1. EUSUSTEL WP5: World Energy Outlook

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[This is the cover page that will not be part of the final report. The information on it simply eases the organization of the final writing. Red texts on brackets are advisory information not included to the final document. Remove the lines including red text, when no other text remains.]

1.1 Introduction

The World Energy Outlook has been the flagship publication of The International Energy Agency (IEA) since 1993. The publication is focusing on global trends in the energy markets as well as regional outlooks for the next two to three decades. Some issues have provided deeper insights to specific subjects, e.g. energy prices and subsidies for end users, energy supply for economic growth, energy investments and in the latest issue in 2005 the Middle East and North Africa with emphasis on the need for investment in the energy industry in this region

Long-term energy projections has been provided using a World Energy Model (WEM). This model has been further developed from issues to issue. For the WEO 2002 the WEM underwent a significant transformation and enhancements, and the time horizon was extended from 2020 to 2030.

This report contains a short survey of the six latest issues of WEO focusing on the shifting policy issues presented in these reports as well as a description of the projection method and latest projection results.

1.2 WEO 2000

The 2000 issue of World Energy Outlook contains global trends to 2020 as a reference scenario and alternative cases. These forecasts are made using the IEA World Energy Model. Regional Outlooks cover OECD North America, Europe and Pacific, plus Russia China and Brazil.

It is emphasised that fossil fuels will continue to dominate the world energy mix, and massive investment in oil production facilities will be needed as well as in electricity generation. Technology advances in combined-cycle gas turbines (CCGTs) have shifted the economics of power generation in favour of gas.

WEO 2000 includes an assessment of WEO projections since 1992, which was presented for the Energy Modelling Forum at Stanford University in June 2000. The oil price assumptions in this period largely *overestimated* the rise in oil prices, while the GDP assumptions largely *underestimated* economic growth over the past decade (1990s). It is shown that the assumptions IEA crude-oil import prices 2000 and 2005 had fallen from WEO93 to 17 $-1990 per barrel for both years in WEO98. Among 21 projections of crude-oil prices for 2010 in the period 1993-1998 only a single was higher than 35 $ (1990) (37 $ in the Global2100 projection from 1993).

In contrast, the forecasts of overall energy demand in 2000 showed a seeming accuracy, which disguised many changes in the fuel mix and in demand among different regions.

The assessment of past projections concludes that oil price projections have clearly much less influence on energy demand than GDP assumptions, which highlights a need for more careful attention to non-OECD demand, which are characterised by less mature economies with higher energy intensities and a lesser role for energy taxes.

1.3 WEO 2001

The subtitle is "Assessing Today's Supplies to Fuel Tomorrow's Growth". The key message is that the worlds possesses abundant supplies of energy, but massive investment in energy infrastructure will be needed to exploit these reserves. The time-horizon of the study is 2020. Beyond 2020, new technologies such as hydrogen-based fuel cells and carbon sequestration, hold on the prospect of plentiful, clean energy supplies in a carbon-constrained world.

1.4 WEO 2002

Extends the project horizon to 2030. Highlights the rapidly expanding importance of China as a strategic buyer on world oil and gas markets.

In Reference Scenario the global energy market is projected to grow by two-thirds over the next three decades, equal to annual demand growth of 1.7% per year. The projected CO_2 emissions from OECD will increase from 11,000 Mt in 2000 to 14,000 in 2030. The study also includes an elaborate Alternatives Policy Scenario, in which the CO_2 emissions from OECD remains below 12,000 Mt during the whole period.

1.5 WEO 2003

Taking up the issue on massive investment from the WEO 2001, the title of this issue is World Energy Investment Outlook. This issue is characterised as a first-ever attempt to quantify global energy investments needs.

Although the investment requirement is large in absolute terms, it is modest relative to the size of the world economy. Following the Reference Scenario of WEO 2002, these investment amounts to only about 1 % of global GDP, but it differs significant among regions. Russia's investment requirement will amount to 5 % of GDP, Africa's to 4 %. Thus the requirement will be much lower than 1 % in OECD countries. Again it is emphasised that the world's energy resources are sufficient to meet projected demands.

Power generation, transmission and distribution require about 60% of the investment requirement, and additional 10 % is needed for fuel requirements to the electricity sector.

It is emphasised that a substantial proportion of all this energy investment is required simply to maintain the present level of supply.

Also financial resources are sufficient on a global level, but the regional distribution of investment requirements indicates that more of the capital needed will have to come from private and foreign sources than in the past.

Domestic savings has been the single most important source of capital for investment in infrastructure projects, but in some regions, energy-capital needs are very large relative to total savings.

The investment pattern will be influenced dramatically by environmental policies in the OECD and the development of new energy technologies.

The last section of the executive summary is devoted to the role of governments. Governments everywhere will have to pay attention to how the policy, legal and

regulatory framework affects investment risks and how barriers to investment can be lowered.

The investment study contains three types of analysis: A short survey of Global Energy Investment Needs to 2030. A much longer discussion of Financing Global Energy Investment, sectoral studies for fossil fuels and electricity, and a few new technologies suitable to include in the investment forecast till 2030.

1.5.1 Investment pattern

The projected world energy investment in all sectors will increase over the next three decades to an annual average in the period 2021-2030 about 50% above the level in year 2000.

New technologies for oil and gas extraction, long-distance pipelines, further advance in Combined Cycle Gas Turbines (CCGT) highly efficient small-scale plants for distributed generation, increased thermal efficiency of coal-fired plants and integrated gasification combined cycle (IGCC) plants. Technological advances and cost reduction for LNG, gas-to-liquid and coal-to-liquid production. The use of advanced coal-mining technology will continue to lower the capital and operating costs of coal extraction and preparation..

The capital costs of renewable energy technologies are expected to fall substantially, and hydrogen-based fuel cells, carbon sequestration and storage technologies, and advanced nuclear reactors could radically change the energy supply outlook and investment patterns in the longer term.

1.5.2 Financial issues

An important feature of energy investments is that the electricity sector is the most capital-intensive of all the major industrial sectors, measured by capital investment per unit of value added. On average the electricity sector requires two or three times as much investment as manufacturing industries, such as automobile manufacturing, in order to generate one dollar of added value. Oil and gas extraction, processing and refining are also relatively capital-intensive.

Among the various risks in energy investments environmental risks were emphasises as a type of regulatory risk. Thus investors may hesitate to provide funds to energy projects which operate to low environmental standards..

1.5.3 Oil

Compared to the regional distribution of oil reserves and oil production, the investments in the oil sector in OECD Europe is relatively high. Nearly 5 % of the global oil cumulative investment 2001-2030 for exploration and development and refining will be in Europe, while European investment in non-conventional oil will be negligible. The relatively large amount of investment in Europe is due to the high cost for exploration and development, $5-5.5 per barrel in EU-15 compared to less than $2 per barrel in the Middle East.

1.5.4 Gas

More than 10 % of the projected global natural gas cumulative investment 2001-2030 for exploration and development, transmission and storage, LNG, and distribution will be in OECD Europe. The European natural gas production is peaking in the period 2001-2010 and is projected to fall by some 10% between 2010 and 2030, while natural gas production in the rest of the world will more than double from 2001-2030.

Investment in gas supply infrastructure within Europe will decline over the next three decades, due to stagnating production and slower demand growth. Upstream investments will remain the largest component as costs rise with the depletion of reserves in the North Sea.

Financing might be a hurdle to investment in new large-scale cross-border pipeline and LNG projects, depending on cost development. Geopolitical factors and regulatory uncertainties.

Demand forecasts show a steady growth in natural gas consumption, so import must increase significantly, mainly from the two current suppliers, Russia and Algeria. The rest will probably come from a mixture of piped gas and LNG from elsewhere.

1.5.5 Coal

Global coal production is projected to increase by about 50% from 2000 to 2030 and world coal trade will increase more, but remain a small proportion (some 15% of global coal production).

In contrast to other regions coal production in OECD Europe is expected to decline

The key uncertainty facing future coal demand and investment is environmental policy. This uncertainty is discouraging investment. In the OECD Alternatives Policy Scenario, new environmental policies cut global coal investment by some 6 % compared to the Reference Scenario, and coal imports to OECD Europe and Japan is 20-30 % lower than in the Reference Scenario.

According to the WEO-2002 Reference Scenario coal's share in electricity generation declines in the period until 2020, but recovers slightly thereafter. Coal remains the largest source of electricity generation throughout the projection period.

1.5.6 Electricity

There are two key reasons that explain why the electricity sector will continue to need large investments: First the electricity sector is very capital intensive, although capital intensity was lower in the 1990s compared to earlier decades. This can be explained to a large extent by the greater use of gas-fired technologies and inadequate investment in networks. Second, the world will continue to shift from primary fuels to electricity, and demand for electricity increases as incomes increases.

For the OECD countries the new investment framework in liberalized markets has created many new challenges and uncertainties. Concerns exist about the adequacy of investment as markets adapts to the new conditions, particularly with regard to peak load. The risks to investors for building peaking capacity are high compared to baseload plant.

Liberalised markets also require increased levels of investment in transmission to accommodate greater volumes of electricity trade. Higher investments in transmission will also be required because of increased use of intermittent renewables.

The OECD Alternatives Policy Scenario illustrates how government policies to address environmental concerns and to increased energy efficiency may affect investment over the next thirty years. Investment in renewables in the Alternatives Policy Scenario will amount to half the investment needed in total new capacity. Given the fact that other generation options are less expensive, investors in renewable energy projects will seek a guarantied market for their electricity.

1.5.7 Advanced technologies

The final short chapter summarise a few advanced technologies, which are considered for the investment projection until 2030. These are CO_2 capture, fuel cells for power generation and vehicles, and advanced nuclear reactors

In the WEO 2002 fuel cells emerge as a new source for electricity generation around 2020. The fuel cells that are expected to achieve commercial viability first will involve the reforming of natural gas. Almost all the fuel cells in use for electricity generation by 2030 will be for distributed power generation. Fuel cells are expected to become competitive in distributes generation when capital costs fall below $ 1,000 per kW, just over a quarter of current costs (compared to $ 400 per kW for large-scale CCGT), and their efficiency approaches 60 %. In the Alternatives Policy Scenario fuel cells start increasing their market share around 2015.

The scenarios developed in the WEO 2002 show a limited role for nuclear power in the next thirty years as a result of unfavourable economics and government policies which constrain use in response to public opinion. Many argue that entirely new nuclear reactor designs are needed if there is to be a major nuclear expansion. Ten countries have pooled their efforts to develop candidate systems for a four generation of nuclear reactors. A table summarise six technologies with best deployment days from 2015 to 2025, e.g. Very-High-Temperature Reactors.

Outside the power sector, hydrogen fuel cell vehicles, where proton exchange membrane (PEM) fuel cells are widely considered the technology of choice for passenger cars.

Some technologies are characterised as speculative and unlikely to become practical before 2050. These include photoelectrochemical water splitting and algal systems for water production.

1.5.8 Tables and methodology

An Annex contains regional tables (world and selected regions, e.g. EU15) that describe cumulative investments in energy supply and infrastructure for each of the next three decades and energy demand and supply forecasts until 2030. The methodology used is demand driven based on the Reference Scenario for WEO 2002. For some technologies experience curves have been used to estimate the evolution of unit costs. Table 1 shows an extract of energy investments in EU 15. The total cumulative investment in EU15 in the three decades are $ 1.6 trillion out of the world total at $ 16 trillion in year 2000 price level.

Table 1. Reference Scenario. Investment in EU15. $bn.

	2001-2010	2011-2020	2021-2030	2001-2030
Oil	53	37	27	117
Gas	137	123	105	365
Coal	5	3	3	10
Electricity	302	401	408	1110
Total Regional Investment	496	564	542	1603

1.6 WEO 2004

The headline of the Executive Summary is "Energy Security in a Dangerous World"

A central message in this Outlook is that short-term risks to energy security will grow.

A truly sustainable energy system will call for technological breakthroughs that radically alter how we produce and use energy.

Oil prices have broken $50 a barrel. Soaring Chinese demand is rocking energy markets.

"We assume in our Reference Scenario that the prices reached in mid-2004 are unsustainable and that market fundamentals will drive them down in the next two years. (…) But a continuing surge in demand and underinvestment in production capacity combined with a large and sustained supply disruption could still result in a new price hike."

The Outlook contains updated sectoral projections for the oil, natural gas, coal and electricity markets, a short survey of regional outlooks, and an in-depth study of Russia, emphasising Russia as an energy supplier. A special chapter is devoted to energy and development with an appendix containing electrification tables. Finally the Reference Scenario is confronted with an Alternative Policy Scenario.

An annex compares past projections and latest estimates as well as a comparison with forecast from other institutions, such as USDOE, OPEC, a Japanese institute of energy economics, the European Commission and others.

The IEA oil price projections for 2010 and 2020 are similar to the US and Japanese forecasts, higher than the OPEC forecasts and significantly lower than the forecasts of the European Commission. The IEA forecast for 2030 is 29 $-2000 per barrel compared with the EC forecast at 40.3 $/bbl. The IEA forecast for global oil demand is similar to the other organisations. However, forecasts from the Center for Global energy Studies (CGES) and Shell are significantly lower (IEA 106 mb/d by 2020, CGES "high price" scenario 90 mb/d). Shell's forecast for 2020 at 95 is much lower than most others, largely because its "Dynamics as Usual" scenario projects a high share of new technologies in place in 2020. All studies foresee the growth in oil demand to be led by the transpoirt sector in developing countries.

In the WEO 2004, the IEA took the unusual step of raising the issue on "The precarious state of energy".

1.7 WEO 2005

The title is "Middle East and North Africa Insigths". The overall focus is the countries in the Middle East and North Africa (MENA), emphasising the need for investment in oil production and oil supply infrastructure. The traditional Reference Scenario is very detailed concerning these countries. In addition to the usual World Alternative Policy Scenario, this issue contains a Deferred Investment Scenario, which analyses how global energy markets might evolve if investments in the upstream oil and gas industry of MENA countries were to be substantially lower than implicitly assumed in the Reference Scenario. This scenario is reported in details for each of the MENA countries.

1.8 World Energy Model

Since 1993, the IEA has provided long-term energy projections using a World Energy Model (WEM). For the WEO 2002 the WEM has undergone a significant transformation and enhancements. Specifically the time horizon has been extended to 2030. The main features of the model are:

- 18 separately modelled countries and regions, e.g. the European Union (EU15) and other OECD Europe.
- For the OECD regions a detailed sectoral representation of the industrial sector and projections of demand by end-use or mode in the transport, residential and service sectors
- A world refinery model that analyses the regional implications of growing oil product demand and product trade.
- A technology-rich power sector model
- A resource-based model on fossil fuel supply.
- Regional energy balances.

The parameters of each module's equations are estimated econometrically, usually with data for the period 1971-2000.

New features are added to the model to address the topics in each issue of WEO. In the WEO 2003 the methodology adopted for calculated the investment required in each supply chain involved, for each fuel and region, the following steps:

- New-build capacity needs were calculated on the basis of projected supply trends, estimated rates of retirement of existing supply infrastructure and decline rates for oil and gas production.
- Unit cost estimates were compiled for each component in the supply chain. These costs were adjusted for each year of the projection period.

1.9 WEO 2004 Projection of electricity generation

The latest projection of electricity generation in details suitable for reporting as shown in Table 2 is from WEO 2004. The European Union with 25 Member States from 1 May 2004 is reported in full details for the Reference Scenario. Neither the Alternatives Policy

Scenario nor the update in WEO 2005 are reported in the same details. The contents of Table 2 is an extract of the published table in WEO 2004.

Table 2. Reporting table for the WEO 2004 Reference Scenario for the European Union (EU25)

Indicator		Fuel	Baseyear	2010	2020	2030
Cost of Electricity Generation [$Euro_{2000}$/MWh]			**n.a**	n.a	n.a.	n.a
Installed Electricity Generation Capacity and Production in Europe by Fuel	**GW_e**	**Coal**	**187**	180	181	183
		Gas	**119**	165	269	399
		Oil	**78**	81	67	32
		Nuclear	**133**	124	93	71
		RES	**164**	221	308	376
	TWh	**Coal**	**920**	969	1099	1076
		Gas	**521**	715	1071	1458
		Oil	**182**	143	107	59
		Nuclear	**961**	964	728	560
		RES	**401**	626	890	1118
CO_2 Emissions by Electricity Generation [Mt]			**1308**	1466	1650	1669
Share of Domestic Primary Energy Supply [%]			**35.06%**	**36.01%**	**37.51%**	**37.19%**

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