCCR), which offers technical assistance as well as finance for developing countries to integrate climate resilience into development plans; and 3) the Scaling up Renewable Energy Plan (SREP), launched in 2009 to enable government support for renewable energy market creation. All these initiatives are complemented by multilateral, bilateral or single-country funding initiatives designed to support mitigation and adaptation projects and programs, with a diversity of priorities and levels of disbursement (www.climatefundsupdate.org).

Such diversity, however, has led scholars to advocate for a better integration of climate funding and development aid to ensure coordination and increase the effectiveness of financial transfers (JB Smith et al., 2011), as well as to suggest ways of improving funds governance and management approaches. Recent analyses of the AF, for example, highlight difficulties in targeting vulnerable areas and populations due to a lack of clear, accepted definitions, as well as strong incentives to consider vulnerability or related information, such as weather events attribution, in the evaluation of project proposals (van Renssen, 2011; Horstmann, 2011; Hulme et al., 2011). The Bretton Woods project has regularly overseen the decisions and performance of the World Bank's CIFs and has also identified a range of social and environmental controversies that lending generates in recipient countries (The Bretton Woods Project, 2012).

In addition, the Clean Development Mechanism (CDM) has proven successful in generating emission reduction projects in several developing countries, but such projects have been very unevenly spread across the world, showing a significant bias towards emerging economies and leaving the African continent aside (UNEP/Risø Centre on Energy, 2011). China has received over 70% of the finance available so far, while India has been the next best beneficiary with 13.5% of the investments. Brazil has received 1.4%, leaving the rest of the participating countries with 13.6% among them (Byrne et al., 2011) (Figure X).

[Note from the authors: Figure to be inserted. Figure X: CDM registered projects and accumulated investment value (USD billion), as at end of May 2011. Key: Country, USD billion, percentage, ROW: Rest of the world. Source: Byrne et al. (2011).]

As a market mechanism, the CDM has created incentives for firms to invest in low-carbon projects that are least-cost and/or will produce the highest returns through the sale of emissions credits.

Thus, "mature" technologies and low-risk investment environments tend to be the most attractive, including hydropower, wind energy, methane avoidance, biomass energy, landfill gas and own energy generation (Byrne et al., 2011) (Figure Y). This suggests that it is unlikely that the CDM can contribute meaningfully to development goals such as improving energy access amongst the world's poorest people and industrialization in the poorer countries, or to achieving widespread sustainability in the developing world. For a review of CDM literature, and further reflections on CDM governance and its implications for national and local sustainable development see Corbera and Jover (2012).

[Note from the authors: Figure to be inserted. Figure Y: Number of registered CDM projects as of the end of May 2011, disaggregated by project type (3145 total registered projects) Source: UNEP Risø (2011); also cited in Byrne et al. (2012).]

The low capacity to mobilize private sector capital for climate change adaptation and mitigation of GHG emissions in non-Annex 1 countries is due to a number of complex interrelated factors, including the high overall cost of doing business; lower public energy R&D spending; market distortionary policies such as subsidies for conventional fuels; absence of credit-worthy off-takers; low access to early-stage financing; too few wealthy consumers willing to pay a premium for "green products"; social and political instability; poor market infrastructure, and weak enforcement of the regulatory frameworks. These usually increase the investment risk factor. Establishing better mechanisms for leveraging private sector finance through innovative financing is therefore essential and being explored (EGTT, 2008).

4.4 Production, trade, consumption and waste patterns

This section concerns patterns of consumption and production from the perspective of sustainable development and equity. This includes review of literatures on sustainable consumption and production that have emerged since the 1992 Earth Summit in Rio and matured since the 2002 World Summit. The main purpose is to provide a broad conceptual guide for subsequent chapters' assessments of the sustainable development and equity implications of specific climate mitigation options, pathways and policies. The section emphasizes the consumption of goods and services by households in different social and geographical settings, and how consumption relates to lifestyle, human well-being, inequality and sustainability. This includes discussion of different consumption-based approaches to GHG emissions accounting, including "carbon footprinting". Hence, while subsequent chapters analyse GHG emissions associated with specific sectors and transformation pathways, this section focuses on a particular group (consumers) and examines their emissions in an integrated way. Finally, we discuss the sustainability dimensions of the increasing distance between centres of consumption and production resulting from globalization, particular regarding flows of resources and emissions "embodied" in trade, and how the choice of spatial scale and other boundary definitions influence sustainability assessments. This is a reminder for subsequent chapters to consider space, scale and locality in their discussions of mitigation options, pathways and policies.

4.4.1 Consumption, the environment, equity and well-being

4.4.1.1 Global consumption patterns and their environmental impacts

Global consumption (in 2008 dollars) of goods and services has increased sixfold in value since 1960 (and 28% since 1996), while consumption expenditures per capita has almost tripled since 1960 (Assadourian, 2010).[1] Indices of material consumption have likewise increased over the last decades (Fine, 2002; UNEP, 2010). [Note from the authors: For the SOD, we present here a table showing

[1] The original data source is World Development Indicators published by the World Bank.

global trends in indicators of material consumption derived from WRI's Earth trends Database (http://www.wri.org/project/earthtrends/), FAO (e.g., irrigated land), EIA (primary energy consumption), and the UNEP publication cited above.]

The spread of consumerism or consumption-based lifestyles is arguably a "mega driver" of global environmental degradation – including global warming. Consumerism can be defined as a cultural paradigm where "the possession and use of an increasing number and variety of goods and services is the principal cultural aspiration and the surest perceived route to personal happiness, social status and national success" (Assadourian, 2010) after Elkins (1991). Assadourian (2010) observes that there is an increasingly common pattern across cultures to find meaning, contentment and acceptance primarily through consumption, and that while consumption obviously is necessary to satisfy basic needs, the level (and type) of consumption is almost completely driven by cultural norms. [Note from the authors: This discussion will be elaborated in the SOD.]

The relationship between more specific patterns of consumption and their environmental impacts has been studied intensely over the last decade (Tukker et al., 2010a). In industrialized countries, mobility (automobile and air transport), food (mainly meat and dairy) and housing (including the use of energy-using products) are responsible for the largest proportion of consumption-related environmental impacts. Together these domains account for 70% to 80% of the life cycle impacts in these countries (ibid.). Yet research has also identified sometimes large differences in consumption-related environmental impacts across households within the industrialized countries. The specific factors responsible for these differences include household income, household size, housing type, spatial organization, dietary patterns, trade, and social and cultural differences (Tukker et al., 2010a). Differences across countries in the materials and emissions (of GHGs and other pollutants) embodied in like products also cause variation in the environmental impact of consumption [insert reference here]. The factors responsible for variations in GHG emissions across households at different scales are discussed in Chapter 5 of this report.

Impacts from luxury consumption

Sociologists emphasize the significant role consumers can play in redirecting the economy towards greater environmental sustainability by changing their lifestyle to depend less on luxury and excessive consumption. This transition in individual behaviour also requires a change in the broader economic and social institutions within which consumption occurs (Obach, 2009). In general, since the production of goods and services is shaped by the market for consumer goods and by income distribution, a disproportionate part of the GHG emissions and other environmental impacts arising from production are linked to the production of luxuries which accrue to a relatively small portion of the world's population. The different nature of the emissions arising from goods used for necessities and for luxuries has been recognized in the literature; for example it has been pointed out that there is an important distinction between "subsistence emissions" (which arise from production of goods by or used by the poor) and "luxury emissions" (which arise from producing goods used by the better off) and that the former would have priority (Shue, 1993) (see Sec. 4.6). Social welfare is increased if financial resources are transferred to a poor person from a rich person, as the former has a higher marginal utility of consumption than the latter.

4.4.1.2 Disparities in consumption across groups

[Note: this section will be edited and further developed (but not made longer) in the SOD]

The magnitude and trend in world income inequality is interesting as an indicator of the effects of global economic integration. Milanović (2007) distinguishes between three concepts of world income inequality: among countries in their levels of average per capita income, with each country counting as a unit; between-country inequality, which is inequality among individuals in the world with each individual assigned the average per capita income of his or her country of residence, and;

among individuals in the world with each individual assigned his or her own (per capita household) income (global interpersonal inequality). Below we discuss each in turn.

Inequality among countries

[Note from the authors: This section will be written for the SOD]

Within-country inequality

A general increase in income inequality in OECD countries from the mid-1980s to the late 2000s has been observed (OECD, 2011b). In 2008, the Gini coefficient ranged between 0.25 and 0.40 for all countries except Mexico and Turkey, while in 1985 it was between 0.20 and 0.35. Only Turkey and Greece experienced a decline in inequality over the period. Looking at the extreme ends of national income distributions, in 2008 the average income of the richest 10% of the population was about nine times that of the poorest 10%, although this ratio varies widely from one country to another.

The OECD study also found that income inequality is generally higher in the large emerging economies (EEs) than in the OECD on average (ibid.). The highest level of inequality is found in South Africa, with a Gini close to 0.7, followed by Brazil, while Indonesia, India and China have the lowest inequality levels within this group of countries. Except for Brazil and Indonesia, inequality has risen in all the EEs over the last two decades, with China and India experiencing the largest increase in Gini coefficient. Hence, changes in national income distributions in both the OECD and the EEs have contributed to the observed increase in within-country inequality. And while both groups of countries now face the same challenge of reducing inequality (or at least avoid rising inequality) while ensuring growth and employment, the urgency and need of job creation is arguably much greater in the EEs.

[Note from the authors: the SOD will provide analyses from developing countries, e.g. from (AB Atkinson et al., 2011)]

Relationship between within-country inequality in income and consumption

There is a large literature examining income and consumption inequality and their relationship at the country level. For example, several recent studies have examined changes in these inequality measures in the United States since the 1960s and more recently (Johnson et al., 2005); (Krueger and Perri, 2006); (Blundell et al., 2008); (BD Meyer and JX Sullivan, 2010). Both income and consumption inequality rise in the early 1980s and remain somewhat flat in the 1990s, but in the 2000s overall consumption inequality shows little change while overall income inequality rises. Most of these studies also find that consumption inequality is less pronounced than income inequality, particularly for the bottom half of the distribution. Financial markets, insurance, benefit schemes, and tax systems played important roles in mitigating the consumption effects of idiosyncratic income fluctuations, although recently financial markets have arguably sometimes had the opposite effect. Similarly, in Italy, between 1980 and 2006 income inequality has been higher and has grown faster than consumption inequality (Jappelli and Pistaferri, 2010).

Some studies focus on consumption and income trends for vulnerable groups in society. For example, Meyer and Sullivan (2008) analyzed the change in well-being of single mother-headed families in the United States between and 1993 and 2003 and found that trends in consumption did not follow those of income, especially for families at the bottom of distribution.

Global interpersonal inequality

Preliminary estimates indicate that the level of global interpersonal inequality is very high, with a Gini coefficient between 0.630 and 0.686 in the 1990s (Anand and Segal, 2008). [Note: In the SOD, this will be verified through other studies and the direction of change in global interpersonal inequality will also be discussed, if appropriate literature exists].

4.4.1.3 The effect of inequality on consumption behaviour

Income distributions within and between countries have significant influence on the patterns of consumption. Due to the unequal distribution of income in the world, a large share of goods and services produced are luxuries that the wealthy are able to pay for, while the poor are unable to afford basic goods and services (Khor, 2011). The impacts of increasing income inequality on consumption behaviour have been examined in several countries, with mixed conclusions. In China, Jin et al. (2010) show that urban households over the period 1997 -2006 tend to save more and consume less for status seeking or upgrading, particularly among poorer and younger people. Income inequality was one of the factors encouraging families in all groups to invest more in children's education. Bradbury (2004) examined the consumption effects of changes in intra-household inequality. He found that in the United Kingdom, within-household income distribution had a significant impact on expenditure, while in Australia changes in income distribution had no significant effect on expenditure.

4.4.1.4 Relationship between consumption and well-being

High and increasing levels of resource consumption are important underlying causes of global warming and environmental degradation in general (Pogutz and Micale, 2011). Reducing the level of material consumption for affluent populations is therefore increasingly being suggested as a necessary element of sustainable development including safeguarding the climate (Assadourian, 2010; Pogutz and Micale, 2011). In this regard it is important to discuss how consumption affects human well-being or happiness (Ahuvia and Friedman, 1998; Tukker et al., 2006).

Happiness is an ambiguous concept that is often used as a catchword for subjective well-being (SWB). SWB is multidimensional and includes both cognitive and affective components (Kahneman et al., 2003). The former refers to the evaluative judgments individuals make when they think about their life and are found in life satisfaction or ladder-of-life data, whereas affective or emotional well-being refers to the emotional quality of an individual's everyday experience and are captured by surveys about the intensity and prevalence of feelings along the day (Kahneman and A Deaton, 2010). [2] Camfield and Skevington (2008) examine the relationship between SWB and quality of life (QoL) as used in the literature. They find that SWB and QoL are virtually synonymous with each other; that they both contain a substantial element of life satisfaction, and that health and income are key determinants of SWB or QoL, while low income and high inequality are both associated with poor health and high morbidity.

The "Easterlin paradox" refers to an emerging body of literature suggesting that while there is little or no relationship between SWB and the aggregate income of countries or long-term GDP growth, there is robust evidence that *within* countries those with more income are happier (Easterlin, 1973, 1995). Absolute income is, it is argued, only important for happiness when income is very low, while relative income (or income equality) is important for happiness at a wide range of income levels (Layard, 2005; AE Clark et al., 2008). These insights have been used to question whether economic growth should be a primary goal of government policy (for rich countries), instead of, for example, focusing on reducing inequality within countries and globally, and on maximizing subjective well-being.

The Easterlin paradox has been contested in comparisons across countries (AS Deaton, 2008) and over time (Stevenson and Wolfers, 2008; Sacks et al., 2010), on the basis of the World Gallup survey of well-being. These works establish a clear linear relationship between average levels of ladder-of-life satisfaction and the logarithm of GDP per capita across countries, and find no satiation point beyond which wealthier countries have no further increases in subjective well-being. Through time series analysis within countries, they also find that economic growth is associated with rising

[2] Kahneman and Deaton (2010) define emotional well-being as "the frequency and intensity of experiences of joy, fascination, anxiety, sadness, anger, and affection that makes one's life pleasant or unpleasant".

happiness over time. On this basis they picture a strong role for absolute income and a more limited role for relative income comparisons in determining happiness.

These results contrast with studies of emotional well-being, which generally find a weak relationship between income and well-being at higher income levels (Kahneman and Deaton 2010). In the US, for example, Kahneman and Deaton (2010) find a clear satiation effect, i.e. beyond around $75,000 (just above the mean US household income) further increases in income no longer improve individuals' ability to do what matters most to their emotional well-being.[3] But even for life satisfaction, there is contrasting evidence. In particular, in Deaton (2008) there is a lot of variation of SWB between countries at the same level of development, and in Sacks et al. (2010) the long term positive relationship between income and life satisfaction is weakly significant and sensitive to the sample of countries (see also Graham (2009), Easterlin et al. (2010), Di Tella and MacCulloch (2010)). Assadourian (2010) argues that increased material wealth above a certain threshold does not contribute to subjective well-being, and that high personal wealth has negative side-effects such as poor health. An important phenomenon is that all components of SWB, in various degrees, adapt to most changes in objective conditions of life, except a few things, such as physical pain (Kahneman et al., 2003; Layard, 2005; AE Clark et al., 2008; Graham, 2009; Di Tella and MacCulloch, 2010).

The great variability of SWB data across individuals and countries and the adaptation phenomenon suggest that these data do not provide indices of well-being that are comparable across individuals and over time. Respondents have different standards when they answer satisfaction questions at different times or in different circumstances. Therefore, the weakness of the observed link between growth and SWB is not only debated but is quite compatible with a strong and firm desire for ever-growing material consumption in the population (Fleurbaey, 2009). Decoupling growth and well-being may be more complicated than suggested by raw SWB indicators.

It has been found that inequality in society has a marked negative effect on average SWB. For example, using General Social Survey data from 1972 to 2008 in the United States, Oishi et al. (2011) found that Americans were on average happier in years with less national income inequality than in years with more inequality. They further demonstrated that this inverse relation between income inequality and happiness was explained by perceived fairness and general trust in the case of lower-income respondents: These Americans trusted other people less and perceived other people to be less fair in the years with more national income inequality than in the years with less national income inequality.

4.4.2 Policies and initiatives on sustainable production and consumption

The concepts of "sustainable consumption" and "sustainable production" represent, respectively, demand and supply side perspectives on sustainability. As pointed out by Moisander el al. (2010) the efforts of producers to minimize the environmental or social impact of a product are futile if consumers do not buy the good or service. Conversely, sustainable consumption behaviour depends on the availability and affordability of such products in the market place. Below we introduce the international policy developments that have been a key driver of the increasing research efforts in this area and then we discuss the two perspectives in turn.

The idea of sustainable consumption and production was first placed high on the policy agenda at the 1992 Earth Summit in Rio de Janeiro, and was made part of Agenda 21. Its importance was reaffirmed at the World Summit on Sustainable Development in 2002, at which governments called for the development of a 10-year Framework of Programmes (10YFP) on sustainable consumption and production, initiated in 2003 as The Marrakech Process under the guidance of UNEP and UNDESA (Tukker et al., 2010b; Schrader and Thøgersen, 2011; Pogutz and Micale, 2011). The aim of

[3] This includes such as aspects as spending time with people they like, avoiding pain and disease, and enjoying leisure. It is stressed that this result is based on a comparison across US households and do not refer to the effects of a *change* in a person's income.

the 10YFP is to "support regional and national initiatives to accelerate the shift towards sustainable consumption and production to promote social and economic development within the carrying capacity of ecosystems by addressing and, where appropriate, delinking economic growth and environmental degradation through improving efficiency and sustainability in the use of resources and production processes and reducing resource degradation, pollution and waste" (UNDESA and UNEP, 2009). An agreed draft of this framework (UNDESA and UNEP, 2009) was proposed for adoption at the UNCSD (Rio+20). [Note from the authors: information to be updated for SOD]

National and regional SCP Policies have also been developed lately. For example, in 2008, the European Commission approved the "Sustainable Consumption and Production and Sustainable Industrial Policy Action Plan", which includes proposals that will "contribute to improving the environmental performance of products and increase the demand for more sustainable goods and production technologies. It also seeks to encourage EU industry to take advantage of opportunities to innovate" (European Commission, 2008).

Other international organizations, both governmental and non-governmental, have placed new emphasis on sustainable production and consumption. For example, The Worldwatch Institute's *2010 State of the World Report* discussed the need for a transformation of cultures "from consumerism to sustainability" (Worldwatch Institute, 2010), while the main theme of the United Nations Industrial Development Organization's General Conference in 2011 was inclusive and sustainable industrial development strategies (UNIDO, 2011).

4.4.3 Sustainable consumption and lifestyle

[Note from the authors: This section will be further developed in the SOD through inputs from Contributing Authors John Thøgersen and Tim Jackson]

A rich research literature on sustainable production and consumption has developed over the past decade, including five special issues of international journals (Tukker et al., 2010b; Le Blanc, 2010; Kilbourne, 2010; I Black, 2010; Schrader and Thøgersen, 2011). Several books, such as *Prosperity without Growth* (T Jackson, 2009), discuss the unsustainable nature of current lifestyles, development trajectories, and economic systems, and how these could be changed in more sustainable directions.

Numerous definitions of *sustainable consumption* have been formulated within policy, business and academia (Pogutz and Micale, 2011). A group of about 40 scientists developed a joint perspective at a meeting in Oslo in 2005:

> *The future course of the world depends on humanity's ability to provide a high quality of life for a prospective nine billion people without exhausting the Earth's resources or irreparably damaging its natural systems … In this context, sustainable consumption focuses on formulating strategies that foster the highest quality of life, the efficient use of natural resources, and the effective satisfaction of human needs while simultaneously promoting equitable social development, economic competitiveness, and technological innovation.* (Tukker et al., 2006)

This broad definition encompasses not only demand-side issues but also production ones, and it addresses all three pillars of sustainable development as well as equity and well-being, illustrating the complexity of sustainable consumption and its connections to a range of other issues.

Research on sustainable consumption demonstrate that consumption practices and patterns are influenced by a range of economic, informational, psychological, sociological, and cultural factors, operating at different levels or spheres in society, including the individual, the family, the locality, the market and the work place. Furthermore, purchasing decisions have proven to be highly contextual and often inconsistent with peoples' values, attitudes, and perceptions of themselves as responsible and green consumers and citizens, as explained below. Studies of consumption behaviour demonstrate the presence of an "attitude-behaviour" or "values-action" gap (W Young et al., 2010; Thøgersen and Schrader, 2012), whereby self-declared green consumers fail to adopt sustainable consumption patterns and lifestyles. This is due to a range of factors affecting purchasing decisions, notably high transactions costs (i.e., time for research, analysis of information, and product search), affordability, and the influence of non-green criteria, such as habit, quality, size, brand, discounts, and retailer preference (W Young et al., 2010). There is also great variation in consumer behaviour across different product categories (regarding, e.g., how information is obtained), and also some variance within sectors (McDonald et al., 2009). These findings question the notion of "the green consumer" and highlights the inconsistencies in individual purchasing behaviour (Csutora, 2012) – i.e., how values and attitudes are translated into consumption practice varies according to sector, product and situation.

The sustainable consumption of goods and services can be viewed in the broader context of lifestyle and everyday life. For example, Hall (2011) observes that ethical consumer discourses inform everyday family consumption processes and narratives. Conversely, sustainable consumption practices are bound up with perceptions of identity, ideas of good life, and so on, and considered alongside other concerns such as affordability and health. Ethical consumption choices are also negotiated among family members with divergent priorities and interpretations of sustainability.

Other research draws attention to the limits placed on consumption and lifestyle choices by factors beyond the influence of the individual, family or community, which tends to lock consumption into unsustainable patterns by reducing "green agency" at the micro level (Pogutz and Micale, 2011). These structural issues include product availability, cultural norms and beliefs, and working life conditions which favour a "work-and-spend lifestyle" (Sanne, 2002). In this regard, by viewing marketing as a technique and practice of government of consumers, where "government" is understood broadly as the *conduct of conduct* following the ideas of Foucault (Dean, 1999), Moisander et al. (2010) questions "the individualistic view of the consumer as a powerful political agent and market actor" independent of her social and cultural environment. Instead, they argue, green consumer behaviour should be analyzed in the context of the different networks of power that constitute the conditions of subjectivity and agency in the market. For example, marketing campaigns tend to emphasize norms and ideas consistent with the logic of economic rationality according to which price is the paramount decision parameter for sensible consumers (ibid.). This preoccupation with discounts and bargains arguably diverts the attention (of consumers and corporate buyers) away from the ethical and environmental attributes of products. Strong price competition at the retail level may also have ramifications for sustainability in upstream segments of the value chain.

It has been observed that the strength and pervasiveness of such structural factors, and the inadequate attention to them by policy, is an important cause of the lack of real progress towards more sustainable consumption patterns (Tukker et al., 2006; Le Blanc, 2010; Schrader and Thøgersen, 2011). Furthermore, the unsustainable lifestyles in industrialized countries seem to be largely reproduced by the growing elites (Pow, 2011) and middle-class populations in developing countries. [Note from the authors: More references will be added on this subject in the SOD.]

4.4.3.1 Consumer attitudes to the environment and to environmental declarations

The achievement of more sustainable consumption patterns depends on how consumers value environmental quality and other dimensions of sustainability. It also depends on whether people believe that their consumption practices make a difference to sustainability, which in turn is influenced by how much they trust the environmental information provided to them by companies and public authorities. Surveys and case studies have been done in recent years that help illuminate these issues. In a recent survey of European attitudes towards the issue of sustainable consumption and production (Gallup Organization, 2009), 84 percent of EU citizens said that the product's impact on the environment is "very important" or "rather important" when making purchasing decisions. This puts the environment in a third place among the product attributes that consumers say influence their shopping practices, after quality and price. Similarly, 77 percent said they always or often take energy efficiency into account when buying electricity or fuel-consuming products.

[Note from the authors: Studies from other regions will be referenced in the SOD]

Information about the carbon footprint of products (see below) is a form of environmental declaration used by producers and retailers to communicate their climate mitigation efforts to, respectively, corporate buyers and consumers. Bolwig et al. (2012) reviewed studies of how consumers perceive the carbon footprinting (including labelling) of products and companies' climate change policies in general.[4] On the whole, consumers are showing some interest in product carbon footprint (PCF) information and would probably prefer carbon-labelled products and firms over others, other things being equal. It is also likely that a minority are, or would be, willing to pay a price premium for products with significantly lower footprints than like ones. But consumers are also sceptical about the credibility of the "climate-friendly" claims made by retailers and manufacturers and show a preference for third-party verification (ibid.). According to the Gallup survey mentioned above, only 10% of European consumers found the carbon footprint to be the most important information that an ecolabel should contain (Gallup Organization, 2009). Strong support for product carbon labelling was nevertheless identified: 72% of EU citizens thought that carbon labelling should be mandatory in the future.

Only limited ex-post information is available on consumers' reactions to carbon labelled products. Vanclay et al. (2010) monitored sales records of 37 products from five high-volume grocery sales lines, using a colour-coded footprint label indicating the relative life-cycle CO_2 emissions compared with other items in the product line. They found a strong purchasing response of 20% when the green-labelled product was also the cheapest, and a much weaker response when green-labelled products were not the cheapest. Interviews of PCF scheme operators reported in Bolwig et al. (2012) suggests that consumers in New Zealand, the United Kingdom and the United States show an increasing understanding of the PCF concept, while consumer understanding in Germany is deemed to be low.

4.4.3.2 Fostering the transition to sustainable consumption and lifestyles

[Note from the authors: This subsection will be completed in the SOD using the following references, among others: (Tukker et al., 2006): The "Oslo Declaration on Sustainable Consumption". (Thøgersen and Schrader, 2012): New paths toward sustainable consumption. (Tukker et al., 2010b): Effective policies for changing consumer behaviour towards more sustainable practices. Assadourian (2010): the need for a cultural transformation from consumerism to sustainability. (IR Black and Cherrier, 2010): Anti-consumption and sustainable lifestyles. (Sheth et al., 2010): A business case for fostering mindful consumption.]

4.4.4 Sustainable production

[Note from the authors: this section will be further developed in the SOD through inputs from Contributing Author Michael Zwicky Hauschild]

Research and initiatives on *sustainable production* have been concerned with increasing the resource efficiency of, and reducing the pollution and waste from, the production of goods and services through technological innovations in process and product design at the plant and product levels, and, more lately, through system-wide innovations at the level of the supply chain or production network (Pogutz and Micale, 2011). Eco-efficiency – a concept coined by the World Business Council for Sustainable Development in 1992 (Schmidheiny and WBSCD, 1992) – is the main management philosophy guiding sustainable production initiatives among companies (Pogutz and

[4] A number of country-level studies have been carried out on climate-change issues since 2006, including at least six studies of UK consumers, two of Swedish consumers, one of US consumers and one of UK and US consumers jointly. Almost all deal with the climate change impacts of food.

Micale, 2011). Technical and natural science research on sustainable production involves the fields of industrial ecology (and its sub-discipline industrial symbiosis) as well as Design for Environment, Life Cycle Assessment (LCA), and other environmental assessment tools. The social dimensions of sustainable production have, naturally, been examined by social science disciplines such as economic sociology, human geography and economics, addressing such issues as worker conditions (Riisgaard, 2009), farm income (Bolwig et al., 2009), inclusion of small producers into value chains (Bolwig et al., 2010; J Mitchell and Coles, 2011) and the role of standards in fostering sustainability in different institutional and economic contexts (Gibbon et al., 2010). Recently, the LCA methodology has been elaborated to include assessment of social impacts along the life-cycle of products, such as labour rights (Dreyer et al., 2010).

4.4.5 Consumption patterns and carbon (or GHG) accounting

Carbon (or GHG) accounting refers to the calculation of the GHG emissions associated with economic activities at a given scale or with respect to a given unit. GHG accounting has traditionally focused on emission sources, but in recent years there has been a growing interest in analyzing the drivers of emissions by calculating the GHG emissions that occur along the supply chain of a functional unit such as a product or household (G Peters, 2010). The result of this calculation is often referred to as “carbon footprint”, even if it involves other GHGs than just CO_2. A carbon footprint in principle includes all emissions generated during the life-cycle of a product, i.e. from production and distribution to end-use and disposal or recycling, where “product” refers to any good or service (see below). Emission drivers are not limited to the consumption behaviour of individuals, however, but include also the wider contexts of consumption such as infrastructure, production systems and energy systems, which are beyond the control of individuals (ibid.) (see Sec. 4.3 and below). Carbon footprints have therefore been estimated with respect to different functional units at different scales, including products, households, companies, countries, cities and regions (G Peters, 2010; D Pandey et al., 2011).

A carbon footprint is expressed in CO_2 equivalents per unit (e.g., household) for a given time period (typically one year) except in the case of product carbon footprints where the time frame is the product life cycle. The emissions associated with the functional unit (but physically not part of the unit) are referred to as “embodied carbon”, “carbon flows” or similar terms (ibid.).

Carbon footprinting involves a range of uncertainties and methodological choices (particularly regarding setting of system boundaries), which can significantly affect the result. And there is no single accepted methodology (D Pandey et al., 2011), although several international carbon footprint standards have been developed, e.g. for product carbon footprints (see below). Neither is there one widely accepted definition of carbon footprint. A definition that attempts to allow for all possible applications across scales is offered by Peters (2010) as “The ‘carbon footprint’ of a functional unit is the climate impact under a specific metric that considers all relevant emission sources, sinks and storage in both consumption and production within the specified spatial and temporal system boundary”.

4.4.5.1 Choice of accounting method

In the last decade, new accounting methods for assessing CO_2 and overall GHG emissions have emerged and proliferated in response to interest in 1) determining whether nations are reducing emissions (Bows and J Barrett, 2010), 2) fixing GHG responsibility (GP Peters and EG Hertwich, 2008; Bows and J Barrett, 2010; SJ Davis and Caldeira, 2010), 3) assuring the accountability of carbon markets (Stechemesser and Guenther, 2012), 4) determining the full implications of alternative energy technologies (von Blottnitz and Curran, 2007; Martínez et al., 2009; Cherubini et al., 2009), 5) helping corporations become greener (TO Wiedmann et al., 2009), and 6) encouraging consumers to reduce their carbon footprints (CM Jones and Kammen, 2011; Bolwig et al., 2012). Most methods simply address CO_2; some also include other GHGs, while others also consider a range of non-GHG environmental impacts. Methods differ, with normative implications, on whether consumers or producers of products are responsible; whether emissions embedded in past or potential replacement of capital investments are included; and whether indirect emissions, for example through global land-use change resulting from changing product prices, are included (Finkbeiner, 2009; Plevin et al., 2010; Plassmann et al., 2010).

Most emissions accounting methods use a life-cycle assessment approach, but differ as to whether the analysis uses economic input-output (EIO) tables to assess emissions (LCA-EIO) or the analysis tailors the approach to the best data and assumptions for the particular uses to which the analysis may be put. LCA-EIO provides analytical consistency across products but incorporates historic average emissions by economic sector.[5] Tailored approaches such as activity-based or process LCA can use more recent and specialized data, be more forward looking, and address incremental changes. Finally, hybrid LCA methods combining LCA-EIO and process-LCA are increasingly been applied (Williams et al., 2009; G Peters, 2010), including the waste input-output model (Suh and Nakamura, 2007) and the multiregional input-output model (EG Hertwich and GP Peters, 2009).

There is no correct way to account for GHG emissions. Better ways may be excessively expensive given the plausible importance of the value of better information in the decision process. Some interests will plead for standardized techniques based on past data because it favours them. Others will argue for tailored approaches that make their technologies or products look good. Producers favour responsibility being assigned to consumers, as do nations that are net exporters of industrial goods.

Controversies over accounting approaches play into issues of GHG and environmental governance more broadly. Whether a consumption decision in one country affects GHG emissions in other countries through the supply chain depends heavily on whether those other countries have GHG policies in place that are enforced. Whether carbon markets are effective or not depends on good accounting and enforcement, but what will be enforced will depend on the accounting measures agreed upon.

[Note from the authors: in the SOD there will be a discussion here of non-technical constraints from, e.g., the legal environment that could bias the choice towards one method or another. There will also be a discussion of how governments, private actors and NGOs negotiate about norms and standards for GHG accounting.]

4.4.5.2 Carbon footprint of consumption (consumption-based GHG accounting)

Consumption-based accounting of GHG emissions, or carbon footprinting, starts from the premise that the responsibility for GHG emissions from economic activity lies with people's attempts to satisfy certain functional needs and desires (Druckman and T Jackson, 2009). These needs and desires are expressed in the consumer demand for goods and services, and it is this demand which drives the production processes that consume resources – including energy resources – and emit pollutants – including CO_2 and other GHGs (ibid.). Hertwich and Peters (2009) analyzed the global carbon footprint (CO_2 and other GHGs) for different consumption categories and final uses. Globally, 72% of embodied GHG emissions are related to household consumption, 10% to government consumption and 18% to investments. The most important consumption category is food, accounting for nearly 20% of emissions (with methane and nitrous oxide emissions from agriculture

[5] Input-output tables are economic accounts representing all activities at the meso (sector) level (TO Wiedmann and J Minx, 2007). In combination with environmental data they can be used to estimate consumption-based GHG emissions, taking into account all higher-order impacts and setting the whole economic system as boundary. EIO analysis is less suitable for assessing micro systems such as products, as it assumes homogeneity of prices, outputs and their carbon emissions at the sector level. EIO analyses emissions vary with respect to the way emissions are estimated, categorised and allocated, which can complicate the comparison of results.

playing significant roles), followed by housing/shelter (19%), mobility (17%), services (16%), and manufactured products (13%).

[Note from the authors: For the SOD, these figures will be summarized and illustrated by a graph]

At the national level, a consumption-based framework for GHG emission accounting differs from the production-based or territorial framework because of imports and exports of goods and services that, directly or indirectly, involve GHG emissions (SJ Davis and Caldeira, 2010). The territorial framework allocates the emissions physically produced within a nation's territorial boundary to that nation. The consumption-based framework allocates the emissions associated with (released by the supply chain of) goods and services consumed by residents of a nation irrespective of their territorial origin. The difference in inventories calculated based on the two frameworks are the emissions embodied in trade (GP Peters and EG Hertwich, 2008; Bows and J Barrett, 2010). One argument put in favour of a consumption-based framework is that, unlike the territorial approach, current emissions inventories cannot be reduced by outsourcing production or increasing the reliance on imports to meet final demand for consumption; both of these mechanisms are strong trends. Hence, it is argued, a consumption-based approach gives a fairer illustration of the responsibility of current emissions (GP Peters and EG Hertwich, 2008; Bows and J Barrett, 2010). A consumption-based approach arguably also increases the range of policy options to reduce emissions reductions by identifying the distribution of GHG emissions among different categories of final uses (demand), geographical locations (e.g. urban, suburban and rural) and household types. This allows for better targeting of policies as well as voluntary actions by actors such as citizens, corporations and cities (Bows and J Barrett, 2010; CM Jones and Kammen, 2011). In this regard, by revealing where emissions are produced along international supply chains and transport routes, the calculation of product life-cycle emissions enables buyers – motivated by corporate policy or consumer pressure – to influence emission reductions in third countries and in shipping and aviation sectors.

Consumption-based approaches also have drawbacks. First, there are important methodological complexities and uncertainties involved, for example in estimating product life-cycle emissions (Finkbeiner, 2009; Plassmann et al., 2010; Bolwig et al., 2012), affecting the credibility, fairness and cost-effectiveness of consumption-based measures. Second, reducing emission at the "consumption end" of supply chains requires changing deeply entrenched patterns of lifestyle and specific behaviours among millions of actors/households with diverse characteristics and preferences (as opposed to among the much fewer actors emitting GHG at the source). Finally, because market dynamics are driven not only by demand but also by supply, consumption-based approaches to emission reduction must be combined with production-based approaches.

4.4.5.3 Carbon footprint of households

Several recent studies have analyzed the climate impact of consumption at the level of the household, using variants of LCA-EIO analysis. Overall this research finds that the carbon footprint of consumption varies substantially between countries and household categories, and that it is increasing. A cross-country study by Hertwich and Peters (2009) analyzed the carbon footprint of consumption as a function of per capita expenditure and grouped by continent. They found that the average per capita footprint varies from around 1 tonne per person per year for several African countries to 28 tons/year for the United States. In the United Kingdom, Druckman and Jackson (2009) estimated the average CO_2 emissions per person at roughly 21 tonnes in 2004. The growth in CO_2 household emissions was 15% on average between 1990 and 2004, and accelerated after 2000 (around 3% per year). The growth in emissions was driven by steadily rising consumption expenditures, and since 1996, increased household energy use. In the United States, Jones and

Kammen (2011) calculated the carbon footprint of the average US household to be 48 tCO_2e per year, or 20 tCO_2e per person, for 2005.[6]

[Note from the authors: For the SOD, these figures will be summarized and illustrated by a graph]

4.4.5.4 Carbon footprint of products

Concern over climate change has stimulated interest in estimating the total amount of GHGs produced during the different stages in the life-cycle of goods and services – i.e. their production, processing, transportation, sale, use and disposal. The outcome of these calculations are often referred to as a "product carbon footprint" (PCF), where "carbon footprint" is the total amount of GHGs produced for a given activity and "product" in any good or service that is marketed.

Calculating PCFs can form the basis for a range of actions undertaken by companies in response to policies and societal trends related to energy and climate change (Sinden, 2009; Bolwig et al., 2012). The outcomes may be environmental, economic, or both. First, the provision of information to consumers about the climate impact of different products through labelling or other means can influence purchasing decisions in a more climate-friendly direction and at the same time enable to differentiate one's products from those of competitors (Edwards-Jones et al., 2009). Second, product carbon footprinting can help companies reduce GHG emissions in a more cost-effective manner by identifying the various emission sources within the company and throughout the entire supply chain (Sinden, 2009; K-H Lee, 2012). A product carbon footprint can also form the basis for reducing emissions elsewhere in the economy through offsetting the life-cycle emissions that cannot so easily be reduced.

Fourth, demonstrating the ability to measure and reduce product (and whole-company) carbon footprints can help inspire confidence in a company's general performance among stakeholders. Increasing investor confidence through carbon measurement and management activities is emphasized especially by company GHG reporting schemes such as the Carbon Disclosure Project, but applies in principle also to PCF activities (Bolwig et al., 2012). However, whether investors and financial analysts incorporate climate-change information into their company analyses and valuations is not well known. In the UK, Sullivan and Gouldson (2012) found limited investor interest in the climate change-related data provided by retailers, due to two main factors. The first is that while investors have encouraged companies to report, they have paid much less attention to the quality of the reported information. The second is that company reporting on climate change falls far short of the quality required for investors to make meaningful comparisons between companies (see also Chapter 15.)

Product carbon footprinting could also have unintended economic, social and environmental outcomes. It could have cost and negative demand effects on producers and exporters in different parts of the world, including in developing countries (Edwards-Jones et al., 2009). In agro-food value chains, retailers and other "lead firms" located near consumers to a large extent define product standards and are able to push the cost of standards compliance upstream to producers (Gibbon and Ponte, 2005). There is also a risk that the implementation of PCF standards through certification schemes may involve discriminatory practices that affect competitiveness and trade (Paul Brenton et al., 2009). Finally, a one-sided focus on GHG emissions in product development and consumer choice could involve serious trade-offs with other environmental impacts (Finkbeiner, 2009). Comparing about 4000 products, technologies, and services from several sectors, Laurent et al. (2012) found that products or systems fulfilling similar functions may show similar carbon footprints but differ significantly with respect to other environmental impacts, notably those related to emissions of toxic substances. In such situations, carbon footprint is a poor representative of the environmental

[6] These figures include emissions from health services, which are counted as private expenditure in the United States.

burden of products, and suggests the use of more broadly encompassing tools to assess and manage environmental sustainability (ibid.).

Recent years have seen a proliferation of standards and certification schemes in the area of product carbon footprinting. Since 2007, two public standards, and four public and around 14 private certification schemes referring to standards for calculating and communicating PCFs have become operational (Bolwig et al., 2012). The first PCF standard with the ambition to cover a wide range of diverse products, PAS 2050, was published in October 2008 by the British Standards Institute (Sinden, 2009). In 2011 the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD) published the GHG Protocol Product Accounting and Reporting standard. And the International Office for Standardization (ISO) is planning to issue the ISO 14067 Carbon Footprint of Products standard in 2012 (Radunsky, 2009).

Most PCF certification schemes are operated by small private consultants or not-for-profit organizations, and a few by public organizations, retailers or manufacturers (Bolwig et al., 2012). Only about 6000 types of carbon-footprinted products have so far found their way to retail outlets, however (ibid.). Retailers, especially of food and beverages, have been involved in the development of several PCF schemes and have a preference for proprietary schemes, while producers generally prefer to use existing schemes (ibid.). In the early stages, national governments and international organizations played a minor role in the development of PCF standards[7] or certification schemes, but their involvement increased markedly after 2009, and they have been influential (Baldo et al., 2009; Bolwig et al., 2012).

With three, possibly quite similar international standards available to guide product carbon footprinting from 2012 (JK Jensen, 2012), the major challenge is to enable an affordable, consistent and credible standard implementation. This will depend on the development of comprehensive and harmonized LCA databases and product category rules and on mutual recognition by other standards of certification to any one of these standards (Bolwig et al., 2012). Common guidelines for communicating PCF information can also increase its credibility and consumer acceptance. A third task ahead is to develop methods and data bases that consider the special characteristics of production systems in developing countries (Plassmann et al., 2010).

4.4.6 Spatial dimensions of consumption and production with respect to the environment

4.4.6.1 The spatial divide between consumption and production

[Note from the authors: Coordination with Chapter 5 will be done in the first phase of writing the SOD to avoid overlap]

A characteristic feature of economic globalization is an increased geographical separation of consumption centres from sites of production, resulting from the ever more sophisticated organization of value chain activities according to the competitive advantage of different regions. This has involved a significant increase in international trade of goods and services as well as in the share of trade in global GDP (see Chapter 5). From a sustainability perspective, a central corollary of economic globalization is the increase in international flows of natural resources and emissions – including GHGs – “embodied” in traded products.

In respect of GHGs, about 25% of all CO_2 produced globally is embodied in internationally traded goods and services, according to one estimate based on 2004 data (The Carbon Trust, 2011). The flow of carbon is composed of about 50% commodities (broadly defined as materials with a spot price, e.g. steel), and 50% finished or semi-finished products (e.g. machinery, electronics and clothing). International carbon flows have been increasing over time both in absolute and relative

[7] The notable exception is standards based on the life-cycle emissions of transport fuels, especially biofuels.

terms, driven mainly by an increasing reliance of consumption in developed countries on imports and the associated increase in emissions embodied in the trade between these countries and developing countries (The Carbon Trust, 2011). For example, in the United Kingdom from 1992 to 2004, emissions from domestic production rose only 2.1%, while the net impact of the import and export of emissions embodied in trade ("net imported emissions") increased by 395% (The Carbon Trust, 2011). As a result, the share of "net imported emissions" increased from 7% to 34% of domestic production emissions over the period, and comprised 40% of the country's consumption emission in 2004.[8]

The dominant net effect of international trade is the export of GHG emissions from China and other emerging markets to consumers in the United States, Japan and Western Europe (SJ Davis and Caldeira, 2010). In Western Europe, net imported emissions are 20% to 50% of consumption, whereas in Japan and United States they are around 18% and 11%, respectively. In contrast, net exports represent about 23% of emissions produced in China (ibid.). In the United Kingdom, only 33% of "net imported emissions" are from Annex 1 countries, and only 13% of these emissions have arisen in the EU ETS zone (The Carbon Trust, 2011).

4.4.6.2 Spatial considerations in sustainability assessments

[Note from the authors: This section will be written for the SOD. It will discuss the importance of the choice of scale and thematic/sectoral boundary definitions for sustainability assessments, and how these choices can affect results and serve specific interests. Two references have been identified so far: (Dresen and Jandewerth, 2012): Integration of spatial analyses into LCA – calculating GHG emissions with geoinformation systems. (van der Horst and Vermeylen, 2011): Spatial scale and social impacts of biofuel production. It is being considered to invite a Contributing author to lead the writing of the section.]

4.5 Development pathways

4.5.1 Development pathways: definition, concepts and examples

4.5.1.1 Definition and examples of development pathways

Though widely used in the literature, the concept of development path (development "path" and development "pathway" are synonymous[9]) has rarely been defined. According to AR4 (IPCC, 2007), a development path is "an evolution based on an array of technological, economic, social, institutional, cultural, and biophysical characteristics that determine the interactions between human and natural systems, including consumption and production patterns in all countries, over time at a particular scale" (Glossary, p.813). AR4 also indicates that "alternative development paths refer to different possible trajectories of development, the continuation of current trends being just one of the many paths".

The AR4 definition suggests that a development path is global ("including consumption and production patterns in all countries"). However, the concept is used in the literature – including in the IPCC AR4 – to describe development trajectories at other scales: regional (e.g., Li and Zhang (2008)), national (e.g., Poteete (2009)) and subnational (e.g., Dusyk et al. (2009) at provincial scale and Yigitcanlar et Velibeyoglu (2008) at city scale). In the present report, a development path will

[8] The net imported emissions are projected to increase further, to 73% to 96% of production emissions by 2025, driven by an increasing trade imbalance and a higher level of decarbonization of production in the United Kingdom compared to its main trading partners (The Carbon Trust, 2011).

[9] In biology, the concept of development pathway has a clear definition: "a sequence of biological or biochemical events that are involved in embryological or cellular development" (National Cancer Institute (NCI), 2011). We thus prefer to use the term development path in this report, which to our knowledge has not been "pre-empted' by other disciplines.

characterize all the interactions between human and natural systems on a particular territory, regardless of scale.

By pointing to all the “interactions between human and natural systems”, the AR4 definition insists on the holistic character of the concept. A development path is broader than the development trajectory of a particular sector, or of a particular group of people within a society. One important implication is that a development path cannot be described by a single indicator. On the contrary, a wide range of economic, social and environmental indicators is necessary, not all of which may be amenable to a quantitative representation.

As defined by AR4, however, a “path” is not taken as a random collection of indicators, but as having an internal narrative and causal consistency that can be captured by the *determinants* of the interactions between human and natural systems. The underlying assumption is that the observed development trajectory – as recorded by various economic, social and environmental indicators – can be explained by identifiable drivers. This roots the concept of development path in the (dominant) intellectual tradition according to which history has some degree of intelligibility (while another tradition holds that history is a chaotic set of events that is essentially not intelligible (Schopenhauer, 1819), with two important methodological consequences.

Looking backward, assessing past development paths amounts not only to describing how a given society has evolved over time, but also to understanding the mechanisms that have shaped this evolution. Past development paths can thus be described using only limited information (i.e., the mechanisms) instead of the whole range of indicators mentioned above. And to the extent the underlying mechanisms are general enough, one can search for typologies of development paths beyond the particular experience of each region. In fact, there is a large literature that describes observed development trajectories for given territories and analyses the underlying processes. In the field of economics only, this literature encompasses most of the growth literature and a large part of the (macro) development literature.[10] In this report, we narrow it down somewhat by concentrating on the links between the development path and the parameters of interest to mitigation, i.e., emissions and mitigative capacity, though the underlying literature remains large as emissions and mitigative capacity derive from the development patterns of virtually all the sectors of the economy.

Looking forward, it is of course impossible to predict how a society will evolve in the future. Still, plausible development paths can be generated by playing with different drivers. There is, again, a large literature of forward-looking studies that construct plausible development paths for the future and that examine the way by which development might be steered towards one path or another. **Error! Reference source not found.** briefly reviews the main forward-looking development paths published since AR4.

[10] This literature can itself be divided in two main groups: papers aimed at identifying individual mechanisms that drive development trajectories, and papers aimed at identifying broad patterns of development. One example of the former is the so-called “EKC” literature on the relationships between GDP and emissions, which is discussed later in the chapter. One example of the latter is the so-called “investment development path” literature, which, following Dunning (1981), identifies stages of development for countries based on the direction of foreign direct investment flows and the competitiveness of domestic firms on international markets.

Box 4.1 Forward-Looking Development Paths since AR4

The role of forward-looking development paths is to illuminate the universe of possible futures, and to provide a sense of the means and constraints of how those futures can be reached or avoided. Plausible paths can be constructed using various techniques, ranging from simulations with numerical models to qualitative scenario construction or group forecasting exercises (van Notten et al., 2003).

AR4 reviews development path scenarios (Sathaye et al. (2007), Sec. 12.2.1.2) and their implications for GHG emissions. New possible development paths have been proposed in the literature since then. At the global scale, they include, inter alia, the World Bank 2010 climate smart path (World Bank, 2010b), Tellus Institute scenarios (Raskin et al. (2010)), or degrowth strategies (Martínez-Alier et al., 2010). In addition, a set of new scenarios has been developed for the AR5 (Moss et al., 2010). They are described in detail in Chapter 6. There has also been considerable effort in designing sectoral pathways, e.g., on biodiversity (P Leadley et al., 2010; Pereira et al., 2010), health (Etienne and Asamoa-Baah, 2010), or agriculture (Paillard et al., 2010).

Another important development since AR4 is the emerging "green growth" concept (OECD, 2011a). Though the term does not have a consensus definition, there is agreement that green growth "is about making growth processes resource efficient, cleaner and more resilient without necessarily slowing them" (Hallegate et al., 2011), effectively putting together the economic and environmental pillars of sustainable development. Under the green growth label, short- to medium-term scenario exercises are underway in many countries and regions (e.g. Republic of Korea (2009), Jaeger et al. (2011)).

4.5.1.2 Development pathways, path dependence and lock-ins

An important issue for policy-making is to understand how and to which extent the mechanisms that drive the pathways create "path dependence" – the tendency for past decisions and events to self-reinforce, thereby diminishing and possibly excluding the prospects for alternatives to emerge. If "path dependence" is not identified ex ante, decisions are taken without taking their full consequences into account. If "path dependence" is identified ex ante, it provides a basis for making better-informed decisions. For example, developing of inter-city highways may both make further extension of the road network more likely (if only for feeder roads) and make further extension of rail networks less cost-effective by drawing out traffic and investment financing. Taking these mechanisms into account does not necessarily mean that the inter-city highway system is not socially beneficial – it merely acknowledges that presence of an extensive highway system influences and may diminish the future prospects for investing in alternative transportation options.

Page (2006) provides a taxonomy of cases in which path dependence occurs. He distinguishes between outcome-dependent processes – in which the outcome at one period (e.g., the best decision at year t) depends on past outcomes – and equilibrium-dependent processes – in which the long-run distribution over outcomes depends on past outcomes. If there are good reasons for looking at the former, the latter is of particular relevance in the perspective of mitigation. Second, he distinguishes between recent-path dependence, in which outcome at year t depend only on outcomes at recent periods, and early-path dependence, in which outcomes at year t depend only on the outcomes of a finite set of early periods. In the latter case, late outcomes are *locked-in*.

On this basis, Page (2006) looks at the mechanisms that may generate path dependence. Among those, "increasing returns" – i.e., mechanisms which make one outcome more likely if the outcome at one period increases the probability of generating that same outcome at next period – are the best known. "Increasing returns" mechanisms include, inter alia, increasing returns to scale, learning by doing, induced technological change, or agglomeration economies. The concept of increasing returns has a long tradition in economic history, and the implications of increasing returns mechanisms have been systematically explored over the past three decades or so, notably around issues of monopolistic competition (Dixit and Stiglitz, 1977), international trade (PR Krugman, 1979), economic geography (Fujita et al., 1999), economic growth (Romer, 1990), industrial organizations or adoption of technologies (Arthur, 1989).

Yet Page demonstrates that “increasing returns” mechanisms are neither sufficient for path dependence – as competing “increasing returns” might cancel out – nor sufficient to generate equilibrium dependence. A much broader array of mechanisms might generate path dependence and equilibrium dependence. First, choices typically involve the use of scarce resources, such as land, labour or exhaustible natural resources. Decisions made at one point in time thus constrain future agents’ options, either temporarily (for labour) or permanently (for exhaustible resources). Second, in the presence of switching costs – e.g., resignation fees imposed by telecom operators on consumers, or costs attached to premature replacement of long-lived capital stock – decisions made at one point in time can partially or totally lock-in decision-makers’ subsequent choices (Farrell and Klemperer, 2007). Third, negative externalities of outcomes at time *t* to outcomes at future periods, such as environmental externalities, can lead to path dependence. Fourth, complementarities between outcomes, and not increasing returns per se, might also generate equilibrium dependence. For example, choosing one type of institution may favour the emergence of other complementary institutions that in turn favour the emergence of the first one, and so on. This list is not comprehensive, as the literature does not provide one, but the key message is that, when analyzing the determinants of pathways (past or anticipated), it is important not to focus only on “increasing returns” but to look more broadly for mechanisms that may generate path dependence.

The most extreme manifestation of path dependence is the lock-in. Though widely used in the economic and innovation literature, the term “lock-in” does not have a single definition, but rather various (if closely related) meanings. In the presence of “switching costs”, decisions made at one point in time can partially or totally lock-in decision-makers’ subsequent choices – making it very costly to reverse ex post choices that were not necessarily economically distinguishable ex ante (Farrell and Klemperer, 2007). One famous example is the competition between technology standards, for example between the AZERTY and the QWERTY keyboards, or between the VHS and BETAMAX video standards. In the economic geography literature, positive feedback such as agglomeration economies can also lock in the growth/expansion path of locations/regions once initial choices are made (Fujita et al., 1999).

Path dependence and lock-ins can be quite significant from the climate standpoint. From an empirical point of view, lock-ins might be significant for emissions. For example, Shalizi and Lecocq (2009) note:

> *...the share of long-lived capital stock in total emissions is large, and because emissions path tends to be locked-in for long periods of time once capacity is installed, inability to influence the emissions from this portion of total capital stock to meet an emissions target by a given date will necessitate greater and possibly earlier effort on the remainder of the capital stock – particularly if, with new information, the emissions reduction targets have to become deeper than currently anticipated.*

Sector chapters provide detail accounts of how path dependence and lock-ins matter in their respective case. From an economic theory point of view, Liebowitz and Margolis (1995) argue that inefficiencies arise with path dependence only when decisions are not optimal based on the information available ex ante. Yet agents need not be irrational for making decisions based only on part of the information available: differences between local and global optimum, time and resource constraints on the decision-making process or information asymmetry can lead rational agents to seemingly irrational decisions (Foray, 1997). So providing more information about potential causes of path dependence (i.e., providing more information) and identifying institutional reasons why agents may not make choices consistent with all the information that is globally available (i.e., examining how information might be better used) are critical for improved decision-marking.

4.5.2 Differences between pathways, with regard to emissions

As outlined above, there are many plausible development paths for the future. In this subsection, we focus on how development paths differ with regard to the level of GHG emissions. Level of emissions is of course essential because it drives concentration and impacts. In the next section, we focus on how development paths differ with regard to mitigative capacity.[11]

The relationship between a development path and GHG emissions is not straightforward. In some cases, there might be direct relationship between the two. For example, choices of coal- vs. non-coal energy futures have direct implications for GHG emissions from electricity and heat generation. In others, the relationship between the two is much less evident. Looking toward the future, for example, the relationship between the shape (compact or extended) of a given city and its transport emissions is controversial, as a lot depends on job localization and on technology (in particular, availability of low or zero emissions technology).

To better understand the implications for GHG emissions, one has to study the material content of the development path, i.e., the combination of consumption patterns, location of people and activities, and nature of technologies. Approaches and tools reviewed in Sec. 4.4 provide basis for such analysis. Case studies pertaining to this line of work include Parag and Darby (2009) for the residential sector in the UK or Shobhakar (2009) for cities in China, Lee and Ryu (1991) for Korea, and Davidson (1993) for energy in Sub-Saharan Africa, among others.

On the other hand, considerable attention has been paid in the literature to the relationship between one component of development path, namely economic growth, and GHG emissions. AR4 (IPCC, 2007) concluded that econometric work on the so-called "environmental Kuznets curve" (ref) neither yielded to the optimistic interpretation that the problem would automatically solve itself with high levels of GDP per capita, nor to the pessimistic conclusion that there was a rigid link between GDP and emissions.

Data suggest that developing countries tend to increase their emission with economic growth as they follow developed countries' consumption pattern. Figure 4.1 shows the CO_2 emissions per capita from energy consumption in different countries. The horizontal X-axis in the figure gives the energy per capita, while the vertical Y-axis gives the carbon intensity of the energy system, in such a way that the product XY = CO_2 emission per capita, represented by the hyperbolae at constant values. Developed countries have higher energy per capita and higher CO_2 emissions per capita from energy systems. Their CO_2 emissions per capita pathways from 1980 to 2005 have no simple dependence on energy per capita. Developing countries have very low energy per capita (X axis) and very low CO_2 emission per capita from energy transformation (hyperbolae more near X Y axis). Their tendency was to increase CO_2 per capita.

[11] Symmetrically, there are two main questions for adaptation to climate change: To what extent are societies adapted to their climate at any point in time? And what is their ability to adapt further, or not, to climate surprises? These two questions are addressed in AR5 WGII [NOTE: Provide reference based on WGII FOD], and we concentrate in emissions and mitigative capacity in this Chapter.

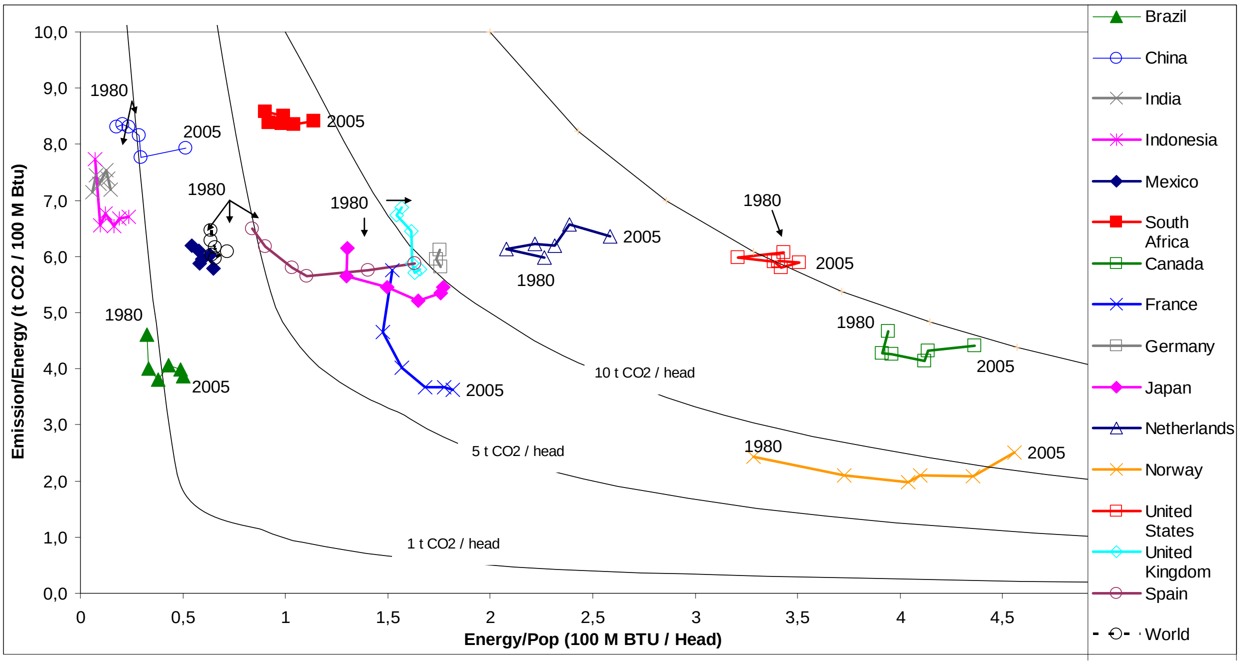

Figure 4.1 CO2 Emissions per Capita from Energy (CO2/Pop = E/Pop x CO2/E). Source: Calculated with data from U.N. Statistics Division. Key Global Indicators, May 2008. Data from years 1980, 85, 90, 85, 2000 and 2005 (Rosa et al., 2009)

Since AR4, new econometric analysis confirms that the environmental Kuznets curve assumption – that GHG emissions follow an inverted U-shaped curve in relation with per capita GDP – is not universally supported. For example, Huang et al. (2008) observe that the economic development and GHG emissions in economies in transition (EITs) exhibit a hockey-stick curve trend (or called quasi-L-shape curve). In addition, through the analysis of single-country time series data and GDP data, the study demonstrated that statistical data for most of the Annex II countries, with better economic status, do not support the EKC hypothesis for GHG emissions. Only seven out of 21 countries in the sample tested exhibit this trend. Similarly, using panel data from individual countries (PK Narayan and S Narayan, 2010) show that only about 35% of their sample exhibit falling emissions over the long run. The study also examines the EKC hypothesis for panels of countries and finds that only for the Middle Eastern and South Asian panels, the income elasticity in the long run is smaller than the short run, implying that CO_2 emissions have fallen with a rise in income. [12]

The econometric literature, however, consistently finds a positive relationship between GDP per capita and emissions at low income levels, which Costantini and Monni (2008) posit comes from the importance of the satisfaction of basic human needs. As previously noted, worldwide, approximately 2.7 billion people rely on traditional biomass for cooking and heating, and about 1.5 billion still lack access to electricity (IEA, 2011). A further 1 billion people have access only to unreliable electricity networks or suffer frequent blackouts due to lack of adequate generation capacity or simply due to power generating infrastructures that are in perennial state of disrepair (UNDP and WHO, 2009). The majority of this population lives in developing countries.

[Note from the authors: For the SOD, the chapter team proposes to insert the next section 4.6 on mitigative capacity as an additional subsection here, entitled: “Differences between pathways, with regard to mitigative capacity”.]

[12] Narayan and Narayan (2010) also note wide disparities in results about the GDP turning point, beyond which emissions start to decrease according to the econometric estimation, and question the robustness of the estimation models.

4.5.3 Transition between pathways

Shifting from a high- to a low-emissions development path could potentially be as important for climate mitigation as implementing "climate" policies (Halsnaes et al., 2011). However, changing development pathways is difficult. First, a development path results from the interactions of decisions by multiple agents, at all level, that create a very complex landscape. Second, the observed shift from "government to governance" implies that public policies[13] alone cannot trigger changes in pathways, and that cooperation between governments, markets and civil societies are necessary – thereby putting a strong premium on participatory and inclusive mechanisms for decision-making (Sathaye et al., 2007).

4.5.3.1 A template for modelling transitions in the context of sustainable development

Analyzing transitions between pathways requires representing specific processes – processes that most models that look at development paths currently do not feature. In fact, a first approach to discussing sustainability of development paths consists in building and comparing plausible images of the future, derived either from quantitative analysis (e.g., energy balances, material balances or economic balances) or from qualitative exercises (Figure (1)). The focus is the long-run, and the aim to reveal inconsistencies between key variables (e.g., economic growth and renewable resources extraction). On the other hand, pathways towards these long-term futures are not part of the approach (though they may be discussed separately).

A second approach to discussing sustainability uses dynamic models to study the *path* towards desirable (or undesirable) long-term futures. Most of the literature studying climate mitigation in the long run relies on growth models, and most particularly on Solow-like growth models. Though most of the earlier growth literature was concerned with short term growth cycles, the Solow growth model (RM Solow, 1956) was explicitly designed as a "thought experiment" (RM Solow, 1988) to explore long-term growth patterns in the US economy. In the model, long-term growth is ultimately driven by the sum of population growth and exogenous total factor productivity growth (exogenous technical change), and it is always possible to adapt savings rate to reach a balanced growth path in the long-run.

In the simplest version of the model, there is thus only one "pathway" to speak of, as determined by human fertility and human ingenuity. What matters is then only at which speed humanity does set up on that path. "Transition" (rather short-term adjustment) in a Solow growth model will typically take the form of a temporary savings rate aimed at adjusting the capital to labour ratio to the optimal level given exogenous labour and technology growth. In fact, Solow growth models are known to have limited explanatory power in explaining observed patterns of short-term growth, be it within countries or across countries (e.g. Easterly (2002)). A second major point is that Solow-type models are typically used with full information about the future. In such setting, setting a path towards a desired long term growth becomes an exercise of (temporal) ballistics (Figure (2)).

Lifting the full information hypothesis strongly alters the picture. To the extent information increases over time, there is a rationale for a sequential decision-making framework (Arrow et al., 1996), in which choices made at one point can be re-considered in light of new information. Thus, the issue is no longer to select a path once and for all, but to make the best first-step (or short-term) decision, given the structure of uncertainties and the potential for increasing information over time (Figure (3)). Inertia plays an especially important role in this context, as the more choices made at one point constrain future opportunity sets; the more difficult it becomes to make advantage of new information (e.g., Ha-Duong et al. (1997)). Choices with the highest embedded inertia – for example, choices about long-lived capital (tree species, transportation infrastructure, building location and design, etc.) must be considered with special care. This approach thus shifts the attention from the

[13] Both "climate" and "non-climate" – though that distinction is being over time as climate considerations pervade all spheres of public action.

long- to the short run, and it provides a test for sorting out the most important choices among those that must be made in the short-run.

Yet to discuss correctly about transitions, one must recognize that short-term economic processes differ from long-term ones. In the short-run indeed, there are important rigidities in the economy (e.g., capital stock, preferences, individual and firm location, institutions, technology, etc.) that make adjustments more difficult. Rigidities play a very important role in the short-run costs of climate change impacts (Hallegatte et al., 2007), and of climate mitigation (Sassi et al., 2010). Solow, again, suggests that at short-term scales, "something sort of 'Keynesian' is a good approximation, and surely better than anything straight 'neoclassical'. At very long time scales, the interesting questions are best studied in a neoclassical framework and attention to the Keynesian side of things would be a minor distraction" (RM Solow, 2000). Models with such features may provide some insights on the transition between pathways (Figure (4)).

Finally, to discuss transitions within a sustainable development context, models must include two additional elements. First, they must represent *key relationships between the economy and the environment*, namely (i) natural resources as inputs to economic activity (e.g., fossil-fuel consumption), (ii) outputs from economy to the environment (e.g., GHG emissions). Though this requirement might appear benign at first glance, it is in fact quite important because it is very difficult to construct robust relationships between aggregate monetary indicators and the underlying physical basis. Thus, to compute consumption of natural resources and output to the environment (i.e., emissions), models must have some minimal representation of the physical flows associated with economic activity (e.g., barrels of oil, hectares of land, numbers of calories associated with alimentation, etc.). The second necessary ingredient for assessing pathways and transitions between pathways within a sustainable development context is some representation of the *distribution* of economic activity within the society. Obviously, distribution across income groups is key for estimating the degree of inclusiveness of a society (see Sec. 4.4.1) , but distribution along other axes might also be relevant. Geographical distribution of economic activity also matters, both at large scale (e.g., distribution between states in large countries) and at smaller ones (e.g., distribution between urban centres, inner periphery and outer suburbs).

To sum up, to assess long-term sustainable pathways, as well as the costs and benefits of transitions thereto, is a major challenge for economic modelling. Ideally, models should (i) be framed in a consistent macroeconomic framework, (ii) impose the relevant technical constraints in each sector, such as views about the direction of technical change, (iii) capture the key relationships between economic activity and the environment, e.g., energy and natural resources consumption or greenhouse gases emissions, (iv) have a horizon long enough to assess "sustainability" – a long-term horizon which also implies, incidentally, that the model must be able to represent structural and technical change – yet (v) recognize short-term economic processes critical for assessing transition pathways, such as market imbalance and rigidities, all this while (vi) providing an explicit representation of how economic activity is distributed within the society, and how this retrofits into the growth pattern.

No model today meets all these specifications. In fact, current models can be classified along two major fault lines: bottom-up vs. top-down, and long-term vs. short-term. By design, computable general equilibrium (CGE) models provide a comprehensive macroeconomic framework (i), and they can be harnessed to analyze distributional issues, at least amongst income groups (vi), but they typically fail to embark key technical constraints. Conversely, bottom-up engineering models provide a detailed account of technical potentials and limitations (ii), but their macro-engine, if at all, is most often rudimentary. Emerging "hybrid" models developed in the context of climate policy assessment are steps towards closing this gap. A similar rift occurs with regard to time horizon. Growth models à la Solow are designed to capture key features of long-term development paths (iv), but they do not include short- or medium-term economic processes such as market rigidities. On the other hand, short-term models (econometric or structural) will meet requirement (v) but are not designed to look deep in the future. Again, emerging models include short-/medium-term processes into analysis of growth in the long-run, but this pretty much remains an open research field.

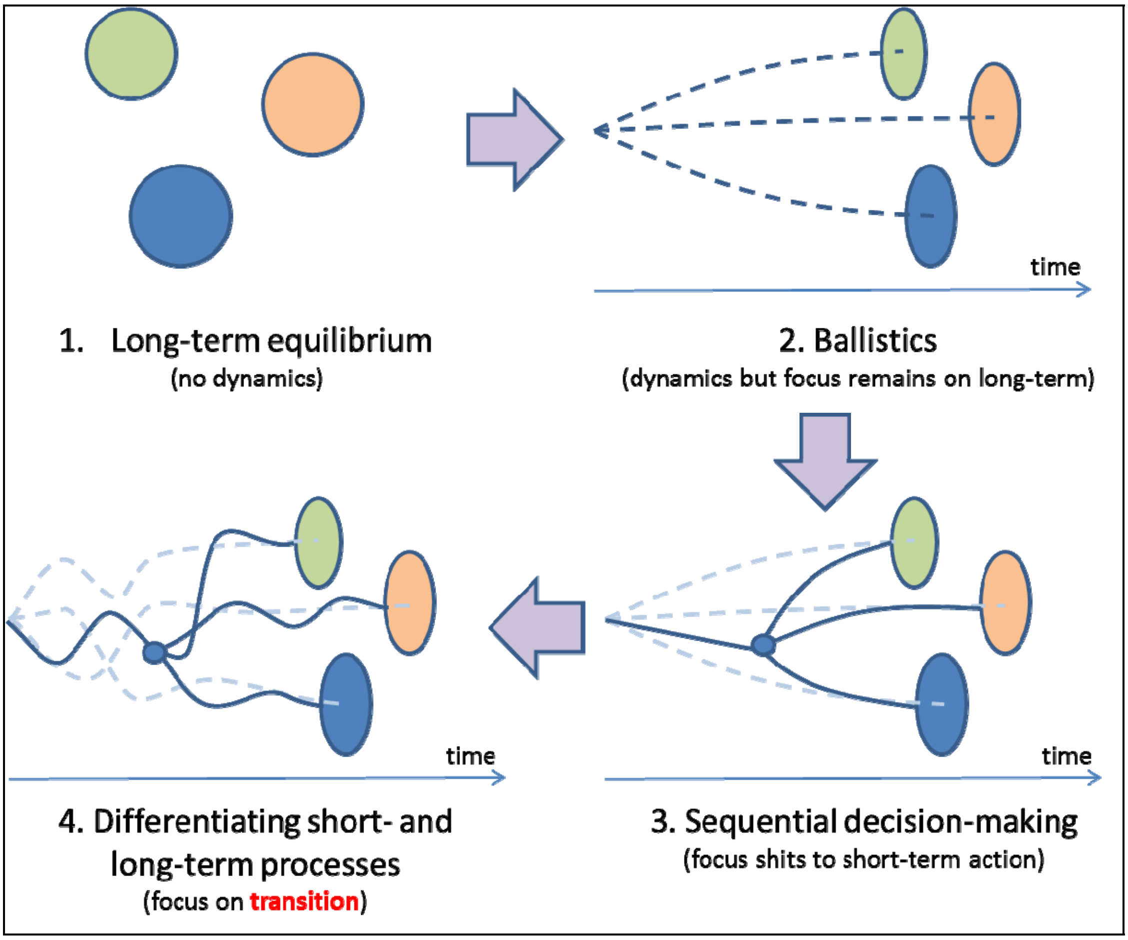

Figure 4.2 Evolution of conceptual thinking about sustainable development pathways: Towards a realistic view of transitions

4.5.3.2 Frameworks for analyzing technological transitions

Changes in technologies, their causes, and their implications for societies have been actively studied in social sciences since the late 18th Century by historians, economists and sociologists. A common starting point is the observation that "technological change is not a haphazard process, but proceeds in certain directions" (Kemp, 1994). For example, processors tend to become faster, planes to become lighter, etc. To characterize these regularities, scholars have developed the concepts of *technological regime* (Nelson and Winter, 2002) and *technological paradigms* (Dosi, 1982; Dosi and Nelson, 1994). Technological regimes refer to shared beliefs among technicians about what is feasible. Technological paradigms refer to the *selected* set of objects engineers are working on, and to the *selected* set of problems they choose to address.

The determinants of changes in technological regimes (such as the development of information technologies) are subject of intense research. The development of radical innovations (e.g., the steam engine) is seen as a necessary condition. But the drivers of radical innovation themselves are not clearly understood. In addition, once an innovation is present, the shift in technological regime is not a straightforward process: The forces that maintain technological regimes (e.g., increasing returns to scale, vested interests, network externalities) are not easy to overcome – all the more so that new technologies are often less efficient, in many respects, than existing ones, and competing technologies may coexist (Arthur, 1989). History thus suggests that the diffusion of new technologies is a slow process (Kemp, 1994). Over the past 20 years, a subset of technology scholars has focused more specifically on “sustainability transitions”. They study the formation of new socio-technical configurations and develop frameworks for analyzing prevailing socio-technical structures, with two major perspectives (Truffer and Coenen, 2012): the multi-level perspective on socio-technical systems (F Geels, 2002) and concept of technological innovations systems (Bergek et al., 2008). The multi-level perspective on socio-technical systems distinguishes three levels of analysis: niche innovations, socio-technical regimes, and socio-technical landscape (F Geels, 2002). Technological niche is the micro-level where radical innovations emerge. Socio-technical regimes correspond to an extended version of the technological regime discussed above. And the socio-technical landscape corresponds to the regulatory, institutional, physical and behavioural environment within which the innovations emerge. The last level has a lot of inertia. Changes in socio-technical regimes emerge from interactions between these three levels, with several possible paths depending on how these interactions proceed. (FW Geels and Schot, 2007) thus introduce a typology with four different paths. *Transformation paths* correspond to cases where moderate changes in the landscape at a time where niche innovation are not yet developed result in a modification in the direction of development paths – an example of which is the implementation of municipal sewer systems in Dutch cities (FW Geels, 2006). *De-alignment and realignment* correspond to sudden changes in the landscape that cause actors to lose faith in the regime; if no clear replacement is ready yet, a large range of technologies may compete until one finally dominates and a new equilibrium is reached. One example of such path is the transition from horse-powered vehicles to cars. If new technologies are already available, then a *transition substitution* might occur, as in the case of the replacement between sailing and steamships between 1850 and 1920. Finally, *reconfiguration* might occur when innovations are initially adopted as part of the regime and progressively subvert it into a new one, an example of which is the transition from traditional factories to mass production in the US.

The Technological Innovation Systems approach (Bergek et al. 2008) adopts a systemic perspective by considering all relevant actors, their interactions and the institutions relevant for innovation success. Early work in this approach argues that beside market failures, “system failures” such as, inter alia, actor deficiencies, coordination deficits or conflicts with existing institutional structures (institutional deficits) can explain non-successful innovation (Jacobsson and Bergek, 2011). More recent analysis focus on core processes critical for innovation. The Technological Innovation Systems concept was developed to inform public policy on how to better support technologies deemed sustainable with an increasing focus on “system innovations” as opposed to innovation in single technologies or products (Truffer and Coenen, 2012).

4.6 Mitigative capacity and mitigation, and link to adaptive capacity and adaptation

[Note from the authors: For the SOD, the chapter team proposes to insert this section into the previous section 4.5.]

This section focuses on the differences between pathways with regard to ability to mitigate, or mitigative capacity. This is as critical as differences with regard to emissions, because regardless of which future emissions path society follows, new information may require to revise our mitigation choices in the future (Ha-Duong et al., 1997). This section first introduces the concepts of mitigative capacity, adaptive capacity and response capacity, and then discusses how new forward looking pathways examine these dimensions.

4.6.1 Mitigative capacity, adaptive capacity and response capacity

Adaptive capacity indicates the ability of a society – including its individuals, corporations, financial sector, scientific institutions, government agencies, and political representatives and policy-makers – to adjust to climate change in order to ameliorate its consequences or to take advantage of possible opportunities. Adaptive capacity entails the ability to foresee change, plan responses, and implement actions in anticipation of the consequences of climate change as well as the ability to respond to unforeseen consequences as they occur. Mitigative capacity requires similar abilities of a society and is thus, from a social capacity perspective, considered a close parallel of adaptive capacity (IPCC and Metz, 2001; Yohe, 2001; Burch and Robinson, 2007; Pelling, 2010; Burch, 2011). The two are thus usefully considered jointly as dimensions of “response capacity”. While the factors that contribute to adaptive and mitigative capacity are similar, there are nevertheless two important distinctions. First, the effects of mitigating and adapting are different. Mitigation is largely a public good that helps everyone. Second, the moral obligations for mitigating and adapting are different (Jagers and Duus-Otterstrom, 2008); for a more in-depth discussion, see Chapter 3.

Of course, the mitigation and adaptation measures that societies undertake may not reflect the response capacity available. A nation, for example, may have the capacity, but lack the necessary political consensus to take action. Some have thus viewed this gap between capacities and actions in terms of a (lack of) political will (Winkler et al., 2007). Understanding the gap between the two can help in devising political solutions that might help bridge it. At the same time, some of the social institutions that enhance response capacity (such as education, regulatory responsiveness, and agencies that can serve new interests) are closely tied to helping people understand how they might care about climate change. Caring enhances political willingness. Thus capacity and willingness are intertwined over time in a positive feedback loop. In effect, while the distinction between capacity and willingness might make sense at any point in time, making this distinction in the design of climate policy, for example by excusing the capable but unwilling from meeting the emission targets of nations both capable and willing (Posner and Weisbach, 2010) , presents a moral hazard that could lead to a reduction in political willingness to maintain and enhance mitigative capacity over time (Schipper and Pelling, 2006).

4.6.1.1 Common elements of mitigative and adaptive capacity

Mitigative capacity and adaptive capacity both refer to human and institutional behaviour and the capabilities of individuals and societies to achieve certain types of objectives related to climate change. Both types of response capacity are closely linked to the level of socioeconomic development and the material and technological resources available. Indeed, there is a strong correlation between the capacity to develop sustainably and climate response capacity (see Sec. 4.2). This helps explain the centrality of equitable burden-sharing in discussions of effective global responses to climate change (see Sec. 4.7.2).

Aggregate economic indicators alone do not fully capture the ability of societies to respond, however. Response capacity also depends on the composition, structure and heterogeneity of populations with respect to characteristics such as age, gender, level of education, distribution of income, place of residence, health status, employment status, national/ethnic identity, political/ideological views, religion and many others. Thus the empowerment of people individually can enhance response capacity. For example, better health, education and awareness, access to skills and technology, security, and enfranchisement are critical to effective responses. This directly links in the issues of distribution and equity within societies (Pelling, 2010).

Beyond the individual level, societal capabilities (often called social capital) contribute to response capacity. They refer to institutional settings concerning the way societies organize themselves, including the issues of governance, rule of law, and institutional capacity along various dimensions, all of which may affect social cohesiveness, capacity to adjust to changing societal needs, ability to equitably manage the distribution of costs and benefits that affect the politics of collectively acting (Yohe, 2001; Intergovernmental Panel on Climate Change and Parry, 2007; Winkler et al., 2007); (Intergovernmental Panel on Climate Change and Bert Metz, 2001; Yohe and Richard S.J. Tol, 2002; Intergovernmental Panel on Climate Change and Parry, 2007; Hallegate et al., 2011).

4.6.1.2 Differences between mitigative and adaptive capacities

A fundamental difference between mitigative and adaptive capacities lies in the fact that, as noted above, mitigation is essentially a global public good, whereas the benefits of adaptation tend to accrue to the individual, local or national actor undertaking the action. Individuals have a strong personal interest to avoid harm to their life, health, livelihood and property as well as to those of their family and friends, and so there is an incentive to undertake adaptation, since it will help to avoid such harm. However, some forms of adaptation have local (e.g., dikes) or even global (e.g., information on impacts, heat-resistant crops) characters, and are likely to be under-provided spontaneously. In addition, because of distributional issues, information asymmetry or spill-overs associated with lack of adaptation, there are also reasons for public support of adaptive capacity (Lecocq and Shalizi, 2007).

While adapting benefits the adapters, mitigation benefits everyone on the globe, and the vast majority of the benefits of reduced climate impacts are not retained by the mitigators, but rather enjoyed by other nations, whether they have mitigated or not (setting aside, for the moment, the issue of co-benefits, which might accrue locally). Even a nation with large emissions receives only a comparatively small reduction in climate impacts from reducing even a large share of its emissions, and so direct benefits are not a sufficient incentive for the ambitious emission reductions that climate stabilization will require (Winkler et al., 2007).

Another difference between mitigation and adaptation is with respect to geographic scale. While mitigation is a truly global concern and it is largely irrelevant from a geo-bio-physical perspective in which part of the world the mitigation happens, the need for adaptation has a succinctly local dimension. The impacts of climate change may vary greatly from one specific location to another. This is true, say, for sea level rise, in which case a few meters difference in elevation can make a major difference. But research shows that even within a specific small geographic area vulnerability may vary significantly among individuals according to age, gender, level of education, income and other factors (Lutz, forthcoming).

4.6.2 Development pathways and response capacity

How development paths influence the ability to mitigate is not well understood. This is in part because more attention has been devoted to the link between development path and emissions, but also because the degree of inertia or flexibility of a particular society in terms of emissions results from a complex combination of factors (Winkler et al., 2007). Box 4.2 explores this relationship.

In fact, ability to mitigate combines (i) availability of low- or zero-carbon technologies; (ii) ability of societies to adopt low- or zero-carbon technologies; and (iii) ability of societies to reduce demand for GHG-intensive goods and services. We review the literature on how development paths affect these three drivers. We concentrate on short-term flexibility, as it conditions ability to react rapidly to new information about climate change.

4.6.2.1 Availability of technologies

Considerable attention has been paid to the drivers of innovation in clean technologies, and to the extent to which innovation is responsive to climate and other sustainable development objectives, (as discussed in Sec. 4.3) and how these are captured in technical analyses of development pathways (L Clarke et al., 2008). But what features of development paths influence the response of innovation to climate policies has been less studied.

If technological change is assumed to be a function of market size, “open” development paths with growing international trade may yield more technological change than “closed” ones, as in the IPCC A1 and A2 SRES scenarios (2000). However, technological change is oriented towards low- or zero-emissions options, however, will depend on policy incentives.

4.6.2.2 Ability of societies to adopt cleaner technologies

Even if cleaner technologies are available, the shift from high- to low-emissions technologies might still be costly if it entails premature retirement of existing capital stock. Economies with a high share of emissions in sectors with long-lived capital stock will face higher short-run abatement costs than economies with a low share (Lecocq et al., 1998); especially given the fact that long-lived capital stock often tends to be implemented in lumpy and time-compressed investment programs (Shalizi and Lecocq, 2009).

4.6.2.3 Ability of societies to reduce demand for GHG-intensive goods and services

On the demand side, similarly, ability to abate depends on the location of people and of activities – which are difficult to change in the short run, and thus constitute barriers to rapid changes. In the short-run, for example, people are unlikely to change location in response to a carbon tax, and demand for transportation will react only to the extent alternative transportation options are available. The presence of alternatives is in turn conditioned by the past investments in transportation infrastructure and by the underlying urban forms.

But the ability to mitigate also relates to institutional and cultural factors, i.e., to desire and ability of societies, individually or collectively to take and implement mitigation decisions (e.g., equity within/across societies, cohesiveness). The presence of institutions apt to pick up signals of impending climate risks, balance interests of all stakeholders involved, and credibly enforce compromises is critical for society's ability to react (World Bank, 2003). There is, however, a tension between what is efficient, which often calls for early action, and what is politically feasible, which often only shifts appreciably after a crisis (Shalizi and Lecocq (2010)).

Box 4.2 Characterizing futures by mitigative and adaptive capacities

The understanding that mitigative and adaptive capacities are key characteristics of any future societal pathway has informed the effort by the global integrated assessment modelling (IAM) and the impact, adaptation and vulnerability (IAV) research communities to develop a common set of Shared Socioeconomic Pathways (SSPs) (NW Arnell, forthcoming). The key differentiating feature of these pathways is the extent to which they manifest mitigative and adaptive capacities and the challenges to those capacities (see Figure Error! No text of specified style in document. and Chapters 5 and 6).

In this scenario exercise effort, challenges to mitigation and adaptation for the purpose of defining SSPs do not include the emission pathway itself, which is determined by the shared climate policy assumptions (SPA) and the representative concentration pathways (RCP) forcing level (Moss et al., 2010; van Vuuren et al., 2011). Rather, these challenges are defined by factors that would make mitigation and adaptation easier or harder *for any given target*. Socioeconomic challenges to mitigation are defined as consisting of: (1) factors that tend to lead to high *reference emissions* in the absence of climate policy because, all else equal, higher reference emissions makes that mitigation task larger; and (2) factors that would tend to reduce the inherent *mitigative capacity* of a society. Underlying drivers such as the economic, technological, political, social, cultural, and demographic factors discussed above determine the extent of mitigative and adaptive capacity.

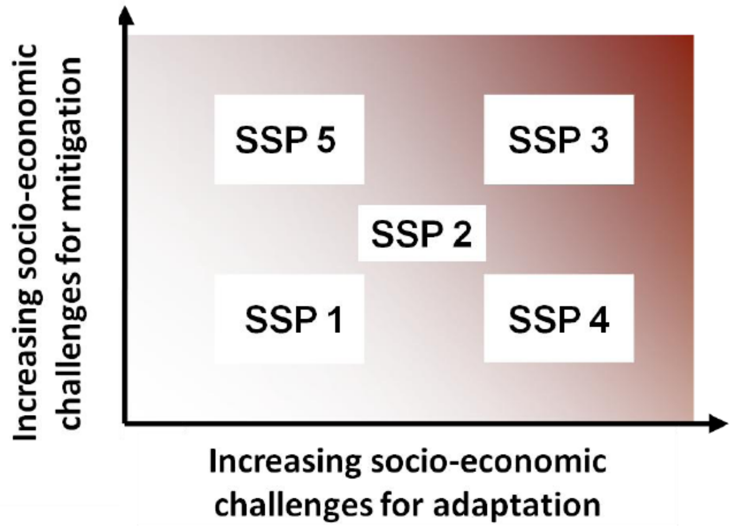

Figure Error! No text of specified style in document.**4.3** The scenario space to be spanned by the SSPs (NW Arnell, forthcoming)

Figure Error! No text of specified style in document. shows different possible associations between the socioeconomic challenges for mitigation and adaptation. SSP1 gives the case of a world in which both challenges are low due to high levels of socioeconomic development combined with a move to green technologies; this is the case of a global pathway to sustainable development. SSP3, in contrast, gives a case in which both challenges are very high: Low levels of education and rapid global population growth, together with relatively low income growth, a very carbon-intensive economy, and weak governance, makes it difficult to mitigate and also to adapt. While SSP1 and SSP3 assume the trends to be fairly even across the world, SSP4 describes a world with great inequalities both between and within populations. Since in this case most of the emissions will come from the well-off, the mitigative capacity is fairly high, but the adaptive capacity of large segments of the world population is very low. SSP5, finally, gives the case of rapid economic growth across the world, but based on carbon-intensive technologies. Due to high levels of socioeconomic development, adaptive capacity is high, and the challenges to adaptation are therefore low, while at the same time, the challenges to mitigation will be particularly high. (SSP2 is an intermediate case displaying features of each of the others.) It is notable that the pathway in which both mitigative and adaptive capacities are highest is the scenario in which society shifts toward sustainable development. Further linkages between mitigative and adaptive capacities and sustainable development may be examined as more regional, socioeconomic and technological differentiations are developed.

4.7 Integration of framing issues in the context of sustainable development

Chapters 2 and 3 of this report review the framing issues related to risk and uncertainty (Chapter 2) and social and economic considerations guiding policy (Chapter 3). They examine how these issues bear on climate policy, both on the mitigation and on the adaptation side of our response to the challenge of climate change. Their general analysis is also directly relevant to the understanding of sustainable development and equity goals. This section examines how the notions developed in these chapters shed light on the topic of the present chapter. This section also draws on this broader perspective to introduce to the issues of equity in burden-sharing in some detail, and to critically review a range of proposals that have been made for indicators of sustainable development.

4.7.1 Risk and uncertainty in sustainability evaluation

Chapter 2 (Sec. 2.3) highlights the difficulty of applying the standard decision model based on expected utility in the context of climate policy. Indeed, this model requires probabilities and utilities, both of which are elusive in the context of large and fundamental uncertainties about the climate and the socio-economic system. It also requires addressing serious conceptual difficulties with the notion of long-term social welfare. Alternative, less ambitious, approaches are therefore used, such as cost-effectiveness (in which an intermediate objective is fixed and the least costly ways of achieving it are sought), methods similar to the financial notion of “value at risk” (that help quantifying how much should be kept safe in order to be able to cope with risks of a certain magnitude), references to the precautionary principle and robust decision-making (assessing worst-case scenarios).

4.7.1.1 The risk of unsustainability

The notion of sustainable development is ordinarily defined without explicit reference to risk. It primarily points more generally to the responsibility of the present generation to preserve the means by which the well-being of future generations can be secured. Implicitly, however, this requires an appreciation of risks imposed on the future, including risks to the natural resources and environmental services on which future well-being depends. The goal of minimizing risks that compromise future human development may thus be considered an important dimension of the sustainability ideal. This objective is less ambitious than maximizing an expected value of social welfare over the whole future. It focuses on avoiding setbacks on development, and is therefore directly akin to the methods of risk management listed in Chapter 2 (Subsec. 2.3.2.3 and Sec. 2.6), in particular those focusing on worst-case scenarios.

However, the notion of sustainable development should perhaps not just be seen as a precautionary way of addressing the future risks. Directly incorporating risk and uncertainty in the evaluation and measurement of sustainability is necessary for a fuller understanding of the stakes. Because sustainability is, in its simplest formulations, something that is achieved or is not achieved, it is easy to imagine that one could seek to assign a probability to the event of sustainability failure, and make this probability a key element of policy evaluation. The decision-makers of each generation would then face the question of how much risk of a less favourable situation and less hospitable planet their descendants will incur. More generally, the distribution of probability of the possibility to sustain various levels of well-being in the future would be a valuable aid to decision-making, as discussed later in this section.

Reciprocally, the scientists who examine scenarios and evaluate risks could be encouraged to put some priority on examining whether the scenarios involve a failure with respect to sustainability, or whether specific risks estimated for a part of the earth system directly jeopardize sustainable development. This report presents special efforts in this direction (see Chapter 6).

4.7.1.2 Multiple hazards and reactions

As highlighted in Chapter 2 (Sec. 2.2), there is a multiplicity of risks and uncertainties, in the climate system itself, the technologies available for mitigation and adaptation, the evolution of the population and its characteristics, all compounded by uncertainties about the response of societies and political systems. In the perspective of sustainability, it is clear that all these sources of risk are relevant. If the climatic risk were eliminated, sustainability would still be uncertain due to uncertainties about the scarcity of resources, about technological progress, and about human behaviour. Widening inequalities within countries and insufficient convergence between countries, as well as economic crises and instability, also threaten the social pillar of sustainability. But it is obvious that climate change adds uncertainty and complicates the assessment and achievement of sustainability.

This chapter has reviewed the actors and determinants of support for policies addressing the climate challenge. Among the relevant considerations, one must include how risk perceptions shape the actors' awareness of the issues and their willingness to do something about them. Chapter 2 (Sec. 2.5) has described how framing and affective associations can be effective and manipulative, how absence or presence of a direct experience of climate extremes makes individuals distort probabilities, and how gradual changes are easy to underestimate. These behavioural phenomena, which appear to be widespread, have to be taken into account not only to understand how climate risk is perceived, but also how it is managed, which directly matters for the perspective of a sustainable development. Achieving sustainability, therefore, may in part depend on the ability of scientists to communicate effectively about the risks they uncover in the climate system.

4.7.1.3 Equity aspects

Risk and uncertainty are also relevant to the dimension of equity, in relation to sustainability. Various regions of the world will be affected differently by climate change, which means that they are submitted to unequal degrees of risk and uncertainty – in particular, the risk of a loss is more problematic than the risk of a gain. This unequal distribution of risk will affect them some time before the risk is realized, when investors and insurers start taking account of the specific local characteristics of the climate risks. This means that effective and precise assessment of the geographical distribution of risks, which appears prima facie desirable, may cut both ways as far as equity is concerned. On the one hand it helps designing more targeted and effective adaptation policies. On the other hand it precipitates the realization of harm even when the risks are ultimately averted.

Better information about the distribution of risks between regions and countries also affects the policy response and negotiations. It raises awareness and motivation in the potential victims, but it may reduce concern for climate risk among those who are less exposed to the risk of a loss. The task of coordinating policies, which is especially needed for mitigation, may be easier to achieve when climate issues are considered a collective threat than when climate risk is an uneven local phenomenon. Lecocq and Shalizi (2007) argue that reduced uncertainty about the location of impacts may reduce incentives for mitigation, and Lecocq and Hourcade (2010) show that the optimal level of mitigation may also decrease.

Chapter 2 (Subsec. 2.3.1.3) describes the fact that climate phenomena appear to involve distributions of risks with fat tails and tail dependence (record-breaking harms remaining equally likely over time, and reinforcing across subsystems). This is a case in which communication about the worst scenarios, which involve widespread harms and life-threatening hazards, may shape the equity concern quite differently than a communication focused on central scenarios with more unequal distributions of gains and losses. Solidarity and cooperation are more easily fostered in front of catastrophic risks.

4.7.2 Socio-economic evaluation

Chapter 3 has reviewed the principles of social and economic evaluation and equity in a general way. It reveals the diversity of approaches that bear on such issues, and that may shape the negotiations and policy debates. There is in particular a divide between the pure consequentialist considerations and the procedural, or more specific, issues of equity.

4.7.2.1 The social welfare approach

The pure consequentialist considerations are useful because they provide clear guidelines about how to structure the evaluation, even when data and applications are hard to come by. In particular, Chapter 3 (Sec. 3.4) recalls that there is now a consensus that methods of cost-benefit analysis that simply add up compensating or equivalent variations (i.e., willingness-to-pay or willingness-to-accept) are consistent and plausible only under very specific assumptions (constant marginal utility of income and absence of priority for the worse off) which are empirically dubious and ethically controversial. It is thus necessary to introduce weights that embody suitable ethical concerns and restore consistency of the evaluation.

As explained in Chapter 3 (Sec. 3.3 and 3.4), such weights in fact correspond to making the evaluation rely on a social welfare function (or at least an ordering). Adler (2011) also makes a detailed argument in favour of this “social welfare function” approach to cost-benefit analysis. An important advantage of this approach is that it makes it possible to capture an essential aspect of equity, which is to give priority to the worse off in assessments of various distributions of well-being.

As for intergenerational equity and sustainability, this approach makes it possible to conceive of such notions as requiring the absence of decrease in social welfare over time. Concern for the preservation of the environment can be mediated by its impact on human well-being. Moreover, in the utilitarian tradition, the social welfare function should incorporate all sentient beings, not just humans. Biodiversity can therefore be incorporated in the social welfare approach.

4.7.2.2 Well-being measurement

Chapter 3 describes the general concepts of social welfare and individual well-being. In applications to the assessment of development paths and sustainability, empirical measures are needed. Even disregarding the complexities due non-humans, and also those due to risk and uncertainty, it is still considered difficult to make a rigorous application of this approach because it requires interpersonally comparable indexes of individual well-being (“utilities”, as they are called in economics).

However, there are practical methods, most of which are discussed in Stiglitz et al. (2009) and Adler (2011). In particular, the capability approach (A Sen, 2001; 2009) is well known for its broad measure of well-being that synthesizes multiple dimensions of human life and incorporates considerations of autonomy and freedom. Most applications of it do not directly rely on individual preferences (Alkire, 2010). Fleurbaey and Maniquet (2011) develop an approach that relies on individual ordinal preferences, in a similar fashion as money-metric utilities. Individual situations are described in terms of wealth and other dimensions (health, quality of the environment, leisure, social status and relations, and so on). If one fixes a reference situation for the non-wealth dimensions, one may compute the “equivalent level of wealth” that, combined with this reference level for non-wealth dimensions, would make individuals as satisfied as in their current situation. It is easy to compute it when data about the joint distribution about wealth, non-wealth variables, and preferences are available. Such data are increasingly produced, for instance, in life satisfaction surveys.

Some authors (e.g., Layard et al. (2008)) even propose to use satisfaction scores directly as utility numbers. This is controversial because different individuals use different standards and calibration strategies when they answer questions about their satisfaction with life, and it is generally considered that the scales of answers cannot be given a cardinal meaning, even though some authors compute average national satisfaction and make comparisons across countries (see Sec. 4.4.1.4 for a discussion of how such issues bear on the link between well-being and material consumption).

Scepticism about the possibility to measure individual well-being and social welfare has been widespread in the last decades. This had led many practitioners to rely on crude measures (income) or questionable methodologies (non-weighted cost-benefit analysis). In fact the theories on which such scepticism is usually buttressed (most conspicuously, Arrow’s impossibility theorem of social choice (Arrow, 1970)) do not point to a radical impossibility, only to informational needs that are indeed met by the methodologies listed above.

4.7.2.3 Application to sustainability and equity

For applications to climate issues and sustainability, the consequentialist approach can be used to refine cost-benefit analysis. It then proposes to monetize the consequences of various policies and strategies, i.e., measuring the costs and benefits for all social groups in monetary equivalent quantities, and use suitable weights. This approach is followed by Anthoff et al. (2009), refining on previous use of equity weights by Fankhauser et al. (1997) and Tol (1999). Note that an advantage in having a well-specified methodology for the choice of weights is the ability to reach more precise conclusions, and to transparently relate such conclusions to ethical assumptions (such as the degree of priority to the worse off).

For the evaluation of development paths, one must decide whether one assesses the evolution of social welfare over generations, or computes a global measure of social welfare for all generations. The former, as will be argued in Sec. 4.7.3, may be more relevant than the latter for sustainability evaluation (because predicting the evolution of welfare over generations is practically more relevant than seeking to compute a total intertemporal welfare), and somewhat easier. Once distributions of well-being indices are estimated at the level of individuals (or at least social groups), one just has to apply a social welfare function that reflects the degree of priority to the worse off deemed appropriate by the decision-maker.[14]

One reason why well-being may be useful as a guiding principle in the assessment of sustainability, as opposed to a more piecemeal analysis of each pillar, is that it helps evaluate the weak versus strong sustainability distinction. As explained in Sec. 4.2, weak sustainability assumes that produced capital can replace natural capital, whereas strong sustainability requires natural capital to be preserved. From the standpoint of well-being, the possibility to substitute produced capital to natural capital depends on the consequences on living beings. If the well-being of humans depends directly on natural capital, if there is option value in preserving natural capital because it may have hidden useful properties that have yet to be discovered, or if non-human living beings depend on natural capital for their flourishing, this gives powerful reasons to support a form of strong sustainability. If, on the contrary, substituting produced capital to natural capital poses no threat to human well-being, then a milder form of sustainability may become acceptable, although the fate of other living beings still requires natural capital to be preserved to a substantial extent.

In summary, the consequentialist part of Chapter 3 is helpful to guide applications for the evaluation of the consequences of various policies and strategies and for the measurement of sustainability, with the incorporation of key aspects of equity.

4.7.2.4 Other forms of equity

Additionally, Chapter 3 (in particular Sec. 3.1 and 3.2) mentions other aspects of equity that are relevant to policy debates and international negotiations on climate responses. Chapter 3 discusses these issues at the level of ethical principles, and given the importance of such issues in policy debates about mitigation efforts, they will be developed in more detail in the next subsection, discussing how these principles have been applied to the issue of burden-sharing in climate regime, and used to develop indicators of obligation and burden-sharing frameworks based on those indicators.

Another set of equity considerations has to do with governance and participation. It has been argued in AR4 and in this chapter that inclusive and participatory strategies are more promising in terms of efficient implementation because they make it possible to tailor policies to population needs and concerns, and to elicit support as well as foster changes in behaviours. The general principles recalled in Chapter 3 (in particular, Sec. 3.7 and 3.8) also point out that inclusive governance and participation are considered to be intrinsically valuable, as part of a conception of the social good that takes account of values of freedom, democracy, and autonomy. For instance, Amartya Sen's capability approach (mentioned in 4.7.2.1) gives an important place to such considerations. This is a context in which it is not difficult to reconcile procedural fairness with the consequentialist

[14] The size of the population changes over generations, but one can ignore it in most policy contexts, and focus on per capita welfare in each generation. A normative view on population size appears needed only when one looks at total human welfare over history.

approach, because it merely requires broadening the conception of well-being in order to introduce dimensions of freedom and autonomy. But, while such reconciliation is easy in principle, it is not simple to operationalize it in empirical computations of social welfare or cost-benefit analysis. As was suggested by Rawls (2000), it may be simpler to take principles of inclusion and participation as constraints within which the standard, narrower computation of consequentialist measures can be performed.

4.7.3 Equity and burden-sharing in the context of climate policy

The climate problem, we have long known, is a classic global commons problem (Hardin, 1968; Soroos, 1997; Buck, 1998): everyone depends on a stable climate, and is thus vulnerable to the GHG emissions of everyone else, which degrade the climate and reduce the availability of the resource to everyone else. Yet actors (whether people, firms, or states) have little direct incentive to mitigate their emissions. Mitigation is an investment in a global public good, with the benefits of the avoided climate impacts shared with all. The small share of the benefits of mitigation that are retained by any given mitigator can only justify a very low level of action by any "rational" mitigator, i.e., that modest level of action available at a very low marginal cost. The sum of the mitigation individual rational mitigators actors would independently undertake is far short of the level of mitigation that is globally optimal. As with any commons problem, the solution lies in cooperation. In this case, an actor accepts the cost of additional mitigation not because it is directly justified by benefits of reduced climate change, but rather with the objective of inducing comparable action among other actors. Inducing that comparable action in others relies, to an important degree, on convincing others that one is doing one's fair share, i.e., one is not free riding. It is for this reason that analyses of equitable burden-sharing in the context of climate change are important. (See also Section 13.2.1.1)

Upon this classic commons problem, climate change superimposes several complicating factors. Actors are not so equal as the proverbial "commoners," where the very name asserts homogeneity (Milanovic et al., 2007), but differ substantially according to contribution to the climate problem, capacity to mitigate the problem, and the extent to which the problem will impact upon them. The beneficiaries of action are to a large degree members of future generations, and different actors today may consider differently our obligations to future generations. For this reason, among others, coming to a common agreement on equitable burden-sharing has proven difficult.

Indeed, the question of the role that equity does or should play in the establishment of global climate policy and burden-sharing in particular has long been controversial (D Victor, 1998). There are many relevant and sometimes contradictory definitions of equity (see Ch. 3 and 4.7.3.2), and various ways of translating these into burden-sharing frameworks (4.7.3.3) and assessing their quantitative implications (Ch 13). Moreover, equity is only one of several principles by which climate policies (and global treaties in particular) may be judged (Chapter 13). The fact that there is no universally accepted global authority to enforce participation is taken by some to mean that sovereignty, not equity is the prevailing principle. Consequently, the bottom-line criterion for a self-enforcing (S Barrett, 2005) cooperative agreement must be simply that everyone is no worse off than the status quo. This has been termed "International Paretianism" (Posner and Weisbach, 2010), and its ironic, even perverse results have been pointed out: "an optimal climate treaty could well require side payments to rich countries like the United States and rising countries like China, and indeed possibly from very poor countries which are extremely vulnerable to climate change - such as Bangladesh." (Ibid., p. 86).

However, given the significant global gains to be had from cooperation, this leaves ample room for discussion of the role of equity in the distribution of those global gains (C Stone, 2004), while still leaving all parties better off. (And, even if the preferential distribution of gains to the poor went beyond pareto efficient, such distribution may still be easily justified on welfarist grounds; from a global perspective one needs only consider that there is a declining marginal utility of income to conclude that global redistribution to the poor is welfare-improving.)

Furthermore, it is plain that whether it is necessary or not, the perception of fairness can only strengthen the commitment of nations to a global regime, reducing the risks of defection and a cooperative collapse. And even though direct economic costs of participation may provide incentives for non-cooperation or defection, the fact is that international politics is not a one-shot game; cooperation at one time and in one venue can be seen in both theory and practice to facilitate broader and longer-term cooperation, with the many associated benefits. And, as has been strongly argued (Singer, 2004; Speth and P Haas, 2006; Kjellen, 2008), climate change is only one of many global problems – environmental, economic, and social – that will require effective cooperative global governance if development – and indeed human welfare – is to be sustained.

It is in this context that the discourse about equitable burden-sharing is to be seen. In this light, we now turn to the UNFCCC and its rhetorical and practical commitment to equity (4.7.3.1 0, followed by a discussion of equity principles 4.7.3.2) and proposals for equitable burden-sharing 4.7.3.3 as developed and analyzed with respect to climate change.

4.7.3.1 Equity and burden-sharing in the UNFCCC

The UNFCC provides broad guidance on the equity principles that should help inform national roles and obligations under a climate regime. In particular, it highlights the inter-generational nature of equity concerns (Pream0ble and Article 3.1 – Definitions), underscores the need for a precautionary approach (Article 3.3 – Principles), and recognizes "that economic and social development and poverty eradication are the first and overriding priorities of the developing country Parties" (Preamble and Article 4.7 – Commitments). The UNFCCC reiterates this latter point in various ways: it acknowledges the right of Parties to promote sustainable development and the obligation of Parties to cooperate toward sustainable ec0onomic growth and development. Specifically, it recognizes and acknowledges the need to take into account different socio-economic circumstances including the concerns of developing countries and countries particularly vulnerable to climate change.

Signatories to the UNFCCC have agreed that: "Parties should protect the climate system for the benefit of present and future generations of humankind, *on the basis of equity and in accordance with their common but differentiated responsibilities and respective capabilities*." The source of this statement is the 1992 Rio Declaration, which elaborates further: "States shall cooperate in a spirit of global partnership to conserve, protect and restore the health and integrity of the Earth's ecosystem. In view of the different contributions to global environmental degradation, States have common but differentiated responsibilities. The developed countries acknowledge the responsibility that they bear in the international pursuit to sustainable development in view of the pressures their societies place on the global environment and of the technologies and financial resources they command." (Rio Declaration on Environment and Development, Principle 7)

Neither in the UNFCCC, nor the in Kyoto Protocol, however, had Parties articulated in explicit and quantified detail the precise meaning of this statement, or of the various other points of Article 3 of the UNFCC relating to equity and obligations among Parties. They had, however, agreed on general guidance as to the allocation of obligations among countries by identifying categories of countries based primarily on per capita income and assigning them distinct obligations: developed countries (listed in Annex 1) are distinguished from developing countries (often called "non-Annex 1" countries), and are obliged to "take the lead on combating climate change and the adverse effects thereof". A subset of Annex 1 countries consisting of wealthier developed countries (and listed in Annex 2) are further obliged to provide financial and technological support to developing countries to enable them to meet their UNFCCC obligations.

Because there is no absolute standard of equity, countries (like people) will tend to advocate interpretations of the UNFCCC and equity in general which tend to favour their (often short term) interests. These differing views may be more or less sincerely held or, alternatively, may be advocated more or less cynically. It is tempting in this light to say that no reasoned resolution is possible, and to advocate, a merely procedural resolution (Müller, 1999). However, there is a basic set of shared ethical premises and precedents that apply to the climate problem, and impartial reasoning (as behind a Rawlsian (Rawls, 2000) "veil of ignorance") can help put bounds on the plausible interpretations of what equity may mean in the burden sharing context. Even in the absence of a formal, globally agreed burden-sharing framework, such principles are important in establishing people's expectations of what may be reasonably required of different actors.

Chapter 3 reviews from a philosophical perspective the overarching equity principles in the philosophical literature and their implications for thinking about different aspects of climate change. Here we assess the applied literature regarding burden-sharing in a global climate regime, which draws upon the general literature and understanding of ethics, with a particular emphasis on the particular equity principles laid out in UNFCCC Article 3.

4.7.3.2 Equity Principles

From the perspective of an international climate regime, many analysts have considered the range of principles for equitable burden-sharing, taking into account the major characteristics of climate change and its causes (Hayes and KR Smith, 1993; Baer et al., 2000; B. Metz et al., 2002; Ringius et al., 2002; Aldy et al., 2003; Ghersi et al., 2003; Gardiner, 2004; Caney, 2005, 2009, 2010; Heyward, 2007; EA Page, 2008; Vanderheiden, 2008; Winkler, Jayaraman, et al., 2011). The principles of equitable burden-sharing have been most frequently applied to costs of mitigation, though similar issues arise with regard to adaptation (Baer, 2006; Jagers and Duus-Otterstrom, 2008; Dellink et al., 2009; Grasso, 2010; Hartzell-Nichols, 2011).

We discuss these principles, organized along four key dimensions – responsibility, capacity, equality, and the right to sustainable development, expanding on the moral philosophical arguments presented in Chapter 3. Table provides a synopsis.

Responsibility

There has been an extensive discussion of responsibility in the climate literature, substantially focused on the moral significance of knowledge of harmful effects (Neumayer, 2000; Caney, 2005; Müller et al., 2009). Common sense ethics (and legal practice) hold persons responsible for harms or risks they knowingly impose, and furthermore for harms or risks that could reasonably been foreseen, and, in certain cases, regardless of whether they could have been foreseen. In the climate context, responsibility is a fundamental principle, appearing in the UNFCCC in the form "*common but differentiated responsibilities,"* and alluded to in the statement noting that "the largest share of historic emissions has originated in developed countries." Responsibility most directly relates to responsibility for contributing to the climate problem, via emissions of greenhouse gases. It is thus closely connected to the Polluter Pays principle, and the burden-sharing principles which derive from it hold that countries should be accountable for their contribution to greenhouse gas emissions and their impacts.

Nations have expressly recognized, most notably in the Stockholm Convention of 1972 and reiterated in Rio Declaration of 1992, that they "have the responsibility to ensure that activities within their jurisdiction or control do not cause damage to the environment of other States or of areas beyond the limits of national jurisdiction." The no-harm rule is a widely recognised principle of customary international law whereby a State is duty-bound to prevent, reduce or control the risk of environmental harm to other States (Schwartz and Byrne 2010). Principle 16 of the Rio Declaration also says in relevant part that "National authorities should endeavour to promote the internalization of environmental costs and the use of economic instruments, taking into account the approach that the polluter should, in principle, bear the cost of pollution.

Historical emissions

Responsibility can be taken to include not only current emissions, but cumulative historical emissions as well (A. Grübler and Fujii, 1991; KR Smith, 1991; Neumayer, 2000). This has been justified on three main grounds. First, climate change is caused by atmospheric concentrations of greenhouse gases, which in turn is caused by the cumulative loading over time of the atmosphere, thus climate impacts and their damages result from accumulated historical emissions. Second, as the total amount of net greenhouse gases that can be emitted to the atmosphere must be constrained (to a level determined by society's particular choice of global climate stabilization goal), the ability of the earth to absorb our emissions constitutes a finite common resource, and users of this resource should be accountable for that use since it depletes the resource and precludes the access of others, whether that use is current or historical. Third, historical emissions reflect the use of a resource from which benefits have been derived in the form of the accumulation of benefits, i.e., wealth, fixed capital, infrastructure, and other physical and technological assets. These benefits constitute a legacy based in part on consuming a common resource that (a) should be paid for, and (b) provides a basis for mitigative capacity (Shue, 1999; Caney, 2006, 2010). The latter moral argument carries the notion of responsibility further back in time, attaching responsibility for the emissions of previous generations to current generation, to the extent that they have inherited benefits from those earlier generations. This argument links responsibility with the capacity equity principle discussed below (Gardiner, 2011a).

Since the scale of emissions from different countries are expected to grow at different rates, an assessment of countries' responsibility will vary depending on the point in time at which their responsibility is assessed. In a hypothetical scenario in which conventional development continues (i.e., trends in technological development and energy resources remains unchanged by mitigation policy or any other factors), the relative responsibility of some nations who currently have relatively low cumulative emissions would match and exceed by mid century the relative responsibility of some nations who currently have high responsibility (Höhne and Blok, 2005; Botzen et al., 2008), on an aggregate – if not per capita – basis. Such analyses do not necessarily provide an ethical argument that the future threat of emissions imposed by a nation ought to determine the responsibility of a nation to respond. However, they do illustrate that the relative distribution of responsibility among countries could vary substantially over time, and that a burden-sharing framework must dynamically reflecting evolving realities if they are to faithfully reflect ethical principles. A second point illustrated by such analyses is that projections of future emissions provide a basis for understanding *where* mitigation might productively be undertaken, though not necessarily *who* should be obliged to bear the costs.

Consumption-based emissions

Each nation's responsibility for emissions is typically defined (as in the IPCC inventory methodologies) to entail emissions within the nation's territorial boundary. An alternative interpretation, which was considered early on (Fermann, 1994) and has become more salient as international trade has grown more important, is to include emissions embodied in internationally traded goods that are consumed by a given nation. Recent studies (Lenzen et al., 2007; Pan et al., 2008; GP Peters et al., 2011) have provided a quantitative basis for better understanding the implications of a consumption-based approach to assessing responsibility. In general, at the aggregate level, developed countries are net importers of emissions, and developing countries are net exporters. The relevance of this to burden-sharing may depend on further factors, such as the distribution between the exporting and importing country of the benefits of carbon-intensive production, and the presence of other climate policies such as border carbon tariffs (See also Sections 3.9, 4.4 and 4.5.)

"Luxury" versus "survival" emissions

Many analysts have suggested that all emissions are not equivalent in how they translate to responsibility. Several approaches have been put forward that distinguish between emissions on the basis of the nature of the benefits with which they are associated. Specifically, analysts have put forward the categories of "survival emissions" (arising from activities associated with meeting basic needs), "development emissions" (arising from consumption associated with a modest level of well-being free from the hardships of poverty), and "luxury" emissions (associated with consumption well in excess of satisfying development needs). Luxury, development, and survival emissions have been treated differently with respect to whether they imply moral responsibility, (Agarwal and Narain, 1991; Shue, 1993; Baer et al., 2009; N Rao and Baer, 2012) and also with regard to implications for the transferability of emissions entitlements; some have argued that survival emissions should be "inalienable" to protect the poor from bargaining away their rights from a position of weakness (Shue, 1993; Pan, 2003), while others have argued that this might equally well prevent the poor from making the best use of their allocation (Hayward 2007)

Methodological issues

Determining responsibility for current, present and future emissions in order to allocate responsibility presents methodological questions. In addition to the standard questions about data availability and reliability, there are also equity-related questions to address.

For instance, there are various rationales for determining how far in the past historical emissions should be reckoned. One rationale is that 1992 is the earliest date, because that is the date at which a global regime was agreed that imposed obligations to curb emissions (Posner and Sunstein, 2007). Some argue that the date should be earlier, corresponding to the time that climate change became reasonably suspected of being a problem, and greenhouse gas emissions thus identifiable as a pollutant. Judging from the warnings issued by scientific advisory panels to the United States presidents Carter and Johnson, this could imply a date as early as the 1970s (G MacDonald et al., 1979), or 1960s (U.S. National Research Council Committee on Atmospheric Sciences, 1966) (though presumably not the date of Fourier's (1827) initial explanation for the natural greenhouse effect, nor the date of Arrhenius's conclusions regarding an anthropogenic greenhouse effect (Arrhenius, 1896). Others argue that a still earlier date is appropriate because the damage is still caused, the stock depleted, and the benefits derived, regardless of whether there is either a legal requirement or knowledge. They would argue that the date may be as early as can be allowed by the availability of emissions data and plausible scientific inference of emissions rates.

Another issue is the question of accounting for the residence time of emissions into the atmosphere, as an alternative to simply considering cumulative emissions over time. Some would argue that, in the case of carbon dioxide at least, responsibility should not exclude emissions because they are no longer resident in the atmosphere, because those emissions (a) have contributed to the warming and climate damages experienced so far, and upon which further warming and damages will be additive, and (b) have been removed from the atmosphere predominantly to the oceans, where they are now causing ocean acidification, which is itself a serious environmental problem (See AR5 WGI).

Capacity

Ability to pay

Beyond the obligation to act that arises from a moral responsibility for causing emissions, a second motivation for action arises from the capacity to contribute to solving the climate problem (Shue, 1999; Caney, 2010). Generally, this is interpreted to mean that the more one can afford to contribute, the more one should. The general moral sentiment is based on the presumption of a hierarchy of human needs, such that a given level of obligation would require a greater levels of sacrifice (or, welfare loss) of someone living in poverty than a rich person. An economist would refer to this as the declining marginal utility of income. In the real world, this is precisely how we tend to distribute the costs of preserving or generating societal public goods, i.e., most societies have progressive income taxation.

Intra-national disparities in ability to pay

With capacity (as with responsibility), nations consist of individuals who are in vastly different situations. Thus having rich people in poor countries and poor people in rich countries can complicate assessments of national capacity. As with luxury and survival emissions, one can consider income as supporting luxury or survival consumption, and treat it accordingly. One proposal that did this was Smith et al. (1993), which suggested GDP as an income based measure of ability-to-pay, subject to a threshold value, determined by an indicator of quality of life. This was developed in Kartha et al. (2009) and Baer (2010) in a manner that analyzed intra-national disparities, thereby avoiding the aggregate GDP in favour of an income distribution.

Response capacity

As discussed in sections 4.6.1 and 4.6.2, response capacity refers to more than just financial wherewithal, encompassing also other characteristics that affect a nation's ability to contribute to solving the climate problem. It recognizes that effective responses require not only financial resources, but also technological, institutional, and human capacity. This issue has been treated by Winkler, Letete and Marquard (2011) by considering Human Development Index as a complement to income in considering capacity.

Mitigation potential

Capacity, even in this broader sense, can be distinguished from mitigation potential, which refers to the presence of techno-economic opportunities for reducing emissions due to, for example, having renewable energy resources that can be exploited, a legacy of high-carbon infrastructure that can be replaced, or a rapidly growing capital stock that can be built based on low-carbon investments. Mitigation potential is a useful characteristic for determining where emissions reductions can be located geographically for reasons of cost-effectiveness, but this can be distinguished from burden-sharing *per se*, in the sense of determining on normative grounds which country should pay for those reductions. This distinction is reflected in the economist's notion that economic efficiency can be decoupled from equity (Coase, 1960).

Equality

Equality means many things, but a common understanding in international law is that each human being has equal moral worth and thus should have equal rights. This has been argued to apply to access to common global resources, and has found its expression in the perspective that each person should have an equal right to emit (M Grubb, 1989; Agarwal and Narain, 1991). This equal right is applied by some to current and future flows, and by some to the cumulative stock as well. (See further below.)

Some analysts (e.g., Caney, 2009) have noted, however, that a commitment to equality does not necessarily translate into an equal right to emit, for various reasons. First, egalitarians generally call for equality of a total package of "resources" (or "capabilities" or "opportunities for welfare") and thus may support inequalities in one good to compensate inequalities in other goods (Starkey, 2011). For example, one might argue that poor people who are disadvantaged with respect to access to a resources such as food or drinking water may be entitled to a greater than per capita share of emissions rights. Second, some individuals may have greater needs than others. For example, poorer people may have less access to alternatives to fossil fuels because of higher cost or less available technologies, say, and thus be entitled to a larger share of emission rights.

Others have suggested that equality can be interpreted as requiring equal sacrifices, either by all parties, or by parties who are equal along some relevant dimension. Then, to the extent that parties are not equal, more responsibility (Gonzalez Miguez and Adriano Santhiago de Oliveira, 2011) or capacity (e.g., Jacoby et al., 2009) would imply more obligation, all else being equal.

Right to development

The right to development approach posits that the interests of poor people and poor countries in meeting basic needs are a global priority (Andreassen and Marks, 2007). In particular, compared to the need to solve the climate problem, meeting basic needs has clear moral precedence, or, at the very least, it should not be hindered by measures taken to address climate change.

The UNFCCC acknowledges "the legitimate priority needs of developing countries for the achievement of sustained economic growth and the eradication of poverty" and recognizes that "economic and social development and poverty eradication are the first and overriding priorities of the developing country Parties." This does not necessarily suggest that nations have the right to unbounded economic growth and unconstrained emissions, an interpretation which would, in any event, expressly conflict with another fundamental objective of the Convention – "to protect the climate system for present and future generations". The right to development is, after all, qualified by the word "sustainable", specifically in Article 3 which states "have a right to, and should, promote sustainable development." Subsequently, Parties agreed that negotiations relating to global and national peaking of emissions should be undertaken in the context of "equitable access to sustainable development" (The Cancun Agreements, UNFCCC Decision 1/CP16).

Safeguarding this right to development constitutes an important dimension of equity in the climate context, particularly if climate change and the demands challenges of avoiding it present challenges to development.

One interpretation is that the right to sustainable development has implications for both *rights-holders* and *duty-bearers*, as is true of rights generally. The poor have a *right* to sustainable development, and the wealthy have a corresponding *duty* to provide the means by which that development may be made sustainable. With respect to climate change obligations, this perspective is reflected in the implicit burden-sharing framework embodied within the UNFCCC, and as reflected in the developed country Parties' Article 4 commitments to provide financial and technological support so that developing country Parties can meet their commitments under the Convention.

Table 4.1 Implications of burden-sharing principles

	Global	Annex 1	Annex 2	Non-Annex 1	LDCs
Responsibility					
Since 1850					
Since 1950					
Since 1990					
Current					
Current, using consumption-based accounting					
Capacity					
Income (MER, 2010)					
Income (PPP), 2010)					
Income (PPP) above $20/day development threshold					
Wealth					
HDI					
Equality					
Right to Development					

[Note from the authors: To be expanded as appropriate and completed for SOD based on common AR5 data sources, showing changes over time (1990-2010).]

4.7.3.3 Frameworks for equitable burden-sharing

[Note from authors: For consistency with Ch3 and Ch 13, additional frameworks may be added and/or existing ones consolidated.] There are various ways interpreting the above equity principles and applying them to the design of a burden-sharing framework. This section reviews a set of burden-sharing frameworks that appear to have some policy-relevance in the climate context, and that demonstrate the range of proposals that have been advanced. It is helpful to categorize climate change burden-sharing frameworks into two broad classes. The first, "resource-sharing" frameworks, are aimed at applying ethical principles to establish a basis for sharing the global greenhouse gas sink capacity, or its equivalent, the "global carbon budget". The second, "effort-sharing" (or "cost-sharing") frameworks, are aimed at applying ethical principles to establish a basis for sharing the costs of the global climate response. Within these two broad categories, individual frameworks emphasize to varying degrees the various key principles discussed above. Neither of these framings is objectively the "correct" one; both can inform policymakers judgments in different ways. Indeed, the two approaches are complementary: any given resource-sharing framework implies a particular distribution of the effort, and any given effort-sharing framework implies a particular distribution of the resource.

Generally, burden-sharing frameworks (whether of the resource-sharing or effort-sharing sort) are formulated as entitlement or allocation systems, meaning they establish a basis for assigning individual countries a certain quantity of rights to emit. This is invariably done with the provision for some mechanism, such as an emissions trading system and/or a global climate fund, through which countries with greater obligations can fund reductions in countries with lesser obligations. Such a mechanism is invoked so that the actual geographic distribution of emissions need not be the same as the allocation of emission rights, and a cost-effective global solution can be achieved in which mitigation is undertaken where it is less costly. A *least*-costly distribution of effort would be achieved under the conditions of full participation and a perfect trading system or global climate fund. (See Chapter 13.)

One important dimension along which both resource sharing and burden-sharing proposals can be compared is the number of categories into which countries are grouped. The UNFCCC in fact had three categories – Annex I, Annex II (the OECD countries within Annex I), and non-Annex 1. Many of the proposals discussed below reproduce this binary distinction. Others increase the number of “bins” to as many as six (the South/North Dialogue). Finally, many others eliminate any qualitative categories, instead allocating emissions rights or obligations on the basis of a continuous index. Such proposals may still lead to important practical distinctions (like between countries with shrinking allocations vs some “headroom” for growth), but based on objective indices that calculate obligations for all countries on the same basis.

Resource sharing approaches

The resource-sharing approach starts by acknowledging that global greenhouse gas sink capacity, or “atmospheric space”, is finite and exhaustible, with its size defined by the agreed climate stabilization target, which thus sets a limit on the ability of nations to emit greenhouse gases. Emissions by any one nation directly reduce the amount that can be used by other nations. This is particularly important in a world where the only demonstrated path to development is one that has historically involved the exploitation of relatively inexpensive and abundant fossil energy resources, and thus the emission of carbon dioxide.

Equal Per Capita Emission Rights (M Grubb, 1990; Agarwal and Narain, 1991; Jamieson, 2001) is a straightforward approach premised on the equal rights to the atmospheric commons to all individuals. All countries would be allocated emission allowances in proportion to their population, and would be free to trade them. The total number of allowances granted globally would decline along a path consistent with an agreed climate stabilization goal.

In response to the concern that an equal per capita allocation would provide an incentive for more rapid population growth, some analysts have argued that the effect would be negligible in comparison to other factors affecting population, and others have proposed solutions such as holding population constant as of some agreed date (Jamieson, 2001), establishing standardized growth expectations (Cline, 1992), or allocating emission in proportion only to adult population (M Grubb, 1990).

Delayed Transition to Equal Per Capita Emission Rights is a framework combining an initial period of grandfathered emission rights with a later period of per capita emission rights, with a transition from the former to the latter over a specified number of years. Countries whose emissions start above the global average would receive allowances that trend down to the global average, while countries whose emissions start below the global average would receive allowances that trend up until they hit the global average, at which point they too must decline. Proposals of this form have been put forward (MJ Grubb and Sebenius, 1992; Welsch, 1993; and Meyer, 2000, under the name "Contraction and Convergence") based on the reasoning that a gradual transition to a per capita allocation is required to avoid unrealistically rapid reductions in those countries whose current emissions are far above the global average. This rationale for the transition period applies specifically to a framework intended to determine actual physical emission pathways. In addition to the political challenges of pursuing such an emissions pathway, the global distribution of mitigation action would not be economically efficient. For a framework intended to assign allocations, the rationale is less applicable: the opportunity to acquire additional allocations through emissions trading would address the economic efficiency issue, and would lessen, though not eliminate, the political challenges, of an immediate equal per capita allocation.

Common but Differentiated Convergence (CDC) (Höhne et al., 2006) developed a proposal in which all countries’ per-capita emission allowances converge to the same low level within a common convergence timeframe, though non-Annex-I countries' obligations are differentiated by requiring them to start converging only once their per-capita emissions have exceed a certain threshold determined by average Annex 1 emissions. (By introducing this income-based cap, the CDC proposal implicitly takes into account capacity as measure of obligations, unlike the above two frameworks, which consider only responsibility.) The Indian Prime Minister (Singh, 2007) has put forward a closely related approach, which offered that India's per capita emissions will not exceed developed country emissions. As average per capita emissions in developed countries decline, they would serve as a cap for India's per capita emissions. This framework can be generalized and quantified by interpreting "developed country" to signify Annex 1 countries, and applying the same allocation rule as India has proposed for itself to all non-Annex 1 countries.

One Billion High Emitters (Chakravarty et al., 2009) determine national allowance caps by looking beyond average national indicators of emissions, and examining distributions of emissions across individuals within countries. Given the projected emission distribution across all individuals, it is possible to calculate the maximum per capita emission level that is consistent with a specified global budget (which declines over time to satisfy the agreed climate stabilization objective). Countries are then assigned emission allowances corresponding to their projected emissions, minus any emissions above the specified maximum per capita emission level. Compared to a strict equal per capita approach, this framework is somewhat more generous to countries with emissions higher than the global average, and somewhat less generous to those with emissions lower than the global average.

Equal Cumulative Per Capita Emission Rights (Bode, 2004; German Advisory Council on Global Change (WBGU), 2009; CASS/DRC Joint Project Team, 2011; Jayaraman et al., 2011) approaches extends the concept of equal per capita rights to include the historical and future carbon budget. This approach has gained political relevance, particularly in China, India, and parts of civil society. Various equal cumulative per capita proposals have been put forward that are identical in their structure, differing only in particulars such as the year at which accounting of historical emissions begins, and the overall global budget to be shared.

This framework accounts for the fact that some countries (which tend to be higher income countries that industrialized earlier) have consumed more than an equal per capita share of the total global budget. This results in a negative allocation for the future, i.e., a "carbon debt", which some analysts have tried to quantify and monetize (KR Smith, 1991; MGJ Elzen et al., 2005). This concept is a subset of a larger "ecological debt", explored for example by Srinivasan et al. (2008), who divides the world into rich, middle income, and poor nations, attributing responsibility to the nations in which goods are consumed, and estimates the monetary value of historic and projected damages from GHG emissions that occurred from 1961 to 2000. Their analysis covers climate change, stratospheric ozone depletion, agricultural intensification and expansion, deforestation, fishing, and mangrove conversion. Their study documents that climate change is by far the largest component of ecological debt, that poor and middle income countries inflict considerable damage upon themselves, and that the ecological debt of the rich nations to the poor nations is roughly comparable to the economic debt of poor nations to rich.

Effort sharing approaches

In contrast with the resource sharing frame, the "effort sharing" frame begins by looking at the costs to be incurred from reducing GHG emissions to an agreed level, and asking how those costs should be fairly divided (effort sharing approaches can also address adaptation costs in a way that resource sharing approaches do not). Two of the equity principles discussed above are typically drawn upon to suggest how to equitably share the costs of solving a problem: "those who bear *responsibility* for causing the problem should pay", and "those who have the *capacity* to solve the problem should pay". Many of the philosophers engaged with the question of burden-sharing in the climate regime have argued that obligations should be proportional in some fashion to responsibility and capacity. (See, for example the analyses of Shue (1993); or Caney (2005)). Indeed, these principles – which mirror the foundational equity principles of "common but differentiated responsibilities and respective capabilities" in the United Nations Framework Convention on Climate Change (UNFCCC) – are widespread in proposed climate policy architectures as well (Klinsky and Dowlatabadi, 2009). Different effort-sharing approaches have put forward different ways of combining these principles to constitute a burden-sharing framework.

South-North dialogue approach is a global "multi-stage approach," based on principles of: responsibility; capability; mitigation potential; right to development. It clusters countries into six groups, which have commitments to mitigate based on indicators of the above principles and contingent on payment of mitigation costs (where these diverge). Countries graduate between groups as they develop, and are permitted to meet some of their obligations by trading. Emissions reduction obligations at home are distinct from obligations to pay for mitigation actions abroad, which depend on responsibility and capability indicators and so falls mostly on rich countries, though some newly industrialised countries also take on some of this burden.

Brazilian Historic Responsibility approach was first put forward as a proposal for setting Kyoto Protocol targets. It is based primarily on historic responsibility for emissions: developed countries are each allocated emissions cuts based on the total contribution of their historic emissions (going back to 1800s) to the current global temperature increase. It has been quantitatively analyzed (Höhne and Blok, 2005) and discussed in the global political context recently (Gonzalez Miguez and Adriano Santhiago de Oliveira, 2011).

Greenhouse Development Rights (Kartha et al., 2009) is a framework wherein the burdens for supporting mitigation (and adaptation) are shared among countries in proportion to in proportion to an indicator based on capacity and responsibility, with each of these defined with respect to a "development threshold" defined at an income level modestly above a global poverty line. Two variants of the Greenhouse Development Rights framework have been developed by Chinese analysts (Yue and S Wang, forthcoming; Cao, 2008).

Graduation and Deepening is an approach (Michaelowa et al., 2005), like the previous framework, that proposes a stringency of mitigation commitments based on an index based on per capita income and per capita emissions, with a threshold level below which countries do not take commitments, but may participate through the CDM.

Responsibility and Capacity Index proposed by Oxfam (J. Richards et al., 2009) is an approach that uses a calculated responsibility and capability index to allocate an overall mitigate target of 40% (and financing target of $150 bn) among developed countries. Developing countries individual need for financing is assessed in line with available economic capability, taking into account intra-national inequality, and hence climate finance is provided on a sliding scale (below a minimum 'available capability threshold').

The Joint Research Centre of the European Commission has devised a method for distributing targets amongst Annex 1 countries, that includes starting with an overall target for Annex 1 countries (of 30% below 1990 levels by 2020) and allocating this target on the following basis: GDP per capita, (representing capacity to pay either domestically or through the global carbon market); emissions intensity, (representing mitigation potential); change in GHG emissions between 1990 and 2005 (representing prior mitigation undertaken by developed countries); and recent population trends, (representing equal per capita rights to emit). The EU approach is highly parameterized and its effort-sharing implications depends sensitively upon the particular choice of values assigned to individual parameters. This approach provides a model for how a burden-sharing framework can serve as a negotiating frameworks for assessing the implications of various equity principles, rather than as a particular proposal.

4.7.4 Indicators of sustainable development and equity

After having recalled the main concepts from the previous framing chapters, and developed the concepts and issues related to equity in burden-sharing, we conclude this section with a critical review of indicators of sustainable development. Various indicators can be used at the global, national, and local (community) level, and for comparative purposes across communities and nations, as well as over time. There is also a need to take into account the specificities of regional and cultural diversity in developing indicators.

4.7.4.1 Indicators of development and intragenerational equity

GDP continues to be the dominant indicator for growth. Considerable research has been undertaken to develop, apply and refine indicators of sustainable and equitable development beyond GDP and income with some degree of application but there remain significant challenges and gaps (Gadrey, 2006; Fleurbaey, 2009; Stiglitz et al., 2009).

The UNDP Human Development Index, inspired by Sen's capability approach, has been widely used by governments and non-State actors. UNDP has developed a new comprehensive poverty index, the Multidimensional Poverty Index, aimed at reflecting the living conditions of people by using a combination of social and economic indicators in a more effective manner (Alkire, 2010).

Indicators have also been developed to measure the progress of the Millennium Development Goals. "Well-being indicators" (such as malnutrition, child mortality, reproductive health and primary education) have been developed to assess poverty according to social performance, and not income alone. A composite of the MDG indicators has been developed into the Basic Capabilities Index (BCI).

The Gross National Happiness Index (GNH), developed in the Kingdom of Bhutan, comprises a set of indicators in nine areas: psychological well-being; time use; community vitality; cultural diversity and resilience; health; education; ecological diversity and resilience; living standard, and good governance. "Gross National Well-Being" is in the Bhutan 2008 Constitution (Centre for Bhutan Studies, 2010).

There is similarity with the Latin American "BuenVivir" approaches that pursues the goal of material, social and spiritual satisfaction among all members of a society, but not at the cost of the other living beings or natural resources. BuenVivir has been adopted in the constitutions of Ecuador (2008), Bolivia (2009) and Peru. In order to implement the principle of BuenVivir in practice and make it workable, it would have to be translated into measurable goals and indicators.

The Economic and Social Rights Empowerment Initiative (2010) (http://www.serfindex.org/about/) provides tools of quantitative measurement and analysis regarding fulfilment of economic and social rights – the right to food, the right to adequate shelter, the right to healthcare, the right to education, the right to decent work, the right to social security, and protection against discrimination. At the core of the Initiative is the composite Index of Social and Economic Rights Fulfilment (the SERF Index) that measures the performance of countries and sub-national units on the fulfilment of economic and social rights obligations. (Fukuda-Parr et al., 2009; Randolph et al., 2010).

4.7.4.2 Indicators of sustainability

The above examples are all indicators of affluence and well-being of the present generation, and one could list many more indicators of inequality and poverty. These indicators do not assess the sustainability of the development path. Specific indicators of sustainability have been proposed.

Green accounting

Some indicators retain the monetary metric of the GDP and fall under the category of "green accounting" or "capital approach". The environmentally adjusted (or green) net national product and the Sustainable Net Domestic Product (SNDP) add to total income positive or negative terms measuring the variation in various forms of human-made and natural capital (Daly, 1996; Lawn, 2003; Dietz and Neumayer, 2007). Roughly, such indices can be interpreted as measuring a comprehensive notion of sustainable income, defined as the quantity that can be consumed while preserving the potential for future consumption. They do not measure sustainability itself, but sustainability can be assessed, in principle, by comparing the current level of consumption to the sustainable level measured by these indices.

Structurally similar are the Index of Sustainable Economic Well-being (ISEW) and the Genuine Progress Indicator (GPI). There are variations between these indices in how they conceptualize income and deal with durable goods, the cost of pollution, defensive expenditures, and inequalities. The theoretical foundations of the ISEW and the GPI have been debated (Neumayer, 1999; Lawn, 2003). The link between these indices and sustainability is even less clear than for green accounting.

The most widely referenced of the green accounting approaches is the indicator of genuine savings (GS), or adjusted net savings, which is the value of the variation in all capital stocks (see Hamilton and Atkinson (2006) for a recent overview and Aronsson et al. (1997) for an important earlier contribution). The valuation of stocks of capital is ideally based on "accounting prices" that reflect the marginal impact of stocks on a synthetic measure of current and future consumption (or utility). This notion has been adopted by the World Bank as its main indicator of sustainability.

There is some disagreement reflected in the literature regarding whether aggregating produced and natural capital as done in these indicators ties them to the weak sustainability approach or whether a full accounting of the cost of depleted natural capital connects to strong sustainability (compare Lawn (2003) and Dietz and Neumayer (2007)). It all depends on how the accounting prices are calibrated. Such prices, by construction, measure the marginal impact of stocks on an objective function. When complementarity between the various forms of capital is assumed in this function, the marginal impact of a stock on the function tends to infinity when the stock becomes essential. It is therefore possible to incorporate a strong sustainability approach in GS by letting the prices of natural capitals increase considerably when their stocks come close to the threshold quantities that should be maintained.

The qualifications of genuine savings as an indicator of sustainability have been debated (Hamilton and Clemens, 1999; Pezzey, 2004; Fleurbaey, 2009). Negative genuine savings is the signal that the current level of consumption is not sustainable, but it does not say when the downturn will occur and how big it will be. Positive genuine savings, on the other hand, does not guarantee that the ongoing path will remain on the upward slope forever. It is not obvious that GS gives more reliable and richer information than an ordinary forecast of possible future growth paths. Moreover, the accounting prices which are the essential ingredient of GS require an estimate of how current and future consumption (or utility) depends on the value of the different stocks in natural and human resources. While market prices do provide this information in a perfectly managed economy (a striking result due to Weitzman (1976)), they may be very misleading in real conditions (Dasgupta and Mäler, 2000; K.J. Arrow et al., 2010) It is at least as easy to undervalue the price of depleted capital as to be overoptimistic over future growth rates in an ordinary forecast exercise. Therefore, an indicator such as GS may help policy-makers be aware of sustainability issues but may also give them undue confidence and optimism about sustainability.

A variant of the genuine savings indicator has been proposed by Cairns and Martinet (2012). It uses accounting prices computed at the "maximin" path, i.e., the path that maximizes the lowest level of welfare over the present and future generations. It can be shown that under quite general assumptions a positive value of net investment at such prices is a sufficient condition for the current levels of consumption, investment, and resource extraction, to be compatible with a non-decreasing welfare path over the future.[15]

[15] The current generation's level of welfare is sustainable if it is below the maximin welfare level for all future generations (Pezzey, 2004). The maximin welfare level for the current and all future generations cannot be

Ecological indicators

Advocates of strong sustainability have proposed specific measures of the state of natural ecosystems. In this vein, a popular indicator of sustainability is the ecological footprint, initially proposed by Wackernagel and Rees (1995), and now regularly updated by the Global Footprint Network. The indicator measures the surface of land needed to sustain current living standards, at the global and at the national level. The measure relies on actual yields of various land uses and therefore does not take account of the depletion of soils or of predicted changes in productivity. To the land surfaces needed to produce various consumer goods, it adds the surface of forest needed to absorb carbon emissions. Given that actual yields are used in the computations, the surface needed for production does not vary much over time at the global level, and carbon emissions make up most of the increase of the indicator. This indicator has been criticized for assuming substitutability between the various forms of natural capital, for adopting too crude a link between GHG and forest surface requirements (Dietz and Neumayer, 2007), as well as for ignoring technical progress and the degradation of soils (K Mori and Christodoulou, 2012).

Many other accounts of natural stocks and flows, and ecosystems health, have been proposed. The System of Integrated Environmental-Economic Accounting (SEEA) of the United Nations offers a wealth of information about the state of ecosystems and is currently under revision and expansion.[16] Material flow accounts have been made in order to compute total inputs and total outputs. Such measures are aggregated by weight and fail to accurately record environmental damages. They have been associated to calls for the reduction by a factor four or more of the use of material resources (von Weizsäcker et al., 1997, 2009). The water footprint (Hoekstra and Chapagain, 2007) and the carbon footprint (the latter is discussed in detail in Sec. 4.5) focus on the quantities of fresh water used, or the quantity of CO_2 emitted, in the production process.

China is developing indicators for low-carbon development and low-carbon society (UN (2010), with many citations) with specific indicators tested on selected cities and provinces (Fu, Jiafeng et al., 2010), providing useful data on challenges and gaps as well as the need for clearly defined goals and definitions of “low carbon” and its sustainable development context.

Hybrid indicators such as the Environmental Sustainability Index and the Well-Being Index (WBI) aggregate various components reflecting the situation of the three pillars. For instance, the WBI is the average of a human WBI and an ecosystem WBI, each of which is an aggregate of five sub-indices. The Environment Performance Index compares countries in terms of impacts on the environment. The Living Planet Index also assesses the impact of human activities on ecosystems, especially on biodiversity (see Mori and Christodoulou (2012) for a review of these various indicators).

The need for straightforward indicators

Martinet (2011) proposes a general approach in which thresholds can be posited for well-being or for various natural or man-made stocks and which can explicitly deal with uncertainty. Sustainability is considered to be achieved when the predicted future path remains forever above the defined thresholds. When the future is uncertain, sustainability can be assessed by the probability that thresholds will be crossed.

In conclusion to this subsection, one may suggest that no sustainability indicator in circulation appears as good as a direct evaluation of the risk of future downturns in well-being or in the state of the ecosystems. This should not be a surprising conclusion. Sustainability is about the future of the

strictly below the current generation’s welfare and the maximin level for future generations. Therefore, when it is lower than the latter (which is equivalent to positive net investment at the maximin prices), the current generation’s level is also below it, and sustainability is guaranteed.

[16] Documentation is available at http://unstats.un.org/unsd/envaccounting/seearev/.

development path, and it is impossible to evaluate without making predictions. The evolution of current stocks of capital tells us something about the opportunities that are passed to the next generations only under an accurate measurement of the value of these stocks for the future generations, and such a measurement is even more difficult than predicting the future.

The literature does not always distinguish between two sustainability issues. One is to predict whether the current situation (welfare, environment) will be preserved in the future: Are we on a sustained development path, i.e., a path without downturn? Another is to determine whether the current generation's decisions leave it possible for future generations to achieve such a path: Is a sustained development path possible given what the current generation does? The latter does not require predicting future decisions, only future constraints and opportunities. For instance, negative genuine savings is a sufficient condition for a negative answer to the former question, whereas positive net investment at maximin prices is a sufficient condition for a positive answer to the latter question.[17] Standard predictions of GDP and human development are inspired by the former, whereas Green GDP and the ecological footprint are concerned with the latter.

In this light, a straightforward indicator of sustainability for the first question could take the form of a family of curves describing the future evolution of a relevant indicator (e.g., of well-being or of the state of the environment) at different probabilities – or at different degrees of confidence if probabilities are hard to specify. Figure illustrates the idea by comparing hypothetical scenarios involving (a) a risky path that promises high growth on average but with a growing risk of unsustainability over time, and (b) a less risky path that promises less on average but is more secure for sustainability.

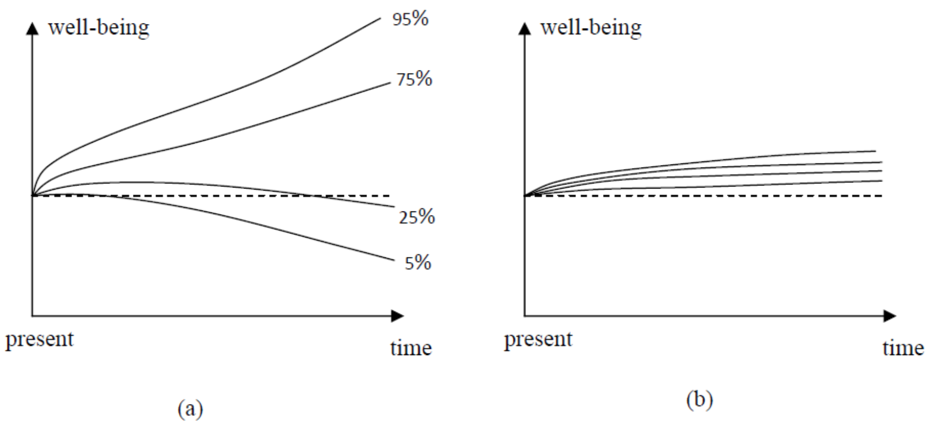

Figure 4.4 Sustainability of the current path measured by risk curves. (The probability that the path will fall below a curve is equal to the number assigned to this curve.)

An appealing criterion for the second question would focus on the comparison between the current situation and the greatest sustainable level (of whatever quantity one seeks to sustain) for future generations. The former is known, albeit imperfectly, and the latter can be predicted in probabilistic terms. The probability that the former is greater than the latter then provides a good indicator of the risk of unsustainability.

[17] Obviously, a negative answer to the second question implies a negative answer to the first. Note that for efficient paths, negative genuine savings is also a sufficient condition for a negative answer to the second question (GB Asheim et al., 2003).

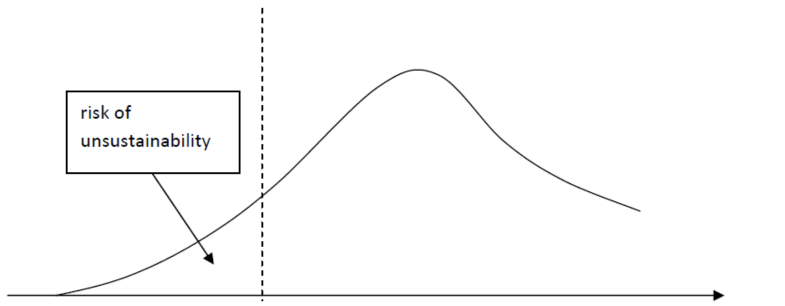

Figure 4.5 Possibility of a sustainable path measured by the comparison of current level with future sustainable level. (The bell curve is the probability density of the latter.)

The curve displayed in Figur also provides information about the risk of the future sustainable level falling well below desirable levels. For a given risk of unsustainability, one may prefer a situation with a lower probability for catastrophic situations. Again, variants of this indicator that involve only qualitative descriptions of confidence can readily be constructed.

4.8 Implications for subsequent chapters

4.8.1 Why sustainability and equity matter

The primary implication of this chapter as a framing for subsequent chapters is to underscore the importance of explicitly scrutinizing the candidate mitigation technologies, approaches, and policies for their broader equity and sustainability implications.

This chapter has focused on examining the extent to which the broader objectives of equitable and sustainable development are supportive – and perhaps preconditions – of an effective, robust, and long-term response to the climate problem. Building both mitigative capacity and adaptive capacity relies to a profound extent on the same factors as those that are integral to equitable and sustainable development. Thus, efforts to advance equitable and sustainable development can generally be expected to make positive long-term contribution to society's climate response. Conversely, it may well be the case that measures that undermine the advancement of broader sustainability objectives might similarly undermine broader climate goals, even when those measures appear in the near-term to provide mitigation benefits.

Hence, the analyses of mitigation technologies, approaches, and policies presented in this assessment are especially helpful and policy-relevant to the extent they assess how these mitigation options contribute to (or undermine) broader sustainable development and on equity objectives. This is why the assessment of sectoral options must not limited to their mitigation potential and the corresponding cost per tCO2 equivalent.

4.8.2 Three levels of analysis of sustainability consequences of climate policy options

As explained in this chapter, sustainability can be assessed either in terms of end results or in terms of capacities.

4.8.2.1 The three pillars

End results of climate policy options can generally be observed in the three spheres related to the three pillars of sustainable development: the economic, the social, and the environmental sphere. Sustainability in the economy refers to the preservation of standards of living and the convergence of developing economies toward the level of developed countries. Sustainability in the social sphere refers to fostering the quality of social relations and reducing causes of conflicts and instability, such as excessive inequalities and poverty, lack of access to basic resources and facilities, and discriminations. Sustainability in the environmental sphere refers to the preservation of biodiversity, habitat, and natural resources.

4.8.2.2 Capacities

Sustainability can also be assessed in terms of capital or capacities, as suggested by some indicators such as genuine savings or the ecological footprint. Preserving the resources transmitted to the future generations is a key step in guaranteeing a sustainable path. Again, it is useful to think of the capacities underlying the functioning of the three spheres: economic, social, ecological. The economic sphere needs various forms of productive capital and raw materials, infrastructures and a propitious environment, but also human capital, institutions, governance, and knowledge. The social sphere needs various forms of institutions and resources for sharing goods and connecting people, which involve certain patterns of distribution of economic resources, transmission of knowledge, and forms of interaction, coordination and cooperation. The ecological sphere needs to keep the bases of its stability, including habitat, climate, and biological integrity. In general, climate policy options can affect capacities in all of these spheres, to varying degrees.

4.8.2.3 Well-being

While capacities contribute to the three pillars, the way the three spheres (and pillars) flourish can be viewed as contributing to the preservation of well-being for humans as well as for other living creatures. Human well-being depends on economic, social, and natural goods, and the other living beings depend on the quality of the ecological system. It may therefore be convenient to summarize the multiple relevant considerations by saying that the ultimate end result, for sustainability assessment, is the well-being of all living beings. Measuring well-being is considered difficult for humans because there are controversies about how best to depict individual well-being, and about how to aggregate over the whole population. However, as explained in Chapter 3 and Section 4.7, many of the difficulties are exaggerated and practical methodologies have been developed. Truly enough, it still remains difficult to assess the well-being of all living beings, humans and non-humans together.

But, even if current methodologies fall short of operationalizing comprehensive measures of well-being of that sort, it is useful for experts who study particular sectors to bear in mind that a narrow notion of living standards for humans does not cover all the aspects of well-being for the purposes of assessing sustainability. It is also useful to try to assess how various interactions between the three spheres can impact on well-being. When there are trade-offs between different aspects of the economic, social, and ecological dimensions, one has to make an assessment of their relative priorities. Well-being is the overarching notion that helps thinking about such issues.

4.8.2.4 How to analyse sustainable development and equity impacts

In summary, the analysis of mitigation (and, secondarily, adaptation) technologies, approaches, and policies made in this report will be most helpful if they help to answer the question of how these options help to advance the broader objectives of sustainable development and equity. This can be done at the three levels listed here, that is, 1) examining how the various stocks of the relevant kinds of capital and capacities are affected; 2) assessing the consequences on the three pillars: economic, social, and ecological; and 3) further downstream, addressing the prospects for the well-being of living beings in the future.

The methodology that can be proposed on this basis is relatively simple, although the choice of indicators in some cases may be subject to debate. For each analysis of a mitigation strategy in a particular sector, one may seek to determine, in addition to the climate impact (emissions), the consequences for:

1) Capacities:

a) productive capital and infrastructure (investment),

b) human capital (technological progress, skills and health),

c) natural capital (replenishment or depletion of natural resources and habitats);

d) social capital (social connections, degree of trust and cooperation);

2) Pillars:

a) economic performance (productivity, production and consumption);

b) social situation (which includes inequalities and disparities within and between countries, as well as migrations, unemployment, poverty, access to utilities);

c) ecological situation (biodiversity, preservation of species);

3) Well-being:

a) Humans (whose well-being is jointly determined by standards of living, health, education, forms of governance, quality of the environment, social relations, among other things);

b) Non-humans (a species may be submitted to stress without risking extinction, therefore biodiversity is not as comprehensive as well-being).

4.8.3 Sustainability and equity issues in sectoral chapters

[Note from the authors: We will revise based on the use of indicators as presented in the sectoral chapters. Include a table including the indicators that are included in the report and assess them. (Note at end of table a disclaimer recognizing that there are many other indicators.)]

Sustainability indicators at the sector level have a very limited role to play in the assessment of global sustainability. The reason is that sustainability involves the combination of actions and conditions (co-evolution) in various parts of the society, the economy, and the environment. It is the combination that makes sustainability possible, not any single part in isolation. There is no simple formula that would compute general sustainability as a function of sectoral indicators. Consider for instance the transportation sector. The development of a particular form of transportation may be compatible with sustainability only provided that other sectors evolve in a specific way. It may even happen that the best contribution to sustainability that the transportation sector can make depends on how other sectors evolve. For instance, when high density urbanization is developed, the most sustainable organization of transportation (network, modality) may be quite different from the best formula for low density habitat. What happens in the energy sector is also of course of key relevance for the transportation sector.

Along these lines, some specific issues and methodologies have been highlighted in this chapter and may help orient the examination of concrete aspects of mitigation.

On the methodological side, an idea emphasized in 4.7.1.1, in relation to Chapter 2, is that risk is a central aspect of sustainability, so that the analysis of mitigation (and adaptation) policies and measures would ideally not just give a central estimate of the consequences on well-being and the three pillars, but also, and perhaps more importantly, seek to determine the magnitude of the likelihood that serious harm may occur in any of these aspects of sustainable development. To give an example, suppose that a particular technological innovation gives good prospects of contributing substantially to the reduction of GHG emissions, but creates a risk for the access to vital resources for some vulnerable populations. While an evaluation based on expected values would perhaps be clearly positive, it might be that the risk to sustainability (introduced in the previous section) would actually be worsened with a generalized use of this innovation, because of the possibility of disastrous social consequences. This does not mean that the analysis should focus on worst-case scenarios and ignore the rest. In particular, it would be too precautionary to ignore best-case scenarios when the worst-case scenarios do not threaten sustainability or are very unlikely.

Obviously, even under a strict concern for sustainability, the relevant scenarios are not the worst-case scenario as such, but all those that jeopardize sustainability (see Figure 4.4).

The assessment of risks and uncertainties requires an evaluation of the resilience of the economic, social, and ecological systems to climate variability and to the other changes and shocks induced by response strategies. This may include the consideration of possible violent conflicts, social unrest and wars. This is why the focus on the likelihood of worst-case scenarios is different from analyses of central scenarios involving a form of "business as usual" for the main economic and social institutions.

4.8.3.1 Examples of sustainability and equity issues arising in climate measures

Let us enumerate various examples of concrete issues that can be brought in during the examination of sustainability impacts.

First, beyond mitigation and climate impacts, it is clearly important to consider the broader (non-climate) environmental impacts of mitigation options, as for instance in the case of habitat loss induced by hydroelectric dams, or the biodiversity benefits of avoided deforestation, or the reduction in local air pollutants arising from greater fuel efficiency.

A second important issue is the distributional impact of climate policies and measures. If there are costs and benefits, how are these distributed across the affected population, and in particular across income classes. For example, analyses have concluded that a carbon tax, in some countries, would be regressive, affecting poorer people disproportionately [add refs]. Other fiscal policies, such as an air travel levy, are progressive [add ref]. What measures, then, can be taken to avoid or compensate any regressive impacts? For example, some studies (Metcalf, 2009) have assessed the compensatory benefit and policy viability of pairing a per capita dividend with a carbon tax to eliminate (and if desired, reverse) its regressive impacts. At a more global level, one has to think of the possible differential effect of various strategies in developing and developed countries, and what this implies for equitable burden-sharing.

A related key line of examination is determining how a climate policy or measure affects access to key basic necessities, especially in developing countries. A particular concern is the link between specific renewable energy options and the access to energy services. In some cases, for example, renewables might make possible decentralized mini-grids in remote areas, thus helping to provide universal access to energy services. In other cases, a greater penetration of renewables onto the grid might affect affordability, thereby constraining access to energy services.

It is also important to examine climate policies with respect to access to other basic needs. For instance, land-intensive options (biofuels in particular) may affect food and water security. Various transport options affect the access to mobility, therefore to markets and jobs.

The very culture-specific social impacts of climate policies and measures is also something to be taken in consideration. For instance, the design and deployment of sectoral strategies may have gender implications, especially in countries and areas in which women can be key agents of implementation. Transport choices and various degrees of access to mobility also affect the social compact and the quality of interactions between individuals and families.

It is also important to consider how climate policies and measures affect well-being in more direct ways. For instance, certain forms of renewable energies, particularly those that are land-intensive or rely on very specific types of landscapes (e.g., wind turbines on mountain ridges) may also affect the aesthetic of the landscapes in a way that directly affects quality of life and well-being. A greater ability to work at home made possible by information technologies, may have important positive consequences on transport demand and emissions, but may also affect social networks and well-being. Zoning and housing policies may reduce emissions by increasing density but an increased density of population may also affect the quality of life in various positive and negative ways. The mix of automobiles, public transport and bicycles in cities is also not neutral for well-being, as well as the spatial distribution of shops and malls. Different fuels and engines have different impacts on health and well-being. There is a great variety of potential synergies and conflicts between immediate well-being and policies addressing the climate issue.

These are but a few examples of the more concrete sustainability considerations that will be brought in, in addition to the most immediate effects of mitigation strategies.

4.8.3.2 Ensuring democratic engagement in implementation and transitions

Beyond measurement methodology and issues of development paths which directly bear on sustainability, there are aspects of implementation that indirectly bear on sustainability, by their importance for the viability of strategies. For instance, an important consideration that comes out of the examination of development paths and transitions in this chapter is that democratic participation and inclusion are instrumental in ensuring an effective implementation of sectoral strategies. This is linked to the contribution of lifestyles to mitigation efforts, but much more broadly it also has to do with the support that various public policies, incentives, and regulations, can obtain among the electorate and the actors of public debates, and how the influence of vested interests can be checked by the larger polity.

Relatedly, as explained in this chapter, the speed of needed transitions is important to assess the possibility for the affected population to bear the induced costs, as well as the support such transitions can gather, or how much attention they can draw from a population afflicted by the standard behavioral biases described in Chapters 2 and 3.

4.9 Gaps in knowledge and data

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

4.10 Frequently Asked Questions

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

FAQ 4.1: Why does IPCC need to think about sustainable development? If we respond to climate change won't sustainable development follow?

Climate change is a threat to sustainable development. Addressing the climate risks is therefore needed in order to achieve a sustained and equitable development for the coming generations. Though addressing climate is necessary, it is not sufficient, as there are other threats such as the depletion of natural resources, pollution hazards, inequalities, or geopolitical tensions. As policymakers are concerned with the broader issues of sustainable development, it is important to reflect on how climate risks and policies fit in the general outlook. Moreover, preparing societies to move to sustainable development pathways provides a favourable setting for building mitigative and adaptive capacity ultimately needed address climate change.

FAQ 4.2: IPCC and UNFCCC just think about GHG emissions within countries. Aren't consumers responsible for all the emissions linked to the goods and services they use, even if they come from other countries?

For any given country, it is possible to compute the emissions embodied in its consumption or those emitted in its productive sector. The consumption-based framework for GHG emission accounting allocates the emissions released during the production and distribution (i.e. along the supply chain) of goods and services to the final consumer and the nation (or another territorial unit) in which she resides, irrespective of the geographical origin of these goods and services. The territorial or production-based framework allocates the emissions physically produced within a nation’s territorial boundary to that nation. The difference in emissions inventories calculated based on the two frameworks are the emissions embodied in trade.

FAQ 4.3: What kind of consumption has the greatest environmental impact?

The relationship between consumer behaviours and their associated environmental impacts is relatively well understood. Generally, higher consumption lifestyles correspond to greater environmental impacts, which connects distributive equity issues with the environment. Beyond that, research has consistently shown that mobility (automobile and air transport), food (specifically, meat- and dairy-intensive diets), and housing are responsible for the largest proportion of consumption-related environmental impacts. Together they account for 70% to 80% of the life-cycle environmental impacts in industrialised countries.

[Note from the authors: Additional question relating to equity and burden-sharing to be added]

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