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Energy for a Shared Development Agenda: Global Scenarios and Governance Implications

Måns Nilsson, Charles Heaps, Åsa Persson, Marcus Carson, Shonali Pachauri, Marcel Kok, Marie Olsson, Ibrahim Rehman, Roberto Schaeffer, Davida Wood, Detlef van Vuuren, Keywan Riahi, Branca Americano and Yacob Mulugetta

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Stockholm Environment Institute
Kräftriket 2B
106 91 Stockholm
Sweden

Tel: +46 8 674 7070
Fax: +46 8 674 7020
Web: www.sei-international.org

Director of Communications: Robert Watt
Publications Manager: Erik Willis
Editor: Tom Gill
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PREFACE AND ACKNOWLEDGMENTS

This study is an analytical contribution to the international deliberations before and after the Rio +20 United Nations Conference on Sustainable Development, organized by the UN Commission on Sustainable Development and held in Rio de Janeiro, June 2012. The Stockholm Environment Institute (SEI) initiated the study in 2010 following a request by the UN Department of Economic and Social Affairs (UNDESA) to develop a forward-looking assessment of the energy challenge in the context of global sustainability and poverty alleviation.

SEI assembled a partnership of leading international research institutions and think tanks to carry out the study: the African Climate Policy Centre (ACPC), the Brazilian Foundation for Sustainable Development (FBDS), the Federal University of Rio de Janeiro (COPPE), the International Institute for Applied Systems Analysis (IIASA), the Netherlands Environmental Assessment Agency (PBL), The Energy and Resources Institute (TERI) and the World Resources Institute (WRI).

Lead and contributing authors for each chapter are:

- Chapter 1: Måns Nilsson, Marcel Kok, Ibrahim Rehman, Shonali Pachauri, Yacob Mulugetta
- Chapter 2: Charles Heaps, Måns Nilsson, Detlef Van Vuuren, Keywan Riahi
- Chapter 3: Marcus Carson, Måns Nilsson, Roberto Schaeffer, Ibrahim Rehman, Marie Olsson
- Chapter 4: Åsa Persson, Davida Wood, Måns Nilsson, Marcel Kok, Ibrahim Rehman, Shonali Pachauri, Branca Americano
- Chapter 5: Måns Nilsson

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EXECUTIVE SUMMARY

This study examines how energy needs for human and economic development can be met in a way that is compatible with long-term sustainable development at the global scale. The study pulls together insights from global energy and sustainability scenarios, case studies of socio-technical transformation of energy systems on both the supply and demand sides, and reviews of policy mechanisms and governance frameworks.

1 The challenge

Providing a clean, affordable, reliable supply of energy to poor households for lighting, cooking and heating is widely regarded as a prerequisite to successfully fight poverty and improve human well-being. Governments around the world, and the international system, increasingly recognize this. The global debate on how to provide access to basic energy services for the world's poor has this year taken centre stage in international policy, with the UN General Assembly naming 2012 as the official year of Sustainable Energy for All. And it seems clear that energy will, in one way or another, be a central component of future development goals, such as the currently discussed sustainable development goals (SDGs).

Achieving basic access to energy for all is no minor feat: worldwide, approximately 2.7 billion people rely on traditional biomass such as wood or dung for cooking and heating. Some 1.3 billion have no access to electricity, and up to a billion more only have access to unreliable electricity networks. Most energy-poor communities are concentrated in South Asia and sub-Saharan Africa.

But if our goal is to achieve *sustainable* energy for all, there are two interrelated challenges that need to be simultaneously addressed. The first concerns the social and economic pillars of sustainability: technical arrangements to provide basic energy access are difficult to sustain over time unless those without access are provided with the tools to lift themselves out of poverty and generate incomes to pay for energy services. Income generation, in turn, requires energy for productive uses. With the strong correlation between income and energy demand, energy for productive uses and development is a legitimate concern shared by governments across the world.

The Energy for All agenda must move beyond the "sticking plaster" approach (i.e. addressing symptoms by securing basic energy access to improve living conditions for the poor) to also secure energy services that enable long term economic development in all countries. This would represent a change in how the energy and climate challenge is understood. However, current trends suggest that new development patterns are already under way. For example, while most OECD countries have experienced annual growth rates of only about 0–2% over the last decade (and facing a dismal medium-term outlook), many countries in Latin America, Asia and Africa have registered annual growth rates in the range of 8–10%. We need to better understand the implications, not least in energy and sustainability terms, of a world in which incomes per capita converge over the long term. Clearly, such a new reality would bring both challenges and opportunities.

The second challenge relates to the environmental pillar of sustainability, that is, the biophysical system constraints that we now increasingly face, with accelerating human pressures on Earth. Of all human activities, energy production and use are key drivers behind a number of critical pressures on the Earth system. These include: greenhouse gas emissions – of which energy-related emissions represent roughly 75% of the global total; scarcity and degradation of land and water – where hydropower and bioenergy, if expanded further, may appropriate significant shares of available land and water resources; and emissions of dangerous pollutants. Energy must be supplied and used in ways which do not undermine other development goals by increasing climate risk, degrading land and using water unsustainably.

Over the coming decade, policy-makers around the world need to address these challenges as part of a shared development agenda. This study aims to contribute to the deliberations around such an agenda. It sketches out:

- pathways of energy system change for a world with sustainable development and prosperity

- illustrative case studies of barriers and opportunities of socio-technical change in basic energy access, low carbon energy supply, energy efficiency and demand side change, and

- what is implied by the needed transformations for governance at global, national and subnational levels.

2 Scenario pathways

Our scenario analysis presents three scenarios for the period 2009 to 2050. The baseline scenario (BAS) examines global "business as usual" trends for population, GHG emissions, macroeconomic indicators, energy consumption and production, and resource use. It assumes that current economic and energy policies will broadly continue and that major efforts to tackle climate change will not materialize.

The **basic energy access** scenario (BEA) explores trends similar to those in the BAS but imposes a constraint on energy systems by assuming that there will be a) major global efforts to tackle climate change, keeping the global average temperature increase to below 2°C, and b) provisioning of basic energy access for all by 2050. In other words, we assume what we call a "sticking plaster" solution: one in which specific efforts are made by the international community to provide basic energy access for all, without necessarily addressing poverty itself in more fundamental ways.

Finally, the **shared development agenda** scenario (SDA) takes BEA as a starting point, but also explores the implications of more equitable trajectories of income growth. It asks the question, what are the implications for energy systems if by 2050 all countries were able to reach per capita income levels equivalent to at least USD 10,000 in 2005 purchasing power parity (PPP) rates? This scenario also assumes (in line with current trends) somewhat lower growth rates in the richest countries than is typically assumed.

Both the BEA and SDA scenarios thus explore the implications of a greenhouse gas emissions budget that accounts for a peak of carbon emissions within the period 2015 to 2020, and a 60% chance of reaching the 2°C target. The scenarios also limit the availability of bioenergy and hydropower, owing to pressures on land and water resources, diminishing biodiversity, and the need to safeguard food production.

Efficiency, sufficiency, expanding low-carbon electricity supply, and electrification are the major strategies deployed to reach the scenario objectives. BEA and SDA entail absolute decreases in total energy demand but large increases in electricity demand. To meet such demands while staying within the CO_2 budget implies that conventional fossil-fuel technologies for electricity generation would need to be virtually phased out well before 2050. Under the BEA and SDA scenarios the only remaining such technologies by 2050 would be CCS-based systems.

Electricity demand would be met through massive increases in renewable power generation (wind, solar, geothermal and, in some regions, additional hydro) as well as nuclear expansion. There appears to be sufficient renewable energy potential to achieve such a scale-up. However, the required rate of expansion is a step change compared to current and recent rates.

The SDA scenario implies that energy intensities need to decline at a rate of 2.8% per year, equalling 32% of their 2010 values by 2050. These reductions would rely heavily on technology but would also require measures that address lifestyles and consumption, which would initially be most relevant in richer regions. Such measures include, for instance, better urban planning, reduced growth rates in transportation, and more efficient and more compact housing.

3 The dynamics of transformation

Both the BEA and SDA scenarios show that incremental changes in energy supply and demand will not enable us to meet energy needs for economic development while respecting environmental and resource constraints. Strong early action towards massive transformation of socio-technical systems and rapid turnovers of infrastructures and technologies are needed on both the supply and demand side. How can such transformations be achieved? Although scenarios show a general pathway, when it comes to implementation, the devil is in the detail. Therefore we have studied the dynamics, barriers and drivers in on-going real-world experience in transformation using a socio-technical systems and transitions perspective. We have examined in more detail the barriers and opportunities for such transitions in three key pathways:

Energy access, including off-grid solar energy, and new cooking and heating technologies.

Renewable energy, including wind, solar, hydropower, and bioenergy production.

Energy efficiency and lifestyle change, including reorganization of and shifts in urban and regional transport and infrastructure; energy efficiency in buildings and industry; and consumption and lifestyle change.

We use the same perspective to also examine case studies within each of these pathways. The cases emphasize the mutually reinforcing and interlocked technologies, institutions, culture, politics and economic structures that shape trajectories of change and act as barriers to or drivers of transformation.

Overall, although the macro-level analysis in the scenarios shows that it will be extremely difficult to attain the objectives, case studies paint an optimistic picture of what can be achieved from the bottom up. For instance, despite the massive challenge, many of the system transformations can make economic sense for both private and public actors. Multiple co-benefits emerge: for example, modern energy access reduces greenhouse gas emissions, protects respiratory health, and, because women and children need spend less time collecting fuel, promotes education. Renewable technology development has created new employment and export markets, not least for China. Efficiency and lifestyle measures contribute to smarter solutions and better lives.

4 Unlocking the potential: multi-level governance of transformation

The case studies identify early signs of progress in all three areas, but also barriers and obstacles. Most of these systems are stuck in a take-off phase and are unable to scale up and accelerate. Political, institutional, cultural and economic barriers remain, due to both policy and market failures (fossil fuel subsidies being the most blatant example). Therefore governance responses are needed at different levels to destabilize these barriers and inject momentum into the drivers of change. Regimes dominate that have an interest in the status quo. New regimes and path dependencies must be created, with actors, institutions and sustainable technologies reinforcing each other.

To set off on new pathways, governance must be stepped up, including much stronger public policies for RD&D, public procurement, carbon pricing, and investment, as well as mechanisms for interactions between the state, the private sector and other actors in society that help to pool and coordinate resources and skills. Mobilizing the private sector requires new thinking about business models and opportunities. Governance can be enacted not only through policies but also through institutional structures and processes.

Our analysis and findings draw on four elements of governance:

- Articulating a *common set of priorities for society*

Our analysis finds that the UN Sustainable Energy for All initiative is a useful unifying framework at the global level. The stated goals on energy access and efficiency and renewable energy up to 2030 do not deviate much in ambition compared with the SDA and BEA scenarios. In order to raise the political profile of energy issues and integrate them effectively across other agendas, the UN system must find a stronger permanent institutional home for them, as well as people to champion them in various parts of the UN system. Also, these or similar goals need to be formally adopted within any SDGs that may be developed, given the centrality of energy to both development and environmental sustainability. It is crucial to choose the right indicators for following up on goals and targets. These must balance the need for uniformity and local adaptation. Voluntary commitments made under the Framework of Action should include short-term output targets next to long-term outcome targets, to ensure that momentum is not lost for transformation that may take decades.

- *coherence* of priorities and goals

Ensuring energy access, efficiency and renewables are integrated and coherent with other political priorities is a major administrative challenge for both international and national governance. However, it must not be understood as merely a technical or administrative task but a political one, and requires that capacity and trust are built over the long-term, as well as more comprehensive and forceful policy assessment frameworks.

- *capacity to steer* towards those goals

Our analysis shows there is no panacea for transforming our energy systems. Policy instruments should be designed as a sequence of steps rather than as one-off ventures. Market-based measures are necessary but not sufficient, and need to be complemented with more ambitious and targeted government efforts on regulation, public procurements, RD&D support, investment and financing mechanisms.

- *accountability* for governing actions

There is a need for transparency in how climate finance and Overseas Development Assistance (ODA) commitments contribute to investment in sustainable energy for all, particularly in developing countries. And with respect to the energy commons in general, mechanisms for transparency and accountability are necessary to promote more open decision-making. In particular, a monitoring and evaluation system is urgently required for the energy access challenge.

1 EXPLORE A SHARED DEVELOPMENT AGENDA. Rio+20 and ensuing discussions must strategize around a shared global development agenda for the long term, a future without "us and them", where development is a shared commitment and benefits of development are shared.

2 SET ENERGY GOALS AS SUSTAINABLE DEVELOPMENT GOALS. Energy needs to be a major constituent of any globally agreed sustainable development goals. This means to include energy services for productive purposes for all countries, and provision of energy services in poor economies as explicit goals. Goals should also encompass efficiency and practices and low carbon energy expansion.

3 RESHAPE GLOBAL CLIMATE AND ENERGY GOVERNANCE. While incremental changes in national governance can in many cases be sufficient, a real transformation of the global framework is needed to coordinate, share and steer the transformation across nations. A global framework should include putting clean energy development efforts more centrally in the global climate change negotiations.

4 STRENGTHEN PUBLIC GOVERNANCE OF INNOVATION. Generic economic instruments such as carbon pricing are necessary but not sufficient as they tend to favor mature technologies. Bringing down the relative cost of new technology through increased public RD&D is central. A more active role of governments is also needed when taking energy innovations through the valley of death.

5 BUILD GOVERNMENT INSTITUTIONAL CAPACITY. Putting technology and industrial policy back on the governmental agenda in turn requires enhanced capacities of governments to manage complex systems and portfolios of projects.

6 ESTABLISH FRAMEWORKS FOR MONITORING AND ASSESSMENT. Frameworks need to be built up internationally and nationally to enable accountable and transparent planning, performance monitoring of targets, and assessments of coherence between energy and other environment and development challenges.

7 MOBILISE CAPITAL AND FINANCE. Finance and investment must be urgently mobilized, directed and governed. Public funding should be set up so that it can be matched with private sector capital, and international funds to be matched by national.

8 ENABLE NEW PRACTICES, LIFESTYLES AND BUSINESS MODELS. Access for the poor, efficiency and smarter energy solutions constitute important business opportunities, but they often require new social and industrial practices, forms of organization, and business models. A growing business community is taking an interest in these opportunities.

1 THE CHALLENGE

Key messages

- All governments share a legitimate aim to secure energy for long-term social and economic development needs and aspirations.
- We can no longer divide the world into rich and poor countries nor conceptualize development based on that notion. Leadership, responsibilities and vulnerabilities are now shared. Global governance must adapt to this new reality and organize discussions on strategic development topics that cut across North and South.
- The challenge for international diplomacy in Rio and beyond is to identify a shared global development agenda. This involves fuller engagement in international processes, such as the climate change negotiations, in ways that correspond with development priorities, such as energy security. At the same time we must ensure the long term sustainability of, for example, land, water, and climatic systems.
- Energy, for development and for basic needs, should be central to sustainable development goals. SDGs should also include goals for efficiency and expanding low-carbon energy in line with the United Nations Sustainable Energy for All initiative.

This report examines how energy needs for social and economic development can be met in a way that is compatible with long term sustainable development at the global scale. The study pulls together insights from energy and global sustainability scenarios, case studies of socio-technical transformation in energy systems, and reviews of policy and governance mechanisms.

Why another assessment study focusing on sustainable energy futures? Over the last few years, there has been a surge in visions, scenarios and road maps that describe in some detail the main elements of low carbon / sustainable energy futures. The International Energy Agency (IEA) regularly publishes its World Energy Outlook and Energy Technology Perspectives (most recently, IEA 2010; IEA 2011). The Organisation for Economic Co-operation and Development and the United Nations Environment Programme provide outlooks focusing on environmental sustainability, and there is a range of independent good quality research initiatives such as the Global Energy Assessment (GEA 2012, Riahi et al. 2012) and the sustainability scenarios from PBL, the Netherlands Environmental Assessment Agency PBL 2012). At the regional level, the European Union has developed energy and efficiency road maps up to 2050, and at the national level many countries, including India, South Africa, Brazil, Sweden and the Netherlands, are producing numerous national scenario studies, road maps and outlooks. And only in the past two to three years dozens of climate, energy, and sustainability outlooks have contributed to a massive knowledge base.

On the whole, these studies demonstrate the technical and economic viability of pathways to sustainable energy systems that meet development needs and mitigate climate change. Existing road map and scenario studies such as those mentioned above, as well as those carried out with model support at the national and regional levels, tend to spend a great deal of analytical energy on scenario modelling, but often treat both socio-technical change dynamics and governance more in passing.

The scenarios in this study do not compete in analytical depth with existing global scenario studies: instead, we build on them. Scenario modelling forms a relatively small part of this study and serves primarily illustrative purposes. Instead, our analytical effort has focused on how technologies, lifestyles and economic systems can change as the scenarios suggest, and how these changes can be governed into the future. We examine the governance of transformation as a multi-dimensional concept, involving a policy dimension (objectives, instruments, strategies and implementation practices), an underlying institutional dimension (the framework of rules, arrangements and mechanisms for decision making) and a political dimension ("good" governance aspects such as accountability, and access to and transparency of decision making.)

1.1 Contribution of this study

Over the past few years, global political processes on sustainable development have struggled to move forward. Preparations for the Rio+20 meeting, set up to address unresolved sustainable development challenges, have been characterized by uncertainty, ambiguity, lack of trust and lack of a shared vision. Similarly, UN-led climate change negotiations have so far failed to reach an agreement that would set us on a pathway to the globally agreed target to limit global warming to 2°C compared with 1990 levels by 2050. Although this political stalemate has real political causes rooted in national economic and political interests, it is also a result of a lack of trust and shared perspectives in the global policy arena.

The challenge for international diplomacy at Rio+20 and beyond is to identify what constitutes a truly shared global development agenda. This involves engaging more fully in international processes in ways that correspond with development interests while at the same time preserving (or ensuring) the long term sustainability of, for example, land, water and climatic systems. International climate negotiations are currently bogged down by discussions on effort sharing and binding emissions restrictions. These discussions are not the focus of this study. Still, we hold that negotiations can be advanced by highlighting a broader set of solutions on energy systems change.

We propose that securing clean energy for development can be a central component of a shared development agenda that speaks directly to a strategic priority for all governments.[1]

What can policy analysts and systems analysts contribute to establishing this agenda? What perspectives will enable the global political system to advance a shared vision for global development? Our hope is that this assessment can contribute to rebuilding joint perspectives in the global policy arena, for instance in relation to creating and meeting sustainable development goals (SDGs) that are genuinely responsive to social and economic development needs. To these ends, three elements need to be centrally built in to the assessment.

First, as welfare distribution between and within countries is changing and as emerging economic and political powers claim their seat at the negotiating table, it has become blatantly clear that we can no longer divide the world into rich and poor countries nor develop prescriptions based on that notion. Abrupt changes in development, global politics and global connectivity mean that leadership, responsibility and vulnerabilities are now shared. Global discussions must adapt to this new reality and *organize discussions on strategic development topics that cut across North and South.*

Second, with increasing evidence that humanity is now a dominant driving force in Earth systems, such as fresh water, land, and climate, scientists have even suggested the designation of a new geological era, the Anthropocene (UN High Level Panel on Global Sustainability 2012). Scientists understand more today about how environmental and energy systems are linked. Evidence also points at much more severe risks as a result of man's impact on the Earth systems. For example, a substantial body of research now indicates that the 2oC warming target, widely accepted as a political goal, is far from "safe". Similarly, low carbon energy options such as bioenergy and hydropower can have serious impacts on land and water resources. Most observers agree that better governance is needed to avoid problem shifting, at and across geographical levels (Biermann et al. 2012). Policy analysts must bring in these insights and relate systems analysis to *interacting sectors and environmental and resource systems*.

Third, insights into how markets, technological development, and globalization work – and how they can be governed – need to be incorporated when we think about governance for the future. Lessons must be learned from recent systemic failures in both the financial markets and the national economies in the EU and US. Also, insights from systems innovation and technological change studies point to governance needs. For example, putting a price on carbon emissions is a necessary and basic market-corrective measure, but not sufficient to trigger and navigate transformative changes of economic activity. Beyond this, society needs to nurture and scale up diverse supply and demand innovations that can contribute to creating new and more sustainable

1 Thus, if global agreements in Rio+20 and beyond acknowledge the right of all nations to secure energy for long-term development, taking into account potentials for efficiency and low carbon supply options, this may relieve some of the rightful concerns of countries that are currently not willing to make binding commitments to mitigate climate change.

energy systems. In order to understand these responses we need to *drill deeper into the dynamics and governance of transformative change*.

This study takes these three elements as a departure point: the need to generate a shared development agenda via global discussions on issues that cut across North and South, while taking into account key interactions between energy and environmental systems and drilling deeper into the dynamics and governance of change.

The following questions are in focus.

- What levels of energy demand are compatible with energy access for households as well as longer term economic development aspirations for the world? What energy systems pathways are possible, from a technical and resource perspective, to meet these levels up to 2050, keeping within what is understood today as sustainable levels of environmental and resource pressure globally and regionally? (Chapter 2)

- What opportunities for socio-technical transformation towards these pathways have already been grasped? Through a range of case studies around the world that illustrate three systemic challenges – expanding energy access, expanding renewable energy, and enhancing efficiency and lifestyle change – we take a comprehensive view of the technological, economic, institutional, political and cultural factors that shape, drive and constrain the development of these systems. (Chapter 3)

- What governance, policy or institutional arrangements are needed at different levels to induce and steer transformation? Of particular relevance to this question are issues around the role of the state and the instruments at its disposal, and the ways in which different governance elements can be coherently pursued. (Chapter 4)

1.2 From basic energy access to energy for development

It is widely accepted that the lack of energy services is a major constraint on human development around the world, and that providing clean, affordable and reliable energy for poor households in developing countries is an important, while not sufficient, prerequisite in the fight against poverty. Worldwide, approximately 3 billion people today rely on traditional biomass and other solid fuels for cooking and heating, and about 1.5 billion have no access to electricity. Up to a billion more have access only to unreliable electricity networks. In 2000, the UN adopted eight Millennium Development Goals, with the ambition to eradicate extreme poverty by 2015 (UN 2000). Although energy was not then considered as an explicit goal, it is now clear that energy is a crucial contributor to several of the MDGs (see Box 1.1).

Box 1.1: Selected links between MDGs and energy access

MDG1: Eradicate extreme poverty and hunger
Modern energy sources can power pumps for drinking water as well as farm machinery and irrigation to improve agricultural yields.

MDG 2: Achieve universal primary education
Modern energy meets basic needs, such as lighting to do homework, and offers access to information technology. It can also free up time for education that women and children now spend for gathering fuel wood, fetching water and cooking.

MDG 3: Promote gender equality and empower women
Modern energy can reduce the burden of gathering water and fuel wood, and through street lighting it can improve safety after dark to enable women to attend school or community activities after work.

MDGs 4, 5 and 6: Reduce child mortality rates; improve maternal health; combat HIV/Aids, malaria, and other diseases
Modern energy for cooking reduces the risk of respiratory diseases from indoor air pollution, allows households to more easily boil water, and support the functioning of health clinics and hospitals.

Energy access can be viewed as a continuum. For those populations that lack access to any modern energy, the immediate objective is to provide basic minimum access to electricity and modern fuels. In such circumstances analysts define access at the household level. Household access might involve a supply connection for electricity, a supply source for modern fuels, and a minimum level of electricity use per capita and year that ensures access to basic lighting services, some use of appliances and affordable access to clean cooking services. The simplest definition of universal access is the physical availability of electricity and modern energy carriers, and improved end-use devices such as cookstoves at affordable prices for all. This is the basis for the target of energy access for all by 2030 set by the UN Secretary-General's Advisory Group on Energy and Climate Change (AGECC 2010):

> *"The global community should aim to provide access for the 2–3 billion people excluded from modern energy services, to a basic minimum threshold of modern energy services for both consumption and productive uses. Access to these modern energy services must be reliable and affordable, sustainable and, where feasible, from low-GHG-emitting energy sources."*[2]

For those who have already achieved this basic energy access the objective is then to provide energy for development. This extends access beyond basic consumptive needs and beyond the needs of households alone. Energy for development represents the level of energy demand needed for income-generating activities in small industries,

2 The Advisory Group notes that consensus has not yet been built on a specific target for a minimum threshold of modern energy services, but notes that the IEA has proposed a lowest threshold of 100 kWh per of electricity and 100 kgoe of modern fuels (equivalent to roughly 1200 kWh) per person per year, which can be used as a starting point.

service sectors, schools, hospitals and other public services that are crucial to long-term economic and social development.

Although it is important to distinguish between basic energy access and energy for development in terms of levels of energy demand, the processes for achieving the two targets are closely linked. This is because development of economic activity is a prerequisite if households are to develop the income necessary to make long term basic energy access viable. Whether basic energy access can be achieved independently of energy for development depends on how willing donors and the public sector are to subsidize energy access in the long term. A robust strategy should rid the system from such long term dependencies.

Both the UN's *Sustainable Energy for All* initiative and its move to name 2012 as the International Year of Sustainable Energy for All have drawn considerable attention to the governance and sustainability of energy systems at the global level. The UN has also produced a framework for action (Secretary-General's High-Level Group on Sustainable Energy for All 2012), which is an important point of reference for this study, particularly in the sense that it highlights a broader set of challenges than basic energy access (see chapter 4). We discuss these issues under three principal types of transformation pathway, mirroring those identified by the UN initiative on Sustainable Energy for All.[3] These pathways are:

- Energy access
- Renewable energy
- Energy efficiency and lifestyle change

With a similar logic, we also acknowledge the diverse challenges faced by different countries as identified by the AGECC (2010). *Low-income countries* need to expand access to energy services substantially. Efforts are needed to create the right institutional, regulatory and policy environment for investment in these countries. *Middle-income countries* need to develop their energy systems in a way that decouples growth from energy consumption through improved energy efficiency, and gradually shift towards low greenhouse gas (GHG) emitting technologies. They should share relevant expertise and good practice that is replicable by lower-income countries. *High-income countries* need to decarbonize their energy sectors and reach a new level of efficiency performance.

3 The Sustainable Energy for All initiative has three linked objectives up to 2030. These are to: 1) ensure universal access to modern energy services, 2) double the global rate of improvement in energy efficiency, and 3) double the share of renewable energy in the global energy mix (see chapter 4).

1.3 The Shared Development Agenda

What does sustainable energy for all imply from the perspective of economic development? This should be discussed in terms of how to make development of energy systems compatible with targets for economic development that poorer countries aspire to in the long term. This implies demand for and supply of electricity and modern fuels for productive uses in, for instance, industrial processes, agriculture and transport, as well as service industries, schools, hospitals and retail. Our Shared Development Agenda scenario (SDA) looks at the energy implications of a long-term global development scenario where poor countries reach at least middle income by 2050 (estimated as USD 10,000 per capita in 2005 purchasing power parity (PPP) rates). For the world's poorest regions, this corresponds to almost a doubling of GDP by 2050, compared with our baseline scenario (see figure 1.1).

The SDA scenario is thus named because it depicts much more equitable economic growth patterns globally. It expresses a state of world development in which the global goal of eliminating large scale poverty has been reached, even though in 2050 there would still be major (though reduced) income gaps, because the richest nations would continue to grow. Although the scenario is explorative and a thought experiment, it is also supported by recent growth trends and forecasts. Over the last decade, while the EU has experienced growth rates of circa 1–2% annually, Asian countries are closing the gap and African countries are experiencing consistent and durable growth patterns. Between 2001 and 2010, six of the world's 10 fastest growing economies were African (see chapter 2). Clearly, the Asian tiger economies of the 1990s may in the not too distant future find their equals in African lion economies..

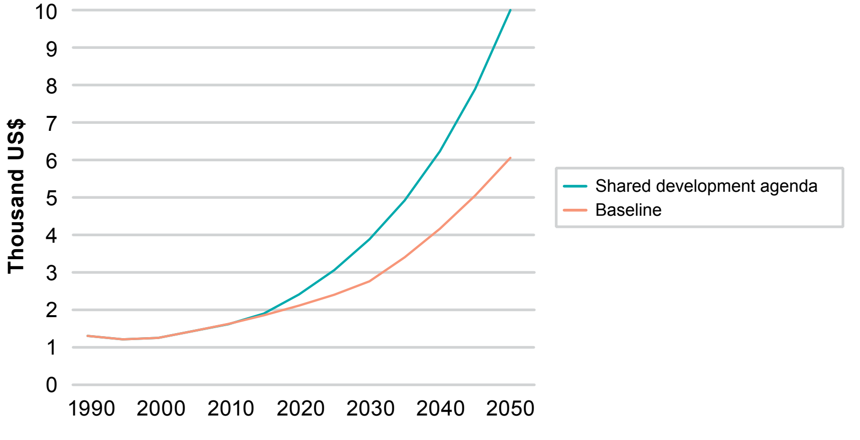

Figure 1.1: Growth in 2005 USD PPP for Western Africa region (see chapter 2) in the shared development agenda (SDA) scenario compared with baseline (BAS) scenario

This study does not dwell on the mechanisms behind growth (such as capital and labour productivity) nor on the likelihood of it occurring. Much of the growth in Africa has been driven by demand for raw materials – especially among the emerging economies and Gulf States – and surging prices. However, prices can go down again, and commodity-based growth does not generate many jobs. In the long term, what matters is the composition of growth, and whether it is accompanied by diversification and structural changes in the economy. Trends are yet to point conclusively in this direction. The convergence of income levels in the 21st Century implies a massive transfer of economic activity worldwide. If we are concerned about well-being for the greatest number of people, this transfer is good news: hundreds of millions of people have escaped poverty during the last decades and more will do so in the future.

1.4 Energy within the constraints of the Earth system

At the same time as we need to rapidly expand energy services for a shared development agenda, it is clear that energy is one key driver behind some of the combined pressures on the Earth system. We may be approaching, or in some instances have actually crossed, critical thresholds in terms of human pressures on the environment. The growing recognition that we may have entered a new geological age – the Anthropocene – and recent advancements in Earth system science have triggered the development of the "planetary boundaries" framework (figure 1.2).

The framework identifies nine interacting Earth system processes (Rockström et al. 2009). While energy systems are first and foremost discussed with respect to their climate impacts, they actually depend and impact upon most Earth systems. For example, energy systems based on fossil sources affect climate change, ozone depletion, aerosol loading and chemical pollution. Some renewable sources may also have negative impacts. For example, hydropower plants with big reservoirs may affect boundaries related to freshwater use, rate of biodiversity loss and land use change. Renewable energy systems based on biomass systems may also move us closer to boundaries for land use, freshwater use, the nitrogen and phosphorus cycles, rates of biodiversity loss, aerosol loading and climate change. However, policies, regulations and assessment frameworks can be deployed to mitigate such impacts.

There is a need for a comprehensive understanding of the processes that underpin the sustainability of the energy system, such as how ecosystems regulate the effects of climate change and the resource base for renewable sources of energy (PBL 2012). Chapter 2 on scenarios takes as a starting point the 2°C target for global warming. However, the analysis also takes into account insights on what it implies for the energy challenges if other internationally agreed goals and targets are met.

Clear synergies but also some trade-offs exist between energy and different environmental and development issues. Existing studies show that modern energy access for basic human needs will, in aggregate, have a limited impact on Earth systems. Taking the issue of climate change as an example, according to the IEA, basic

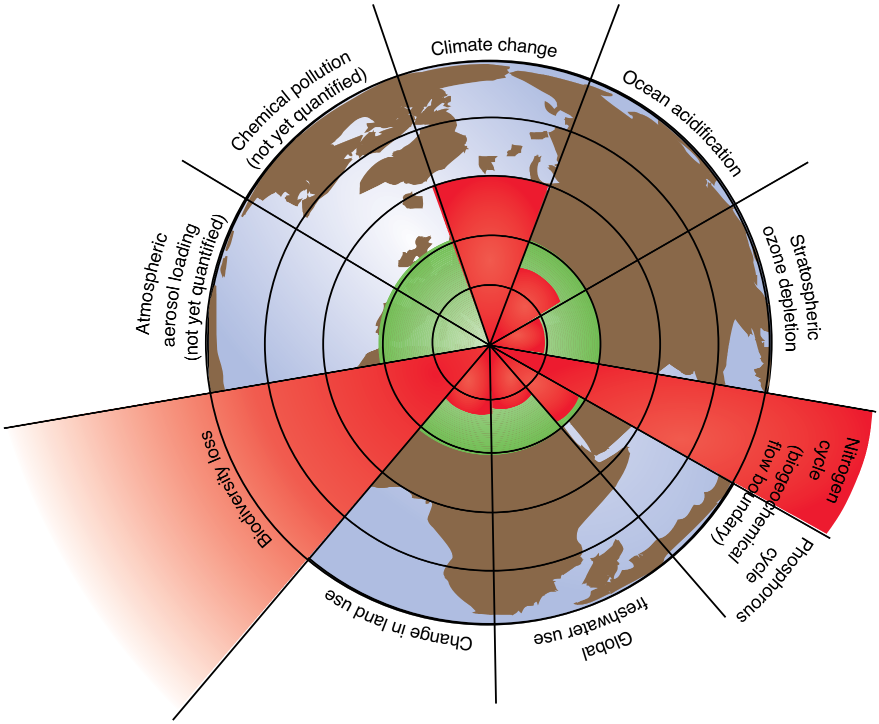

Figure 1.2: The planetary boundaries framework (Rockström et al. 2009)

universal electricity access would merely add around 1.3% of total carbon emissions in 2030. Transitions from traditional biomass to modern cooking fuels, even if these are fossil based, could in fact be GHG emission neutral or even beneficial, because current traditional biomass use is four to five times less efficient than cooking with gas. It is also associated with significant emissions of non-CO_2 GHG gases (e.g. methane nitrous oxide), as well as aerosols due to incomplete combustion. Energy access policies for clean cooking fuels could lead to a net decrease in overall GHG emissions, as well as local environmental improvements through reduced emissions of particulates (UNEP and WMO 2011).

1.5 Scope, dynamics and governance of change: structure of the report

A growing global population is already demanding increasing levels of energy services, a demand that will grow with today's trends. If we can, in line with our SDA scenario, eradicate poverty and enable development for all countries, large fractions of the world population, in particular in Asia and Africa, will require even more energy for household use, for economic activity and for modern life in general. More buildings will be heated and cooled, more transportation will occur, and more electricity will be used in businesses and households. At the same time global GHG emissions must drop radically. As the scenarios in chapter 2 show, incremental improvements are not enough: despite important improvements in efficiency and renewable expansion, even those countries that lead the world in mitigation are merely keeping their emissions level. A transformation is needed to an energy system that is capable of delivering services at much lower emissions. Moreover, the energy system cannot appropriate unlimited amounts of land and water, since they need to accommodate food production and functioning ecosystems.

This transformation will take place in all kinds of subsystem: modern energy needs to be extended to communities in rural areas with little purchasing power; power transmission and grids must become smarter and more efficient; buildings and services need to become more efficient; consumers need to meet their needs without using excessive amounts of energy; and power and heat production and transport must turn to low or zero carbon alternatives that are managed sustainably.

Chapter 2 analyzes and describes the scope of this challenge and what types of system transformation must be implemented in the coming decades. Chapter 3 examines how such transformations might come about, based on empirical studies of 20 case studies around the world. With a socio-technical systems perspective, the chapter identifies key barriers and drivers of transformation, including both “soft” and “hard” factors, such as institutions, politics, technology costs, and cultural habits. Finally, chapter 4 links these insights to governance frameworks and mechanisms, and examines what public policies as well institutional frameworks are needed to induce transformation to sustainable energy systems at a global scale. Chapter 5, finally, summarizes the conclusions from the assessment and presents a set of eight key recommendations for the international deliberations at Rio+20 and beyond.

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2 SCENARIOS OF ENERGY FOR ALL

Key messages

- The shared development agenda (SDA) scenario explores a future in which economic growth provides significant levels of development in the poorest regions, underpinned by energy for economic activity and productive uses. Even allowing for the increase in energy demand that will result from the increased income in these regions, we find that the scenario has minimal additional impacts on overall energy consumption and CO_2 emissions compared to the basic energy access (BEA) scenario.
- Efficiency, electrification, and expanding the supply of low-carbon options are the major strategies deployed to reach the scenario objectives.
- The BEA and SDA scenarios entail absolute decreases in total energy use but large increases in electricity consumption. To meet such demands while staying within our CO_2 budget implies that conventional fossil fuel technologies for electricity generation will need to be virtually phased out well before 2050. Under the BEA and SDA scenarios the only remaining such technologies by 2050 would be carbon capture and storage (CCS) based systems.
- Electricity demand would be met through expansions in low carbon power generation (wind, solar, geothermal and, in some regions, hydro and nuclear). There appears to be sufficient renewable energy potential to achieve such a scale-up. However, the required rate of expansion needs to be fast and important barriers with respect to system integrated need to be overcome.
- The SDA scenario implies that energy intensities need to decline at a rate of 2.8% per year to only 32% of their 2010 values by 2050. These reductions would rely heavily on technology improvements, but would also require measures that address lifestyles and consumption which would initially be most relevant in richer regions. Such measures include better urban planning, reduced growth rates in transportation, and more efficient and more compact housing.
- Keeping global emissions within a 2°C pathway will be extremely difficult, particularly since roughly 30% of the aggregate of the allowable CO_2 budget for 2000–2050 has already been emitted up to 2012.

2.1 Introduction

This chapter presents a macro-scale exploration of how global energy supply and demand might be reconfigured over the coming four decades to provide the basis for development for all, while at the same time meeting global objectives for climate change mitigation. The scenario analysis also limits the availability of bioenergy and hydropower, owing to pressures on land and water resources, diminishing biodiversity and the need to safeguard food production.

Our scenarios are intended as a preliminary exploration of how the world's energy systems will need to be transformed to meet sustainable development goals. They are created as a *backcast* that explores what *needs* to be done, sector by sector and region by region, to meet these goals. Overall, our scenarios are intended as a conversation starter: an initial and readily understandable contribution to the urgent dialogue on how global energy systems need to be transformed in the coming four decades.

Our analysis is constructed as a single set of historical data, for the years 1990 to 2008, and three forward-looking scenarios for the years 2009 to 2050.

Baseline (BAS) scenario: The BAS scenario examines global "business as usual" trends for population, greenhouse gas (GHG) emissions, macroeconomic indicators, energy consumption and production, and resource use. It assumes that current economic and energy policies will broadly continue and that major efforts to tackle climate change will not materialize.

Basic energy access (BEA) scenario: The BEA scenario explores trends similar to those in the BAS scenario but imposes a constraint on energy systems by assuming that there will be a) major global efforts to tackle climate change, keeping the global average temperature increase to below 2°C, and b) provisioning of basic energy access for all by 2050, albeit without any additional deviation in average income levels in the poorest countries relative to the BAS scenario. In other words, we assume what we call a "sticking plaster" solution to energy for all: one in which specific efforts are made by the international community to provide basic energy access for the world's poor, without necessarily addressing poverty itself in more fundamental ways.

Shared development agenda (SDA) scenario: This third scenario builds on the BEA scenario. In addition to applying the same constraints on CO_2 emissions, the scenario explores what is implied for the energy system if more energy were provided for economic activity and productive purposes. The scenario also assumes stronger economic growth rates in the poorest regions, and a stronger convergence of economic development patterns across the world towards more balanced patterns of income distribution. Thus, in terms of energy demand, SDA goes beyond the provision of basic energy access by exploring what a more fundamental reorientation of global economic growth means for energy and GHGs, where growth rates in the rich countries slow down compared to what is conventionally assumed, and growth rates in the poor countries accelerate.

Both the BEA and the SDA scenarios are designed to stay within basic resource limits that are broadly consistent with other aspects of sustainability. In particular, our scenarios limit the use of bioenergy and forms of renewable energy such as hydro, solar and wind to levels that are consistent with the sustainable availability of those resources. Table 2.1 presents a summary of the three scenarios.

Table 2.1: A summary of the three scenarios used in this study

Scenario	Demographics	Economics	Climate policy	Energy
Baseline (BAS)	Business as usual	Business as usual	No major new policies	No major new policies
Basic energy access (BEA)	Same as above	Same as above	Major effort to mitigate climate change	Provision of basic energy services
Shared development agenda (SDA)	Same as above	Same global GDP. More growth in poorest regions, less in richest. Average incomes grow in all. Improved income distribution within regions.	Same as above	Energy in all regions at least consistent with middle income development (beyond basic access to reflect more productive uses of energy).

2.2 Approach, assumptions and methodology

Our primary research goal is to examine future global energy pathways consistent with sustainability and meaningful development.[4] Our scenarios are constructed as a relatively simple global data set developed within the Long-range Energy Alternatives (LEAP) modelling system, a transparent and user-friendly software tool developed at the Stockholm Environment Institute (SEI) that is now widely used around the world by energy planners and practitioners of climate change mitigation assessment. Figure 2.1 is a screenshot from the LEAP software system.

Our three forward-looking scenarios build on the baseline and efficiency scenarios already created for the Global Energy Assessment (Riahi et al. 2012). The GEA scenarios are based on use of the MESSAGE model (maintained at IIASA in Austria) and the IMAGE/TIMER model (maintained at PBL, the Netherlands Environmental Assessment Agency).[5] These models are based on sophisticated least-cost assessments of what technologies will be required to meet goals for climate mitigation, sustainability and basic energy access. As such, the GEA modeling employs a cost-effectiveness approach for greenhouse gas emissions reductions. This means that

4 A secondary goal in constructing these scenarios is to create a transparent, open source, global data set that is freely available to all. Both LEAP and the global LEAP data set containing our scenarios are available either for download at the LEAP website (www.energycommunity.org) or by emailing leap@sei-us.org. In the longer term, SEI plans to make the data set directly available via an interactive website.

5 For MESSAGE, see http://www.iiasa.ac.at/Research/ENE/model/message.html. For IMAGE, see http://themasites.pbl.nl/en/themasites/image/index.html.

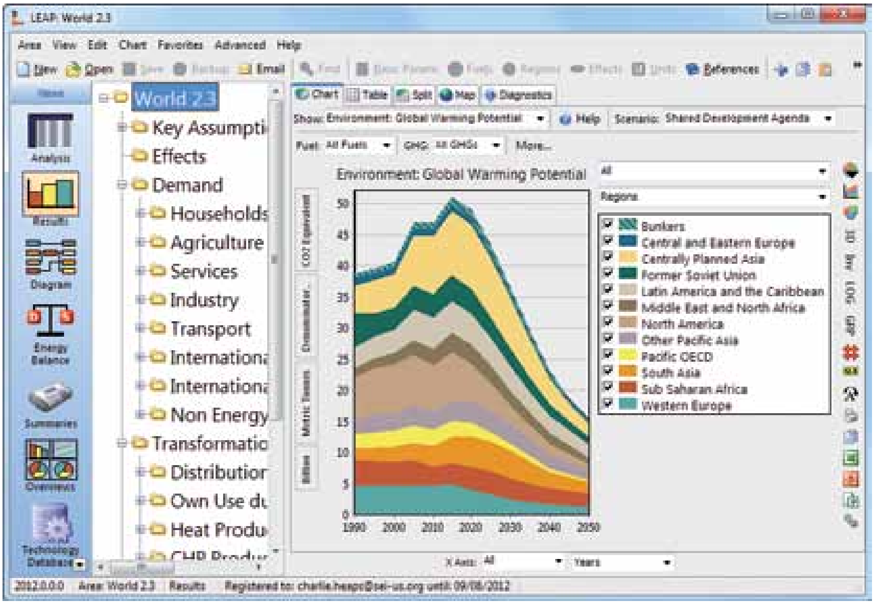

Figure 2.1: A screenshot from the LEAP software system

emissions reductions are realized over time and in regions where they are most cost-effective. The associated costs or investments, do not need to be necessarily borne by the affected region, and may also come from eg international finance.

2.2.1 Regional disaggregation

Our analysis divides the world into 20 geographic regions plus two non-geographic regions ("bunkers") used to account for energy use and emissions from international aviation and shipping (see table 2.2 for details of the regional structure). The analysis includes a full accounting for both types of energy-related GHG emissions, that is, those that come from the final combustion of fuels in households, industry, transport, services and agriculture, and those from the production of secondary energy in sectors such as electricity generation, heat production and oil refining. The data set also describes the sources and sinks of GHGs in non-energy related sources, and sinks of GHGs from industrial processes, agriculture, land-use change, forestry, solid waste and fugitive emissions.

2.2.2 Historical data and baseline scenario projections

To enable comparison of future projections and past trends, our analysis includes historical data for the period 1990–2008. These data are drawn from a variety of sources, with national-level data aggregated into the 23 regions listed in table 2.2. Data on energy consumption and production are taken from the IEA's World Energy Balances (IEA 2011b). Population data are taken from the 2010 revision of the UN's World Population Prospects data set (UN 2011). Macroeconomic data, including gross domestic product (GDP) and value added by sector, are taken from the World

Table 2.2: Regional groupings used for the SEI/LEAP scenarios

Region	11 region grouping	Six region grouping	Three region grouping
Brazil	Latin America and the Caribbean	Latin America and the Caribbean	South
Central America and the Caribbean	Latin America and the Caribbean	Latin America and the Caribbean	South
Central Asia	Former Soviet Union	Asia	South
Central Europe	Central and Eastern Europe	Reforming economies	North
China+	Centrally Planned Asia	Asia	South
Eastern Africa	Sub-Saharan Africa	Middle East and Africa	South
India	South Asia	Asia	South
Indonesia+	Other Pacific Asia	Asia	South
Mexico	Latin America and the Caribbean	Latin America and the Caribbean	South
Middle East	Middle East and North Africa	Middle East and Africa	South
Northern Africa	Middle East and North Africa	Middle East and Africa	South
Other South America	Latin America and the Caribbean	Latin America and the Caribbean	South
Other South Asia	South Asia	Asia	South
Other Southern Africa	Sub-Saharan Africa	Middle East and Africa	South
Pacific OECD	Pacific OECD	OECD	North
Russia and Ukraine+	Former Soviet Union	Reforming economies	North
South Africa	Sub-Saharan Africa	Middle East and Africa	South
Southeastern Asia	Other Pacific Asia	Asia	South
USA and Canada	North America	OECD	North
Western Africa	Sub-Saharan Africa	Middle East and Africa	South
Western Europe	Western Europe	OECD	North
World aviation bunkers	Bunkers	Bunkers	Bunkers
World marine bunkers	Bunkers	Bunkers	Bunkers

Bank's *World Development Indicators* (World Bank 2011). Historical data describing non-energy sector sources and sinks of GHGs are taken from the EDGAR database developed at JRC/PBL in the Netherlands (JRC/PBL 2011).

Emissions of CO_2 are projected using straightforward and non-controversial accounting calculations in all scenarios. Based on the data sources described above, historical energy intensities are first calculated for each sector (households, industry, services, transport and agriculture) and each of the 20 regions for each historical year (1990–2008). For the household and transport sectors these intensities are calculated as annual energy use in each region per unit of total GDP, measured in market exchange rate (MER) terms. For the industry, agriculture and services sectors, intensities are calculated per unit of value added, which is calculated by multiplying total GDP by the appropriate value added shares for each sector. Total sectoral energy use is then allocated down to individual major fuel categories, using historical fuel share trends.

Our scenarios start with a simplified representation of the macroeconomic, demographic and energy technology trends developed in the GEA efficiency scenarios. In the baseline scenario, overall GDP and value added shares are, where possible, projected forward using the trends of the GEA baseline scenario (using data taken from the PBL IMAGE model as supplied by PBL). Energy intensity and fuel share trends are projected forward based on the trends described in IIASA's MESSAGE model, which produces results for 11 regions of the world. These results, downloaded from the IIASA website (IIASA 2012), are mapped on to the 20 regions used in our data set. Energy used in international aviation and international shipping is projected forward using the trends for global GDP and the global transport energy intensity trends foreseen in the GEA baseline scenario.

Energy conversion and energy supply are also modelled in a relatively simple fashion. In particular we have only modelled the following sectors: electricity transmission and distribution, electricity generation, heat production, combined heat and power (CHP), oil refining and liquefaction (producing liquid fuels from solid fuels). We have not explored potentially important but longer-range conversion options, such as coproduction of fuels and electricity or hydrogen-based energy systems, due to their complexity and associated uncertainty. Historical data on the included conversion sectors are again taken from the IEA's World Energy Balances (IEA 2011b), with regional baseline trends in the efficiencies and fuel mixes in each sector based on the trends in the GEA Scenario Explorer mapped to the 20 regions used in our data set.

Energy sector CO_2 emissions for all years (1990–2050) are calculated using standard IPCC Tier 1 emission factors (IPCC 1996) applied to the energy consumption and production values calculated in each region and sector. Trends for non-energy sector sources and sinks of CO_2 are based on the non-energy sector CO_2 projections in the GEA scenario explorer. Non-energy sector emissions of all other GHGs are assumed to stay constant, and are thus based on the most recent annual data available in the EDGAR database.

2.2.3 The basic energy access scenario

As noted above, the BEA scenario explores similar economic trends to the baseline scenario but assumes that major global efforts to tackle climate change and to provide basic energy services to the world's poor will be enacted. Our BEA and SDA scenarios make additional ad hoc adjustments to those trends to explore two specific variations.

First, our scenarios assume a more stringent budget for cumulative CO_2 emissions up to 2050, corresponding to an approximately 60% probability of keeping global average temperature rises to under 2°C.[6] Based on Meinshausen et al. (2009), a 60% chance translates into a global cumulative budget for CO_2 emissions of approximately 1,300 Gt CO_2 between 2000 and 2050.[7] Keeping global emissions within such a pathway will be extremely difficult, particularly since approximately 31% of that budget (406 Gt CO_2) has already been emitted up to 2012.

The GEA scenarios aim for a 50% chance by 2050, which corresponds to an overall CO_2 budget of roughly 1,440 Gt CO_2 between 2000 and 2050. Note, however, that because 406 Gt CO_2 of this has already been emitted, the differences between the two sets of scenarios are quite significant. It should also be noted that the GEA scenarios extend to 2100, whereas our scenarios stop at 2050. Over this longer time frame, the GEA foresees options that may lead to significant overall sequestration of CO_2 in the last quarter of the century, so that for the century as a whole the GEA scenarios correspond to a 60–70% probability of keeping global average temperature rises to within 2°C. Since our scenario only projects to 2050, we felt that adopting a more stringent path was appropriate.

Second, our scenarios assume a later start date for significant mitigation efforts. While mitigation efforts are assumed in the GEA scenarios to have started in 2010, our scenarios assume no significant mitigation efforts (beyond those already in the baseline) until at least 2015. In lower income regions, efforts are assumed to start even later, with the poorest regions beginning significant efforts in 2020. Given the current status of international climate negotiations we felt that these starting dates were appropriate.

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6 It should be noted that 2°C is a value that has commonly been used in international dialogues as a synonym for the concept of avoiding dangerous anthropogenic interference with the climate system, the concept to which signatory nations to the United Nations Framework Convention on Climate Change (UNFCCC) have committed. However, a substantial body of research now indicates that this level of warming is likely to be far from safe (e.g. see a broad summary of reasons for concern in the IPCC's famous "burning embers" diagram (Smith et al. 2009)) commits signatory nations to stabilizing greenhouse gas concentrations in the atmosphere at a level that "would prevent dangerous anthropogenic interference (DAI). However, as this chapter shows, limiting climate change to no more than 2°C will be extremely challenging. Thus, despite the growing evidence that this value is not safe, any lower target would be politically unworkable.

7 This is less than the typical value of 67% adopted in other studies, which corresponds to what the IPCC refers to as "likely but not very likely" to succeed in achieving the 2°C target. The reason we have used a less stringent probability is because our analysis shows that achieving the emissions reductions implied by the 67% probability is now almost impossible even with extremely ambitious assumptions about mitigation.

2.2.4 The shared development agenda scenario

The SDA scenario explores alternative patterns of global economic development compared to the GEA scenarios (and our BEA scenario). Specifically, the SDA assumes faster economic growth in the poorest regions (Southern, Western and Eastern Africa, and South and Southeast Asia) so that average GDP per capita, measured in constant international purchasing power parity dollars (PPP, 2005 rates), reaches a minimum of USD 10,000 PPP by 2050 in all regions. At the same time, growth in the richest region (the U.S. and Canada) is assumed to continue more slowly so that average GDP per capita reaches USD 39,000 PPP by 2050.[8] However, average GDP per capita continues to grow in all regions. Total global GDP growth is roughly equal in all scenarios (about 2.8% per year between 2010 and 2050). This overall story can be contrasted to the baseline scenario, in which the average incomes of those in the richest countries continue to diverge from those in the poorest even as GDP per capita growth rates increase in many poor regions.

The net result of these assumptions is shown in the income trajectories for the BAS and SDA scenarios shown in figure 2.2 and the map of income levels shown in figure 2.3. Note that we assume that average growth rates would be curtailed only in the richest region (the U.S. and Canada). One could of course assume lower rates of growth in other regions.

While many may view a more equitable future as a good thing in itself, it can also be viewed as a necessary precondition for greater global solidarity. Such solidarity will undoubtedly be needed if poorer regions of the world are expected to take on a significant share of the burden of achieving the ambitious climate mitigation goals seen in these scenarios.

As is argued in Chapter 1, growth trajectories in the SDA scenario can be said to represent a future in which the world has largely met the goal of eliminating poverty. At the same time, these types of trajectories are already emerging in some developing countries. For example, in the most recent forecasts of the International Monetary Fund, over the next five years seven of the 10 fastest growing countries will be in Africa[9] (see table 3.3). Rapid economic growth is already occurring in many countries in this region. Ethiopia, for example, has seen average GDP growth rates of 8.1% since 2000 (World Bank 2011).[10] While some of the countries listed in table 2.3 are net oil exporters, it is worth noting that many of the countries on the list are net oil importers, which shows that high rates of growth are possible even in a climate of high oil prices.

8 This assumption also draws on critiques of GDP as conventionally defined (e.g. Jackson 2009), which argue that it fails to adequately measure improvements in well-being beyond certain income levels.

9 *The Economist* (2011), 'Africa's impressive growth'. Daily chart, 6 January. http://www.economist.com/blogs/dailychart/2011/01/daily_chart.

10 The SDA scenario requires sustained growth rates of between 8% and 9% per year in Africa until 2050. The GEA baseline scenario already assumes rapid economic development in these regions. The additional growth assumed in the SDA scenarios over and above the GEA baseline amounts to between 0.6% and 1.4%.

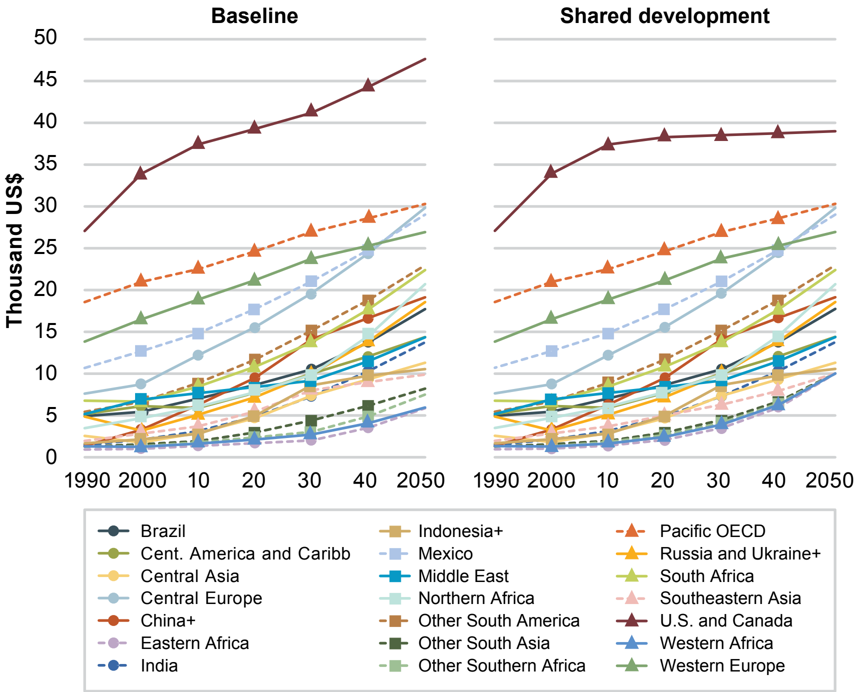

Figure 2.2: Income trajectories of selected countries and regions in the SEI baseline and SDA scenarios

Table 2.3: Past and projected future growth rates for the 10 fastest growing countries in the world

Recent growth rates (%) (2001–2010)		Forecast growth rates (%) (2011–2015)	
Angola	11	China	9.5
China	11	India	8.2
Myanmar	10	Ethiopia	8.1
Nigeria	8.9	Mozambique	7.7
Ethiopia	8.4	Tanzania	7.2
Kazakhstan	8.2	Vietnam	7.2
Chad	7.9	Democratic Republic of the Congo	7
Mozambique	7.9	Ghana	7
Cambodia	7.7	Zambia	6.9
Rwanda	7.6	Nigeria	6.8

Source: *The Economist* (2011) 'Africa's impressive growth'. Daily chart, 6 January.

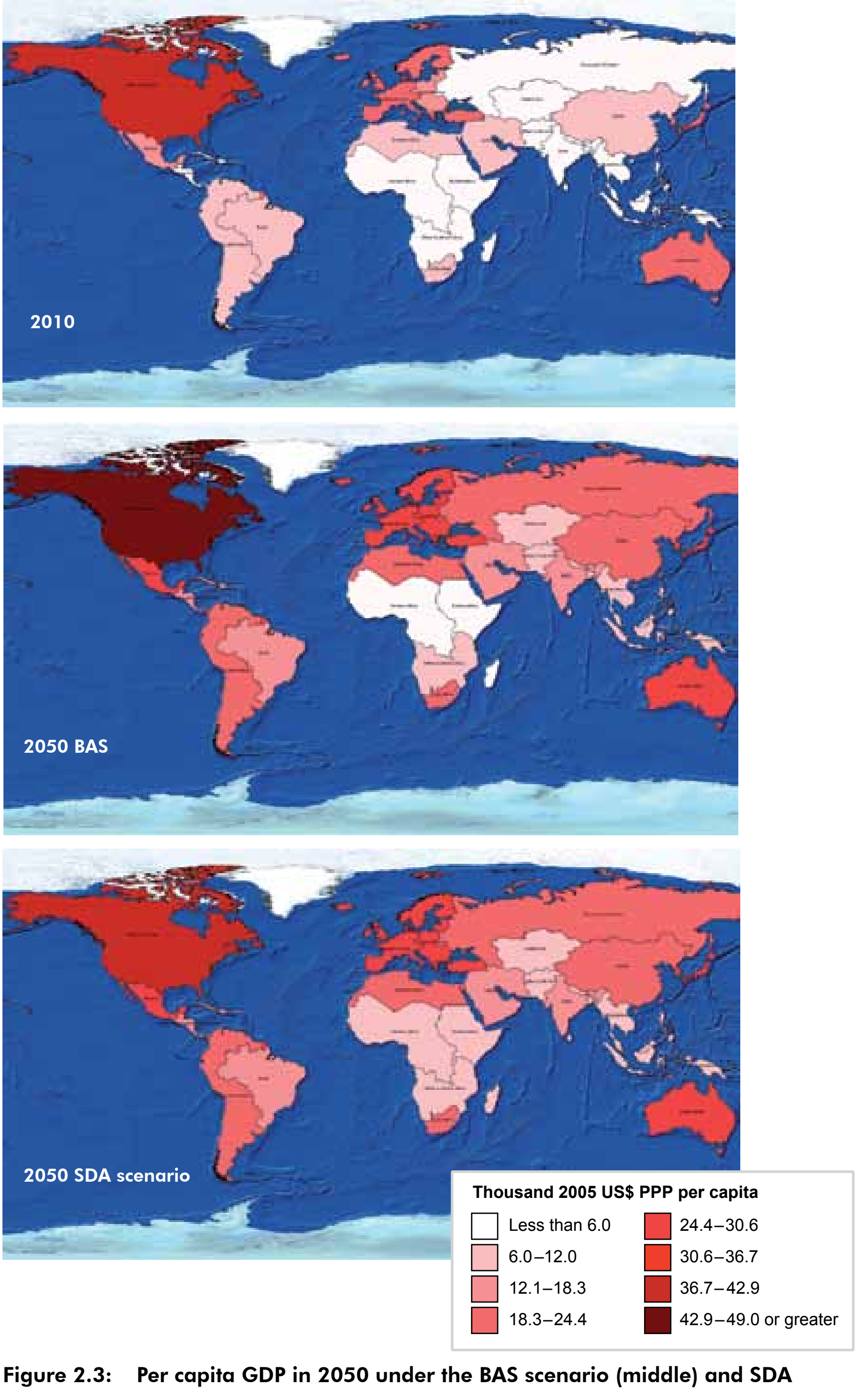

Figure 2.3: Per capita GDP in 2050 under the BAS scenario (middle) and SDA scenario (bottom), compared with 2010 (top). The SDA scenario shows a more equitable growth path.

The SDA scenario also explores alternative patterns of income distribution within each region in order to project likely levels of poverty (with poverty defined as those living on less than USD 1.25 PPP per day). While the BAS and BEA scenarios assume roughly constant patterns of income distribution (as measured by the Gini coefficients of the countries in each region),[11] the SDA scenario assumes a more optimistic storyline with Gini coefficients assumed to improve in each region as levels of democratic participation improve and countries become better governed. This storyline is based on two recent papers that fit Gini data using linear regression to a model that uses political variables to explain differences (Kemp-Benedict 2011; 2010) we demonstrate that political regime (whether extractive, redistributive, or reinvestment-oriented. The Gini coefficient assumptions in each scenario are shown in figure 2.4, which shows a larger number of countries with lower Gini coefficients (i.e. better income equality) in 2050 compared with 2010 in the SDA scenario.

Figure 2.5 shows the total level of poverty in each scenario. Even under the BAS scenario the total number of people living in poverty is expected to decrease dramatically (from 990 million people in 2010 to 86 million people in 2050, with the vast majority of those still in poverty expected to be living in Africa and Asia). However, the impact of more rapid GDP growth and improved income distribution under the SDA scenario results in even more significant reductions, with the number of those living in poverty reduced to 11 million in 2050.

Our modelling of income distribution within regions has not been explicitly examined with respect to its possible impact on energy consumption and GHG emissions. However, the intention is to reflect the beginning of a transition to a more equitable world consistent with the overall storyline of the SDA scenario.

2.2.5 Energy and emissions

In the BEA and SDA scenarios we take a deliberately conservative approach to technology by only including options that are either already commercially available, or are in development now and expected to be commercialized in the coming 20–30 years. We exclude potentially major pathways such as hydrogen fuel cells and nuclear fusion, which appear to be many decades away from the market, but we have included options such as electric vehicles and carbon capture and storage (CCS) as key components of the BEA and SDA scenarios, although only in the last two decades of the analysis.

The two scenarios use as a starting point the regional energy intensity trends and fuel share trends in the GEA efficiency scenarios. However, we further accelerate these trends to reflect the particular additional constraints envisaged in our scenarios – a more stringent CO_2 budget and a later start date for major mitigation efforts (no earlier than 2015 and as late as 2020 for the poorest regions) – described above.

11 Gini coefficients are a measure of income equality within a country or a region. They range from zero to one. A Gini coefficient of zero expresses perfect equality (i.e. equal income among all people) while a coefficient of one (100%) represents perfect inequality (i.e. one person earns all the income).

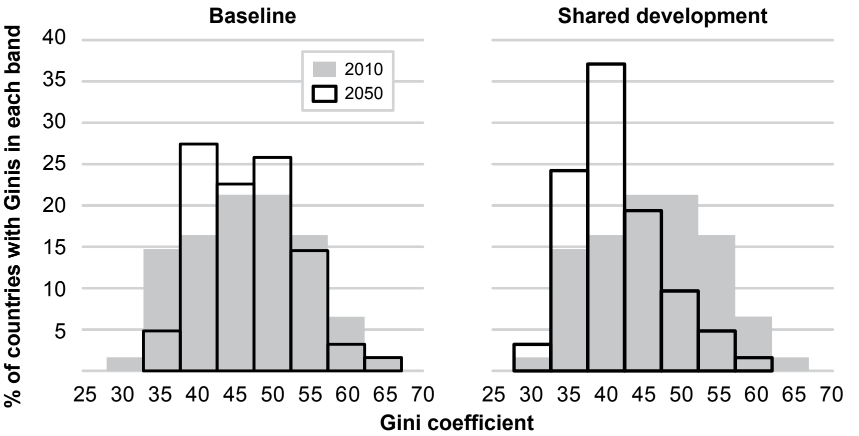

Figure 2.4: Income equality of countries in the baseline/basic energy access scenarios compared with the SDA scenario, in 2010 and 2050

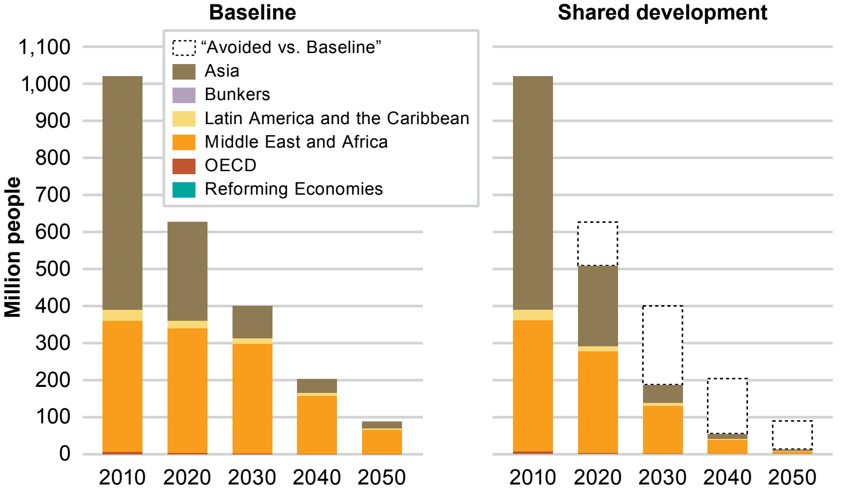

Figure 2.5: Poverty levels by region in the BAS and BEA scenarios, and the SDA scenario

This implies more stringent actions to reduce energy intensities and thereafter expansion of renewable energy, while staying within the overall limits of sustainable use for each type of renewable resource. While the GEA scenarios already assume ambitious targets for energy efficiency improvement, we assume that energy intensities can be further reduced, both through measures to further encourage energy efficiency and through a wide range of non-technical measures designed to make the behaviour of consumers and producers less energy-intensive. These might include measures such as curbing growth in energy intensive modes of transportation and policies that discourage wasteful use of lighting, heating and cooling, as well as measures aimed at "dematerializing" economies and encouraging citizens to choose more sustainable patterns of consumption, such as adopting healthier, less meat-intensive diets or reducing the amount of heating and cooling in buildings.

Our BEA and SDA scenarios also imply that final energy intensities can be further driven down through electrification: efficient electrical devices are substituted for fossil fuels wherever possible and at the same time the world's energy supply systems are radically overhauled so that they can produce the electricity needed with close to zero emissions of CO_2. This approach, while leading to large overall reductions in energy intensities, causes electricity demand to grow substantially to 2050, particularly in the developing world.

It is assumed that nuclear and hydropower will grow along the lines of the ambitious expansion plans already envisaged in the GEA scenarios. These levels represent reasonable estimates related to long-term economic potential. Any additional major expansion of these technologies is likely to face significant hurdles both in terms of cost and in terms of public acceptance. Moreover, the stringent CO_2 reduction targets require a staggered phasing-out of conventional fossil-fired thermal power plants, with all oil-fired generation phased out by 2035, natural gas generation by 2050, and coal generation by 2030 in OECD nations, and in all other regions by 2045. By 2050, the only fossil-based generation remaining is in those coal and natural gas CCS power plants able to capture and store up to 85% of their CO_2 emissions. Given that CCS is still far from commercialization, the market penetration of these technologies is assumed to be limited by 2050. Coal CCS is restricted to highly coal-dependent developing regions (primarily China, India, Indonesia and South Africa). CCS plants are likely to operate at lower overall thermal efficiencies than conventional fossil fuel plants due to the additional electrical power needed to capture and store CO_2.

The BEA and SDA scenarios also assume that sustainable supplies of biomass will be used as a feedstock in three main ways: to produce transport fuels, especially for road transport and for aviation and shipping fuels; to produce heat and electricity in CHP plants; and for particular industrial sectors where large scale electrification is not possible, such as the iron and steel and cement sectors. In these sectors biomass use combined with CCS technologies could potentially provide energy with net negative CO_2 emissions. However, we have conservatively assumed that no biomass CCS is deployed before 2050.

The remaining demand for electricity in our scenarios is met by hydropower wind, solar and other renewable energy resources, such as wave, tidal and geothermal energy (which may be especially important in some key regions such as Indonesia and Africa). Meeting this demand requires a huge increase in the installed capacity of these technologies and rapid growth in their deployment (because of their inherent variability). Our stringent CO_2 budget means that even faster growth in these technologies is required. For example, our BEA scenario estimates that globally as much as 8,900 GW of wind-powered electricity generation would be required by

2050. Reaching such a level would require building an astonishing 248 GW per year on average between 2015 and 2050, 25 times the recent global build rate of about 10 GW per year.

Nevertheless, assuming that wind and solar plants can be built sufficiently rapidly, we find that the deployment envisaged in 2050 for these and other renewable technologies is within the overall sustainable resource base available for each renewable energy resource (see table 2.4). Note also that while the BEA scenario requires 93 exajoules (EJ) per year of biomass primary energy by 2050, this lies within the GEA global estimate of 78–239 EJ per year for the maximum sustainable utilization of bioenergy. However, another, more recent, study by PBL indicates that the maximum sustainable utilization may be as low as 50–90 EJ/yr (Kram et al. 2012).

Table 2.4: Primary energy requirements in exajoules (EJ) compared to sustainable resource base as estimated in the GEA scenario

	Primary requirements (EJ)				Sustainable resource base (EJ)
Resource	**1990**	**2010**	**2030**	**2050**	
Coal	86	134	110	34	n/a
Oil	141	174	120	31	n/a
Natural gas	71	116	107	57	n/a
Nuclear	26	31	53	82	n/a
Geothermal	1	3	10	13	1–12
Hydro	7	12	24	26	49–80
Solar	0	2	21	55	7–285
Wind	-	1	31	58	28–134
Biomass	35	49	66	93	78–139
Total	**368**	**521**	**543**	**448**	

It is a big challenge to integrate a large amount of variable renewable generation into the world's energy systems. A variety of options will be required to balance supply and demand, including flexible high-capacity regional electric interconnections, greatly increased infrastructure for storing energy and much more controllable demand for electricity. These options are collectively referred to as "smart grids". Fortunately, a wide range of options are being developed that can address this challenge, although it must be noted that these new options are still far from commercialization. Significant efforts in research, development and demonstration (RD&D) are needed before they can be applied on a large scale, including:

- **Advanced demand-side management (DSM).** Electrical devices and facilities that can be turned down or switched off when needed to help balance short-term slews in electricity supply. Refrigeration, air conditioning, household appliances and heat pumps are all good candidates for use in advanced DSM systems.

- **Geographic balance and resource diversity.** Much more substantial regional interconnections could help the world's energy systems benefit from regionally diverse renewable supplies. For example, for future European electricity systems, hydropower resources are concentrated in Scandinavia while huge solar potential is located in southern Europe, the Middle East and North Africa. These geographic variations create opportunities for better management of loads. Taking advantage of these variations will require a major upgrade of electricity transmission systems, for example, building high voltage direct current (HVDC) electricity "superhighways" to help stabilize loads and transport power over very long distances. However, a major expansion of transmission lines will be costly and subject to strong public resistance, especially in more developed and more densely populated regions.

- **Storage.** Increased energy storage will be key to achieving very high penetration of renewable power generation systems. This is not only because wind and solar power are only intermittently available, but also because renewable resources are often far from centres of demand, which often means that it is prohibitively expensive to construct new transmission lines. This problem can be addressed by coupling renewable generation with localized and relatively long-term energy storage, which would transform intermittent sources of power into a reliable, dispatchable and therefore much more valuable source of base-load power. Potential storage options include pumped-storage hydropower, fly-wheels, batteries, molten salt storage tanks used in conjunction with concentrating solar power facilities, and compressed air energy storage used in conjunction with wind power. In the longer term, electric plug-in hybrid and pure electric vehicles might also be used as short-term grid storage. Vehicles not being actively driven could be designed to feed energy back into the grid at times when renewable sources are unavailable and the price of electricity is high.

2.3 Implications of the baseline scenario

The baseline scenario shows that without urgent and concerted action, the world has very little chance of achieving even a semblance of climate protection. Our baseline scenario foresees net global CO_2 emissions (including both energy and non-energy sector emissions) almost doubling from 2010 to 2050, growing from 36.4 Gt CO_2 in 2010 to 70.5 Gt in 2050. Over the period 2000 to 2050, this corresponds to cumulative emissions of approximately 2491 Gt CO_2. According to the meta-analysis of Meinshausen et al. (2009), these emissions correspond to a 98% chance of the globe's average temperature increase exceeding 2°C – in other words, near certainty.

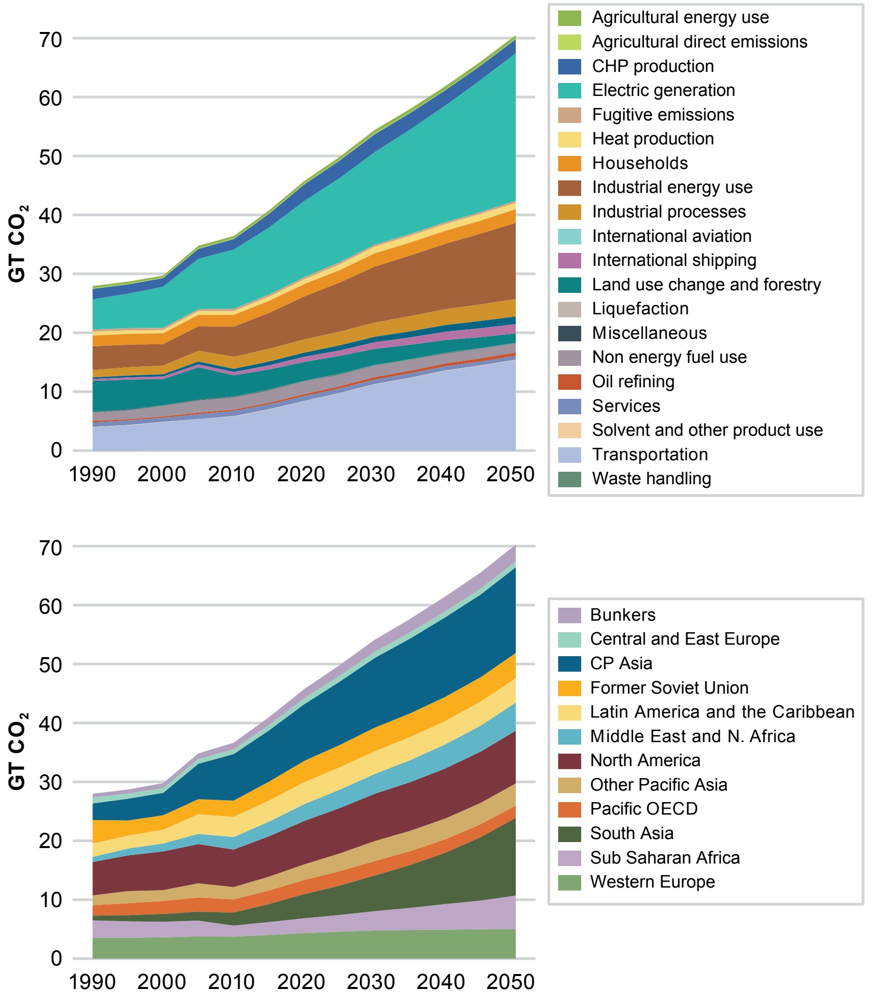

Figure 2.6: Global CO_2 emissions in gigatonnes (Gt) CO_2 by sector and region in the SEI baseline scenario

Figure 2.6 shows baseline emissions growth over time by both sector and geographic region. The transportation and power sectors are the largest and fastest growing sectors, while total emissions grow most rapidly in South Asia and Centrally Planned Asia.[12]

The dramatic growth in emissions under the BAS scenario results from rapid population and economic growth, particularly in the developing regions. Even so, emissions intensities (tons of CO_2 per USD) show significant improvements as energy efficiency converges towards the lower values generally seen in the OECD nations. In the developed world, per capita energy intensities remain roughly constant, reflecting

12 Centrally Planned Asia comprises China, Laos, Mongolia, North Korea, South Korea and Vietnam.

how the trend for greater energy efficiency is cancelled out by increases in energy use due to higher levels of income. The developing regions show increasing emissions intensities per person as their incomes grow rapidly. However, their emissions per capita remain far below those in the richer regions, reflecting continued disparities in wealth between developed and developing nations (see figure 2.7).

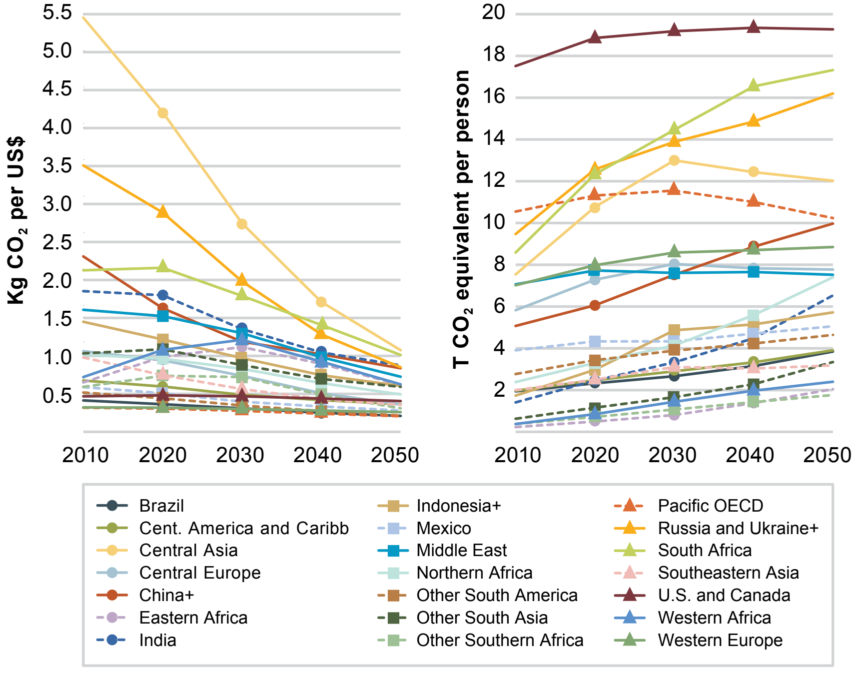

Figure 2.7: Baseline energy sector emissions intensities by region from 2010 to 2050, in kg CO_2 per USD MER (left) and tonnes CO_2 per person (right)

The baseline scenario foresees a continued growth in energy consumption, with the largest growth in the transport and industrial sectors (see figure 2.8) Energy demand would increase from 365 EJ in 2010 to 775 EJ in 2050. By 2050, South Asia would surpass Centrally Planned Asia to become the region with the highest energy consumption. In terms of fuel use, final energy demand is dominated by consumption of oil products in the transport and other sectors, by natural gas for heating and by electricity. The use of biomass in the form of wood, charcoal and other traditional fuels remains significant to 2050.

Electricity generation in the baseline scenario almost triples, from 19,000 terawatt hours (TW/h) in 2010 to 57,000 TWh in 2050 (see figure 2.9). Conventional fossil fuel technologies continue to dominate generation, while wind and solar generation are expected to grow significantly, reaching 13% of global generation by 2050. Under

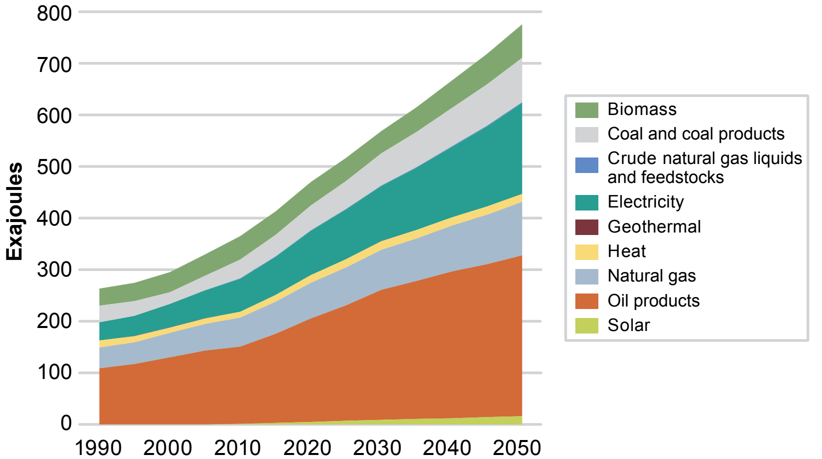

Figure 2.8: Global final energy demand from 1990 to 2050 in exajoules (EJ) by fuel under the SEI baseline scenario

the scenario, fossil fuels also increase their share of global generation, which grows from 65% in 2010 to 68% in 2050. However, CCS technologies are not expected to be significantly deployed in the baseline. Hydro generation more than doubles from 2010 to 2050, while nuclear generation declines slightly in absolute terms, reflecting its high cost and lack of popular support in regions where it is most likely to develop. As a result, both hydro and nuclear power decrease their shares of generation due to the high level of overall growth in electricity generation.

Baseline primary energy use roughly doubles, growing from 506 EJ in 2010 to 1069 EJ in 2050 (see figure 2.10). Coal, oil and gas continue to dominate primary energy use. The share of primary energy provided by fossil fuels is projected to increase slightly: from 81% in 2010 to 83% in 2050. The pattern of primary energy use is projected to shift enormously to become dominated by the developing countries. In 1990, more than 66% of primary energy use was in the developed world. However, under the BAS scenario this picture is exactly reversed by 2050, so that 65% occurs in the developing world.

2.4 Implications of the basic energy access scenario

In the BEA scenario, energy demand dramatically reduces relative to the baseline scenario due to the impact of measures to improve energy efficiency and reduce the energy intensity of economies (see figure 2.11). These improvements are also driven by a general focus on the electrification of energy consumption where possible – including in transportation, households and industry. Under this scenario, while consumption of fossil fuels declines enormously, by 2050 the demand for electricity grows to roughly the same level (174.5 EJ) as in the baseline scenario (175.9 EJ).

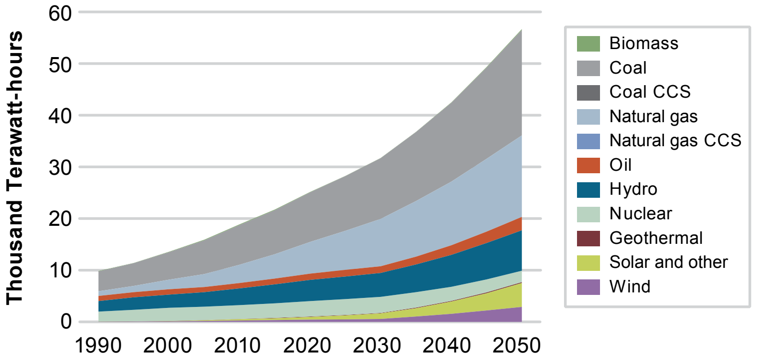

Figure 2.9: Global electric generation by fuel under the baseline scenario from 1990 to 2050, in thousands of terawatt hours (TWh)

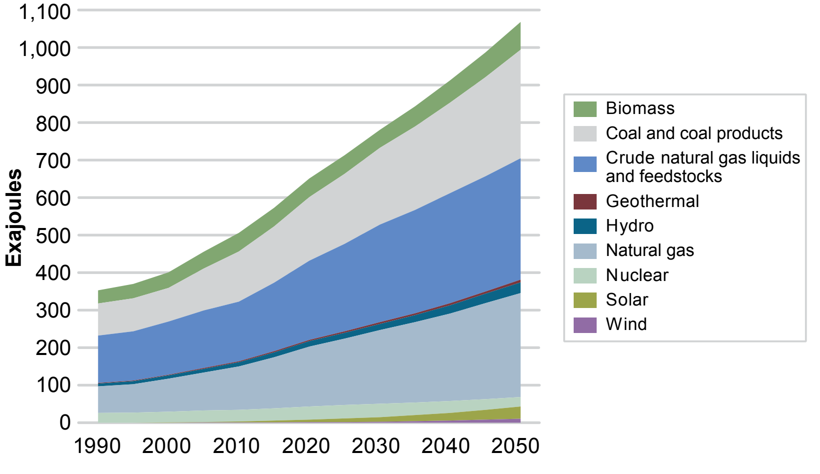

Figure 2.10: Global primary energy requirements by fuel in Exajoules under the baseline scenario from 1990 to 2050

The BEA scenario also shows dramatically different electricity generation trends, as figure 2.12 shows. Conventional fossil fuels are phased out before 2050, with the increased demand for electricity met by huge increases in wind, solar and other renewable forms of electricity generation. Between 2010 and 2050, generation from these sources grows by a factor of 8.8. Generation from nuclear power grows by a factor of 2.8 over the same period, while the new technology of CCS-based generation from coal and natural gas emerges so that by 2050 it provides almost 20% of global electric power, reflecting significant implementation of this technology.

Primary energy use continues to grow (to 575 EJ) until 2020 but then declines as trends toward a reduction in energy intensity overwhelm economic growth in different

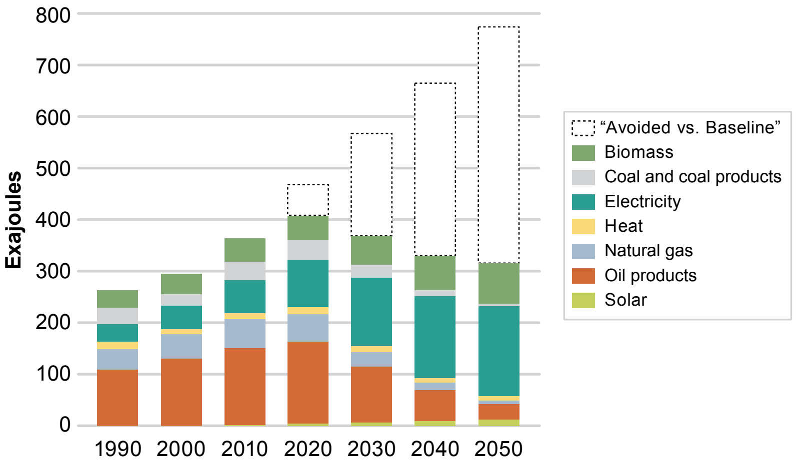

Figure 2.11: Energy demand by fuel in exajoules under the BEA scenario

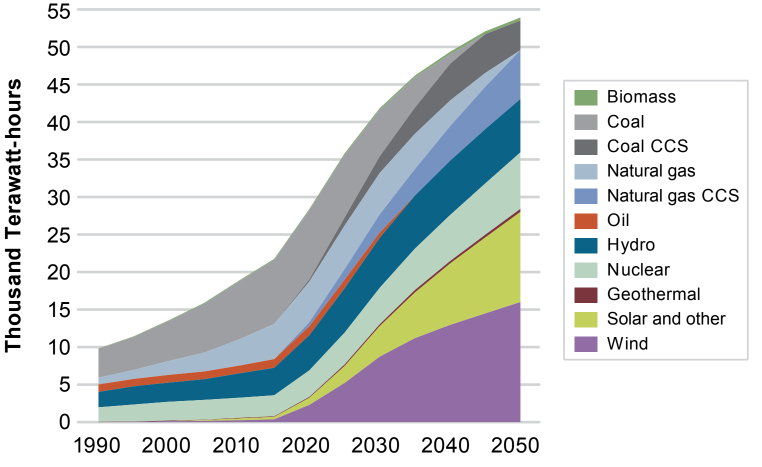

Figure 2.12: Electricity generation in thousands of TWh by fuel under the BEA scenario

regions of the globe (see figure 2.13). By 2050, primary energy use is reduced to 441 EJ. Fossil fuel use is reduced by 76% from its peak of 469 EJ in 2015 to 114 EJ in 2050, with remaining fossil fuel use concentrated in electricity generation and large scale industry where in some sectors it is combined with CCS technologies to reduce its emissions of CO_2. While it will be a challenge to develop CCS technologies sufficiently rapidly in the period to 2050 (especially in the industrial sector) it will be almost impossible to meet the CO_2 budget constraints on the scenario without using these technologies in these sectors.

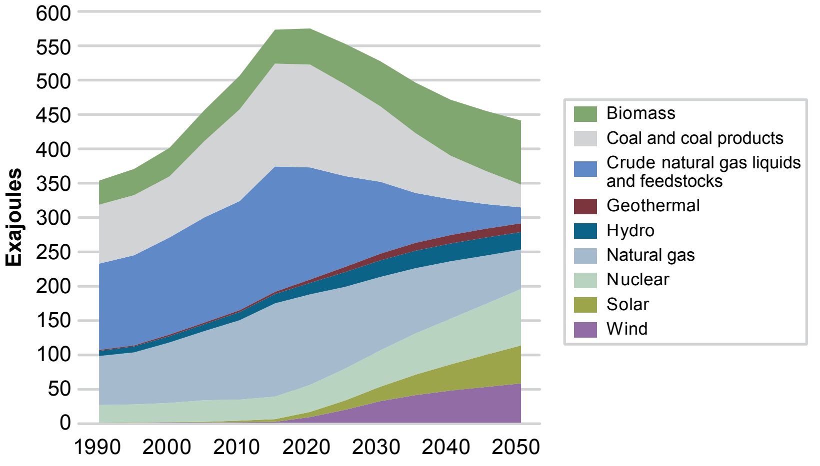

Figure 2.13: Primary energy use in Exajoules by fuel under the BEA scenario

Biomass use in the BEA scenario almost doubles, from 49 EJ in 2010 to 93 EJ in 2050. Its use is assumed to be concentrated in transportation (especially cars, shipping and aviation), in heavy industrial sectors where replacement of fossil fuels with electricity is extremely difficult (especially the iron and steel and chemicals sectors) as well as in CHP plants where the products of combustion can be used most efficiently. Although this is a huge increase in biomass use, as discussed above, there are indications that this level of use is consistent with what can be produced to meet overall sustainable development goals, both for environmental protection and food production. Likewise, while wind and solar energy also increase dramatically,[13] their planned exploitation in the scenario stays within the resources available. Solar energy use in particular remains far below its exploitable potential.

The regional pattern of primary energy use is shown in figure 2.14. Because of the slower growth and more stringent reductions in energy intensity in the North, northern regions show a marked decrease in primary energy use, peaking at 257 EJ in 2010 and declining to 99 EJ in 2050. Primary energy use in the South stays essentially flat after 2020 at about 330 EJ, because energy intensity reductions are roughly balanced by the more rapid economic growth in southern regions.

Figure 2.15 illustrates how under the BEA scenario global baseline emissions are reduced by emissions reductions in different sectors. Globally, total CO_2 emissions increase by 38% in 2020 relative to 1990, but by 2050 decrease by 92% on 1990 levels.

13 The large decrease in primary energy use partly reflects the way that solar and wind power generation are measured. As with hydropower, their primary energy content is based on the electricity generated by these resources. Thus they appear by convention smaller than fossil fuel and biomass energy resources, which are measured not in terms of electricity generated from their use but the energy content of the feedstock fuel itself. Nuclear energy, by convention, is also measured roughly in terms of fossil-equivalent energy.

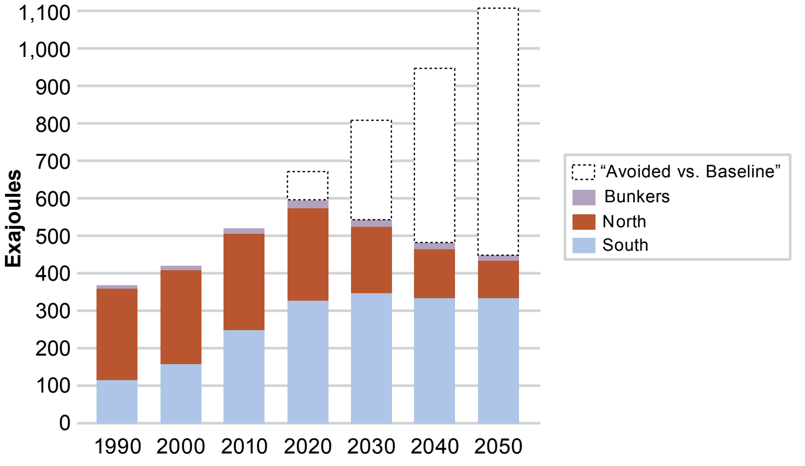

Figure 2.14: Global primary energy use in exajoules by region under the BEA scenario

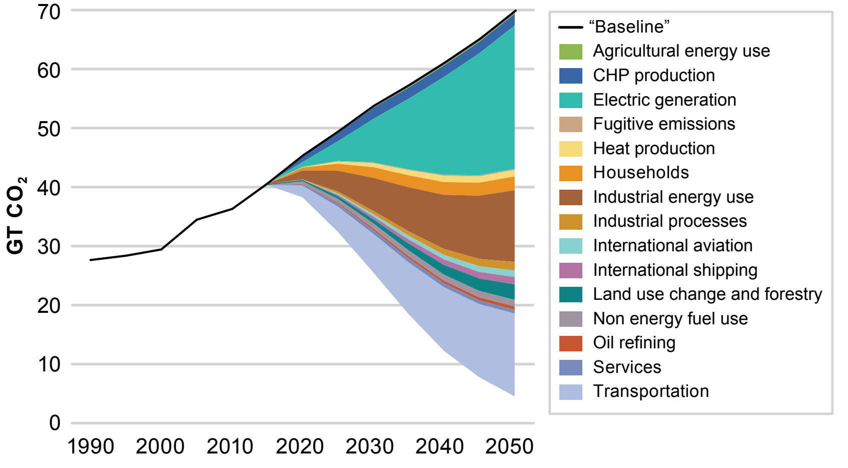

Figure 2.15: CO_2 emissions reductions in gigatonnes (Gt) by sector under the BEA scenario

This can be contrasted with net increases in the baseline scenario of 64% in 2020 and 152% in 2050 on 1990 levels.

The largest reductions in emissions come from energy supply sectors; most notably electricity generation and CHP, transportation and industrial energy use. Figure 2.16 shows how CO_2 emissions are reduced by region under the scenario. Note how emissions in the North rapidly approach zero: something that will be necessary to provide sufficient emissions development space in the South.

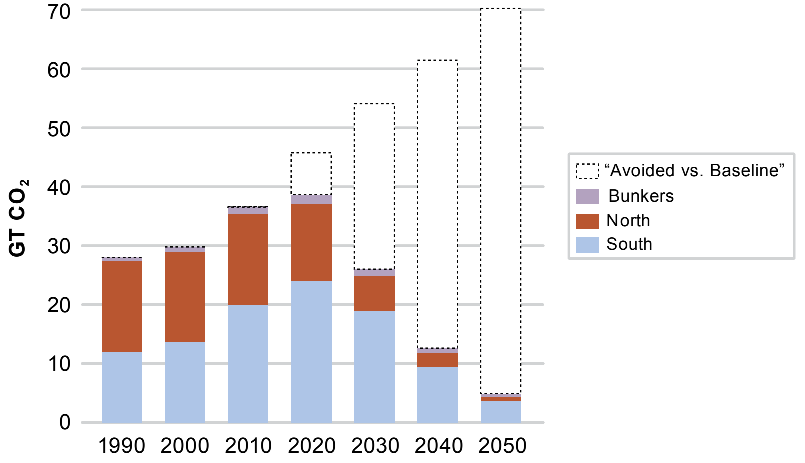

Figure 2.16: CO_2 emissions in gigatonnes by region under the BEA scenario

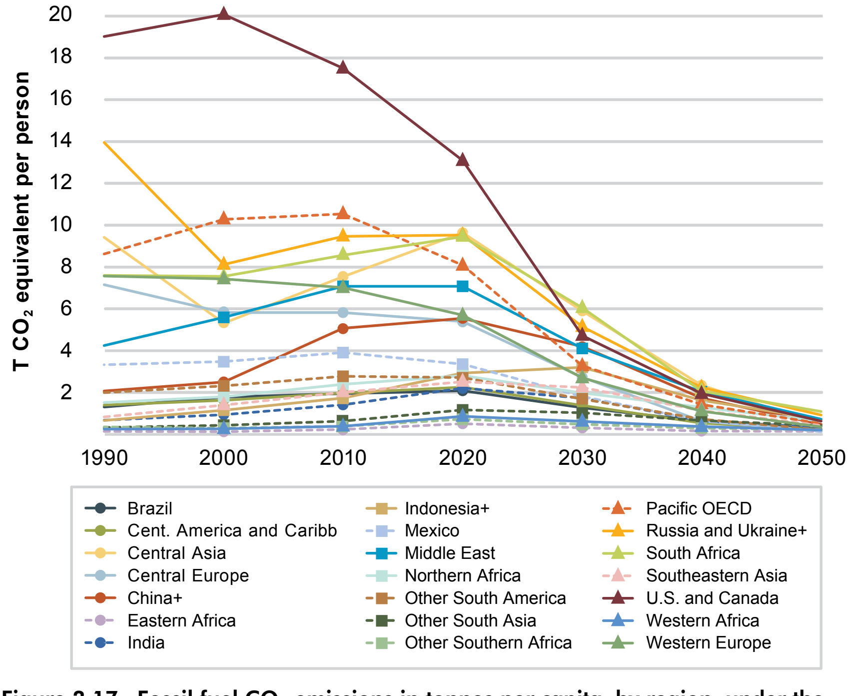

Figure 2.17: Fossil fuel CO_2 emissions in tonnes per capita, by region, under the BEA scenario

In terms of fossil fuel CO_2 emissions per capita, the BEA scenario results in near convergence of emissions across all regions (see figure 2.17) with average emissions reduced by a factor of ten, from an annual average of 4.42 tons CO_2 per capita in 2010 to only 0.45 tons per capita in 2050.

2.5 Implications of the shared development agenda scenario

As noted in section 2.2.4, the SDA scenario has similar goals for CO_2 reduction to the BEA, but also explores faster economic growth in the poorest regions and lower growth in the richest region (the U.S. and Canada) so that total global GDP growth in all scenarios is roughly equal.

Even allowing for the increase in energy demand that will result from the increased income in some regions, the SDA scenario has minimal impacts on overall energy consumption and CO_2 emissions compared to the BEA scenario. Under the SDA scenario, final energy demand increases by only 33.5 EJ in 2050 compared to the BEA's total energy demand of 295.5 EJ, an increase of only 11%. The overall increase is small because only a few countries increase their consumption as a result of the scenario (Southern, Western and Eastern Africa, and South Asia), while one region (the U.S. and Canada) decreases its consumption due to its lower rate of GDP growth. These regions (including the U.S. and Canada) account for 32% of the globe's population in 2050. Consumption in all other regions is unaffected.

Total CO_2 emissions hardly increase at all in the SDA scenario versus the BEA, because significant additional decarbonization occurs up until 2050 in both scenarios, especially in the U.S. and Canada.

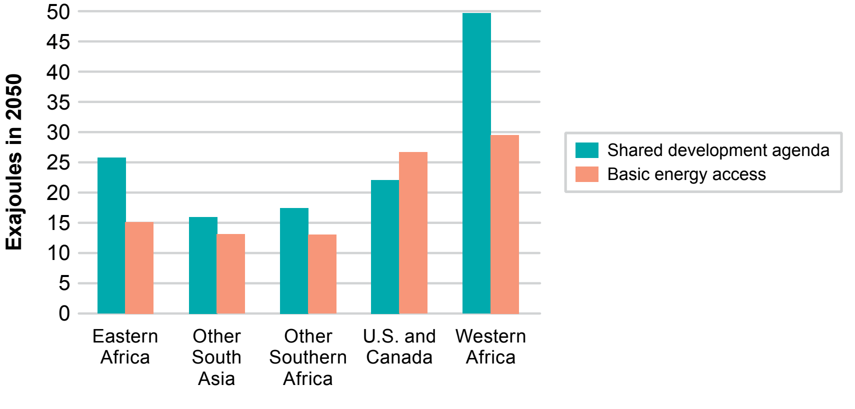

Figure 2.18: Total energy demand in 2050 in exajoules (EJ) in affected regions under the SDA and BEA scenarios

Note, however, that while the more fundamental development goals in the SDA scenario have little global impact on primary energy use and CO_2 emissions versus the BEA scenario, the scenario does lead to significant increases in energy consumption in the poorer affected regions (see figure 2.18). In 2050 energy demand is almost twice as high in the SDA scenario as in the BEA scenario in Eastern Africa and Western Africa. These increases come about due to higher demand in households as incomes increase, reflecting greater levels of development. Energy demand is also increased in all other sectors, reflecting greater productive use of energy consistent with more economic development.

2.6 Comparisons with other studies

The scenarios presented in this chapter can be compared to other recent global energy and emissions scenarios. Figure 2.19 shows total global energy sector-related emissions of CO_2 from a selection of energy studies. Our baseline scenario emissions are similar to those projected in other baseline scenarios: lower in 2050 than the GEA baseline, but somewhat higher than those in the IEA's *Energy Technology Perspectives* (2010) baseline.

Our BEA and SDA scenarios (only one of which is plotted here because of their very similar results), show significantly lower CO_2 emissions in 2050 compared to other mitigation scenarios. There are two primary reasons for this: first, our adoption of stricter CO_2 emissions constraints between 2000 and 2050; and, second, our assumption that significant mitigation efforts will not begin until 2015 at the earliest

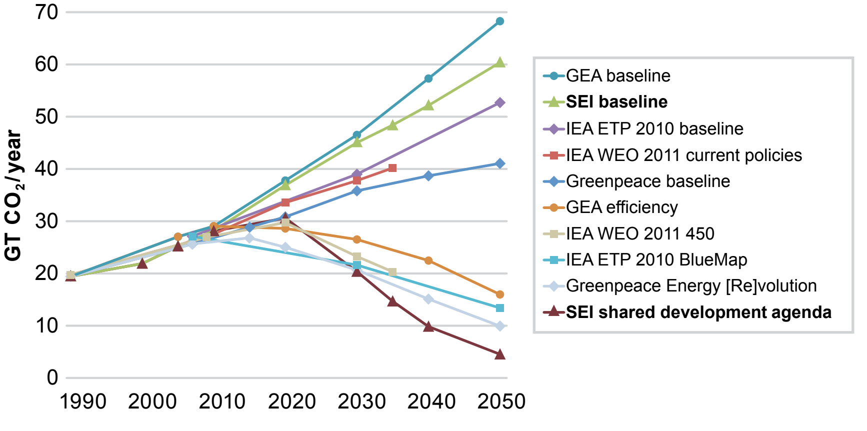

Figure 2.19: Comparison of global energy sector CO_2 emissions in gigatonnes (Gt) per year in SEI and selected scenarios

Sources: SEI (2012); Global Energy Assessment (Riahi et al. 2012); World Energy Outlook (IEA 2011a); Energy Technology Perspectives (IEA 2010), Energy [Re]volution (Greenpeace and EREC 2010).

(and in many regions not until 2020). This provision can be clearly seen in figure 2.19. Note how the energy sector's CO_2 emissions in our SDA scenario peak later than in the other scenarios. This forces the emissions in the SDA scenario to drop more quickly and to a lower final value than in the other scenarios in order to meet the stricter emissions constraints.

Figure 2.20 shows the implications of these different pathways for final energy intensity. Many of the scenarios show similar baseline decreases in final energy intensities. These intensities represent the change in total global final energy demand per unit of global GDP, measured in MER terms. All of the values are shown relative to 2010 values (2010 = 1.0 in all scenarios).

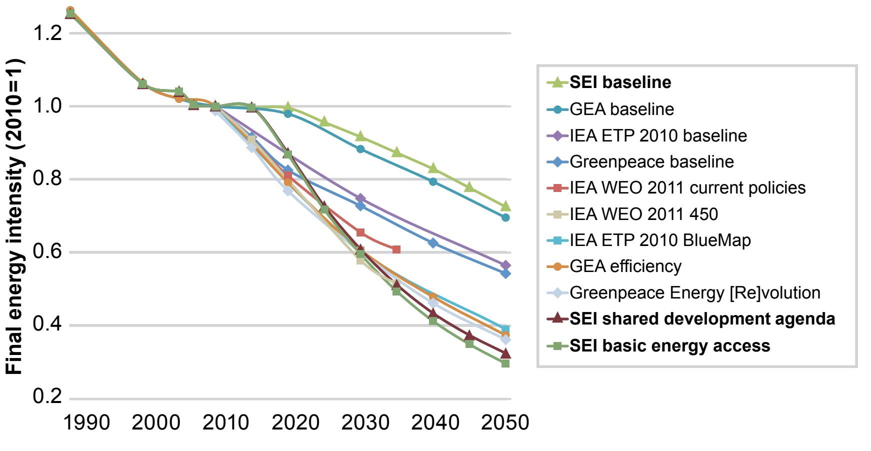

Figure 2.20: Comparison of global final energy intensity in SEI and selected scenarios

Sources: SEI, Global Energy Assessment (GEA 2012); World Energy Outlook (IEA 2011a); Energy Technology Perspectives (IEA 2010), Energy [Re]volution (Greenpeace and EREC 2010).

In SEI's baseline scenario, intensities decline at a rate of 0.8% per year between 2010 and 2050 (which by definition is broadly similar to the decline in the GEA baseline scenario). By 2050 average energy intensities decline to 72% of their value in 2010, or 58% of their value in 1990. Other studies expect even more substantial baseline decreases in intensities. For example, the IEA ETP scenario expects intensities to decline to only 56% of their 2010 values. Thus, while there is considerable uncertainty over these values it seems clear that there is considerable scope for energy efficiency improvements even in the absence of specific new policies to combat climate change.

Our SDA scenario shows higher levels of decline in energy intensities than in other scenarios (for the same reasons listed above). To meet the targets of the scenario, intensities decline at a rate of 2.8% per year in the SDA scenario (and 3.0% in the BEA scenario). By 2050, the average global energy intensity in the SDA scenario is only 32% of its 2010 value. These values are clearly very ambitious, especially when compared to the levels seen in other scenarios (e.g. 39% in the IEA Blue Map scenario or 37% in the GEA Efficiency scenario). How might this extra decline in intensity be achieved? Pursuing additional energy efficiency measures beyond those foreseen in the other scenarios is one possibility, but it is also important to note that the other scenarios presented in these figures primarily focus on energy efficiency. Energy intensity can also be reduced through improved planning and changes in lifestyle. For example, better urban planning could reduce the need for transportation regardless of the efficiency of vehicles; curtailing the expected growth in house size (i.e. the number of square metres of floor space per person), especially in richer countries, would reduce residential heating and cooling energy demands regardless of the efficiency of boilers and air conditioners. Numerous other non-technical measures might occur that could have a profound impact on energy intensities, regardless of the level of efficiency achieved in the scenario.

2.7 Implications for selected regions

Although our analysis includes results for 20 different regions of the globe, presenting results in detail for every region goes beyond the scope of this report. Here we include only selected charts to illustrate how the scenarios capture regional differences, in terms of both energy consumption and production patterns, which in turn are closely linked to national circumstances such as level of income and resource availability.

Figure 2.21 shows the regional differences in primary energy requirements in 2050 for the baseline and SDA scenarios for five of the 20 regions: China+, Eastern Africa, Indonesia, the U.S. and Canada, and Western Europe. In the baseline scenario, different types of fossil fuel dominate in different regions, while in the SDA scenario a degree of convergence has occurred by 2050, with renewable resources becoming more important in all regions. Nevertheless, regional differences persist in 2050 even in the SDA scenario. For example, coal (used in CCS plants) remains important in China and Indonesia where that fuel is abundant. Similarly, geothermal energy is expected to become an important renewable resource in Indonesia. Wind and solar are important resources in all regions in 2050 in the SDA scenario, although particularly so in the U.S. and Canada, and Western Europe.

Biomass plays an important role in both the baseline and the SDA scenarios in 2050 in two of the poorer regions: East Africa and Indonesia. However, it should be noted that treating biomass as a single "bar" masks quite important differences between the two scenarios. In the baseline scenario, much of the biomass in these regions continues to be consumed in the form of traditional fuels used by low-income households. The SDA, on the other hand, reflects much greater development, with biomass emerging as a key modern energy form in all regions.

These regional differences can also be seen when comparing the possible evolution of electricity generating technologies under the SDA scenario, as shown in three

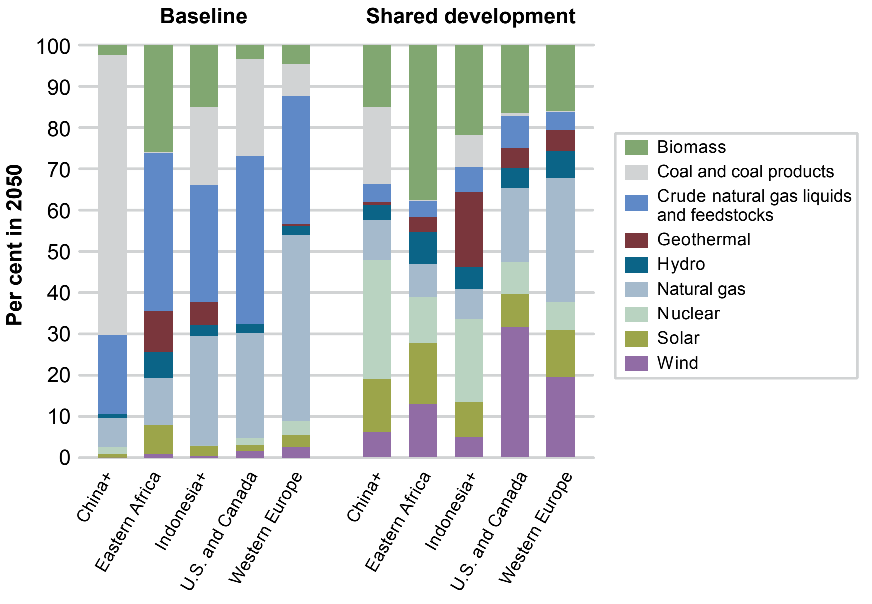

Figure 2.21: Differences in primary energy use in 2050 by fuel in selected countries and regions under the baseline and SDA scenarios

examples in figure 2.22. In Western Europe, coal and oil are phased out relatively quickly, so that by 2050 electricity generation relies only on renewable energy, hydropower, small amounts of nuclear power (e.g. in France) and natural gas, which by 2050 is wholly CCS-based. By contrast, in India – a country that is poorer and much more dependent on coal – coal-fired power plants that rely on current technology are phased out more slowly (not until 2035) and thereafter are partially supplanted by coal-fired CCS power plants. Nuclear power is also expected to play a growing role in India. In the Middle East – a region rich in oil, natural gas and solar energy – fossil fuels are replaced over time by the emergence of renewable energy generation, especially solar power. By 2050 natural gas with CCS is the only remaining form of fossil fuel-based generation in the Middle East. In all regions, renewable energy, especially solar and wind power, are expected to be very important for electricity generation.

These regional differences can also be seen when examining the evolution of energy demands (see figure 2.23). In the richer regions such as Western Europe, where populations are not growing significantly and economic growth rates are expected to be relatively low, significant improvements in energy intensity lead to dramatic declines in overall energy demand. The relative share of energy used in each sector stays fairly constant, reflecting the fairly mature structure of these economies and the near-saturation of the housing and road transport sectors, coupled with across-the-board efforts to improve energy efficiency. The major exception is the industrial sector, which increases its share of overall energy demand. This is because it is more

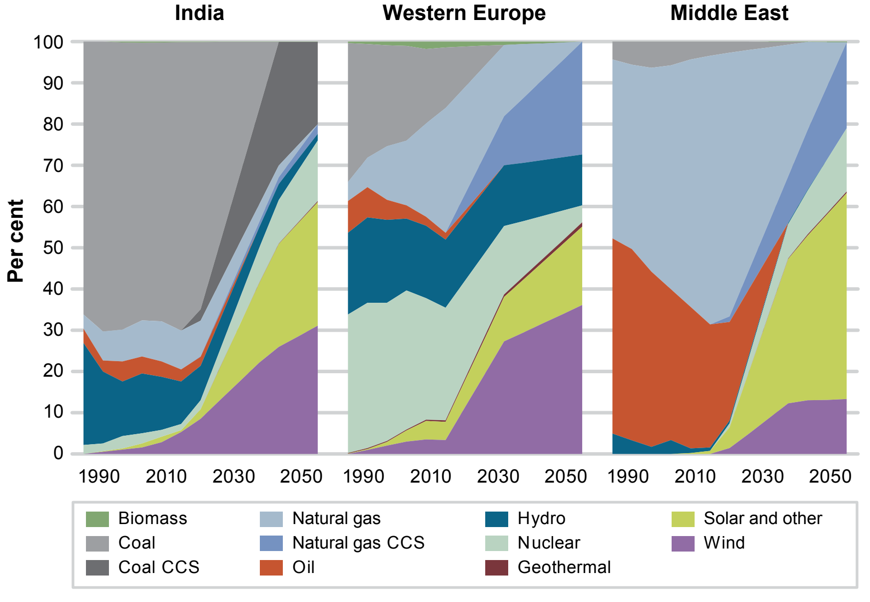

Figure 2.22: The evolution of electricity generation in percentage terms, by fuel, in the SDA scenario in India, Western Europe and the Middle East

difficult to achieve emissions reductions in industrial processes relative to buildings and vehicles.

Poorer and demographically younger regions such as India as well as most of Africa and South Asia are assumed to grow rapidly throughout the SDA scenario, both in terms of their populations and their economies. These regions see their demand for energy continue to grow quite rapidly, even as they undertake very significant efforts to improve their energy efficiency. Moreover, many of these regions see significant shifts in the structure of energy consumption as less developed sectors, such as transport and industry, grow in importance.

Rapidly maturing developing regions such as China exhibit trends somewhere between these two extremes. Initially, energy consumption in China grows rapidly, but from 2030 to 2050, as the population and workforce peak and economic growth is expected to slow, the significant energy intensity improvements seen in the SDA scenario are sufficient to cause a large decline in overall final energy consumption.

2.8 Sectoral policy implications

In earlier sections we outlined the types of energy systems that will be needed to deliver a low carbon future compatible with meaningful development in the poorest parts of the world. But what specific policies would be needed to foster such a transformation?

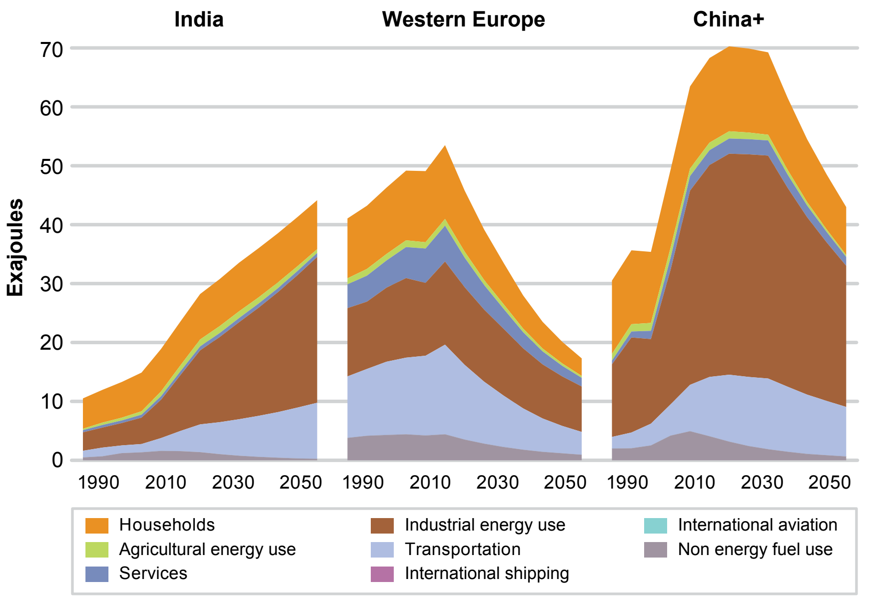

Figure 2.23: The evolution of energy demand by sector in exajoules (EJ) in three regions: India, Western Europe and China+ under the SDA scenario

Chapters 3 and 4 explore this question in detail. In this chapter we simply summarize examples of the type of policy that might be required in each sector.

2.8.1 Buildings efficiency

New building performance standards will be needed to ensure that all new buildings perform to passive energy standards. To update existing building stock, standards and incentives for retrofitting existing buildings will be essential. Energy use inside the built environment can be reduced through stronger performance targets for appliances and standards for the use of renewables in buildings.

2.8.2 Industry

RD&D of low-carbon technologies will be important for developing new industrial processes, while regulations and subsidies are likely to be required to encourage their adoption. National incentives to promote a shift towards less carbon-intensive production techniques as well as the reform and extension of international market mechanisms will also be vital.

2.8.3 Transport

Fuel economy improvements and strict vehicle emissions standards for passenger and freight vehicles will be essential to reduce individual vehicle emissions. Public vehicle procurement programmes can help speed up the introduction of lower-emitting vehicles. A combination of instruments can shift patterns of transport behaviour, including congestion charges, car-free zones in cities, road pricing, freight charges and weight taxes. Tax reforms can encourage the adoption of smaller and lower emitting vehicles, and counterproductive subsidies for road and air transport will need to be abolished. At the institutional level, it will be important to invest in infrastructure for electric vehicles and rail transport, and to improve urban planning to create cities that are desirable, compact and less energy- and transport-intensive.

2.8.4 Energy supply

Continued RD&D of low carbon technologies will be essential for scaling-up clean technologies. Rethinking business models (e.g. energy service companies as opposed to electricity supply companies) should help realign interests to pursue cleaner pathways. Much more substantial progress on internalizing CO_2 and other pollution costs (e.g. via a carbon price and the abolition of fossil fuel subsidies) will be key for phasing out fossil energy, while feed-in tariffs and Renewable Portfolio Standards will play an important role in encouraging renewable options. Richer regions will need to make greater efforts to transfer low carbon technologies to developing economies. It will also be important to expand and deepen market-based instruments such as the Emissions Trading Scheme (ETS) and the Clean Development Mechanism (CDM), and loopholes in such instruments will need to be closed.

2.9 Caveats and additional options

Based on GEA projections and expert judgments, we have mapped out what we think is a possible pathway for achieving the emissions reductions required by the overall CO_2 budgets imposed. However, because our two scenarios make ad hoc adjustments to the results of the GEA, they should not be viewed as representing least-cost paths. We have not yet been able to examine the economic costs and benefits of the mitigation options envisaged in our scenarios. We hope that this dimension of the problem can be explored in future work. A range of alternative pathways could potentially yield similar or lower total emissions, and do so at lower costs and with greater social benefits. Our scenarios reflect a very strong role for renewables and energy efficiency. Others might prefer to see a stronger role for nuclear power and fossil-based CCS technologies. However, note that because of the magnitude of the mitigation challenge in the BEA and SDA scenarios, these two technologies are assumed to rapidly expand – albeit at a slower rate than renewables and energy efficiency. Resource constraints, especially water scarcity, could also make it necessary to adjust the technology mix, at least in some countries or regions.[14]

While our BEA and SDA scenarios examine dramatic reductions in global GHG emissions, which will not be achievable without a wholesale transformation of global energy systems, it is important to recognize that even these scenarios entail significant risks. First, they aim for only a 60% chance of keeping global average temperature

14 A recent SEI project done in partnership with the 3C (Combat Climate Change) initiative explored the implications of resource scarcity for the low-carbon economy in three realms: biomass use, metals used in key technologies, and water for electricity generation. The resulting reports are available at http://sei-international.org/projects?prid=1736.

rises to within 2°C. Many will consider this to be poor odds of achieving such a critical sustainability goal. Second, as is described in chapter 1, the latest scientific evidence indicates that the 2°C goal itself is likely to be insufficient to protect the planet's climate.

Third, our scenario assumes that all biomass energy is sustainably produced and has net zero CO_2 emissions. In other words, we assume that all CO_2 emitted from combusting bioenergy is balanced by CO_2 sequestered from the atmosphere as plants grow. This assumption may be reasonable for historical emissions estimates because traditional biomass use has, up until now, dominated overall biomass use. CO_2 from unsustainable biomass harvesting is accounted for under non-energy sector accounts for land-use change and forestry. However, this assumption is problematic for scenarios that envisage large scale expansion of commercial bioenergy. In these situations the full life-cycle emissions associated with fertilizing, irrigating, harvesting, transporting and processing biomass into usable forms of bioenergy need to be fully accounted for. Even making a relatively optimistic assumption that full life-cycle bioenergy emissions (for all uses of biomass) are only 20% of those of oil products causes the total cumulative CO_2 emissions from 2015 to 2050 to grow by 36 Gt CO_2; an amount that would prevent the scenario from meeting its mitigation target. Furthermore, some technologies, when expanded on a large scale, produce significant GHG emissions in their non-operational phase (i.e. set-up phase) compared to conventional nuclear and fossil fuel technologies. In our scenario this includes wind- and solar-based generation, and we hope to more fully estimate the scale of this issue in future revisions to our scenarios. However, potential emissions here are of a much lower quantity relative to those of large scale bioenergy.

Of course our scenarios are only examples of potential pathways, and it is possible to imagine other pathways that could potentially deliver greater levels of mitigation. So what more could be done to reduce emissions beyond the measures envisaged in our scenarios? A number of additional options are possible. First, it might be argued that some of the options included in our BEA and SDA scenarios could be deployed more fully. For example, vehicle electrification could perhaps go beyond the levels included in our two policy scenarios. However, given its likely high costs, the developing world's burgeoning middle classes may not be able to afford the technology in the coming four decades; and these are precisely the people who will be causing the biggest expansion in road transportation in that period. Second, some have argued that solar energy could be deployed more extensively, particularly if its capital costs continue to decline. However, it may be hard to find a market for ever increasing supplies of intermittent renewable power unless smart grids emerge. In our BEA and SDA scenarios, the CO_2 emissions from the energy sector that remain by 2050 are concentrated in a few key areas (see figure 2.24). These are: uncaptured CO_2 emissions from coal and natural gas used in CCS plants; emissions from natural gas used in CHP systems; emissions from the remaining use of oil in the transportation sector (especially cars, aircraft and ships) and fossil fuel use in various industries. While electricity systems can be envisaged that fully eliminate fossil fuels, it would be harder to eliminate their use from transportation and industry.

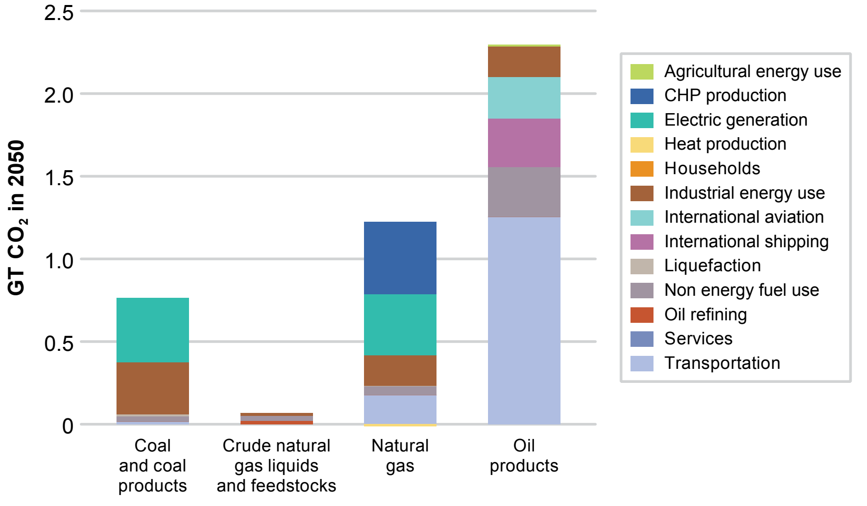

Figure 2.24: Remaining CO_2 emissions in gigatonnes of CO_2 in 2050, by fuel and sector under the BEA and SDA scenarios

In the latter decades of the century it is also possible that many new low carbon technologies will emerge. It is hard to foresee what shape such new technologies will take, but possibilities include new types of "green" cement that absorb carbon (Pearce 2002), and hydrogen fuels derived from a further expansion of renewable electricity generating technologies. We have not considered such technologies in our scenarios because they are far from commercialization. However, they do present the potential for significant levels of net CO_2 sequestration in the latter decades of this century, a possibility that provides some comfort given the extreme challenges involved in meeting climate protection goals by 2050.

2.10 Conclusions

Our main conclusion is that it is likely to be extremely challenging to achieve the climate change mitigation objective of the BEA and SDA scenarios. Because action at the scale required to keep global average temperature rises to within 2°C has been delayed so long, the window of opportunity for achieving the 2°C target is now almost closed.[15] With a huge level of effort, we find that the world could potentially achieve levels of mitigation compatible with providing a 60% chance of meeting the 2°C goal. However, achieving the emissions reductions implied by a 67% probability now appears impossible.

While energy intensities (final energy use per USD of GDP) have fallen dramatically over the past 20 years and are expected to continue to decline by about 28% on average

15 See also IEA (2011a).

in the coming four decades, it will require further dramatic improvements in energy intensities to achieve the goals of our two policy scenarios. Our SDA scenario implies that energy intensities need to decline at a rate of 2.8% per year, so that by 2050 they are only 32% of their 2010 values.

One of the key strategies for efficiency is electrification coupled with a transition to low carbon supply. The BEA and SDA scenarios thus entail large increases in the demand for electricity even as total energy demands are decreased. To meet such demands while staying within our CO_2 budget implies that conventional fossil fuel generating technologies will need to be virtually phased out well before 2050. By 2050, the only remaining fossil fuel technologies used for electricity generation are CCS-based systems. Given that CCS technology is still far from commercialization, its market penetration is likely to be limited by 2050. Nevertheless, our two policy scenarios assume an ambitious implementation of this technology. Nuclear power is also assumed to expand in some regions.

The remaining electricity demand is met by a huge scale-up of renewable energy sources (wind, solar, geothermal and in some regions additional hydro). There does appear to be sufficient renewable energy potential to meet the needs of such a scale-up (as shown in table 2.4). However, because of the intermittent nature of wind and solar power, the need for generating capacity would grow even more rapidly than the demand for electrical energy. For example, our BEA scenario implies that globally as much as 8,900 GW of wind energy would be required by 2050. Reaching such a figure would require the building of 248 GW per year on average between 2015 and 2050, 25 times the recent global build rate of about 10 GW per year. Whether such rates are plausible can be debated. Chapters 3 and 4 discuss what measures are needed to move faster in this direction.

Still, the needed energy intensity reductions will be extremely hard to achieve by technical efficiency measures alone. Additional measures, which would initially be most relevant in richer nations and address overall levels of consumption, are also likely to be needed. Such measures include better urban planning, reduced growth in transportation, healthier diets, and smaller and more efficient housing. Examples of measures are discussed under the efficiency and lifestyle pathways in chapter 3.

The SDA scenario explores a future in which global economic growth provides more significant levels of development in the poorest regions. Even allowing for the increase in energy demand that will result from the increased income in these regions, we find that the SDA scenario has minimal additional impacts on overall energy consumption and CO_2 emissions compared to the BEA scenario. Final energy demand increases by 33.5 EJ in 2050 compared to the BEA's total energy demand of 295.5 EJ, an increase of 11%, but the total CO_2 emissions increase is insignificant due to the additional decarbonization that occurs up to 2050 in both scenarios.

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3 BARRIERS AND DRIVERS OF TRANSFORMATION

Key messages

- Socio-technical regimes shape and constrain the transformation of energy systems. A range of interrelated factors perpetuates these regimes, including cost structures, institutional rules, social and political relationships and routines, cultural practice and habit. Transformation efforts must engage with these factors to succeed. Persistence and long-term commitment are essential, not least because vested interests and incumbents can be expected to resist transformation.
- Deployment of even shelf-ready energy technologies involves practical problems, and many of these problems need to be solved locally, where people live and work. This is especially the case when transformation requires that people change their behaviour.
- Transformation efforts at the local scale are often relatively mature, but face difficulties scaling up to the national and international levels. There is a clear need for international coordination of technology development in order to facilitate the embrace of clean energy and improved efficiency at the national level and beyond.
- Innovative new business models and social engagement are addressing barriers. Such innovations include: micro-finance for energy access; a re-emphasis on community and social linkages in commercial transactions; and distributed generation and changed practices. However, more is needed to drive transformation.
- The state must take an active role in driving energy transformation. Governments need to create policy frameworks, provide additional capital, do more public procurement, and support innovations through "the valley of death". Private capital is equally crucial but will not generate enough traction on its own.

3.1 Introduction

The scenarios in chapter 2 demonstrate that to meet global energy challenges, energy supply and demand must be fundamentally transformed. In this chapter, our concern is how such a process might unfold. It looks at both barriers to and opportunities for transformation, and what they tell us about current and future governance challenges. We examine 20 cases of systems change that span different geographic regions, different scales ranging from local to regional, and different types of energy system characteristics. These cases are analysed within the framework of three principal transformation pathways:

- Energy access (cases 1–7)
- Renewable[16] energy (cases 8–15)
- Energy efficiency and lifestyle change (16–20)

These pathways overlap with the three objectives of the United Nations Sustainable Energy for All initiative, which by 2030 aim to: ensure universal access to modern energy services; double the share of renewable energy in the global energy mix; and double the global rate of improvement in energy efficiency.

Each case represents a significant socio-technical systems change process, and like the scenarios in chapter 2, each is centred on the use of commercially available technologies and practices. We have selected cases where there are significant activities and experiences to learn from. Some of the cases are mainly niche developments, whereas others are gathering momentum to scale-up. Collectively, they provide a map of the drivers of and barriers to transformation, and depict a number of typical challenges for systems change. They also point to key junctures where governments and/or other actors can intervene to facilitate transformation.

3.1.1 Analytical framework

Using a socio-technical systems perspective, we look at energy systems as: "highly interrelated institutional, technological and cognitive structures characterised by established products and production technologies, supporting infrastructures, stocks of knowledge, engineering and user practices, social relations and networks, norms, institutions and regulations".[17] This definition emphasizes the mutually reinforcing soft and hard factors which shape (if not determine) trajectories of social and technological change, and impose barriers to innovation and transformation.

Transformation in this light can be understood as the evolution of a socio-technical system over time, but with fundamental changes in technologies or social practices that give the transformed system different characteristics to its predecessor. Such changes are typically a response to endogenous and/or exogenous forces (including emerging problems and new solutions) that destabilize established systems and also contribute to the scaling up and institutionalization of a new system.

We examine transformations in the case studies through two linked analytical lenses.

16 Although non-renewable low-carbon options such as nuclear and carbon capture and storage (CCS) are part of our scenarios, we have for reasons of delimitation of effort not included them in the case study selection.

17 See Frantzeskaki (2011) for an account of various definitions in the literature.

The first is the multi-phase "S-curve", most commonly employed to analyse technology systems change and market penetration for products or technologies.[18] This approach has a long history in sociology, technology studies and evolutionary economics (Rogers 1962), and is currently attracting interest from policy analysts in the energy sector (IEA 2011b). We distinguish four stages of development: inception (also called formation), take-off, acceleration, and stabilization (also called consolidation). When plotted on a graph, these stages represent an "S" shape.

It is important to note that the S-curve represents processes of socio-technical change in aggregate. However, sub-processes may move at different speeds, be driven by their own particular logic, and yet be interconnected and influenced by one another. This goes a long way toward explaining why so often technology is ready long before the social innovation is able to gain traction. And while socio-technical transformations may generate important new opportunities for entrepreneurial actors, they may also signal the end of the line for some established interests. These transformations are therefore met by established interests sometimes with reluctance, and sometimes with active opposition.

The second lens is the multi-level perspective, which examines the structure of and interactions between niches, socio-technical regimes and external ("landscape") drivers. Niches, at the micro level, are new technologies or socio-technical practices which emerge and develop in relative isolation from the selection pressures of normal markets or regimes. Socio-technical regimes are characterized by a high level of stability and interrelatedness. They are reinforced by institutional, technological and cognitive structures, which include user practices, social relations and networks. Socio-technical regimes shape, if not determine, trajectories of social and technological development (Grin et al. 2010).

From a multilevel perspective, system transitions depend on the destabilization of established regimes, followed by the institutionalization of new (and hopefully more sustainable) regimes. Destabilization can be generated from the same "level" through emulation of new practices (often referred to as diffusion), where practices identified as desirable and beneficial are adopted across niches or regimes, or it may originate from another level. Many socio-technical transformation processes are "organic" and destabilize from below; that is, they are initially niche-level developments that catch on and gain momentum to profoundly influence institutionalized practice.

To sum up, the multi-phase perspective allows us to account for the sequence and timeline (from the past into the future of the transformation) of key change dynamics, as well as the sequence and timeline of policy and governance. The multi-level perspective complements the phases by allowing us to account for how niches of transformation relate to existing vested interests and institutions, as well as external drivers, and to understand how governance can help to deal with these relations.

18 However, the S-curve has been used and popularized in many contexts, for instance, to explain the spread of ideas, fashion items, viruses and other things or phenomena that diffuse through contact and experience

3.2 Energy access

3.2.1 Introduction: pathways to clean energy access

Our basic energy access (BEA) and shared development agenda (SDA) scenarios project two different levels of energy access for the world's poor regions. The SDA scenario presents ambitions for energy access compatible with more robust economic growth. For example, in th regions of sub-Saharan Africa, overall energy use in households by 2050 in the SDA scenario is almost double that expected under the BEA scenario, reaching levels roughly comparable to those in the EU or U.S. with significant efficiency improvements. Indeed, access to energy lies at the heart of many of the important advances of development, from labour-saving devices to a safer and more secure built environment, the ability to transport ourselves for work or pleasure, improved education, greater equality between women and men, lower child mortality, better health and longer life expectancy. It should come as no surprise, therefore, that if energy fundamentally enables a higher quality of life, lack of access to basic energy services is the source of a host of problems.

The most widely cited data on energy access indicates that roughly 1.3 billion people lack access to electricity (IEA 2011a), while nearly a billion more only have access to electricity grids that are unreliable. Close to 3 billion people burn scrap wood, animal dung or other traditional biomass in inefficient stoves or furnaces to meet their cooking and heating needs. Similarly, lanterns that burn kerosene or oil are widely used to extend the useable hours of the day. The indoor pollution caused by this inefficient burning of biomass or fossil fuel in poorly ventilated spaces is one of the top five overall health hazards for individuals in developing countries. Women and children are most affected by this exposure to smoke, soot and chemical residues, and the World Health Organization estimates that each year it accounts for over two million premature deaths. This is double the number of annual deaths from malaria.

The lack of access to modern energy has other consequences as well. Health, education and community services are hamstrung because these kinds of services themselves typically require some level of energy, while the time demands of basic maintenance tasks such as gathering fuel, retrieving water and cooking leave little room for other activities. All but the most rudimentary medical services require electricity, while community services such as education are more effectively carried out where adequate lighting permits evening classes and home study, where buildings are equipped with heating or cooling and where there is access to educational media and modern information technology. Even the freeing up of time from mundane survival tasks such as gathering fuel is an important contribution, and affects especially children and women, since such tasks often fall disproportionately upon them (UNDP 2011).

It is now well recognized that limited energy access not only poses serious social and health problems at the household level, but also adversely impacts local economic development and the environment. Neither of these connections is entirely straightforward, however. In general, energy use increases the output for a given amount of human effort, as in agriculture or manufacturing. However, as case study 3 on cook stove use in Zambia highlights, there are also economic relationships involved in the production of inefficient stoves. Case study 1 on household lighting in India illustrates similar relationships with lighting; there is an entire supply chain involved in the use of kerosene lanterns, and people's livelihoods can be disrupted when people stop using these lanterns. As is shown in several of the cases in this chapter, the fact that some actors stand to lose when old technologies are abandoned contributes to the "stickiness" of established technologies and practices.

Environmental problems related to energy access also represent a complex picture. While achieving energy access for all does entail a small increase in GHG emissions, there are many potentially positive trade-offs, although these can be difficult to properly estimate. For example, harvesting biomass for fuel can lead to deforestation, as shown in the Zambia cook-stove study. Inefficiently burned biomass and fossil fuels produce black carbon[19] and other environmental pollutants. Current estimates suggest that use of solid biomass fuels for cooking and heating is responsible for 25% of global black carbon emissions (Rehman et al. 2011). In South Asia, emissions from domestic use of biofuels for cooking (wood, crop residue, dung) are the largest source of atmospheric black carbon concentrations.

The twin focus on environment and development in the sustainable development debate has put energy access at its centre. But it has done so in a way that means increasing access to energy entails not only an increase in overall consumption, but also a shift to cleaner fuels and technologies. While this poses a significant challenge for both the technical and investment capacities of developing countries, the emphasis on clean fuels and technologies also offers an opportunity to leapfrog the development path followed by the wealthy countries, thus avoiding the negative consequences of the energy transition paths.

Cooking

Of all human activities that require energy, cooking is one of the most basic and is enmeshed in a broad range of social and cultural practices. Traditional cooking stoves, for example, are embedded in the local economy, in culture and in food habits. Fuels used in such stoves are often acquired outside of the cash economy. Creativity and a wide menu of options are required to overcome this entanglement of traditional stoves in daily life, and to facilitate transitions to cleaner cooking stoves and fuels. Flexibility is also required in order to break down the problem into its component parts, and to make progress incrementally on multiple fronts. One such strategy is to first move to more efficient use of solid biomass, then look for ways to make the transition to relatively cleaner liquid fuels and eventually to cleaner gas fuels. The transitions related to cooking energy need not be taken in a single leap, but can be taken step-wise and strategically.

19 Black carbon (commonly referred to as "soot") is a fine particulate matter resulting from incomplete combustion of fossil and biomass fuels. As it is one of the strongest absorbers of solar radiation in the atmosphere, black carbon is now recognized as an important short-lived climate forcer.

"Fuel stacking" is another example of such a step-wise process, which involves making multiple options available at the same time. Even households that do have access to liquefied petroleum gas (LPG) might continue to use solid biomass fuels, but may opt to discard the traditional stove in favour of a more efficient design. While LPG-fuelled cooking is significantly less polluting and more energy efficient than use of traditional biomass, forcing a household to choose only between tradition and LPG cooking creates a higher than necessary threshold for change. Therefore transitions from a mix of solid biomass fuels to cleaner liquid gaseous fuels, such as LPG, natural gas (NG), biogas and efficient stoves, can follow a more incremental path. Parallel policies to promote efficient cooking energy options, such as biogas and improved cooking stoves, and renewable liquid fuels such as ethanol, offer a variety of opportunities to navigate the path to cleaner cooking. Diverse types of improvements need to be promoted simultaneously. Single-track strategies have often produced weak results because the transition challenges are multiple and interlinked.

Many transitions offer a cost advantage, with alternatives being less expensive. This is not currently the case with cooking energy transitions, since available alternative technologies or fuels cannot match the negligible investment required for traditional stoves and fuels. Clean cooking transitions are therefore expensive compared to use of traditional stoves and, at least initially, potential users may not see the value of switching. It would seem important, then, to reduce the cost of improved stoves. Two of our case studies (case studies 3 and 5) illustrate the importance of doing so, while also improving specific features such as efficiency (using a fan to force air), as well as making easy credit available for their purchase. For stove users it also appears that entry costs (i.e. buying the stove) and recurrent costs (i.e. the cost of fuel and maintenance) are equally important, a conclusion supported by our case study of overall progress with clean cookstoves in South Asia (case study 4). If cleaner and more efficient cooking methods are to be promoted successfully and on a large scale, it might be necessary (though not sufficient), to provide support to users to overcome at least one of these cost obstacles.

As is noted above, the health benefits alone are sufficient to warrant a major effort to promote cleaner cooking stoves, and indeed such efforts are under way at the global level. However, end-users often trade-off long-term health benefits in favour of immediate cost savings. Concerns about environmental degradation might be felt in some cases, but low-income households are in a poor position to finance the much larger task of "saving the planet". Bringing about a cooking stove transition thus poses a complex mix of significant problems related to technology and social and economic relationships, and even to institutional structure. One size does *not* fit all – making innovation of all sorts (technical, social, economic and policy-based) especially important in developing strategies and options that are tailored to particular circumstances.

Rural electricity access for lighting and beyond

Access to electricity is clearly vital for addressing basic lighting needs as well as productive and modern energy needs. Here, too, breaking down the problem into its component parts can mean that pathways to transition are initially less steep. In the case of lighting, quite substantial improvements can be achieved without the enormous investments required to extend electrical grids, or even the smaller but still substantial investments needed for some of the creative efforts to micro-generate electricity (see case study 7).

The challenge of providing lighting shares many characteristics with that of advancing the use of clean cookstoves. For example, kerosene lanterns and fuel are not only polluting and a threat to health, they are components in local social and economic flows. And as with traditional cookstoves they lack specific design standards. However, the technological, socio-cultural and institutional issues associated with lighting provision are in many ways much simpler. Nevertheless, there are important challenges to overcome. Facilitating a transition to clean lighting entails addressing two key issues: a source of electricity and of low energy lighting.

Decentralized renewable energy options for lighting, such as solar photovoltaic systems, can be feasible both for remote off-grid areas and for areas that have grid access but where supply is unreliable. For instance, solar photovoltaic or any other micro-grid based on renewable energy can meet lighting energy needs during peak hours. The approach has found success in efforts such as the Lighting a Billion Lives initiative.

Case study 1: The Lighting a Billion Lives programme, India

The Energy and Resources Institute (TERI) made a commitment in 2007 to bring a billion people out of darkness using solar lanterns under a programme called Lighting a Billion Lives. The initiative is based on an entrepreneurial model of energy service delivery that seeks to provide high-quality and cost-effective solar lanterns, disseminated through micro-solar enterprises set up in un-electrified or poorly electrified villages. The charging station is operated and managed by a local entrepreneur trained under the initiative, who every evening rents the solar lanterns for an affordable fee to the rural populace. Among other things, the project focuses on creating a renewable energy-based rural distribution network to provide multiple services, including mobile charging stations for purposes other than lighting, such as cooking. The initiative provides illumination that advances education, health and livelihood activities; facilitates creation of new jobs by training villagers to operate and maintain equipment; and replaces the use of polluting kerosene as a lighting fuel. The project technology mimics existing cultural practices. Patterns of social and economic relationships and even the ways the lantern is used remain largely the same, while the lantern itself has been swapped for one that is clean and even provides a higher quality of light.

Smita Rakesh, The Energy and Resources Institute

For energy access in general, a combination of centralized and decentralized approaches is most effective in bringing about a transition to cleaner options. In practical terms, this means combining grid extension, micro-grid and off-grid access. Previously, options other than grid extension have been widely considered inferior, resulting in significant resources in most developing countries being invested in extending grid-based power (Rehman and Kar 2012). For example, through massive investments over the past several years China and Vietnam have successfully demonstrated that it is feasible to extend grids to rural areas. However, centralized grid extension may not be fully feasible for many developing countries because it not only requires massive investments, but also demands excess generating capacity and systems to recover costs.

As with cookstoves, the perfect should not be the enemy of the good. Energy transitions are often best facilitated through a more incremental approach where there is scope to focus on alternatives that can provide interim benefits – both in terms of physical coverage and meaningful energy access. Alternative decentralized options need not only be restricted to remote locations where grid extension may not be viable. Such options may also be feasible for non-remote locations where extending the centralized grid may not be immediately beneficial because there would still be substantial gaps between demand and supply. Because a single institutional model is not likely to manage all the potential obstacles to electrification, a mix of centralized and decentralized approaches is preferable because it is more flexible and adaptable to varied and changing circumstances (AGECC 2010). Such a mix would include large utilities as well as decentralized energy entrepreneurship operating through public and private channels and public-private partnerships.

Because it is increasingly recognized that a combination of decentralized and centralized energy options is key to extending energy access, numerous solar photovoltaic initiatives are being promoted. However, the solar products market needs to overcome a range of obstacles. The off-grid sector in particular needs regulation to assure quality, in part because the user group generally lacks the tools to judge product quality. Given that there has been some market spoilage already, improved and more consistent product quality will be especially important for up-scaling such initiatives. To drive down costs and improve efficiency in the off-grid solar energy sector, it will be vital to develop stringent quality control mechanisms across the entire value chain of product development and dissemination, along with standard operating and monitoring procedures, and continuous research and development (R&D) in product design in collaboration with leading manufacturers and lighting companies.

After-sales service is another very important component of the off-grid renewable energy sector that has been widely overlooked. This will be critical to ensuring the long-term sustainability of any programme.

3.2.2 Barriers and drivers of transformation

Our case studies illustrate that "one size fits all" solutions are likely to lead to dead-ends. Similarly, while the scenarios provide a useful bird's-eye perspective, they lack the kind of nuance required to grapple with and resolve the array of more subtle issues

Case study 2: Solar micro-grids in India

To further extend centralized grid electricity to remote rural areas and to address the increasing demand and supply gap in electrified rural areas, TERI has initiated a strategy to set up solar micro grids that can cater to a segment of households or small enterprises (shops) in a village. The initiative takes into consideration the socio-cultural settings of rural communities, where cohesive social units can join together to manage electricity provision. The micro-grids run on an entrepreneurial model, in which a local entrepreneur invests in the installation of the system and consumers pay for the energy they receive. A subsidy is provided to the entrepreneur, making the operational costs for generating electricity for lighting comparable to using kerosene and diesel. Thus, with some amount of capital subsidy, local entrepreneurs are willing to take this forward, and the users are willing to pay for higher levels of illumination and a cleaner environment. Up-scaling and promoting this endeavour would serve two purposes: i) to provide access to quality lighting in rural areas, and ii) to enhance income for both the entrepreneurs and end-users.

Ibrahim Hafeezur Rehman, The Energy and Resources Institute

that act as barriers to energy transformation. There is not one story, but many stories that represent diverse variations on a more general theme of access to clean(er) modern energy. For some segments of populations, technologies such as solar lanterns offer the most rapid and meaningful initial steps forward. In other areas, innovations such as small-scale PV grids and micro-hydropower are feasible – especially where the necessary level of technical and financial capacity can be reached.

Knowledge and cultural factors

The transition to modern cooking is hampered by a surprisingly complex set of interdependent barriers – apparent in their various forms in our case studies. The traditional *Mabula* charcoal stove used in Zambia (see case study 3) is manufactured by local tinsmiths and is a well-integrated part of the local economy. It is also widely appreciated and valued as an omnipresent cultural object. This illustrates how local economic relationships connected to stove and fuel supply can make such a socio-technical regime highly stable.

Gender and power relationships can also be a stubborn barrier to change. The role of women in the household, including responsibility for gathering fuel and preparing food, can lock the females of the family into roles far away from the cash economy. Where there are few opportunities for a “real” job in the cash economy, there will be little incentive in the household to phase out the cooking-related chores around which many of the daily routines revolve.

Because many poor people lack knowledge of alternative technologies and familiarity with practices connected to them, new devices tend to exist outside of their day-to-day consciousness. As a result, end- users do not demand such devices. In this sense, a lack of knowledge is a barrier to initiating transformation. This is apparent in all case

Case study 3: Cookstoves in urban Zambia

The traditional Mabula stoves in Zambia use charcoal or firewood, and are made from locally available recycled metal. The same stove model is replicated over and over without any innovation in the stove design. Dependence on traditional fuels and stoves remains high for rural populations. Reasons for this include low and irregular incomes, low levels of literacy and low female labour force participation, as well as easy access to traditional biomass. In urban areas, coal remains the preferred option even when electricity is available, a preference largely explained by the much higher price of electricity. A lack of knowledge about the severe health consequences of inhaling the smoke emitted while burning these fuels has also contributed to the rather slow transition away from coal and biomass. There is no apparent urgent desire among Zambians to stop using the Mabula stoves: "We are used to it", many say. Furthermore, the livelihoods of charcoal producers and transporters depend on continued use of the stoves. Producers, transporters and tinsmiths all have a vested interest in current behaviour, and all will be impacted by changes. These people probably have very little power in formal institutions, but the networks that have been developed undoubtedly play some part in reinforcing existing practices.

Aaron Atteridge, SEI

studies on cookstoves, especially urban Zambia, and is especially the case with regard to achieving the most basic level of energy access.

At the most basic level of access, it appears that knowledge for change most often has to be introduced from the outside. However, this requirement runs much deeper than a simple awareness that better alternatives might be available; it extends to the familiarity that comes from using objects in daily routines. Here, innovations that engage well with the user's socio-cultural needs and wants are an essential component in transforming markets. Enough knowledge and experience to be able to imagine a "different reality" is key to triggering change at the level of end use.

Our cases also illustrate the importance of culture, as represented in the commonly held understandings and practices that derive from it. Where clean energy access can be achieved with minimal disturbance of established routines and practices, and the relationships that come with them, there appears to be less resistance, as TERI's efforts with cookstoves and LED lanterns illustrate. In both instances, social practices connected to lanterns or stoves are largely maintained, with only the technological objects swapped.

There are also knowledge-based barriers associated with health issues. However, these are due not so much to a complete lack of awareness as the fact that many unwanted health effects are longer-term considerations. As such, they are seldom the primary drivers of transformation. The poorest end-users make consumer choices primarily to save money, with long-term personal health concerns a secondary consideration.

Economic factors

Compared to cultural barriers, economic obstacles are easy to identify. They may nevertheless be more complex than they initially appear, as in the case study of cookstoves in South Asia (case study 4), where both entry costs and ongoing fuel cost issues need to be addressed for the poorest households. At the household and local level, the case studies on energy access show several different types of economic obstacle:

- Competition between the cash and non-cash economy: low and irregular cash earnings for households create tight competition for items that require cash outlays, particularly when functional alternatives can be found, such as biomass, that do not require cash outlays.

- Entry costs: comparatively high entry costs for stoves, lanterns or other devices bar households from transition, even where recurring costs might be lower. This means that loans subsidies or other creative solutions are needed in order to enable households to switch.

- Disrupted social and economic relationships: since more primitive cookstoves and lanterns are part of the local social and economic exchange, changes have the potential to disrupt these relationships and disadvantage those whose livelihoods depend on them.

Case study 4: Cleaner cookstoves in South Asia

South Asia is today home to over 1.65 billion people, about 75% of whom depend on traditional solid fuels for their home heating and cooking needs. To accelerate a transition way from traditional cooking fuels, several socio-economic barriers have to be addressed, including easy access to biomass and lack of knowledge regarding the severe health consequences from inhaling fumes from burning stoves. However, recent analysis also suggests that two key policy levers, when pursued in tandem, can help increase the adoption of modern cooking fuels and devices among low-income and rural households. These include price support mechanisms such as targeted fuel subsidies for modern fuels, and easy access to affordable credit/capital, such as that provided by microfinance institutes to low-income households for the purchase of stoves or for acquiring LPG connections. Neither of these measures alone is as effective as when they are pursued in combination. This is because for low-income households, both the recurrent costs (associated with shifting to using higher-priced more efficient fuels) and the upfront costs associated with switching to the use of new fuels (stove purchases, deposits and connection fees) are a constraint on their wider adoption.

Shonali Pachauri, International Institute of Applied Systems Analysis

Case study 5: Traditional cooking and regime stability – Project Surya

The Energy and Resources Institute (TERI) undertook an assessment of biomass stoves, and developed and disseminated close to 1,000 improved biomass stoves. Survey work identified the zero or low monetary costs involved in using traditional stoves and biomass to be the primary factor for continuing with the existing regime. The second and third most important were reduction in cooking time and convenience, respectively. Another important factor for regime stability – but not one that shows up in survey work – was the way that current stoves are embedded in existing cultural practices and food habits. (Rehman et al. 2011)

Ibrahim Hafeezur Rehman, The Energy and Resources Institute

Given that end-users are often motivated by a short-term need to save money, a sustainable transformation must be broadly demonstrated to be cost efficient in terms that they can appreciate. Destabilizing an established regime requires low cost and marked improvements in technology, or fuel options which offer tangible and affordable benefits to end users. Although technical efficiency parameters, such as combustion efficiency (an indicator for fuel savings and emissions improvements), are important, they rarely exclusively determine whether an improved cook stove is widely adopted. Rather it is understanding how end users make choices about everyday expenses, such as buying fuel, that will be key to overcoming barriers to introducing new technologies. Extensive survey work in India on the regime stability of cookstoves also identifies affordability as the most important factor in attracting users to a new technology (Rehman et al. 2011).

Policies can also serve to facilitate large-scale stove dissemination. Such policies might include tax incentives for stove manufacture on a large-scale, and loans to end users to purchase stoves. While it is essential to understand and address user preferences and improve the technology, scaling up will depend on cost reductions, which can be achieved through further research and through creative and effective financing schemes or support structures. In this regard it is important to foster public-private partnerships that can help put such schemes in place.

Such partnerships must take into account local entrepreneurship and the local economy, which may already be linked to fuel and stove supply.

It is useful to distinguish between drivers and enablers of transition. The integration of new technology into the local economy operates as a clear driver: where local merchants and entrepreneurs incorporate upgraded stoves or lanterns into their business activity, and where energy surpluses can be sold to the grid to bring more resources into a community, people are engaged in creating new and viable markets and opportunities. The increased local stake can be the difference between a stalled effort and a success. Loans and subsidies to lower the threshold for making the switch to sustainable energy are enablers, because they reduce or remove obstacles. Private sector finance will be necessary to secure the larger financial packages needed to scale-up projects, as is

Case study 6: Energy for All Partnership

In 2009, some 675 million people in Asia had no access to electricity, and 1.9 billion people were dependent on fuels such as wood, charcoal and rubbish. With the goal of providing 100 million people with energy access through financially sustainable solutions beyond grant funding, the Energy for All Partnership was launched in 2007 to bring together governments, the private sector and civil society to share and provide knowledge and linkages, build capacity, and generate projects that provide sustainable business solutions for the poor. Inclusion of the private sector is essential, yet also a major challenge. The partnership is therefore working with many small and medium-sized companies that have reached the poor by making social aims a priority. Supporting social enterprises in setting up businesses in rural and remote areas not only services the poor but also establishes a market for the long-term provision of energy services. The Asian Development Bank invested USD 1.8 billion in energy access between 2008 and 2010, which resulted in more than 2.2 million households getting improved access to energy for lighting, heating and cooking.

Asian Development Bank

seen in the case study by the Asian Development Bank (case study 6, below). Larger projects carry an inherent risk, which can be reduced if there is a clear ownership structure. The case of micro-hydropower in Indonesia illustrates how the willingness of relatively low-income communities to engage can help to overcome a financial barrier when return on investment is largely assured, through, for example, the ability to sell surpluses to the grid.

Institutional factors

Most of the cases examined above are at or near the take-off phase. Many of these efforts have been under way for quite some time, but it is the recognition of important non-technological factors that appears to be positioning several of them for replication or scaling up. Poor infrastructure ranks among the largest institutional factors that impair or facilitate clean energy transitions. For example, the technical barrier posed by the absence of the grid in many areas obviously sets a much higher threshold for making clean energy available, particularly in poor rural areas where infrastructure is generally weak, if not largely absent. Another barrier in the short run is unreliable access to electricity, caused by weak infrastructure or insufficient generating capacity. The institutional innovation that appears to be effective in addressing both these barriers is to abandon single strategy centralized approaches. Off-grid solutions that are scalable promise to be more sustainable long-term, based on results from models such as IBEKA (see case study 7) and LBL (see case study 1). Such solutions are not dead ends or temporary fixes. They are instead likely to be either complements of future systems such as grids (in the higher income scenario) or integrated elements of a more distributed system of electricity generation.

Case study 7: IBEKA – Micro-hydropower

IBEKA (People Centered Economic and Business Institute) is an Indonesian NGO that has pioneered projects to unlock the potential of rural energy by prioritizing local resources and community ownership. Communities enter into joint ventures with a private company, and own and operate micro-hydropower plants that sell power to the national grid. The profits result in grid connection for poor families, health clinics, education for disadvantaged children, and seed money for productive uses. The community-based cooperatives play a special role in bringing electricity to those regions that have been perceived as unprofitable. IBEKA occupies a niche by helping international donors to invest in communities and by innovating a unique profit-sharing strategy. The project has expanded to 55 sites throughout Indonesia, connecting a total of more than 20,000 households that previously relied on diesel and kerosene for energy. IBEKA has begun to implement a global vision for scaling up. So far, expansion plans for Fiji, Rwanda, Cameroon, Tanzania, South Sudan and Tanzania are at various stages of preparation.

Davida Wood, WRI

A key governance element that has ensured the success of IBEKA's experiment in Indonesia is a legislative framework enabling private sector participation, supported by regulation to sell renewable energy to the grid to ensure a return on investment. International donor support and the waving of duties on imported equipment further incentivized successful implementation of the initiative. Disincentives include fossil fuel subsidies and regulations that make it difficult to sell to the grid. As long as polluting fuels are substantially cheaper than clean ones, as is often the case with coal (used in cities), consumers will find it difficult to resist the temptation to opt for the most tangibly low-cost option, despite the health, environmental and efficiency benefits of alternatives. As is noted above, the various supply chains that provide polluting energy represent a set of institutionalized relationships that may for understandable reasons resist transitions to clean energy. On the other hand, such resistance can be flipped to support if the actors in these supply chains can be engaged in selling and supplying the new technologies. Similarly, off-grid and on-grid actors may perceive themselves as competitors. Shifting focus to potential convergence scenarios will help find ways to meet development goals without locking us into fossil systems.

3.2.3 Implications

Transformations to improved energy access in developing countries are non-linear and are influenced by a range of factors. These include whether clean energy sources are available, how reliable the devices are that use such sources, whether it is affordable to move from polluting to cleaner technologies and how effectively clean energy can be integrated into existing cultural practice. For example, once electricity is made available there is typically a rapid shift to using it for lighting, which eventually spills over into other uses. However, if the electricity supply proves unreliable, people will hedge their bets and the transition will be only partial.

Furthermore, even if income increases slightly and better options are available, people often still prefer to continue to use “free” biomass in traditional stoves. It is only after there is a substantial increase in income and more options such as LPG are available that a complete transition to cleaner cooking takes place. To bring about these conditions requires an enabling environment consisting of a suite of technology choices, financial mechanisms, business models, and institutional and human capacities.

The fact that it is largely locally based initiatives that appear to be near or in the take-off phase argues that the target of governance should be to replicate key characteristics in other initiatives: sharing of information and experience at the community-level, fine-tuning particular models of clean energy access that are easily adaptable to local conditions and engaging diverse groupings of local actors in goal setting, planning and executing those plans.

While the engagement of local community members and public officials can generate powerful momentum, such action can be far more effective in a responsive regulatory and investment environment. To this end, it would be appropriate to closely examine national regulations that might influence community-based projects’ prospects of success with an eye to removing legal and regulatory obstacles and, where appropriate, replacing them with support. Straightforward examples of such action include: reducing or eliminating financial subsidies that lower the price of fossil fuels; providing technical and financial assistance to commercial actors that wish to shift their business activities towards sustainable energy production; requiring grid operators to allow distributed generation and to charge fair prices for the energy produced; and setting quality standards for the manufacture and sale of new or more advanced technologies.

Finally, energy access for all is fundamentally a public good that will be achieved to a large extent through infrastructure improvements financed with public resources. Markets can be appropriate for elements of this infrastructure, but many of these markets do not yet exist, and betting on them entails a level of uncertainty that many enterprises find unpalatable or unacceptable. This suggests that collaboration between public and private funding sources will be essential, through matching funds and loan guarantees, and by coupling potential investors with promising projects and channelling international investments in ways that maximize benefit.

3.3 Renewable energy

3.3.1 Introduction: energy production and system transition pathways

The second transformation pathway is the expansion of renewable energy technologies and supporting infrastructures. Our scenarios show the need for a massive global roll-out of these supply options. Renewables currently contribute around 17% of world total primary energy use, predominantly from traditional biomass and hydropower. Under the SDA scenario, this would increase to 30% by 2030 and 56% by 2050. For the power sector specifically, which represents 41% of energy-related CO_2 emissions, renewables represent around 20% today (most of it hydropower). Under the SDA scenario, the share of renewables in electricity production rises to 48% by 2030, and to 70% by 2050.

Trends in wind and solar power in many of the world's regions show that these technologies are in an acceleration phase. Rapid growth is required in both the BEA and SDA scenarios, with power generated from wind and solar power in the range of 13–16,000 TWh per year by 2050. Wind power has taken off significantly in the last decade, increasing from 24 GW of global capacity in 2001 to almost 197 GW in 2010 (Vos 2012). The IEA envisages that there could be as much as 2,000 GW of installed capacity by 2050 (IEA 2010a, p.519). The leading countries in absolute terms include the U.S., China, Spain, and Germany. Germany and Spain also lead in percentage terms, along with Ireland, Portugal and Denmark, with rates between 10 and 20% of total power production in their respective countries (IEA 2009). Nevertheless, the steps taken are small in relation to the challenge ahead. For example, case study 13 on wind power in China shows that, with the largest installed wind capacity in the world today, the country's wind power industry has developed very rapidly over the past five years, with installed capacity increasing from 1.3 GW in 2005 to 42 GW in 2010. China now has the largest installed wind capacity in the world, with a 64% increase in 2010. Yet in 2010, its wind power represented only 1% of total installed power generation capacity.

Turning to solar, the IEA envisages that photovoltaics could constitute 11% of global installed capacity by 2050, equaling 5,000 GW and generating close to 4,500 TWh per year. Case studies 11 and 14 focus on solar PV developments in the EU and China.

Another major growth area is bioenergy. The term bioenergy includes both biofuels (i.e. liquid and gaseous fuels from organic matter) and solid fuels from biomass (e.g. wood chips). Biofuels are primarily used for cooking and propelling vehicles, but also for some industrial purposes. In cooking, biofuels typically substitute for traditional cooking fuels and in transport they replace fossil fuels, in particular petrol and diesel. The first generation of biofuels for transport has developed into a truly global market, with major producers in the U.S. and Brazil. While transport represents 23% of energy-related CO_2 emissions, renewables (in the form of biofuels) account for only around 3% of total road transport energy globally (IEA 2011c). Certain countries have taken a lead, with for instance Brazil meeting 21% of its road transport fuel demand with biofuels in 2008.

Bioenergy is a major part of meeting the climate change challenge. At the same time, many see it as potentially generating much needed export business and added value in the bioresource sector. This is an opportunity for those parts of the developing world with vast areas of unexploited land and where population density is low. It also promises greater independence from increasingly expensive and insecure oil imports. The dual benefit for exports and energy security becomes particularly important if locally adapted crops can be deployed, and value chains, including biorefineries, can be developed in-country. Under these conditions, bioenergy could be a key element in more robust and sustainable economic development, particularly in Africa (Juma 2011).

Indeed, the most potential for expansion lies in Africa and Latin America. Several African nations, including Mali, Tanzania, Kenya, Mozambique and Zambia plan to expand biofuels production in the coming years. In these countries, the potential for expansion is linked to low yields and vast areas of virtually unused terrain. In Latin America, potential is linked to areas that are currently fallow or used as pastureland. For example, from 2008 to 2017 Brazil plans to almost double the area that it devotes to the production of sugar cane to around 8 Mha, and half of the sugarcane produced will be converted into biofuels. Potential has also been identified in Eastern Europe, whereas in Asia, rapidly growing populations and greater competition for land mean that there is less potential for bioenergy expansion. Growth is expected, however, in China, Thailand and Indonesia (IEA 2011b). The global demand for bioenergy is potentially very large. However, the potential for bioenergy is contested, mainly because available land and water are limited and because biofuel crops can potentially compete with food crops for land. While some estimates suggest that biofuels can supply around 250–500 EJ per year globally, recent estimates from PBL, the Netherlands Environmental Assessment Agency, propose that a more realistic potential, taking into account food security, water availability and land use constraints, is no more than 100 EJ per year (PBL 2012; see chapter 2). Currently bioenergy accounts for around 50 EJ of energy per year.

In our BEA scenario, biomass energy represents 93 EJ per year; in the SDA scenario this grows to 110 EJ. This can be compared with the IEA's roadmap of 65 EJ of biofuel feedstock plus 80 EJ of biomass for combined heat and power. Our three case studies on bioenergy (8, 10 and 12) report different experiences and approaches to bioenergy development.

Finally, modern hydroelectric power is a mature technology. It currently represents 16% of global electricity production. The IEA estimates that the world's total technically feasible potential for hydropower generation is 14,000 TWh/year, of which about 8,000 TWh/year is currently considered economically feasible for development (IEA 2010d). Hydropower potential is unevenly distributed among regions and countries, with the greatest potential in the U.S., China, Brazil, Russia and Canada, followed by Democratic Republic of Congo (DRC), India, Indonesia, Peru and Tajikistan. Barriers and opportunities for new hydropower development are examined in case study 7 on micro-hydropower in Indonesia, and case study 9 on large-scale hydropower in Southern Africa.

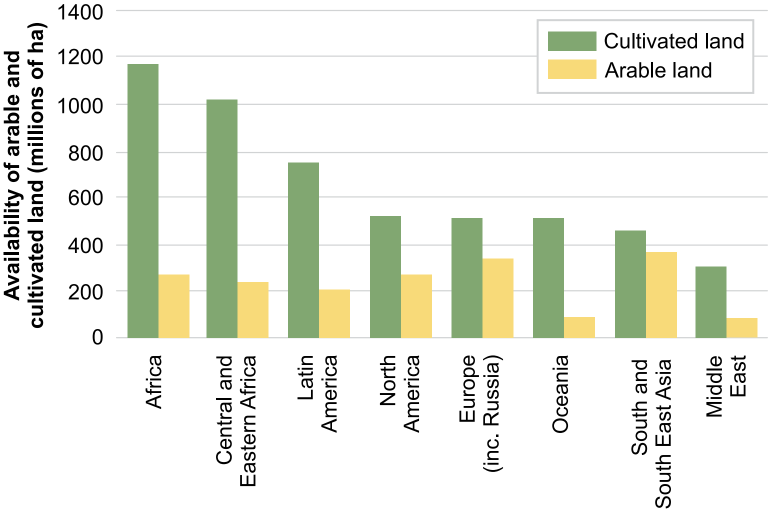

Figure 3.1: Availability of arable and cultivated land by region (millions of hectares)

Source: Mo Ibrahim Foundation (2011)

To accommodate growth in renewable energy, electricity demand and energy access, it will be necessary to invest in and upgrade transmission lines and grids worldwide. However, the challenges differ by region. In the low growth regions such as North America and Europe, infrastructure is ageing and there are gaps in high voltage transmission capacity. For instance, the EU is prioritizing offshore grids in the North

Case study 8: Bioenergy value chain in Mali

Mali is a landlocked country in sub-Saharan Africa that relies on oil imports to meet most of its energy needs. In 2009, the National Biofuels Development Agency (ANADEB) was established to elaborate, steer and implement Mali's biofuels strategy. The agency intends to stimulate the private sector by using economic incentives such as exemptions from import and duty taxes on equipment for biofuel production, and VAT exemption for biofuels companies for up to five years. As the biofuels sector is in its infancy, careful management and planning are needed to alleviate a number of barriers that could hinder the development process. While jatropha oil and ethanol have been produced and used locally for soap production, among other things, shifting towards using them as sources of energy will require a significant increase in production and the set up of appropriate local/national processing facilities and output markets to absorb production. Furthermore, bioenergy production requires knowledge of processes and of technologies, both of which need to be transferred to and adopted by the producers. Therefore, large and robust private investments for infrastructure development are needed, as well as public institutions to further coordinate actions and elaborate cohesive policies.

Mohamed Sokona, Mali Folk Center

Case study 9: Hydropower in Africa

The hydro potential of Africa is vast, and only 7% of the potential is currently developed. Some countries have already embarked on strategies to massively upscale their hydropower to widen access to modern energy, boost investment and revenue streams, and feed into regional power pools (interconnections). Ethiopia and the Democratic Republic of Congo (DRC) are two interesting cases where massive projects are currently under construction or in the early stages of implementation. In both countries, while development remains the principal driver for the pursuit of such energy strategies, the on-going international discussion on climate change has provided further justification for them. Until recently hydropower was considered to be a "sunset" technology due to its association with negative social and environmental impacts. This has led a growing number of "donor" countries with a strong hydropower tradition and corporate actors to declare their support for such initiatives. However, challenges remain. These include: 1) a lack of capacity to plan, develop and implement such complex engineering projects and reliance on external technical support; 2) finance and the long payback period; 3) social and environmental impacts, including transboundary impacts; and 4) potential trade-offs between electricity for export and the development need to widen energy access to rural areas.

Yacob Mulugetta, African Climate Policy Centre

Sea; interconnections to Central Europe; and interconnections in South Western Europe to accommodate wind, hydro and solar power, in particular between the Iberian Peninsula and France. The EU also plans to improve grid connectivity to make best use of renewable energy sources in Northern African, especially solar.

3.3.2 Barriers and drivers of transformation

Knowledge factors

Lack of knowledge and of knowledge sharing are barriers that are most strongly manifested in early stage technologies. Knowledge gaps are often of a very practical kind, as is illustrated by case study 10 on ethanol micro-distilleries and case study 11 on solar PV in Europe. This is because practitioners and industries need to gain experience in the design, installation, maintenance and operation of new systems. In the 1980s and 1990s wind power and heat pumps, which have now reached market maturity, experienced serious problems in the first generation of widespread application. Subsequently, technical guidelines and standardization helped to facilitate the process of system integration for operators, and also for upstream development.

RD&D (research, development & demonstration) and best practice are so far predominantly a national affair. Although international mechanisms for knowledge sharing, such as the IEA, have been useful for learning and exchanging information across the countries of the Organisation for Economic Co-operation and development (OECD) and cooperating countries, there is a great need for a similar mechanism that has global reach. The IEA's latest report on R&D efforts for energy shows that while there was a recent increase in energy RD&D due to stimulus spending, there has been

Case study 10: Ethanol-fuelled cooking stoves in Ethiopia

In Ethiopia, ethanol micro-distilleries (EMDs) have recently been proposed as a way to spread the production of ethanol. The idea is that distributed production will enhance the reliability of supply and distribution for cooking across the country. The most significant challenges associated with introducing and scaling up the EMD programme are: 1) technology transfer will be necessary which is likely to be a costly and bureaucratic process; 2) there is no mechanism for coordination between key ministries and government agencies, making issues such as the pricing of ethanol, international procurement and importation of equipment difficult; and 3) although the government envisages a strong role for the private sector, the Ethiopian economy is highly controlled making it difficult for private actors to operate. Given that the EMD concept is being driven from senior levels within the government, the likelihood is that, over time, the various obstacles will be overcome. For instance, the very large potential market for ethanol as a cooking fuel has attracted much interest from private sector actors. These actors hope that the decentralized EMD model will alleviate the supply bottleneck, which has been the main impediment to developing the stove business

Fiona Lambe, SEI; Hilawe Lakew, Ethio Resource Group

a downward trend in real terms for three decades. Furthermore, the shares of RD&D going to renewables and efficiency measures are small compared to spending on fossil fuels and nuclear power (IEA 2010c).

Technical knowledge plays a central role in national energy planning. Traditionally this knowledge has been generated in relatively closed processes with specific support from analytical models. Case study 15 on integrated planning in South Africa and Thailand shows the importance of enhancing and diversifying the knowledge base by opening up planning to more analytical approaches and perspectives. This may broaden the range of technologies considered during the planning process, as well as ensuring that critical resource constraints, and social and environmental issues are taken into consideration.

Economic factors

Economic barriers and opportunities manifest themselves in different ways throughout the transformation cycle. In the take-off stage and acceleration, lack of markets and experience contribute to high costs. In more mature systems, failing to tackle harmful externalities can distort markets in ways that disadvantage renewable energy technologies.

Economic drivers and barriers look quite different for individual technology subsystems. Mature technologies like hydropower and bioenergy (from biomass) for heat and power production are largely competitive under current market conditions. Also, when placed on-shore, wind power is already competitive in some instances and close to competitive in others. Further cost decreases of 23% are expected by 2050 (IEA 2009). This competitiveness can be further enhanced if carbon costs are internalized for fossil fuels. Although off-shore wind energy is more expensive, it also has potential for more cost decreases (see figure 3.2). Current costs for on-shore wind power are estimated to be USD 70–130 per MWh (with even lower costs possible in beneficial locations), and for off-shore between USD 110–130 per MWh (ibid.). Installed capacity costs for off-shore are more disparate, but it may generate much more electricity due to higher and more stable wind speeds.

While bioenergy for heat and power is a mature and competitive technology, biofuels for transport need to move to the second and third generation to be cost effective. (There are exceptions to this, such as first-generation sugar cane ethanol in Brazil, which is very competitive both in terms of costs and life-cycle GHG emissions.) Although demonstration and pilot plants for next-generation fuels are up and running, today's market only involves first generation biofuels. In the end, experience and rate of learning, as well as long-term oil price developments, will determine the competitiveness of biofuels and therefore what governance measures are needed to support its development. Current trends in oil prices and electricity prices do not suggest significant cost barriers even for first-generation fuels.

For solar PV and concentrated solar power (CSP), high costs are still a major constraint to global adoption. The learning curve will here be crucial here for long-term viability. Costs have come down in recent years, thanks in particular to Chinese manufacturing. Still, to be truly competitive, a further 50% reduction is needed, even though in certain distributed systems solar PV can already be competitive (IPCC 2011). For CSP, the IEA envisages that today's costs – in the range of USD 180–280 per MWh – will come down to USD 50–75 per MWh in 2050, depending on location and solar irradiation. For solar PV, the IEA predicts that by 2050 costs will decrease from USD 240-480 per MWh to USD 45–135 per MWh, depending on sector and location (IEA 2010b).

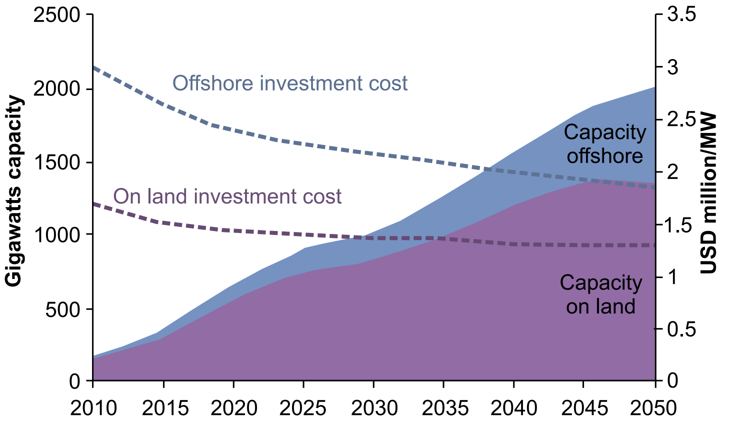

Figure 3.2: Projected cost developments for wind energy capacity
Source: IEA (2009).

Case study 11: Solar photovoltaics in Europe

Solar PV power is one of the fastest growing energy technologies, and markets in Europe constitute around 75% of the global PV demand. In spite of the reduced costs of PV systems achieved historically and in recent years, the technology is still relatively pricey compared to other alternatives. Implementation to date has been entirely dependent on supporting policy frameworks. In the European Union, the main policy measures used at the national level are feed-in tariffs and tradable green certificates. The implementation of such policies has contributed to the development of a solar PV industry across the globe, and many parts of the innovation system for solar PV today are also found outside Europe. However, markets remain largely dependent on supportive policies in Europe, leaving the global solar PV industry vulnerable to political decisions in a few countries. For the technology to continue to develop and the industry to continue to grow, further market development outside Europe is needed. Furthermore, while feed-in tariffs have been highly effective at creating markets for PV, in the long term PV will have to be efficient without subsidies

Annika Varnäs, SEI

Renewable energy technologies are available on the global market, with major cost reductions in wind and solar in particular over the past decade. For the global market, however, rapidly decreasing costs represent a double-edged sword. While lower cost promotes deployment, it can also make for an unstable industry base, undermine material quality, and push out market actors investing in innovation. For instance, the Chinese wind industry is thus far dominated by state-owned enterprises that have drawn criticism for their disinterest in innovation. In the case of solar, European manufacturers have complained that Chinese companies are offering prices below production cost in order to gain market share. On the other hand, some Chinese manufacturers are closely cooperating with European technology institutes to further develop the technologies.

Institutional factors

Institutional barriers often come to the fore in the take-off and acceleration phases, and are related to the structures established around the existing (often fossil fuel-related) regime. These barriers are typically associated with costs connected with fossil fuel investment and the longevity of infrastructure.

Case study 12 on the introduction of biofuels in Brazil illustrates how institutional and cultural factors can become positive drivers of system transformation. There is even evidence of lock-in for some technologies, for instance electric vehicles. A new regime has formed, with mutually dependent actors, technologies and institutions. The successful inclusion of biofuels in the Brazilian fuel structure in recent years was the result of a combination of leverage mechanisms, which acted, simultaneously and comprehensively, in different parts of the ethanol and biodiesel value-chains. The state played a key role in establishing the institutional rules that enabled the development of the biofuels industry. The national ethanol programme, Proalcool, was a major state intervention that included a variety of measures: shaping agricultural and industrial policies towards the goals of the programme; investing public resources in research and development (R&D); regulating and incentivizing the private sector to pursue innovation and invest in ethanol-related activities; and offering incentives to drivers to switch to ethanol-fuelled cars.

Institutional issues also relate to questions about effective implementation, such as technical standards and criteria and market rules. These are critical factors in the acceleration and stabilization phases of energy transitions, and their absence can act as a key barrier. In China, the general reluctance of grid companies to accept wind power into their networks poses a significant problem for the wind industry (see case study 13). While grid companies are required by law to utilize increasing volumes of renewable energy, there are no penalties if this is not done. Without proper incentives – market competition or penalty mechanisms for not complying with regulation – grid operators have very little motivation to expand the services to match the rapid development of generation capacity.

Political factors

Case study 14 on solar PV in China illustrates how political priorities and goals can be key drivers for expanding renewable energy sources. While in 2007 the government aimed for the installation of 1.8 GW of solar PV capacity by 2020, in 2009 this figure was increased tenfold to 20 GW, and has now more than doubled again to 50 GW. China's target is 200 GW by 2020, which is near the maximum estimated potential. Strong national policy goals can help to expand wind power globally.

For a still relatively expensive technology, the political commitment benefits manufacturers that can make long-term investments in equipment and installations.

Case study 12: Biofuels in Brazil

The successful inclusion of biofuels in the Brazilian fuel structure in recent years was the result of a combination of leverage mechanisms that acted simultaneously in different parts of the ethanol and biodiesel value-chains. The Brazilian National Alcohol Programme, Proalcool, was an enormous state intervention, which after several different phases (1975–79, 1979–85, 1985–2003), led to an increase in ethanol production due to direct interventions in various sectors related to the biofuel value chain. The most recent notable rise in ethanol use came in 2003 as a result of increased use of vehicles with flexi-fuel motors. The National Programme for the Production and Use of Biodiesel (PNPB) has since 2008 made it obligatory to add a fixed percentage of biodiesel to mineral diesel in Brazil. Initially launched with a compulsory addition of 2% in volume to diesel oil (B2), the level is currently 5% of volume. In Brazil, ethanol and biodiesel production is based mainly on the sugar cane and soy production chains, respectively. In 2010, sugar cane occupied over 8.6 million hectares of the country's arable areas (half of which is for sugar production, and half for ethanol production) and produced 689 million tons of crop at a productivity rate of around 80 tons per hectare. The soybean crop supplied 84% of the demand for vegetable oil for biodiesel production in 2010.

Roberto Schaeffer, COPPE/FBDS

Case study 13: Wind power development in China

China's wind power industry has grown very rapidly since 2005, and the country now has the largest installed wind capacity in the world – 42 GW in total. Despite this explosive expansion, the share of wind-generated power in China's electricity mix remains low, at only 0.35% of total consumed electricity in 2008. This is partly explained by an underdeveloped transmission grid that cannot facilitate a transfer over the long distances from the production hub to the consumption centres. Furthermore, grid development is under-financed: from 2002 to 2007, state-led investment in wind power generation capacity increased at an average annual rate of 28%, while grid investments rose by only 9%. Because supply naturally fluctuates and is more difficult and expensive to accommodate than electricity from conventional sources, grid companies are generally reluctant to accept it in their networks. Furthermore, to accommodate a connection for wind energy requires additional services, which increase the operational costs and risks for grid companies. The legislation that demands grid companies purchase all electricity output from wind farms lacks teeth, with no penalties for grid companies that do not purchase wind power electricity. To expand the distribution of electricity generated from wind in China, stronger efforts are needed to overcome the institutional reluctance of state-owned grid companies, as well as increased funding to develop smart grids that can accommodate the rapidly increasing generation capacity.

Marie Olsson, SEI

Case study 14: Solar photovoltaics development in China

Chinese energy demand doubled between 2000 and 2010, something which few accurately predicted. Because almost 70% of its electricity comes from coal, diversifying and decarbonizing the energy mix are priorities for the country's leadership. The first national target on renewables in the energy mix was set in 2006. It aims for 15% of the country's energy mix to come from renewables, including nuclear, by 2020. Domestic installations of solar photovoltaic (PV) have so far been limited to the rural areas, and solar constituted only 0.10% of total electricity generation in 2010. The low installation rate is explained by the high installation and production costs, limited capacity for technology development and innovations as well as slow grid installations of large-scale solar parks. To overcome these barriers, two major initiatives have been launched. In 2009, a subsidy scheme and a series of national research support programmes were introduced. In 2011, a national feed-in tariff for solar was set in place. While it is too early to assess the effects of these policy mechanisms, the International Energy Agency estimates that Chinese growth in solar PV will begin to outpace European growth sometime between 2020 and 2035.

Kerstin Geppert, SEI

Although Spain and Germany have been forerunners in expanding solar PV, Asian producers have turned to domestic markets since the drop in European demand in the wake of the financial crisis.

There is normally not a great number of political barriers to renewable energy, but where they do exist, they tend to be closely linked to the interests and position of the prevailing regime, making them quite robust. They are usually most important during the take-off and acceleration stages of a technology, during which resistance from economic or political interests is likely to be strongest. Biofuels are a case in point: when deployment accelerated globally, political resistance emerged from many different groups, including green NGOs, industries and consumer groups, largely because of the negative side-effects of poorly managed bioenergy production. Similarly, local resistance has sometimes been an impediment to grid expansion and to the deployment of wind power – even where green local governments enjoy majorities.

Political capture of energy planning is documented in case study 15 on integrated electricity planning in South Africa and Thailand. Here, opening the process to a broader set of stakeholders than those normally involved in energy planning changed the political dynamic and opened up space for a wider set of solutions, including more renewables in the process.

3.3.3 Implications

For technologies that are in the inception phase, more investment is needed in both R&D and in the development of technical and market standards and rules. The lack of political commitment over the past few decades has led to insufficient financial

Case study 15: Integrated planning in Thailand and South Africa

Civil society organizations in Thailand and South Africa have been pursuing multi-stakeholder strategies to shift the resource mix of national long-term electricity plans, which determine the future investment in power generation in the country over a 15–20 year horizon. In both countries, civil society efforts have been an important factor in increasing the share of renewable energy in the resource mix; in opening the process to public consultation; and in persuading the respective ministries to explain to the public the key assumptions underpinning the plan. So far, energy efficiency as a supply option has not been integrated into Thailand's long-term planning, in spite of analysis demonstrating its potential. Nevertheless, an opportunity exists to link the current national energy efficiency target to the planning process. South Africa's first open long-term planning process took place in 2010, during which renewable energy businesses and civil society organizations succeeded in convincing the planners to disaggregate renewable energy technologies so that the costs and learning curves of each could be more precisely understood. As a result, the percentage of renewable energy included in the long-term electricity plan increased by more than 50%.

Davida Wood, World Resources Institute resources. However, although R&D spending is once again on the rise, IEA (2010c) estimates indicate a short-term peak in 2009 as a result of stimulus packages (which were to some degree used to support energy R&D). Stimulus packages are one-off arrangements, and sustained efforts are needed to maintain knowledge and niche development for new technologies over extended periods.

International RD&D should be accelerated. This would make it easier to deploy new technologies beyond the national scale, lead to long-term cost savings and more rapid learning curves, as well as harmonized technological standards, which brings down implementation costs for operators. Multilateral platforms for technology collaboration that operate both North-South and South-South could be connected to the Green Climate Fund, where parts of climate finance could be effectively deployed.

Governments must mobilize public capital and procurement, and enable more investment and capital from the private sector. According to the U.S. National Science Board (2010), energy firms' RD&D funding is merely 0.23% of their revenue, a dismal figure compared with other technology-heavy sectors such as pharmaceuticals (20%) and information and communications technology (15%). Public procurement is key for early stage technologies such as second generation biofuels, electric vehicles, or solar. Investor confidence is key to enabling the required levels of investment. Through the use of feed-in tariffs, governments can ensure a relatively stable market situation for the years ahead. In Germany, China and Spain, for example, feed-in tariffs have helped spawn major investments and accelerations of deployment.

For technologies further up the transformation path, such as forest biomass or hydropower, more traditional policy instruments are highly relevant and effective. A variety of economic instruments can help induce investment, including tax reductions, investment support and loan guarantees.

Mature technologies that generate public goods need ongoing market adjustment to account for externalities. The playing field can best be levelled by removing fossil fuel subsidies and applying a tax rate that corresponds with the external cost. At the same time, bioenergy and hydropower need to be subject to formal and transparent policy and planning assessment frameworks due to their strong interactions with environmental resources and other economic sectors.

3.4 Energy efficiency and lifestyle change

3.4.1 Introduction: modes of energy use and pathways to reduced energy consumption

Both the SDA and the BEA scenarios require not only a relative de-coupling of growth and energy use, but also an absolute reduction in overall energy use, from roughly 370 EJ in 2010 to between 250–300 EJ in 2050. This will take place in a world where overall demand for energy services will expand in step with increasing economic activity and population growth. Under the SDA scenario overall global energy intensities as measured by energy per unit of GDP need to decrease by 2.8% per year up to 2050.

Technical efficiency improvements are essential for reducing energy consumption, but not sufficient in themselves. The efficiency gains in the BEA and the SDA scenarios are met through both technical efficiency enhancements (such as improving insulation in buildings), and through changes in practices and lifestyles. The so-called rebound effect, in which consumption increases in response to technical efficiency gains, only adds weight to the argument that both technical efficiency and consumption need to be addressed (Greening et al. 2000). Furthermore, changes in technology are frequently linked to changes in practice – at least at the level of end-users. For instance, installations of smart grids and metering raise awareness of wasteful behaviour, providing new incentives and opportunities for behavioural change.

In the short term, most of these improvements will need to occur in OECD countries. Therefore the five case studies in this section are drawn from Europe and North America. The cases engage with the challenges of making these improvements in a variety of ways. While the cases focus on different scales, each of them is anchored in actions at the community level that couple emissions reductions with other goals. The cases highlight just how important it is for engagement, learning, goal-setting and problem-solving processes at the community level to be channelled into implementation. In three of the five cases (16, 17 and 18) it is municipal governments that channel or facilitate community engagement. The other two cases (19 and 20) involve community at another level, in the form of networks of municipalities or of local groups. Either way, it is at the local level that the "rubber meets the road". As a result, local efforts and initiatives are every bit as important as global action for bringing energy use within environmental limits.

The built environment offers important opportunities to increase efficiency, both in the modes and means of transport people use and, more broadly, in the consumption choices people make. While municipalities often have an important influence on energy supply, they exert their most decisive influence on efficiency and consumption, through the design and operation of transport systems, and by regulating the built environment (not least through their own efficiency-related investments). Municipalities also have an indirect influence through both public sector and private consumption that takes place where people live and work. Of these three general categories, local government has the most direct influence over the built environment and transport. Waste and waste management are also to a large degree influenced by local regulation, and waste offers significant potential – not least as a potential source of energy.

Table 3.1 illustrates the numerous areas where significant savings can be achieved, quite often by eliminating or reducing energy waste. Case studies 16 and 20 focus on the built environment, while the other three represent efforts to engage with a mix of transport, built environment, energy supply, consumption and waste management. Of the eight subcategories, consumer goods is the area where local governments are least able to directly influence developments. Some functions, such as dealing with waste, are fairly centralized. Others, such as retrofitting buildings, are highly decentralized. In this section we focus primarily on the general categories of the built environment and transport, but also briefly examine the Transition Town movement's efforts around consumption.

One of the more encouraging aspects of reducing energy consumption is that it also entails substantial cost savings. These areas truly offer "low-hanging fruit", yet goals have proved harder to achieve than the expected savings would lead one to believe. Furthermore, the Electric Power Research Institute argues that the actual energy savings are considerably larger than reductions gained at the point of consumption, since energy not produced and transported is not subject to transmission losses, which can be quite substantial. "While energy efficiency measures have traditionally focused on end-use efficiency, the energy industry is itself the largest user of electricity in the nation; and there may be significant opportunities to realize significant efficiency gains from the Transmission and Distribution system" (EPRI 2009).

Table 3.1: Community-level sectors and areas of activity with potential for reducing energy use

Built environment	Transport	Consumption/ waste	Energy supply
Residential: -new building design -retrofit/renovation -upgrade of heating systems	Personal/ passenger -reduction of travel distances -changes in mode of transport	Consumer goods -food -consumer products -services	Residential/commercial heating and cooling -district heating/cooling -biomass energy -heat pumps and similar technology -low-carbon distributed generation
Commercial: -new building design -retrofit/renovation -upgrade of heating systems	Freight/goods -reduction of travel distances -mode shifts	Waste -recycling -composting -energy production	Transport -Infrastructure for electric vehicles

Case study 16: Energy efficiency in rental accommodation in Alingsås, Sweden

In Sweden, the housing and service sectors represent some 35% of total energy use, with rather few efficiency improvements made since the 1980s. There are exceptions to this, however. In Alingsås, a town of 30,000 people, the municipality and its housing company have successfully reduced energy use per m2 by careful refurbishment focusing on both increased standards of living (especially for older and disabled people) and energy efficiency measures. This has been achieved through a) a constructive local dialogue, b) raising political consciousness and providing support, c) technical competence in passive house design and construction, and d) a successful business plan that includes future costs in relation to various scenarios, including the status quo. The most extraordinary thing about this case is that two discourses that seldom meet – short-term profit-seeking business plans and long-term energy efficiency investments – have been combined successfully. By considering the aging population of the municipality, and what it would cost to house a significant number of tenants when they have reached an age where they need care and adapted homes, the local housing company has internalized the long-term dimension, and found a feasible investment plan that a normal business plan would not have allowed for.

Ylva Norén Bretzler, Gothenburg University

Buildings

Roughly 40% of primary energy consumption in OECD countries is in the built environment(IEA 2010a). The vast majority of that energy is used for heating, much of it in residential buildings. This points to the significant potential for savings through building retrofits such as insulation or more efficient heating systems. However, these savings have proved difficult to harvest. A wide range of technologies is available, but for a variety of reasons (discussed specifically in case study 20 on the built environment in the Netherlands) these are embraced all too slowly. While more stringent energy efficiency requirements for future buildings and vehicles are quite important, they typically have little impact on existing infrastructure, and it is estimated that some 85% of the built environment that will be present in 2030 is already standing today. In just one example of the effect of time lags, the EU is meeting many of its goals related to reducing greenhouse gas emissions, but on track to hit only about half of its 20% goal for energy efficiency. However, legislative plans are being ramped up in response. Preparations for a new European Directive on buildings efficiency are exploring binding commitments for member states to achieve 1.5% annual final energy reductions, with public buildings being renovated at a rate of 3% per year (double the rate today). Properly implemented, such measures can show the way towards achieving the kinds of efficiency improvements outlined in the scenarios.

Transport

Freight and passenger transport produce some 30% of all global greenhouse gas emissions (IEA 2010e). Roughly three-quarters of those emissions come from road transport. Here the potential savings are also substantial, although challenging to properly estimate.

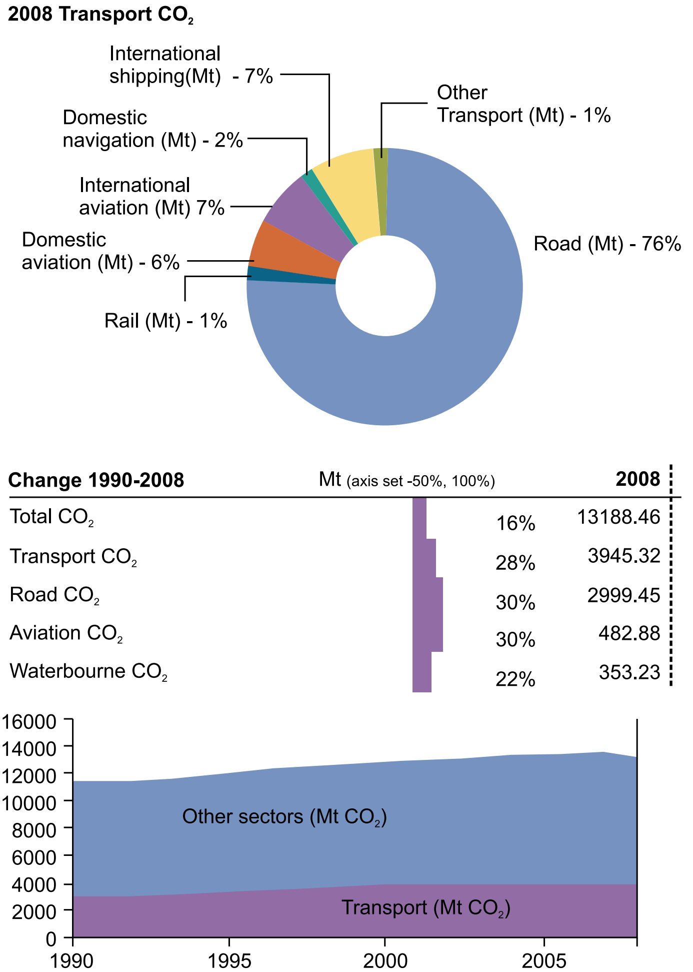

Figure 3.3: CO_2 emissions in megatonnes (Mt) from transport in 2008 (top) and change in CO_2 emissions from transport from 1990 to 2008, compared with other sectors (bottom)

Source: IEA (2010e)

Given transport's large footprint, it is not surprising that the IEA has developed a list of 25 separate recommendations for reducing energy use and emissions in the transport sector (IEA 2010e). As of March of 2009, the IEA found that the implementation of these recommendations by OECD member countries was "poor". Even so, only a small proportion of those recommendations can be meaningfully applied at the local level. Within the "energy paradigm" for transport – ^{E}road transport = (vehicle fuel efficiency) x (vehicle travel) x (the vehicle population) – it is primarily the second parameter – vehicle travel – that is subject to significant influence at the local level. Here one can point to three specific areas where local initiatives and planning offer significant potential:

- *Switching* modes of transport – key elements of the modal shift toward public transport are infrastructure, incentives and disincentives

- *Reducing* distance travelled – planning for more efficient passenger and freight transport, urban planning that reduces the need to travel long distances.

- *Shifting* to vehicles and infrastructure that support low-carbon fuels

Municipalities have significant influence over the first two of these areas, and some over the third (e.g. public transit vehicles that run on renewable fuels). However implementation of the different strategies requires quite different kinds of resources, and the timeframes for implementation vary widely. Measures such as city congestion charges, higher parking fees and pedestrian zones can take comparatively little time to propose, adopt and implement (from two to five years depending on the extent of political opposition, or whether completely new routines need to be established, etc.). However, it might require investment in new infrastructure, such as additional bus or rail lines, to make such measures effective. And re-routing traffic or facilitating a shift of transport modes (i.e. from private vehicles to public transport) may require 5–10 years or more for planning and execution.

Consumption and waste

The high consumption lifestyles that are prevalent in the wealthiest communities globally are increasingly being called into question – not only because heavy consumption draws on limited resources at one end of the pipeline and emits harmful waste at the other, but also because it is increasingly doubtful that, past a certain point, consumption improves quality of life (Schipper et al. 1989). Leaving aside the consumption of luxury goods, and focusing, for example, on our immediate physical environment, it has been noted that "in global terms, the energy cost of maintaining standardized 'comfort' conditions in buildings and in outdoor environments is ultimately unsustainable" (Shove et al. 2008, p.307).

A diverse group of actors is voicing calls for success to be redefined in terms other than what conventional economic measures such as GDP can provide. From philosophy and ethics, people like Peter Singer (2011) now argue for the pursuit "Gross National Happiness". A growing number of economists subscribe to a similar logic, arguing that prosperity does not necessarily require growth and, indeed, circumstances may well require us to redefine "the good life" (Jackson 2009).

The last item in the sequence of consumption is waste – resource use or loss from which little or no benefit is derived. According to EU estimates, annual food waste in the EU27 is in the neighbourhood of 89Mt – roughly 179kg per capita/year. It is of course not only the food that is wasted, but also the energy used in its production, transport and refrigeration, not to mention loss of nutrients and other resources. Current expectations are that EU food waste will rise to near 126 Mt by 2020 in the absence of some new effort (European Commission 2011). Most waste is collected and managed by (or on behalf of) municipalities. At the end of the production-consumption cycle there remains potential energy embedded in waste, particularly organic waste. Efforts to recover or produce energy from waste are increasingly widespread. For example, the City of Seattle is investigating the potential to create energy from waste to make an eventual contribution to the city's zero-net carbon ambitions.

3.4.2 Barriers and drivers of transformation

Knowledge and cultural factors

The Global Energy Assessment and Energy Technology Perspectives studies show efficiency potentials in technological terms (see chapter 2). But, for a variety of reasons, technological advancement does not automatically bring efficiency. There is a considerable body of research on efforts to address knowledge barriers to and create knowledge-based drivers for energy efficiency. Such efforts include labelling programmes, energy auditing and feedback mechanisms, and education about the problems that reducing energy use are intended to help resolve.

One important lesson is that knowledge of even long-established technologies does not disperse without active help, and this is particularly true for newly available technologies. Nor is it sufficient that a few important actors are alert to the potential of particular technologies, since implementing those solutions typically requires multiple actors. As case study 20 on the Netherlands illustrates, knowledge gaps among only a few of the relevant actors are sufficient to drag the process to a standstill.

A second knowledge lesson – apparent in case studies 16 on Alingsås and 18 on Seattle – is that "shelf-ready" technologies must often be adapted to particular circumstances and settings. In Alingsås a number of adaptations were necessary to fit the reasonably low-tech technical solutions to the buildings in question. Such an effort requires both the capacity and the motivation for problem solving. On a much larger scale, Seattle is now pursuing this problem solving process by setting ambitious overall goals, and by breaking down the diverse challenges into smaller problem categories through planning. Many of the practical problems to be resolved will be embedded in the implementation of the various plans.

A third lesson is embodied in the networking processes involved in the Covenant of Mayors network (case study 17) and the Transition Town (TT) movement (case study

Case study 17: Covenant of Mayors (European Union)

The Covenant of Mayors (CoM) was created by the European Commission (EC) in 2007 as part of the European Union's efforts to decrease greenhouse gas emissions. The primary intersection between the CoM and EU climate policy is through the Sustainable Energy Action Plan benchmarks that commit members to reduce their CO2 emissions by at least 20% by 2020. In exchange, CoM municipalities are given access to funding for technical and financial assistance used to support capacity building. Monies for these purposes are provided by the Intelligent Energy – Europe programme and the European Investment Bank and directly support local investments in renewable energy and energy efficiency. They also provide advice and consultation for project financing. Since its launch, the CoM has dramatically expanded its membership from 27 municipalities in 2008, to over 3,000 by the autumn of 2011, making it the largest Trans-Municipal Network (TMN) in Europe. While membership includes metropolises such as London and Rome, the bulk of signatories are small to mid-sized municipalities in Southern Europe. Eastern European participation is notably absent. The CoM also suffers from a noticeable lack of participation by national environmental ministries and governance bodies. Despite these limitations, the lack of progress in international climate negotiations has ensured a continued commitment on the part of the EU. With nearly 150 million people currently living in signatory communities, the CoM presents an important regional model for supporting sub-national actors in accomplishing meaningful policy outcomes.

Andrew Isaac and Gregor Vulturius, SEI

18). Both of these networks seek to fill knowledge gaps and bring about more concrete problem solving processes by learning from the successes and frustrations of others, and by sharing problem solving strategies that can be adapted for local use.

Cultural opportunities and obstacles refer to the "soft" drivers that subtly guide behavior – shared values, meanings and (often unconscious) routine practices. With respect to consumption, they are intertwined with perceptions of what constitutes the "good life", in pursuit of which a variety of consumption activities are carried out. Yet, a growing body of research suggests many of these activities neither produce real satisfaction and happiness, nor help achieve the good life (Jackson 2009). One of the real challenges is that so much of what we refer to as culture moves below the radar of policy-makers and the public alike. If it is the unexamined consumption of comfort, entertainment and consumer goods that has contributed to high energy use, then two related tracks offer promise. The first is to promote reflection about and reconsideration of these activities, an effort that lies at the core of the TT movement. The other is to examine the role of cultural factors in learning and change processes.

One of the more interesting aspects of the TT movement is its mode of collective reflection at the local level. The movement engages in an ongoing critique of quality of life as defined in GDP terms, and focuses on "creation of a space for enabling people to express their 'alternative' green and socially progressive values" (Haxeltine and

Case study 18: Transition Towns

Since the first "transition town" was officially established in 2006 in Totnes, UK, the movement has quickly mushroomed. As of November 2011, a total of 406 communities had officially joined, mostly in Europe, North America and Australia. The TT movement claims to use the opportunities embedded in peak oil and climate change to strengthen communities, promote local entrepreneurship and improve quality of life. The TT model is not without trade-offs, which could involve important unwanted side-effects. Relocalization could easily morph into isolation, and food and energy self-sufficiency might have a negative impact on other locations that are dependent on the exports of foodstuffs. Both supporters and critics have noted that the movement faces important limitations. One critique is that the movement appeals most to communities with strong environmental sympathies, interest in self-sufficiency and non-materialist values. Another is that even in TT communities, it is proving to be no simple matter to reduce the gap between declared intentions and concrete action. On the other hand, if an alternative model can be developed, it is likely to find an easier path in these communities than many other places.

Marcus Carson, SEI

Seyfang 2009; Seyfang and Smith 2007). In many ways an ongoing experiment, the efforts of the TT movement emphasize process, with end goals that are more diffuse and distant. This process, however, does not preclude focused short-term localized goals that are important interim measures of success.

Technologies and practices that engender path dependencies make it difficult for some new approaches to catch on. For example, the short distance that electric cars can travel without battery recharge compared with conventional cars remains an impediment for sales, even where the majority of travel is well within the range of electric vehicles. Another is the difficulty of dislodging practices that are by no means essential or are even subtly destructive to a culture, for instance driving a private vehicle even when public transport is faster and more efficient. Overall, we need to consider how to more effectively capture the energy reductions that can be achieved through lifestyle and consumption changes among wealthy populations. In this regard, cities become hubs of change and transformation.

Broader lessons from various local scale successes relate to change processes more generally. Apart from change being driven by "push" factors, such as the urgency that crisis can generate, it is also facilitated by observation and emulation of practices that appear desirable. A great deal of activity is informed by what we see others doing or believe others are doing, making emulation a potentially powerful factor for transformation (Cialdini 2009, pp.97–138). In this emulation, there are threshold effects that substantially influence when and whether a particular new trend moves from niche activity to widespread practice (Gladwell 2000).

Economic factors

The magnitude of the eventual economic savings that can be derived from efficiency improvements and from energy savings should operate as a powerful driver for both communities and individuals. The most obvious of such improvements is additional insulation in buildings, which entails no quality or convenience reductions and provides a comparatively rapid payback of the investments made.[20] The size of the largely untapped potential benefit suggests two problems. The first is that more detailed knowledge of the cost/benefit equation is required. (It is widely know that more insulation pays off, but arguably few home or building owners are aware of the precise nature of the savings available.) The second is that overcoming economic barriers is largely a question of time frame and the capacity to make up-front investments that generate longer term savings in money and avoided emissions. This points to a) the need for investment capital to overcome the initial threshold effect, and b) the need to find new ways to align or reconcile the splitting of investment and benefit. However, the built environment, transport and general consumption each pose their own particular challenges.

Case study 20 on the built environment in the Netherlands is a striking example of a situation in which the technologies are mature and readily available, but seem to lack the power to take off – at least at the national scale. One apparent gap is the absence of entrepreneurial actors at the national level to drive the process forward. Interest is there, but at every turn the various costs outweigh the incentives to take action to improve energy efficiency. One clear remedy to this inertia is to creatively combine multiple goals to increase the drive to embrace efficiency improvements, and to boost the rate of recovery of investment, thereby contributing to a take-off process. In the case of Alingsås (case study 16), successful confluence involves two key factors: housing stock that is due for renovation, and an aging population that will require physical modifications to their living space. Given that long-term care is a municipal responsibility in Sweden, Alingsås has had the opportunity to weigh the costs of a more extensive retrofitting of apartments against both the costs of institutional long-term care and the long-term benefits of state-of-the art energy efficiency measures. In this instance, the pay-back period is accelerated due to the combination of factors, equipping the investment with more immediate benefits.

Transport offers a different set of challenges and opportunities. The real challenge here is that the energy cost per 100 km travelled does not correspond especially clearly with economic costs. The cost of a private vehicle plus fuel is spread differently to the costs for collective transport, which is almost invariably more energy efficient. Two simple key rules of passenger transport are that greater efficiency is gained by: 1) travelling shorter distances, or 2) travelling with others (unless the distance is short enough to be human energy-driven). These rules apply in a similar manner to the transport of goods. Two of our cases deal directly with transport: Seattle (case study

20 Adding attic and wall insulation to a typical old house in the UK (built between 1940 and 1980) reduces heat loss by around 25%. This translates into a 40% reduction in heating consumption and a comparable reduction in heating costs (MacKay 2009, p.142).

19) and Transition Towns (case study 18). For Seattle, the challenge will be over time to redesign passenger transport to permit shorter average distances and, at the same time, to construct a public transport infrastructure that encourages people to use public modes of transport while making private transport less appealing (using, for example, higher parking costs and congestion charges). Other changes, such as making private vehicles more energy efficient, are mostly tied to measures adopted at a regional or national scale, such as fuel efficiency requirements.

Institutional factors

A diverse array of institutional rules and culturally rooted practices conspire to leave efficiency an unfulfilled promise and to keep consumption on established tracks. Much, but not all, of this is unintentional. In the case of the built environment, tax codes and other regulation may influence investment cycles so that retrofitting with more efficient technologies prior to full depreciation is more costly. Many unreflective practices, such as selecting disposable packaging or leaving appliances in stand-by mode consume energy with little payback in quality-of-life terms. In many instances, formal structure and culture represent opposite sides of a single coin. This is certainly true in the cases mentioned above, where disposable packaging may be the most available or only option, while standby mode is a default feature with many consumer electronic devices.

Efficiency improvements to buildings continue to lag behind the available technical capacity. The established regimes appear to be working against these efficiency improvements, in spite of a variety of efforts to open space for movement in particular elements of those regimes. As in the Netherlands (case study 20), structural features of the market and enterprises that make up much of the construction sector mean that there

Case study 19: A zero-carbon Seattle

Seattle constitutes the urban core and economic engine of a metropolitan area with over 3 million residents. Hydroelectricity has helped the municipally owned electricity utility, Seattle City Light, make Seattle the only major U.S. city with net zero carbon electricity. Despite this unique feature, Seattle's challenges in reducing GHGs are similar to those faced by other cities: providing lower-carbon transportation options, improving building efficiency, and increasing the share of energy needs met by low-carbon energy sources. Seattle met its Kyoto-inspired goal – of reducing emissions 7% below 1990 levels by 2012 – early, in 2008; and this occurred when the population had grown by 16% since 1990, demonstrating that a city can grow substantially while still reducing absolute emissions. Among the factors in the emissions decline are a transition away from oil heat in single-family homes, and the City's electric utility divesting from partial ownership of a coal-fired power plant. Some other sources of emissions have continued to rise, however; notably emissions associated with personal and freight transportation, suggesting the importance of these sources of emissions going forward.

Pete Erickson, Chelsea Chandler, SEI

Case study 20: A sustainable built environment in the Netherlands

About 19% of total annual greenhouse gas emissions in the Netherlands are attributed to the built environment. While there is considerable scope for energy efficiency improvements to the housing stock using readily already available technologies, adoption levels are still low with little sign of increases in the near future. The difficulties in harvesting the technological and economic potential for sustainable energy solutions reveal an apparent paradox: how can it be that technologically available and economically attractive technological options are not applied at a much larger scale?

Three main systemic barriers can be identified that hamper the diffusion of green energy innovations in the Dutch housing sector. First, a number of regulations block the application of innovative technologies, including a fixed minimum standard for energy specifications for new buildings, rather than a maximum, which would drive innovation. Also, there is a strong tendency toward generic regulations in the sector, which leaves little room for innovative experiments. Second, the market for housing is (or was, until the present crisis in the Dutch housing market) highly supply-driven. On the supply side, this leads to a strong strategic focus on economies of scale, which impedes the ability to cater for specific demand and to account for context and flexibility. On the demand side, domination by social housing corporations and large-scale project developments create a strong lack of variation in the market. This in turn limits the scope for diversity in supply options, leading to a "deadlock" in a market of limited diversity in supply and demand. Third, sectoral fragmentation and myopic competition on price (rather than quality improvements) block the supply of integrated energy solutions, as there is only a limited interaction between many sectoral stakeholders.

The scope for public policy is thus more complex than it would be in a more straightforward analysis of market failures. The main policy challenge is to contribute to unlocking structures that inhibit the innovation and the diffusion of energy measures in the housing sector. Such a strategic shift from economies of scale to economies-of-sustainable-scope could also contribute to unlocking the present crisis in the housing market. Since the Dutch regulatory framework is itself also considered to be an important barrier, a first step would be to remove inherent regulatory contradictions and to shift policy scope to innovative front runners.

Albert Faber, PBL (Netherlands Environmental Assessment Agency)

is little interest in adopting practices that increase the time required to carry out the construction tasks, and little time to learn new techniques, especially if they are not in obvious demand. These features, combined with split incentives and initial investment thresholds, drain momentum from the take-up of promising technology or practices. The Netherlands case also indicates that building codes often do not keep up with the pace of technological development, sometimes with the perverse effect that regulations slow rather than speed up adoption of improved materials, methods and designs.

Looking at these and similar difficulties from a local scale, one recent report highlights how "it is clear that 'technology projects' alone will not deliver the benefits"

(Webb et al. 2011). A key reason – more easily seen at the municipal than the national scale – is the fragmentation of the logics and purposes guiding different elements of the regime. Recommendations pointing to the need to "align organizational structures with a vision" and for stronger leadership would seem to border on the cliché, yet our cases illustrate how many obstacles are not entirely obvious, and are nevertheless more easily observed than remedied.

Particular kinds of institutional arrangements appear to be able to facilitate the coherence and leadership needs noted above, as is illustrated in the Alingsås and Seattle cases (case studies 16 and 19). As is discussed above, significant municipal responsibility for both rental housing and long-term care in Sweden helps solve the split incentive problem. In countries where these functions lie in separate hands, the split incentive problem remains. Similarly, municipal ownership of Seattle's electricity utility gives the city control over a significant proportion of its energy supply.

3.4.3 Implications

The cases examined in this section illustrate both the challenges and the opportunities in collective decision-making processes for reducing energy consumption. These challenges and their implications fall into three rough categories and are summarized below.

Goal setting and alignment of vision. As shown in chapter 2, major efficiency enhancements are required to reduce greenhouse gas emissions to levels consistent with the 2°C goal while expanding energy access, and these also entail changes in consumption in OECD countries. Energy intensity reductions are needed in the order of 2–3% annually over the long term. Creativity will be needed to identify overlap between different goals that pull in the same direction. This is important for expanding constituencies that support change, and for increasing the drive for change. This is also a question of leadership. Efficiency goals need to be part of global development goals; a thread we pick up in chapter 4.

Leadership as catalyst: focus, inspiration, responsibility and drive. Change is often driven by policy "entrepreneurs", who are not necessarily the people conventionally defined as leaders. These entrepreneurs often perform a bridging function across diverse organizational logics and may assume responsibility for ensuring that problem solving is well-targeted and effectively carried out. Even where there appear to be one-size-fits-all solutions available, these solutions have to be adapted to nuances at the level of buildings, roads, vehicle, groups and individual households. This requires problem solving that is eminently doable, but which requires entrepreneurial will to follow through to completion.

Multiple overlapping incentives are more powerful than single incentives. Following this logic, there is much to learn from public health efforts to persuade people to change behaviour. Public health practitioners have learned that a combination of carrots and sticks provides the most effective incentive for change.

One comparatively straightforward kind of leadership that the public sector can exercise is to align products and services that perform well in terms of energy efficiency with public procurement rules. This sends clear signals (leading by example), helps support the creation of viable markets (given the role and size of the public sector) and improves long-term energy sustainability for public institutions.

Infrastructural, institutional, cultural and relational factors. Attempting to govern cultural change is clearly a different kind of challenge than creating or changing regulations, largely because it is amorphous. At the micro/local level, cultural change is most likely to be facilitated through social learning processes that involve knowledge sharing, shared goal setting, priority setting and planning among diverse stakeholders. Institutional and cultural practices are intertwined so that change typically requires elements of both to be changed simultaneously (at least in the absence of crisis).

3.5 Conclusions and implications

A first observation is that more often than not, barriers and drivers do not neatly fit into a particular category: knowledge issues are intertwined with economic influences, and those are in turn interconnected with institutional and cultural factors. However, the three pathways do display different characteristics. One notable characteristic of cases in both the energy access and efficiency and lifestyle pathways is that the progress made along the change curve is a function of defining scale and scope (the nature of the sector involved and of the number of different activities they engage with). This appears to be less the case for renewable energy, for reasons we speculate on below.

Expansion of renewable energy can in some places occur within existing regimes. This is particularly true where the energy utilities are not integrated with the fuel industries, and so can more easily convert. In other places, for example where the coal industry is heavily involved in political and market decision making, regime resistance is much greater. In either case, since incumbent regimes tend to favour inertia and stability, there is still a need for inclusive energy planning processes that establish new goals and priorities, and also for creating space to allow new actors to enter the sector (both commercial and civil society actors). In the energy access cases, new regimes are being created, but are expanding into unoccupied territory and are therefore less likely to pose a serious challenge to existing regimes. In the case of efficiency and lifestyles, these pathways of change more decidedly run counter to – or outside of – existing regimes. Here, there is a need to open space for ideas and competition that can disrupt the regime and promote new public or market actors willing to invest in public goods.

The extent to which behavioural and cultural change are required to expand energy access and increase efficiency is only now beginning to be properly understood. Many of the enabling technologies have long been available but have not been embraced, and that embrace appears easier to achieve where new technologies are skilfully inserted into an existing socio-cultural and economic structure. While the uptake of cleaner cookstoves in urban Zambia (case study 3) elegantly illustrates this kind of challenge, the clean cookstove and solar lantern projects run by TERI illustrate how neatly the process can work when technical solutions are matched to the context in which they will be used. These models appear to be moving into the take-off phase and are most likely to expand via emulation. In contrast, our micro-generation cases (micro-solar and micro-hydropower, case studies 2 and 7) illustrate how culture can change by actively engaging a wide range of stakeholders and a mix of concrete opportunities and incentives. Here, cultural and behavioural patterns change because people actively grapple with problem solving and change processes at a level that is tangible. These cases also appear to be moving toward the take-off phase, most likely through replication and emulation, as in case study 7. At a regional level, it is more difficult to identify where momentum might be building, even if progress has been noted in for example the Asian Development Bank partnership case (case study 6).

Among the "efficiency and lifestyle" cases, the Swedish municipality Alingsås (case study 16) is arguably scaling up in its implementation of energy efficiency plans. Similarly, Seattle (case study 19) has successfully managed its self-imposed Kyoto obligations and is now setting its sights on the much more challenging target of zero net carbon emissions. There are many other similar examples of successful community-scale efforts where the level of penetration of a new approach is high. However, much less progress has been made in scaling up to the country or regional level, and at these scales, successful cases still represent relatively small niches and marginal experiments. This suggests that barriers and drivers are unevenly distributed, and that networks that provide channels for sharing knowledge, strategies, inspiration and motivation will have an essential role to play in scaling up at the national, regional and global scales. This highlights the need for coordination across scales.

Renewable energy expansion is somewhat different in that in many instances it is more centralized. These are often large-scale efforts where scope is narrowed through focus on a particular sector and sometimes on a particular technology. Further development of technology is required to adapt not to local circumstances (the electricity supplied through the grids is the same regardless of how it was produced), but to the cost and investment requirements of energy companies and the technical requirements of the distribution network. Companies that move ahead may do so seeking a more predictable environment or comparative advantage over fossil fuel competitors, or to contribute to solving a global problem.

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4 GOVERNANCE OF CHANGE: UNLOCKING THE POTENTIAL

Key messages

- Increasingly, national governments and the United Nations engage in target- and priority-setting for energy access, energy efficiency and the deployment of renewables. While these priorities and targets are not quite as transformational as those implied by our scenarios, the level of ambition is high. The challenge is now to develop credible and effective systems for buy-in, implementation and accountability so that the targets become powerful signals in a "noisy" environment, and to develop medium-term milestones that connect short- and long-term targets (i.e. between 2020 and 2050).
- Energy targets need a strong institutional home in the UN system. Progress reporting at the national level could be streamlined with the many relevant reporting processes that currently exist.
- Although there is progress on integrating energy with other policy areas (e.g. growth, development, Official Development Assistance, environmental policy) incoherence remains, and practices such as subsidizing fossil fuels still outweigh advances. More comprehensive assessment frameworks are needed to deal with "problem shifting".
- Societies can do more to steer towards and stimulate transformation to sustainable energy systems. For example: markets need to give stronger signals on energy targets; governance and regulation needs to systematically address imbalances in information and power; and direct spending on research, development and demonstration (RD&D) needs to increase.
- There is a need for more investment in energy access in developing countries. Novel financial approaches, including joint public-private mechanisms, are needed to generate this investment. Climate finance, which for the most part has not yet been delivered, should not be relied on to fill the investment gap. As a first step, governments could redirect fossil-fuel subsidies to investments in access, efficiency and renewable energy.
- Good governance of energy transformation requires effective monitoring and evaluation systems. Mechanisms for transparency and accountability are particularly important during a period of major change in the energy sector. Civil society can be mobilized to independently track progress on agreed energy goals.

As our scenarios in chapter 2 show, massive changes to the world's energy systems are required to meet both development and climate goals within broader environmental constraints and following a shared development agenda. Chapter 3 breaks down the transformation into three complementary pathways, and identifies barriers and drivers in specific cases. While each of the pathways has *specific* challenges, there are *general* governance opportunities and challenges common to all three. For example: energy planning processes must be more inclusive in order to displace incumbent regimes; there needs to be better exchange and coordination of information across levels of governance, including the international level; the state needs to take a lead role; and small-scale successes in energy system change can be a powerful tool for governance.

This chapter builds on our scenarios and case studies to identify the types of governance needed to steer a transformation of global energy systems. While we maintain a global perspective, we also recognize that global governance alone cannot provide solutions, and that instead we need to approach transformation as a multi-level governance problem. These issues are complex, and this chapter does not provide a detailed inventory of possible policy instruments. Rather, it draws more general lessons for energy governance.

Based on a definition and discussion of governance in section 4.1, the remainder of the chapter is structured around the following governance questions:

- Have priorities been articulated and goals set to help steer the transformation of energy systems (section 4.2)?

- How can energy and other policy areas be better integrated so that coherent signals are sent to markets and actors (section 4.3)?

- What concrete policy instruments and investments for steering transformation need to be further developed (section 4.4)?

- What role do monitoring systems and accountability mechanisms play in ensuring that real progress is made and all voices are heard, and how can they be designed to do so (section 4.5)?

4.1 What do we mean by governance?

Over the last two decades, the term *governance* has gradually come to replace, or at least extend, the notion of *government*. (see box 4.1). In this report, we define governance as any effort of social coordination that employs formal and informal steering mechanisms to make demands, frame goals, issue directives, pursue policies, and generate compliance (Rosenau 2004:, p.32). We understand governance as something “bigger” than energy policy instruments (e.g. feed-in tariffs, energy efficiency standards, R&D programmes for low-cost modern cooking stoves). Following this definition, governance also includes decision-making processes, institutional arrangements and relationships which produce concrete “outputs”, such as public policies.

Box 4.1: From government to governance: examples from the energy sector

There are several reasons behind the shift from government to governance. First, it was observed that other modes of governing than traditional governmental regulation were increasingly used, such as *markets and networks* (Thompson et al. 1991).* For example, within climate policy and promotion of low carbon energy, there appears to be relatively little reliance on control through direct regulation, and high reliance on markets, such as the European Union Emissions Trading System and regional carbon markets in the U.S. and elsewhere. Most market-based instruments are, however, a mix of regulation (e.g. a legally binding emission cap) and voluntary market exchange (e.g. trading of emissions allowances).

Networks are also an increasingly common feature in global climate governance, and cities or companies are increasingly linking up to exchange best practices. With regard to energy efficiency, regulation appears to be more common (e.g. efficiency standards for products). For energy access, finally, much of the initiative behind access programmes relies on state-led investment, which may then be carried out though public-private partnerships. The boundaries between these modes of governance are generally quite blurred. After initial excitement with non-hierarchical modes (or "new governance"), it has become clear that governments still have a clear role in relation to each.

A second, and closely related, reason was that *non-state actors* are increasingly engaged in governance, either at their own initiative or because governments, keen to broaden their repertoire of tools, encourage their participation. This trend is also seen in the energy field. For example, the private sector has been active in developing visions, road maps and strategies for low carbon transitions, which are sometimes remarkably similar to those produced by the public sector (EURELECTRIC 2010). Other examples where non-state actors engage in governance include industry standards and benchmarking schemes.

Along with the shift from government to governance, we increasingly observe *multi-level governance*. The term does not refer to top-down hierarchical governance from the international to local levels, or levels of governance that operate independently from each other. Rather, under multi-level governance there is interaction and continuous negotiation between levels, rather than vertical implementation relationships (Marks 1993).

The trend towards multi-level governance is seen as a consequence of the decentralization of central government tasks and authority to local government, as well as the transfer of powers "upwards" to the international level. In the energy sector, multi-level governance has been found to characterize, for example, energy efficiency (Jollands et al. 2009), city action on climate change (Betsill and Bulkeley 2006), and the oil and gas sector in North America (Spruyt 2010). Energy access is a case in point, where national and sub-national initiatives have dominated the picture on the ground, but where actors such as the Asian Development Bank take an international approach and the UN system pursues a global framework. The UN Sustainable Energy for All initiative actively plans to tap local and national levels of governance by providing a global framework under which lower-level commitments can be put forward (see section 4.2). In the case of renewable energy and energy efficiency, our case studies (see chapter 3) show that authority is much more concentrated at the national level of governance, and that efforts need to be stepped up to enhance the global and regional mechanisms.

* Hierarchies, markets and networks are identified as three alternative models of coordination of social life (Thompson et al. 1991). Coordination here refers to bringing otherwise disparate activities or events into a relationship. A market coordinates by the "invisible hand" of market exchange and the price system it supports. Hierarchies coordinate by exercising control through administrative means. Networks coordinate by informal mechanisms among independent elements or actors.

To operationalize what we mean by governance and to provide an analytical framework around which to structure the discussion, we use the four key elements of governance defined by Pierre and Peters (2005) :

i articulating a *common set of priorities* for society at different levels;

ii ensuring that those priorities and goals are *coherent* and arrived at through integrated policymaking processes;

iii a capacity for *steering* towards those goals, including designing and implementing instruments and initiatives that change behaviour; and

iv ensuring *accountability* for governing actions, including monitoring efforts and transparent procedures for decision-making.

The following sections discuss each of these four elements. We take primarily a *functional* approach to governance, where the basic functions of governance are identified with a view to achieving societal goals, whether environmental, economic or social (Nilsson and Persson 2012). Importantly, governance can also be approached from a *procedural* point of view, in terms of how well democratic norms are upheld in decision-making processes. While the fourth element above clearly addresses this procedural dimension, there are additional principles of "good governance" which cut across all four elements. Building on the Aarhus Convention, Nakhooda et al. (2007) have identified four principles of good governance relevant to the energy sector:

- *Transparency and access to information*. Information should be comprehensive, timely, available and comprehensible.

- *Participation*. This includes formal space for participation in forums; appropriate or sufficient mechanisms to invite participation; inclusiveness and openness of such processes; and the extent to which input is taken into account.

- *Accountability and redress mechanisms*. These require clarity about the role of various institutions in sector decision-making; systematic monitoring of sector operations and processes; clear or justified bases for decisions; and legal systems to uphold the public interest.

- *Capacity*. This includes the capacity of government and official institutions to act autonomously and independently; resource availability (human, financial), and the capacity of civil society (NGOs, the media) to analyse the issues and participate effectively.

Note that the functional and procedural dimensions of governance are interrelated, for example in that more participatory decision-making can lead to more informed and therefore more effective policy outputs, and to greater acceptance of outcomes among the public. The following sections describe how each of Pierre and Peters' four elements of governance can be and have been carried out across levels to support transformation in energy access, shift to low carbon energy and enhance efficiency across levels.

4.2 Articulating a common set of priorities

Recently, setting priorities for energy access, efficiency and low-carbon energy has become increasingly open and transparent. Although existing national targets and proposed UN targets are ambitious, they are not quite ambitious enough to meet the challenges set out in chapter 2. To ensure that common goals and targets mobilize action effectively, lessons need to be learned from management-by-objectives systems (see section 4.2.3).

4.2.1 Energy priorities and targets

Lack of global targets and priorities

The goals for energy access, energy efficiency and renewables recently set by the UN Sustainable Energy for All initiative (see section 4.2.2) are a clear break with the past. Although at the national level, a secure and cheap energy supply has historically been a top priority for many countries, efforts to govern energy at the global level have been very limited, despite the many cross-border "public good" problems and externalities associated with energy production (Florini and Sovacool 2009, Goldthau 2011). This is reflected in the lack of strong institutions that could bring together economic, social and environmental concerns around energy (Karlsson-Vinkhuyzen and Kok 2011). However, momentum for broader and deeper global governance of energy is increasing: not only has energy access been described as the "missing" Millennium Development Goal (MDG), because of its instrumental role in achieving other MDGs (Global Network on Energy for Sustainable Development 2007, Modi et al. 2005), but also a summary of all national submissions to the Rio+20 process shows that energy access was the second most mentioned social or environmental issue, after climate change (Raworth 2012).

Furthermore, the environmental impacts of energy provision and questions of social justice have moved up the agenda. Spurred by international climate policy, explicit and quantified goal-setting for greenhouse gas (GHG) emissions from the energy sector started in the 1990s, and this trend seems to now be spilling over into other aspects of the sector.

Current energy targets at the national level

Renewable energy targets. A growing number of countries have set quantified targets for renewable energy (see box 4.2). These targets come in different forms, referring to share of electricity production, final energy consumption or installed capacity. A recent study found that by 2011 at least 96 countries had adopted renewables targets, more than half of which were developing countries (REN21 2011). In addition, a range of local governments have also set targets for the share of renewables in their energy

Box 4.2: Examples of national and regional policy targets on renewable energy

- The **EU**'s '20/20/20' package of targets states that 20% of EU gross final energy consumption in 2020 should come from renewable sources. This target is translated into legally binding national targets for all member states, which will be reviewed for progress in 2020.
- The **U.S.** has no federal renewables target. However, in 2007 it did adopt (through the Energy Independence and Security Act) a biofuels target stating that 36 billion gallons of biofuels shall be provided by 2022. At state level, a majority of states have adopted binding or voluntary renewables targets.
- In **India**, the Solar India campaign aims to establish the country as a global leader in solar energy, and has set a target of 20,000 MW by 2022, for various components, including grid connected solar power.
- **Kenya** has set a goal to double its renewables capacity by 2020 and increase geothermal power to 4GW by 2030.

For more information see (IEA/IRENA 2012) and (REN21 2011)

mix. A range of national targets for 2010 were met or exceeded. The study also found that current targets typically aim for a 10–30% share of electricity production from renewable sources within a couple of decades. Considering the challenges that our scenarios present, these levels are not likely to be enough, even if they were fully achieved and enjoyed continuous government support. According to the shared development agenda (SDA) scenario, renewables' share of total electricity production (including hydropower) needs to be almost 50% by 2030, and 67% by 2050.

Energy efficiency targets. There are fewer national policy targets for energy efficiency than for renewables, and data are less readily comparable. Some examples are listed in box 4.3. Within the G8/G20, the International Partnership for Energy Efficiency Cooperation has been set up to identify and support national strategies for energy efficiency and to support more coordinated data management by the International Energy Agency. The EU has developed a resource efficiency road map and is preparing a new efficiency directive, with targets such as renovating 3% of public buildings on an annual basis.[21] The aim of the road map is to speed up efficiency efforts and tap the still large potential for economically viable efficiency gains.

Overall, current political commitments to efficiency are much lower than the efficiency improvement rates discussed in the SDA as well as in other scenarios such as GEA efficiency (see chapter 2 section 5). The SDA implies annual reductions in average global energy intensity overall of 2.8%, so that by 2050 it would be 32% of the 2010 value.

21 COM 2011/370 and COM 2011/571.

Box 4.3: Some examples of national policy targets for energy efficiency

- The **EU** has set a target to reduce primary energy use by 20% by 2020 compared with projected levels. To reach the target, a new piece of legislation has been proposed which would require member states to adopt national targets and join energy efficiency schemes.
- **China** had a target to reduce energy intensity by 20% in 2006–2010. This target was met, although total energy consumption increased.
- **South Africa** adopted an energy efficiency target in 2004, which states that energy efficiency should be improved by 12% by 2014.

Energy access targets. A review of least developed countries (LDCs) and sub-Saharan African countries found that around half of 140 developing countries had set targets for access to electricity (Legros et al. 2009). Some examples are listed in box 4.4. In comparison, very few have set targets for access to modern cooking fuels, to improved cooking stoves and to mechanical power. The targets range from the long-term and aspirational (e.g. 100% access rate by 2030) to the short-term and realistic. They also demonstrate that different developing countries face different challenges, depending on access to resources, technical capacity and geographic conditions. For example, Costa Rica's electricity access target was 100% for 2010, while Liberia's was 10%.

Box 4.4: Examples of national policy targets for energy access

- **South Africa** stated in 2004 its policy goal of universal access to electricity by 2012. However, it is uncertain whether the goal will be met due to financial and capacity constraints. Unreliable data also complicate the picture.
- **Rwanda**'s Vision 2020 foresees that 35% of the population will have access to electricity by 2020.
- **Mali** has set a target that by 2015 54% of the population will have access to modern fuels, and 40–50% should have access to improved cooking stoves.

Critical issues

To sum up, there is a trend of increased target-setting at the national level, although apparently there are fewer targets for energy efficiency. Although we lack a systematic comparative review of targets and present performance, we can nevertheless identify two critical issues.

First, the real value of these targets will depend on whether there is an effective system for monitoring progress. It will also depend on citizens and non-governmental actors holding their governments accountable for successes and failures (see section 4.4).

Although there are a range of energy targets for the short term (say, up to 2020) and the long term (say, from 2050 and beyond), there appears to be a lack of targets for the medium term. Short-term targets matter on a political and electoral horizon and are therefore more carefully implemented and monitored, which means that they may be set at the more moderate – and less transformational – end of the spectrum. Long-term targets are well beyond any current politician's reach and can therefore be set at more ambitious levels. However, mechanisms do exist that could create longer term accountability (Sprinz 2009).

4.2.2 New UN targets for Sustainable Energy for All

Quantified and measurable goals on sustainable energy supply were not politically agreed at the *international* level until 2010, despite it being a core issue on the environment and development agendas. In that year, the Advisory Group on Energy and Climate Change (AGECC), set up by UN Secretary-General Ban Ki-Moon, reported on its proposal for two specific targets (AGECC 2010).[22] In 2011, a third target on renewables was added to form the third pillar of the Sustainable Energy for All campaign. The two existing targets were also slightly reformulated. It is now proposed that the world should, by 2030 (UN Secretary-General 2011):

- Ensure universal access to modern energy services
- Double the global rate of improvement in energy efficiency
- Double the share of renewable energy in the global energy mix

The Secretary-General's High-Level Group on Sustainable Energy for All, appointed in November 2011, considers these targets ambitious but achievable (UN Secretary-General's High-Level Group on Sustainable Energy for All 2012). Figure 4.1 shows the key indicators against which progress will be measured, with 2009 as the baseline year.

What is the level of ambition of these objectives, compared to our scenarios in chapter 2?

For the *energy efficiency* objective, the level of ambition is not far below our scenarios, although the difference is still significant: while the UN objective is to double by 2030 the global rate of improvement in energy efficiency to 2.4% compared with the 2009 level, our SDA scenario requires overall reductions in annual energy intensities of 2.8% over the same period. Energy intensity is measured as the quantity of energy per unit of economic activity or output (GDP).

The *renewables* objective aims for a 30% share of global final energy demand by 2030, and is only slightly lower than the numbers discussed in our basic energy access (BEA) and SDA scenarios, which suggest we need to reach a share of circa 35% by 2030 (and continued rapid expansion up to a 67–68% share by 2050).

22 Note that global targets had been suggested by a range of public agencies, independent research institutes and private sector entities as part of the MDG process, see GNESD (2007).

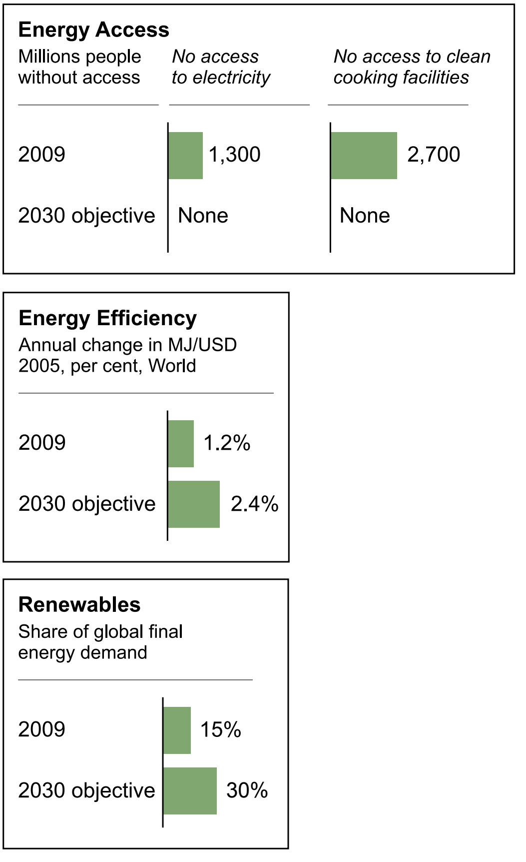

Figure 4.1: UN Sustainable Energy for All objectives for 2030, versus the baseline year of 2009, with progress indicators

Source: UN Secretary-General's High-Level Group on Sustainable Energy for All (2012), p. 10.

Three aspects of the *energy access* objective currently prevent straightforward comparison. First, no minimum threshold for what constitutes "modern energy services" has yet been agreed. The AGECC report proposes that a definition of energy access should include both "basic human needs" and "productive uses" (AGECC 2010:13), but also states that a threshold for "basic human needs" – estimated by the IEA to be 100 kWh of electricity and 100 kg oil equivalent (kgoe) of modern fuels per person per year – should be used as a starting target (ibid. p. 9). The "basic human needs" target is considerably less ambitious than our scenarios. However, this is a *minimum* value that should be delivered to all, whereas our scenarios show the *average* kWh per person. Even though the average value is higher, this does not mean that the minimum threshold value is available to all.

Second, AGECC qualified the access objective by stipulating that access should be reliable. Not only would this require more efficient distribution systems, it may also imply a certain need for overcapacity.

Third, another qualification is that access to energy should be affordable. Affordability is defined by AGECC as "[when] the cost to end users is compatible with their income levels and no higher than the cost of traditional fuels", although temporary subsidies might be required to reach affordability in the short term. Our scenarios do not take this factor into account.

Clearly, significant work remains to further operationalize the energy access objective, as well as to define indicators and criteria or thresholds for it. While the objective could in principle allow for country-specific definitions and indicators – not least to ensure that the improvement of energy access is a country-led development – some degree of standardization will be required so that international finance can be distributed according, inter alia, to comparative need and/or performance.

Have the UN goals been endorsed by relevant actors and are they politically realistic? It is still too early to answer these questions. In the Rio+20 preparatory process, the objectives were endorsed in the Zero Draft document, but implementation was not further discussed, for example, as part of the proposed Sustainable Development Goals. The campaign was launched only recently, with a Framework of Action presented in January 2012. Rio+20 is set to be a formative moment for the future political significance of these objectives.

However, the proposed Framework of Action does envisage a highly voluntary approach to the uptake of these targets at the national and sub-national levels, as well as in the private and civic sectors (UN Secretary-General's High-Level Group on Sustainable Energy for All 2012). The framework proposes a cycle where actors – including national governments, local governments, the private sector and civil society – make voluntary commitments in relation to the targets and register them with the UN. The UN would then formally recognize and publicly commend success. However, by the end of April 2012, only a handful of commitments had been entered.[23] Furthermore, formal recognition is a fairly weak incentive, and considering that in many cases it will take 20 years or more to verify the success of commitments, carrying the risk that momentum will be lost over time, the system will have to build on organizations' self-identification as proactive leaders in this field.

4.2.3 Lessons from management-by-objectives systems

Since the UN goals and national-level policy targets are quite recent phenomena, it is too early to assess their impact, level of support and steering power across different levels of governance. However, it is helpful to look at general lessons from target-

23 See: http://www.sustainableenergyforall.org/commitments

setting practices and the management-by-objectives approach when discussing conditions for successful achievement.[24]

Initially, it should be emphasized that setting a quantified and time-bound target does not necessarily mean “articulating a common set of priorities” (the first functional component of governance). First, a target may be intended only to provide a vision rather than lead to implementation. Unless national governments signal commitment there is a risk that the UN targets will only play such a visionary role. Second, the plural “priorities” suggests that issues compete for resources and attention, and that societies must weigh them up. National governments are traditionally seen as the most legitimate actors to make that evaluation. Their commitment is crucial in order to translate targets from one set among many to *true* priorities, in terms of allocating budgets and making these targets into electoral issues. On the other hand, the UN Secretary-General’s High-Level Group can influence the extent to which the UN system prioritizes the targets within the UN system and, when calling for cooperation by nation states, can refer to principles adopted in international law and conventions.

The formulation of the three goals thus represents only the first step on a journey that will probably have to become increasingly politicized, and where more trade-offs will have to be made. This means that the energy sector will need to become more transparent. On the other hand, there are positive synergies between these energy goals and other priorities for societies (see section 4.3). As an example, a country and its energy industry could articulate as a common priority a wish to lead in the “green race” by securing higher market shares for clean and efficient technologies and practices.

The management-by-objectives literature (see e.g. Hood 1991, Vedung 1997) offers the following principles for setting effective targets, at the UN or national level. First, goals should be *clear and measurable*. Goals can be defined as both “outcome” goals (i.e. desired changes in society, such as the current three UN goals) and “output” goals (i.e. on policies adopted and the performance of primary agents). The following output goals, or commitments, could be complementary:

- removal of perverse policy incentives such as fossil fuel subsidies
- introduction of policy and regulation to scale-up improvements in energy access, efficiency and renewables
- investment by government, the private sector and donor countries, and
- adoption and application of safeguard policies and procedures for sustainability.

The second principle concerns *delegation of decision-making*. Relevant people should be allowed to decide how to achieve a goal, and set appropriate operational targets

24 This approach became popular in management and public administration in the 1980s under the assumption it led to more effective and efficient implementation.

and action plans. With the UN energy goals there is clearly an effort to delegate, although it is perhaps more of a gesture than real delegation, because the UN does not have genuine decision-making authority. Strong ownership of goals, as a prerequisite for effective implementation, is easier to achieve if the goal-setting process is participatory. There are “good governance” frameworks which provide indicators for how this principle may be operationalized for national policy and regulatory processes, including procurement and tariff setting.[25] However, these need to be further tailored for the transition to a low carbon pathway.

The third principle is *objective monitoring and evaluation of results*. This is the least developed aspect of the current UN goals. To ensure that monitoring and evaluation are effective and objective, it is necessary to: choose appropriate indicators and data; designate a body to be responsible for monitoring; ensure the independence of that body; maintain regular reporting; nominate a recipient of the reporting and results; and introduce systems of enforcement and sanction. Importantly, there also needs to be a demand for evaluations, so that results are widely disseminated and responsible actors held to account. Section 4.5 presents ideas for how to progress on these fronts.

Commitment to the UN energy goals will only be maintained if a strong and effective institutional home is found for them at the international level. UN-Energy would be a natural candidate, but this is only a coordinating mechanism and currently lacks resources and a strong mandate. The UN Environment Programme (UNEP) has an environmental mandate, but not the developmental mandate, and vice versa for the UN Development Programme (UNDP). The International Renewable Energy Agency (IRENA) could be a home for the renewables targets, but it may not be appropriate to split them and place them under different institutional responsibility in case they evolve into competitors for resources, and in case synergies and trade-offs cannot be captured. Furthermore, membership of IRENA is not global. The IEA is not a global body and the World Bank may be seen as too controversial a choice by some countries. Possibly a better resourced UN-Energy, with a clearer mandate, would be an appropriate choice as a starting point. Alternatively, if the energy goals become subsumed into a set of Sustainable Development Goals, the institutional apparatus for such a broader set of goals (e.g. a UN Sustainable Development Council) would be their home. Key issues for success will be the level of resources attached to the targets, effective internal and external communication about them, and the political priority assigned to them in various international policy processes.

However, if an institutional home for monitoring and evaluation is found, this does not mean that mechanisms in other institutions and decision-making arenas cannot be used. The renewable and efficiency targets could be more actively pursued under the United Nations Framework Convention on Climate Change (UNFCCC), linked, for example, to Nationally Appropriate Mitigation Actions. The energy access target could be promoted in development cooperation (e.g. with the UNDP, the Organisation for Economic Co-operation and Development, its Development Assistance Committee

25 See the Electricity Governance Initiative, http://electricitygovernance.wri.org/.

and the World Bank). Mainstreaming can and should also be addressed at a concrete level. Several existing reporting systems could be relevant at the international level, for example: national communications submitted under the UNFCCC; national progress reports on the MDGs; Poverty Reduction Strategy Papers and other development strategies prepared in partnership with donors; and IEA country reviews. This leads us to the issue of integration and coherence.

4.3 Ensuring integration and coherence

Articulating common priorities in relation to sustainable energy for all is only the first element of a governance approach. The next is to ensure that those priorities are not contradicted or undermined by other priorities, and vice versa. When implementing actions to achieve goals and priorities, they must not lead to *problem shifting*; that is, making it more difficult to reach other goals. Ideally, all policy priorities should form a coherent whole. While this is probably impossible to achieve, much can be done to improve coherence and integration.

4.3.1 Concepts of integration and coherence

Coherence is here understood as the degree to which policy outputs are compatible or positively synergistic. *Integration* is the activity or process through which coherence is achieved (Nilsson, Zamparutti et al. 2012).

Experience with policy integration and coherence has become increasingly rich in recent decades, for example under the banner of *environmental* policy integration (EPI) in policy sectors with high environmental impact (European Environment Agency 2005, Nilsson and Eckerberg 2007) and policy coherence for *development* (PCD) as pursued within the development assistance community (OECD 2008). One reason for this growing interest is to avoid *problem shifting* as far as possible, and try to find integrative and holistic problem solutions, or at least to be aware of possible trade-offs. Explicit and implicit *policy contradictions* and *goal conflicts* should be avoided to provide clear and unambiguous signals to markets and actors. Signals will of course be very much dependent on from what perspective you approach policy coherence. From an EPI perspective one may favour the use of (more expensive) renewable energy to improve access for the poor, or, from a PCD perspective one may favour modern fossil fuel options such as liquid petroleum gas, if they are currently cheaper, to maximize the number of people to provide with access to modern energy.

There is also a more positive rationale behind the interest in integration and coherence. For example, notions of *positive synergies* and win-win opportunities between societies' priorities have led to ideas such as the green growth concept. If the goals, and actions taken to achieve them, are not synergistic (as in producing a sum larger than its parts), then at least they should be compatible. A concrete expression of this positive rationale is the interest in reaping *co-benefits* of policy goals and actions, for example reducing emissions that would otherwise lead to both climate change and local air pollution. It may also be that what is a *side-effect* from one perspective is a main driver for action from another, climate mitigation and energy security being prime examples in the energy field.

With regard to governance of energy, what exactly should be integrated into what? There are several relevant interactions to consider. *First*, the UN targets manifest the critical need to better integrate environmental concerns (e.g. mitigating climate change) and developmental concerns (e.g. achieving MDGs) into the energy sector and decision-making. *Second*, energy access also needs to be better integrated into development and ODA planning, so that it is prioritized more highly. This would also mean that synergies with other objectives for development could be identified more systematically, such as private sector development and empowerment of local communities. *Third*, energy targets also need to be made more coherent with other environmental objectives, so that, for example, tough land use policies and industrial permitting procedures do not excessively obstruct new renewable capacity. *Finally*, energy efficiency must be advanced through various policies within various sectors (e.g. buildings, transport). Lifestyle change, on the other hand, could be addressed within fiscal and health policy.

4.3.2 Renewable energy

Expansion of renewable energy in both the North and the South is increasingly coherent with not only climate change policy but also energy security policy. However, at the operational level, renewable energy expansion is not yet integrated into utility planning processes. National utilities based around centralized fossil fuel generation may initially find it difficult to scale back reliance on traditional fuel sources and shift to renewable options in their long-term plans. This is especially the case when renewable energy is being generated by independent power producers, which requires new regulatory frameworks and procurement processes. Another source of incoherence is the use of fossil fuel subsidies, estimated by the IEA at USD 557 billion in 2008 and over 400 billion in 2010 globally. The G20 has committed to "rationalise and phase-out over the medium term inefficient fossil fuel subsidies that encourage wasteful consumption, while providing targeted support for the poorest", and required its members to regularly report on progress. However, the G20 has not yet set a time schedule or quantified targets (G20 2011).

On the environmental side, given that all energy sources have environmental implications and could involve difficult environmental trade-offs, a comprehensive environmental assessment framework is needed to improve coherence of renewable energy with sustainability goals. For example, the environmental performance of large-scale biofuel plantations has been hotly debated, with climate advantages being weighed against high water consumption and land area requirements. In the EU, sustainability criteria address these issues to some extent (Council of the European Union 2009), but a more complete framework is required (Nilsson et al. 2012).

This and other examples (such as biodiversity impacts from hydropower and land requirements for wind and solar) highlight the need for integration to avoid problem shifting. There are also signs that both developing and developed countries are seeking to create more synergies, for instance through implementing low-carbon development strategies. China, for example, although it is the world's largest fossil energy user, is also a world leader in renewable technologies (see case studies 13 and 14 in chapter 3). This has come about because China has successfully integrated renewable energy into its overall industrial development strategies. Similarly, many countries in Africa (see case studies 8 and 10 in chapter 3) are beginning to use its bioresources (for energy, food, fibre and chemicals) to build for innovation, growth and exports (Juma 2011).

4.3.3 Energy efficiency and lifestyles

Energy efficiency resonates strongly with a policy integration approach, since it is aligned with many other political and economic priorities, including: lowering emissions, lowering energy costs, improving energy security through lower demand, creating jobs and promoting innovation. Still, on the whole, energy efficiency has not figured strongly on the political agenda until recently. In the age of relatively cheap energy in the 1980s and 1990s, energy efficiency was not a political priority in most countries. Another factor behind the limited interest in efficiency at that time was market liberalism, which asserts that governments should only intervene to correct market failures. Today, there are promising signs that energy efficiency and lifestyle considerations are being integrated into future visions for economic development and well-being in some high-income countries. For example, the IEA has launched an international partnership programme (see above) and the EU has developed a resource efficiency road map for 2050. Case study 15 in chapter 3 on power planning in Thailand and South Africa is one example where government officials have recognized that energy efficiency targets need to be integrated into power development planning, although this has not yet been accomplished.

Questions of efficiency and lifestyles also need to be more strongly integrated with infrastructure planning. This an urgent question because of the lock-in periods that result from the longevity of infrastructure such as roads and buildings. For example, land use planning for urban and peri-urban areas has often failed to successfully integrate energy efficiency, resulting in sprawl and difficulties with public transport.

4.3.4 Energy access

The process of integrating energy access policy into other policy domains has only just emerged. As is noted in chapter 1, energy access is not integrated into the MDGs, despite their central role in alleviating poverty. Therefore the ongoing international process to update the MDGs needs to clearly articulate goals for energy access. In terms of what has been achieved, UNDP has successfully worked with countries to integrate energy considerations into national and regional development strategies through the Regional Energy for Poverty Programme (REPP), and in partnership with three African Regional Economic Communities. More recently, the EnergyPlus initiative has proposed the creation of National Multisectoral Committees in participating countries, whose mandate is to coordinate national stakeholder efforts in developing Energy for Poverty Reduction Action Plans and national investment programmes.

At the national level, while it is recognized that cooperation among different levels of government is essential, there are still various opinions on burden sharing among local, regional and national governments. In addition, there is limited integration across ministries or sectors of the government. If micro-level evidence were linked to national-level policy formulation processes, through an analysis of the impacts of access on a variety of development objectives (income generation, education, health, gender, etc.), this might go some way towards improving such cross-sectoral integration.

Finally, energy access is only weakly integrated with renewable energy and efficiency. While the synergies in achieving energy access through increased deployment of renewables are quite well understood and are being realized to some degree, synergies in energy efficiency and access policies are scarcely considered. However, pursuing energy efficiency and energy access policies in tandem can generate substantial synergies, as this can potentially increase the level of energy services that can be provided by existing infrastructure, reduce energy costs, and avoid lock-in to inefficient technologies and practices (Pachauri et al. 2012).

4.3.5 Lessons learned from policy integration practice

Several governments and organizations have set up systems for integrated policy-making, including organizational adaptations (e.g. merging ministries and units, extending mandates), procedures (e.g. impact assessments of new policy proposals, monitoring of environmental performance), and knowledge and training initiatives (Jordan and Lenschow 2008). It should be noted that organizational adaptations include not only merging ministries, but also the opposite: establishing specialized departments or new agencies, for example ministries for renewable energy or energy efficiency. When it comes to integration, the fact that energy does not have a clear home in the UN system can have both advantages and disadvantages, but at this stage we argue that the disadvantages outweigh the advantages (see section 4.2.3).

In a globalized world, coherence is not only an internal concern for national governments or international organizations. It is increasingly considered in the external dimension of policies. Within the OECD, the PCD focus is on member countries' policies on trade, investment, migration, agriculture, health and the environment. The European Commission recently proposed that a priority PCD issue for Europe is to ensure that the developmental component of EU policies combats climate change (i.e. supports both climate-friendly and climate-safe development).[26] Some of the tools within the EU for realising the PCD agenda include consultation mechanisms, impact assessments, and Commission Country and Regional Strategy Papers.

While it is progressive to address integration through various administrative routines and tools, it also risks building on a false assumption that integration is an administrative problem, in that an effective and rational bureaucracy would be able to deliver it if it was properly resourced and mandated to do so. However, integration and coherence also involve political value judgments which accountable decision

26 SEC(2011) 1627 final.

makers should make, and those judgements should be transparent. Thus, another perspective is to consider integration as an arena of conflict between different interests in the policymaking process. For example, green interests confront industrial interests, and if the power balance is tilted sectoral policies could become more green. A third perspective considers integration as a policy learning process, in which sectoral policy-makers come to see environmental issues as integral components of their own sectors' problems, objectives and strategies. Box 4.5 shows the key principles for policy integration from this perspective.

Box 4.5: Key principles for policy integration as a learning process

Building trust. Integration requires that different stakeholders within and outside government engage in some kind of interactive process. This means taking a risk: accepting that there are more valid arguments and possibly having to change your mind. For stakeholders to take this risk they need to have full trust in the process and its leadership. How to create this trust is a key challenge in integration.

Transferring ownership. Integration requires that sectoral actors take on board new issues at the heart of their policies. They will only do this if they are the "owners" of the issue, both in competency and accountability for delivering results. This also means that the previous owner of an issue has to give up part of its competency.

Building capacity. Integration requires a capacity to engage in knowledge assimilation, interpretation, strategic thinking and interactions with different stakeholders. This takes time and requires highly qualified staff with time and resources to engage (see also section 4.4 on steering capacity).

Developing knowledge. Currently, sectors have only a piecemeal and partial understanding of the implications of sectoral decisions. Although anything resembling a "complete" understanding is an illusion, there is a need for better policy assessment frameworks, both before decisions are made and when evaluating their results.

Source: Nilsson and Eckerberg (2007).

4.4 Enhancing steering capacity

The steering capacity of a society – its ability to achieve its goals and priorities in a coherent way – can involve a very wide range of policy instruments, institutions and administrative mechanisms. In this context, these can range from an international climate agreement down to a local subsidy programme for energy access. Taking the multi-phase concept of transformation as a point of departure, our case studies identify different barriers to and drivers of transformation. Extending this perspective suggests that different instruments are needed at different phases and for different barriers, an insight that also confirms the past two decades' research about innovation and technological change (see figure 4.2). It is now widely agreed that the inception phase typically requires targeted and industry-led RD&D, removal of fossil subsidies, network building and knowledge sharing. Take-off and acceleration typically require public procurement and niche market support. Consolidation and stabilization typically require ongoing market adjustment and continuous RD&D for improving and enhancing efficiencies (IEA 2011a).

Experience also shows that combinations of policies are needed, and the exact combination depends on the status of technology, the institutional and political context and the resource base. Enhancing steering capacity for transformation is a very broad topic which is not comprehensively addressed here. Below we highlight key issues around policy instruments and investment and financing that might stimulate transformation.

4.4.1 Policy instruments

Two kinds of market failure often justify policy intervention in energy systems. First, because individual investors do not reap the benefits of new energy technologies, this means that there is under-investment in new technologies and systems, which calls for public support. Various instruments can address this problem, including provision of risk capital, RD&D spending and legislation on intellectual property rights (IPR).

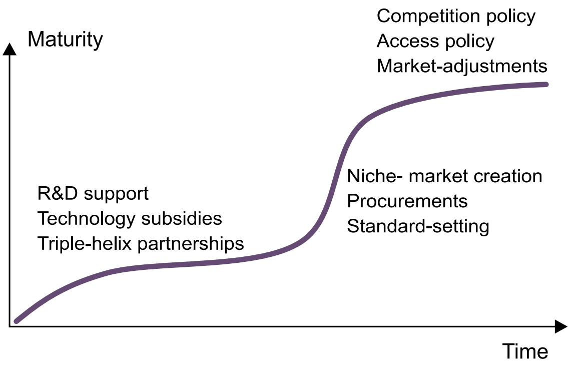

Figure 4.2: Governance instruments along the S-curve
Source: Nilsson et al. (2009), figure 18

Second, the external social and environmental costs of energy production and use usually call for generic market mechanisms, such as taxes. These and other issues call for public governance.

Market incentives

For renewables, a popular approach has been to deploy technology-specific market instruments. In power production, *feed-in tariffs* have been a strong driver. By 2010 they were being used by around 50 countries They have enabled renewable technologies to evolve from small niches to significant parts of the energy mix in, for instance, Brazil and the EU. Some have put forward the idea of a global feed-in tariff, funded by developed countries, to increase both energy access and the use of renewables in the developing world (DeMartino and Le Blanc 2010).

However, governance problems with feed-in tariffs can occur, because regulators find it difficult to establish the real costs of renewable energy technologies in this highly dynamic sector. A variety of mechanisms for transparency and benchmarking can be put in place to ensure that the feed-in tariff is set appropriately; that is, high enough to attract investors yet applied over appropriate timescales to ensure improvements in costs and performance. Furthermore, markets need to be monitored to ascertain whether at any given moment a feed-in tariff or competitive bidding is the most appropriate instrument. Countries such as India and Brazil have moved from one to the other, or used both in combination (Weischer et al. 2011). Feed-in tariffs can also be an innovative way to empower community electricity cooperatives. The case of IBEKA in Indonesia demonstrates how communities can earn revenue by selling excess hydropower to the grid, while at the same time extending energy access to the rural poor (case study 7, chapter 3).

Market signals are a necessary (but insufficient) condition for transformation, and they need to become more stable than they currently are in carbon and renewables markets. The EU Emission Trading System (EU-ETS) is case in point. In practice, what is needed is a market stabilization mechanism (e.g. a floor and ceiling on carbon prices). Furthermore, it is not only market failures that prevent transformative expansion of renewables, but also policy failures, such as fossil fuel subsidies.

To increase energy access, market incentives are required for producers and suppliers and for consumers. For consumers, incentives are needed to make both the cost of fuel and the cost of end-use devices, such as stoves, more affordable. One typical policy instrument aimed at increasing affordability is price support mechanisms, such as targeted subsidies, lifeline entitlements, progressive pricing and direct cash transfers. Easy access to credit has also been an important incentive for producers and suppliers to engage in businesses that could accelerate access to modern energy, along with tax rebates, prizes for technological innovation and energy market reforms.

Regulation

A growing number of governments – currently 10 (REN21 2011) – use *quota obligations*[27] to increase the share of renewables in power production and transport fuels. Quota obligations with a market for tradable certificates combine regulatory and market mechanisms, and can be a powerful driver for transformation. The mechanism has the potential to ensure that fixed quantitative targets in medium-term plans are met, but the risk of windfall profits needs to be mitigated.

In recent years policymakers have paid increasing attention to the regulation of energy efficiency. For example, performance standards have been applied for energy use in cars, buildings and household appliances. While industries often strongly resist hard regulation, it can provide for a long term, stable and competition-neutral framework to which industries quickly adapt. A few countries have also introduced white certificates, which are similar to quota obligations, but where saved energy is the traded product (Lees 2007).

RD&D

As is noted in the introduction, firms typically under-invest in energy RD&D. From both a political and an economic perspective it can be argued that public RD&D support is vital for steering innovation. From a political perspective, scenarios like our SDA, where deep emissions cuts are implemented, will not be politically acceptable unless technological innovation reduces costs. From an economic perspective, there is a need to intervene with public support because of the market failure that the full benefits of innovation cannot be appropriated by individual firms but spill over to other firms as public goods.

In a recent survey of 29 U.S. industries, electric utilities were the lowest R&D spenders by far, followed by the petroleum sector (Victor 2011). Government spending on energy R&D is on the rise again, after some decades of decline. The share of spending, currently at around USD 10 billion per year, on clean energy is rapidly increasing. Nuclear accounts for 40% of spending, renewables for 28%, and energy efficiency for 17% (IEA 2010). The IEA estimates that this amount must increase by USD 40–90 billion annually to enable an energy transformation in line with their BLUE map scenario, with the largest needs in low carbon vehicles (USD 20–40 billion), followed by carbon capture and storage (CCS) and smart grids. Energy efficiency for industry is estimated at around 4–10 billion. Wind and solar together account for relatively minor R&D needs (USD 1–2 billion each per year).

Instruments to overcome lock-out

To unleash transformation of socio-technical regimes, governance is needed to lower the barriers to entry for new actors. For example, governments are beginning to discover the central role of public procurement of niche technologies (Henderson and Newell 2011). Because of close ties between incumbents and the state, transparent processes are also important. Important levers to open up these processes and facilitate actor

27 These instruments are also referred to as renewable portfolio standards (RPS) or renewables obligations.

interactions could include overarching accountability mechanisms, such as freedom of information and public consultation legislation. Principle 10 of the Rio Declaration – which promotes access to information, decision-making processes and justice – can be adapted to the energy sector to provide a global framework.

4.4.2 Investment and financing

There is a growing number of estimates of the level of investment required to transform energy access, efficiency and low-carbon energy, in accordance with scenarios for 450 ppm of CO_2 and universal energy access. We do not review methodologies here, but it is clear that current levels need to multiply several times. For *energy access*, the IEA estimates that USD 48 billion per year will be required up to 2030 to provide universal access to modern energy services. This represents a five-fold increase from the observed level of investment in 2009 (IEA 2011b). To meet the UN 2030 goal on *energy efficiency*, it is estimated that for low-income countries USD 30–35 billion in additional capital is required annually until 2030, and USD 140–170 billion for middle-income countries (AGECC 2010). For *renewables*, it was estimated that a record-high total of USD 263 billion was invested in 2011 (Pew Charitable Trust 2012). The IEA in its baseline scenario estimates that power sector investments of USD 500 billion on average are needed annually. Additionally, around USD 150 billion per year is needed in the IEA 450 ppm scenario. This excludes buildings, industry and transport (IEA 2011b).

Because the incentives and disincentives to make these additional investments differ widely across the three issues, it is hard to generalize about them. However, to the extent that developed countries should support developing countries in a global energy transformation, a key policy question is where exactly the finance should come from. The AGECC report identified climate funds agreed in Copenhagen as a key source, but their potential has limitations. First, the “new and additional” climate finance agreed in Copenhagen should have a balanced allocation between adaptation and mitigation. On the mitigation side, the energy sector accounts for 60% of GHG emissions (75% of CO_2 emissions). Other key economic sectors such as agriculture and water will also lay claim to climate finance. Second, the Fast-Start Finance period ends in 2012, and as yet no new agreement has been made on how to phase up to the USD 100 billion per year committed to be mobilized by 2020. Third, there are no guarantees that climate finance would be allocated to energy access to meet basic needs prior to ensuring access to modern energy services, in line with the sequential targets suggested by AGECC.

Besides the direct support from ODA budgets (which is troubled by the concern that this ODA is “diverted” from other purposes, such as health and education), one proposal is to expand the use of carbon markets, such as the Clean Development Mechanism (CDM), to mobilize new and additional funds. Other proposals could possibly generate more reliable funds, such as proposed levies on international bunker fuels and aviation (UN 2010; World Bank 2011). However, as is mentioned above, there are other candidate sectors and issues for receiving climate finance. What is crucial is to match public funding to private sector capital, and match international to national funds. On the funds needed for energy access (USD 48 billion annually;

see above), the AGECC report suggests a shared burden: multilateral organizations to provide USD 18 billion, domestic governments USD 15 billion and the private sector USD 15 billion (AGECC 2010). The rapidly increasing purchasing power in the poor countries described in the SDA scenario will make these levels of investments within reach for national governments. A greater difficulty lies in making these business opportunities attractive for the private sector but, as our case studies on energy access show, innovations in business models at the local level allow for profitable investments that are purely commercial.

While the investment needs are daunting and not easily resolved, it should be noted as a comparison that subsidies to fossil fuels were estimated by the IEA at over USD 500 billion in 2008. Comparison with other government priorities, such as economic stimulus and the military, suggests that it may not be a capacity problem to ramp up investment, at least in some countries. Furthermore, fuel cost savings have been estimated at more than twice the investment amounts (IEA 2011b).

4.5 Ensuring accountability and monitoring

Section 4.4 shows how society's collective steering capacity can be strengthened by specific policy instruments and investments. In addition to such substantive instruments, open decision-making processes are essential for lowering barriers for new actors and perspectives. Also, as increased public funds (both national and international) are channelled to the energy sector, good governance will be necessary to limit corruption and maximize impact. Overall, higher-quality and better-informed energy plans and investments are more likely to occur when supported by good governance frameworks.

Below, we briefly discuss two issues, both of which are relevant at multiple levels. First, if countries commit to energy targets within the UN Sustainable Energy for All initiative, there will be a need for mechanisms to track progress towards commitments. A global governance framework would need to develop, in particular, agreed definitions of energy access and metrics for measuring progress and impact. Metrics are more readily available for share of renewables and energy efficiency improvement rates (see e.g. IEA 2012). Second, at the national and sub-national levels, mechanisms for transparency and accountability will become important in decision-making processes that are not only technical and administrative, but also political.

4.5.1 Tracking progress towards energy targets

As is noted in section 4.2.2, out of the three proposed UN targets, the energy access target lacks not only a clear definition, but also metrics that allow for international comparison and yet which are responsive to national and local needs and priorities. A survey of attempts to define and measure energy access concluded that most are inadequate, because they focus mainly on dimensions of quantity rather than quality (Bazilian et al. 2010). Monitoring the number of "stoves disseminated" might not provide an accurate reflection of whether households have adopted the stoves, or

Box 4.6: Operationalizing a definition of energy access

Based on a review of existing definitions and metrics, Pachauri (2011) describes how the different circumstances and the priorities of different nations mean that the mix of energy carriers and technology need to be decided locally. Affordability will also have to be assessed locally in relation to income levels and standards of living. International consensus could be strived for when it comes to defining minimum energy services to be included in a basket of basic needs. For example, the non-governmental organization Practical Action has defined nine such energy access minimum standards (e.g. 300 lumen for a minimum of four hours per night per household; 1 kg wood fuel or 0.3 kg charcoal or 0.04 kg of liquid petroleum gas or 0.2 litres of kerosene or ethanol per person per day, taking less than 30 minutes per household per day to obtain) (Practical Action 2010).

Pachauri identifies three steps in operationalizing a definition of energy access which allows monitoring of progress:

- Agreeing on a set of basic energy needs to include in the basket of energy services that comprise those for which access needs to be improved or enhanced.
- Setting minimum service thresholds, both quantitative and qualitative, that can then be defined in final or useful energy terms to provide a range that can be used as a benchmark against which progress can be measured.
- Estimating the costs of providing the energy services through the new mix of energy carriers and technologies being introduced, to compare with existing expenditures to ensure affordability for the poorest and sustainability of efforts in the long term.

whether the new stoves are having a beneficial impact on their well-being. Clearly, projects need to define indicators for “output”, “outcome” and “impact” to properly assess the adoption process and evaluate the outcomes of specific interventions (Pachauri and Spreng 2011) (see box 4.6). Quality of products (e.g. cooking stoves) and services (e.g. quality of electric supply) are as important as the number of connections made or stoves supplied. There is also an emerging feeling that metrics should reflect development gains (for health, education, gender, convenience, etc.) that do not show up on balance sheets. The Energy+ Technical Working Group initiated by Norway has suggested that targets might need to be set for specific programmes that address the three types of energy need: energy for basic needs, energy for productive uses and energy for modern society, with indicators that would be appropriate to each of these. Within these programmes, the role of renewable energy and energy efficiency would be defined, and the indicators would need to be developed with input from both suppliers and consumers. There are also lessons to draw for monitoring from e-applications and mobile applications.[28]

28 E.g., see http://www.projectsurya.org/storage/ProjectSuryaWEB-Feb23.pdf.

According to standard guidance on monitoring and evaluation (M&E) systems, bringing results-based information into the public arena can change the dynamics of institutional relations, allocating budgets and resources, personal political agendas and the public perception of government effectiveness (Kusek and Rist 2004). A results-based M&E system, with its emphasis on demonstrable outcomes, can provide policymakers with a strong tool to identify gaps in implementation and provide mid-course corrections. A governance system based on quantified and measurable targets is only as good as its mechanisms for measuring performance, as well as for holding actors accountable for their performance, whether through legal procedures or public opinion (e.g. via "naming-and-shaming" or media attention). Several examples are emerging of third party monitoring for global agreements. For example, the Open Government Partnership (OGP),[29] in which partner countries voluntarily commit to take defined steps to improve access to information, has provisions for independent progress assessments. Multiple actors are considering using OGP as a model or receptacle for the commitments on open government made at Rio. A similar framework could be used for the Sustainable Energy for All initiative (see above).

4.5.3 National level decision-making processes: the need for good governance

It is not only policy choices that need to be made in a transparent way. At the operational level, transparency is also required for planning, procurement and other regulatory decisions, such as allocation of subsidies. Institutional mechanisms will need to be put in place more systematically for disclosing information (e.g. methodologies used, key background documents, clarity about roles and responsibilities) and engaging stakeholders (e.g. public hearings, technical workshops, advisory boards) in measuring trade-offs and assessing benefits.

Information disclosure also enables independent analysis, which can support decision-making processes. Civil society has an important role to play in providing independent analysis and benchmarking, developing information that can support regulators and other decision makers. Legal frameworks would also need to provide for information disclosure – that is, legal mandates will need to be developed to ensure that institutions are authorized to put information in the public domain and consult stakeholders. Beyond legal frameworks, capacity building will be necessary to ensure that institutions are equipped to implement these mechanisms, and that stakeholders can access them effectively.

A framework that encompasses the principles of good governance as they apply to the energy sector, and specifically to extending energy access, would be helpful for developing a road map for effective design and implementation of policy. Examples of existing frameworks which could be built on are those developed by the Electricity Governance Initiative (see box 4.7).

29 See http://www.opengovpartnership.org/.

Box 4.7: The Electricity Governance Initiative

The role of the state should be to supply procedural as well as substantive steering functions. On the demand side, the available procedural spaces must be taken up by non-governmental actors. The Electricity Governance Initiative (EGI) framework is a capacity building tool to enable civil society to participate in these spaces, and to promote increased transparency and accountability in sector reform processes.

As the sector redefines itself to integrate low-carbon technologies while extending access to energy, these spaces are taking on renewed importance. New indicators may be needed and civil society capacity will need to be built so that it can provide substantive inputs and play an oversight role. EGI is participating in the recently established Open Climate Network to develop new indicators for enhancing the transparency and accountability of low-carbon policy.

Electricity Governance Assessment Toolkit

The EGI has attempted to define indicators of good governance for the power sector. The indicators address four basic elements of good governance – transparency, accountability, participation and capacity – and the extent to which they are practiced in policy and regulatory decision-making processes. Processes that affect environmental and social concerns are emphasized.

Four indicators that are particularly relevant to energy access are:

- PP28: Transparency and accountability in the design and implementation of subsidies
- PP36: Participation in decision-making on access to electricity services

Illustrative additional indicators that could be developed or customized for rural energy access:

- Accountability mechanisms for financial management standards
- Transparent selection of private sector service providers

Policy Implementation Assessment Framework (in collaboration with the Open Climate Network)

This framework builds on the Electricity Governance Assessment Toolkit by focusing on the implementation of governments' low carbon policies. It is organized around four dimensions of effective policy implementation: finance, policy administration (including monitoring and reporting), and compliance and enforcement. Each of these dimensions can be analysed in terms of provisions for good governance, including legal provisions and implementation in practice.

For further information see www.electricitygovernance.wri.org.

4.6 Conclusions

This chapter discusses how key elements of governance need to be in place in order to facilitate and enable a transformation of the global energy system. While the case studies in chapter 3 suggest that some barriers to change have deep-seated cultural roots, and that governance may only take us so far, the broad review presented here shows that we need to think about governance as something more than just single policy instruments, such as a feed-in tariff or a carbon tax.

National governments are increasingly setting targets for energy access, energy efficiency and renewables, but it remains to be seen how effectively these targets will be promoted and enforced, and whether they translate into effective medium-term action plans that catalyse transformation. Long-term aspirational goals provide necessary vision, but they clearly extend beyond current electoral cycles and hence risk being peripheral to current decisions. The UN targets for Sustainable Energy for All offer a promising uniting framework and fill an important gap at the global level. The stated goals on access, efficiency and renewables up to 2030 do not deviate far from our SDA and BEA scenario pathways (see chapter 2).

In order to raise the political profile of energy issues and integrate them effectively across other agendas, the UN system must find a stronger permanent institutional home for these issues, as well as people who can champion them in various parts of the UN system. However, these or similar targets need also to be formally adopted within the Sustainable Development Goals (SDGs). The choice of indicators for follow-up is critical and must balance the need for uniformity and adaptability. Voluntary commitments made under the Framework of Action should include short-term output targets next to long-term outcome targets, to ensure that momentum is not lost.

Coherently integrating issues of energy access, energy efficiency and renewables with other political priorities at various governance levels should be understood not only as a technical or administrative task, but also as a political task: one that requires long-term building of capacity and more comprehensive and forceful policy assessment frameworks.

When examining these issues from a socio-technical transformation perspective, it becomes clear that there is no silver bullet for overcoming barriers. To do so, policy instruments should be sequenced and durable. Market forces will be key, but so will a much more active role for the state. Not only does it need to establish the rules of the game through regulatory frameworks, planning, monitoring, assessment procedures and market-adjustment policies, but it must also invest in infrastructure, provide capital and support innovation. Private sector investments in new systems will not be enough.

Transparency is vital to ensure that funds are not diverted from other development priorities, when and if climate finance and ODA investments support sustainable energy for all. More open decision-making in the energy sector is also crucial, and requires effective mechanisms for transparency and accountability. In particular, an international monitoring and evaluation system is urgently required.

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5 CONCLUSIONS AND KEY MESSAGES

This study asks what it means for governance and energy systems to provide sustainable energy for all by 2050, while staying within environmental constraints. We developed three global energy scenarios – the baseline (BAS), basic energy access (BEA) and shared development agenda (SDA) scenarios. The BEA scenario examines the implications of meeting global energy needs while staying within a 2°C greenhouse gas budget with 60% probability. The SDA scenario builds on the BEA scenario, and goes a step further to examine the implications of more equitable global economic development with more rapid growth in the poor regions of the world; assumptions that other scenarios do not conventionally make.

Our scenarios show that ambitious objectives for "energy for all" are compatible with the 2°C degree climate target, without making it significantly harder to achieve. Furthermore, meeting energy needs through modern sources can have important positive outcomes for the environment and for health (GEA 2012). Still, the BEA and SDA scenarios show that reaching both energy and climate goals will be very difficult, and requires major transformations in energy systems, including a massive expansion of low carbon energy and a major shift away from high carbon fuels, and a step change in efforts towards both energy efficiency and sufficiency. There is no doubt that this will require massive investments, but as other studies have convincingly shown, there are many profitable measures that can be taken (McKinsey 2009). Our case studies confirm this picture: some measures, like ramping up solar photovoltaics (PV), are still relatively costly and require policy support, whereas others represent opportunities for synergies between access, efficiency, and cost-effective renewables. The envisaged socio-technical transformation will have to be different to previous ones in that it must take place within a timeframe of two to four decades; a shorter period than is typical for technology revolutions.

Even though a fundamental transformation of the global energy system is required, several of our case studies suggest that incremental change of governance arrangements can sometimes remove barriers to innovation and change within socio-technical systems. When looking at particular cases and systems, we found that potentially transformative effects can flow from overcoming implementation deficits within existing national and subnational governance. However, we also found that more structural change is required at the global level of governance, where there are currently major gaps.

The analysis of drivers, barriers and governance responses in chapter 3 shows that clear and ambitious goals are required to provide market signals that are strong enough to drive transformation. Such goals and related instruments could well be technology-neutral. However, in order to transform socio-technical systems, more technology-based targets will also be required in order to scale-up the necessary array of supply and demand options.

Instruments such as carbon pricing and removal of fossil-fuel subsidies – the mainstream prescriptions of economists – are necessary but not sufficient to achieve transformation. Beyond such measures, governance responses need to accelerate the process through regulatory measures such as technology standards, market mechanisms (e.g. green and white certificates and feed-in tariffs), international financial mechanisms (such as the Green Fund), increased support for and coordination of RD&D, public procurement and investment, and expanded access to finance and capital. If combined, such measures would help to nurture and scale up new socio-technical regimes, as well as destabilizing old and unsustainable ones.

Crucially, persistence and long term commitment are required. Much greater risks need to be taken and more experimentation will be required, and failures along the way must be accepted. While on the one hand it may seem a small price to pay in the greater scheme of things that decision makers take on the political risk of investing in technologies that could fail, on the other hand it will be difficult for them when investing public resources to assess environmental and health risks and acceptable levels of opportunity cost. That said, reluctance to diversify the technology mix entails its own risks, related both to energy security and climate impacts. As shown in the case study on long-term electricity planning in Thailand and South Africa (chapter 3, case study 15), decision-makers are becoming more sophisticated at analyzing the risks associated with new technologies and weighing them against the need to diversify reliance on fossil fuels. The assumptions that underpin such decisions are also being made more transparent and subject to stakeholder review.

5.1 Implications of the three energy pathways

Chapter 3 presents 20 case studies organized according to three pathways of transformation: energy access, renewable energy, and energy efficiency and lifestyle change. This section pulls together some of the conclusions under each pathway.

Extending *basic energy access* requires a concerted focus on assuring that a wide range of policies converge, as well as the effective implementation of and an enabling environment for technology choices. Appropriate financial mechanisms, business models, and institutional and human capacity are also needed. With respect to traditional biomass stoves, cultural habits in particular play an important role in determining use. Governance mechanisms must facilitate replication of successful efforts, sharing of information and experience at the community-level, and help to fine tune business models of clean energy access that are easily adaptable to local conditions. The following elements are required for successful scale-up of technologies:

- quality standards for new or more advanced technologies
- public finance or other ways of financing infrastructure improvements
- new business models and technical and financial assistance to commercial actors

- collaboration between public and private actors within conducive national policy frameworks
- change in culture and social practices
- affordable loans to households and small businesses, and
- national level commitments linking to global commitments, targets and monitoring systems.

Turning to *renewable energy,* the process of change is somewhat less politically challenging, and there are many experiences to learn from. Political resistance from existing regimes, although it does exist, is usually not a strong barrier. However, renewable energy is still challenged when it scales up. There is no lack of ideas, business models, or technologies to help drive expansion; but what is especially lacking is investment capital and institutional frameworks that enable early-stage technologies to cross "the valley of death". Scaling out requires the following elements:

- incentives – both for investment (levelling the playing field between fossil-fuel based energy and clean energy) and for the permitting process (finding local benefits)
- requirements for grid operators to open up for distributed generation
- international coordination of technology development, including global innovation and technology sharing mechanisms
- capital provision and market formation at national levels through a stronger industrial policy
- local and national public procurement at a large scale
- significantly larger RD&D efforts at national and international levels, and
- inclusive energy planning processes that allow new actors to enter the sector.

For *energy efficiency and lifestyle change*, finally, our scenarios require ambitious reductions in energy intensity. Part of this will take place through electrification and other technical measures, but efficiency enhancements at this level can likely not be met by technology alone; lifestyles and social practice must also change, as well must sectors such as the built environment, transportation, and consumption and waste. Energy efficiency and elimination of waste are essential components of living in a world in which conventional energy resources and pollution space are increasingly limited, and where even arable land, rare metals and other resources needed for expanding renewable energy sources may prove to be a limiting factor. Still, it has proven politically challenging to improve efficiency and change lifestyles through governance. The market logic which has dominated the economic policy of most OECD nations suggests that efficiency measures, being “low-hanging fruit”, will be captured by market actors without intervention, and politicians are wary of being seen to intervene in people’s personal choice. This study shows that governance efforts are needed on a number of fronts to induce processes for change. These include:

- knowledge dissemination and networking on best practice in different sectors
- stable and predictable regulations, in particular on building codes, efficiency standards and bans on wasteful products and processes
- social learning and reflections about smart consumption and lifestyle
- economic incentives to overcome the split incentives between investors and users
- enabling urban planning and infrastructure – to make it easy to follow the incentives

It is well known that these drivers and barriers play out at multiple scales, and therefore need to be address across different levels of governance. Table 5.1 presents a selection of the key challenges according to level of governance.

5.2 Implications for governments and for business

5.2.1 Implications for national and federal governments

Our study shows that governments must in many areas take a more central role in governance, for several reasons: the urgency of environmental pressures; the fact that the environment is often a public good; the need for very long-term investments in infrastructure; and the fact that not enough investments are made in energy RD&D. On the latter point, some inherent features of the energy sector have made the energy industry historically one of the lowest investors in radical innovation (see chapter 4). Most R&D focuses on incremental improvements within existing systems. Paradoxically, considering the mounting challenges, global public R&D efforts declined for two decades, before the most recent revamping as a result of the stimulus packages following the 2008 financial crisis. Furthermore, historically, R&D budgets have not been aligned with the potential of technologies to reduce GHG emissions (Grubler and Riahi 2010).

Thus, massive political will be required to achieve sustainable energy for all, as well as major public investments up front, and a set of coherent policies and institutional arrangements that push the system in the desired direction. The main challenge is to progressively withdraw subsidies from the fossil fuel industry and from other perverse incentives. Another important challenge for nation states is to mobilize the political and economic resources needed. Investment costs and commercial risks for industry

Table 5.1: Ten governance challenges for energy efficiency and lifestyle change, and possible responses across levels of governance

Barriers	Governance responses		
	International level of governance	**National level of governance**	**Subnational levels of governance**
Split incentives	International harmonization of regulation	Strict regulations on performance of buildings, cars, appliances, installations	Implementing norms and regulations in local concession and permitting processes
Lack of incentive of energy companies	International agreement on climate mitigation	Carbon pricing, subsidy removal, industrial and technology policy, white and green certificates Requiring grid operators to open up for distributed generation	Inclusive planning processes
Lack of investment capital and credit	Stronger focus on the energy agenda in multilateral lending institutions, and new energy investment mechanism	Governments take a stronger role in providing capital	Emulate and scale out micro-credit schemes
Insufficient RD&D	Set up global technology fund with transfer capabilities	Strengthening public and public-private RD&D budgets	Enable inclusion of local stakeholders and beneficiaries in RD&D projects
Poor state implementation capacity	UN coordinated development of monitoring and assessment systems	Establish national monitoring systems and rebuild capacities for national energy planning and policy	Establish local monitoring systems
Unsustainable cultures and lifestyles in rich communities	Norm creation through global dialogue within and outside of the UN as part of a sustainable development goals agenda	Information policies, campaigns and economic incentives through taxation and subsidy	Inclusive planning processes, social learning and reflection
Lack of viable business models and entrepreneurship	Exchange of best practice and experiments in academia and among practitioners	Public procurement to establish niche markets and investor confidence	Fostering of new entrepreneurs and experimenting with local partnerships
Lack of political will	Establish international SDGs on energy efficiency, access and renewables	National commitments and benchmarking related to international goals Capture and display benefits and opportunities from investing in the energy transformation	Innovation clusters and local model projects
Lack of knowledge about risks and benefits of energy transformation	Global information sharing and monitoring systems	Policy assessment frameworks Cooperation between partners with a view to long-term road-maps	Project assessment systems and planning rules

will be immense if the new systems are to be scaled out, and the pay-off time will be long – in many cases much longer than they care to wait. If private capital is at all available on this scale, they will turn to governments for incentives and risk reduction measures to take on these efforts. Thus, overall, transformation will rely on market forces but with a very active role for the state. It will need to establish the rules of the game through regulatory frameworks, planning, monitoring, assessment procedures, and market-adjustment policies, and must also be actively involved in infrastructure investment, capital provision, and innovation support.

This implies a new role for both technology policy and industrial policy, but also a need for active ownership and provisioning of capital. Putting the state back in the game[30] in this way is politically complicated, first, because of past weak performance in industrial policy in the 1970s and 1980s, and second due to the more general belief in deregulated markets that took hold in their wake for everything from telecom, to railroads, energy and healthcare and education. Furthermore, pressure group interests have often had too great an influence on regulatory processes. These factors have combined to sideline industrial policy for decades, and have been major drivers for market liberalization. The mantra that the state should not be "picking winners" has made it more difficult to induce viable pathways and supporting technologies towards more sustainable energy systems. In several OECD countries it has impeded support for new renewable technologies and constrained investment in public infrastructure. But, due to several features of the imperfectly functioning energy market, the role of picking winners is not necessarily better handled by the market. On the contrary; in recent years many deregulated markets, when left to their own forces, have proven to be dysfunctional. The proper balance point between market and state has yet to be found (Hall and Soskice 2001).

5.2.2 Implications for the international system

The international level of governance is a major challenge. Whereas at the national level, institutions and policies are often in place and only require incremental change to support transformation, international energy governance probably requires an entirely new structure (Biermann et al. 2012).

To date, global energy governance has been too weak, mostly limited to some platforms for knowledge and practice arranged under the International Energy Agency (IEA), the International Atomic Energy Agency (IAEA) and various UN bodies, but with weak political mandates and resources. The gap in international governance probably weakens the coordination of technology policy and the emulation and diffusion of best practice. The innovation systems that produce new technologies, and the markets that deploy them, are today global (Nilsson et al. 2012). Yet, current innovation system policies are almost always national. In the same way as firms underinvest in energy

30 The re-emergence of the state is of course visible already in current trends, both in the Western world, where advocates of market liberalism in financial as well as welfare sectors have taken serious blows in the last couple of years, and in emerging economies such as Brazil, Russia, China and India, where "state-led capitalism" characterizes much of the economic activity (The Economist, 21 January 2012).

R&D because benefits cannot be appropriated, so countries tend to underinvest in R&D because benefits "leak" to other countries. The last 20–30 years has already witnessed an industrial transformation of the energy industry to a globalized market, in which technologies for boilers and turbines are supplied not from local or national sources, but by global ones. This increases chances of diffusion, but it also sheds light on the lack of coordination of energy innovation globally.

Current international regimes, and in particular the climate regime, have not advanced convincing policies to stimulate innovation and diffusion of new technologies and social practices. It is necessary to bring energy conversations into the heart of global climate discussions, and in doing so: a) focus on clean energy services, not emissions, because these directly address universal interests in energy security and development, and b) focus on opportunities and efforts for innovation, not constraints, because those are in the interest of governments. Today no one gets credit for innovation efforts, and there is virtually no coordination mechanism at all for innovation at the global level.

Moving forward on new global governance for climate and energy does not have to involve all countries. In fact, both emissions and the major innovation systems for energy technologies involve a small fraction of countries, for instance U.S., China, Brazil, India, Germany, France, and Japan. The top-ten energy-related CO_2 emitters represent 67% of global emissions. Similarly, the top ten innovators represent 82% of global R&D spending and 95% of global patents. In this context, having 200 countries around the table agreeing on everything is neither viable nor an effective use of diplomatic effort (Victor 2011).

5.2.3 Implications for business

Common wisdom has it that governments cannot resolve global sustainable development challenges all on their own. Companies, NGO's, academia and other innovators outside the governmental and intergovernmental system may be our best hope to bring change. However, this is likely to require a new framing of business and its role in society. Viable business models for deployment of new technologies are rare, and the tight connections between existing technologies, institutions and actor interests create inertia and sluggishness. A number of business scholars are now arguing for a whole new business approach – that the narrow focus on profits of conventional capitalism is limiting the commercial potential of business (Porter and Kramer 2011). The new generation of business, rather than taking responsibility for the problems it causes, can actually address social and environmental problems in its core strategies.[31] Pursuing "shared value" will open up new commercial opportunities that align strongly with the challenges discussed in this report.

- *Commercialization of new green technologies*. This requires innovation in technologies and applications, and may occur through traditional forms of business supplying smart grids, solar photovoltaics, or wind turbines, but will

31 Shared value may be put in contrast with the CSR concept which (albeit implicitly) suggests that there is a tension between share-holder value and that companies must act responsibly.

also give rise to new ones, such as renewable energy cooperatives, energy service companies etc.

- *Reaching markets within poor communities.* Although income levels are low, "the base of the pyramid" offers a potentially very large market for instance for services such as telecom, energy, and financial services. However, accessing these markets often requires innovation in business organization (community shared), income /business models, and distribution (Hart 2005). The point is that business becomes truly embedded in and drawing upon potentials and powers in the communities it serves. Our case studies on energy access gave several examples of what this looks like in practice.

When the private sector starts operating under a shared value perspective, taking into consideration community welfare and public benefits in their strategies, at the same time as states become more active through industrial policy and active investment, the boundaries between the spheres will become less pronounced. The clear-cut separation of roles between the private and the public sphere that has been advocated over the last decades will become increasingly blurred.

5.3 Eight key messages for Rio+20 and beyond

Any governance message on transformation of energy systems and development needs to be accompanied by a clear note of caution. Development strategies and programmes are often driven from implicit theories of change. A clear hierarchy of objectives, consistent targets, and plans of implementation are supposed to deliver anticipated results. In reality, of course, the world is much messier than this. Development is like an ecosystem, a complex network of processes and structures, with actors pursuing their own missions and agendas and interacting and adapting to each other. Similarly, although here we focus on energy challenges, the diversity of interacting factors hindering energy system change could well be likened to an ecosystem. Obviously, the factors that contribute to underdevelopment more broadly go far beyond this energy system in terms of complexity. In fact, we will never fully understand the conundrum of historical, economic, medical, social, political, cultural and natural drivers of poverty.

Governing this complexity, one needs a diverse approach using diverse instruments, resources, and arrangements. In fact, since all governance is contextual, what will actually work is largely unknown. Under these conditions of uncertainty it is necessary to experiment with a fragmented and polycentric approach, rather than rely only on centralized solutions. Because we are fundamentally uncertain about what works best, governance should take as diverse an approach as possible, combining different market, regulatory and cognitive mechanisms at different levels from the local to the global, and hope that they will start to connect, interact and generate positive feedback loops.

With those caveats in mind, the following messages emerge from our assessment.

1 **EXPLORE A SHARED DEVELOPMENT AGENDA.** Rio+20 and international discussions that follow it must advance a shared development agenda for the long term; a future without "us and them" where development is a shared commitment and its benefits are more evenly distributed. The first step is to build trust and common perspectives around development priorities, interests and goals. This report is a partial expression, in terms of energy, of such an agenda.

2 **SET ENERGY GOALS AS SUSTAINABLE DEVELOPMENT GOALS.** Energy needs to be a key constituent of any globally agreed set of SDGs. In this context we need a broad-based definition of sustainable energy for all. The aims should be for all countries to have energy services for productive purposes, and the provision of energy services in poor economies should be an explicit goal. Similarly, SDGs should include goals for efficiency and practices and low carbon energy expansion in line with the UN Sustainable Energy for All initiative. Building on experience from the Millennium Development Goals, governments need to agree on commitments, resources, and road maps for delivery, as well as mobilize expertise to mainstream this delivery into national policy.

3 **RESHAPE GLOBAL ENERGY GOVERNANCE.** There is a need for a stronger global governance framework for energy, to enable and mirror national and local governance. While incremental changes in national governance can in many cases be sufficient, a real structural transformation of the global framework is needed to coordinate, share and steer the transformation across nation states. Efforts for clean energy development should be central to the global climate change negotiations. It is also vital to establish specific and additional international mechanisms to enable the development and diffusion of energy technology, as well as monitoring and assessment of it. Inernational finance is also needed (see below).

4 **STRENGTHEN GOVERNANCE OF PUBLIC INNOVATION.** While energy system transformation is already under way, renewable energy technologies are still in many cases costlier than fossil fuel-dependent ones. Generic economic instruments such as carbon pricing can go some way to reduce costs, but are not enough because they tend to favour mature technologies. All pathways to energy transformation require significant innovations and new ways to apply them. It is crucial to bring down the relative cost of new technology through increased public RD&D, because it will in the long term determine the political acceptability of the transformation. A more active role of governments is also needed when taking energy innovations through the "valley of death", requiring long term and strong public commitment, major investments up front, and efforts to maintain the political will, even though some pathways and measures might fail.

5 **BUILD GOVERNMENT INSTITUTIONAL CAPACITY.** Putting technology and industrial policy back on the governmental agenda requires enhanced governmental capacity to manage complex systems and portfolios of projects.

Such capacities, e.g. for coordination, technology foresight and assessment, are largely lacking in many governmental machineries, in both South and North. The same applies to less developed countries, where capacity for energy access is lacking, both in terms of strategy and implementation. Greater capacity would support lesson learning and scaling up of successful initiatives.

6 **ESTABLISH FRAMEWORKS FOR MONITORING AND ASSESSMENT**. There is a need to develop frameworks for accountable and transparent planning and performance monitoring of targets, Assessments of the coherence between energy and other environment and development challenges need to be developed internationally, and implemented nationally. Strategies to scale out low carbon energy need to be assessed in the context of interactions with other key sectors such as water and food, and with environmental systems such as water, land, and biodiversity.

7 **MOBILIZE CAPITAL AND FINANCE.** It is urgent to mobilize, direct and govern finance and investment. Climate funds, revenues from carbon markets, and levies on international bunker fuels and aviation are possible sources. Donor countries should make sustainable energy for all a priority for development cooperation. Public funds should be set up so that they can be matched with private capital, and international funds should be set up so that they can be matched with national funds.

8 **ENABLE NEW PRACTICES, LIFESTYLES AND BUSINESS MODELS.** Wastage of energy and inefficient solutions permeate societies around the globe. Energy access for the poor, energy efficiency and smarter energy solutions are important business opportunities, but they often require new social and industrial practices, forms of organization, and business models. This is an issue for all countries, not just the rich world. A growing business community is taking an interest in these opportunities, and governance measures are needed to facilitate them.

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How can the world meet energy needs for human and economic development in a way that is compatible with sustainable development? What is required is nothing less than a massive transformation of energy systems and rapid turnovers of infrastructure and technology, all of which must be achieved while staying within climate and resource constraints.

Though the challenge is great, the energy and sustainability scenarios in this report show that it can be met. However, while these scenarios sketch out transformation pathways in broad strokes, the devil is in the detail. This study also explores how to successfully implement change, via case studies of energy transformation and reviews of policy mechanisms and governance frameworks.

Over the coming decade, policy-makers around the world need to build a shared development agenda to address these challenges. It is hoped that this study will help to lay the foundations for such an effort.

Måns Nilsson is Deputy Director and Research Director at the Stockholm Environment Institute (SEI) and Visiting Professor at the Royal Institute of Technology (KTH) in Stockholm. **Charles Heaps** is Senior Scientist at SEI and Director of SEI's U.S Center. **Åsa Persson** is a Research Fellow at SEI. **Marcus Carson** is Senior Research Fellow at SEI and Associate Professor of Sociology at Stockholm University. **Shonali Pachauri** is Senior Research Scholar in the Energy Program at the International Institute for Applied Systems Analysis. **Marcel Kok** is Senior Researcher at the Netherlands Environmental Assessment Agency. **Marie Olsson** is with the Swedish Energy Agency. **Ibrahim Rehman** is Director of the Social Transformation Division of the Energy and Resources Institute. **Roberto Schaeffer** is Professor at the Energy Planning Program, COPPE/Federal University of Rio de Janeiro. **Davida Wood** is Senior Associate at the World Resources Institute (WRI) and Project Manager of the Electricity Governance Initiative. **Detlef van Vuuren** is senior researcher at PBL Netherlands Environmental Assessment Agency and Professor of Integrated Assessment of Global Environmental Change at Utrecht University, The Netherlands. **Keywan Riahi** is Program Leader of the Energy Program at the International Institute for Applied Systems Analysis. **Branca Americano** is a Fellow with the Brazilian Foundation for Sustainable Development. **Yacob Mulugetta** is a Senior Energy & Climate Specialist at the African Climate Policy Center.

COPPE UFRJ

ACPC African Climate Policy Centre

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