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CONSEIL MONDIAL DE L'ÉNERGIE

Deciding the Future: Energy Policy Scenarios to 2050

World Energy Council 2007

Promoting the sustainable supply and use
of energy for the greatest benefit of all



Deciding the Future: Energy Policy Scenarios to 2050

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Foreword

Deciding the Future: Energy Policy Scenarios to 2050 is a major study from the 2005–2007 work cycle of the World Energy Council (WEC). It follows earlier WEC work, *Energy for Tomorrow's World* (1993)¹ and *Global Energy Perspectives* (1998)² that were updated in WEC's Millennium Statement *Energy for Tomorrow's World - Acting Now!* (2000)³ and *Drivers of the Energy Scene* (2003)⁴.

WEC decided at its Sydney Congress in 2004 to build new energy scenarios with three principal changes from previous work. First, the scenarios should be based on policy and on “bottom-up” regional and specialist work of the Member Committees of WEC. Second, they should test plausible storylines against the criteria of the WEC sustainability goals of energy Accessibility, Availability and Acceptability (the 3 A's). Finally, they should have a sufficiently long-term focus to underpin clear recommendations on policies and actions that will achieve targeted results by 2050.

With this study WEC seeks to contribute further to the debate on global energy sustainability and to the understanding of prospective collective roles in achieving WEC's mission, “to promote the sustainable supply and use of energy for the greatest benefit of all.” The study aims to:

- Better understand possible energy futures;
- Assess the challenges presented in these energy futures; and
- Identify the role that policy may play to help or hinder the achievement of WEC's Millennium Goals of Accessibility, Availability, and Acceptability.

Key issues for the energy scene covered in this report include:

Supply pressures involving risk in the security of global resources; the outlook for infrastructure investment and alternative energy sources; research, development, demonstration and deployment (RDD&D); and the introduction of new technologies.

Demand pressures related to forecasts of economic growth, expectations of consumer and industrial demand, constraints imposed by existing infrastructures, and related expectations of global economic volatility, all in key regional markets,

Environmental pressures and the likelihood of political, legislative, and social action to reduce carbon emissions in the near future, and;

Political pressures linked to potential political actions in key regions, including the Middle East, Russia, Latin America, and Central and West Africa; a major question is whether national governments will use energy resources to

¹ *Energy for Tomorrow's World*, World Energy Council, London, 1993.

² *Global Energy Perspectives*, World Energy Council, London, 1998.

³ *Energy for Tomorrow's World: Acting Now*, World Energy Council Statement 2000, London.

⁴ *Drivers of the Energy Scene*, Study Report, World Energy Council, London, 2004.

increase their political influence on global policy and to what degree;

I am grateful to the WEC Studies Committee and the Officers Council for their analytical and financial support for this work and I want to particularly thank Brian Statham of Eskom for his leadership as Chair of the Scenarios Study Group over the last three years.

CP Jain, Chair,
WEC Studies Committee

September 2007

Preface

Back in September 2004 when I accepted the invitation to Chair this study I expected this would be a challenging and exciting project. I have not been disappointed.

During the three years of this study I have been exposed to a wide range of thoughts and opinions, many of which have been quite different from my own. I have been challenged in so many different ways to review, justify or change my perceptions and opinions about the role energy plays in our global society. I have come to better understand the different peoples of our world; their aspirations, their fears, their strengths, their vulnerabilities and most of all their common vision and drive to achieve excellence in terms of Accessibility, Availability and Acceptability of energy systems.

This study does not claim to have found “The Ideal Energy Policy.” It certainly does not claim to be the last word on the topic of Global Energy Policy Scenarios. To do so would be presumptuous in the extreme. To the contrary, one of the key lessons from this study is that the policy imperatives are quite different from one region to another. An understanding and, more significantly, empathy for why this is so will greatly enhance the quality and the effectiveness of policy formulation and implementation

However, it does claim to be a reflection of the thoughts and opinions of more than 400 people working at policy decision-making level around the world, drawn from industry, government, academic and non-governmental organisations.

This is not a theoretical study and neither is it people in one region writing about what might happen in another region. It is the product of many workshops held in various locations during which leaders in that region discussed and debated the policy issues facing their region within the context of particular global scenarios and circumstances.

These workshops initiated, and this report aims to perpetuate, a vigorous and robust discussion about energy policy and its impact on the achievement and sustainability of the goals of Accessibility, Availability and Acceptability of energy systems. It is my hope that as you read this report you will be challenged, as I have been, and that you will be encouraged to take the debate further.

But more than that, I hope that you will recognise that there is much still to be done, and much that each of us can do, to improve our progress towards the 3 A goals. Dialogue and the debate are very important but it is even more important to convert this into meaningful action. This report is entitled “Deciding the Future” because the study group believes it is long past the time when decisions need to be made about the world’s sustainable energy future. This report points the way for policymakers to make important decisions now which can deliver desirable progress on the 3 A’s in the period from 2030-2050. This report shows that irrespective of whether we are in the public or private sector, there are issues within our own range of decision capability that we can act on immediately. I hope that we each find the

courage to make those decisions, wisely and timely. In doing so, we will be “Deciding the Future.”

Two contracts were let to help complete the tasks involved in this study. Ernst and Young (London) provided services to help plan and manage the diverse parts of the project and Enerdata (Grenoble) provided quantitative baseline data from their mathematical simulation model.

Many others have contributed to this study; too many to mention all by name. The Regional and Specialist Study Co-ordinators and the Members of the Study Group have been tireless in their efforts. Rogerio Manso for enthusiastically launching the work in the Latin American region; Dr Pietro Erber, Dr Latsoucabe Fall, Ian Hayhow for refining the work of their regions; Dr Angela Wilkinson and Wim Thomas for specialist advice and guidance, especially on scenarios; Dr Emad El-Sharkawi, Yasuo Hosoya, Oskar Sigvaldason, Ed Weeda; Harald Haegermark, Jean-Eudes Moncomble and Dr Hardiv Situmeang for diligently reading and commenting on draft after draft; Don Elder, Nigel Lucas and Dr Nebojsa Nakicenovic for taking the time to independently review the draft report and provide valuable comments; J.K. Mehta of WEC India and Marion Frieppess who kept diligent record of thousands of documents and exchanges.

My personal appreciation goes to Jean-Marie Bourdairé and the late Jan Murray for their passion and dedication in helping me launch this

study; Michael Cupit, Chris Mole and Samantha Palfrey of Ernst and Young for keeping the entire project on track; Bertrand Chateau of Enerdata for stimulating discussions of the relevant parameters; François Ailleret and Dr Rob Whitney for their wisdom, advice and encouragement and finally to Dr Robert Schock of WEC, colleague and friend, who has walked much of this road with me, sharing the breakthroughs and setbacks and never flinching from the task that lay ahead.

Brian A Statham

Chairman: WEC Energy Policy Scenarios to 2050 Study

Chairman: South African National Energy Association

September 2007

1. Introduction

“The only limit to our realisation of tomorrow will be our doubts about today.”

Franklin D. Roosevelt

1.1. Objectives of the Study

So much has changed in the world of energy since WEC last prepared scenarios in the 1990s. While these were updated at the turn of the century to take into account new assumptions about population, the prices of oil and gas, climate change, and technology developments, it became apparent that the real issues today are the emergence of massive new energy demand in China and India, the market power of fewer and fewer large suppliers of oil and natural gas, the shift to generally higher energy prices worldwide, the role of government policy and regulation in determining the energy mix and the value of carbon, and the regionalisation of energy markets which require harmonised standards and regulations.

The Terms of Reference for this study contain three analytical elements, explained in more detail below. The study’s basic scope is to evaluate the impact of four possible scenarios on the fulfillment of the WEC 3 A’s of **Accessibility, Availability, and Acceptability** as defined in Section 2. The three analytical elements are:

- Two axes that characterise the nature of the policy landscape. These are high or low engagement by governments, and

high or low cooperation and integration among nations and regions, and among the public and private sectors.

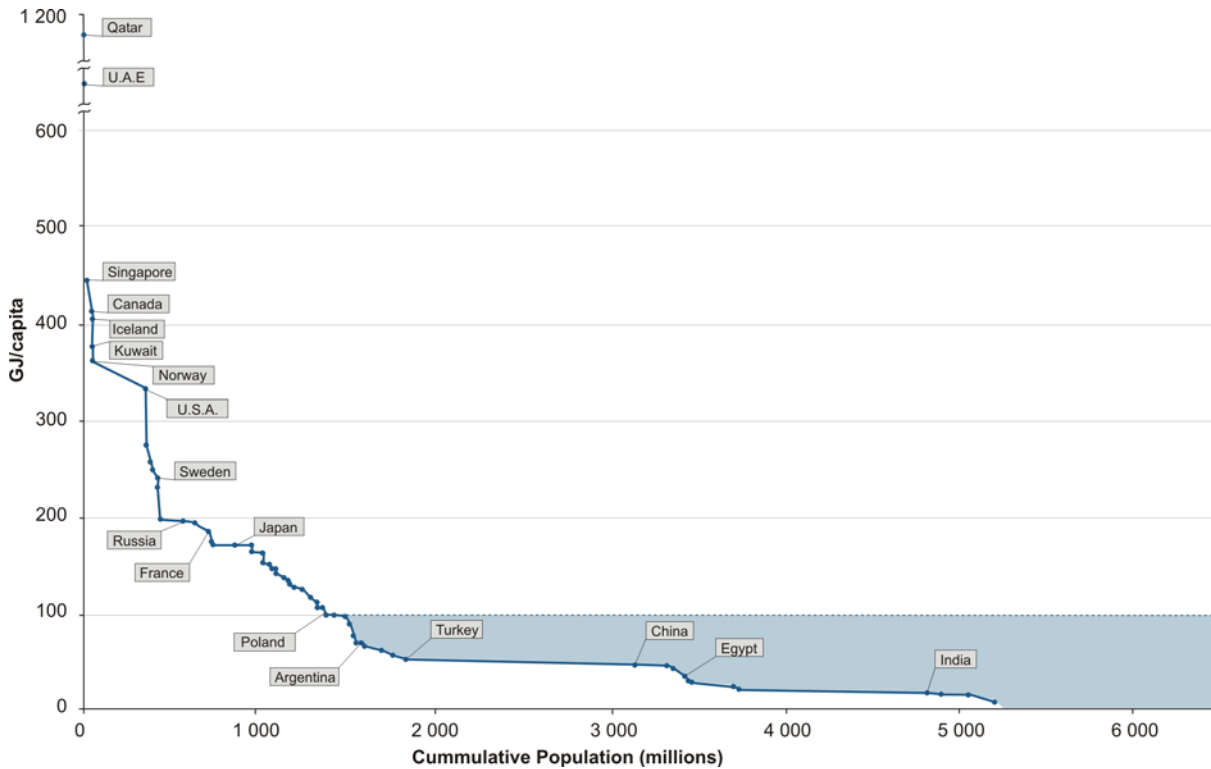
- Four scenarios that overlap through the development of these two axes.
- A number of energy sector metrics that assist in understanding the details of the long-term physical energy landscape.

The key challenge facing governments, business, and society at large is summarised in Figure 1-1. Average energy consumption per capita is shown for the nations of the world today (plotted as cumulative population), keeping in mind another one billion people (approximately) have no recorded energy use. To allow everyone in the world to attain just the energy use per person of Poland today, or about 100 GJ/capita,⁵ would require about twice the amount of energy the entire world *already* uses today, assuming that people who are already above Poland’s level maintain their current energy use per capita. To achieve the level of Russia’s energy use today (~200 GJ/capita), more than three times as much energy is required over what is used today.

Where will this energy come from? How will it be used? What will it cost? What are the ancillary impacts? These are profound questions that policymakers have to address, and soon.

⁵ 1EJ = 10¹⁸ joules = 10⁹ GJ = 24 million tonnes of oil equivalent (toe)

Figure 1-1 Energy per capita as a function of cumulative population. (Area between dashed line and data points is 500 EJ/year and represents everyone below Poland today achieving this same energy usage of 100 EJ per capita.)



1.2. Two Axes - Government Engagement and Cooperation/Integration

WEC Member Committees represent a large and diverse global community in terms of geographic, political, social, environmental, and economic conditions. While achieving the 3 A's is largely determined by the social, political, and economic environment - and the extent to which these factors facilitate or hinder sustainable energy development - the study group members investigated choices that can be made by key decision makers in countries and regions around the world.

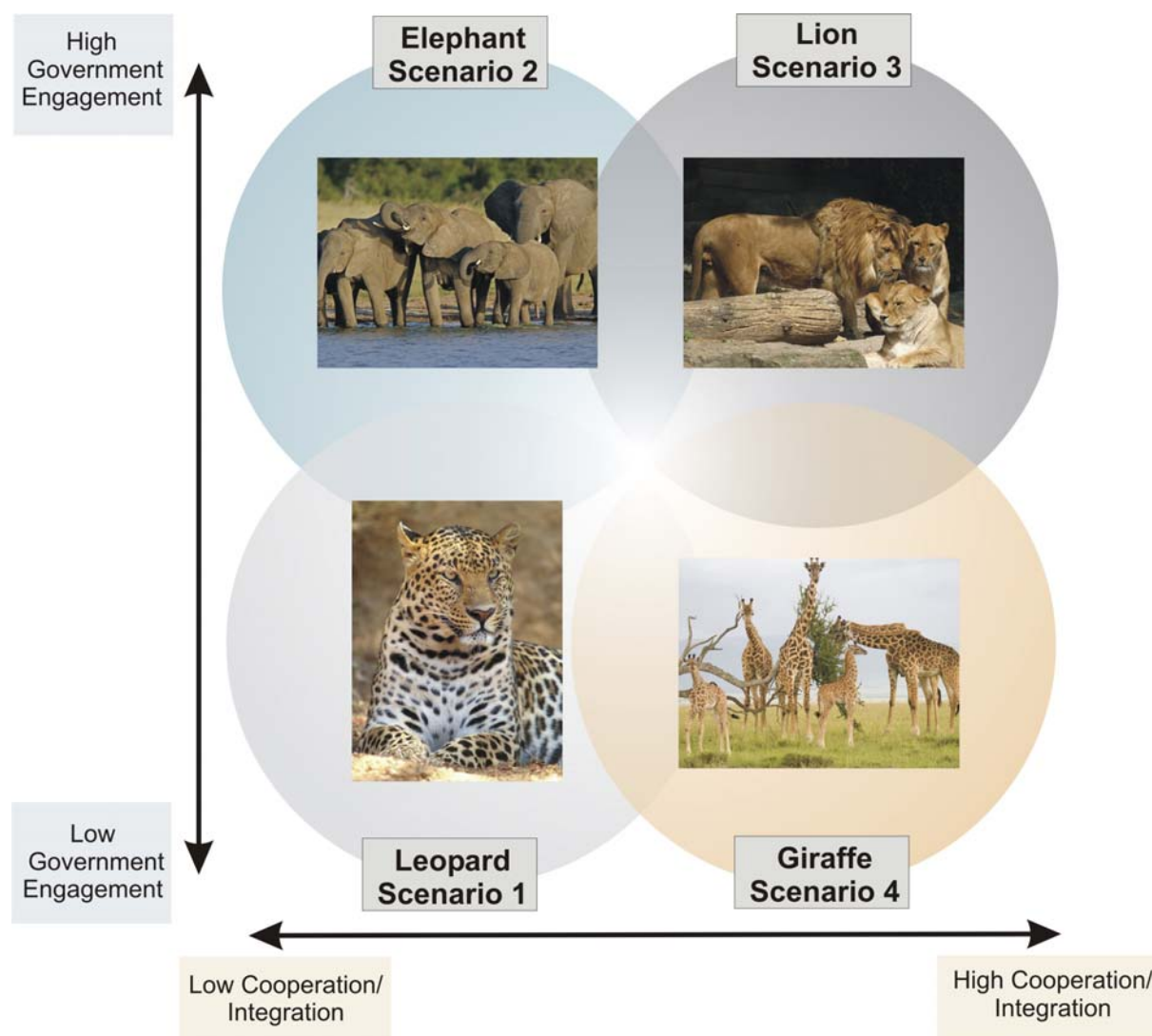
In Figure 1-2, the two axes lead to four overlapping scenarios or plausible storylines (remembering that all scenarios are *a priori* equally possible):

1. **Government Engagement.** Between two extremes of no government or a dictatorship, there is clearly a continuous spectrum of

“government engagement.” On the one hand, the policy environment may support competition in the private sector, unleashing the power of the markets. Or, governments can compensate for a lack of private enterprise capacity. This study has reflected on three key aspects of the government role in energy development: engagement, involvement, and interference. *Engagement* occurs when government is fully aware of what is going on, what the issues are, and what is required of it. It is doing what is necessary to ensure that energy systems function optimally. *Involvement* occurs when the government is carrying out a number of functions, possibly in competition with other providers. This may distort the market due to inequity of power. *Interference* occurs when the government’s actions or regulations are so obtrusive as to affect the market negatively; energy systems are not developed as effectively and efficiently as they could otherwise be.

Figure 1-2 Schematic representation of the four energy policy scenarios

Source: WEC Study Group



2. **Cooperation and Integration.** Alliances and cooperative initiatives between people allow them to survive and prosper. In some cases, cooperation is driven by mutual need to deal with a common problem; in other cases, it is driven by the need to share complementary resources and wisdom for mutual benefit. Whatever the underlying reason, some degree of cooperation and integration in energy development has always existed, sometimes only bilaterally, often regionally, and in some cases internationally, and on a global scale. This study has reflected on three forms of cooperation and integration: first, there is *government to government* collaboration in the form of treaties or

international agreements, for example on standards or rules of trade; second, there are *private-public partnerships* to design specific programmes or regulations to achieve specific policy goals; and third, there are *company to company agreements*, for example on the development of new technology or voluntary agreements to address specific business goals.

The nations of the world do not enjoy equal shares of available primary energy resources, know-how and technology, financial resources, human capacity, and raw materials. This inequality means there is always a dynamic for some degree of

redistribution. Ideally, this happens through a process of mutually beneficial cooperation between countries. While cooperation can occur naturally, driven by market forces, this is by no means true in all cases. There are numerous examples throughout history where countries went to war to gain or deny access to resources.

A nation poor in natural and financial resources has little to offer and is unlikely to attract support from the rich. The private sector will not invest there because it cannot earn returns commensurate with the risks, and the country is too poor to pay appropriate returns to attract investors. There is no transfer of know-how and technology and no development of human capacity. A poverty spiral often results unless there is some form of goodwill (e.g., Development Agencies) that bridges the gap and supports cooperation.

Many countries have entered into cooperative agreements to their mutual benefit. Exchanges of goods and services and international trade agreements are examples. In some cases, cooperative agreements are driven by a need to share common resources, such as the case with the development of hydropower (the river being the common element). The development of international power pools is another example where parties have come together for mutual benefit. Such arrangements often require specific international treaties or agreements to

enable them. However, there are also cases of little or no cooperation. In some cases, opposing political ideologies prevent cooperation.

Cooperation and integration also has a broad enough spectrum to embrace the aspirations and ideologies of all the WEC Member Committees and is material to the achievement of the 3 A's.

The core of this report is the assessment of the four policy scenarios within the context of these two axes. It details the policy choices and actions necessary to advance the achievement of the 3 A's.

1.3. Process

The methodology adopted in this report comprises group analysis with consistency checks using mathematical simulations. That means that, in essence, this is a modified Delphi study.⁶ It is also "normative" because it defines desirable characteristics of the future related to the WEC 3 A's (see Section 2 for more detail).

Regional groups, in a series of several workshops, developed descriptions of how the world would look in terms of the 3 A's, including relative changes in quantitative estimates of the chosen indicators. Any Delphi study may be faulted in having a built-in tendency to limit itself to conventional wisdom and prevailing

⁶ Energy to 2050: Scenarios for a Sustainable Future, IEA, Paris, 2003.

prejudices. Nevertheless, the significant strength of this study is that it is a “bottom-up” effort and thus represents “on the ground” thinking about the future and addresses important areas of uncertainty.

Each region developed its descriptions of the energy landscape using the key indicators, starting in 2005 and in 15-year intervals (2020, 2035, and 2050). Against this physical landscape (see Section 3), the regional groups then considered how these indicators could be improved so as to better achieve the 3 A’s.

Between July 2005 and April 2007, over 20 workshops were held in five WEC regions involving some 400 individuals representing the energy industry (producers, suppliers, users, and financiers), government ministries, academia, non-governmental organisations, and trade groups. Each region prepared a report containing results for its regions. These reports are summarised in this synthesis and are available online at <http://www.worldenergy.org>.

In addition to the regional groups, seven “specialist groups” supported the regional workshops. These specialist groups developed reports that provided:

1. The latest information on specific areas of importance pertaining to the overall study objectives of the regional working groups.
2. Consistency in the regional reports with established norms of the specialist

communities and feedback to the regional groups.

These specialist areas (their reports are available online - see Appendix A) are:

- ▶ Electricity generation
- ▶ Electricity end-use
- ▶ Stationary end-use
- ▶ Transport
- ▶ Energy-price drivers
- ▶ Investment and finance
- ▶ Climate change

The perspectives of these groups are summarised in Appendix B.

1.4. Mathematical Simulation

The heart of this study is a qualitative assessment of how policies and measures can meet emerging challenges and achieve outcomes closer to the 3 A’s than would otherwise be the case.

To provide the regional groups with a consistency check on their internal thinking, a mathematical simulation model⁷ of the energy

⁷ Energy Scenario Development and Climate Policy Analysis with the POLES Modelling System, Enerdata, Grenoble, 2007, a report prepared for the WEC study group on future scenarios.

sector was used. This provided quantitative baseline data to compare with the qualitative regional output, and iterations were made with the regional groups to identify potential inconsistencies and disagreements. In many cases, the model was altered to account for these inconsistencies, and its results were thus strengthened.

The model is a global simulation model for the energy sector with a year-by-year recursive simulation and partial equilibrium framework, endogenous international energy prices, and lagged adjustments of supply and demand by region. It has a hierarchical structure of interconnected regional and national sub-models (e.g., individual countries and sub-regions).

In brief, economic (GDP) and population growth rates are captured with assumptions about annual rates of growth for each region and sub-region. Technology trends and energy prices at the consumer level are the other two main drivers of energy demand. Energy intensity is calculated on the basis of energy demand and GDP projections to capture energy efficiency trends. Primary energy mix is derived either directly through assumptions about public and private investments, or through assumptions on parameters reflecting the necessary market conditions for these investments to be made by private decision makers. Greenhouse gas emissions result from projections for energy demand, fuel mix, and carbon capture and storage. Supply–demand tensions are addressed through exogenous inputs related to business development conditions. In the case of

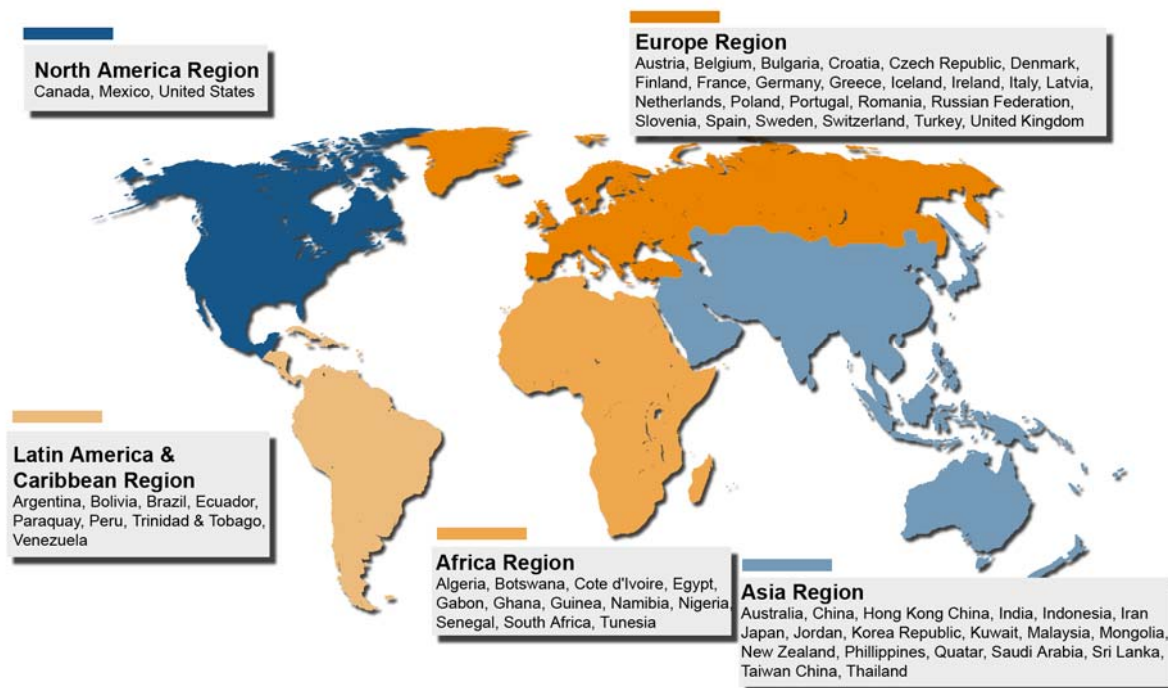
oil and gas, supply–demand tensions reflect the development of business conditions worldwide that push international prices up or down.

Inconsistencies between model projections and study group analyses fell into three general categories: the need for more precision in the qualitative storylines, the need to modify the quantitative assumptions in the model based on input from the regional study, and the need by one study region to accommodate developments in another region that affect global development and prices.

It is important to note that (1) the model is top-down, (2) this version of the model is aimed at projections (likely outcomes), and (3) it is aimed to a large extent at showing the need to reduce carbon emissions from energy use. The study group, on the other hand, was by definition looking at plausible (realistic) storylines (bottom-up) with a number of drivers in play.

For example, study group members questioned assumptions in the model about whether the Middle East can or will supply oil at the projected levels, whether China will decrease its coal use to the levels assumed in the simulation, and whether North America can produce oil at a level high enough to become a net exporter. This is not to imply that the model is wrong and the study group right, only that they come from different perspectives. Nevertheless, the results from the model do show, after iterations with the study group and modifications to identify key indicators and scenario constraints, the quantitative effect of different scenarios on the

Figure 1-3 Countries of the Member Committees participating in the workshops (67 Member Committees and 398 individual participants)



achievement of the 3 A's and on the qualitative elements identified in Section 3. The trends about achieving the 3 A's are addressed in Section 4.

1.5. The Regions

The study uses a bottom-up process integrating WEC's network of Member Committees (Figure 1-3). The world was divided into five regions:

- ▶ **Africa** - defined as the African continent, including Madagascar and the Cape Verde Islands.
- ▶ **Asia** - including East and Southeast Asia, Oceania, Central Asia, and the Middle East (Gulf States).
- ▶ **Europe** - includes the European Union (EU-27) and EFTA nations (Norway, Iceland, Switzerland, etc.), the Balkan countries, Turkey, Russia, Ukraine, and Belarus.

- ▶ **Latin America and the Caribbean** - South America, Central America, and the Caribbean nations.
- ▶ **North America** - Canada, Mexico, and the United States of America.

Each of the regions prepared their own analyses, which have been taken into account in this report and are separately available in their entirety (see Appendix A).

1.6. Structure of the Report

This report is organised as follows:

- Section 2 defines the 3 A's and outlines the study group's views on their current state of achievement.
- Section 3 gives a brief description of the four scenarios and labels them for easy reference.
- Section 4 presents findings at a global level and for each of the study's regions.

- Section 5 discusses likely outcomes in relation to the 3 A's in terms of the regions.
- Section 6 lays out the principal observations and conclusions.
- Section 7 is an action plan for energy sector stakeholders to better approach the achievement of the 3 A's.
- Section 8 briefly describes next steps and some of the areas where WEC might pursue this work in its next Business Cycle.

Additional information and access to other parts of the study are available at www.worldenergy.org (see Appendix A).

2. The 3 A's

"He knows nothing of these events but takes delight in their likeness, lifting onto his shoulders now the fame and fates of all his children's children."

Virgil (*The Aeneid*)

2.1. What are the 3 A's?

In its *Millennium Statement*,⁸ WEC established three sustainability objectives. Coined the 3 A's they are *Accessibility* to modern, affordable energy for all; *Availability* in terms of continuity of supply and quality and reliability of service; and *Acceptability* in terms of social and environmental goals. These objectives have provided the basis for WEC's work since then and they underpin the analysis of *Energy Policy Scenarios to 2050*.

In more detail,

- ▶ **Accessibility** means that a minimum level of commercial energy services (in the form of electricity, stationary uses, and transport) is available at prices that are both affordable (low enough to meet the needs of the poor) and sustainable (prices reflecting the full marginal costs of energy production, transmission, and distribution to support the financial ability of suppliers to maintain and develop these energy services). Getting access to the two billion people in the world without reliable commercial energy of any kind is the key.
- ▶ **Availability** relates to the long-term continuity of supply as well as to the short-term quality of service. Energy shortages can disrupt economic development, so a well-diversified

portfolio of domestic or imported (or regionally) traded fuels and energy services is required. Keeping all energy options open is the key.

- ▶ **Acceptability** addresses public attitudes and the environment, covering many issues: deforestation, land degradation or soil acidification at the regional level; indoor or local pollution such as that from the burning of traditional biomass fuels, or because of poor quality coal briquettes or charcoal production; greenhouse gas emissions and climate change on a global scale; nuclear security, safety, waste management, and proliferation; and the possible negative impact of the large dams or large-scale modern biomass developments. Clean technologies and their transfer to developing countries is the key.

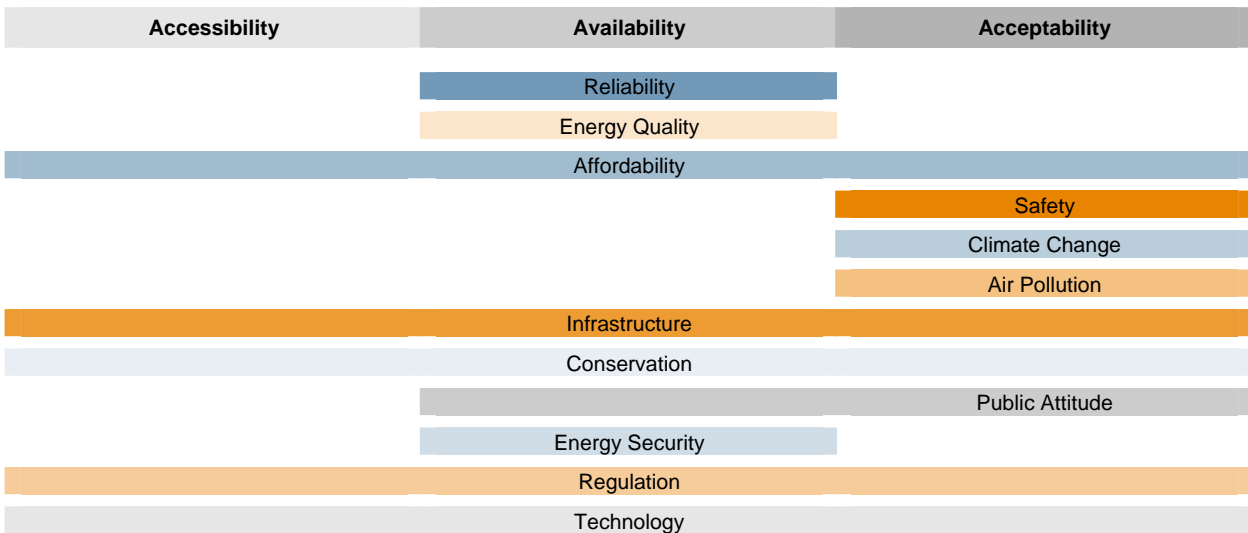
Figure 2-1 relates these 3 A objectives in a general way to some drivers, goals, or constraints commonly used by others (exact boundaries are flexible and subject to individual interpretation).

2.2. Where are we now on the 3 A's?

A starting point for this study is gauging the current state of the 3 A's globally and region by region. Opinions were collected from the WEC Member Committees across each of the major regions of the world. There was neither enough time nor manpower to accomplish the significant task of agreeing on an inter-regional comparison

⁸ Energy for Tomorrow's World - Acting Now, World Energy Council Statement, 2000, London.

Figure 2-1 A comparison between each of the WEC 3 A's and commonly used energy related metrics



of the present state of achieving the 3 A's, and so only qualitative future trends under four scenarios are discussed.

2.2.1. Africa

The African region rates itself low on the current state of achieving the 3 A's, and there are several reasons behind this assessment. Despite the fact that Africa is rich in natural resources, it is still the least developed region in the world overall. Three significant factors are the lack of investments in infrastructure, the lack of capacity in institutional capabilities, and a low capacity of the private sector to provide energy services. Rapid changes in energy prices and nascent markets represent a burden not only to the economies of the countries on both macro and micro levels, but also to the daily lives of the inhabitants, especially those living in remote areas.

There is no doubt that securing energy supplies on an affordable, accessible, available, and environmentally acceptable basis is one of the key elements for sustainable development in Africa over the coming decades. Moreover, cooperation among its regions on the one hand, as well as between the continent's countries and the whole world on the other, will play a significant role in realising the goals of reaching a minimum level of prosperity for Africans.

Accessibility

For Africa, only about one-third of its population has access to modern energy services (mostly in the northern African countries and in South Africa). The remaining two-thirds, representing a largely rural population, do not have the same level of access.

Availability

Oil currently dominates the primary energy mix and will likely remain the prime source of commercial energy for some time to come. Cleaner fossil fuels and large-scale regional hydropower (e.g., the Inga hydro projects on the Congo River) are realistic options for achieving energy security, sustainable economic development, and access to modern energy services. However, developing the enormous energy potential of Africa, thus improving the domestic supply of energy, requires huge investments. Energy efficiency measures in end-use, and improvements in production, transmission, and distribution of electricity in most of the countries are not being realised. This is clearly demonstrated in measures of energy intensity: the average energy intensity in Africa is 21 MJ/\$ (ppp), more than double the world average (about 10 MJ/\$ (ppp)). The main drivers of growing demand for energy in Africa are population growth, economic development, and improvement in standards of

The African region is currently low in terms of achieving the 3 A's. Significant factors are the lack of investments in infrastructure, the lack of capacity in institutional entities, and a low capacity of the private sector to provide energy services.

living. Nevertheless, energy supply, based on fossil fuels, is not corresponding to the demand, and thus poses problems.

Acceptability

Energy-related carbon emissions in African countries come mainly from thermal-power generation, road transportation, and direct burning of traditional biomass. Carbon emissions from commercial energy vary greatly among sub-regions. For example, North and Southern Africa emit more carbon dioxide than the other sub-regions, because their electricity generation from fossil fuels contributes almost 90% to the total.

Africa possesses significant resources of hydropower. Estimated potentials amount to more than one million GWh/year (economically feasible), 78% of which is concentrated in three countries (Democratic Republic of Congo, Ethiopia, and Cameroon). A key challenge is large-scale hydropower flooding potentially valuable rainforest and agricultural land, requiring the relocation of people.

Modern renewable energies, such as wind, solar, and biomass, are valuable alternatives for supplying electricity to rural populations. Wind power is becoming increasingly competitive in Africa (as elsewhere), and certain applications of solar thermal energy for water heating (solar water heaters), water pumping, cooking, and crop drying, in addition to photovoltaic applications, are being introduced gradually.

Desertification and deforestation are also of great concern, exacerbated by intense use of

traditional biomass, mainly fuel wood, for cooking and heating by most of the poor households.

Public awareness and concern for the environment has to become an important factor among decision makers in their strategies to evolve toward a sustainable path. With that perspective, more efficient, modern, and environmentally sound technologies should be introduced (by leapfrogging to the best technologies of the developed world) through technology transfer and deployment. For example, the use of cleaner fossil fuel technologies, and biofuels for road transport, could contribute greatly to a reduction in emissions.

2.2.2. Asia

Asia rates itself in the mid-range as to its current state of achieving the 3 A's, demonstrating that much improvement is needed. Most Asian economies are dynamic and their impact on the global energy market is considerable, especially with rapidly growing energy demand in China, India, and the other Asian "tiger" economies. The Asian region is diverse geographically, economically, and socially and its energy issues and concerns vary greatly from sub-region to sub-region.

Accessibility

Asia is a diverse region and demonstrates clear variations as a consequence of different economic, social, and political patterns. The developed countries in the Middle East, Korea,

Renewable and other non-conventional sources of energy must be encouraged in Asia, but developing countries are not obsessed with them, Accessibility and Availability having priority.

Japan, New Zealand, and Australia also have good and nearly complete access. The remaining countries of Central and Southeast Asia, India, and China are on paths to provide complete access while some areas will not achieve high levels of access for many years to come.

Availability

Asian countries have attained high economic growth (4.0% on average over the past 20 years), significantly exceeding that of the world economy (2.7%), thanks to an active cycle of investment and export brought about by foreign direct investment, as well as significant technology imports and a plentiful, high quality workforce. Thus, Asian countries have driven the world economy. In line with this economic growth, the Asian region (including the Middle East) has an extremely large impact on both the world's energy supply and its demand. Asia's share in the world's primary energy consumption is currently around 40% while its primary energy production is approaching 45% of the total. GDP growth rate and other economic aspects, as well as energy demand and supply, will to a large extent depend on the strength of the economies of China and India. These two countries alone account for one-half the global increase in energy use between 2000 and 2005⁹.

Energy production in Asia (as defined in this study) is now about 200 EJ/year, with the highest share being coal (35%), followed by oil

(30%), and gas (15%). The Gulf States have a 60% share of Asian production of oil and gas, while coal is 65%, 12%, and 12% from China, Australia, and India, respectively.

Developing Asian economies are fast becoming more motorised as their standards of living improve. This, in turn, will dramatically increase demand for oil as part of an expanded demand for transport fuel.

Acceptability

Increasing CO₂ emissions is an issue in a delicate balance with Availability. For some developed regions, this might seem to be less serious, yet it is also quite difficult to address. There are high hopes for the diffusion of renewable energy sources with little environmental burden, such as hydropower, geothermal energy, new renewable energy, and in some countries, nuclear power. However, it is difficult for renewable energy to compete on par with fossil resources for base energy supplies due to higher costs. Renewable and other non-conventional sources of energy must be encouraged, but developing countries are not obsessed with them, Accessibility and Availability having priority.

2.2.3. Europe

Europe rates itself as high with respect to its current state regarding all 3 A's, with some room for progress still available. Europe has sub-regions from major energy-consuming nations in the West to a major energy supplier in the East (Russia), with differing trends and current states

⁹ *World Energy Outlook 2007*, International Energy Agency, Paris, 2007

Across Europe there are wide differences in goals and objectives, including the definition of energy security (security of supplies in the West, security of demand for Russia).

as well as economic fabric and energy structures. Thus, within the region, there are wide differences in goals and objectives, including the definition of energy security (security of supplies in the West, security of demand for Russia).

Accessibility

Nearly all of Western Europe has 100% access. Eastward, the region shows increasingly lower levels of access, with several of the new European Union (EU) countries having lower levels. This will be addressed over the next few years.

Availability

There is an important interdependency between Russia and the rest of the European region. Russia, having enormous reserves of oil, natural gas, and coal, is in a unique position to maintain regional supply. That said, Availability in Russia itself is not perfect, although current investments are improving this position. At the supply end, Europe's Availability status is driven in large part by the level and conditions of imports from Russia. Recent experience with supply disruptions has demonstrated that this poses a risk to wider European Availability.

Acceptability

The combination of market-based instruments with strong regulation and public service obligations has meant that Acceptability has been driven to the top of the European agenda. The ethos of the market is strong, as are the regions' legislative capabilities to ensure that

social and environmental capital are protected. Many of the elements that will have a fundamental effect on Acceptability were not in force in 2005, for example, the EU Emissions Trading Scheme, or the revised emission limits (for SO₂, NO_x, and particulates) and the Large Combustion Plant Directive. Consequently, while Acceptability is high, progress is still occurring.

2.2.4. Latin American and the Caribbean

The Latin American and the Caribbean region rates itself in the middle with regard to its current state of achieving the 3 A's, indicating much work is needed. The nations of the Latin American and the Caribbean region are diverse in size, economies, natural resources, social development, and political systems. A specific feature of the Latin American and the Caribbean region is the high percentage of its population - over 75% - that live in urban areas. In terms of energy, the region is distinctive for its large renewable resources (mainly hydropower and biomass). Given the region's characteristics, the elimination of poverty through increasing Accessibility and Availability is a natural focus. Meeting the needs of transport, harnessing natural resources (particularly agricultural land and hydroelectric potential), and accessing modern sources, as well as any relationships to climate change, and Acceptability are priorities.

Accessibility

The region has a high degree of access to commercial energy, although this does not mean that energy usage is evenly disseminated, principally because of economic differences

Much work is needed in Latin America and the Caribbean to achieve the 3 A's. The region is distinctive for its large renewable resources (mainly hydropower and biomass). Meeting the needs of transport, harnessing natural resources (particularly agricultural land and hydroelectric potential), and accessing modern sources are priorities.

between countries and sub-regions. Nevertheless, governments have been investing to overcome these shortcomings. Urban areas are mostly covered by energy supply networks and delivery services of electricity and gas, mainly liquefied petroleum gas (LPG), although some urban areas have natural-gas supply networks. Important efforts have been made to extend electricity supply to remote rural areas and small communities, either by network extension or by local generation. Another feature that contributes to Accessibility is low electricity tariffs and gas prices for low-income populations, as practiced in most of the region.

Availability

In overall terms, the region has substantial sources of energy, although its distribution among the various countries is far from uniform. Of particular note are the major heavy-oil reserves in Venezuela. The Atlantic drainage basin also has huge hydropower potential, of which less than half has been harnessed, as well as a major capacity for producing biomass for electricity and biofuel.

Annual per capita consumption of energy varies significantly from country to country, being 300 GJ/capita in Trinidad and Tobago and only 10 GJ/capita in Haiti. Another indicator pointing to the highly diverse nature of the region is the energy intensity of the different countries, varying from 36 MJ/\$(ppp) in Trinidad and Tobago (a large exporter of natural gas) to 4 MJ/\$(ppp) in Barbados. The Latin America and the Caribbean region's average value is around

11 MJ/\$(ppp), slightly above the world average of about 10 MJ/\$(ppp).

Acceptability

The region has a number of achievements in the use of biofuels and hydroelectricity. For example, Brazil is responsible for the most extensive global programme introducing biofuels into its energy matrix (the ethanol programme) and charcoal in iron and steel production. In this latter context, renewable biomass is favoured over that derived from the extraction of native wood. The region's dedication to bio-energy was recently underlined with the development of biodiesel as an alternative fuel, principally for transport. As a result, the region's carbon emissions per unit GDP are comparatively low.

On the other hand, some parts of the region still demand large quantities of firewood for residential as well as industrial purposes. Besides being an inefficient and polluting energy source, the origin of this resource is mostly native forests, not always close to the point of consumption - implying high costs for the transport of firewood or charcoal. This process also destroys a valuable CO₂ sink. The most serious aspect related to the use of firewood, including charcoal production, is the accelerated deforestation of certain regions with enormous damage to the environment, which significantly contributes to the region's CO₂ emissions. Unconditional use of this source of energy is due to poor Accessibility to modern sources of energy.

In North America Acceptability is a large issue, particularly in the areas of large future energy developments (unconventional and enhanced oil development, new nuclear power plants, development of frontier lands (oil, natural gas, and hydropower). The challenge is to implement more effective public information and education programmes, as well as more effective approval and regulatory processes to ensure reliable and timely improvements in energy infrastructure.

Environmental questions of a local nature, such as those related to hydroelectric generation or monocultures as energy sources, are common in the majority of the region's countries. Questions of a global nature, particularly emissions from burning fossil fuels, are common to all countries, all of which must introduce measures to reduce such global impacts.

2.2.5. North America

The North America region rates itself as above the middle with regard to its current state of achieving the 3 A's and still has to make some progress. In the context of the 3 A's, the dominant one for North America is Acceptability. The challenge for both Availability and Acceptability is to implement more effective public information and education programmes, as well as more effective approval and regulatory processes to ensure reliable and timely improvements in energy infrastructure.

Accessibility

For North America, access to abundant energy resources, combined with its successful development and utilisation, has contributed to its overall economic development and prosperity. In all three countries (Canada, Mexico, and the United States of America), extensive energy resources, with appropriate stewardship and management, will continue to contribute to economic prosperity of the region for the next half-century. This is particularly true in the United States and Canada; in Mexico, however, there is greater concern. Some 5% of the Mexican population has no access to

electricity. In addition, in a few isolated communities in Canada and the United States, access is an issue either because of isolation or because of cost.

Availability

In North America, there are two issues with respect to security of energy supply. The first is related to the high degree of dependence on imported oil from other regions of the world, which is perceived to be unreliable. This is a problem especially for the United States, because it imports 50% of its oil. The second issue is the combination of reliability and vulnerability of existing energy systems to maintain a reliable supply - because of supply-demand tightness and vulnerability to extreme climatic (e.g., hurricanes) and terrorist attacks. Although 95% of the Mexican population has access to electricity, this supply is unreliable and the present level of reliability is only on the order of 15% that of the rest of North America.

Lastly, there is a related issue in all three North American countries arising from challenges in the approval of energy plants and infrastructure. Local opposition, referred to as the NIMBY (Not In My Back Yard) phenomenon, is increasing. Demand has continued to grow, while supply has not kept pace, which results in situations where the supply-demand balance has become very tight, with consequent increase in vulnerability to supply interruptions. Supply being curtailed or voltage being reduced (for electricity systems) is increasingly being implemented to maintain supply. In addition,

aging energy plants and infrastructure need to be upgraded to meet rising standards of technical or environmental performance, or simply replaced at their end-of-life.

Acceptability

In North America, Acceptability is a large issue, particularly in the areas of large future energy developments, such as:

- Unconventional and enhanced oil development
- New nuclear power plants
- Development of frontier lands (oil, natural gas, and hydropower)

3. Four Scenarios in a Nutshell

"The unexpected happens - and prepare for it!"

Margaret Thatcher

3.1. Scenario 1: Leopard (Low Government Engagement - Low Cooperation and Integration)

The Leopard is chosen as a name as this large animal is silent and enjoys the more solitary existence characteristic of this scenario. It looks out for itself with very little cooperation, scanning the landscape for opportunities and it is swift to act when they arise, but acts alone. Most of the time, it remains within its territory and interacts very little with other animals. It protects its territory and does not share its food resources with others of its species. This scenario might be thought of as being *laissez-faire* or simply restrained.

This scenario has the least government engagement and global or regional cooperation and integration. Domestic economic development is the primary driver, underpinned by domestic energy security. World market forces and free trade tend to be hindered by national barriers that protect local production, which may lead to higher prices and lower efficiencies. Government engagement is constrained and there are few levies or subsidies. Many industrialised countries are reluctant to pursue structural reforms and continue to rely on welfare policies, increasing the level of unemployment and limiting economic dynamism. Most developing countries see their economic growth limited by the lack of equitable

policies in terms of gender equality, education, telecommunication, electricity, water, health, and infrastructures (road, pipeline, and electricity transmission).

The low level or lack of government engagement and international cooperation results in less-than-optimal reactivity to external events such as energy shocks or worldwide recessions. However, the capacity of market forces to foster new technologies mitigates the impact on those countries with domestic resources to fund innovation. The lack of international cooperation reinforces the poverty spiral for countries already impoverished. It will affect developing nations in different ways.

The transfer of know-how and technologies is relatively constrained under this scenario. Few international cooperation treaties encourage such exchanges and few market drivers justify exchanges between highly developed and less developed countries. Less developed countries have neither the market capacity to justify entrepreneurial investment nor the wealth to pay expected returns on investments. Energy intensity tends to be relatively high, due to low energy efficiency, both on the supply side and more so on the consumption side of the energy balance.

In this scenario, there are no rules of trade for energy services established under the World Trade Organisation and no international post-Kyoto treaty on climate change. Many actions also compromise the environment in other ways. As some countries go on their own to ensure their domestic energy supply, more

internationally traded oil and gas become available for the rest of the world and may alleviate to some extent shortages and price volatility.

Finally, most policy actions initiated under this scenario probably benefit “have” nations rather than “have-not” nations, as there is little, if any, cooperation or proactive policies to aid the poorer, less developed areas of the world.

3.2. Scenario 2: Elephant (High Government Engagement - Low Cooperation and Integration)

The Elephant is a social animal with a strong hierarchical nature to the family. However, while the family unit is strong, there is little inclination to cooperate between families, and families strive for self-sufficiency. The Elephant also has a very good memory. In spite of a very structured existence, the elephant is slow to adapt. This scenario might be thought of in terms such as governance, or nationalistic energy security.

This scenario has significant government engagement but minimal international or regional cooperation and integration. The first priority is energy security to support economic activity and growth. Governments intervene and nations take responsibility for their energy security (short-, medium-, and long-term) through such actions as diversification of

primary energy sources, development of indigenous resources, controlling exports, and/or securing imports by bilateral negotiations. In response to potential oil and gas shortages, governments may take specific steps to ensure national and/or regional security of supply through actions such as:

- Conservation programmes
- Coal- or gas-to-liquid projects for countries with appropriate resources
- Enhanced and more expensive oil-recovery projects such as oil sands and oil shale
- Biofuel projects
- Bilateral development of offshore energy resources
- Nuclear power programmes
- Large-scale hydropower
- Infrastructure investment
- Subsidies for renewable technologies.

As some countries move to ensure domestic energy supplies, more internationally traded oil and gas might become available for the rest of the world and alleviate or even curtail shortages. Oil price shocks may be less likely. On the other hand, bilateral agreements might have just the opposite effect.

Countries will act independently to enhance their energy security, such as relying on synthetic liquid fuels for transport, but this comes with a price. For the rest of the world, oil not sold

elsewhere is available, somewhat mitigating the price spikes caused by supply constraints. This scenario does not end globalisation, but it creates challenges for international traded goods (e.g., petrochemicals) that have become cheaper under globalisation and free trade.

A strong sense of national pride and strong incentives drive the development of domestic capacity and supporting capabilities. The transfer of know-how and technologies is relatively constrained under this scenario, as the primary focus is inward toward domestic needs. Under this scenario, the role of international institutions (e.g., the United Nations) in driving global programmes is less effective than it might otherwise be. Countries are much more concerned about their own interests. This inward focus has a negative impact on economic growth, as some domestic solutions are sub-optimal and/or reliant on older and less efficient technologies.

Many of the actions also compromise environmental issues:

- More reliance on coal without carbon capture and storage increases carbon emissions from CTL projects.
- An increasing share of nuclear power in the energy mix requires more sophisticated and reliable storage for the additional nuclear waste.
- More agricultural land and fertiliser use is devoted to biomass production.

- Populations are displaced and methane emissions are increased by large-scale hydropower development.
- Decreases in energy use combined with an increase in renewable and nuclear energy are positives with respect to climate change. CTL and oil shale projects need to be coupled to carbon capture and storage (CCS) to avoid increased greenhouse gas emissions.

3.3. Scenario 3: Lion (High Government Engagement - High Cooperation and Integration)

The Lion is chosen for its sociability. Adults transfer experience and expertise to the young. Gathering food through hunting is a very cooperative effort with careful planning, clear identification of the goal, and executed in a controlled, disciplined manner. All members of a pride share in the results. This scenario might be thought of in terms of energy globalism or global coherence.

This scenario has significant government engagement and significant international or regional cooperation/integration. Governments actively share their experience and expertise, primarily in achieving basic human rights and alleviating poverty. In some cases, this strengthens regional integration initiatives. Countries cooperate on key energy issues of

sustainable development. The global concerns of greenhouse gas emissions and energy poverty are the subjects of intense negotiations and strong international agreements and programmes. Yet measures to mitigate concerns may often conflict with each other (e.g., greenhouse gas emission mitigation may raise prices and thus affect access for the poor).

Reducing energy poverty and introducing efficient and effective technology boosts energy use in developing countries. This puts pressure on energy use in the developed world. This may be a short-term effect if the reduction in energy poverty enhances global productivity. The stimulus for regional integration or bilateral cooperation enhances prospects for the poor. The reduction of energy poverty comes with increased demand, putting pressure on energy supplies and infrastructures.

There is a stimulus to develop technologies appropriate to the needs of developing markets and time-to-market is shortened, although still significant. Funding such development work and funding the implementation of successful technologies in developing countries needs to be encouraged through proactive, cooperative energy policies, bilateral and regional inter-government agreements, and specific fiscal incentives. The technology focus helps to mitigate some energy constraints. This is a time of innovation and pushing back technological boundaries because government is funding marginal ventures.

International donor agencies and development banks play a big role. Aid is linked to environmental goals. Intellectual property is more effectively protected, deployed, and transferred.

Better control of energy resources improves local, regional, and global prospects. Greenhouse gas emissions remain under check with performance targets implicitly or explicitly collectively agreed on and respected. Managing environmental impacts, and especially emissions, has a significant cost that has a negative impact on GDP, thereby making it harder to reduce energy poverty.

Thanks to the avoidance of energy shocks and stimulation of developing country economies, GDP growth may be dynamic. However, benefits are offset by the cost of greenhouse gas emissions mitigation.

This scenario leads to burden sharing between the haves and have-nots at a national and an international level.

3.4. Scenario 4: Giraffe (Low Government Engagement - High Cooperation and Integration)

The Giraffe, the tallest animal on earth, is chosen because it strolls calmly across the plains and sees both danger and opportunity at

great distances. Giraffes are also very adaptable and can exist on their own. Leadership is a very loose arrangement with no established overall hierarchy. The giraffe is not constrained by a strong social structure and individual animals have great freedom of choice. The giraffe is essentially an entrepreneur and can readily adapt to different circumstances. It is also able to defend itself, either by running away on its long legs (avoiding conflict) or by using its legs as weapons. This scenario might be thought of as market driven or enterprise dominated.

This scenario has minimal government engagement but significant international and regional cooperation and integration. In this scenario, the primary driver is economic development. The main preoccupation is freeing up global markets to promote GDP growth through affordable energy and international trade. There is increased reliance on market mechanisms, including in the developing world. Government involvement is constrained (predominantly directed to market regulation, when necessary) and there are few levies or subsidies. There are few restrictions on global movement of goods and services.

Little is done by governments to proactively avoid energy shocks and their effects on all countries, and what little is done tends to be short-term oriented. On the positive side is the capacity of market forces to foster new technologies and the role of improved private sector governance and fewer access limitations. The poor benefit from the open border policies

and possibly from new World Trade Organisation agreements.

The opening of markets and the reducing of trade barriers encourage a freer flow of goods and services. Entrepreneurs actively seek to enter emerging markets, stimulating innovation. Market driven interchange leads to more rapid transfer of technology and experience. International market opportunities stimulate new energy-technology development and methods to protect intellectual property, which plays a very important role in enabling countries to profit from these international market opportunities.

Those countries slow to liberalise their markets are left behind as the entrepreneurs go where they see better opportunities. Appropriate rewards are expected for entrepreneurial risks and this results in a downward poverty spiral for the already impoverished because they cannot afford the necessary returns to stimulate investment in the private sector.

Environmental awareness is enhanced at local and regional levels, but increasing reliance on coal and increased energy demand increases greenhouse gas emissions. Carbon capture and storage tends to be limited in developing countries because of a lack of financial and technological resources and government inaction.

Because of the lack of proactive government policy intervention and anticipation, severe energy shocks probably happen, but the open

world economy is resilient and rebounds from recessions.

Success in this scenario depends on the market delivering technologies to increase security and reduce greenhouse gas emissions and other environmental impacts. Overall energy and economic performance could be better in this scenario, but it may be less equitable than in Scenario 3.

3.5. Key Indicators

To assess how proactive policies can meet the challenges of the physical, social, and economic world while achieving outcomes closer to the 3 A's, this Report applies the following key indicators to the four policy scenarios:

- Growth in gross domestic product
- Demographic growth
- Energy intensity
- Primary energy mix
- Total primary energy required (TPER)
- Greenhouse gas emissions
- Supply–demand tensions (the balance between the two)
- Oil
- Gas
- Coal
- Nuclear power
- Renewable energy

- Non-commercial or traditional energy

GDP growth (or economic growth) examines how regional and global economic development changes. Together with population growth, economic growth represents a clear energy-demand driver. Over the long-term, global economic growth has historically followed a consistent upward trajectory (ignoring short- and medium-term periods of stagnation or deflation in some countries), but the rate of increase in that growth in real purchasing power parity terms has declined. Maintaining positive rates of economic growth in all regions of the world is therefore an essential scenario backdrop.

Demographic growth examines how regional and global demography change over the period to 2050. Historic trends and existing forecasts suggest that population continues to grow and peaks at some point prior to 2050. The migration of people to large cities is a second element that needs to be addressed. Both are key drivers of growth and the demand for energy services and they will vary according to each scenario.

Energy intensity is measured as the energy required to produce a unit of economic activity (e.g., GDP on a PPP basis), allowing for the explicit consideration of technological development. While reductions in energy intensity are a sign that energy conversion, distribution, and end-use technologies have become more efficient, these gains may also lead to increased energy demand.

Energy mix captures the balance of primary energy sources in a country's portfolio, hence measuring diversity and possible security of the

supply. This is done using concentration indices that, for an improvement, should show a growing range of energy sources, either in terms of the number of energy carriers or the sources of supply within and outside the country (e.g., securing gas from several countries rather than from one). A decline shows a narrowing of the supply base. This is an important indicator in assessing availability and in parallel with supply and demand tensions clearly describes market conditions.

Total primary energy required (TPER)

describes the total energy supplies, usually in tonnes of oil equivalent, for the satisfaction of energy demand in an economy or the world as a whole. Driven by socio-economic factors (and technological change), this is a key “top-line” indicator of an economy’s energy scene. We should not underestimate the importance of technological change which can affect energy demand directly but also indirectly in terms of an economy’s energy intensity.

Greenhouse gas emissions need to be measured over time within a country, a region or globally. These are clearly linked to TPER and energy mix, but we also need to recognise the role of technologies, particularly those that successfully reduce the link between emissions and energy demand growth, e.g., fossil fuel use with carbon capture and storage, nuclear power, renewables including biofuels.

Supply–demand tension measures the relative balance between the demand for an energy carrier (solid, liquid, gas, or electricity) with its

source. Tensions capture the state of the market for each commodity and indicate likely or possible energy price changes in each region or market. These have a pivotal role in determining market development and mapping futures. High tension signals imbalance while low tension suggests good balance.

4. Results of Analysis

"The significant problems we face today cannot be solved at the same level of thinking as when they were created."

Albert Einstein

Section 4 describes the results from the scenario analyses using 2005 as the departure point. Relative winners and losers and the dilemmas in each scenario are presented. Quantitative values from the model are given where appropriate. Access to the five regional reports in their entirety, along with the model results, are noted in Appendix A.

4.1. Scenario 1: Leopard

4.1.1. Global Story

Gross Domestic Product

In this scenario, most regions see slower economic growth compared with recent years, due to a lack of coordination, inadequate physical and institutional infrastructure, and a high degree of uncertainty - all unfavourable in general to private investment. Research and development, as well as technology transfer, are relatively constrained compared with today. Economic growth improves first in North America (around 2035), while Latin America and the Caribbean see improvements possibly only late in the period. There is a high degree of uncertainty about the future economy in Europe, centred on differing perceptions in Western Europe, Eastern Europe, and Russia. Most African countries see their economic growth decreasing due to inadequate governmental policies related to energy-capacity development, electricity and water development, and non-energy infrastructures (roads, telecommunications, health, and education), and declining investment from within the country or from outside investors.

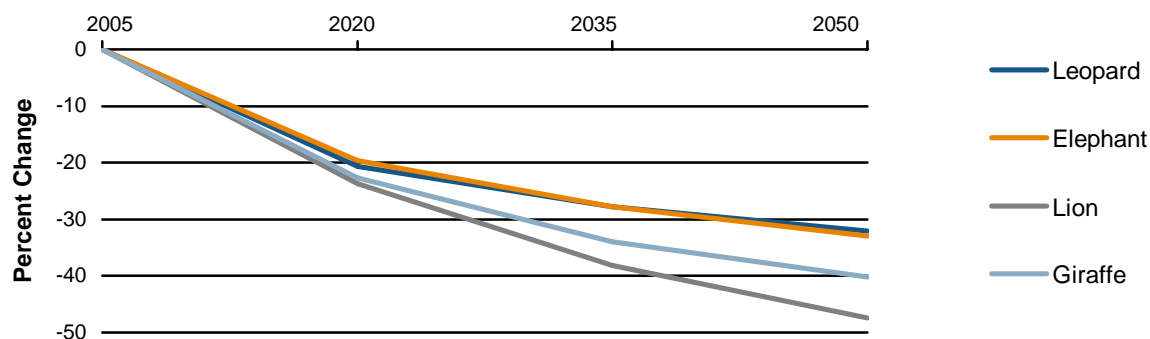
North America still sees its economy growing, albeit initially at a slower rate than today, and then increasing its rate of growth later in the study period, driven primarily by the United States. Asia does not see the situation depicted in this scenario as positive, and the lack of proactive government or international strategic interventions make it impossibly difficult to secure necessary energy resources.

Population

Global population growth maintains its present trends. Asia, the dominant contributor to population growth today, sees an annual growth rate of 0.8%, resulting in a population increase from 3.9 billion today to somewhat more than 5 billion in 2050. The IEA WEO2007 predicts China's population to reach only 1.46 billion in 2030 from 1.31 billion today, while India's is predicted to grow "much more quickly and reach the overall level of China by 2030"¹⁰. In Africa, little change from the present growth rate of 2.2 % is noted until 2035 when the population growth rate decreases due to a slowing of economic growth, a decrease in living standards, and the general expansion of poverty. The decline is contrary to the usually expected case because there is increasingly an emancipation of women. In Latin America, the current population growth rate of 1.9% decreases until 2020 and then remains constant to 2050 without active government measures to control birth rates and overall mortality rates increase with respect to present levels. North

¹⁰ World Energy Outlook 2007, International Energy Agency, Paris, 2007

Figure 4-1 Percent change in global energy intensity (E/GDP) for the four scenarios from the mathematical model projections



America sees its already decreasing growth rates persisting out to 2050. Europe is already experiencing a downward trend with several countries having negative growth rates.

Energy Intensity

Africa and Latin America see energy intensity increasing because of a deteriorating energy infrastructure combined with limited global cooperation and little local or international investment. Asia is generally more optimistic about this scenario and believes existing trends will continue to drive down energy intensity, and this occurs at an average annual rate of about -0.8% to 2050. The IEA WEO2007 focus on China and India indicates energy intensity continuing to fall in India and resuming a decline in China after increasing earlier in this decade¹¹. North America and Europe see new technologies introduced regardless of the constraints in this scenario and intensities continue to be reduced, although at rates lower than in the other scenarios.

The mathematical model shows global energy intensities decreasing by more than 20% by 2020, about 30% by 2035, and over 35% by 2050, compared with 9.7 MJ/\$ppp in 2005 (see Figure 4.1).

Energy Mix

Asia and Europe see the mix of energy technologies as unchanging from today

throughout the period to 2050 because of weak incentives and as countries look inward. The IEA WEO2007 reference scenario sees continuing growth in all fuels except for biomass and waste, while China's coal demand, with a significant coal to liquids market, is seen as growing as fast as TPER, keeping the share of coal constant¹². Africa is pessimistic and sees the inward looking aspects implying that countries focus only on existing energy within their borders. Latin America also sees a decrease because of the difficulty of attracting significant capital outlays demanded by large projects. North America is optimistic that the diversification of energy sources will continue, emphasising the introduction of low carbon technologies.

TPER

With the exception of North America, the early demand for energy (2020) in other regions, driven mostly by population increase, results in an increase in the growth of overall energy requirements. In some cases (e.g., Africa), an increase in energy intensity exacerbates this trend. North America sees a correlation with economic growth, and when combined with declines in energy intensity, TPER remains at current levels.

The model shows primary energy (modern) production in this scenario increasing over that of today by 35% in 2020, 65% in 2035, and doubling by 2050 (see Figure 4-2). TPER levels

¹¹ World Energy Outlook 2007, International Energy Agency, Paris, 2007

¹² World Energy Outlook 2007, International Energy Agency, Paris, 2007

Figure 4-2 Percent change in primary energy production for the four scenarios from the mathematical model projections

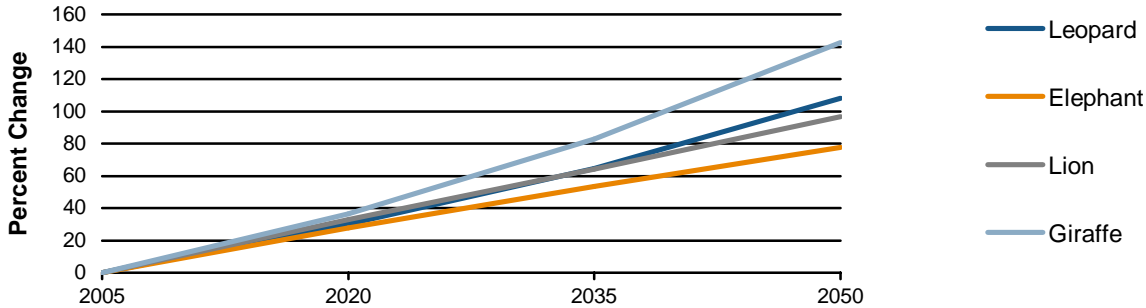
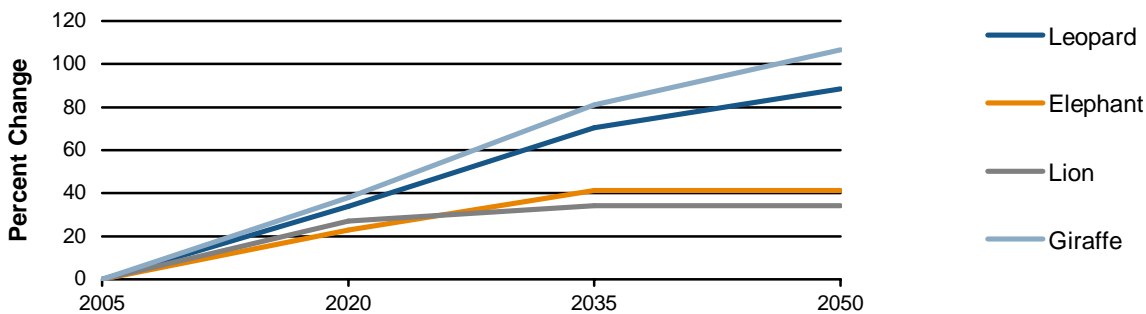


Figure 4-3 Percent change in greenhouse gas emissions (as CO₂ equivalent) for the four scenarios from the mathematical model projections



in 2005 were just under 500 EJ. The IEA WEO2007 reference scenario shows China’s and India’s primary energy needs alone doubling by 2030, results that are consistent with this study, bearing in mind that the growth rate in other countries will be lower.

Greenhouse Gases

Greenhouse gas emissions increase in all regions initially and decrease only in later periods, first in Europe and then in the Americas - in the former with the introduction of significantly more hydropower, and in the latter with more non-carbon-emitting sources of electricity.

By comparison, the quantitative results from the model indicate CO₂ emissions increasing between 30–40% in 2020, over 70% in 2035, and nearly 90% in 2050 (see Figure 4-3).

Supply–Demand Tension

Oil. Tension increases in all cases except near 2050 in North America and Europe due to the introduction of new oil production technologies.

Gas. Tension increases everywhere but becomes neutral in Asia and North America between 2035 and 2050 as new exploration technologies are introduced.

Coal. For the most part, all regions see present trends continuing, supported by ample supplies; however, Africa and Latin America see immediate increases followed by stabilisation.

Nuclear Power. Without strong government involvement, study participants see the current uncertainty and ambivalence continuing, with a slight increase in tension in Europe due to increased demand.

Renewable Energies. Without government engagement, all regions (with the exception of Africa, where an imbalance is due to low international cooperation) see present trends continuing. In North America there is the possibility of a gap between demand and supply after 2035. Renewable energy from wastes (wood waste and sawdust, sugar-cane bagasse, rice straw, municipal waste) should increase since their utilisation involves neither high technology nor large capital investments.

Non-commercial Energy. The results here are mixed, with Africa seeing an increase due to more poverty and dwindling forests. This is not considered an issue in North America today and is not expected to be so in the future.

4.1.2. Winners, Losers, and Dilemmas

In a relative sense, oil and coal suppliers fare better in this scenario, because without cooperation and government engagement, there are likely to be fewer regulations aimed at increasing fuel security or reducing greenhouse gas emissions.

Correspondingly, achieving the 3 A goals is likely to suffer, including reductions in greenhouse gas emissions. Because government is an essential player in any nuclear power renaissance, this is less likely to happen and on a relatively smaller scale if it does. Finally, lower cooperation and integration internationally has a negative effect on international finance and investment, particularly in energy systems and products.

The major dilemma in this scenario is the limited policy instruments or partnership opportunities to address the negative outcomes. It is likely the situation could become unstable and major disruptions in the energy sector could result, affecting entire economies.

4.2. Scenario 2: Elephant

4.2.1. Global Story

Gross Domestic Product

This scenario produces more positive economic results, in general, than the Leopard scenario, but Latin America sees government efforts as insufficient, while Africa goes further and sees government interventions distorting the markets in the 2035–2050 timeframe with deleterious effects on Africa's economies. North America is more optimistic and sees growth increasing by the 2035–2050 timeframe, largely driven by the United States, with Canada and Mexico being more pessimistic. In Latin America, this scenario represents the situation existing in most of Latin America until the early 1990s when democratically elected governments began to flourish.

Population

Most see population growth as stable, with Asia continuing to show rates increasing slightly and Latin America seeing demographic growth decreasing as per recent trends. The combination of low economic growth and insufficient government actions leading to less emphasis on controlling birth rates means that

the growth rate remains stable. The population growth rate in Africa declines in the period between 2035 and 2050 as poverty persists, birth rates actually decrease with the emancipation of women, and economies decline.

Energy Intensity

Intensity decreases in Asia, Europe, and North America as new technologies are introduced and governments push strongly for improvements in energy efficiency. Africa sees the benefits of these actions earlier, but then cannot sustain its gains due to its lack of access to new technology because of low international cooperation. In Latin America, an increase in the ratio of thermal power generation versus more efficient hydropower generation and an increase in agricultural and industrial exports to compensate for dependence on foreign high technology goods also delays improvements and increases energy intensity.

The model indicates energy intensities in this scenario decreasing 20% by 2020, about 30 % by 2035, and nearly 35% by 2050, compared with today (see Figure 4-1).

Energy Mix

The diversification of the energy mix improves generally, except in North America where it is already diverse and stays that way. In Latin America, expansions are seen in natural gas, biofuels, wind, and solar heating early in the period and later toward 2050 with the substitution of nuclear power and coal for

hydropower. Governments diversify the energy supply for security reasons. The same situation is generally seen for Africa, except that, at the end of the period, the expansion of the mix stagnates due to limitations in financial resources and limitations on technology transfer because of the lack of international cooperation. Asia sees an increase in the mix because of government mandates shifting away from fossil energy.

TPER

The rate of growth in the TPER increases early in the period and then stabilises and even decreases later, due primarily to government pressure and improvements in energy efficiency. In Latin America, this trend is exacerbated by a falling GDP growth rate.

In the model, primary energy (modern) production in this scenario increases by about 30% by 2020, between 50–60% by 2035, and around 80% by 2050, reflecting the perceived influence of governments introducing policies that reduce energy consumption, primarily through improvements in energy efficiency (see Figure 4-2).

Greenhouse Gases

Due directly to government engagement in this scenario, North America and Europe see a reduction in the growth of greenhouse gas emissions compared with the Leopard scenario. In contrast, Africa and Latin America do not believe governments by themselves have the power to curb emissions. Limited international

cooperation is a major impediment to accomplishing meaningful emissions reductions. In Asia, emissions increase until late in the period when any realistic application of high efficiency technologies has an impact.

The model for this scenario leads to lower future CO₂ emissions than the Leopard scenario: around a 25% increase by 2020, just over a 40% increase by 2035, and staying level until 2050 (see Figure 4-3).

Supply–Demand Tension

Oil. In general, tension around oil decreases in comparison with the Leopard scenario; however, Africa does not see governments being strong enough to affect the situation and sees tension increasing the same as in the Leopard scenario. Perhaps the biggest change from Leopard is in North America, where governments have an impact on creating alternative fuels (e.g., biofuels, oil from sands).

Gas. Gas tension is for the most part seen as the same as the Leopard scenario. Demand increases, but new exploration meets increasing demand to some extent. Much is unknown about the future of this energy source. Gas is assumed to maintain its position in all regions.

Coal. With government engagement, coal loses some of its importance in Europe. Other regions show little or no change, with coal continuing to be exploited as an abundant and relatively inexpensive energy source.

Nuclear Power. The active engagement of governments in this scenario increases the

supply of nuclear power, and therefore tension, as demand may outstrip industry's ability to provide the necessary manufacturing infrastructure. This increase in tension is a clear and recurring signal that everyone sees strong government engagement as absolutely essential if nuclear power is to play a significant role in the global energy mix. Africa is the exception, and sees strong international cooperation (technology and financing) as essential for the development of nuclear power on the continent. Thus, for Africa to benefit, a combination of government engagement in other regions is required together with regional cooperation and integration in Africa.

Renewable Energies. With government engagement and encouragement, everyone sees renewable energy demand increasing, along with tension due to inability to keep up with demand, and as a response to public concerns about the effects of climate change.

Non-commercial Energy. Little change is seen from the Leopard scenario. Africa sees population growth increasing the tension here and as before, this is not an issue now in North America or Western Europe and not seen as one in the future. This may be an issue in Asia, and somewhat less in Latin America, with negative effects relating to deforestation.

4.2.2. Winners, Losers, and Dilemmas

Because of the stronger role of government in this scenario in comparison with the Leopard scenario, people who need access to energy and energy services are likely to benefit.

However, because there is no change in international cooperation and integration, international financing and investment in energy products and services is not improved. There is also lower relative energy security as a result of supply regions not cooperating to an optimum extent with demand regions and nations. Energy industries might also suffer due to a lack of uniform regulation across regions and nations.

A dilemma in this scenario may be how Africa and Latin America would reduce carbon emissions, as high government involvement by relatively weak governments could prove to be counterproductive.

4.2.3. Oil Production Limits

For illustration, the model examines the effect of limits on oil production by the Gulf States. Rather than using the 45 million barrels per day in 2035 in the model, 25 million barrels per day were used. In this case, the model shows no change in energy intensity from this scenario. Primary modern energy requirements and thus CO₂ emissions are only slightly lower than the results for the Leopard scenario in all time periods.

4.3. Scenario 3: Lion

4.3.1. Global Story

Gross Domestic Product

This scenario produced the most optimistic estimates in many respects, especially in the development of the global economy. In Asia, the

high growth rates of today continue with the combination of significant government engagement and high degrees of cooperation and integration. In Africa, these conditions help with technology transfer and technology leapfrogging, as well as financing. In Latin America, there is concern that active government engagement leaves insufficient room for private enterprise, both domestic and foreign, which can bring managerial and technical improvements to the region and, therefore, an increase in economic efficiency. This effect is felt more intensely in the later period.

Population

Demographic growth continues at stable rates in Asia and is somewhat higher initially in North America. In Africa and Latin America, population growth rates decline after the initial period due to achieving higher GDP/capita ratios, therefore improved standards of living.

Energy Intensity

In this scenario energy intensity declines worldwide. As population growth stabilises in Latin America and declines in Africa, and standards of living improve, energy efficiency gains take place and, despite new energy demand, lead to lower energy intensity. In Asia and Europe, a large number of government initiatives leads to increases in energy efficiency and lower energy intensity. Canada and Mexico expect improvements to the levels already seen in the United States where the degree of improvement is expected to continue.

The model indicates energy intensities decreasing by almost 25% by 2020, nearly 40% by 2035, and close to 50% by 2050, compared with today. These are significant improvements over the projections in the Leopard and Elephant scenarios (see Figure 4-1).

Energy Mix

The mix of energy sources, which became more diverse under government support in the Elephant scenario, diversifies further with global cooperation and integration. The effects are felt in Africa after the initial period (2035). In Asia, the curbing of energy demand and a shift from fossil fuels to renewable and nuclear energies is primarily responsible for improvements in the energy mix. In Latin America, government actions support oil, gas, biomass, and hydroelectric shares in the first two periods (2020 and 2035) and only later, with increased scarcities of oil and gas, does the mix change (after 2035).

TPER

There are dramatic improvements over the previous two scenarios. After initial increases, there are decreases in all regions.

The mathematical model suggests that in this scenario primary energy (modern) production increases by over 30% in 2020, between 64–70% by 2035, and nearly 100% by 2050. This is higher than with government engagement alone, mostly because international and regional cooperation and integration leads to more economic growth (see Figure 4.2).

Greenhouse Gases

A strong international framework results in significant decreases in greenhouse gas emissions. Emissions rates in this scenario initially increase in Asia, Africa, and Latin America (more oil and gas) and then decline after 2035. In Latin America, coal substitutes for hydropower initially. The rates decline in Europe and are mixed in North America, being higher in Canada, lower in Mexico, and stable in the United States, the dominant player in the region. The introduction of significant renewable and nuclear energies in Asia before 2035 leads to a reduction in emissions there.

The model shows this scenario with slightly higher CO₂ emissions earlier, increasing by around 30% by 2020, before decreasing relative to other scenarios and being almost 35% higher in 2035 and in 2050, compared with 27.6 Gtonne in 2005 (see Figure 4-3).

Supply–Demand Tension

Oil. There is less tension for oil in this scenario, especially late in the period toward 2050. This is because of decreasing oil availability, more use of renewable energy, and falling demand from the transport sector toward the end of the period (2050) in Africa. North America and Asia see a movement toward non-conventional oil late in the period. Latin America sees scarcities late in the period, as new discoveries cannot keep up with demand.

Gas. Tension increases in Asia, Latin America, and Africa due to energy demand growth,

although it eases in Latin America and later in Asia as supply systems begin to catch up with demand. Canada and Mexico have similar views, although the United States sees demand and tension decreasing (stable markets and supplies).

Coal. Africa, Asia, and North America (United States) show increases due to growth in energy demand. This is partly due to CTL technology supplying transport fuels, although decreases in tension occur later in the period as nuclear and renewable power become more pronounced.¹³ Coal is abundant and meets demand (i.e., no tension) in Latin America. Europe sees coal losing importance throughout the period despite the expected development of carbon capture and storage technologies.

Nuclear Power. There is a nuclear power resurgence with the drivers being GDP growth, government incentives to reduce carbon emissions and high cooperation among limited suppliers.

Renewable Energies. As in the other scenarios but more so, renewable energy grows substantially in this scenario, tripling in Europe by 2050. Thus, the range of renewable resources is in continual tension. A combination of government incentives, increased cooperation, and environmental concerns provide the drivers. Europe sees a 21% share for this scenario in 2050 in contrast to the much higher targets set by some governments, but

this share could be reached sooner. Hydropower and biomass are likely to have increased tension by the end of the period in Latin America and in Africa, due to the use of scarce agricultural land for food crops.

Non-commercial Energy. Not an issue in North America and Europe, it decreases in significance and tension in Asia and is neutral in Latin America as governments provide incentives for the expansion of commercial fuels. In Africa, the introduction of new alternative technologies now eases tension from 2035.

4.3.2. Winners, Losers, and Dilemmas

Because this scenario envisages both high government engagement and international cooperation and integration, all 3 A's benefit, especially access to energy for the poor and less developed areas. Regional carbon emissions control regimes are more likely to be linked to a global method which sets a carbon value high enough to address greenhouse gas emissions but low enough to avoid undue impact on the growth potential of different regions. This scenario thus optimises the possibilities for the revitalisation of nuclear power, as well as for the introduction of large amounts of renewable energy, especially biomass and biofuels, wind, and solar (photovoltaic and thermal).

It is not clear if there are any losers in this scenario, as governments and industry are believed to be capable, when working together, to solve the problems of energy supply and environmental concerns. However, this scenario

¹³ Canada and Mexico see no tension in this sector in this scenario.

creates a dilemma almost unique to it: as things begin to work effectively on a regional scale, issues will then be raised over how to transition this cooperation from a regional to a global scale and manage the result. If the world is to have a sustainable energy future, international cooperative schemes on an unprecedented scale (e.g., on the rules of energy trade in the WTO) will likely have to be devised and enforced.

4.4. Scenario 4: Giraffe

4.4.1. Global Story

Gross Domestic Product

Every region sees this scenario as favourable to economic growth, driven by private sector cooperation and interdependence and strong cooperation, perhaps benign, between nations. This is limited only in Latin America by the inadequacies of existing infrastructures requiring significant government action, which does not occur in this scenario.

Population

Neutral to declining rates of growth occur everywhere, although still positive. Higher migration to large cities and improved standards of living lead to declining birth rates.

Energy Intensity

Neutral to declining rates occur everywhere. This trend begins later in Africa and Latin America as technology transfer protocols take

time to implement and create measurable effects.

The model leads to decreasing energy intensities although somewhat less than in the Lion scenario: 23% in 2020, 36% in 2035, and 40% in 2050 (see Figure 4-1).

Energy Mix

The energy mix in this scenario is more diversified everywhere, although later in Africa and North America. In the former, this is due to the delayed development of renewable energy without strong government incentives. In the latter, it is because of non-conventional oil and biofuels becoming more dominant. Nuclear power does not enjoy a resurgence under this scenario because of the low government involvement.

TPER

This continues to increase but begins to stabilise late in the period, most notably in Latin America and Africa, due mostly to decreasing energy intensity.

In the model, primary energy (modern) production for this scenario increases between 30–40% by 2020, over 80% by 2035, and over 140% by 2050, the result of unfettered cooperation and technology dissemination by industry (see Figure 4-2)

Greenhouse Gases

Due to the lack of strong government involvement, Asia, Africa, and Latin America see greenhouse gases increasing until perhaps late

in the period. In Asia, this increase is a factor of 3 to 4 in 45 years with 70–80% being from the economies of China and India.

The model for this scenario predicts CO₂ emissions much greater than with any scenarios involving significant government involvement: almost 40% more in 2020 than 2005, about 80% more in 2035, and almost 110% more in 2050. These levels are the highest of all scenarios (see Figure 4-3).

Supply–Demand Tension

Oil. Tension tends to increase due to high oil prices driven by robust economies. The exception is Europe, which sees markedly decreasing demand because of those very same high oil prices.

Gas. Tension in the gas markets increases in all regions due to demand growth, industrial competition for the resource, and high oil prices. Europe sees the growth of high efficiency, gas-powered electricity generation in response to high oil prices. Latin America sees natural gas scarcity late in the period due to demand outstripping supply.

Coal. Tension is seen to increase in all regions, primarily as a result of weak government controls on emissions. Africa sees increased supplies of imported coal in its energy mix, but tension remains high during the period. The increase in tension in North America is lower than elsewhere as coal markets are well established and supplies are large. High

efficiency coal (and gas) electricity generation result in increasing tension in Europe.

Nuclear Power. In the absence of strong government involvement, nuclear power grows more slowly than in the Lion scenario, but tensions increase because demand outstrips supplies that are too small because of government inaction. Asia sees growth in all three periods nevertheless; with the exception of North America, all regions believe that growth will increase significantly in the last period to meet growing demand in expanding economies. North America believes that the demand will be met earlier and growth will stabilise.

Renewable Energies. As in other scenarios, renewable energy demand outstrips supply, thereby increasing tension with little government ability to reduce these tensions. Africa sees cooperation enabling the introduction of renewable technologies. In Latin America, tension results in this scenario from a dilemma with hydropower, being desirable but forecasting difficulty for expansion due to environmental concerns (land use, loss of biodiversity, and resettlement). Solar and biofuels continue to expand.

Non-commercial Energy. The results with this energy source are mixed, but in all cases, tension decreases with time as the private sector provides more modern energy services in electricity and transport. This is not surprisingly slowest to happen in Africa. It is again not an issue in North America or Western Europe.

High degrees of cooperation and integration, together with a healthy degree of engagement by governments are constructive for Africa.

4.4.2. Winners, Losers and Dilemmas

Due to the high degree of cooperation and integration on an international scale, energy companies prosper more in this scenario than in the Leopard or the Elephant scenarios.

However, because governments are crucial to any effective global regime for reducing carbon emissions, any attempt to do this will meet with less success than in either the Elephant or the Lion scenarios. Little progress is also foreseen in this scenario on access to energy and energy services for the poor regions of the world.

An obvious dilemma with this scenario is how, with less government engagement, to provide guidelines and keep markets in check.

4.5. Regional Perspectives

4.5.1. Africa

Africa is the second largest continent of the world with an area of 30 million km², representing 15% of the world's area and having a population of 865 million representing 13.5% of the world's population. Despite Africa being a rich continent in terms of abundant natural resources, diversified geographical regions, and different climate conditions, it is the least developed area in the world. The most important challenges are inadequate health care, education, a lack of clean water, energy poverty, very limited investments, weak infrastructure, lack of institutional capabilities and capacity-building, and inefficient utilities.

Increases in energy prices and rapid changes in energy markets represent a burden not only on the economies of the most African countries on both macro- and micro-levels, but also on the daily life of the inhabitants, particularly those living in scattered remote areas. Securing affordable modern energy supplies and services is a necessity for sustainable development. Governments are required to strengthen cooperation and integration among its sub-regions as well as cooperation between the countries of the continent and the rest of the world. The role of private sector investment in accelerating development is vital, along with international cooperation.

Scenarios without high degrees of cooperation or integration are not favourable for Africa. A situation without government involvement means that all 3 A's will not be achieved. With government engagement alone, Accessibility will be sustained, Availability maintained, and Acceptability will decline.

High degrees of cooperation and integration, together with a healthy degree of engagement by governments (see Scenario 3: Lion) - when mitigated by appropriate policies - are constructive for Africa to 2035, as Accessibility and Availability will improve and Acceptability is kept from becoming worse.

High degrees of cooperation and integration (regionally and internationally) alone are applicable for Africa for the period 2035–2050, and even before then for those countries with strong private sector participation. Achieving

Developing Asian economies are becoming motorised societies as their standards of living improve, which in turn brings an increase in the demand for transportation fuel, oil and coal liquids and additional stress on Acceptability.

Acceptability and Availability, as well as maintaining Accessibility, is subject to rationalising governmental engagement and balancing international cooperation for all parties (shared benefits). Due to the effect of large, fast emerging economies on the global energy market, the perspective for this scenario from 2035–2050 could be revised and adjusted at intervals of time (e.g., every 5 years) to cope with any rapid changes of the market.

Maximising the use of natural gas, associated gases, and promoting LPG, are essential for securing access to modern energy services, particularly in rural areas, as well as creating new job opportunities at local village levels. Promoting the use of nuclear power is considered one of the main solutions for the long-term energy sustainability of Africa.

4.5.2. Asia

The population of Asia continues to grow at the annual average rate of about 0.8% over the period to 2050. Though China's population growth rate decreases towards 2050, the average growth of India is assumed to continue at about 1.1%. As a result, the population of Asia will increase from 3.9 billion in 2005 to more than 5 billion in 2050.

Due to market-oriented economic reforms and progress in information technology, the world economy has become globalised at a rapid pace and has achieved an annual growth rate of 2.7% over the past 20 years. In particular, Asian countries have attained high economic growth

(4.0%), far exceeding that of the world economy thanks to the virtuous cycle of investment and export brought about by foreign direct investment, as well as active technology imports and a plentiful supply of a high quality workforce. Thus, Asian countries have been the driving force for the world's economy, and Asia has an extremely large impact on the world's energy demand. The Asian share of the world's primary energy consumption is currently around 40%, while primary energy production is around 45%, positioning Asia (including Middle East) as an energy supplier with large supply reserves for the future.

With the support of its surging domestic demand, China's economy will sustain high rates of growth, and India has recently been rivaling China. By 2035, the economic growth rate of India might be higher than that of China and over the period to 2050 India may attain 7–8%/year sustained GDP annual growth (primary energy growth rate of India might be 5–6%/year). Thus, every aspect of this region (e.g., GDP growth rate, energy demand and supply, etc.) will for the most part depend on these two countries.

Asia's primary energy demand will grow at an average of 2–3%/year to 2050. They require some 15 billion tons of oil equivalent or 625 EJ/year, about 3 times more than the current level of about 200 EJ/year. About 60% of the increase is for China and India. Fossil fuels account for almost 70% of the increase in consumption, therefore are expected to be an important energy resource until 2050. Coal is

assumed to have the lion's share of the increase, followed by oil and natural gas.

Developing Asian economies are becoming motorised societies as their standards of living improve and this trend will continue. This in turn brings an increase in the demand for transportation fuel, oil, and to the extent that oil is scarce, coal conversion to liquid.

Production of oil in Asia (i.e., Middle East, China, etc.) decelerates in the coming decades; however, total global production would meet increasing demands if combined with innovative, unconventional sources, thus avoiding an interruption of supplies, such as examined in Section 4.2.3. Neither China nor India produces enough oil or natural gas to meet its needs today and the shortfall is expected to grow¹⁴.

Natural gas is assumed to decline faster and shortages are made up to some extent with unconventional gas sources (tight gas sands, fractured shale, coal-bed methane, and methane hydrates).

Coal resources are much more abundant. As oil and gas supplies tighten, proven technologies for production of synthetic fuels through gasification/liquefaction of coal will be put into place as necessary.

Electricity supply expands along with the standard of living, boosted by its economic growth. Over the period to 2050, electricity

consumption increases five-fold as a result of growing demand. In oil-equivalent terms, electricity generated by nuclear power is assumed to rise from 160 mtoe (million tons oil equivalent) in 2005 to the level of 1,200–1,500 mtoe in 2050, for an average annual growth rate of about 5%. Nuclear power plays a vital role in Asia, especially in China and India, which is predicted to account for about 70% of the nuclear power increase in Asia.

There are high hopes for the diffusion of renewable energy sources with little environmental burden, such as hydropower, geothermal energy, and new renewable energy (solar, wind, and biomass). Their share in primary energy production is anticipated to increase from 2% in 2005 to around 10% in 2050. However, collectively, they are not going to rank on a par with fossil resources as pillars of the base energy supply, due to their continuing high supply cost. New renewable sources of energy have to be encouraged, but developing countries cannot afford to be obsessed with it.

4.5.3. Europe

The region realises that for a long time its culture and politics have inclined toward international orientation and cooperation. Looking from a world perspective, energy consumption per capita in the region is at a medium high level. An emissions trading regime has come into force in the region, and finding the right balance between regulation and market now matters. Most important to Europe is

¹⁴ *World Energy Outlook 2007*, International Energy Agency, Paris, 2007

Europe has for a long time been inclined toward international orientation and cooperation. An emissions trading regime has come into force and finding the balance between regulation and market has priority. Europe believes it must significantly reduce carbon emissions to balance energy development in the developing world.

accommodating the world at large, especially in China and India. This means that Europe (possibly with North America) believes it must significantly reduce carbon emissions.

A number of general reflections can be made about the scenarios:

A decreasing trend in energy intensity is in all scenarios. Energy supply, however, is increasing in three of the four scenarios and is only stabilised in the Lion scenario. Here, we witness the beginning of a decline in the EU, which makes it the only storyline consistent with the direction of ambitious decisions taken by the EU heads of state in the spring of 2007. We should keep in mind, however, that this development is largely due to the high levels of economic growth in the period concerned. Russia sees improved levels of energy intensity of around 3% in all scenarios from 2020 onward, but the rate of decrease slows because of the lower economic growth expectation in all scenarios.

It is to be noted that, for the EU, these levels are the highest in the high cooperation and integration scenarios over the whole period, where they remain more or less around the 50% level of 2005, and attain 60% in 2050 in the Lion scenario. This might seem illogical, as the larger drive for bilateralism in the low cooperation and integration scenarios (Leopard and Elephant) should produce better results. For the EU, however, the high cooperation and integration worlds are those where the discount rates for nuclear and renewables are the lowest because

of a more certain and predictable world, which would improve the competitiveness of these energy forms and the self-sufficiency of the EU. Differences in oil, gas, and coal prices between the high and low cooperation scenarios are too low to significantly alter improvement in competitiveness of nuclear and renewables in the high cooperation scenarios. Bilateralism seems to tend to secure the supply from abroad rather than 'forcing' the development of insufficiently competitive endogenous resources. As for Russia's self-sufficiency, that is at 100% in all cases.

Coal in the European energy mix will be mostly for electricity generation. In that respect, it has to compete with other primary sources of electricity, mostly nuclear and renewables (including biomass). Unless supported by dedicated policies, coal use in electricity generation is determined by the costs of the various competing technologies, the prices of inputs, and the discount rate applied in the economic calculation. Socio-political constraints on nuclear power and renewable energy development might be larger than assumed.

In all four scenarios, oil loses its share of the energy supply, even with relatively similar shares in all four. The decline is highly dependent on the transportation sectors.

Gas is the stable story, maintaining its overall share in 2050 in all scenarios. Remarkable as well is that Russia is and will be a largely gas-based economy. It is yet unclear, however, what this means for exports. Although the model

indicates that for all scenarios the share of gas in 2050 is close to its share in 2005, it increases greatly between 2005 and 2020 and declines afterward. The reason is linked to the competitiveness of gas in some specific end-uses and sectors, which is somewhat independent of the scenarios. Thus, gas is very competitive everywhere for peak and mid-load electricity generation, in particular in tandem with renewables, leading to a stable share of gas in electricity generation. In addition, gas is very competitive for thermal uses in residential, tertiary, and industry sectors as well, leading also to stable and high shares in these markets. The reason why the gas market share increases strongly up to 2020 is because of further rapid development of gas distribution infrastructures in those European countries not so well equipped today. It decreases afterward because of less rapid development (if not stagnation) of stationary thermal end-uses as compared with electricity uses and motor fuel. In general terms, it is questionable whether Russian gas exports in the period 2035 to 2050 can service Europe when these would total some 2.5 times today's levels, while at the same time some 200 billion m³/year of exports to Asia are assumed.

Nuclear power is revitalising in the EU in all scenarios, passing coal in almost all scenarios. This is not happening equally in Russia where the performance of coal is stronger. It could be worthwhile to explore further what this nuclear power revival in the EU would mean in terms of building programmes and fuel-cycle facilities.

The most optimistic scenario for renewable energy (Lion) gives the EU a 'modest' 24% share, which is much lower than targets of 40–50% mentioned by some EU governments. It should be noted that the perspectives for hydropower are rather similar from one scenario to another. This means that almost all the increase in renewable energy comes from biomass, solar, and wind (geothermal energy is included with hydro, but at a very minor level). The only possibility to increase this share of renewable energy further would be to decrease dramatically the demand for electricity and thermal uses, while maintaining the output of wind, solar, and biomass at the same absolute levels.

4.5.4. Latin America and the Caribbean

The region has a strong interest in the use of biofuels and hydroelectricity. For example, Brazil is responsible for the most extensive global programme introducing biofuels into its energy matrix (by the ethanol programme). In this context, renewable biomass is favored over that derived from the extraction of native woods. Not only is the Brazilian programme responsible for the development of the domestic market and technologies, resulting in a high degree of efficiency along the entire ethanol production chain, but it also enabled the country to develop the sector that supplies foreign demand on a competitive basis. The region's dedication to bio-energy was recently underlined with the development of biodiesel as an alternative fuel, principally for transport.

Latin America and the Caribbean require substantial investments to successfully increase energy independence and security.

However, the region still demands large quantities of firewood for residential and industrial purposes. Besides being an inefficient and polluting energy source, the origin of this resource is mostly native forests, not always close to the point of consumption - implying high costs for the transportation of firewood or charcoal. The most serious aspect related to the use of firewood, including charcoal, is the accelerated deforestation of certain regions with enormous damage to the environment. In the context of the evaluation of the 3 A's, this has a negative impact on Acceptability to the extent that the unconditional use of this source of energy is due to poor Accessibility and limited local Availability of modern sources of energy. In terms of primary sources for electricity generation, the region is undergoing a process of diversification in its energy mix. Coal will likely become an alternative as technological advances mitigate the local air-pollution effects of generating electricity from coal.

Other sources of energy could become more expensive (principally natural gas) with highly volatile international prices and heavy demand competition from developed countries. Furthermore, capital expenditures involved in harnessing some renewable energy sources and nuclear energy are still very high and their payback period very long (primarily in the case of nuclear power).

With regard to transportation, there is a need for more hybrid vehicles (conventional and the plug-in type), as well as pure electrically driven cars and buses. This would diminish the region's dependence on oil products, and improve the

environment from the reduction in greenhouse gas and other emissions. The region faces enormous expansion and technological progress possibilities in terms of transport and related subjects. Its telecommunications sector offers an increasingly large range of products and services that reduce the need for moving people and printed information from one place to another, and consequently, should entail a significant reduction of energy consumption.

Investments in biofuels exports expand and as the interest in this product grows in other countries. A major effort on the part of the region is needed to leverage its competitive advantages, both existing and potential, in biofuel production. From the standpoint of imports, advances in technology for clean power generation from coal allow the region to import this product because a significant part of its own reserves are of comparatively low quality.

The region has to make substantial investments if it is to successfully increase its energy independence and maximise local potential (natural gas in Bolivia and Trinidad and Tobago, oil and natural gas in Venezuela, hydroelectric power in Brazil and Colombia) to the benefit of the region as a whole. The socio-economic question is also fundamental, principally with respect to economic growth and income distribution because this provides the population with access to products of a higher quality and more advanced technology, thus making for the more efficient use of energy.

Finally, by 2050, fossil fuels will still play a major role in the energy supply structure. In most

scenarios, their share is expected to be reduced to less than 50%, but the absolute value of their consumption is probably a lot higher than at present. By 2050, scarcity of conventional oil and gas is believed to be one of the energy market's main features. There may be a need to avoid or to sequester greenhouse gas emissions. Practically, little more hydro development is possible, although equipment manufacturers are still in business due to old power plant refurbishment. Biomass production for energy purposes is likely to meet competition from edible biomass needs, at least in some areas. So, even though the demographic pressure is very much reduced, the energy balance requires very significant improvements of end-use efficiency and of primary energy transformations.

4.5.5. North America

The issues of prime importance for North America are grouped under six themes: energy supply; end-use; environmental impact; technology; global market reform and financing; and policy and coordination.

Energy Supply

In North America, the need for energy supply continues to expand. It is projected that demand growth in North America will be more than 30% by 2030 and could be as much as 50-70% by 2050. To meet this growth, North America will need to continue increasing its supply from all traditional sources, including oil, natural gas, coal, nuclear power, hydropower, and various renewable sources. In addition, strong support is

needed for new types of energy supply, including non-conventional sources, such as oil sands, oil shale, coal-bed methane, tight gas, and methane hydrates. There is also a need for additional supply from biofuels.

Supply of oil from conventional sources in all three countries is projected to decline. Canada's overall production of oil, however, is projected to increase as the oil sands are further developed. For Mexico, undeveloped oil reserves are substantial, especially in the sedimentary basin on the east side of the Sierra Madre Oriental and in the Gulf of Mexico. However, investment in exploration and development of these reserves has lagged, as profits from Pemex finance other government priorities. This raises the question of needed fiscal reform so that oil production can increase. Over the next half-century, it is projected that North America will continue as a net importer of energy, especially oil. North America may move toward regional self-sufficiency, if there is a deterioration of global trade relations, especially with oil-exporting nations. Furthermore, self-sufficiency would be in a North America regional context.

It is expected that energy supply from fossil fuels in North America will change substantially over the next half-century. There will be increasing reliance on coal and associated facilities for producing hydrocarbon derivatives (gaseous and liquid fuels).

End-Use

North America's use of energy is high, compared with other regions of the world.

Over the next half-century, it is projected that North America will continue as a net importer of energy, especially oil.

Substantial opportunities exist for using energy more efficiently (see Appendix B, sub-sections 10.2.1 and 10.2.3). The potential for reducing energy use and implementing energy efficiency and conservation practices is substantial and deserves a high priority. The greatest potential is in transport systems, especially land transport, an area in which demand is growing most rapidly, in both absolute and percentage terms. This problem is made more acute because of the dependence on petroleum derivatives. In the United States and Canada, roughly 80% of people live in urban areas. Therefore, substantial opportunities exist to make cities and their residents more energy efficient through investments in comprehensive, integrated, public transportation systems. There are also opportunities for urban planning that emphasises densification and the development of business and residential clusters, thereby reducing commute times and energy use.

Environmental Impact

Climate change is a major environmental concern. In North America, as elsewhere, public awareness of the seriousness of climate change and the need for action is rapidly growing. Systems and technologies which help reduce the dependence on, or emissions from, continued production and use of fossil fuels are being seriously considered, with nuclear power, hydropower, and various renewable sources including biofuels playing a bigger role in the energy mix. Additionally, there are efforts to develop more fuel-efficient vehicles, plug-in hybrids, and hydrogen-powered vehicles. Carbon capture and storage is a promising

technology to mitigate greenhouse gas emissions, the main focus being storage in geologic formations. Other options include the increased use of agricultural and forest sinks.

Technology

In meeting the challenges of the 3 A's, the process of selecting and implementing emerging technologies needs to improve. In particular, selection should be based on a comprehensive appreciation of the long-term consequences of such developments and with full participation of all stakeholders - government, industry, research institutions, and universities. It is also important that commitments be made for promising technologies and that the process of bringing such technologies into operation be accelerated.

Global Market Reform and Financing

Free trade for North America is an important consideration for all three countries, especially energy. Canada and Mexico rank number 1 and 2, respectively, in exporting oil to the United States. There is also extensive trade in natural gas, uranium, coal, and electricity. Despite the abundance of indigenous energy resources in North America, there will be major energy trading outside North America. For example, the North America region will continue to be a major net importer of oil and natural gas and a significant net exporter of coal and uranium. In North America, a variety of financing instruments is available for energy development and the risks are manageable, but some utility assets are discounted due to low returns (particularly in transmission) and it is difficult to attract

investment to new projects. While the United States and Canada are generally considered attractive locations for such investment, Mexico is in a different situation which is related to the ownership and control of resources. As a consequence, Pemex's financial resources are constrained for exploration and development activities, resulting in the decline of proven oil and gas reserves. There is a need for national fiscal reform to overcome this financing challenge to accelerate oil and gas supply.

Policy and Coordination

Regional coordination is important for all three countries. The three countries entered into a North America Free Trade Agreement (NAFTA) in 1994 that provided opportunities for increased trade and the progressive removal of trade barriers. In 2005, the three countries entered into a subsequent agreement, referred to as the Security and Prosperity Partnership (SPP). Both agreements provided opportunities for increased trade in energy commodities, including progressive interlinking of the energy systems.

5. Regional Achievement of the 3 A's

"Treat the earth well: it was not given to you by your parents, it was loaned to you by your children."

Native American proverb

This section summarises regional perspectives on achieving WEC's goals of Accessibility, Availability, and Acceptability. All regions are shown, in the figures in this section, as if they were at the same starting point today (2005). Their progress toward full achievement of the 3 A's is measured in units of change (positive or negative) relative to their starting point. All regions were asked to measure their expected progress from today under different scenarios on a scale of 0-10, where 10 is full achievement. For example, if they believe their progress is at 5 against any goal today, full achievement would be a relative change of +5. This allows for relatively consistent comparison on progress against goals between regions.

5.1. Scenario 1: Leopard

5.1.1. Africa (Figure 5-1)

The combination of low government involvement and low cooperation restricts regional integration

projects, transfer of technologies and know-how, access to foreign funds, and access to alternative energy sources, making improvement in Accessibility and Availability problematic. Renewable energy is neither competitive nor incentivised and CO₂ emissions continue to rise. Poverty worsens, exacerbated by a lack of appropriate social and energy policies. Demand for non-commercial fuel sources increases.

5.1.2. Asia (Figure 5-2)

Low but steady economic growth facilitates the gradual extension of the main electricity grid, improving Accessibility slowly and meeting energy demand and energy security expectations. Oil and gas reserves may last longer due to decelerating demand growth. Due to low government engagement and low cooperation and integration, nuclear power generation and renewable energy cannot be developed, leading to lower energy Availability in the long-term. Energy security is first priority with

Figure 5-1 Relative change from 2005 for Africa for the Leopard scenario

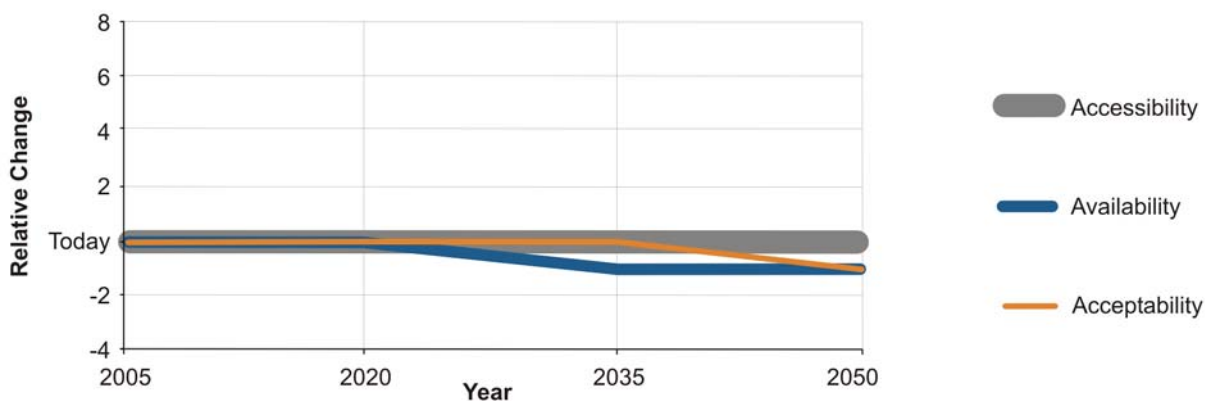
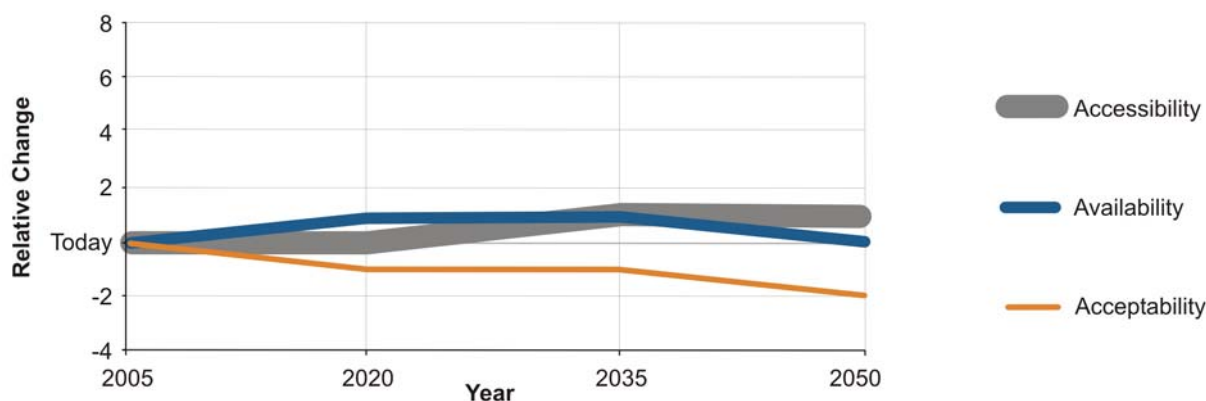
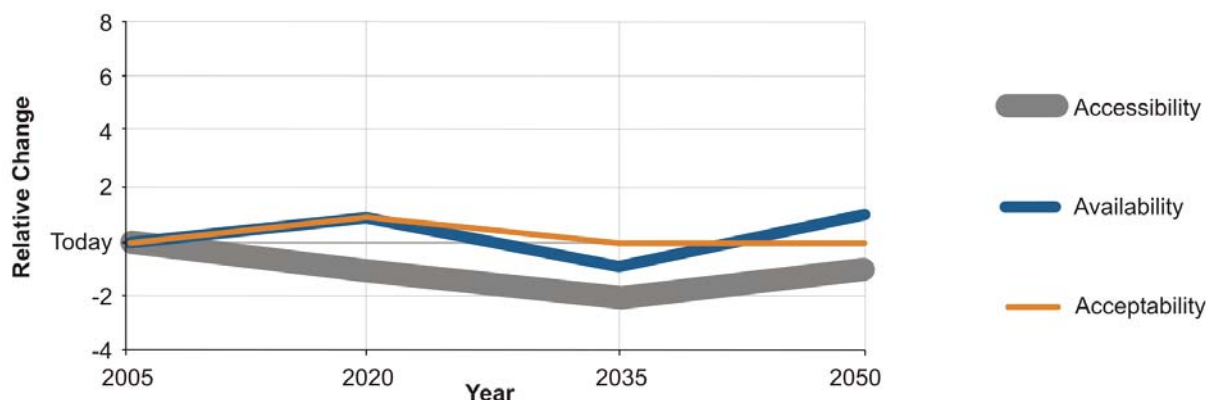


Figure 5-2 Relative change from 2005 for Asia for the Leopard scenario**Figure 5-3** Relative change from 2005 for Europe for the Leopard scenario

little attention given to climate change and Acceptability does not improve.

5.1.3. Europe (Figure 5-3)

All 3 A's decline through the initial period. Low government engagement and low cooperation inhibit technology transfer and development of common policies. Availability is particularly affected as Russia tends to follow its own governmental agenda and Scandinavian markets become more insular in their approach. Plenty of opportunity exists for the development of "national champions" in the energy field. These companies prosper by following their own profit motives and have little regard for social investment. Access to markets becomes increasingly difficult for non-EU companies. Toward the end of the period, the private sector takes a stronger social role and there is some

improvement in achieving the 3 A's.

Disappointing as these implications are, they are not nearly as detrimental as those experienced in Africa and Latin America.

5.1.4. Latin America and the Caribbean (Figure 5-4)

Low cooperation and integration, coupled with governments unwilling to step in and take a direct role in the energy sector, has disastrous consequences. The Leopard scenario is the least favorable for the economy, the environment, and energy consumers. This scenario can lead to rationing, high prices, cartels, low economic growth, and low efficiency with negative environmental impacts. Accessibility, Availability, and Acceptability are all negatively affected, and in the long run the region collapses to a level approaching that of Africa.

Figure 5-4 Relative change from 2005 for Latin America & Caribbean for the Leopard scenario

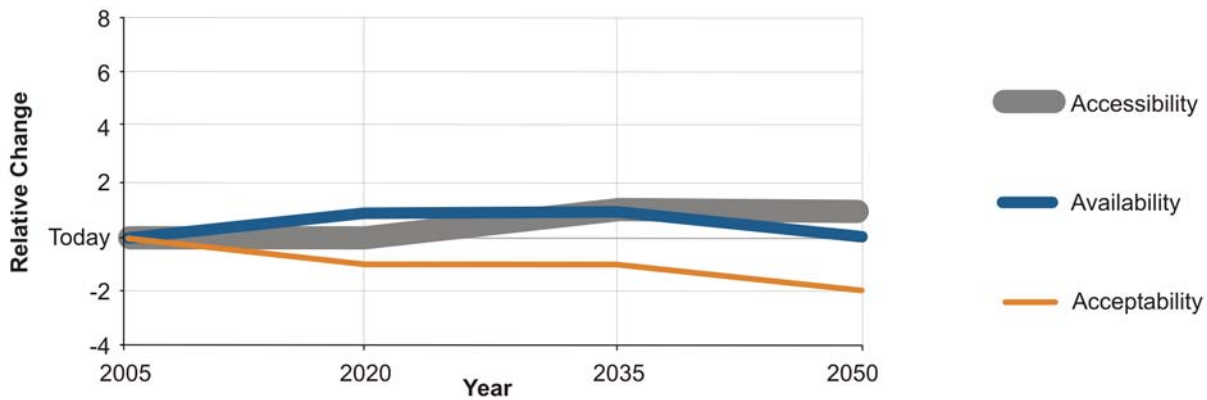
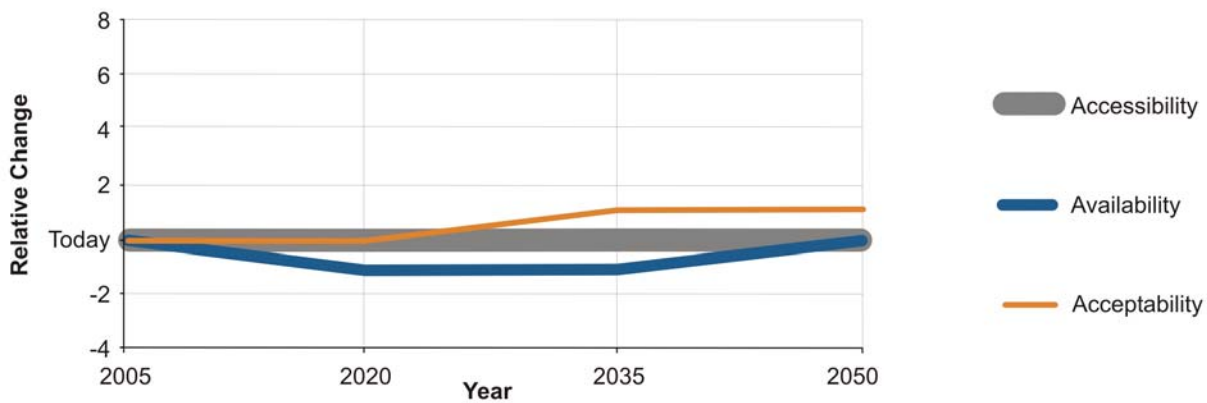
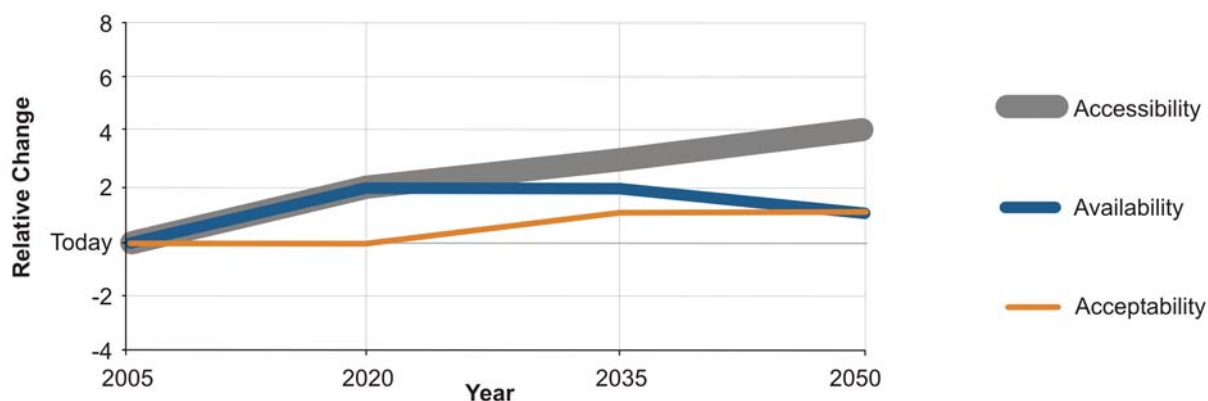
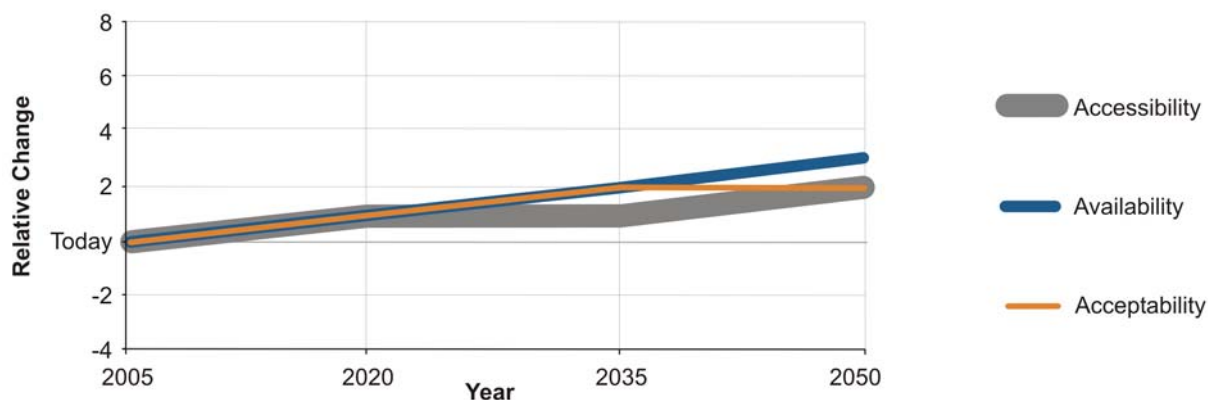


Figure 5-5 Relative change from 2005 for North America for the Leopard scenario



5.1.5. North America (Figure 5-5)

Access remains steady with no improvement, reflecting the ongoing problem of access in Mexico and rural areas of the United States. Availability drops for a while because there is no clear accountability for the maintenance and development of infrastructure. Also, because there is low cooperation, the supply of primary energy is not as secure as it was in the past and this has a negative impact on availability. In the last period, the private sector steps in to take responsibility for infrastructure and to develop local sources of primary energy, hitherto unexploited. Due to these interventions, the situation recovers back to the 2005 level. Acceptability shows slow and slight improvement over the period, but this is not a policy priority under this scenario.

Figure 5-6 Relative change from 2005 for Africa for the Elephant scenario**Figure 5-7** Relative change from 2005 for Asia for the Elephant scenario

5.2. Scenario 2: Elephant

5.2.1. Africa (Figure 5-6)

Governments adopt policies and act to ensure energy security (diversifying domestic resources, controlling exports, and securing imports), thereby improving Availability. A high sense of nationalism and thus strong incentives ensure the development of domestic capabilities. This is constrained in cases where governments do not have the financial capacity to fund energy infrastructure, while the private sector is at an early stage of development and unable to meet the challenge of financing these projects. Transfer of technology and know-how is relatively constrained because of low international cooperation, and the role of international institutions and agencies in driving

aid programmes is less effective. In the long-term, there is an accelerated exhaustion of energy resources due to low cooperation and limited financial resources. Poverty continues to rise but higher government involvement ensures initiatives to facilitate access to energy for most people. Acceptability is not high on the priority list of governments.

5.2.2. Asia (Figure 5-7)

Proactive government policies encourage the deployment of large electricity supply options, such as nuclear, especially in China and India, although within the limits of a low cooperation environment. Decentralised solutions based on renewables improve Accessibility and Availability. Market reforms facilitate development of power distribution systems, enhancing Accessibility. Energy demand for

Figure 5-8 Relative change from 2005 for Europe for the Elephant scenario

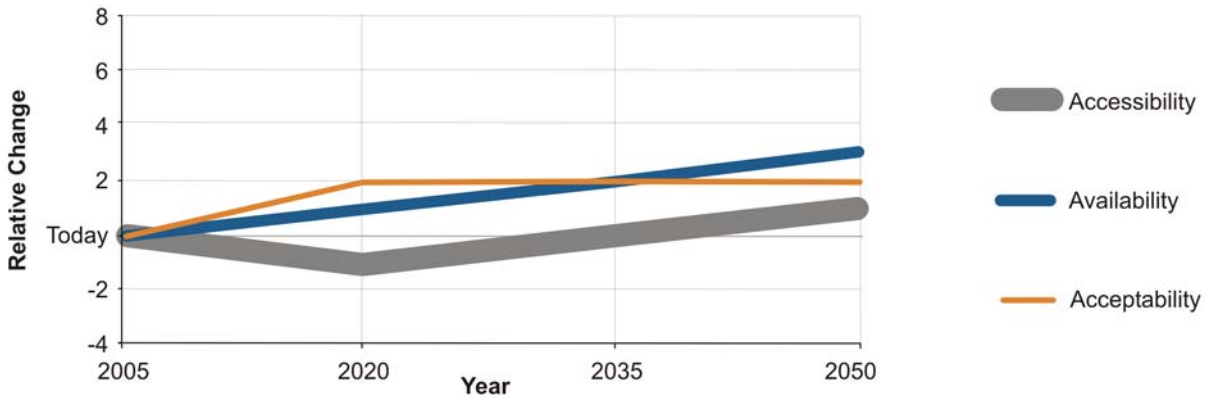
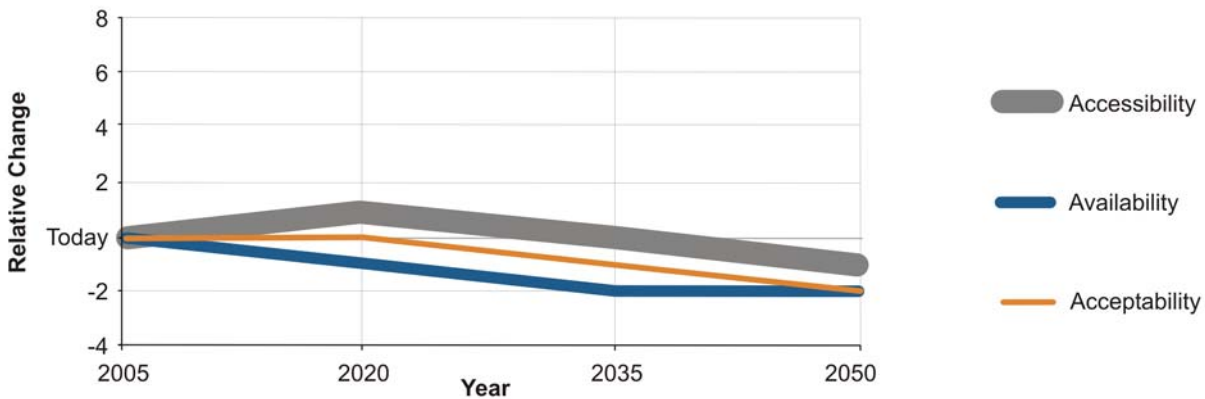


Figure 5-9 Relative change from 2005 for Latin America & Caribbean for the Elephant scenario



fossil fuels decelerates due to slower GDP growth and government intervention that leads to improved Availability. Top priority goes to sustainable energy security and governments intervene to promote the use of cleaner fuels with less carbon. In that sense, Acceptability improves although the level of improvement depends on the level of international cooperation.

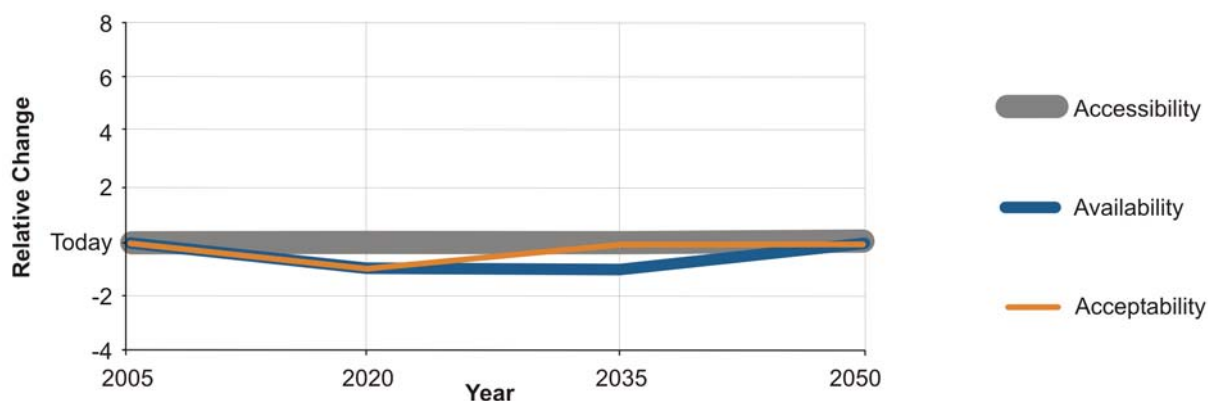
5.2.3. Europe (Figure 5-8)

More government engagement stimulates and supports the emergence and growth of “national champions” companies in the energy sector. Strong bilateral trade agreements are attempted within Europe. This concentration of resources drives improvement in Availability and Acceptability through the first period. However, governments on their own cannot drive

sustained improvements in Accessibility or Availability. This needs the direct support and contribution of the private sector. This is not forthcoming in this scenario and Accessibility and Availability decline again. Over the longer term, there is no change in performance on these goals. Acceptability improves slightly due to the more direct intervention of government and the well-established position of Europe as a leader in performance against this goal.

5.2.4. Latin America and the Caribbean (Figure 5-9)

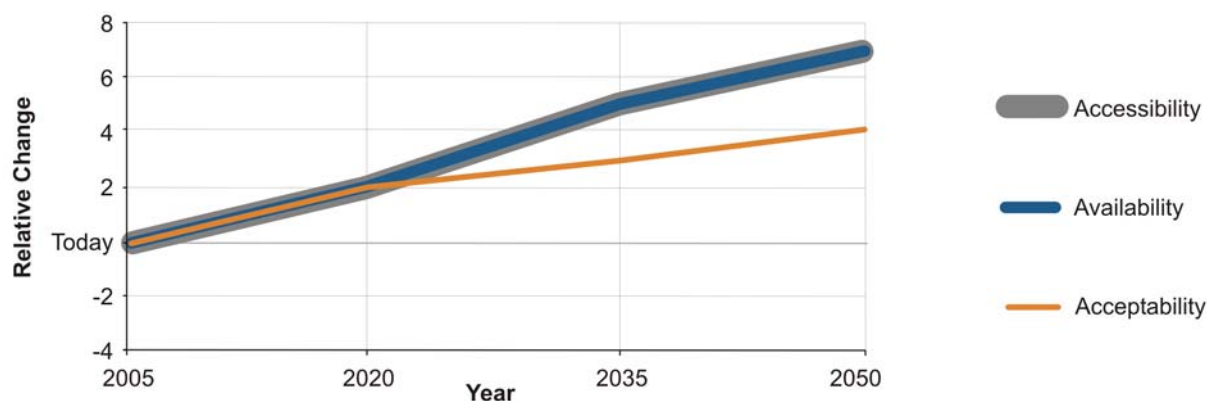
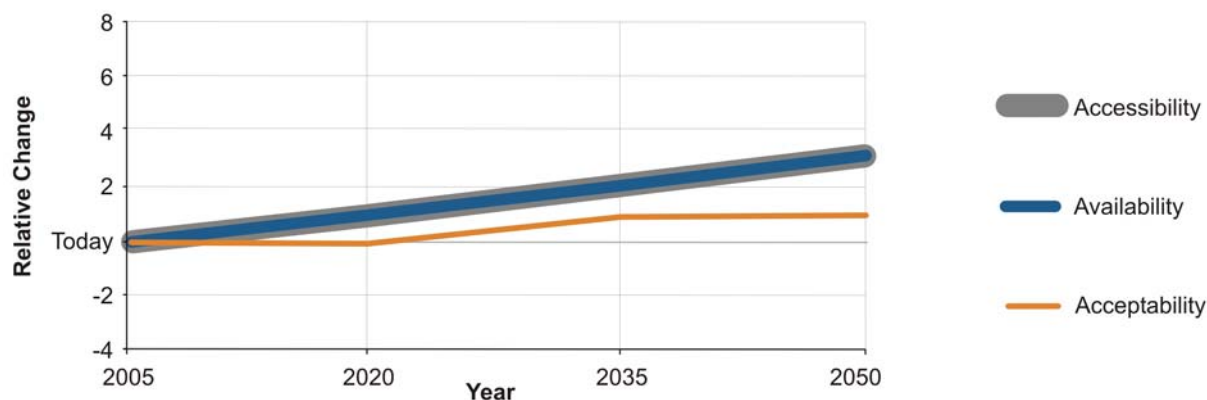
The high level of intervention by government has an initial positive impact on Accessibility; however, this cannot be sustained without cooperation. More government engagement is responsible for the viability of important projects, resulting in a degree of self-sufficiency, and

Figure 5-10 Relative change from 2005 for North America for the Elephant scenario

consequently, security of supply. Government engagement also stimulates research and development of local technology, although costs are frequently high, both in terms of management as well as final products. The absence of private sector participation and relative isolation is responsible for relative technological backwardness and absence of investment in the mitigation and offsetting of environmental impacts. Artificially set tariffs prejudice business, including state-owned entities.

5.2.5. North America (Figure 5-10)

In this region, the high level of engagement by government together with the low cooperation ends up displacing private sector initiatives. Government does not have the capacity to substitute for private enterprise and the performance of infrastructure generally declines with negative consequences for Availability in the middle of the period. There is some recovery toward the end as government builds capacity and moves further up the learning curve. Acceptability declines during the middle periods because of low cooperation. Government is unable to sustain historic levels of performance without the cooperation of the private sector. Toward the end of the period, government intervenes with strong legislation forcing a return to the 2005 levels of Acceptability, but there is no further improvement.

Figure 5-11 Relative change from 2005 for Africa for the Lion scenario**Figure 5-12** Relative change from 2005 for Asia for the Lion scenario

5.3. Scenario 3: Lion

5.3.1. Africa (Figure 5-11)

Governments are highly engaged and intervene actively pursuing the following policy objectives: security of energy supply, the eradication of energy poverty, and the mitigation of climate change, all with the help and engagement of the international community. There is strong improvement in achieving the Accessibility goal.

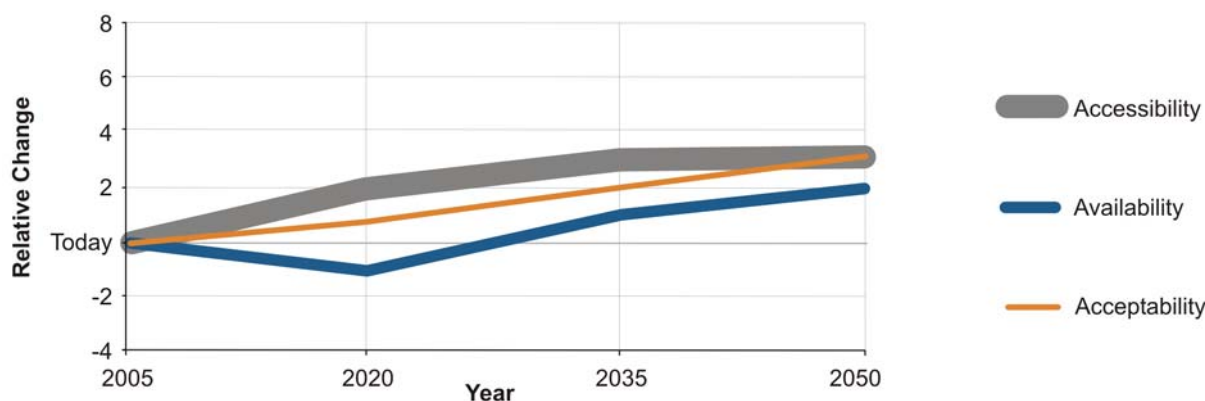
Energy security and supply are reinforced through intensive cooperation and integration with the other producer countries. International institutions play a major role in the financing of the energy infrastructure and projects, locally and regionally, and the private sector is heavily engaged. There is a stimulus to develop

appropriate technologies for the needs of local and regional developing markets. All of these developments serve to improve Availability.

Primary energy mix is diversified with an increasing share of natural gas, renewable energies, and the introduction of massive biofuels in road transportation. Modern biomass is also extensively utilised by rural populations, improving both Accessibility and Acceptability.

5.3.2. Asia (Figure 5-12)

High economic growth leads to the deployment of main electricity supply options, such as nuclear, especially for China and India, and decentralised solutions based on renewables, especially modern biomass, in the medium-term, and other renewables in the long run. Accessibility is improving, but at considerable cost.

Figure 5-13 Relative change from 2005 for Europe for the Lion scenario

Regional cooperation encourages integrated projects that enhance Availability. Cooperation between industrialised and developing countries enhances investment from the developed to the developing, which further enhances Accessibility.

Oil and gas reserves grow as the result of new discoveries or the re-evaluation of reserves, based on the use of new technologies and energy investment, which leads to higher Availability.

First priority in this scenario is sustainable development. Governments' policies drive energy efficiency improvement that in turn curbs energy demand. International cooperation accelerates technological leapfrogging, resulting in new technologies being deployed more rapidly across the region.

All this leads to an improvement in Acceptability. On the other hand, economic growth to some extent offsets the effects of the shift to cleaner energy.

5.3.3. Europe (Figure 5-13)

Accessibility improves due to the intervention of governments opening markets in the spirit of high cooperation and interaction. This relaxation of constraints increases competition, which improves quality and reduces prices. The reduction in prices has a direct and very positive impact on affordability that is a key element of all 3 A's.

Consumer countries are quite willing to enter into longer-term discussions with supplier

countries. The improvement in demand security is an incentive for suppliers and so, after initially declining, Availability improves to the benefit of all parties.

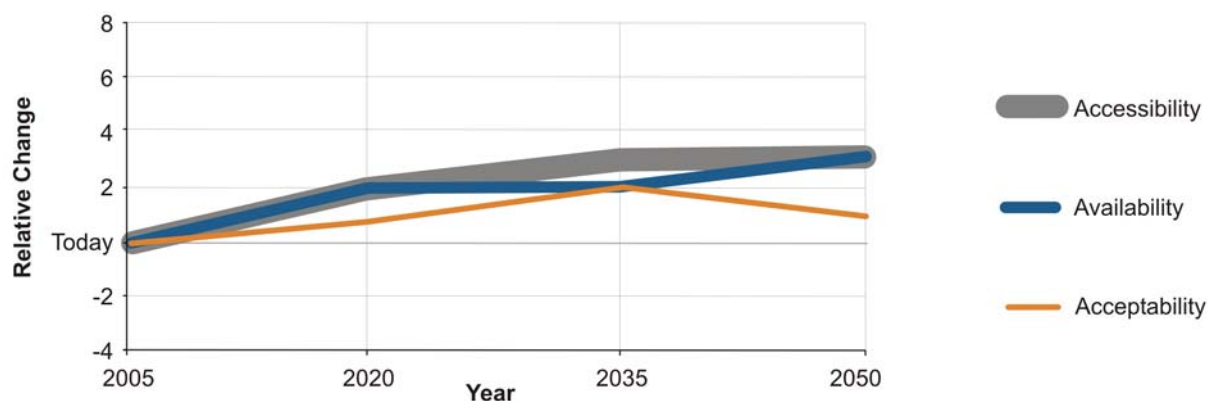
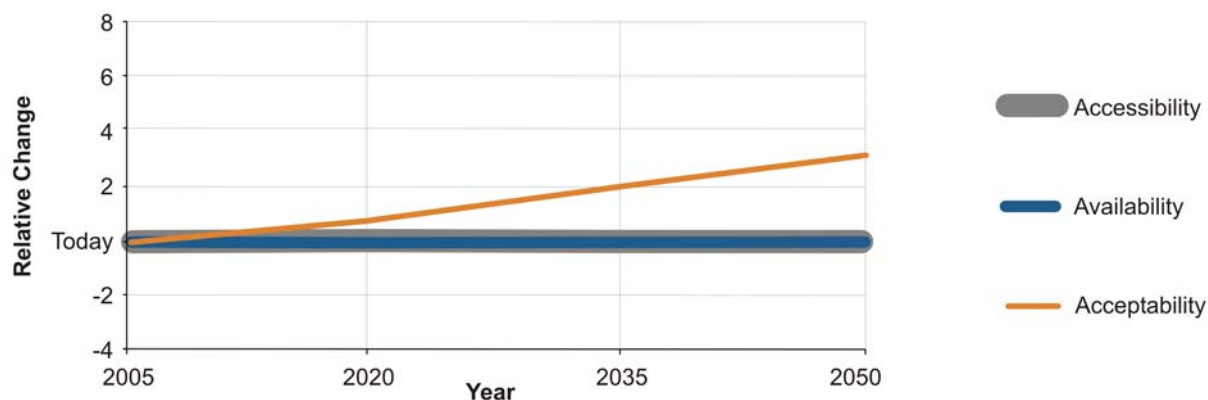
Partially because of this high Availability, the EU is able to reduce its dependence on coal by about 50% over the period through increased use of secure natural gas. This has a significant impact on Acceptability that improves during the first period.

The improved performance on Acceptability is sustained, driven by the proactive policies of government that are well received by business under a high cooperation and integration scenario.

5.3.4. Latin America and the Caribbean (Figure 5-14)

There is more access to financial, managerial, and technological input than in the Elephant scenario. This makes it possible to execute large-scale projects with long lead times for modernising infrastructure. Opportunities exist for complementary participation on the part of private enterprise

Using up-to-date technologies by the government and a greater diversity of foreign trade, than in the Elephant scenario, reduces the importance of intermediate goods (steel, aluminum, pulp, etc.) in the composition of exports, contributing to a reduction in energy intensity. There is greater attention to protecting

Figure 5-14 Relative change from 2005 for Latin America & Caribbean for the Lion scenario**Figure 5-15** Relative change from 2005 for North America for the Lion scenario

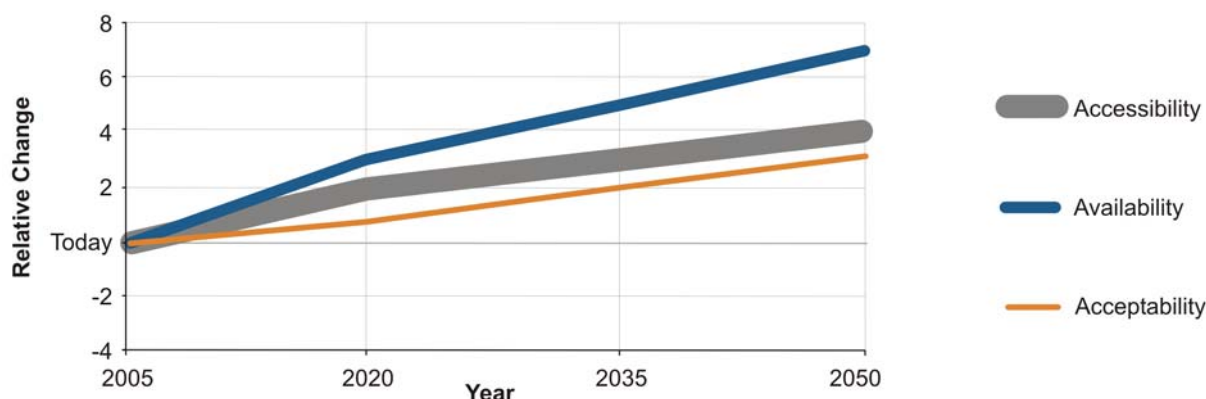
the environment as a result of domestic and overseas pressures.

Cooperation, especially international, drives steady improvement in Acceptability.

5.3.5. North America (Figure 5-15)

North America is largely unaffected in the Lion scenario. This is surprising in that there is no implied improvement in Accessibility and Availability in Mexico, even though this is a high cooperation and integration scenario. This performance is in stark contrast to that of the Latin America and the Caribbean region where high cooperation and integration makes a very significant impact.

Under the Lion scenario, North America directs much of its effort toward improving Accessibility and Availability in other regions of the world. Performance within the region remains essentially static.

Figure 5-16 Relative change from 2005 for Africa for the Giraffe scenario

5.4. Scenario 4: Giraffe

5.4.1. Africa (Figure 5-16)

Better performance of national economies occurs due to increased involvement of the private sector in the energy market. This drives up GDP growth throughout the periods, which in turn assists in decreasing population growth rate due to removal of both subsidies and illiteracy, increased job creation, and other factors. Innovations actively contribute to reduce energy costs and increase modern energy access. This assists in ensuring Accessibility to energy throughout the continent.

Availability improves strongly throughout the period. Market driven behavior leads to the transfer of technology and know-how and adoption of energy efficiency and energy conservation measures through the introduction of modern technologies and higher energy prices. There are opportunities for technology leapfrogging through accelerated development and deployment of energy and energy-based technologies.

There is an increasing use of fossil fuels (with substantial use of natural gas and coal) in the energy mix, as well as a large introduction of biofuels in transportation. Consequently, CO₂ emissions remain high. However, this is partly compensated by active market mechanisms,

such as Clean Development Mechanism (CDM). Energy intensity improves through access to technologies, and primary energy mix is enhanced through regional cooperation and integration.

Cooperation means pressures to comply with international Acceptability standards. More cooperation drives Availability very strongly. However, the low engagement of government means there is not the same drive to improve Accessibility and Acceptability, so they lag relative to the Lion scenario.

5.4.2. Asia (Figure 5-17)

Robust economic growth is maintained, augmenting the main electricity supply with options such as decentralised energy based on affordable renewables. Cooperation enhances investment from the developed to the developing countries, which in turn enhances Accessibility.

Oil and gas reserves grow as the result of new discoveries or the re-evaluation of reserves in already discovered fields, based on international cooperative use of new technologies and major investment in the energy sector. Regional integration of markets and energy trade, especially cross-border energy grids such as Trans-ASEAN Gas Pipeline and ASEAN Power Grid, further improves Availability.

Figure 5-17 Relative change from 2005 for Asia for the Giraffe scenario

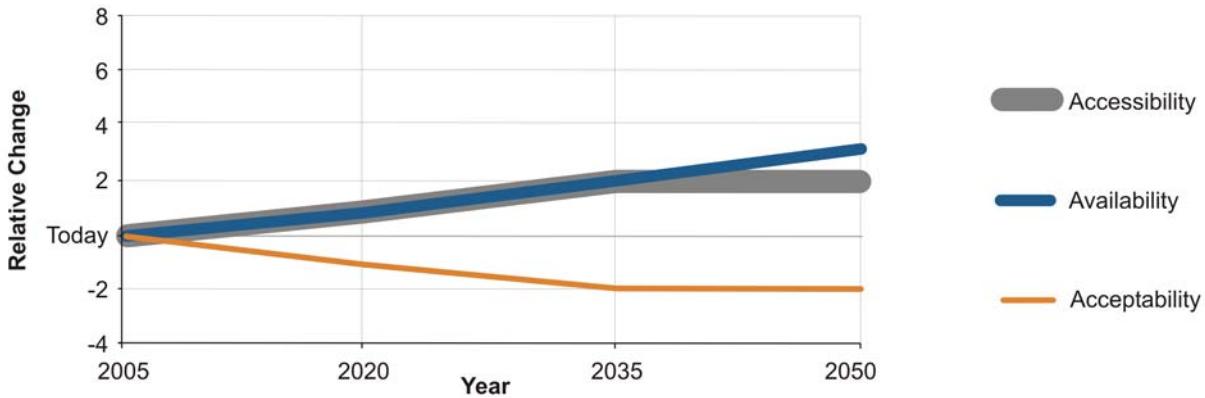
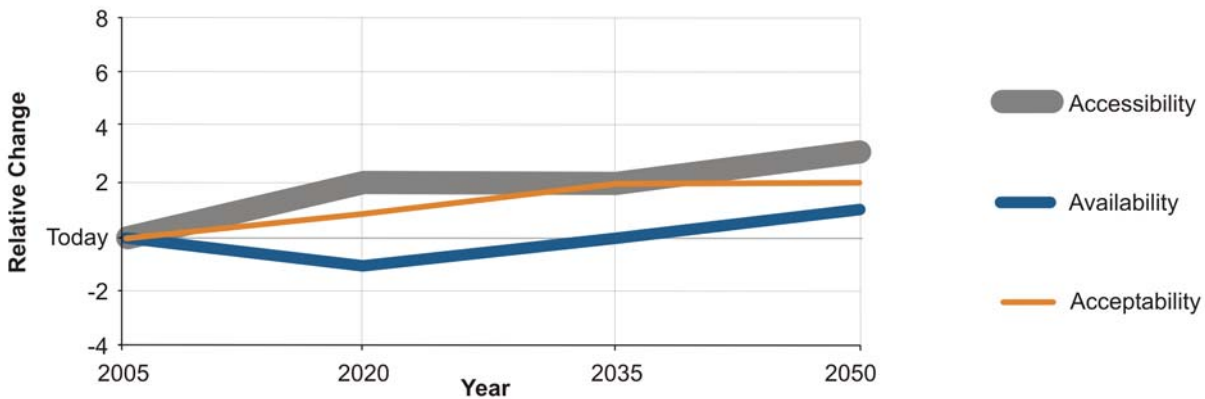


Figure 5-18 Relative change from 2005 for Europe for the Giraffe scenario



The first priority in this scenario is high and stable economic development. This leads to increasing usage of cheaper fossil fuels, and in turn, makes local and regional pollution more serious and CO₂ emissions increase. Consequently, Acceptability becomes worse. Attempts to mitigate this trend are not effective.

5.4.3. Europe (Figure 5-18)

The performance on all 3 A's remains fairly static through the period. Availability is at an acceptable level and business is prospering. There is little concern about Availability and no drive to improve it because the high cooperation makes it relatively easy to find alternative supplies.

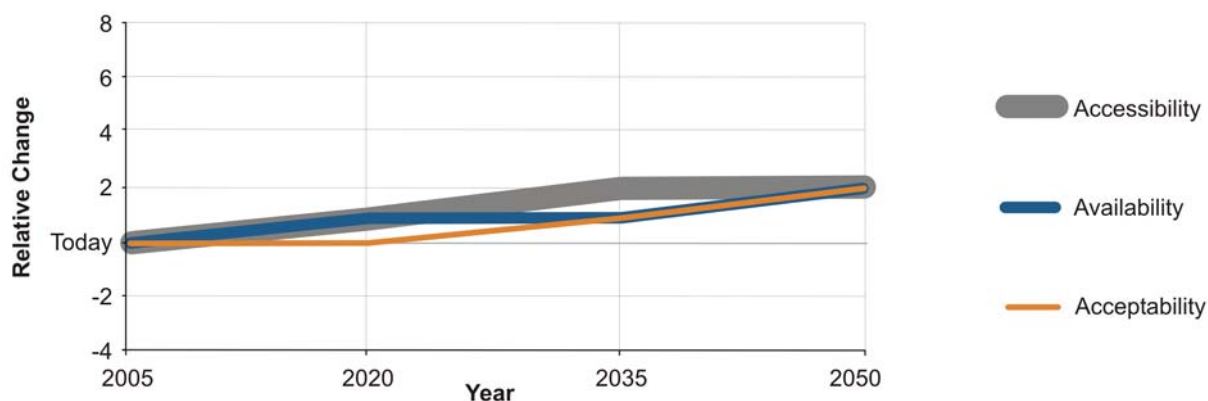
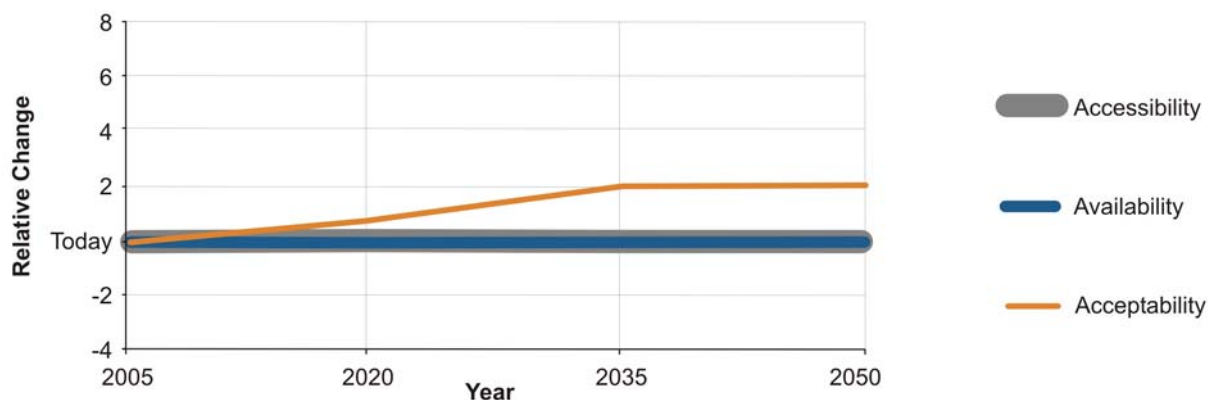
Markets are flourishing across Europe and there is little need for government intervention. Market

forces succeed in constraining the size of the multi-national corporations and there is a balance of market power (i.e., consumers are better off).

Because of the high levels of cooperation and integration, there is an effort to deal with Acceptability.

5.4.4. Latin America and the Caribbean (Figure 5-19)

Private sector companies provide greater access to financial, managerial, and technological resources than in the Lion scenario, although the selection of these resources may not be fully aligned to the needs of the economy of the country and its consumers. Therefore, achievement of Accessibility and Availability are not as good as in the Lion scenario.

Figure 5-19 Relative change from 2005 for Latin America & Caribbean for the Giraffe scenario**Figure 5-20** Relative change from 2005 for North America for the Giraffe scenario

There is lower investment in the protection of the environment and in the mitigation of environmental impacts than in the Lion scenario, which is partially mitigated by legislation.

There is broad participation of multinational companies, including associations with domestic companies, state or private sector owned, in production and in meeting the needs of the energy market. However, the risk of collusion and other forms of association is detrimental to competition and consumers. There is a need for an independent regulatory agency, in tune with the current business environment, to ensure attractiveness, competition, and good performance of sector entities.

5.4.5. North America (Figure 5-20)

The low level of government engagement means that there is little drive to improve the

levels of Accessibility and Availability in this scenario. This is a problem for Mexico in particular since this is the worst affected country in the region. The high levels of cooperation introduce a lot of effort but this seems to be directed mainly towards countries outside the region where the goodwill has value in exchange for greater security of primary energy supply

Acceptability shows some improvement, driven by high levels of international cooperation and integration and pressures brought to bear through the recognition that Acceptability is a global problem. Developed countries such as the United States and Canada are under particular pressure to lead the way in addressing this issue. There is however little improvement in Mexico as it still has Accessibility as its first priority.

5.5. Regional Policy Recommendations

The regions have considered a range of specific policy actions that might be used to mitigate the impacts of the different scenarios. These are listed here and are elaborated in the regional reports, which are accessible as described in Appendix A, Section 10.1.

5.5.1. Africa

Africa has a number of challenges to ensure its smooth energy development. In all scenarios, even with mitigation options, it is unlikely that the 3 A's will be completely achieved. The private sector will grow to take a more substantive role; however, the role of governments is unlikely to decline as they will always be required to facilitate growth, and more likely promote, energy services.

In all of the scenarios, there are a number of common mitigation options, particularly a need to:

- Improve economic performance through better governance, raising productivity, and enhancing capacity development.
- Develop local and regional industries for manufacturing electrical equipment adapted to the countries' energy needs as well as energy service companies.
- Develop better state and corporate governance to create an attractive investment climate and a favourable business environment that encourages foreign and private finance through multilateral Institutions and investments funds. This needs to be complemented through the mobilisation of domestic financial markets to account for potential reductions, or complement international aid budgets.
- Foster a better investment climate for investors and improve the conditions for attracting private investments in the energy sector, in particular through actions to reduce investment risks, including sound institutions and appropriate regulations and policies. This climate needs to allow for the development of energy infrastructure and facilities.
- Encourage innovative solutions for energy efficiency on the supply and demand side through national and regional programmes (supported by legislation), starting with simple initiatives, such as driving less to save energy and eliminating the import of old and inefficient cars. A key element is raising awareness.
- Initiate or maintain energy subsidies where required (e.g., expanding electricity access for the poor); limit their damage by appropriate measures.
- Provide stimuli to energy trade within neighbouring countries and inside the countries' sub-regions through power pools and cross-border pipelines, and share the benefits of exchanging surplus

of petroleum products and natural gas, particularly for the 15 land-locked African countries.

- Support energy technology innovation and a wider and accelerated deployment and dissemination of sustainable and proven energy technologies by incentives so that technologies can penetrate at a faster rate. This may include feed-in type arrangements, but these must be backed by appropriate regulatory reform and rigor.
- Build human capacity in sustainable energy and promoting knowledge, as well as organising energy education and training seminars to inject entrepreneurial and technical skills, particularly among youth and women.
- Ensure appropriate market reform that allows a slow move to market operations, resulting in pricing through markets and phasing out subsidies for conventional energy supply and use.

5.5.2. Asia

To ensure progress toward achieving the 3 A's within the scenarios, there is a clear need in the Asian region to balance its complexities - particularly those of regional/national interests and those of the public and private sectors. Technological and financial features of the options need to be analysed as indispensable factors for policy implementation. Following are some, albeit not exhaustive, examples of

recommendations of policy options; these include the need to:

- Establish multilateral schemes for energy security, including APEC, ASEAN+3, Gulf States, India, Russia, as well as the Middle East region, strengthening ties between energy-producing regions/countries and energy-importing regions/countries.
- Strengthen regional partnerships for energy security through broader cooperation in resource exploitation, installations of trans-border gas pipelines or transmission grids, or stockpiles for emergencies.
- Enhance technology transfer/cooperation for resource exploitation and energy efficiency as well as climate change mitigation/adaptation technologies, including those through the CDM/Joint Implementation processes.
- Focus on international collaborations and agreements for information exchange and cost sharing for promotion of technology innovation and Research Development, Demonstration, and Deployment (RDD&D) of energy-related technologies, such as Asia-Pacific Partnership, the South Asian Association for Regional Cooperation (SAARC).
- Form global collaborative networks of research for accelerating clean coal technologies, both resources and commitment.

To implement these recommendations, it is clear that:

- Governments should accept responsibilities to establish clear, long-term energy policies, frameworks for healthy markets, the enhancement of private sector capabilities, proper and sound environments for investment in energy networks, infrastructure, etc.
- Governments should reduce energy poverty to improve Accessibility.
- Directly or indirectly, governments should have investment policies for energy-related technology RDD&D.
- Governments should formulate international schemes for cooperation on technology and information exchanges, emergency measures, and mitigation of climate change.
- Governments should promote partnerships between regions and countries, public and private sectors, and among consumers in terms of energy savings, etc.
- Standards, benchmarks, or performance criteria might stimulate energy savings, etc., according to the situation.
- Internalising costs would enhance sustainability of energy supply–demand chains.
- Governments should enhance public awareness of saving energy.

5.5.3. Europe

The scenarios and the corresponding data show much remains to be done to achieve the 3 A's, therefore, additional measures are needed. The following recommendations yield 'no regret' policy options in all of the scenarios:

- A substantial increase in energy efficiency could and should be realised. A huge range of technical and other options can achieve this. Strong policy measures are required based on price incentives and on regulation.
- In the case of transportation, unconventional measures are necessary. Pricing of externalities along with regulatory approaches is unavoidable.
- Whatever the energy mix, a strong long-term infrastructure investment policy, especially for energy transmission, is required. The flexibility of grid systems should be substantially improved to service the effects of the required large-scale transformations in power generation.
- There is a need for global energy producer–consumer dialogue. Massive investment efforts do require security of both supply and stability of demand. These mechanisms should be complemented by (sub-) regional consultative facilities providing frameworks for review.

- All energy supply options should be pursued, coupled with guaranteed long-term carbon pricing. A market-oriented pricing mechanism building on the European Emissions Trading Scheme (ETS) is a good starting point, including for air transport. Attention should be devoted to further developing the international preconditions for nuclear power.
- Looking at the unprecedented challenges ahead, and also being aware of the existing promises in RDD&D, it is important that governments, national and regional, and private industry increase their level of funding of energy and climate RDD&D, and especially increase their efforts to deploy results commercially.
- Energy and climate RDD&D cooperation between governments and industry, nationally and internationally, should be strengthened and improved to make it more effective by sharing costs and decreasing the duplication of work within and between countries. Attention should be focused on options such as ITER, carbon capture and treatment, and electricity storage.
- Long lead times and the duration of investments require clear prices and stable political and regulatory environments. Such action will ensure private sector participation, particularly where project financing of infrastructure is required.
- Ensure local capital markets are involved appropriately. In doing so, clarity is gained, helping to ensure that foreign investment is forthcoming.
- Prices must reflect cost and not be subsidised. This needs to be balanced to ensure that the population is not driven to poverty, but this can be achieved with careful support and targeting of investments.
- Development of management capabilities, and wider economic development, must be encouraged to allow for effective world trade in energy services and products, as well as reinforcing and strengthening the wider economic base in the region.
- Effective contracts are essential in ensuring investment (through mitigating risk) and for protecting security of supply.
- Major infrastructure needs better planning, prioritising beneficial projects.
- Improvements in the efficiency of state-owned entities must be a goal, saving resources and improving economic potential. This is a lengthy and difficult process, usually requiring support from across the political spectrum (thus

5.5.4. Latin America and the Caribbean

As with other regions, a number of actions need to be taken to enhance progress toward achieving the 3 A's:

ensuring long-term progress). Such change will contribute to the wider ability to attract foreign direct investment (FDI).

- Training is paramount to improve management capabilities and drive development to “best-in-class.”
- The region must exploit its generous resource endowment, such as mineral deposits, land, forestry, biodiversity, climate and soil conditions favourable to agriculture, and water and hydroelectric potential. The benefit of using these resources should be shared among local communities and bring wider economic and social benefit.
- International agreements and supply contracts, diversification of supply sources, and efficient supply logistics should create sufficiently reliable supplies.
- Regional energy companies, such as ARPEL or CIER, and government-sponsored entities, like OLADE, may be instrumental in improving the region’s energy security.
- Diversification of energy sources by increasing the share and improving the overall efficiency of renewable energy (as well as hydropower, nuclear power, and biofuels) will reduce greenhouse gas emissions and to improve energy supply security. A number of other environmental barriers also need to be overcome, though in this context not least of which is the acceptability of hydropower.
- There is a need to reduce traditional biomass usage, particularly charcoal.
- The region should foster the efficient use of agricultural byproducts for energy.
- Energy efficiency should be a major goal because it will reduce primary energy needs, reduce environmental effects, and improve overall competitiveness of the economy. Energy efficiency should be evaluated on a life-cycle basis. This should indicate the most appropriate primary sources and secondary energies to serve end-users.

5.5.5. North America

North America has identified the most important areas for developing energy policy. Most of the policies apply to each of the three countries in the region and also to the four scenarios:

- Decision makers clearly need to balance current and long-term considerations in energy policy. It is important that energy-policy development is based on a clear, long-term vision, in-depth understanding of consequences over the full economic life of any associated developments, and full appreciation of inherent complexities. Certain improvements are desirable:
 - There is a need to strengthen integrated policy development for North America, building on the North America Energy Working Group, and the subsequent Security and Prosperity Partnership Agreement.

- There is a need for ongoing reviews of the respective roles of the public and private sector entities in the stewardship, development, and management of energy resources and systems.
- A clear need to develop relationships in and outside of North America to ensure continued supply of fossil fuels, particularly oil, coal, and natural gas. This may take the form of relationships with, say, oil-exporting countries, relationships focused on alternate oil sources, e.g., oil sands, or relationships to promote technology development such as carbon capture and storage. Specific actions focus on:
 - RD&D for projects including coal to liquids, advanced oil recovery techniques, use of oil shales, and methane hydrates.
 - Policy reviews of current exploration and production activity, particularly focused on environmentally sensitive areas.
 - Streamlining of licensing for hydropower, uranium mining, and nuclear power.
 - The use of tax incentives to encourage renewables and biofuels.
- Energy efficiency in all aspects of supply and end-use is important. New and changing systems, approaches, and technologies are required to ensure that viable options are developed and implemented. In addition, public education is necessary. Specifically this may manifest as:
 - RD&D support for new technologies.
 - Changes to energy efficiency regulations, e.g., building codes, labelling, etc.
 - Raising of public awareness.
- Higher efficiency of transport systems, especially land-based transportation systems, is required. The development of efficient transport technology alternatives; expanding urban and inter-urban transportation systems; a focus on urban development planning and densification to reduce commuting time and distances are among critical areas of research and development.
- Technology is key to achieving sustainable growth. Close collaboration between public and private sectors is therefore important, with transparency of funding into the long-term. Managing innovation necessitates a systems approach.

6. Principal Observations and Conclusions

"Energy and persistence conquer all things."

Benjamin Franklin

6.1. Global Observations

It is clear that all the scenarios involve a substantial increase in global energy supplies by 2050 on the order of a 100% increase. To achieve this the WEC standard of keeping all energy options open and on the energy policy table continues to hold true. The energy mix of countries and regions will depend on individual resources and relationships, but all potential resources and trade opportunities need to be addressed against the WEC 3 A's.

It is also apparent that a substantial increase in global energy supplies will take time but can be accomplished in the timeframe of this study with cleaner technologies to underpin a low carbon economy. A low carbon economy does not mean taking fossil fuels off the policy table. It means increasing the efficient production and use of fossil fuels and managing the greenhouse gases which are generated by them.

The participants in this study see population growth as stable or diminishing in every scenario. Economic growth, on the other hand, depends absolutely on high levels of cooperation, and cooperation about energy matters in particular.

Energy intensity decreases so long as there is either cooperation with integration in the private sector or significant government engagement. Obviously, if both are present, energy intensity gains are faster and more significant. Likewise, most study participants see a more diversified

mix of energy sources with both cooperation and government engagement.

However, the global energy mix does not evolve in the same way under all scenarios. Important differences of degree and timing need to be understood. There is potential to offset the world's reliance on fossil fuels by an energy mix that uses more nuclear power with adequate waste management, additional hydro resources, and renewables including biomass and biofuels with an affordable, low carbon footprint. Key drivers in all scenarios regarding the potential evolution of the energy mix are efficiency gains from stronger standards for production and end-use choices and a value for carbon which is high enough to affect choices but low enough to avoid harmful costs to growing economies.

TPER increases in all cases initially, with economic growth rates in some scenarios and at some times being counterbalanced by technology-induced reductions in energy intensity. In some areas, this happens late in the study period, as there is little expectation that governments will act rapidly.

Study participants clearly believe that without strong government involvement and cooperation among governments on an international scale, greenhouse gas emissions cannot and will not be controlled. This points to the importance of a post-Kyoto regime.

Figure 6-1 Relative change normalized to 2005 for key indicators in Section 3.5 for the Leopard scenario

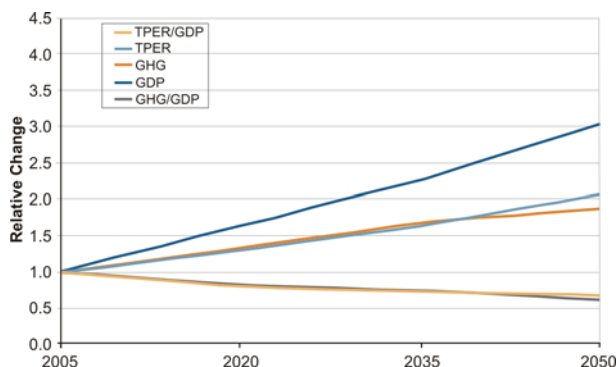


Figure 6-2 Relative change normalized to 2005 for key indicators in Section 3.5 for the Elephant scenario

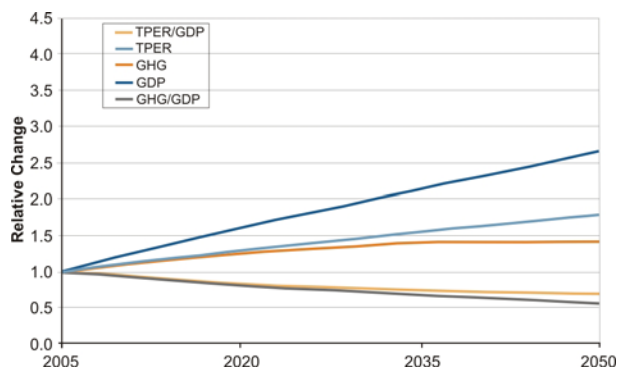


Figure 6-3 Relative change normalized to 2005 for key indicators in Section 3.5 for the Lion scenario

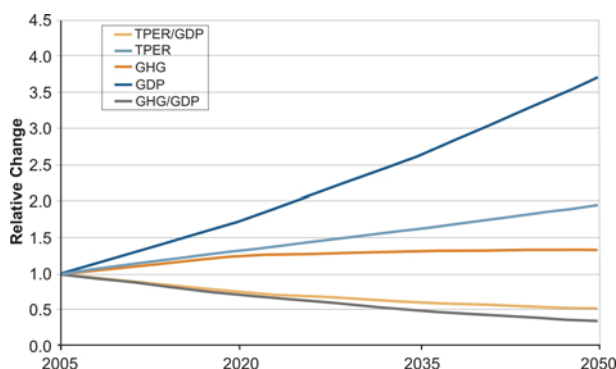
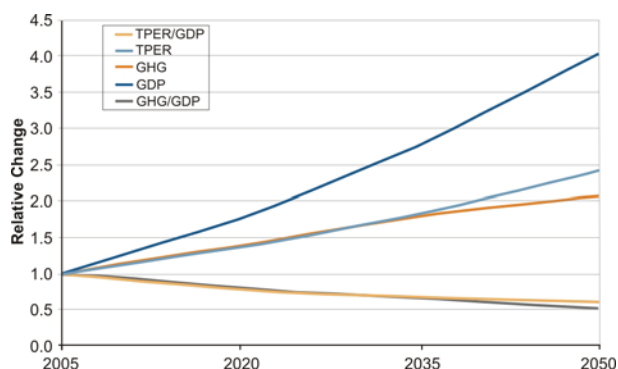


Figure 6-4 Relative change normalized to 2005 for key indicators in Section 3.5 for the Giraffe scenario



Figures 6-1 to 6-4 show results from the model of the normalised movement relative to 2005 for some key indicators that are used to frame the four scenarios:

- ▶ Economic Activity (GDP)
- ▶ Energy Intensity (TPER/GDP)
- ▶ Total Primary Energy Requirement (TPER)
- ▶ Greenhouse Gas Emissions (GHG)
- ▶ Emissions Intensity (GHG/GDP)

The participants in the study express great hope for renewable energies, but reasonable expectations. Starting from a low base number, these sources will make an important impact but will not dominate any markets in the time period

up to 2050. Nuclear power clearly needs strong government engagement to play an increasing role in the energy mix and in reducing climate emissions, but also strong international cooperation for countries that need to master the technology.

Government engagement decreases tension in the oil markets, and when combined with private sector cooperation and integration, the effect is more pronounced. Perhaps surprisingly, private sector cooperation and integration is generally not seen as reducing supply–demand tension, mostly because this is also seen as leading to robust economic growth and thus demand. There is also concern that uncontrolled private initiative may lead to higher prices rather than widespread and accessible supplies. Another factor that may influence oil tension in general is a large reduction in production from the Middle East, whether by design or technical limits.

Tension in gas markets is mixed but seen as increasing in most regions, especially early in the period to 2050 due to both demand and a push to reduce greenhouse gas emissions. Russia becomes a gas-based economy, which in turn could increase tension, especially in European and Asian markets. In North and Latin America, tension increases early in the period due to demand and then is relieved due to increased exploration after 2035.

Coal may see increased tension late in the period as CTL technologies add significant demand. Up until then, coal, in great supply, seems poised to meet demand on short notice in most of world. Environmental pressure is exerted through governments and can increase tension around coal when demand is high. Tension may be further increased if cost-effective carbon capture and storage technologies become feasible, thereby fostering demand that might otherwise be lost over concerns about climate change.

To the extent that nuclear power grows in response to economic demand and environmental constraints, governments drive it and tension increases in this case because of concerns about infrastructure requirements in what is a complex conversion system. Africa sees strong international cooperation as also being essential for significant nuclear power development.

There is increasing supply–demand tension in all periods in all regions for renewable energy. This reflects that consumers would like much

more renewable energy and have it sooner, but concerns about costs, siting of wind turbines, and the net carbon footprint of renewables will keep the tension high.

Non-conventional energy use decreases in most scenarios where it is currently significant (Africa, Latin America, and Asia). This happens earliest in Asia where progress is being made today, and last in Africa where the highest percentage use exists now and where government engagement is least effective.

6.2. Regional Observations

The assessments in Sections 4 and 5 conducted by the regions were, by design, qualitative in nature. Any relative positioning or absolute quantification toward the achievement of the 3 A goals is tenuous at best. The result is that regional policy recommendations tend to have only regional benefit without much consideration of the potential for consequences (positive or negative) for other regions.

The five regions are at different stages of economic and social development and have different levels of achievement of the 3 A goals. Not surprisingly, their policy imperatives are different. One of the major learning points from this work is that it cannot be expected that dissimilar regions will share similar policy objectives. Africa is concerned about Accessibility while Europe has moved beyond and is now concerned more with Acceptability. International treaties and protocols must allow for these differences.

Cooperation and Integration have a significant impact on the achievement of energy sustainability goals and is most marked for developing regions. Government Engagement has a much smaller impact, though it is generally positive.

It is immediately clear that cooperation and integration has a significant impact on the achievement of the goals. This is most marked for the developing regions (Africa, Asia and Latin America) where the scenarios with less cooperation and integration perform much worse than those with more cooperation and integration. This is not a surprising result, but it does emphasise the importance of knowledge transfer and expertise and the integration of resources in achieving the 3 A's. Legislation, agreements, and treaties will not be sufficient. The developed nations will have to partner with the developing nations on the basis of priorities set by the regions.

Government engagement has a much smaller impact, though generally government engagement has a positive influence on achieving of the goals. Again the impact is more pronounced in the developing regions, and this is most probably due to the lack of private sector capacity to drive these goals without government support and risk sharing. The oil security of China and India¹⁵ will be increasingly dependent on a stable and sustainable international oil market, an incentive for engagement of those governments.

While there may be subtleties and nuances in individual drivers and applications from region to region, there are a number of common themes in possible policy options. These can be grouped as follows:

Appropriate Economic Climates. Ensure appropriate economic climates to facilitate investment and ensure sustainable infrastructure development. The host countries need to provide fiscal, legal and commercial frameworks that are clearly defined and robust and which limit the risk to the investors. Donor countries and Investors on the other hand need to be realistic in stating their pre-conditions for investment and rational in their risk/return expectations.

Market Integration and Dialogue. Integrate markets at both a regional and inter-regional level and seek global dialogue on security of supply and demand. Integration will permit gains from economies of scale and from access to a greater diversity of sources and consumers (e.g., sharing production margins and aggregating energy demand).

Technology Transfer and Intellectual Property Rights. Ensure an agreed upon approach to technology transfer that respects the value of intellectual property and the need to grow local competencies while allowing all nations to better develop and deploy technologies (new and existing) appropriate to their needs in terms of the 3 A priorities.

Energy Efficiency Gains. Promote and drive energy efficiency in all aspects of the value chain utilizing appropriate mechanisms - education, financial incentives, standards and regulation. In the poorer nations Accessibility and Affordability considerations will drive the desire to make the best use of every possible

¹⁵ World Energy Outlook 2007, International Energy Agency, Paris, 2007

resource while in the wealthier nations
Acceptability considerations will underpin the energy efficiency drive. Global achievement of the Accessibility goal will make a significant contribution to efficiency (and Acceptability) since non-commercial forms of energy are frequently far less efficient than commercial forms (e.g., boiling water over an open fire vs. in an electric kettle).

New Infrastructure Investments. Ensure the development of infrastructure that will support the growth in energy demand that is anticipated in all four scenarios. For this development to be timely and appropriate it will be necessary for governments to clearly articulate their long-term policy objectives. This will permit the development of integrated plans and the creation of appropriate mechanisms to achieve these goals (national and regional Development Funds, Public Private Partnerships, Private Equity Investments etc.). Furthermore, both the public and private sectors will be able to build capability (both competency and capacity) against the backdrop of clear rollout plans.

Transportation Services. Raise the profile/importance of transportation in achieving realistic efficiencies in energy consumption. This will be achieved through changes in urban planning and urbanisation patterns with consequent changes in transport infrastructure planning. Technology development and especially energy efficiency measures in the transport sector will also be important contributors to the Acceptability goal.

7. Recommendations

“L’intelligence c’est la faculté d’adaptation.” (Intelligence is the ability to adapt.)

André Gide

7.1. Setting Realistic Global Targets

This report shows there is much to be done to achieve the goals of energy Accessibility, Availability, and Acceptability in a timely and cost-efficient manner. All countries and regions need to produce and use energy more efficiently throughout the value chain, keep all energy options open, and improve public awareness and the timely acceptance of clean and affordable energy technologies. The need for large and prudent investments in the energy supply infrastructure is acute.

Setting targets is important so that policies can be defined and progress measured. The study group believes that the following targets are achievable, assuming the political will exists in governments and industry to work closely together on the policies, regulations and investments required to move forward.

7.1.1. Accessibility

At present, almost two billion people do not have access to commercial forms of energy and another billion have only periodic unreliable access. If about half of the world’s population continues in this condition, the world as a whole faces a significant threat to stability and the quality of life everywhere. Based on input from the study participants, the following targets can be set with some confidence:

- By 2035, the number of people without access to modern energy services can be

halved from two to one billion. In its Millennium Statement WEC has already defined the minimum level of access for all households in the world as the electricity equivalent of 500 kWh per person per year.

- By 2050, this number can be halved again to 500 million.

To achieve this will take an unprecedented level of international cooperation and engagement by governments and industry, as well as introducing new paradigms for the transfer of advanced technology from OECD countries to the poorest, including incentives for the investment of capital.

7.1.2. Availability

In recent years, there have been significant disturbances in getting energy resources from where they are plentiful to where they are needed and converting them to sustainable stationary, electricity, and transport services. Sustainable means linking the availability targets of governments and industry with the accessibility and acceptability targets set out here. Most of the disturbances have been related to physical infrastructure inadequacies (e.g., shipping, pipes, terminals, etc.) resulting from insufficient investment (North America, Western Europe, Latin America), although some have occurred because of commercial, regulatory, political, or market failures (California, Ukraine, Belarus).

The investment needs of the energy sector are huge, estimated by the IEA to be \$20 trillion by

By 2035, the number of people without access to modern energy services can be halved from two to one billion. By 2050, this number can be halved again to 500 million.

One of the keys to adequate energy production and infrastructure investment is setting the rules of energy investment, transmission and trade.

2030 alone. One of the keys to adequate energy production and infrastructure investment is setting the rules of energy investment, transmission and trade. Apart from the North America Free Trade Agreement and the Energy Charter Treaty, there is no global agreement on such rules. The World Trade Organisation should be called on to prepare an energy chapter for the round of trade negotiations beyond Doha that covers all aspects of energy development including the value to be placed on carbon by signatories. Countering nationalistic, parochial, or corrupt energy policy and practice is a key element in energy availability.

By 2035, capable and reliable physical and commercial systems supplying energy in North America, Europe, and some of Asia can be achieved. Performance levels of both the physical and the commercial systems should be above 99% (less than 2 hours per week without supply). The reliability of supplies to certain high technology commercial enterprises must be at least 99.999% or greater for them to be competitive. By 2050, this condition can be extended to most of Asia, Africa, and Latin America.

To achieve this requires a deep commitment by industry to cooperate and integrate on a global scale. At the same time, governments play a crucial role in making certain that the conditions for investment are present and that the finance community can foresee reasonable returns.

7.1.3. Acceptability

Environmental concerns are among the most important factors shaping the future of the

energy industry around the world. While the study group believes it will be very difficult and is not optimistic that it will happen (Table 7-1), the following targets are achievable but necessitate substantial engagement of governments and international cooperation and integration on a broad and unprecedented scale. These targets can form the basis of discussions on a post-Kyoto agreement:

Slow the rate of emissions growth from energy use significantly by 2020, in spite of a significant increase in overall energy consumption. This can be achieved principally by setting a value for carbon globally which is high enough to drive prices and affect behaviour but low enough to be compatible with strong economic growth in all regions of the world.

Building on this foundation, by 2035, stabilise CO₂ emissions and initiate the process of absolute carbon emission reductions by decoupling economic growth from greenhouse gas emissions.

Over the succeeding decades to 2050, steadily reduce CO₂ emissions without compromising the universal availability of commercial energy services. Ever cleaner energy resources, zero-emissions technologies coupled with advanced energy storage technologies, an increasingly robust portfolio of advanced power generation and transportation technologies can facilitate further carbon reductions, leading to a truly low carbon world.

The transportation end-use sector is perhaps the most vexing of all energy sectors if energy-related emissions are to be stabilised and then

Table 7-1 Regional level of progress toward the Acceptability goal

	2005–2020	2020–2035	2035–2050
Africa	Accessibility focus	Accessibility and Availability focus	Acceptability focus - Reduced emissions growth
Asia	Accessibility and Availability focus	Availability and Accessibility focus	Acceptability focus - Reduced Emissions Growth
Europe	Acceptability focus - Reduced emissions growth	Acceptability focus -Stable emissions growth	Acceptability Focus – Low Carbon Economy
Latin America	Accessibility focus	Availability focus	Acceptability focus – Reduced emissions growth
North America	Acceptability focus - Reduced emissions growth	Acceptability focus -Stable emissions growth	Acceptability focus – Low carbon economy

reduced. Bold and unconventional steps are called for. Governments, working with industry, must identify the issues, available technologies, research and development needs, standards, and the paths forward - with the goals of ensuring security of energy for transportation and dealing with greenhouse gas emissions.

Not to be overlooked are local and regional emissions and other environmental impacts (e.g., water and agricultural land use). WEC should work with the United Nations and other NGOs to ensure its energy targets take into account the water, health, agriculture, and biodiversity concerns, which have been addressed in the UN Millennium goals.

Without public awareness of the importance of energy - its generation, distribution, and supply, and the issues of security, access, and environmental effects surrounding energy - people will not be able to decide which course to follow. Strong and coordinated steps are needed to educate all people in the world about energy, from basic principles to explanations of the critical decisions that must be made by society. Useful information must be disseminated clearly and uniformly to the public at large by governments and industry in a timely and effective way.

7.2. Associated Messages

This study has drawn on the collective wisdom and experience of people actively engaged in the field of energy supplies and services, as well as those who study energy from the outside. A

broad range of issues, concerns, and aspirations were gathered from the energy community at large. Not surprisingly, although the view of the future differs from region to region, overarching messages emerged. These messages resonate in all regions of the world and are fundamental to the achievement of the WEC Goals of Accessibility, Availability, and Acceptability.

These messages are a clarion call to those accountable for the formulation and implementation of energy policy throughout the world and highlight some fundamental gaps in the energy fabric of today's society. These messages are grouped into three main themes:

- Managing change and complexity through partnerships.
- Demand-side mobilisation.
- Energy leadership.

7.2.1. Managing Change and Complexity through Partnerships

The global energy sector will transform through 2050 and will become increasingly complex. The pressure on decision makers in both the public and private sectors will increase and, in particular, the demands on those responsible for energy policy will intensify. Policies formulated today and the resulting actions and behaviours of citizens will have effects and consequences far into the future. Political expediency will have dire consequences for energy sustainability.

The future is far from certain and the rate of technology change in both the supply and

Public Private-Partners, adapted for specific regional needs, can provide a sound mechanism for the transfer of resources (energy, knowledge, skills, capital) to where it is needed.

A partnership between the public and private sectors - within and across regions - is essential, through which risk and reward are apportioned.

demand sides of the energy sector is increasing. Government policies must therefore be quite clear in their intent and less prescriptive in terms of the means, permitting those responsible for implementation the requisite degree of freedom to apply the best technology solutions and systems to meet the objectives. Countries or corporations where policy explicitly favours or restricts certain technology options may find it difficult to keep up with the evolution of the global energy sector.

Just as it is expected of governments to become more direct in expressing policy intent, at the national level but increasingly also at the regional or global level, it is also necessary for private enterprise to become overtly engaged in policy implementation. Industry leaders have to ensure that corporate policy, investment criteria, and business practices are all geared to deliver the goods and services that support the government's policy intent.

Policy initiatives are not only necessary at the national level but also must consistently cascade down to sub-national and local levels. These initiatives have to pay particular attention to the development of transportation systems, planning towns and cities, modernisation of communication systems, and work practices.

Business Practices, Transportation, and Urban Planning

Energy for transportation is or is becoming a significant portion of peoples' daily discretionary energy usage, depending on locality. The effectiveness (efficiency, convenience, and cost)

of the mode of transportation is a key factor. It is necessary for policymakers in the public and private sectors to seriously consider transportation requirements. Transportation corridors and systems must be both effective in meeting the needs of consumers and efficient in terms of energy and environmental performance. This is a complex challenge interwoven with city planning and the business and social habits of commuters.

Private sector leaders can review business policies and practices. A majority of businesses still require office workers to commute daily to a central office. This consumes both time and energy and the commute itself is often a stressful experience. Modern communication systems make it possible to carry out much office work from remote locations and rapid advances in computer and communications technology are making it easier.

By taking the lead, private sector leaders send a clear signal to their employees that personal transport considerations are to be encouraged, with potential spillover into attendant social behaviour. This may trigger a new approach to mid- and long-range planning at all levels of government as well as appropriate integration with town and urban planning. In the developing world, significant opportunities to plan towns and cities exist in such a way that as these cities grow, they remain efficient and effective in their energy use. The early provision of mass-transport systems is essential, as the cost of retrofitting is exorbitantly expensive and disruptive to daily business and social concourse. Lessons learned in urban planning

by the developed world can be shared with the developing world and there is a significant opportunity for governments to facilitate transfer of knowledge, expertise, and experience.

Innovation

The demand for energy will continue to grow to 2050, although the rate of growth indicated in this study slows during the later years. Thus, energy tensions (the imbalance between supply and demand) will continue to grow for most forms of energy. In some cases, tension may be due to physical or economic constraints relating to the exploitation of resources of primary energy. In other cases, tension may be due to constrained transfer of technology for political, ideological, or capability reasons (e.g., the deployment of advanced nuclear power technology to the developing world).

To achieve the 3 A's and the aspiration of energy sustainability, it is necessary to relax or alleviate these tensions. New technologies are required. On the supply side, it is necessary to find the means to explore, develop, extract, and convert diverse sources of primary energy that can be economically and sustainably exploited. On the demand side, the price of energy will likely increase as more and more marginal sources are exploited and more and more consumers are supplied. The precise role of clean technology will be the key to affordability and achieving the 3 A's.

Innovation has traditionally been the preserve of entrepreneurs and scientists and most new inventions of the 19th century arose from the

private sector. In the 20th century, the cost and risk of fundamental research and development grew and so did the role of governments in undertaking (or at least funding) major research. National research programmes were established and networks of national laboratories were set up, mainly in the developed world. With the drive toward privatisation and deregulation, and new priorities in the last part of the 20th century (post-Cold War), many of these programmes were scaled down. Governments assumed the market would take care of RDD&D, and regulators had a hard time taking private research into account.

Long-term, energy-related research and the associated risk are now beyond the investment appetite of all but the largest of private sector institutions. As a result, innovation in the energy sector over the last 20 years has not anticipated or kept up with need. Innovative capability has not been entirely lost, but has instead been directed at projects that have a shorter time-to-market and a quicker payback profile.

If the 3 A goals are to be achieved, this situation must be reversed. Governments can assist by having clear policies, both in terms of long-term energy goals and with long-term funding, that foster the RD&D. This will help mitigate the private sector risk of undertaking such work and also attract individuals to government-funded projects.

Partnerships between the public and private sectors are essential, if the risks associated with long-term R&D are to be managed and mitigated. The private sector will deliver

It is very important that public and private sectors engage one another and form partnerships that ensure the achievement of the 3 A's.

innovation and ensure that R&D programmes are meaningful, relevant, and that they will deliver new technologies efficiently and effectively. For the demonstration and deployment phase, careful handling of financial support until such time as they are established in the market is required, demonstrating the benefit of cooperative effort of the public and private sectors to achieve the 3 A goals.

Cooperation and Integration (including Public–Private Partnerships)

Energy sustainability is a golden thread that runs through the long-term survival of economies and indeed society. Government has a clear role to formulate, approve, and issue policies that support society's need for energy. At the same time, wasteful exploitation of resources or careless damage to the environment cannot be condoned. Clear and consistent policies that respect the environment while providing the energy necessary are required. An integrated view across the many facets of government is necessary. In fact, it is difficult to identify any one facet of government that does not contribute to and at the same time depend on a sustainable supply of energy.

Delivery of energy systems and technologies is the role of the private sector. The efficient and effective delivery of programmes and projects are private sector competencies. The private sector is accountable in giving effect to government policy. Therefore, partnerships between the public and private sectors are essential if long-term sustainability is to be

ensured through the achievement of the 3 A's. This study has shown that the nature of this partnership is one of the most noticeable differences among regions.

There are many examples where cooperation within regions and between regions has delivered benefits to all participants (e.g., power pools). Integrated planning on a broad scale can provide for the development of plans necessary to achieve the 3 A's. This helps to ensure buy-in from all sectors and assurance that the goals of the plans are achieved. Such plans clearly indicate requirements for technology and funding and provide a basis for action by the private sector. Through the assessment of plans, the developed world can clearly understand the aspirations and needs of the developing world and can work toward mutually beneficial exchanges of experience and capability. New mechanisms for the transfer of technology and funding can thus be found based on the clarity of intent and respect under established rules of clear property rights. These can also be encouraged and promoted between the regions and countries in the developing world.

In developed countries, the private sector is well developed and fully capable of taking on the described role. For the most part, government is then able to play an enabling role, setting policy that states intent and leaves it to the private sector to deliver. However, in developing regions, the private sector is often less mature and does not always have the capacity or the capability to deliver, at least on a macro scale. In

these regions, the opportunity exists for the private sector to initiate the transfer of capability and capacity from the developed to the developing regions. If this does not happen, or if it happens in an inequitable fashion, developing country governments will have no choice but to move into the void and take on some of the roles normally expected of the private sector.

However, the public sector may not yet have the capacity to assume this responsibility. In such cases, international development agencies or governments in the developed world can play a significant supporting role.

Whatever the level of development, a partnership between the public and private sectors - within and across regions - is essential, through which risk and reward are apportioned. This is achieved when there is regular and constructive dialogue and a joint commitment to a national, regional, or even inter-regional vision, backed by a measurable action plan.

7.2.2. Demand-Side Mobilisation

Study participants confirmed that achievement of the 3 A goals is an important measure of the achievement of energy sustainability. It is also generally accepted that acting now to achieve the 3 A's is less costly than doing it later, when measured in terms of future social, economic, and environmental costs.

While all the 3 A's are important, it is difficult to place equal priority on their achievement. In the developing world, Accessibility demands priority. People who have no access to a minimum level

of commercial energy services have little interest in the issues of Availability and Acceptability. Conversely, in the developed world where access is generally no longer an issue, great strides have been made in dealing with Availability and attention is now focused more on Acceptability.

Accessibility remains a major problem and threatens global society and the environment. If people do not have access to commercial forms of energy, they will continue to survive by foraging. The demand for traditional biomass is unsustainable and environmentally debilitating as it exceeds the rate of regeneration. Access therefore needs continued strong focus. Because environmental degradation knows no political boundaries, it behooves the developed and the developing worlds to understand the root cause of this energy poverty spiral and to work toward achieving universal access. While overtly working toward the achievement of the Accessibility goal, this will as a matter of course also contribute significantly toward the Acceptability goal.

Historically, governments and supply-side private sector players drive the achievement of the 3 A's. Pressure has been directed at energy supply companies to deliver access, ensure availability, and do so in an acceptable manner. Under this paradigm, some progress has been made toward achieving the 3 A's. However, if we are to make significant progress toward these goals over the next 50 years, then we need a step-change in our approach. It is time for consumers to become as actively engaged in

matters of energy sustainability from the end-use side of the equation.

It is in the transportation and stationary energy-use sectors that the biggest opportunities for change exist. Educated energy consumers commit to conducting business and their daily lives in a more energy efficient manner.

Examples of this need abound:

- The motor vehicle industry has improved energy efficiency through better engine and body design. In many regions, consumer behaviour trends toward larger and more powerful vehicles, somewhat negating these achievements.
- There is a great need for education in all sectors of the energy economy (political, residential, commercial, and industrial). A public poorly informed as to the energy implications of its daily choices and decisions is not helpful. In turn, a poorly informed government can be counter-productive.
- In the building industry, there has been progress in the developed world and new buildings are much more energy efficient than in the past. However, these technologies have not been implemented in old buildings and in the developing world, either because the technology has not been made available or it is too expensive, and so houses, factories, warehouses, and many public buildings remain energy inefficient.
- Governments, particularly in the developing world, can introduce policies to improve Accessibility and also address Availability and Acceptability. The experience from the developed world can be used to design entry level housing that is energy efficient, appropriate, and affordable for those without access. This, coupled with education, can help inhabitants use energy effectively in an affordable manner with a positive affect on the human condition.
- The private sector can play a major role in investing in the quality of life of its workforce. Assisting employees to acquire housing, offering courses on basic home maintenance and handicrafts, safety, etc. can contribute toward helping the poor while improving productivity.
- Transfer of technology and skills is not solely the preserve of large corporations. Every business can make a contribution and individual employees can share their knowledge and skills with others, thereby working toward a general elevation of skills, productivity and employability. Key is sound integrated planning that addresses the supply and demand for energy. At a national level, this can only be achieved through effective cooperation of the public and private sectors on both the supply and demand sides of the energy sector. "Competitive advantage" can be used as an excuse for withholding information that is really essential for the

national planning of energy systems and the formulation of integrated policies that support the achievement of the 3 A's.

7.2.3. Energy Leadership¹⁶

The study focused on energy policy and did not attempt to delve into questions of energy resources and other physical dimensions. Importantly, "policy" is something people have control over. Policy is not determined or pre-ordained by physical states of nature but represents conscious human choices. The burden placed on policymakers is therefore onerous.

It is common to consider policy formulation and approval as the domain of government, but it is not exclusive to government. Captains of industry and commerce as well as civil society also have a crucial role to play in terms of policy, both in terms of their capacity to influence government policy and in terms of their own business policies and their effect on energy sustainability (e.g., a policy to only conduct RD&D where the time to market is relatively short or a policy to only invest in projects where there is minimal location risk).

There is a common misconception that free and open energy markets are sufficient and that governments' role is limited to benign oversight.

This would be plausible if all players in the market have equivalent market power and freedom of choice. Where this is not the case, some players can dominate and, over time, the energy market can become increasingly distorted, to the detriment of the public interest. At some stage, governments may have to intervene to prevent exploitation of the weak and to restore balance. This is usually achieved through regulations and/or laws.

It is also apparent that market forces, if left to themselves, may create considerable volatility and attendant risk for market participants. Therefore, some form of pragmatic regulation is necessary to ensure sustainable energy supply, particularly in developing countries. It is most certainly necessary for governments to play a larger role than is now the case, to provide a risk-mitigation damper on highly volatile markets, to ensure equitable treatment of all players, and to provide longer-term direction for the development of necessary infrastructure. This role requires very strong leadership from government. There is a fine balance for governments so as to reap the full benefits of good markets while still ensuring that market power is not abused. Governments are expected to issue policies that are clear on their intentions with regard to supplying sustainable energy and that these policies provide frameworks that guide and encourage the private sector to deliver energy goods and services that achieve the policy intent.

At the same time, those at the head of business must engage with government to ensure that

¹⁶ "Leadership" means providing vision, direction, guidance, encouragement, and resources. It is not to be confused with "management" that deals with detailed planning, control, and resource allocation. Leadership is concerned with the "What" and the "Why," whereas management is concerned with the "How."

they fully understand policy intent and are able to influence it, should that be necessary. Corporate leaders are expected to exhibit strong leadership to ensure market effectiveness and delivery of the policy intent. Strong partnerships are required between the public and private sectors to see that risk is appropriately allocated and mitigated and that rewards are commensurate with the real risks involved.

It is important that corporate leaders in the developed world consider the basis on which they transfer knowledge, technology, education, and funding to the developing world. For the 3 A's to be achieved, this needs to happen in an equitable and affordable manner, otherwise the developing regions may continue to struggle and the energy poverty spiral might accelerate. Such a situation may invite greater international governance that might quickly turn into interference at the national level. However, the successful transfer of technology to developing countries could lead to new opportunities elsewhere. Again, it is very important that public and private sectors engage one another and form partnerships that ensure the achievement of the 3 A's. Particularly, the role of civil society should be stressed and valuable stakeholder involvement in many areas must be encouraged.

Governments need to articulate energy policy and be prepared to help mitigate the risk of long-term R&D. The provision of energy infrastructure may also need to be supported by government policy.

The private sector must take the lead in the delivery of the goods and services necessary to

give effect to the national or regional energy policy, doing so within the frameworks provided and making use of the knowledge and technology of the day. At the same time, the private sector needs to work with government on the longer-term vision to try to ensure there is an appropriate balance between the real risk of the project and the reward.

In addition to such public-private partnerships, corporate leaders can actively partner with like-minded corporations as a means of mitigating the risk of projects in developing countries. It may be desirable to partner with local companies in developing countries as a means of achieving effective transfer of technology and funds.

It is important that developing country governments have policies and institutions that support foreign investment and technology transfer. These policies are on such important matters as intellectual property rights and mitigation of financial risk. If not in place, it is unrealistic to expect the developed world to become involved in the developing world.

7.3. Energy Policies for Action

At the end of this study, a question that may be asked is, "In a global sense, are governments and the private sector on a path today to sustainable energy development, as defined by the 3 A's of Accessibility, Availability, and Acceptability?" The clear answer - in terms of any of the plausible scenarios - is NO. It is

A new level of wise energy policy, energy regulation, and energy investment is required now and in the next few years if we are to achieve energy sustainability in the 2035-2050 timeframe.

obvious that a new level of wise energy policy, energy regulation, and energy investment is required now and in the next few years if we are to achieve energy sustainability in the 2035-2050 timeframe.

There is a critical need for unprecedented levels of cooperation and integration in both the private and public sectors if GDP growth is to continue, sustainable energy supply and end-use systems are to be achieved for the benefit of mankind, and anthropogenic climate change is to be mitigated. Public-private partnerships must become even more important than they are today.

These levels of cooperation are also essential if global energy intensity (E/GDP) is to continue to decline, but it will take some time (at least to the very end of the period) for overall energy demand to stabilise. The goal of having more rather than fewer energy primary sources and conversion options available is in fact achievable in the shorter term. The result is that the energy mix will continue to diversify.

Perhaps surprisingly, careful government regulation is desired by the private sector to ensure attractiveness and fair competition for energy industries and services, and rules of trade across national borders and globally are also supported by the private sector. However, consistent long-term signals also need to be sent, lest investments focus only on the short to medium-term.

While the level of public awareness has increased as the security of energy supplies and

climate change attract attention, it needs to be markedly increased even further. People cannot make informed decisions without adequate information offered in plain language. Concerted public-private efforts need to be made to increase the public's awareness of the issues involved with energy security and sustainability.

In terms of differences between regions, Europe is generally more optimistic about its ability to decrease energy intensity than others, but it worries about the security of supply. Africa believes it will take longer to decrease energy intensity (already the highest) and expand its energy mix than other regions, owing to its position of using significantly less energy per capita than others today. Asia and Africa both see continued use of coal until late in the time period. Africa and Latin America see serious dilemmas surrounding Acceptability in the face of low levels of Accessibility. North America sees Acceptability as the largest issue in this region with the exception of Mexico, where Accessibility is still a major problem.

Policy actions to deal with this situation are:

- ▶ **Strong and consistent long-term signals about energy goals and policies.** These signals should be designed on two principles: that all energy options are on the table, the choice depending on individual country resources and regional market integration, and that it is possible to achieve a doubling of global energy supplies and continued economic growth in harmony with a low carbon society.

Clear, reliable signals are necessary for the financial community to feel confident investing in sustainable energy projects with some assurance of a return on investment. Necessary energy development depends directly on ensured investments and steady financing. Governments have tended not to send strong and consistent signals to markets about energy policies; as energy is intimately tied to other societal goals, such as the environment and standards of living, where signals have been sent, investors have tended to avoid long-term sustainable energy projects in favour of quick solutions.

- ▶ **Regulatory frameworks that ensure attractiveness of markets and competitiveness to industry.** Energy security depends on the ability to produce and utilise energy resources efficiently and with minimal damage to the environment. For energy markets to prosper, it is necessary that governments establish basic ground rules for competition, as chaos is detrimental to markets and the population. However, too much government interference hinders the ability of industry to efficiently provide energy services to keep up with demand. Four areas for improved policy and regulatory signals are: rules of energy trade including environmental protection; renewed efforts to harmonise regulations across regions; the application of competition rules to energy companies which need scale to capture efficiencies and manage risk; and, reasonable costing of RDD&D and the timely

replacement of old technology with clean technology.

- ▶ **Public and private sectors together identify specific RDD&D projects and outline funding frameworks to accomplish them.** As political attention has been paid more and more to short-term issues intimately related to energy, pre-competitive energy research and development for longer term requirements, necessarily led by governments, has fallen to levels lower than at any time since the early 1970s. If the problems of energy sustainability (defined by Accessibility, Availability, and Acceptability) for the global population are to be met, then much more, and much better integrated (government and industry) funding for research, development, and demonstration of sustainable energy technologies are needed, and now. Because R&D process takes both time and consistent investment, global society cannot wait until the problem becomes acute.
- ▶ **Coordinated international transportation research, development and demonstrations, and incentives supporting market penetration of new technologies.** The transportation end-use sector is the most vexing of all energy sectors if secure energy supplies and energy-related emissions are to be stabilised and then reduced. Bold and unconventional steps are called for. Governments - working with industry - must identify the issues, available technologies, R&D needs, and the paths

forward, with the goal of ensuring the security of clean energy for transportation and its conversion and to deal with the difficult problem of greenhouse gas emissions from this sector.

- ▶ **New paradigms for technology transfer.** These must recognise that success may be either way (developed to developing or vice versa) and vary in terms of time. Developing an international framework to assure the smooth transfer of technology is critical to energy sustainability.
- ▶ **Strong and coordinated steps to educate people about energy, from basic principles to critical decisions that must be made.** Without public awareness and understanding of the importance of energy and the issues surrounding it, people cannot make informed decisions about the course societies are to follow.

These policy actions will go a long way toward ensuring that sustainable energy development, with its derivative benefits for mankind, can go forward without the detrimental effects often associated with production or use of different energy sources or carriers.

8. Next Steps

“Nous sommes responsables non seulement de ce que nous faisons, mais aussi de ce que nous ne faisons pas.”

(We are not only responsible for what we do, but also for what we do not do.)

Molière (Jean Baptiste Poquelin)

The scenarios described in this study consider ways in which the global community might react to different sets of circumstances. With two primary dimensions - high or low engagement of government and high or low cooperation and integration between the public and private sectors of nations and between regions - four sets of circumstances arise. These circumstances are not mutually exclusive and each may include characteristics of the others, but they do define general areas of policy actions. The study has considered the impact that policy options will have on achieving the Accessibility, Availability, and Acceptability goals from 2005 to 2050.

The impact of the postulated scenarios differs from region to region and clearly illustrates the fallacy of a “one size fits all” approach to energy policy. Each region grapples with a unique set of energy issues. While there are things in common, there is much that is unique to a region(s). It is important to accept that energy policy will be different from region to region and even between nations, especially within some of the more complex regions. There will also be inter-regional effects such as the way conflicts in the Middle East affect energy prices around the world.

The study, as is typical for scenarios studies, raised many issues for which there are no easy answers. While these issues are either in total or part beyond the scope of this study, they point the way to further study.

- All four scenarios point to a doubling of TPER over the period to 2050.
 - It is not clear where this additional energy will come from. Individual countries and large cities must address not only their requirements but also the distribution and cost of energy services.
 - Decisions will have to be made about whether specific energy systems are based on public preference or on economics, or some combination. It is not clear which course markets will take and policy actions are likely critical to determine the answer.
- Energy systems will be under stress in all four scenarios.
 - This stress will force both governments and markets to make choices.
 - National oil companies may replace international oil corporations, changing the dynamic.
 - Significant investments in oil shale and sands, carbon capture and storage, biofuels, nuclear power, and very efficient transport will clearly depend on government decisions.
 - There may be more competition between energy producers and end-users than between energy sources.
 - Volatility and liquidity of the markets will almost certainly be impacted by the overall stress on the energy system.
 - Oil price shocks and are likely to accelerate a transition away from oil and gas with consequent effects (both

Energy policy will be different from region to region and even between nations, especially within more complex regions.

positive and negative) on the achievement of the 3 A's.

- It is not clear that plant and equipment manufacturing capability will exist to meet the energy supply and demand needs of the future. The same may be said about the human capability to design, construct and operate the systems as well as the infrastructure capacity to transmit and deliver the energy. Clean water affects the means to produce energy and as a product of energy investment. New World Bank country procurement standards will hopefully be more effective at achieving sustainable energy systems than conventional global standards.
 - Human capacity to operate energy systems may not be in the most desirable locations and may necessitate extensive migration within and between regions. This migration could place further stress on cities.
 - Higher fossil energy prices may open the door for introduction of cleaner alternatives or they could force economically marginal countries and peoples to use dirtier ones.
 - The scenarios with high cooperation indicate enhanced performance relative to the achievement of the 3 A goals.
 - It is not clear what form global energy markets (trade agreements), regional or worldwide will take. Yet they are likely to drive political alliances of the future.
 - It is by no means clear whether the emerging energy “giants” as producers
- or as consumers of energy (China, India, Brazil and Russia will form alliances or whether they will focus on competing with each other. More public-private partnerships in energy development will clearly play an important role in future alliances.
- Most people argue that more energy R&D is needed, but it is not clear what level is necessary to provide insurance for a sustainable energy future.
 - The performance on achieving “Acceptability” is an issue under all scenarios.
 - Carbon markets, of whatever design, may lead to a stable value for carbon with incentives lower emissions in harmony with growth, or someone could just make a lot of money. It is not clear if carbon taxes a better bet?

The Study Group recommends these issues to the leadership and Member Committees of WEC. The input of delegates to the World Energy Congress and other energy institutions is critical on how to address and promote profitable policy actions.

9. Further Reading

“All things are ready if our minds be so.”

William Shakespeare

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2. 2007 Survey of Energy Resources, World Energy Council, London, 2007
3. Energy Technology Perspectives: Scenarios & Strategies to 2050, International Energy Agency, Paris, 2006
4. World Energy Outlook 2007, International Energy Agency, Paris, 2007
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6. Curbing Global Energy Demand Growth: The Energy Productivity Opportunity, McKinsey Global Institute, New York, 2007
7. Transport Technologies and Policy Scenarios to 2050, World Energy Council, London, 2007
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9. Facing the Hard Truth About Energy, National Petroleum Council, Washington, D.C., 2007
10. Framework for a Post-2012 Agreement on Climate Change, Global Leadership for Climate Action, 2007.
11. Regional Energy Integration in Africa Study, 2005.
12. Energy Integration in Latin American Study, 2007.

10. Appendices

10.1. Appendix A: URLs

Energy Policy Scenarios to 2050

http://www.worldenergy.org/publications/energy_policy_scenarios_to_2050/

Electricity generation

http://www.worldenergy.org/publications/energy_policy_scenarios_to_2050/electricity_generation/

Electricity end-use

http://www.worldenergy.org/publications/energy_policy_scenarios_to_2050/electricity_enduse/

Stationary end-use

http://www.worldenergy.org/publications/energy_policy_scenarios_to_2050/stationary_enduse/

Transport

http://www.worldenergy.org/publications/energy_policy_scenarios_to_2050/transport/

Energy-price drivers

http://www.worldenergy.org/publications/energy_policy_scenarios_to_2050/energy_price_drivers/

Investment and finance

http://www.worldenergy.org/publications/energy_policy_scenarios_to_2050/investment_and_finance/

Climate change

http://www.worldenergy.org/publications/energy_policy_scenarios_to_2050/climate_change/

POLES

http://www.worldenergy.org/publications/energy_policy_scenarios_to_2050/poles/

Appendix B: Specialist Perspectives

10.1.1. Electricity Generation and End-Use

Alongside transportation, the production, transmission, and use of electricity is one of the most vital technology-development areas to achieve the 3 A's. Rapid global growth in electricity-generation capacity, fueled by growing demand, places clear requirements on the broad deployment of technologies, and along with other objectives (such as reducing greenhouse gas emissions), global growth will drive technological evolution.

Electricity generation technology is likely to be based on coal, and in the medium-term, on clean coal technologies. Large increases in electricity-generation capacity are anticipated in India and China, which will most likely utilise their indigenous coal resources. Together with revitalised coal programmes in North America and Europe, coal technology is likely to develop rapidly, moving through a series of evolutionary cycles from currently available sub-, critical, and super-critical technologies, culminating in the development and deployment of advanced technologies, e.g., integrated gasification combined cycle (IGCC).

Key to using coal-based generation technologies, however, is the analogous development of pollution-control technologies. These technologies need to focus on micro-pollutants such as sulfur dioxide, nitrogen oxides, and particulates and on the wider and

pressing issue of carbon dioxide. Further development and deployment of carbon capture-and-storage technologies is essential.

In addition to coal, other generation technologies will continue to evolve and play a growing role in electricity supply. The use of natural gas will increase and the widespread application of state-of-the-art combined-cycle gas turbine (CCGT) technology will continue. However, access to natural gas is key. It is therefore highly likely that electricity generation from natural gas will be limited in its regional and geographical extent. There is little doubt that imported liquid natural gas (LNG) will also play a role, as domestic supplies are unable to keep up with demand.

It is expected that nuclear power will undergo something of a renaissance with programmes in Europe, North America, Russia, China, and India already confirmed. These programmes slowly improve technologies into a third and fourth generation set from the current generation technologies.

Renewables (including hydropower) continue to play a growing role. Deployment of electricity generation via wind and biomass is expected across the globe, playing key roles in all regions. Similarly, the development of hydropower will rise, recognising its role as a cost-effective provider of electricity. However, the development of hydropower is constrained by environmental challenges (displacement of people, methane production, competition for fertile land), particularly where large dams are required.

Electricity consumption will continue to be a focal point. Current end-use patterns, particularly in Europe and North America, and to an extent Asia, are at the forefront of policymakers' minds. This political pressure is driving the development of technologies that reduce usage. Tackling "stand-by" loss is a key low-hanging fruit. Ongoing work and innovation could reduce these losses, saving considerable quantities of electricity.

Technological innovation in electricity end-use is also expected. Innovations in lighting (e.g., LED lights), heating and cooling (e.g., advanced heat pumps), and industrial applications (e.g., pumps, motors, and drives) will have a considerable impact. The adoption of minimum efficiency standards for electrical motors and appliances, energy oriented architectural design, that will reduce the need of electric lighting and air conditioning and the reduction of transmission and distribution losses will contribute to save electricity. Also, a more holistic approach to electricity-consumption management (e.g., monitoring and control systems) will also come to the fore.

Estimates from our study suggest that 67 EJ could be saved through the global deployment of some of the technologies discussed. This is 14% of the electricity used today and shows the potential of the demand side to play a significant role in the electricity sector.

It is clear that keeping all options open is key to future success. Further, to allow for the options

to be kept open, RD&D and technology transfer will be of paramount importance.

10.1.2. Stationary End-Use

Stationary end-use is an important and growing area, encompassing innovative energy efficient technologies. In this area, technological innovation is likely to lead to significant change through the application of more and more novel materials and processes, e.g., nanotechnology for energy supply, or ceramics and other materials to improve the efficiency of electricity transmission and distribution.

The pervading cultural and socio-economic climate will heavily influence the implementation of innovative technology. Key is the development of working and living practices and the development of the "knowledge society." As society becomes ever more knowledge-based, driven by increasingly intelligent systems, the pattern and form of energy consumption will likewise change. Telecommuting and virtual teaming will change the face of our social interactions and also significantly influence energy consumption (hence, supply). Matching the energy supply to these evolving, and potentially more efficient, usage patterns is essential.

Step changes are also important to recognise and encourage. In recent history, technology has gone through evolutionary stages, from slow improvements (e.g., water-heating efficiencies) to large leaps (e.g., compact fluorescent bulbs). Both processes will undoubtedly continue; however, encouraging technological leaps is

essential to long-term management of the demand side. The process of innovation should not be stifled and methods for testing and deployment should be encouraged.

10.1.3. Transportation

Perhaps the most important technological innovations needed between now and 2050 deal with transportation, mainly personal transportation, due to its major contribution to the consumption of oil derivatives. Diesel and hybrid electric vehicles present a cost-effective short-, medium-, and long-term method to increase energy efficiency and reduce total energy consumption. Government incentives to support initial market penetration are appropriate. Fuel cell and battery electric vehicles have high total use potential, but are expected to be less cost-effective than more conventional technologies, even by 2050. Further research toward breakthroughs in technology and cost are necessary for high penetration. Government incentives for consumers, production, and technology research are appropriate, along with continuous assessments of future potential.

Biomass-to-liquid (BTL) and cellulosic ethanol fuels represent significant potential for saving fossil fuel and petroleum. Their long-term cost-effectiveness, therefore market penetration, depends on production costs and the price of oil. Proportional production incentives from governments on these and other alternative fuels, which directly foster lower petroleum or fossil fuel energy consumption, are appropriate to support higher penetration. Government

assistance in overcoming initial research and production investment barriers is also appropriate in the short to medium-term. The price of oil is an unknown variable and government policy must be flexible to account for future market developments. CTL (CTL) fuel represents a significant potential for reducing petroleum use and government incentives are appropriate where reduction in petroleum use, rather than fossil fuel consumption, is the priority. Gas-to-liquid (GTL) represents significant potential for supplying liquid fuels with GHG emissions at the same level as diesel fuel.

Investment incentives and research support should be in accord with a full assessment of the potential of each technology in achieving a government's energy objectives. In selecting the method of applying incentives, the level of production or consumer incentive should ideally be technology-neutral and proportional to the performance of the technology or fuel in achieving the relevant energy objective, which is to be established by the government.

Hybrid vehicles can become more competitive and should displace conventional cars in a few decades. Less expensive and better performing electricity storage methods than those presently available with current batteries should make pure electric automobiles, and eventually buses, a competitive solution, thus reducing urban pollution. Even in areas where power generation is mostly thermal, the well-to-wheel efficiency tends to be higher if vehicles are electrically powered.

Table B-1 Energy price drivers

Driver	Oil	Gas	Coal	Uranium
Demand	<ul style="list-style-type: none"> – Strong growth – Global trend +1-2% per annum 	<ul style="list-style-type: none"> – Growth similar to oil – Globally +1.5-2% per annum 	<ul style="list-style-type: none"> – Growth similar to oil – Globally +1.4-2% per annum 	<ul style="list-style-type: none"> – 2004 demand outstripped supply – Secondary sources
Reserves	<ul style="list-style-type: none"> – Currently consumed one-third of proven conventional reserves – Peak oil not an issue for some time 	<ul style="list-style-type: none"> – Very large reserves – 65 years of proven reserves estimated – At least as much again – Non-conventional, too 	<ul style="list-style-type: none"> – Huge reserves >200 years – Well distributed 	<ul style="list-style-type: none"> – >50 years – Geographically concentrated though
Costs	<ul style="list-style-type: none"> – Production costs USD2-25 (conventional), >USD40 (non-conventional) – Rise of oil synthetics? 	<ul style="list-style-type: none"> – Shipping costs are key 	<ul style="list-style-type: none"> – If not locally extracted and used, freight rates key driver 	<ul style="list-style-type: none"> – Driver is the cost of extraction and shipping
Market Power	<ul style="list-style-type: none"> – Strength of OPEC? 	<ul style="list-style-type: none"> – Three countries with 55% of reserves 	<ul style="list-style-type: none"> – Limited 	<ul style="list-style-type: none"> – Small number of suppliers – Impact limited
Other	<ul style="list-style-type: none"> – Development of reserve capacity 	<ul style="list-style-type: none"> – Importance of “gas-to-gas” competition – Oil de-link 	<ul style="list-style-type: none"> – Fuel substitution – Environmental regulation 	<ul style="list-style-type: none"> – Much investment in mining needed
Possible Price Outcome	<ul style="list-style-type: none"> – EIA price, falling to USD47/bbl in 2014 (2004 value) – IEA more aggressive 	<ul style="list-style-type: none"> – Regional markets important – No price as yet 	<ul style="list-style-type: none"> – Reasonably static at around USD50/t 	<ul style="list-style-type: none"> – Nothing reported

10.1.4. Energy Price Drivers

Energy prices continue to drive investments and play a vital role in the development of energy systems, and indeed in driving (or limiting) economic growth. No forecasts of future prices are presented here; instead, we focus on pricing the drivers themselves:

- ▶ Demand
- ▶ Reserves
- ▶ Costs
- ▶ Market Power.

Table B-1 summarises some key potential outcomes by energy carrier.

Overall, it is expected that:

- Demand for all energy commodities will remain strong over the coming years, with a considerable potential for demand to outstrip supply.
- Reserves do not appear to present a significant constraint in the period covered by the study.
- Production costs will vary, and in several circumstances, will drive overall prices upwards. This is particularly so for oil and to an extent gas. Oil and gas costs will increase, driven not only by declining reserves, but also from the inclusion of alternates such as oil sands and tight gas.
- Market power seems most likely to diminish, although some countries, as a consequence of their dominant market position, may be likely to dictate market terms to their own benefit.
- Overall, environmental regulation and mitigation costs are seen as being key in the coming years, influencing fuel choice, hence changing the pattern for demand.
- Energy sector financial structures must allow for adequate returns to be generated from investments.

10.1.5. Investment and Finance

Over the coming decades, estimates of investment requirements in the energy sector are huge - on a scale never before seen. Published investment requirements total USD 20 trillion over the next 25 years and are likely to be considerably greater by 2050. This investment is required across the value chain and for all energy carriers, although it is expected that slightly more than half is required in electricity generation and the remainder mostly in oil and gas.

There is consensus that this investment can be achieved over time, although there is much to do to facilitate this investment, particularly in emerging markets. The private sector, multi-lateral agencies, and governments are all in agreement that while the scale of the challenge is enormous, there are sufficient funds available. It is however important to understand that these funds compete for the best projects within the energy sector and also with other infrastructure projects.

However, in making investments, a number of critical factors must be actively considered, with some requiring attention so that they do not become barriers:

- ▶ Economic and political stability in the country of investment
- ▶ Stable regulation of the business environment
- ▶ Institutional climate (e.g., contract law)

- ▶ Labour availability
- ▶ Efficient financial system
- ▶ Personal security
- ▶ Environmental regulation stability.

Discussions with potential financiers continually suggest that their most preferred investment is one contracted with credit-worthy counterparts in an open and transparent market place established in law. Such requirements are clearly not evident in countries with an uncertain regulatory framework, an unproven market model, as well as in emerging markets, and as such, will undoubtedly require considerable further effort to make investments acceptable.

A sound framework to attract these funds is based on two pillars. First, the regulatory environment needs to be robust. Regulatory risk is one of the key risks in the energy sector and has many faces:

- ▶ Discretionary exercise of powers - arbitrary change of quality standards
- ▶ Will the tariff and other key parameters allow investors to reach their return objectives?
- ▶ Impartial dispute resolution
- ▶ CO₂ market after Kyoto?

The key requirements for a regulatory framework are that it should protect both public and investors' short-term and long-term interests and be transparent, stable, and predictable over the long-term and independent from political authorities, which pleads for national rather than local regulation.

The second pillar is the predictability of revenues, a cornerstone for financing such efforts.

Energy markets must be organised to offer predictability. A number of solutions, however, exist to this seemingly intractable position. These solutions (especially for electricity power) reflect differing levels of market evolution:

“Energy Only” - effectively free trade and competitive market solutions

“Capacity Payments” - a way to foster provision/availability of capacity, with variable rewards following those of the Energy-Only option

“PPA” model - long-term contracts are signed for the purchase of electricity, providing clarity and certainty.

Each potential market model has its place in all countries, although precise solutions depend on the level of political will and the ability to support market development. Without such models (and possibly in countries where such models exist), further political and credit support will still be required. It should, however, be acknowledged

that credit support to emerging markets through aid mechanisms should be closely tied to a commitment by the host government to put in place the above referred predictable legal, political, and commercial framework. This credit support should thus be seen as a catalyst, enabling the transition toward subsequent non-subsidised investments.

Overall, there are clearly sufficient funds and there has been sufficient thought on solutions. The key is for all of the stakeholders to work together to develop an appropriate system that is robust and above all transparent.

10.1.6. Climate Change¹⁷

If policies are to be effective at dealing with climate change, they have to be aimed at the right targets - those parts of the energy sector significant in their emissions and their opportunities for cost-effective reductions. Sustainability will not be achieved if lower emissions are reached at the cost of social and economic development, especially for the two billion people who lack access to modern energy and its attendant services. The analysis shows how different the emissions trends are in different regions of the world and how different are the underlying drivers. It is clear that each country will have to develop its own response to climate change - no simple single solution or even set of solutions will solve all problems for every country.

¹⁷ Energy and Climate Change, World Energy Council, London, 2007.

Table B-2 Emissions Intensity in terms of energy and GDP for selected countries (data from IEA, 2005, and World Energy Council, 2007).

	CO ₂ /E (Mtonne/Mtoe)	CO ₂ /GDP (tonnes/kUSD)		CO ₂ /E (Mtonne/Mtoe)	CO ₂ /GDP (tonnes/kUSD)
Argentina	2.12	303.0	Republic of Korea	2.24	521.6
Australia	2.99	597.2	Mexico	2.39	419.0
Bangladesh	1.54	144.9	Russia	2.44	1247.6
Brazil	1.62	238.7	Saudi Arabia	2.41	1118.5
Canada	2.05	577.1	South Africa	3.18	841.6
China	2.90	671.8	Sweden	1.05	216.0
France	1.41	238.2	Syria	2.68	812.3
Germany	2.44	406.8	Tanzania	0.17	139.3
India	1.96	377.9	Thailand	2.26	448.0
Iran	2.73	853.3	United Kingdom	2.36	342.5
Japan	2.37	360.6	United States	2.50	553.8

There are some overall patterns - greenhouse gas emissions tend to rise as the population grows and gets wealthier. If this were the whole story, reducing emissions would indeed be incompatible with sustainable development - the only way of reducing emissions is to slow population or economic growth.

Fortunately, it is not the whole picture. The emission intensity of economies varies significantly (Table B-2). While big, populous economies like the United States and China naturally have the highest level of overall emissions, there are many examples of economies at similar levels of development but with very different levels of emission intensity. France and Sweden, for instance, have relatively low levels of emissions intensity compared with broadly similar countries like Germany and Australia; similarly, Brazil's emissions are lower than South Africa's. There are different reasons for this such as climate differences (there is less demand for heating in some countries than in others) and differences in industrial activity and efficiency, and differing fuel mixes.

Decades are required, even with the most effective application of policy and technologies, to achieve significant sustainable reductions in CO₂ emissions from the world's energy economy, in large part because of the time and cost involved in replacing existing and building new infrastructure and other long-lived assets. Just to keep pace with the world's growing

energy demands will require \$800 billion per year of investment over the next 25 years, according to the IEA. To make this investment climate-friendly is an even greater challenge, but it is possible to scope out a roadmap to try and meet this challenge in three stages:

10.1.7. 2020: Credible commitments and slower emissions growth

Measures might include long-term carbon tax credits with a specific focus on promoting investment; specific schemes of support for low-carbon; power-generation alternatives; and stronger renewable energy portfolio standards facilitated by intelligent electricity-delivery technology. In addition, broad commercial introduction of advanced clean coal technology, particularly in rapidly industrialising nations such as China and India. However, there are questions about China's and/or India's willingness to be bound to limits on emissions in the framework of any post-Kyoto Protocol¹⁸. In the transportation sector, growth in emissions should be restrained by a combination of measures - technical approaches via vehicle efficiency, hybrid vehicles, and biofuels, along with non-technical measures aimed at changing behaviour to lower carbon-transport modes via taxation, regulation, or other means. Achieving and maintaining a significantly greater global investment in technology development and

¹⁸ *World Energy Outlook 2007*, International Energy Agency, Paris, 2007

deployment is equally important and lays down the essential basis for realising subsequent sustainable carbon reductions.

10.1.8. 2035: Emissions stabilisation

Building on the foundations of the first phase, it will in time be possible to take advantage of new energy-related infrastructure and major technology advances, in areas such as advanced nuclear power plants, some utilising breeder technology, and supercritical coal and/or IGCC with CCS, thus enabling zero-carbon-emission, fossil fueled power plants. Other important emission-reduction technologies include advanced solar thermal, building-integrated photovoltaics, and micro-combined heat and power plants. All of these are further stimulated by breakthroughs in energy-storage technology. In addition, advanced building technologies produce major energy savings, perhaps including converting buildings from energy consumers to net producers. Hybrid vehicles, plus other advanced clean transportation options (including the widely expanded production and use of biofuels that do not interfere with the food cycle) will also significantly contribute to lower carbon emissions while reducing petroleum consumption.

10.1.9. 2050: Sustainable emissions reduction

As time goes on, zero-carbon technologies, coupled with advanced energy storage, continue the decline in emissions, leading to a truly post-

carbon world. The potential for nuclear fusion and a universal electro-hydrogen energy economy may also be established. All of this continued progress, however, is predicated on sustained major global commitment to technological development with prompt transfer and deployment into the world's energy infrastructure.

This timeline may seem lengthy but it only underscores the urgency needed if global CO₂ emissions are to be returned to or below current levels by 2050. Some are costly in the short-term, but will produce longer-term benefits. The sooner society acts with a real commitment and effective measures to stabilise and reduce CO₂ emissions, the better.

A recently released report, "Framework for a Post-2012 Agreement on Climate Change"¹⁹, by the UN convened Global Leadership for Climate Action, focuses on urgent actionable recommendations, including complementary pathways, also suggesting as this study does that energy related carbon emissions can be reduced to current levels by 2050. In addition, the WEC study and this GLCA study both believe that market based mechanisms are important to achieving realistic carbon reductions. This WEC study further recommends that an international agency modeled after the World Trade Organization (WTO) is required to monitor and police any global market with the appropriate authority delegated to and honored by each participating nation.

¹⁹ Framework for a Post-2012 Agreement on Climate Change, Global Leadership for Climate Action, 2007.

Appendix C: Study Group Members

Chair:

Brian Statham (South Africa)

Members:

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 Tanvir Nawaz Khan (Bangladesh)
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 Theofilos Likos (Greece-2005)
 Abou Kawass Camara (Guinea)
 B.P. Rao (India)
 R.S. Sharma (India)
 Djoko Prasetyo (Indonesia)
 Mohsen Bakhtiar (Iran)
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 Rob Whitney (New Zealand)
 Olugbenga Adesanya (Nigeria)
 Marek Jaczewski (Poland)
 Francisco Saraiva (Portugal)
 Anton Vladescu (Romania)
 Vladimir Mirolyubov (Russia)

Victor Sergeev (Russia-2005)
 Mahmoud Al-Osaimy (Saudi Arabia)
 Natan Bernot (Slovenia)
 Alison von Ketelhodt (South Africa)
 Eloy Álvarez Pelegry (Spain)
 G.B.A. Fernando (Sri Lanka)
 Jürg Bartlome (Switzerland)
 David Small (Trinidad & Tobago)
 Nabil Bouraoui (Tunisia)
 Wim Thomas (UK)
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Steering Committee:

Brian Statham (South Africa)
 Rogério Manso (for Latin America and the Caribbean)
 Oskar Sigvaldason (for North America)
 Emad El-Sharkawi (for Africa)
 Yasuo Hosoya (for Asia)
 Ed Weeda (for Europe)
 François Ailleret (Special Advisor)
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Energy-price drivers - H.W. Schiffer (Germany)
Electricity generation - B.P. Rao (India)
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Electricity end-use - Makoto Suto (Japan)
Stationary end-use - Natan Bernot (Slovenia)
Climate change - Malcolm Keay (UK)
Transport - Simon Godwin (USA)

Invited Experts:

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Simon Cocks (UK)
David Lewis (UK)
Angela Wilkinson (UK)

Consultants:

Michael Cupit (Ernst & Young)
Chris Mole (Ernst & Young)
Sam Palfrey (Ernst & Young)

Director of Studies:

Robert Schock (USA)

Secretary:

J. K. Mehta (Special Advisor to Director of Studies)

10.2. Appendix D: Glossary

Factor	Name	Symbol
10 ¹⁸	exa-	E
10 ¹⁵	peta-	P
10 ¹²	tera-	T
10 ⁹	giga-	G
10 ⁶	mega-	M
10 ³	kilo-	K

\$(ppp) Purchasing power parity

Accessibility Convenience, cost, and efficiency of energy and energy services

Availability Quality and reliability of energy and energy services

Acceptability Environmental acceptability of energy and energy services

Biofuel Any liquid, gaseous, or solid fuel produced from plant or animal organic matter. Second-generation biofuels are derived from ligno-cellulosic biomass by chemical or biological processes, yielding products like ethanol and biodiesel.

BTL Biomass-to-liquid

BTU British thermal unit (amount needed to raise one pound of

water 1 degree F, equivalent to 1.055 x 10³ joules

C Carbon

CO₂ Carbon dioxide

CCS Carbon capture and storage. A process of separating CO₂ from industrial and energy-related sources, transporting it to a storage location, and isolating it from the atmosphere for the long-term.

CDM Clean Development Mechanism (defined in the Kyoto Protocol)

CTL Coal-to-liquid

EFTA European Free Trade Association

EJ 10¹⁸ Joules (~10¹⁵ BTU)

End-use technology Conversion to useful work, as in process heat, lighting, or transport

EU European Union

GDP Gross domestic product

IGCC Integrated gasification combined cycle

LPG Liquefied petroleum gas

Modern energy	The use of fossil fuels, nuclear power, and renewables (biomass, solar, geothermal, wind, and ocean)
mtoe	million tons oil equivalent
NAFTA	North America Free Trade Agreement
NIMBY	Not In My Back Yard

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