FINAL REPORT –
GLOBAL ENERGY SCENARIOS

Analysis of thematic emphasis, main drivers and communication strategies

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11.4 Literature/Sources
1 Introduction
Within the current EFDA task nine important global energy resources have been analysed, regarding their time horizon, the main drivers used in the scenarios, the constraints and the dissemination strategy. A concept for communication strategies for the results of the current results of EFDA scenarios is developed and new scenarios are computed. A survey on impacts triggered by varying demand growth rates on the potential fusion share in the future energy system has been elaborated as well. As part of the dissemination activities within SERF this analysis feeds into a scientific journal publication. Further on a prototype for an ETM website has been started.

2 Global Energy Scenarios
During the last years global energy scenarios have been developed by several institutions. Nine of these scenarios have been analysed within the current EFDA task. The majority of the scenarios has a time horizon of 2050, the others deliver results until 2100 and 2035. All scenarios use population and GDP as the main drivers, some use additional drivers such as prices. The scenarios also include constraints regarding e.g. emissions, available technologies, policy, available resources, etc. Table 1 gives an overview of the scenarios analysed and their general framework.

<table>
<thead>
<tr>
<th>Global energy models/scenarios</th>
<th>Horizon</th>
<th>Drivers</th>
<th>Constraints</th>
<th>Dissemination</th>
</tr>
</thead>
<tbody>
<tr>
<td>IEA Energy Technology Perspectives</td>
<td>2050</td>
<td>Population, GDP, Prices</td>
<td>Emissions, technologies</td>
<td>Report (online), Website</td>
</tr>
<tr>
<td>IEA World Energy Outlook 2011</td>
<td>2035</td>
<td>Population, GDP, Prices</td>
<td>Policy, emissions, technologies</td>
<td>Report (online), Website</td>
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<td>IIASA GGI scenarios</td>
<td>2100</td>
<td>Population, GDP, Prices</td>
<td>Policy, emissions, technologies, etc.</td>
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<td>2050</td>
<td>Population, GWP, Prices</td>
<td>Policy, emissions, technologies, etc.</td>
<td>Book, Website</td>
</tr>
<tr>
<td>IPCC emission scenarios</td>
<td>2100</td>
<td>Population, GDP, Prices</td>
<td>Policy, emissions, technologies, etc.</td>
<td>Report (online), Scenario DB</td>
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<td>Policy, emissions, technologies, etc.</td>
<td>Papers, Website</td>
</tr>
<tr>
<td>SHELL energy scenarios</td>
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<td>Population, GDP, Prices</td>
<td>Policy, resources, technologies, etc.</td>
<td>Report (online), Website</td>
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<td>WETO World energy technology outlook</td>
<td>2050</td>
<td>Population, GDP</td>
<td>Policy, resources, technologies, etc.</td>
<td>Report (online)</td>
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<tr>
<td>WEC energy policy scenarios</td>
<td>2050</td>
<td>Population, GDP</td>
<td>Policy, resources, technologies, etc.</td>
<td>Report (online)</td>
</tr>
</tbody>
</table>

Table 1 Overview of scenarios analysed
3 IEA – Energy Technology Perspectives – Scenarios & Strategies to 2050

3.1 General description
The Energy Technology Perspectives (ETP) 2010 shows opportunities for a more secure and sustainable energy future. Two main scenarios are investigated, the “Baseline scenario” and the “Blue Map scenario”. Also some variants of the main scenarios are developed.

The Baseline scenario uses the Reference scenario from the World Energy Outlook 2009 which has a scenario horizon until 2030 and extends it to the year 2050. No new energy and climate policies are assumed in this scenario.

The Blue Map scenario integrates some future targets regarding emission reductions and the use of new low-carbon technologies, energy efficiency aspects and economic development. The Blue Map scenario has several variants.

Figure 3.1 outlines the different primary energy demands by fuel for the Baseline and the BLUE map scenario in the year 2050.

![Figure 3.1 Demand for primary energy in the baseline and blue map scenario](image)

To achieve the objective of a significant reduction of emissions in the blue map scenario a variety of existing and new low-carbon technologies will be necessary. Figure 3.2 shows the range of technologies in the BLUE map scenario.
3.2 Scenario storylines and main drivers

3.2.1 Baseline scenario
The baseline scenario uses the reference scenario from the World Energy Outlook 2009 until the year 2030 and extends it to 2050. Therefore no new policies for climate or energy aspects are included in the scenario. This scenario assumes an average growth of the world economy of 3.1% per year between 2007 and 2050. This average growth is assumed although after the year 2030 population growth slows down and economies of developing countries begin to mature.

The baseline scenario also has one variant scenario, the “High Baseline” scenario. This scenario assumes a higher growth in industrial production for key energy-intensive materials and in the transport sector it assumes a higher growth in passenger light-duty vehicle ownership in developing countries and a faster growth in vehicle travel and freight transport.

3.2.2 Blue Map scenario
The Blue map scenario was developed with a number of variants regarding the development of the different sectors electricity, buildings, industry and transport. In general the blue map scenarios assume a 50% reduction of global energy related CO₂ emissions until 2050 (base year 2005). A least-cost approach is applied to investigate how new and existing technologies can be used to fulfil this objective. The blue map scenarios are able to limit the long-term temperature rise to 2 – 3°C with a combination of the reduction of energy-related CO₂ emissions and a significant reduction of other greenhouse-gas emissions. The scenarios also lead to benefits in energy security as the dependence of oil and gas can be reduced and benefits in health due to a reduction of air pollutants. The assumptions on population and macro-economic aspects are the same than in the baseline scenario. Regarding technology development the BLUE map scenarios assume that technologies which are not available today are developed to a commercial standard.

The basis for the envisaged cleaner and more efficient energy technologies that are the main part of the BLUE map scenarios have to be an increased support for R&D, demonstration programmes,
deployment programmes, CO$_2$ reduction incentives and policy instruments to overcome commercialisation barriers.

There are several variants of the BLUE map scenario, defined by different assumptions in the various sectors.

In the electricity sector four variants of the blue map scenario are investigated.

- **BLUE hi NUC**: a nuclear capacity of 2,000 GW is assumed (the blue map scenario assumes a maximum of 1,200 GW)
- **BLUE no CCS**: no commercially deployed CCS
- **BLUE hi REN**: 75% of global electricity production in 2050 is provided by renewables
- **BLUE 3%**: uses a uniform discount rate of 3% for all electricity generating technologies (the blue map scenario uses market rates of 8 – 14%)

In the building sector three variants are examined.

- **BLUE CHP**: more rapid declines of costs for hydrogen using fuel-cell combined heat and power (CHP) units
- **BLUE Solar Thermal**: availability of low-cost compact thermal storage by 2020; more rapid short-term decrease of system costs
- **BLUE Heat Pumps**: faster cost reductions for space and water heating applications and development of ultra-high efficiency air-conditioners

In the industry sector one variant of the blue line scenario is used.

- **High BLUE**: the assumptions are the same as for the industrial production in the High Baseline scenario and therefore a higher growth in industrial production for key energy-intensive materials is assumed

Two variants of the Blue map scenario are done regarding the transport sector.

- **BLUE Shifts**: assumes a modest reduction of total travel growth and a shift of travel to more efficient modes
- **BLUE Map/Shifts**: is a combination using the technology changes of the Blue map scenario and the travel changes assumptions from the Blue Shifts scenario

### 3.2.3 Main scenario drivers

The main drivers of the IEA – Energy Technologies Perspectives scenarios are demographic assumptions (Population), macroeconomic assumptions (GDP) and International energy prices. While population and GDP projections are the same for the Baseline and the BLUE map scenarios, energy prices are assumed to be different.

**Population**

World population is projected to grow to 9.1 billion, what corresponds to a rise of 32%. Asia and Africa show the highest growth, while OECD countries show a decrease of population.
It is projected that global GDP will grow by more than three times until 2050 to a level of USD 225 trillion per year.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>OECD</td>
<td>1.4</td>
<td>1.9</td>
<td>1.2</td>
</tr>
<tr>
<td>OECD North America</td>
<td>1.8</td>
<td>2.3</td>
<td>1.4</td>
</tr>
<tr>
<td>United States</td>
<td>1.8</td>
<td>2.2</td>
<td>1.3</td>
</tr>
<tr>
<td>OECD Europe</td>
<td>1.0</td>
<td>1.8</td>
<td>0.7</td>
</tr>
<tr>
<td>OECD Pacific</td>
<td>1.3</td>
<td>1.3</td>
<td>1.7</td>
</tr>
<tr>
<td>Non-OECD</td>
<td>5.7</td>
<td>4.1</td>
<td>3.4</td>
</tr>
<tr>
<td>Economies in transition and non-OECD Europe</td>
<td>3.3</td>
<td>3.3</td>
<td>3.5</td>
</tr>
<tr>
<td>Middle East</td>
<td>4.5</td>
<td>4.0</td>
<td>2.5</td>
</tr>
<tr>
<td>Africa</td>
<td>4.7</td>
<td>3.1</td>
<td>3.1</td>
</tr>
<tr>
<td>Latin America</td>
<td>3.1</td>
<td>2.5</td>
<td>2.5</td>
</tr>
<tr>
<td>China</td>
<td>8.8</td>
<td>4.4</td>
<td>3.8</td>
</tr>
<tr>
<td>India</td>
<td>7.0</td>
<td>5.9</td>
<td>3.3</td>
</tr>
<tr>
<td>Other developing Asia</td>
<td>3.2</td>
<td>3.5</td>
<td>2.6</td>
</tr>
<tr>
<td>World</td>
<td>3.3</td>
<td>3.0</td>
<td>2.6</td>
</tr>
</tbody>
</table>

Sources: Hawksworth (2006); IEA (2009c).

Figure 3.4 GDP projections (% per year, based on purchasing power parity) [IEA 2010]
International energy prices

<table>
<thead>
<tr>
<th></th>
<th>Unit</th>
<th>2008</th>
<th>2030</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>IEA crude oil imports</td>
<td>Barrel</td>
<td>97</td>
<td>115</td>
<td>120</td>
</tr>
<tr>
<td>Natural gas</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>European imports</td>
<td>MBtu</td>
<td>10.3</td>
<td>14.0</td>
<td>14.7</td>
</tr>
<tr>
<td>Japanese imports</td>
<td>MBtu</td>
<td>12.6</td>
<td>15.9</td>
<td>16.7</td>
</tr>
<tr>
<td>OECD steam coal imports</td>
<td>Tonne</td>
<td>121</td>
<td>109</td>
<td>115</td>
</tr>
</tbody>
</table>

Note: MBtu is million British thermal units.
Sources: IEA (2009c); IEA analysis.

Figure 3.5 Oil, gas and coal price projections for Baseline scenarios (in 2008 USD per unit)

<table>
<thead>
<tr>
<th></th>
<th>Unit</th>
<th>2008</th>
<th>2030</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>IEA crude oil imports</td>
<td>Barrel</td>
<td>97</td>
<td>90</td>
<td>70</td>
</tr>
<tr>
<td>Natural gas</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>United States imports</td>
<td>MBtu</td>
<td>8.3</td>
<td>10.2</td>
<td>7.9</td>
</tr>
<tr>
<td>European imports</td>
<td>MBtu</td>
<td>10.3</td>
<td>11.0</td>
<td>8.6</td>
</tr>
<tr>
<td>Japanese imports</td>
<td>MBtu</td>
<td>12.6</td>
<td>12.5</td>
<td>9.7</td>
</tr>
<tr>
<td>OECD steam coal imports</td>
<td>Tonne</td>
<td>121</td>
<td>65</td>
<td>58</td>
</tr>
</tbody>
</table>

Note: MBtu is million British thermal units.
Sources: IEA (2009c); IEA analysis.

Figure 3.6 Oil, gas and coal price projections for BLUE map scenarios (in 2008 USD per unit)

3.3 Communication Strategy

3.3.1 Publications

3.3.2 Online
The reports of the Energy Technology Perspectives are available via the IEA website. The index of the reports can be found at [http://www.iea.org/techno/etp/index.asp](http://www.iea.org/techno/etp/index.asp) [accessed 18. October 2012]. Besides the report also Key summaries and key figures can be accessed.

3.4 Literature/Sources
4 IEA – World Energy Outlook 2011

4.1 General description

In the World Energy Outlook 2011 implications of global energy markets of different assumptions regarding energy and climate policy are evaluated. The World Energy Outlook 2011 includes three scenarios, the Current Policies Scenario, the New Policies Scenario and the 450 Scenario and also some variations of these central scenarios are examined. The central scenario is the New Policies Scenario, assuming that recent government policy commitments are implemented in a cautious manner. The Current Policies Scenario only incorporates policies that have been implemented until mid-2011. After that time it is assumed that no new policies come into force. The 450 Scenario tries to achieve the goal to limit the long-term global mean temperature rise to 2°C. The variations of the central scenarios include a Low GDP Case, a Deferred Investment Case (deferred investment in oil in North Africa and Middle East), a Golden Age of Gas (optimistic scenario for natural gas), a Delayed Carbon Capture and Storage Case and a Low Nuclear Case.

The scenarios offer internally consistent projections until the year 2035, with the starting year 2010.

4.2 Scenario storylines and main drivers

4.2.1 New Policies Scenario

In this scenario it is assumed, that policies and plans to tackle climate change, energy insecurity and environmental pollution which have been announced by countries are set into force. This includes renewable energy and energy efficiency targets and support, plans for phase-out of nuclear energy and other national agreements for greenhouse-gas emission reductions. For countries where uncertainty over climate policy is very high the scenarios assume, that the policies adopted are not able to reach their target.

The assumptions on economic growth and population are assumed to be the same in all scenarios and are described in section 2.2.4. Regarding international energy prices oil prices are assumed to rise continuously until 2035. The average price assumed for IEA crude oil imports is $109/barrel (in real 2010 dollars) in 2020 and $120 in 2035. For natural gas the prices are assumed differently for World regions (see Figure 4.4). For steam coal a gradual rise of price is assumed for the projection period with $110/tonne by 2035. Regarding CO₂ prices besides the existing EU Emission Trading System and the New Zealand Emission Trading Scheme it is also assumed that prices for CO₂ emissions will also be introduced for Australia (starting in 2012), Korea (from 2015) and China (from 2020). The United States and Canada do not implement carbon pricing but in this scenario a “shadow price” for carbon is assumed starting in 2015. Also for Japan’s power sector a shadow price is introduced from 2015.

4.2.2 Current Policies Scenario

In this scenario no new policies are assumed to be implemented and therefore only those policies that have been adopted until mid-2011 are in force.

The price for IEA crude oil imports is assumed to rise fast after 2020, leading to prices of $118/barrel in 2020 and $140 in 2035. Natural gas prices in the Current Policies Scenario are assumed to be higher than in the New Policies Scenario (see Figure 4.4), which is also true for steam coal prices reaching $118/tonne by 2035. Regarding CO₂ prices only the already implemented EU Emission trading system and the New Zealand Emissions Trading scheme are available. The price for CO₂ in the European Union is assumed to reach $30/tonne in 2020 and $45/tonne in 2035 (each in year-2010 dollars). In the Current Policies Scenario technological change is assumed to be quite slow (slowest of
all three scenarios), as no new public policies are implemented. But due to higher energy prices also in this scenario technological change occurs – especially regarding energy efficiency aspects.

4.2.3 450 Scenario
The 450 Scenario assumes measures in the energy system that are able to meet the global objective of limiting the global temperature rise to 2°C (in comparison to the pre-industrial levels) with a chance of 50%. For the achievement of this goal a long-term stabilisation of CO₂-equivalent concentrations of 450 ppm in the atmosphere is necessary. Therefore the scenario assumes an ambitious policy action until 2020 and afterwards economy-wide emissions targets for 2035 and beyond for OECD countries and other major economies. Due to lower demands for oil the price is assumed to be at $97/tonne and to stay at this level until 2035. It has to be noted, that in this scenario the end-user prices for oil-based transport fuels is kept at a similar level as in the Current Policies Scenario by administrative regulations. By this it can be assured that there are no rebound effects in transport through lower end-user prices. The price for natural gas is assumed to be lower than in the other two scenarios in Europe and Japan, but in the United States price in 2025 and 2030 is slightly higher (see Figure 4.4). The price for steam coal is at $93/tonne in 2020 and $68/tonne in 2035. Regarding CO₂ emissions it is assumed, that in this scenario all OECD countries introduce CO₂ pricing systems with the prices converging from 2025 and reaching a price of $120/tonne in 2035. CO₂ prices are also assumed for important non-OECD countries. The 450 Scenario assumes fast technological development, mainly due to the effect of different types of government support and direct public-sector investment.

4.2.4 Main scenario drivers

Policy
Energy policy assumptions define the framework of the storyline. They define the scenario storyline and have impacts on energy prices, technology developments, etc. The key policy assumptions are different for world regions within the three main scenarios.

<table>
<thead>
<tr>
<th>OECD</th>
<th>Current Policies Scenario</th>
<th>New Policies Scenario</th>
<th>450 Scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>New appliance standards; state-level support schemes for renewables; enhanced CAFE standards; tax credits for renewable energy sources.</td>
<td>Shadow price of carbon adopted from 2015, affecting investment decisions in power generation, new HVD standards for each model year from 2014 to 2018, EPA regulations on mercury and other pollutants in the power sector.</td>
<td>Staggered introduction of CO₂ prices in all countries; $100 billion annual financing provided to non-OECD countries by 2020; on-road PUD emissions average 65 g/km in 2025.</td>
</tr>
<tr>
<td>European Union</td>
<td>ETS, covering power, industry and from 2012 aviation; Energy Performance of Buildings directive; emissions standards for PLUVs; 20% reduction in emissions compared with 1990 by 2020; renewables to reach 20% share in energy demand in 2020.</td>
<td>ETS, covering power, industry and (from 2013) aviation; new LCV standards; more stringent PLUV standards.</td>
<td>A 30% reduction in emissions compared with 1990 by 2020; ETS strengthened in line with the 2010 roadmap.</td>
</tr>
<tr>
<td>Korea</td>
<td>A 30% reduction in emissions compared with business-as-usual by 2020; CO₂ pricing from 2015.</td>
<td></td>
<td>A 30% reduction in emissions compared with business-as-usual by 2020; higher CO₂ pricing.</td>
</tr>
</tbody>
</table>
Economy

Assumptions on economic growth are the same for all scenarios in the World Energy Outlook 2011. The growth of GDP (expressed in real purchasing power parity PPP) is assumed to be 3.6% on average between 2009 and 2035. The medium-term GDP growth assumptions are mainly based on IMF projections, with further recent inputs from national and other sources.
Population

Population, as one of the main drivers for energy demand and therefore also for future energy trends, grows in each of the scenarios from 6.8 billion in 2009 to around 8.6 billion in 2035. This means an average annual growth rate of 0.9%. Non-OECD countries are expected to have the greatest part of population growth. Also the degree of urbanisation has an influence on energy demand. This is because energy use is connected to income and especially urban population in developing countries usually has higher income and a better access to energy services.
Energy prices have a high influence on energy trends. They affect the amount of fuel the consumer of energy services wants to consume and if a greater effort is taken to enhance energy efficiency of technologies.

Oil prices are assumed differently in the three scenarios. A rising price for oil is assumed for all except the 450 Scenario. In the 450 Scenario from 2015 and beyond a stagnating price of $97/barrel is assumed. Gas prices show a significant upward trend in all regions, especially for the New Policies and the Current Policies Scenario. In the 450 Scenario the rise of natural gas import prices is lower than in the other scenarios and between 2030 and 2035 stagnation and decrease of prices is assumed respectively. The prices for steam coal vary considerably between the scenarios, with highest price assumptions in the Current Policies Scenario. An overview of the assumptions on energy prices is given in Figure 4.4.
CO₂ prices
The scenarios assume different CO₂ prices and carbon pricing systems in the different world regions. The assumptions are outlined in

<table>
<thead>
<tr>
<th>Region</th>
<th>Sectors</th>
<th>2020</th>
<th>2030</th>
<th>2035</th>
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<td>Korea</td>
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<td></td>
<td>Power and industry</td>
<td>30</td>
<td>40</td>
<td>45</td>
</tr>
<tr>
<td></td>
<td>Australia, New Zealand</td>
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<tr>
<td></td>
<td>All</td>
<td></td>
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<tr>
<td></td>
<td>China</td>
<td>10</td>
<td>23</td>
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</tr>
<tr>
<td>450 Scenario</td>
<td>United States, Canada</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Power and industry</td>
<td>20</td>
<td>87</td>
<td>120</td>
</tr>
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<td></td>
<td>European Union</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Power, industry and aviation</td>
<td>45</td>
<td>95</td>
<td>120</td>
</tr>
<tr>
<td></td>
<td>Japan, Korea, Australia, New Zealand</td>
<td>35</td>
<td>90</td>
<td>120</td>
</tr>
<tr>
<td></td>
<td>Power and industry **</td>
<td>10</td>
<td>65</td>
<td>95</td>
</tr>
</tbody>
</table>

*All sectors in Australia and New Zealand. **All sectors in China.

Note: In the New Policies Scenario, the United States, Canada and Japan are assumed to adopt a shadow price for CO₂ in the power sector as of 2015; it starts at $15/tonne, rising to $35/tonne in 2035.

Figure 4.4 Import prices for fossil fuels by scenario (dollar per unit)

Figure 4.5 Assumptions for CO₂ prices by scenario and region

Technology
As technology development is highly dependent on energy prices and CO₂ pricing the assumptions are different between the scenarios. The 450 Scenario assumes the fastest technology change and the slowest change in the Current Policies Scenario. No completely new technologies are assumed in the scenarios, but technologies that are currently approaching commercialisation phase are included.

4.3 Communication Strategy

4.3.1 Publications

“World Energy Outlook” reports are available for the years 1994 to 2010. 2012 report will be presented in November 2012.

4.3.2 Online

The complete reports for previous years are available for free download in the section publications, while for the actual World Energy Outlooks only the Summary is for free. The complete report can be ordered directly on the website. Additional information is available for the reports, such as press releases, presentations to the press, fact sheets and key figures.

Also general information on the WEO is given on the website (Overview, Team, FAQ, Awards, Workshops). Workshops in the thematic field of WEO are carried out mostly internal and with special invitation.

A description of the “World Energy Model” (WEM), which is the basis tool for the World Energy Outlook, is available on the website. Further resources about the energy topic are available for download, including media files (e.g. videos on interviews).

4.4 Literature/Sources
Website http://www.worldenergyoutlook.org/

5 IIASA – GGI (Greenhouse Gas Initiative) scenarios

5.1 General description
The greenhouse gas Initiative (GGI) developed scenarios using the IIASA Integrated Assessment Modelling Framework. There are three baseline scenarios using different socio-economic and technological development assumptions A2r, B1 and B2. These scenarios do not directly include explicit climate policies. But there have been climate stabilisation scenarios imposed to the baseline scenarios. The scenarios are derived from the IPCC SRES scenarios, by including new information and using the Integrated Assessment Modelling Framework. The scenarios derived use the same name conventions as the IPCC SRES scenarios.
While the IPCC SRES scenarios mainly use four “macroregions” (OECD, REF, ASIA and ALM), the GGI scenarios downscale them and generally use a spatial resolution of 11 world regions: North America (NAM), Western Europe (WEU), Pacific OECD (PAO), Central and Eastern Europe (EEU), Newly independent states of the former Soviet Union (FSU), Centrally planned Asia and China (CPA), South Asia (SAS), Other Pacific Asia (PAS), Middle East and North Africa (MEA), Latin America and the Caribbean (LAM), Sub-Saharan Africa (AFR). For some indicators also a higher spatial resolution on grid cells is available. Figure 5.1 shows the general setup of the IIASA Integrated Assessment Modeling Framework, which consists of several different models operating on different spatial scales.

**Figure 5.1 IIASA Integrated Assessment Modeling Framework**

### 5.2 Scenario storylines and main drivers

#### 5.2.1 Scenario A2r (revised SRES A2)

This scenario keeps its main structural and qualitative characteristics already used in the IPCC SRES A2 scenario, but major changes have been made regarding long-term demographic developments. It is assumed that fertility levels initially do not decline (until 2030) but then they are assumed to decline slowly. The differences in higher fertility rates in developing countries and lower fertility rates in developed countries still remain. The focus regarding economic development stays primarily at the regional level with a relatively slow per capita economic growth and technological change, as in the SRES A2 scenario. In the A2r scenario per capita GDP growth and the potentials for economic catch-up become available when the demographic transition is assumed to begin (post 2030). Among the
scenarios per capita income in the A2r scenario is lowest, regionally and internationally, and the harmonisation between developed and developing countries progresses slowly. Due to the combination of high population and quite low income per capita migration processes arise. The migration processes primarily happen via internal migration into cities, as A2 assumes that international migration is controlled strictly. Therefore the urbanisation rate is high in this scenario. Also income disparities both within cities and between rural and urban areas are high. Improvements in resource efficiency are quite low and therefore the demand of energy, food and natural resources is at a high level. An expansion of agricultural lands and deforestation is assumed. There is no extensive international diffusion of advanced technologies.

5.2.2 Scenario B1
The SRES storyline for B1 assumes a low global population growth with a peak in 2050 and a decrease to 7 billion people afterwards. Regarding economics fast structural changes are expected. The GGI B1 scenario retains the assumptions on population development of the SRES B1. The growth of per capita income is assumed to be highest of all scenarios reported. A convergence of incomes is assumed on international and domestic level. The concept of “conditional convergence” is central in the B1 scenario. Also domestic and international distributive policies are an important factor, and they lead to policy-driven convergence of per capita income rates. The urbanisation rates in this scenario are low. Productivity levels still show differences, but at lower levels than in other scenarios. Additionally a global availability of clean and high-efficiency production technologies for food, energy, raw materials and manufacturing is assumed. A significant reduction of differences in resource and environmental productivities is expected.

5.2.3 Scenario B2
The B2 SRES scenario sets the focus on the local and national level. Population is assumed to continually rise in this scenario, but at a lower rate than scenario A2. Generally the B2 scenario can be described as an intermediary scenario, using change rates that represent “dynamics as usual”. The population development is assumed to be the same as in the SRES B2 scenario, with 10 billion by 2100. The urbanisation rate in this scenario is also assumed to be at an intermediary level. The per capita income growth and also the convergence are estimated to be between scenarios A2 and B1. The dynamics of income growth are assumed to correlate with social modernisation – and therefore with the dynamics of demographic transition. The per capita productivity is assumed to be higher in regions with low-income where the demographic transition has progressed more. Resources availability and differing income levels lead to a slow convergence of differences in domestic and international demands, productivities and prices.

5.2.4 Main drivers
The main drivers in the scenarios are:

- Demographic development (Population size; Demographic transition; Long-term fertility levels)
- Economic development (Income growth; Income convergence; Domestic/international price differences)
- Technology (Technology dynamics - fossil and non-fossil)
- Resource Use Efficiency
- Emission
- Urbanisation (Urbanisation rates; Megacity growth; Urban-rural gradient)
- Vulnerability
- Stabilisation targets (Exogenous input; scale of required reduction)

<table>
<thead>
<tr>
<th>Taxonomy of scenarios</th>
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<tbody>
<tr>
<td>Uncertainty type</td>
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<td></td>
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<tr>
<td>Emission (magnitude cumulative carbon)</td>
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<td>Income</td>
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<tr>
<td>Resource use efficiency</td>
</tr>
<tr>
<td>Technology dynamics, fossil</td>
</tr>
<tr>
<td>Technology dynamics, non-fossil</td>
</tr>
<tr>
<td>Emission</td>
</tr>
<tr>
<td>Vulnerability</td>
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<td>Urbanization</td>
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<tr>
<td>Income</td>
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<tr>
<td>Vulnerability</td>
</tr>
<tr>
<td>Target (for stabilization)</td>
</tr>
<tr>
<td>Scale of required reduction</td>
</tr>
</tbody>
</table>

Figure 5.2 Taxonomy of scenarios

5.3 Communication strategy

5.3.1 Publications

5.3.2 Online
Website of the GGI database is available online at [http://www.iiasa.ac.at/Research/GGI/DB/](http://www.iiasa.ac.at/Research/GGI/DB/).
A short description of the background of the database, the taxonomy and main characteristics of the three different baseline scenarios A2r, B1 and B2 is available.

The GGI database allows for an interactive query of scenarios. The database has different tabs, indicating the level of aggregation of data (regions, sectors, series, countries). When the database is entered via one of these tabs three query fields open:
1. Regions – different levels of aggregation can be chosen
2. Scenarios – scenario(s) can be chosen for which the data are provided
3. Variables – here one or more variables to be shown can be selected

The data are presented in a slightly different way depending on the tab chosen (Regions, Sectors, Series) to enter the scenario section.

The query results are available as chart and table. They can also be downloaded in different formats.
The study includes three cases on how future could look like in terms of economic growth, population trends and energy use – cases A, B and C. In total six scenarios are grouped within these cases. Three scenarios are part of case A (A1, A2 and A3), case B consists of one scenario and case C includes two scenarios (C1 and C2). The definition of cases was carried out before the scenarios were defined. The cases are based on the cases in Energy for Tomorrow’s World (WEC, 1993) and Global Energy Perspectives to 2050 and Beyond (IIASA–WEC, 1995).

In the scenarios the world is grouped into 11 subregions (Figure 6.1). The base year is 1990 and the time horizon of the scenarios generally is the year 2050, but some aspects are extended to the year 2100.
Case A (High growth) includes three scenarios (A1, A2, and A3) and reflects basically a future of high-growth in terms of income, energy, and technology. Case B (Middle course) has more modest growth assumptions with intermediate economic growth and modest technological developments. It represents one single scenario. Case C (Ecologically driven) includes two scenarios (C1 and C2). It assumes environmental and energy taxes, international cooperation focused on environmental protection and international equity. This leads to the lowest energy use in Case C, compared to the other cases.

Regarding the scenario type case B is a descriptive scenario, where the possible future developments are outlined without significant changes in policies, economics or technologies. Case C is defined as a normative (prescriptive) scenario, where the results and consequences of specific modifications in current policies, institutions and technologies are incorporated. Case A has descriptive as well as normative elements.

### 6.2 Scenario storylines and main drivers

All scenarios show some commonalities. They all foresee a significant social and economic development, especially in the developing world. An improvement of energy efficiencies and environmental compatibility is provided. The demographic development is assumed to be the same in all three cases. Population in 2050 is assumed to be 10 billion people and in 2100 it grows to nearly 12 billion.

The other assumptions for the basic driving forces are dependent on the case (Table 6.1).
**Table 6.1 Drivers in the three cases (Nakicenovic et al. 1998)**

<table>
<thead>
<tr>
<th></th>
<th>Case</th>
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<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td></td>
<td>High growth</td>
<td>Middle course</td>
<td>Ecologically driven</td>
<td></td>
</tr>
<tr>
<td>Population, billion</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
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<td>5.3</td>
<td>5.3</td>
<td>5.3</td>
<td></td>
</tr>
<tr>
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<td>10.1</td>
<td>10.1</td>
<td></td>
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<td>11.7</td>
<td>11.7</td>
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<tr>
<td>GWP, trillion US(1990)$</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>1990</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>2050</td>
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<td>75</td>
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<td>2100</td>
<td>300</td>
<td>200</td>
<td>220</td>
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<td>High</td>
<td></td>
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<td>−0.8</td>
<td>−1.4</td>
<td></td>
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<td>−1.4</td>
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<td>9</td>
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<td></td>
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<td>Resource availability</td>
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<td>Medium</td>
<td>Low</td>
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<td>Medium</td>
<td>High</td>
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<tr>
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<td>Non-fossil</td>
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<td>Medium</td>
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<td>Medium</td>
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<tr>
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<tr>
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<td>No</td>
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<td></td>
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<tr>
<td>Net carbon emissions, GtC</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>1990</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>2050</td>
<td>9−15</td>
<td>10</td>
<td>5</td>
<td></td>
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<td>2100</td>
<td>6−20</td>
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<tr>
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</table>

Abbreviations: GWP = gross world product; Gtoe = gigatons oil equivalent; CO₂ = carbon dioxide; GtC = gigatons of carbon.

### 6.2.1 Case A – “High Growth”

This case assumes very high rates of economic and technological growth. Economic growth is assumed to be around 4% per year in developing countries and 2% in OECD countries. Efficiency improvements and technological progress are facilitated by the ambitiously assumed economic growth rates. Free markets and a high global average per capita income – even surpassing today’s highest levels – are assumed in case A. Case A contains three scenarios – whereby the main difference between them is in the future energy supply. As scenario A1 shows a high availability of oil and gas resources, they dominate the energy supply system until the end of the 21st century. Technological developments focus on the exploitation of oil and gas resources. Coal does not have a central position in this scenario and its share in energy supply continuously declines.
Scenario A2 uses coal as a main part of the energy supply. Not much policy incentives are provided to substitute fossil fuels in an early stage. As the resources of conventional oil and gas are limited to currently known reserves, coal is also used as a “backstop” technology.
In Scenario A3 renewables and new nuclear technologies are the characteristics of the change from the fossil-fuel age. No efforts are taken to further explore oil resources, as natural gas is seen as the substitute fossil fuel of choice. In the year 2100 the energy supply is based to almost equal parts on nuclear energy, natural gas, biomass and a category of further renewables (solar, wind, other new renewables).

6.2.2 Case B – “Middle Course”
Case B has only one scenario. It is defined by modest economic growth and technology development. International exchange is eased and trade barriers are reduced. The reliance on fossil fuels stays high in this scenario, mainly due to the modest energy demand and slower technology developments. Oil and gas have a significant share in the global energy supply until around 2070, but getting more costly.

6.2.3 Case C – “Ecologically driven”
Case C includes two scenarios. In general this case assumes high international cooperation with a special focus on environmental protection and international equity. The case includes a broad variation of environmental policies and technologies, also using incentives for boosting the use of renewables. Main components assumed here are incentives for an efficient use of energy, “green” taxes, international economic and environmental agreements and technology transfer. The case includes the possibility of policies for emission reductions, such as a carbon tax. Nuclear energy takes a special part in case C, as it is on its crossroads. Scenario C1 assumes that nuclear energy phases out entirely by the end of the 21st century. In scenario C2 a new generation of nuclear reactors is developed that find broad acceptance.

6.3 Communication Strategy

6.3.1 Publications

Information: The final results are published in the book.

Information: Chapter 9 deals with energy scenarios – and especially the IIASA-WEC scenarios

6.3.2 Online presentation
Website: http://www.iiasa.ac.at/cgi-bin/ecs/book_dyn/bookcnt.py
The website gives a brief overview of the scenarios. Regarding the results of the study most links are damaged. Some graphics of the results are available on the website. The entire book cannot be downloaded on the website.

The website includes an individual query section:
Figure 6.2 Query section on the website

6.4 Sources/Literature

[http://www.iiasa.ac.at/cgi-bin/ecs/book_dyn/bookcnt.py](http://www.iiasa.ac.at/cgi-bin/ecs/book_dyn/bookcnt.py)

7 IPCC Emission scenarios

7.1 General description
The IPCC emission scenarios include four narrative scenario storylines. Each storyline describes different demographic, economic, social, technological and environmental developments. In total 40 scenarios have been developed within the four storylines.
The SRES scenarios distinguish four main world regions, with several sub-regions.

- **OECD90 REGION**: North America (NAM), Western Europe (WEU), Pacific OECD (PAO)
- **ASIA REGION**: Centrally planned Asia and China (CPA), South Asia (SAS), Other Pacific Asia (PAS)
- **REF REGION (countries undergoing economic reform)**: Central and Eastern Europe (CEU), Newly independent States (NIS) of the Former Soviet Union (FSU), Sub-Saharan Africa (AFR)
- **ALM REGION (Africa and Latin America)**: Middle East and North Africa (MEA), Latin America and the Caribbean (LAM)

### 7.2 Scenario storylines and main drivers

#### 7.2.1 A1 Storyline and Scenario Family

In the A1 scenario economic development is fast and successful, the global differences in average income per capita decline. There are some primary dynamics in this scenario. It is characterized by a strong commitment to market-based solutions, high savings and commitment to education at the household level, high rates of investment and innovation in education, technology and institutions at the national and international level, international mobility of people, ideas and technology.

Global population grows in this scenario until 2050 to 9 billion and then goes down to 7 billion in 2100. The average age increases.

The growth rate of the global economy is about 3% per year to 2100 and the global average income per capita goes up to US$ 21,000 by 2050. This leads to a change of nutriment and more meat and dairy products are consumed. The high average income also leads to an increase of car ownership, sprawling suburbia and dense transport networks. This scenario family does not have problems with shortages of energy or minerals. Final energy intensity decreases with an annual rate of 1.3%.

Regarding environmental aspects an active “management” of natural and environmental services comes into focus. In the different scenarios within the scenario family there are different assumptions on the development of energy sources and conversion technologies. Some use a carbon-intensive energy path, others intensify the dependence on (unconventional) oil and natural
gas resources, some see a significant use of renewables and nuclear and some assume a balanced mix of supply resources and technologies.

7.2.2 A2 Storyline and Scenario Family
Economic growth is different in the single economic regions and also the income gap between industrialised countries and developing countries remains. Therefore this scenario assumes several different economic regions. Besides the disparities in income per capita also the productivity disparities are maintained. This scenario shows less international cooperation than A1 or B1. The mobility of people, capital and ideas is not that vivid and therefore technology diffusion is more slowly than in other scenarios. A2 shows the highest population growth of all scenario families and total population is assumed to be 15 billion by 2100. Global average per capita income is US$ 7,200 by 2050 and US$ 16,000 by 2100, and therefore low in relation to other storylines. Technological change is quite heterogeneous. Countries that have abundant energy and mineral resources have quite resource intensive economies while those countries that are poor in resources improve resource efficiency. Resource availability also has high influence on the fuel mix. Countries with plenty resources but low income tend to stay at fossil technologies, while resource-poor countries with high income tend to change to the use of more renewables and nuclear. Final energy intensities annually decline by 0.5 – 0.7%. Global environmental concerns are quite weak in this scenario.

7.2.3 B1 Storyline and Scenario Family
B1 scenarios are characterised by a global coherent approach towards sustainability, environmental and social consciousness. Increased focus is set on social and environmental aspects of development and technological change is a core theme. The B1 storyline does not include climate policies at all, what does not have negative effects on the development of a sustainable future. Population increases to nine billion by 2050 and then declines to about seven billion by 2100. The development of an equitable distribution of income is achieved and also the general economic development is balanced. Global income per capita is around US$ 13,000 in 2050. Increased resource efficiency is another special focus within this storyline. The rapid diffusion of cleaner technologies is enabled also by incentive systems. Recycling and a maximisation of reuse are pushed also by organisational measures, leading to high levels of material and energy saving and significant reductions in pollution. The transition to alternative energy systems is seen as quite smooth in this scenario family. Conventional and unconventional gas is used extensively during the transition and then the trend goes towards post-fossil technologies. With the measures set in this scenario family the environmental quality is high, transboundary air pollution is eliminated, land use is managed carefully and public transport is enlarged. Agriculture is guided into a low-input, low-impact system, what leads to higher prices for food. Therefore meat consumption decreases. GHG emissions are quite low, although there are no explicit measures for climate change mitigation.

7.2.4 B2 Storyline and Scenario Family
The B2 storyline also shows increased concern for sustainability in social and environmental aspects, more than in A2. The focus of this scenario family lies more in the national and local level than globally. Environmentally aware and active citizens influence government policies and business strategies on the local and national level, what also leads to stronger communities. The importance
of international institutions is reduced. Local and regional environmental strategies are more successful than on the international level.

Global population is assumed with about 10 billion by 2100. Income per capita shows an intermediate growth and is about US$ 12,000 by 2050. Internationally income levels converge, although not as fast as in other storylines. The international diffusion of know-how and technologies is less than in scenarios A1 and B1. Because of that some regions have faster technical change than others. Energy systems diverge in the different regions, depending on the availability of natural resources. In some regions the necessity of a more efficient use of resources and energy leads to the development of less carbon-intensive technologies. From the global perspective the energy system remains mainly based on hydrocarbon until 2100, but a slow transition away from fossil energy resources can be seen.

7.2.5 Main drivers
The IPCC SRES scenarios focus on the possible future emissions. The major drivers for past and future anthropogenic greenhouse gas emissions are described as demographics, economics, resources, technology, and (non-climate) policies.

Demographics:
For GHG emission scenarios population projections are described as the “backbone”. Population development mainly depends on fertility rates and to a lesser extent to mortality and migration. Two other effects correlated with population are ageing and urbanization, what might have effects on several system factors (economy, health care, infrastructure, etc.).

Economic and social development:
To integrate these aspects into the scenario storylines two main drivers were used.
- World GDP
- Per capita income ratio: developed countries and economies in transition (Annex I countries) to developing countries (Non-Annex I countries)

Energy and technology:
In this thematic field the most important aspects include
- energy end-use
- resources
- technologies

All three aspects have great influence on future greenhouse gas emissions.

Agriculture and land-use emissions:
In the field of land-use emissions four main sources are included.
- CO₂ from deforestation
- CH₄ coming from rice farming
- CH₄ emissions from ruminal fermentation of cattle farming
- N₂O emissions from fertiliser use.

Other greenhouse gas emissions:
Also other emissions than CO₂ and CH₄ and N₂O resulting from agriculture and land-use are considered. They include N₂O emissions from industrial processes, Methane resulting from the use of
fossil fuels and waste disposal, $\text{SO}_2$ emissions, ozone, NOX, CO, Non-Methane Hydrocarbons, halocarbons and other industrial gases.

Policies:
Different policy areas are considered such as population and social welfare policies, Policies that target economic development and technological innovation, energy, agriculture and other resource management policies. Policies and instruments are difficult to represent in scenario models. Instead the qualitative SRES storylines give a broad characterization of the areas of policy emphasis thought to be associated with particular economic, technological, and environmental outcomes.

Table 7.1 and Table 7.2 show the main driving forces and the numbers used in the different scenarios.

Table 7.1 Overview of main primary driving forces in 1990, 2020, 2050, and 2100. Bold numbers show the value for the illustrative scenario and the numbers between brackets show the value for the range across all 40 SRES scenarios in the six scenario groups that constitute the four families. Units are given in the table. Technological change is not quantified in the table. (IPCC 2000 b)

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<tr>
<td>Population (billion)</td>
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</tr>
<tr>
<td>1990</td>
<td>6.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2020</td>
<td>7.6 (7.4-7.8)</td>
<td>7.5 (7.2-7.8)</td>
<td><strong>7.6 (7.4-7.6)</strong></td>
<td>8.2 (7.5-8.2)</td>
<td>7.6 (7.4-7.6)</td>
<td>7.6 (7.4-7.8)</td>
<td></td>
</tr>
<tr>
<td>2050</td>
<td>8.7</td>
<td>8.7 (8.3-8.7)</td>
<td>8.7</td>
<td><strong>11.3 (9.7-11.3)</strong></td>
<td>8.7 (8.6-8.7)</td>
<td>9.3 (9.3-9.8)</td>
<td></td>
</tr>
<tr>
<td>2100</td>
<td>7.1 (7.0-7.1)</td>
<td>7.1 (7.0-7.7)</td>
<td><strong>7.0</strong></td>
<td>15.1 (12.0-15.1)</td>
<td>7.0 (6.9-7.1)</td>
<td><strong>10.4 (10.3-10.4)</strong></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>World GDP ($10^{12}$ 1990 US$/ yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
</tr>
<tr>
<td>2020</td>
</tr>
<tr>
<td>2050</td>
</tr>
<tr>
<td>2100</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Per capita income ratio: developed countries and economies in transition (Annex-I) to developing countries (Non-Annex-I)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
</tr>
<tr>
<td>2020</td>
</tr>
<tr>
<td>2050</td>
</tr>
<tr>
<td>2100</td>
</tr>
</tbody>
</table>

* For some driving forces, no range is indicated because all scenario runs have adopted exactly the same assumptions.

Table 7.2 Overview of main secondary scenario driving forces in 1990, 2020, 2050, and 2100. Bold numbers show the value for the illustrative scenario and the numbers between brackets show the value for the range across all 40 SRES scenarios in the six scenario groups that constitute the four families. Units are given in the table.
### 7.3 Communication Strategy

#### 7.3.1 Publications


#### 7.3.2 Online

An online version of the report on “Emission Scenarios”, the “Summary for Policy-Makers” and the “Technical Summary” are available here:

The development of the scenario storylines was carried out in a quite open process, where experts in the field of long-term scenarios and their driving forces could take part. The website of that “open process” is still online at http://sres.ciesin.org/OpenProcess/index.html.

8 Kanors – Tiam World scenarios

8.1 General description
The scenarios are computed with the TIAM model (TIMES Integrated Assessment Model), which is a detailed multi-regional partial equilibrium model of the energy system for the entire world divided into several regions. The scenario time horizon ranges from the year 2000 to 2100. This time horizon can be divided into periods of different lengths. The regional modules are linked via trade variables of the main energy forms (coal, oil, gas) and of emission permits.
For each model run, TIAM simultaneously recalculates the energy produced and consumed, Energy prices, Technology adoption and abandonment, Emissions, Emission prices, Climate variables and Demands for energy services.

The latest version of TIAM includes 16 regions: Africa (AFR), Australia, New-Zealand, Oceania (AUS), Central Asia & Caucase (CAC), Canada (CAN), China (CHI), Central & South America (CSA), Europe 27+ Iceland, Norway and Switzerland (EUR), India (IND), Japan (JPN), Middle East (MEA), Mexico (MEX), Other Developing Asia (ODA), Other East Europe (OEE), Russian Federation (RUS), South Korea (SKO) and USA (USA).

8.2 Scenario storylines and main drivers

8.2.1 TIAM Reference case
The main drivers of the Reference case are shown in Table 8.1. The main drivers for energy service demands in TIAM are GDP, GDP per capita, Population, Households and outputs of service sectors.

<table>
<thead>
<tr>
<th>Topic</th>
<th>TIAM’s Reference Case</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geographical coverage</td>
<td>World divided in 16 regions</td>
</tr>
<tr>
<td>Time horizon</td>
<td>2005-2105</td>
</tr>
<tr>
<td>GDP, POP</td>
<td>Exogenous</td>
</tr>
<tr>
<td>Initial year</td>
<td>2005, based on the IEA Energy Balances</td>
</tr>
<tr>
<td>Supply side</td>
<td>Annual or cumulative amounts of fossil and renewable resources, representing the available resources and techno-economic limits to their extraction</td>
</tr>
<tr>
<td>Power plants</td>
<td>Annual or cumulative amount of renewable resources</td>
</tr>
<tr>
<td>--------------</td>
<td>---------------------------------------------------</td>
</tr>
<tr>
<td>End-use sectors</td>
<td>Range of nuclear generation</td>
</tr>
<tr>
<td></td>
<td>No long-term market shares</td>
</tr>
<tr>
<td>Energy markets</td>
<td>Industry: Both energy and feedstocks are included</td>
</tr>
<tr>
<td>Climate policies</td>
<td>Socially optimal: no regional production quotas apart from the technico-economic limits of extraction</td>
</tr>
<tr>
<td></td>
<td>Not included</td>
</tr>
</tbody>
</table>

8.3 Communication Strategy

8.3.1 Publications


8.3.2 Online presentation
No specific scenarios with the underlying storylines are presented in detail.

8.4 Literature


9 SHELL – Energy scenarios to 2050:

9.1 General description

The authors of the study see massive transitions in the future energy supply and demand. They see three main drivers of the future energy system, namely (1) “step-change in energy use”, (2) “supply will struggle to keep pace” and (3) “environmental stresses are increasing”.

As big developing nations such as China or India show increasing demand for energy, alternative energy supply and energy efficiency can be stimulated – but this alone does not seem to be sufficient to offset the demand pressure. Easily accessible oil and gas resources will not be able to satisfy the projected growth of demand. The extended use of coal also has its limits. Alternative energy might gain a more significant role in energy supply. Greenhouse gas emission levels are a further critical point in future energy supply.

9.2 Scenario storylines and main drivers

Figure 9.1 shows the timeline of the two scenarios Scramble and Blueprints as well as the main aspects of the storylines. A description of both scenarios can be found in Section 2.2.1 and 2.2.2.
9.2.1 Scramble:
In scenario Scramble the national energy security is in focus – especially the short term energy supply. This leads to an enhanced growth of coal and biofuels. There is a lack of international cooperation, what leads to a quite uncoordinated variety of incentives and mandates regarding the development of energy supply. In the Scramble scenario the prices for energy are generally high. Major resource holders show growing prominence and influence international policies.
Countries show vast differences in their economic and energy performance. Developing countries try to provide enough energy to enhance economic progress, developed countries try to keep their current lifestyles and struggle to adapt their energy consumption patterns. The overall economic development continues for the first quarter of the century, especially due to the extended use of coal. The Scramble scenario shows a sequential supply response to the increasing energy demand. First coal use increases significantly, then there is a great push for biofuels quite early in this scenario. At last also other renewables gain more importance.
Progress in tackling climate change or to foster energy efficiency is delayed and pushed into the future. Demand-side policy as well as environmental policy is not addressed seriously until severe events force political actions.
9.2.2 Blueprint:
In the Blueprint scenario new coalitions of interest are formed on the combination of supply concerns, environmental interests and entrepreneurial opportunities. New alliances are built in developed and developing countries. Substantial actions become politically possible because consumers and investors see that a change towards a more sustainable energy system does not have to be painful. The global economic development stays vital and turns to a less energy intensive manner. Beginning in 2012 emissions-trading schemes are set up, where a critical mass of countries participates. These schemes stimulate innovation and investment in new energy technologies and also enabling CO₂ capture and storage after 2020. Power generation from renewables grows rapidly. Electric transport is accelerated, also by technological developments in wind and solar energy. Also a more efficient end-use of electricity is achieved and by this a slower increase in primary energy demand. On the political level an increased synergy between national policies and policies on sub-national and international levels is achieved.

9.2.3 Main drivers:
The most powerful drivers of the energy system are demand, supply and effects on the environment. For the demand population development and prosperity expressed in GDP are important drivers. Regarding population development an increase of 40% by 2050 is expected.
Table 9.1 shows the relevant drivers of the two scenarios Scramble and Blueprints and the differences between them.

<table>
<thead>
<tr>
<th>Drivers</th>
<th>Scramble</th>
<th>Blueprints</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demand</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Choice</td>
<td>Mandates</td>
<td>Market driven but incentivised</td>
</tr>
<tr>
<td>Prices</td>
<td>Externalities not included</td>
<td>Externalities included</td>
</tr>
<tr>
<td>Efficiency technology</td>
<td>Mandates</td>
<td>Economic incentives &amp; standards</td>
</tr>
<tr>
<td>Efficiency behaviour</td>
<td>Necessity</td>
<td>Designed in</td>
</tr>
<tr>
<td>Resources</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oil &amp; gas</td>
<td>Constrained growth</td>
<td>Long plateau</td>
</tr>
<tr>
<td>Coal</td>
<td>Flight into coal</td>
<td>Coal not wanted unless “clean”</td>
</tr>
<tr>
<td>Nuclear</td>
<td>Modest uptake</td>
<td>Continued growth</td>
</tr>
<tr>
<td>Electric renewables</td>
<td>Sequential – wind, solar</td>
<td>Incentivise early stage technologies</td>
</tr>
<tr>
<td>Biomass</td>
<td>Strong growth</td>
<td>Complements alternative fuel mix</td>
</tr>
<tr>
<td>Technology</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Innovation</td>
<td>Strongly guarded</td>
<td>Extensively shared</td>
</tr>
<tr>
<td>Implementation</td>
<td>National “docking points”</td>
<td>International “tipping points”</td>
</tr>
<tr>
<td>Mobility</td>
<td>Hybrids &amp; downsizing</td>
<td>Hybrids &amp; electrification</td>
</tr>
<tr>
<td>Power</td>
<td>Efficiency</td>
<td>Carbon capture &amp; storage</td>
</tr>
<tr>
<td>IT</td>
<td>Supply optimisation</td>
<td>Demand load management systems</td>
</tr>
<tr>
<td>Environment</td>
<td>Land use</td>
<td>Energy vs. food principle</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sustainability principle</td>
</tr>
</tbody>
</table>
In 2011 the report “Signals and signposts” was published (Shell 2011). The report updates the scenarios regarding the economic and financial crisis. The fundamental drivers and uncertainties of the Scramble and Blueprint scenario in “Shell Energy Scenarios to 2050” stay fully relevant. The new report adds some factors and drivers and can be interpreted as an amendment, taking into account the consequences of the financial crash, to the original scenarios.

Key new factors since the financial crisis are:
- Greater economic volatility and cyclicalit
- More uncertainty and risk
- Natural gas developments
- Iraqi energy industry

9.3 Communication Strategy

9.3.1 Publications
Shell International BV (2008) Shell energy scenarios to 2050

Shell International BV (2011) Shell energy scenarios to 2050 – signals and signposts
Update of the Scramble and Blueprint scenarios regarding the impact of the global economic and financial crisis.

9.3.2 Online
Own section for the scenarios up to 2050 within the Shell website. The report can be downloaded and there is an interactive presentation of the scenarios.
http://www.shell.com/home/content/future_energy/scenarios/2050/

The interactive online illustration is placed on top of the section on scenarios up to 2050. It gives an easy to understand overview of both scenarios. It has a separate menu where the user can choose the information to be displayed. The colourful presentation attracts the attention of users (Figure 9.2). It brings face to face the two scenarios showing the timeline and the most important aspects.
Shell energy scenarios to 2050

Figure 9.2 Online illustration of the scenarios

9.4 Literature/Sources

Shell (2008) Shell energy scenarios to 2050, online http://www.shell.com/home/content/future_energy/scenarios/2050/ (accessed 1 August 2012)

Shell (2011) Shell energy scenarios to 2050 – Signals and signposts; online http://www.shell.com/home/content/future_energy/scenarios/signals_signposts/ (accessed 1 August 2012)
10 World Energy Technology Outlook – 2050; WETO-H2

10.1 General description
In this study three scenarios are developed, a reference scenario, a carbon constraint scenario and a hydrogen scenario. With these scenarios options for technology and climate policies are investigated up to the year 2050.

The reference projection uses exogenous forecasts for population and economic growth. Additionally assumptions about the available fossil energy resources, costs and performance of future technologies are made. The development of national and regional energy systems and their interactions with international energy markets up to the year 2050, under the aspect of climate policy and available resources, is described. For that the POLES model, a world energy sector simulation model, is used.

In the Carbon Constraint scenario moderately ambitious climate targets are assumed, that are able to keep long-term CO₂ concentration levels below 550 ppmv. The hydrogen scenario shows possible ways how hydrogen could be incorporated in the world energy system. A number of technology breakthroughs are assumed, making hydrogen use more cost effective.

10.2 Scenario storylines and main drivers

10.2.1 Reference scenario
The reference projection continues currently existing economic and technological trends. It considers short-term constraints on the development of oil and gas production. Climate policy is assumed to stay moderate. Climate policies are incorporated by an exogenous carbon value, which influences consumption and investment decisions of system agents.

The world energy consumption is assumed to increase from currently 10 Gtoe/yr to 22 Gtoe/yr in 2050. The energy consumption shows high growth in developing countries and is assumed to account for two thirds of the global consumption in the year 2050. The share of fuels in energy consumption is considered to be 70% fossil and 30% non-fossil. The non-fossil part consists of 50% nuclear and 50% renewables. Regarding the oil and gas production it is assumed that the production of conventional oil will be around 100 Mbl/d after 2025 and non-conventional oil is assumed to be about 28 Mbl/d in 2050. Also the production of natural gas will increase. Prices will increase for oil and gas, reaching 110 $/bl and 100 $/boe respectively in 2050.

Until the year 2050 an improvement in energy efficiency can be achieved, as the world economy will be four times as large as today, but global energy consumption only increases by a factor of 2.2. Electricity production in 2050 will be four times higher as today, as it steadily increases with economic growth. Coal comes in focus for electricity production again and new advanced technologies will be implemented. The price for coal is expected to be around 110 $/ton in 2050. After the year 2020 the increase of renewable energy resources and nuclear energy starts and after 2030 a massive increase is foreseen. The CO₂ emissions are expected to increase almost proportionally to the total energy consumption. The CO₂ concentration is assumed to be 900 – 1000 ppmv in 2050.
10.2.2 Carbon constraint scenario
In this scenario consequences of carbon policies are in the focus. A stabilisation of the long-term CO\textsubscript{2} atmospheric concentration of 500 ppmv is targeted. It is assumed that Annex B countries set early action, while emerging and developing countries get more time for actions towards carbon reduction. The carbon constraints are included in the POLES model using a carbon price that includes the shadow price of the constraint and is thereby included in the consumer energy prices. The global CO\textsubscript{2} emissions are quite stable around 40% above the 1990 level between 2015 and 2030, after that they decrease. In 2050 they still are 25% above the 1990 level. The total global demand is 3 Gtoe/yr lower than in the reference case. By 2050 the demand is satisfied by each > 20% nuclear and renewables. Electricity demand in 2050 is only 10% less than in the reference case and electricity generation is dominated by nuclear power (40%) and renewable energy (30%). Carbon capture and storage gains more importance until 2050. Hydrogen production is 60% higher than in the reference case.

10.2.3 Hydrogen scenario
The hydrogen scenario is based on the carbon constraint scenario. Additionally to the assumptions of the carbon constraint case it assumes several technological breakthroughs leading to more cost efficient hydrogen technologies, which is especially true for hydrogen end-use. The total energy demand in this scenario is about 8% less compared to the Reference case in 2050. A significant change in fuel mix can be recognised. Fossil fuels have a share of less than 60% in 2050. Coal use drops significantly, the use of nuclear and renewable energy enhances notably from 2030 to 2050. Regarding electricity production nuclear reaches a share of 38%. Also thermal electricity production grows and normally is associated with carbon capture and storage systems. After the year 2030 hydrogen production is boosted significantly and in 2050 hydrogen provides 13% of final energy consumption. The major amount of hydrogen is used in the transport sector.

10.2.4 Main scenario drivers
The POLES model is used for developing the Reference projection of the energy system in 2050 resulting from on-going trends and structural changes in the world economy. The model categorises the world into 46 regions, divides 22 energy demand sectors and around 40 energy technologies. “Each scenario can be described as the set of economically consistent transformations of the initial reference case that is induced by the introduction of policy constraints.”

There are some important exogenous inputs to the Reference projection: The main drivers of energy demand are world population and economic growth. Gas and oil resources are seen as critical factors for energy supply. Future costs as well as the performance of technologies are also substantial constraints of feasible solutions of a future energy system.

Regarding world economic growth it is assumed that the annual growth rate is at 3% until 2030, slowing down to an average of 2%/yr between 2030 and 2050. The reduced growth rate has it’s reasons partly in a lower per capita GDP growth and partly in the reduced growth of population, which also represent the two key drivers of economic growth.
Regarding the drivers oil and gas resources the POLES model calculates production for every key producing region or country. The model also includes technological progress in exploration and production of oil and gas.

The driver technology performance significantly affects resources and emissions in the scenarios. The WETO-H2 study includes 39 technology options, within the 5 technology groups “Large scale Power Generation”, “Renewable Energy Sources”, “Distributed Power Generation” “Hydrogen Production” and “Very Low Emission Vehicles/Buildings”.

10.3 Communication Strategy

10.3.1 Publications

10.3.2 Online presentation
There is no specific online presentation of the project. The final report is available online at http://ec.europa.eu/research/energy/pdf/weto-h2_en.pdf.

10.4 Literature

11 World Energy Council – Deciding the future: Energy Policy scenarios to 2050

11.1 General description
The study was published in 2007. It’s basic objective is the evaluation of the impact of four scenarios on the fulfilment of WECs three A’s, namely Accessibility, Availability and Acceptability. The time horizon of the study is the year 2050, starting in 2005 and using 15-year intervals. Four equally possible scenarios are developed using two axes: Government Engagement and Cooperation/Integration. Regarding Government Engagement the study included three aspects of the role of a government in energy development: Engagement, Involvement and Interference. With the aspect of engagement the government actively sets measures for an optimal function of energy systems. With involvement the government the market might be distorted due to inequity of power, as the government carries out a number of functions, probably in competition with other providers. Interference of the government means that the energy systems are not developed in such an effective and efficient way as they could be, due to government’s actions or regulations. Regarding cooperation/integration also three aspects have been differentiated: the cooperation form government to government is characterised by treaties or international agreements, private-public
partnerships design specific programs/regulations for the achievement of specific goals and company to company agreements, addressing specific business goals.

For the building of the scenarios regional groups developed descriptions on how the future world will look with special regard on the 3 A’s. A mathematical simulation model of the energy sector (Energy Scenario Development and Climate Policy Analysis with the POLES Modelling System, Enerdata, 2007, a report prepared for the WEC study group on future scenarios) was used for a consistency check of the storylines developed.

The WEC study distinguishes five world regions in their study (Figure 11.1).

![Figure 11.1 Regions in the WEC scenarios](image)

11.2 Scenario storylines and main drivers

The storylines of the four scenarios are described in WEC (2007).

11.2.1 Scenario 1: Leopard (Low Government Engagement – Low Cooperation and Integration)

This scenario is characterised by very low government engagement as well as low global or regional cooperation and integration. Countries are very focused on their own domestic economic development and domestic energy security. Therefore the protection of national products is high, tending to impede world market forces and free trade. There are few levies or subsidies. The reactivity to external events such as energy shocks or recessions is very low, due to the lack of government engagement. Know-how or technology transfer is constrained. The economic growth in developing countries is limited, due to lack of appropriate infrastructure and policy. The scenario is characterised of high energy intensity as energy efficiency is not seen as a critical point both on demand side and supply side. Also CO₂ mitigation strategies are not in the focus of this scenario. Energy demand continues to rise and oil and gas play an important role, although the price level is quite high.
11.2.2 Scenario 2: Elephant (High Government Engagement – Low Cooperation and Integration)
The engagement of the government in this scenario is significant but regional or international cooperation and integration is minimal. Energy security plays a central role in this scenario and the governments/nations set actions to ensure it (e.g. diversification of primary energy carriers, development of indigenous resources, bilateral negotiations for securing imports). Countries act independently regarding their intention to ensure their energy security. As the focus of some countries lies in a domestic energy supply, oil and gas resources might become available for the rest of the world. Another effect of the emphasis on domestic aspects is that there is little transfer of know-how or technologies. The scenario shows an increase in renewable and nuclear energy together with a decrease in energy use.

11.2.3 Scenario 3: Lion (High Government Engagement – High Cooperation and Integration)
This scenario is characterised by both significant government engagement and high cooperation and integration on the regional and international level. Countries cooperate in questions of sustainable development and key energy issues. International agreements and programmes are set up regarding greenhouse gas emissions and energy poverty. The reduction of energy poverty and the use of more efficient and effective technologies lead to enhanced energy demand in developing countries, followed by increased pressure on energy supplies and infrastructures. The development of new technologies and innovation is enabled. The scenario has a focus on environmental goals, better control of energy resources and greenhouse gases. There is a negative impact on GDP, due to the costs of the management of environmental impacts. Burden-sharing on national and international level is another attribute of the Lion scenario.

11.2.4 Scenario 4: Giraffe (Low Government Engagement – High Cooperation and Integration)
Regional and international cooperation and integration play a key role in this scenario, while the government engagement is on a minimum. The main driver in this scenario is economic development, with the attempt of free global markets with reduces trade barriers. The innovation potential is high and a rapid transfer of technology and experience is assumed. There are few levies and subsidies as the engagement of the government is very low. On the local and regional level environmental awareness is enhanced, but coal still plays an important role and also the increasing energy demand leads to increasing greenhouse gas emissions.

11.2.5 Main scenario drivers
For the assessment of the four WEC scenarios some key indicators are used, to assess how physical, social and economic challenges can be met while outcomes closer to the 3 A’s can be achieved. These indicators include:
- GDP growth (economic growth),
- Demographic growth,
- Energy intensity,
- Energy mix,
- Total primary energy required (TPER),
- Greenhouse gas emissions,
- Supply-demand tension.

The POLES model, a mathematical simulation model, is used for the consistency check of the storylines of the regional expert groups. The qualitative information of the storylines from the expert groups had to be translated into quantitative assumptions on variables and parameters in the POLES model, with a clear relationship between the qualitative information and the quantitative assumption (WEC 2007b). The main exogenous variables and parameters used in the POLES model are shown in Figure 11.2.

![Figure 11.2 Main drivers of the POLES model (WEC 2007b)](image)

11.3 Communication Strategy

11.3.1 Publications:

11.3.2 Online:
Website: [http://www.worldenergy.org/](http://www.worldenergy.org/)
The report “Energy Policy Scenarios to 2050”, a short summary of the report as well as a video presentation can be downloaded in the section “Publications” on the website.

11.4 Literature/Sources