EU-Russia Energy Dialogue
Thematic Group on Energy Strategies, Forecasts and Scenarios
Energy-Economics Subgroup

Energy Forecasts and Scenarios 2009–2010 Research

Final Report

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Any comments and suggestions regarding this Report are welcome and should be sent to Vitaly Protasov at an e-mail address v_protasov@fief.ru.

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Executive Summary

This book is the outcome of a two year research program on existing energy models, scenarios and forecasts, conducted in the framework of the EU-Russia Energy Dialogue. The Report includes data on most relevant scenarios and forecasts published in 1993-2011, with a focus on 2008-2010 period, as well as detailed reviews of scenarios and modeling assumptions, modelling mechanisms and a variety of scenarios and forecasts in use at the European Commission (PRIMES), the International Energy Agency (IEA), US Energy Information Administration (EIA), MIT, ExxonMobil, Shell, Eurogas, ENTSOG, International Gas Union (IGU), specific models such as TIMES, POLES and POLES in SECURE project. The Report reviews opinions on future of energy with an emphasis on natural gas perspectives and EU-Russia energy interrelations.

Governments, international organizations, corporations and scientists publish every year 10-15 authoritative reports and myriad of lesser known reports on energy scenarios and forecasts. Analysis of world consumption forecasts produced by this substantial volume of research, even when limited to an individual energy resource during next decade reveals a range of discrepancies in excess of 100 percent or over 3 billion tones of oil equivalent. These scenarios are used as decision support tools for major policies and investment projects. It is obvious that is not possible to predict the future. According to current prevailing views, the field of energy will undergo significant structural changes in coming decades, making it radically different from what we know today. Thus, the many researchers and organizations envision distinct paths of energy development. In the context of such diversity of options, it is important to note that models and scenarios do not usually disclose its technical details. In practice this means an even higher degree of complexity and heightened risks in decision making.

This research does not aim to present a single "right" future energy trend or an ideal methodology for every task. But users of scenarios and forecasts and decision makers should have a range of options and several transparent models and scenarios, with clear understanding of their advantages and disadvantages. The aim of the research is to give such an informational and analytical tool for those involved in both decision making and scenario development. The original demand for this analysis was created in the framework of the EU-Russia Energy Dialogue and is heavily utilized for its purposes.

The methodology of this report is based on a comprehensive analysis of all assumptions, methodologies and results on each scenario under research. The correct ranking and weight of major assumptions, backed by specific energy policies will impact favorably the accuracy of cost estimates for the energy consumers.

Key findings:

- The research confirms that scenarios cannot produce precise long term quantitative projections; they are, however, essential tools for identifying energy trend patterns, sensitivity analysis and policy implementation cost impact estimates.
- There seem to be significant discrepancies in applied methodologies and estimated energy trends in European and Russian forecasts (Section 2.1). There are also diverging opinions among governments and companies on the future role of natural gas: e.g. European gas consumption growth rates in 2010-2020 range from -1% in PRIMES Reference Scenario to 2% in gas industry projections (subsection 1.3.3). These discrepancies may introduce distortions of the policy and investment planning dimension, as well as inflated political risk perception.
- There are signs of consensus on analyzed trends, such as growth of world energy consumption (0.8-1.6% per annum in 2008-2030), slight decrease of oil weight in the energy

mix, high growth in global consumption of renewables (2-8% per annum in 2008-2030). There is no consensus on future "fuels of choice" (wind, biofuels, gas, coal, nuclear) in each region and globally.

- Annual dynamics of projected natural gas consumption indicate stable trends growth from mid 1990-th to 2000-th followed by a decrease to current levels. There are signs of a new upward trend in 2010-2011 as per IEA statements on the "golden age of gas", new reports of MIT and BP.
- The price ratio of energy resources is a key indicator in modeling. Under PRIMES, a number of scenarios (Section 3.1) project an atypical price pattern – a sharper growth of gas prices vs. oil and coal prices. This assumption under the PRIMES model is a result of modeling under another model, since PRIMES is not set up for pricing modeling. Thus, the assumption of one model becomes the result of another, but in itself, it does not validate the correctness of the assumption. This report will assist the reader to understand the context, harmonize assumptions and validate results of modeling with multiple models, as for example, in the MIT research report, which is based on a combined application of seven models (Section 4.3).
- A tradition of an insufficient disclosure – lack of detailed information ("black box") is still dominated most models and scenarios in the energy sphere and this creates problems for all policy makers and analysts alike.
- Most analyzed papers do not estimate the impact of the scenario implementation on the economy and society (e.g. impact on end-user prices). The high CO_2 emission prices such as 110 $/ton (IEA) or 180 €/ton (SECURE) would affect people welfare and future economic growth.

There seem to be several ways to improve quality of published scenarios and forecasts: build consensus on technical issues of scenario data, develop permanent monitoring and possibly an independent audit of new scenarios with publicly available results, develop special databases on projections (such as proposed EU-Russia database on energy scenarios), improve communication within the expert society, etc (subsection 1.1.2.).

Chapter 1 provides an overview of each scenario, their quantitative comparisons, main conclusions of comprehensive analysis and implications, particularly on decision-making process as well as options to amend existing problems of energy scenarios and forecasts. Chapter 2 is focused on methodological aspects, including comparisons of methodological approaches in formulation of scenarios used for policy support in Russia and European Union, comparative tables with all important elements of analyzed models and scenarios. A detailed description and critical analysis of the European and World energy scenarios are presented in Chapter 3 and 4 respectively.

Introduction

Today's sources of energy are still mainly fossil-based. Oil, natural gas and coal are the dominant fuels in the energy mix. And despite many efforts to lighten the carbon weight of global energy supply, it is generally agreed that the world demand for these fossil fuels will continue over at least the next few decades. Oil, natural gas and coal are natural resources. They are not found everywhere but are spread unevenly over the various geographical areas. Furthermore, the areas where these resources are produced tend not to coincide with the main areas of consumption. The Russian Federation is blessed with the availability of vast quantities of oil, natural gas and coal. In contrast, whereas the European Union (or the wider European Economic Area) has some indigenous production of these resources, these are not sufficient to cover the energy demand of its vast market. Therefore, the European Union depends on the import of energy.

Long-term commitments between producer and consumer are an essential feature of the pipeline business as they are necessary to underpin the massive investments required to bring the gas to the market and to mitigate the lack of flexibility due to the facts that the infrastructure will represent sunk cost once developed. It must be noted that even in global LNG trade the amount of LNG traded on the spot is still a fraction of trade based on long-term commitments.

With so much of the natural energy resources within the Russian Federation and with such a vast market for energy in the European Union, it is clear that energy relations are an important element of the overall cooperation between the Russian Federation and the European Union. It is also clear that, due to the fact that natural gas is not as much a global commodity as oil and coal, natural gas deserves special attention in the dialogue process.

It is becoming more and more clear that by number of reasons energy sector came now in a transition stage. It contributed a large extent of uncertainty to a vision of future picture of energy supplies and demand, development of the energy mix for various areas, sectors of economy and time horizons. As a result within last years energy scenarios and forecasts are becoming very diverse. As far as one of main targets of the TG-1[1] was determined as a harmonization of the EU and Russia energy strategies, it has been decided to provide deeper analysis and to develop expert based discussion within the framework of the EU-Russia Energy Dialogue to the topic of energy scenarios and forecasts.

It has to be noted that over the last several decades, energy supplies have been taking place from the Russian Federation and countries within the European Union on the basis of commercial arrangements involving private businesses. These arrangements have been very successful and were carried through uninterruptedly even in the midst of political tensions caused by the Cold War. What are the new elements that would require discussion at policy level?

The first element of what has changed is the process of liberalization of the EU's internal market. The Third Energy Package that was recently adopted presents another step in the ongoing development of the internal market for gas and electricity in the EU. A key feature in this process is the unbundling of production and supply interests on the one hand, from transmission interests on the other. Together with the provisions on non-discriminatory treatment of third-party access, this is resulting in a hard separation of different segments of the value chain. Vertically integrated energy companies are now forced to unbundle. Whether through ownership unbundling or through other means, industry is becoming more fragmented and is no longer as able to oversee and control the full gas value chain as it used to be.

Previously, energy companies in the EU typically were able to make long-term commitments for the supply of gas based on their knowledge of the demand in their market, and their control over the transmission and distribution infrastructure. With liberalization, market knowledge held by

[1] Thematic Group on Energy Strategies, Forecasts and Scenarios of the EU-Russia Energy Dialogue.

individual parties is decreasing as more and more companies are competing for the same markets. Transmission capacity can less easily be reserved for long-term use by parties building the capacity. Long-term contracts on the downstream side are under pressure. It is therefore becoming increasingly difficult for companies to arrange long-term commitments for supplies from the Russian Federation and provide the security to underpin the required investments. The recent thoughts about setting up a coordinated purchasing consortium on the EU side provide some further demonstration of this.

The second element concerns the heightened awareness around energy and global warming and the initiatives to address climate change. There is near global consensus that measures are necessary to reduce the amount of greenhouse gases emitted to atmosphere. Under societal pressure, international targets have been agreed. The EU has also agreed some ambitious targets through the Energy & Climate Package that was adopted by the end of 2008. These targets, better known as the "20-20-20" targets, may, if achieved, significantly affect the volume of energy consumed in the EU as well as the mix of energy that is consumed. For suppliers of energy to the EU this raises questions and increases uncertainty about the long-term viability of investments for the future EU energy supply.

The third element involves the different political constellation that has arisen following the break-up of the former Soviet Union, giving rise to a number of states that are now – quite literally – between the European Union and the Russian Federation. Some of these states are important transit channels for gas flowing from the Russian Federation to the European Union. This has resulted in a number of concerns related to the reliability and security of the transit through these countries and has even led in some cases (e.g. the January 2009 gas crisis) to concrete interruptions of the gas flow.

Finally, the global credit crisis, a relatively recent development, has given rise to revise existing expectations around future energy demand and makes it more difficult to raise capital for necessary investments.

The factors pointed out above all point to the need for increased dialogue between the Russian Federation (as the main supplier of energy to the European Union) and the EU (as the main energy market for the Russian Federation). The EU-Russia Energy Dialogue process can provide a convenient and useful vehicle in this regard. However, in order to have a constructive discussion it is essential that, when considering future options and future policy, there is a shared understanding of the facts and assumptions that underpin each side's expectations of the future.

It is precisely the creation of such mutual understanding that is the focus of the present study. Many different scenarios and forecasts exist that attempt to provide a description of the future. By analysing these more closely it is becoming possible to establish what they are based on: the assumptions and facts that make up their fabric and that provide an explanation for the direction they point towards. A full understanding of these scenarios and forecasts is thus an assumption for the formulation of a commonly understood set of facts and assumptions that could be used to better align energy policies and scenarios between the Russian Federation and the European Union.

When discussing scenarios and forecasts it is important to note the difference between the two. Forecasts are predictions of the future. The best information available, e.g. from market analysis, is used to make a prediction of what will happen in the future. Scenarios, on the other hand, merely reflect thinking on how potentially the future may evolve. This is used in different ways. Quite often, scenarios are used to describe extreme views of the future, with one or more specific elements becoming highly dominant. A set of such scenarios is then typically used to test a company or country strategy. The better strategy seem to be a strategy that does at least reasonably well against all scenarios considered and does not fall apart for any one of them. Such strategy can be said to be robust against all foreseeable developments. This reduces the risk associated with this strategy.

Alternatively, scenarios can also be used 'backward'. A certain vision of the future is described and then one or more scenarios are developed that describe how one could move from the present situation to this point in the future. Good examples of this latter approach can be found in the

Strategic European Energy Review of the European Commission and in the scenarios developed in line with the "20-20-20" targets. In the latter case, at first the targets are set at the political level, and then a programme of measures is being developed that are necessary to meet these targets. To develop this programme the scenarios are used to set a baseline (the 'business as usual' scenario) and some alternative scenarios that investigate different options and measures available to reach the targets in an optimal way.

In this study a number of forecasts and scenarios are analysed in detail. Initial focus was on the scenarios and forecasts used by policy makers both in the Russian Federation and the European Union. In a later stage also scenarios and forecasts developed by industry are included in the analysis.

It is crucial for the success of this project that the analysis is carried out under full transparency. This implies that whenever the analysis reveals certain facts and assumptions underpinning the scenario or forecast that these are carefully documented and discussed between both sides in order to agree them. Only facts and assumptions that are agreed between the two sides should be added to the fact base. This is an essential point, because only in this way can we guarantee that the fact base will constitute a useful vehicle for further dialogue and for better alignment of energy policies.

Chapter 1. Overview of models and scenarios

Section 1.1. Scenarios and forecasts analysis – preliminary findings

1.1.1. Impact on government decisions and investment policies

The emerging body of knowledge regarding the impact of scenarios and forecasts on government policies and investment strategies point to the following:

- No current or future scenario, no matter how sophisticated, can produce a precise pictures and key indicators at a given point in the mid- or long -term future. Moreover, the "status quo" scenarios (business as usual, the baseline scenarios) will not reflect exactly the business environment since market conditions and government policies will obviously change with time, especially in the long term. Such scenarios may be used for sensitivity or trend analysis, but cannot be used for specific indicators with projected values. This finding is corroborated in the IEA World Energy Outlook 2010.
- Scenarios are effective decision-support instruments, when applied as "*scenario field*",[2] with a set of variable indicators for each scenario. When scenarios are used to support or justify an action, a "*scenario audit*" by a third party would validate and add credibility to such an approach. In addition in cases, when forecasts are produced by a decision-making organization, external review by third party is also recommended. If the information used in certain types of scenarios e.g. "black box" scenarios cannot be verified, inaccurate or nonverifiable scenarios should be avoided by consensus.
- Scenarios, forecasts, and models, are not perfect, they all have shortcomings and limitations. For instance, when a model is constructed to determine the maximum sustainable energy flows in a transport infrastructure the resulting figures cannot be applied cross the board in similar forecasts, as these are extreme values, and not average indicator values. The aim of scenario (see Section 2.2.) should be taken into account when making a decision.
- Objectivity and neutrality in forecasting are guardians against conflicts of interest, and needless to say, are strongly recommended. These goals should be constantly re-enforced, as often scenario makers represent the same organisations and stakeholders, and are, at the same time, both scenario producers and users , who use own projections and visions in real, day to day business. The same applies to Agencies which formulate their own, defined policies and may be reluctant to use data which may question certain results in that context.
- Self fulfilling prophecies, assuming the probability that an outcome unlikely to happen, may still happen, even though initial premises in such scenarios do not support such out come. For example, a strong consensus on projected low energy resource output in a certain region, – because of low estimated returns on investment or because of resource shortages may affect a company's investment plans for that region – the company may stop investments projects, which in turn, will actually reduce output of that resource in that region.
- A consensus building process regarding a common forecasts format may alleviate such drawbacks. There are still challenges, such as a large number of scenarios with marked diffusion of output values and methodological obstacles for drafting common forecast formats. In addition, subjective selection of assumptions in support of certain expectations or in support of government policies and investment strategies may still need to be addressed.
- Nevertheless, we believe that the decision-support value of forecasts increases when it is based on comprehensive analysis of all relevant factors, indicators and input data, and not solely on exact values, but single, not representative numbers produced by energy

[2] Scenario field is a set of all existing models, scenarios, forecasts, and estimates in an area (in this case - world energy).

forecasts. Here, using a range of assumptions included in scenarios, as well as ranking of priorities are crucial.

The creation of the Scenario Expertise Unit (e.g. in the network of the EU-Russia Energy Dialog) could enforce the usage of accurate and valid data, could alleviate and filter the perceived subjectivity of outputs and could create a reference and benchmark tool for policy makers and major trends forecasts.

1.1.2. Options to improve quality of the scenario field

The analysis described in the following sections does not allow a verification of scenario's accuracy that is discrepancy between projected outputs and actual results; in addition, only a very limited number of models allow access to meaningful historical data dynamics. The accuracy of a model can be determined by placing in the version of the model on the forecast date the factual indicators of initially included assumptions, such as the GDP, pricing, technologies, etc.

However, the results of such verification are rarely made public, as disclosures may affect the external perception of the forecast quality, reputation and credibility.

In this context, the best potential for improving accuracy of scenarios with a multitude of authors may be achieved through agreements and consensus on how best to tackle technical aspects of scenario data. Thus, identification of discrepancies in statistical databases, when such information is available, is a relatively easy task, provided there is consensus on the usefulness of such an exercise (see review in the following sections).

The set of recommendations proposed below is intended to improve the quality of the scenario field including consensus building on technical issues (see more in subsection 1.3.3.). We recommend to:

- Create a transparent, accessible pool and database of scenarios.[3] The Database will provide accumulation and systematization of quantitative data on the Scenario field and will give to expert society a tool for making world energy scenarios comparisons.
- Introduce scenario ranking based on set criteria e.g. number of indicators, policy preferences, input data type. The recommended primary criterion is the policy factor, since any policy changes would necessarily override and trigger modifications of most assumptions and indicators.
- Publish and make available to the public summaries and abstracts of policies, scenarios and major forecasts outputs, for further research on policy goals, policy implementation and outcomes. At this stage, policy economics and cost analysis based research should provide future pricing related data.
- Establish a permanent independent Scenario Expertise Unit based on the platform and professional expertise at the EU-Russia Energy Dialogue, to review all existing and accepted scenarios and forecasts in use at the Russian Federation and the European Union as decision support instruments.
- Analyse in great detail the obtained information and disseminate widely to scenario authors, to the expert community and to the major users (this work has already started during the research on this report).
- Organize and conduct a series of seminars, exchange information among statisticians and experts on modelling, and collaborate on other resources as (for example, the web-based Information portal – see below).
- Stimulate and continue cooperation among experts, as in the framework of the EU-Russia Energy Dialog.
- Extend the conclusions and recommendations presented in this report to the current work on the EU-Russia Energy Cooperation Roadmap until 2050. The Roadmap 2050 may provide the strategic framework on scenarios and forecasts under the EU-Russia Energy Dialogue.

[3] The idea of creating such database was supported at the Thematic Group meeting in Moscow on September 21, 2010 and at the Energy Economics Subgroup meeting in Paris on April 13-14, 2010.

Additional improvements to the Scenario field can be achieved through data exchanges and sharing of analytical instruments, such as existing supply contracts, or planned infrastructure facilities. Discrepancies such as, for example, contract volumes in excess over forecasted consumption or excessive imports forecasts above the import infrastructure capacity, should trigger additional analysis of adequacy model and resulting corrections.

The EU-Russia Energy Dialogue Database and Discussion portal on energy scenarios and forecasts

It is proposed that a web-based Information portal of the EU-Russia Energy Dialogue will be divided into two parts. The Database will contain quantitative information. The Discussion portal will allow expert society debating the figures from the Database and communicate regarding all questions on energy scenarios and forecasts. Discussion portal may contain analytical papers.

To achieve these aims a database should possess following features:

- It should contain data from the majority of existing energy models, scenarios, and forecasts mainly focused on European Union and Russian Federation (including internal Russian forecasts about Russia and internal European forecasts about EU). Database should contain not only new scenarios but its previous versions too. It would allow comparisons of model results over time and sensitivity for assumptions change.
- There are three main parts of any model and scenario: assumptions, modeling mechanism, and results which should be taken into account in comparison. Database may include only quantitative data such as assumptions and results. To consider modeling mechanism, model descriptions should be included in the database, which might contribute towards better understanding how quantitative assumptions influence results.
- It is necessary to attract scenario authors to the database creation and maintaining. On the one hand authors may give information about their models and scenarios, check correctness of operator-entered data. On the other hand authors will get instrument to compare their model results with the others and get a feedback from users of forecasts and colleagues through informational portal.
- A panel should have universal structure which will allow changing structure in future owing to revisions in methodological approach or in the database goals.

The database should be controlled and managed both by European and Russian representatives.

Each figure in the Database will have several measures: periods (e.g. 2010, 2020, 2030, and beyond), scenarios (PRIMES2009BL, IEA2009Ref, EIA2010HOG, etc), indicators (production, import, price, GDP growth), energy sources (oil, natural gas, nuclear, various RES), regions (EU-27, Russia, other regions), units (mtoe, bcm, kwh), data types (assumption, result, base year data). It would allow creating the multidimensional data cube to compare figures by foregoing measures.

The problem of different definitions of terms e.g. meanings of natural gas or oil terms, billion cubic meters of gas and ton of coal terms should be solved with a help of scenario authors and clear definitions of the various units in terms of MJ per specific unit. The data from the scenario might be adjusted to the standard which should be chosen by EU-Russia Energy Dialog experts. At least the fact of the differences in terms definitions should be mentioned in the discussion portal.

There are several propositions of the database functionality:

- It should contain instrument for scenario comparison by any of the above mentioned measures;
- It should be bilingual (Russian and English) at least;
- It should present some standard comparative tables and allow also constructing tables by users for their personal purposes;
- It should allow creating graphical illustrations;
- Each scenario author (employees of corresponding organizations) should have ability to enter and change data in the Database;
- It should allow uploading data in Excel format.

Section 1.2. General overview of models and scenarios under investigation: issues for further dialogue and consensus building

1.2.1. The PRIMES model

The PRIMES model is the main energy forecasting instrument of the European Commission. The PRIMES model, as a key support instrument in the EU policy formulation process, is essential in for estimating future trends and development of the EU energy system.

Energy balance. Between 2003-2010 the energy mix in PRIMES scenarios evolved considerably; the energy mix in forecasts based on traditional growth of consumption and balanced demand for traditional energy sources – environmentally friendly and efficient energy, mostly natural gas and renewable energy sources, has changed to an energy mix, dominated by the growth of renewable energy sources.

The share of renewable energy sources in the EU primary energy mix follows an upward trend, but to only 15 percent by 2030. Furthermore, in the Baseline Scenario 2009 (BL-2009) we find a minor downward trend and a slow decline of natural gas share in the energy sector. The changes in nuclear power weight in the energy mix of BL-2009 are also negligible, but we mention the upward trend from 14 percent to 15 percent. Finally, the oil share falls from 36 percent to 32 percent, and coal drops from 16 percent to 14 percent

When compared to the Baseline Scenario 2009, the Reference Scenario 2010 assumes a 3 percent drop in 2020-2030 consumption level, a natural gas share drop to 2.4 and 2.3 percentage points in 2020 and 2030 respectively, a lower share of nuclear energy by 1.4 and one percentage points in 2020 and 2030 respectively. Coal's share drops at first 2.1 percent by 2020, but assumes an upward trend by 2030, with only 0.2 percent difference to the Baseline projections. The growth of renewables share will compensate the drop in coal consumption, and will increase by 4 percentage points by 2020 and further by 1.7 percent by 2030.

Energy pricing. The 2007-2008 scenarios assume stable coal prices and high growth rates for oil and gas prices. However, PRIMES 2007-2008 scenarios assume a different pattern of oil- gas prices linkages – gas prices will grow faster -33-134 percent for gas, as opposed to only 12-84 percent for oil. Historical price dynamics and the oil-gas price correlation in long term supply contracts do not match such patterns and assumptions. A comparison of projected gas consumption in 2007 v 2005 Baseline scenarios reveals significant discrepancies and a need for re-examination of assumptions for consensus building.

EU energy policy. The Baseline Scenario 2009 projects that 20-20-20 targets will not be met in 2020 or 2030. In this scenario, the share of renewable energy sources in the end consumption mix will fall short of target; it will increase, but only to 14.8 percent in 2020 and to 18.4 percent in 2030. The GHG green gas emissions reduction target will be met by 2030, with only 13.9 percent in 2020.

Assumptions. Few implied assumptions which impact the models end results are not fully described. Notably, the volume of projected long term gas supply to Europe exceeds the import gas volume calculated with the New Energy Policy (NEP) scenario. Apparently, the model disregards the existing long term gas supply contracts, on the assumption of mass cancellation of many long-term contracts, a highly improbable outcome even in the long term.

1.2.2. The TYNDP (ENTSOG) and the Eurogas report

Objectivity of analysis. A substantial difference with respect to forecasts for Europe is observed not only between international organisations, global companies and independent experts, but also between European state bodies, i.e. the European Commission (the PRIMES model) and the forecasts of European regulators (referred to in the ENTSOG report). In general, the ENTSOG report assumes quite high growth rates of both consumption and imports in Europe, as well as the growth of Russia's gas export potential. It can be concluded thatt forecasts based on gas industry estimates (such as ENTSOG and Eurogas) have much more optimistic view on gas consumption and import then the majority of other forecasts.

EU gas balance. Eurogas forecasts that natural gas consumption in EU-27 will reach 482-507 mtoe in 2020 (up to 10% higher than in PRIMES-2009-Baseline) and 500-535 mtoe in 2030 (up to 10% higher than in PRIMES-2009-Baseline). ENTSOG analysis shows that gas consumption in EU-27 in 2019 will be 555.7 mtoe which is 20% higher than in PRIMES-2009-Baseline in 2020.

1.2.3. The POLES Model

The Poles model is among the better known energy forecasts models in use at the European Commission, the World Energy Council, the IPCC or others. The model is distinct in its geographical coverage and aims to capture a broad spectrum of interactions within the energy system: price formation, end-user reaction, energy-economy link, penetration of new technologies and the impacts on demand, energy mix, resource sufficiency etc. All interactions are considered in the short and long-term perspective. Various aspects of the model and of the scenarios/forecasts, developed with it, are presented in section 4.1.

Despite the wide spread of the model, the modeling mechanisms and the source/structure of input data are presented at an insufficient level of methodological and informational transparency.

Principles of modeling with POLES. It is important to understand the underlying reasons for such trends in the results of the POLES simulations, as significant growth of oil-to-gas ratio in a degree, which seems to be not compensated by so-called "natural gas premium". Moreover, such result leads to the loss of gas competitiveness with subsequent diminishing of the gas share in the EU's energy mix – be it scenarios of POLES or other models, which use POLES output as input indicators. Such a scenario is highly unlikely, especially when taking into account available abundant natural gas reserves and a price (formula-based or a self-financing price) based on market conditions and gas competition. A joint review with authors of POLES of model particularities and POLES modeling principles in energy and gas markets would most likely help to close the gap.

Energy demand in POLES. It would be also beneficial to discuss several matters of applicability of the POLES models and sub-models, which deal with energy demand. These sub-models include a great number of input parameters, which naturally require a significant sample of historical data for calibration. Given the complexity of identification of such a model, the requirements for informational support for these calculations shall be quite high. There are as well technical obstacles for reaching sustainable identification.

As it could be observed, in the recent years, the energy prices have entered an unprecedented price band and today, the market fundamentals exhibit rather unstable dependency on external factors. Among the variety of such factors one could highlight the rapid global economic growth and the corresponding temporal deficit of energy resources; impact of the world financial and economic crisis; and recently -intensive attempts to introduce national and international energy saving policies, which aim at transformation of the energy system.

Available documentation on POLES does not enlighten the ways these demand models take such factors into account.

Discrepancies. In addition to clarifications on methodology and informational sources various applications of POLES , further clarifications are needed in instances when simulation outputs are used to formulate critical conclusions with high reach and visibility. Relevant examples are the alternative forecasts produced by the European Commission and the scenarios produced by the World Energy Council (see section 3.4). These forecasts establish and trace linkages between various government and/or international cooperation initiatives. There are preconditions to assume that the authors of these reports were basing on factors and feedbacks, which were not initially implied in the POLES model. It is also possible that these factors and feedbacks are not fully compatible with the initial POLES model assumptions.

1.2.4. The World Energy Model (IEA)

The World Energy Outlook Reports published by the International Energy Agency (IEA) are based on simulations of the World Energy Model (WEM) tracing the impact of government policies, investments and emissions trend in the global energy system. The IEA model is considered one of the most professional and credible models in its class. In this context, however, several items may require further analysis and clarification, as follows.

Forecasts. In WEO-2010 IEA experts note that Current Policy Scenario and New Policy Scenario are not forecasts because factual government policies will substantially differ from scenario assumptions. This conclusion could be spread at all business-as-usual scenario at least.

Discrepancies among scenario versions – demand projections. The World Energy Outlook WEO-2008 projects an increase in 2030 EU natural gas demand to 681 bcm, while the WEO-2009 update, suggests a decrease in the EU 2030 demand for natural to 619 bcm, together with a steep drop before 2015. While the basis for this projection is not immediately clear, the discrepancy in forecasts and demand dynamics could be possibly, explained in the context of the current economic and financial crisis. The perceived energy security risk posed by the high concentration of resources within a limited number of producer states, including Russia may in part explain the discrepancy in projections.

Pipeline capacities. In spite of expected drop in demand, WEO-2009 scenarios project a steady increase of gas transport capacities, assumed, according to IEA experts -as competition boosters in natural gas markets. WEO-2010 anticipates a huge excess gas pipeline capacities in Europe (150 bcm in 2020) which could provide a gas glut in Europe. But substantial part of this unused capacity is belonging to the Ukrainian GTS which would not provide excess gas supply to the Europe.

Incomplete or erroneous data. There is a discrepancy in estimated Russian gas transportation costs, significantly higher in WEO reports, than in other similar studies. These figures could be reviewed and updated.

Consistency. The report also introduces a certain degree of complexity with regard to results interpretation: volumetric figures are presented in different calorific values depending on report's section and region. Since there is no clear indication which calorific value is used, data verification is hardly manageable.

Impact on investments. Analysis of investments in oil and gas sectors may overestimate the impact of economic crisis on the rate of investment decrease. In addition, devaluations of national currencies, with resulting lower costs in investment projects (in oil&gas sectors) are not taken into account. Moreover, the investments figures in 2009 are close to 2007 figures, considered, at the time, sufficient to meet the projected hydrocarbons demand. Finally, future investment dynamics in WEO-2009 are computed based mostly on a 2008-2009 two-year trend, too short for meaningful projections.

Of interest is also the fact that, as opposed to the oil and gas case, projected lower investments in the biofuel sector do not lead to lower future production.

Oil-gas price correlation. The Reference-2009 scenario for 2008-2015 period assumes a 1.6 percent drop of oil prices in parallel with a 0.2 percent increase of gas prices. It is not clear what is the basis for such an assumption, since the prices for major EU gas import contracts are linked to oil or oil products prices. Until 2008 oil prices were growing faster than EU gas import prices (according to IEA), and the relative oil price change in 2015-2030 model assumptions is tightly correlated with EU gas price dynamics; The rationale for modifying the previously trend in 2015-2030 need to be reviewed and clarified.

CO_2 Pricing. The 2030 CO_2 price in OECD+ countries, as suggested under the 450 scenario, is US$100/ t. This rather high price point may boost the price of conventional energy supplies to an unacceptably high level and, may also create a large end-user price hike, and, because of the low price elasticity, to a decline in national welfare.

The model description does not disclose fully the pricing mechanism, not does it provide data on end-user prices, a context which makes it difficult to quantify social effects and evaluate the impact after the "450" government policies implementation.

1.2.5. The Study by International Gas Union (IGU)[4]

Methodology. This study is quite distinct in the context of materials under investigation. First of all, the study is not based on an analysis of an integrated model or an integrated methodological approach, but rather on a result of a dual process:

- Bottom-up collection of data, of analytical and forecast materials among the IGU members and gas companies.
- Centralized analysis of the collected data by experts and departments of IGU, forming of the correcting signals (as it could be derived - on the basis of primary data sources) and later – building a unified forecast.

The authors are gas experts; therefore the report covers this area in greater detail. Nevertheless, all energy sources are covered (mostly in graphical charts) with allocating a share and a role to basic energy sources within regional energy balances.

Results. The resulting two scenarios relate to rapid and moderate gas demand growth, demonstrate that in general the gas industry is capable of satisfying the requirements of the economy. Possible bottlenecks closer to 2020 are signaled in the rapid gas demand growth scenario.

In the baseline IGU scenario, as in other studies, GHG emissions are show significant growth in time. An alternative scenario, which takes into account recent trends – high energy efficiency and emission reduction requirements, is considered in less detail. In this scenario – which differentiates the study – the role of gas as energy source is constantly increasing over time and in the interval to 2020 it is the rising consumption that leads to stabilization and later abatement of the GHG emissions. The role of renewables is also increasing with sustained growth in consumption after 2020. By 2030, that would cause a sharp reduction of GHG emissions to the 2000 level.

It is worth mentioning that the IGU report takes into account a proper and logical evolution trend for natural gas share in the energy mix in the forthcoming transition to a more sustainable and environmentally compatible world energy system. Considering these issues from a pragmatic and politically unbiased position, the authors come to natural conclusions: natural gas is an environmentally friendly and economically efficient energy resource (with known and developed technologies for production and consumption) might play an important role aforementioned in the transition, especially in the mid-term perspective, when renewable technologies will be still at a development or testing phase.

1.2.6. Energy Information Administration of the US Department of Energy (EIA DOE)

Consistency of results. Modelling environment of EIA DOE has started forming its current shape from the IFFS model, which was mostly used to evaluate the US energy perspectives, with subsequent introduction of the NEMS and WEPS models and later enhancement/expansion by the GWOB, WEPS+ and SAGE models. Starting from 1998, at various points in time each of the models was used as a central tool for main scenario output. There are grounds to assume that, inconsistent application of different models at various points in time has had an impact on the coherence of EIA

[4] Full review of the IGU study is not included in the Report.

yearly forecasts. When comparing IEO reports from different periods, sometimes significant volatility in both, input data (mainly oil prices) and results can be observed.

Transparency. Another difficulty, which the authors encountered, is the lack of transparency in the model algorithms, especially, what concerns the latest versions (GWOB, WEPS+ etc.).

Energy balance. According to the Reference scenario, the highest growth of share in the energy balance during the period 2007-2035 is expected from the Renewable and alternative energy sources, as well as from nuclear energy. It is also notable that the resulting coal supply increase rate (1.6% per annum) is in general higher, than the growth rate of total primary energy consumption.

1.2.7. The MIT report

The main conclusions drawn from the research are as follows:

- The existence of enormous natural gas reserves has led to a considerable increase in its utilisation, especially in the energy sector.
- The role of natural gas in the US energy balance will grow in the next few decades and, as part of that trend, unconventional gas sources will play a key role.
- The share of natural gas in the energy balance will be even greater once restrictions on CO_2 emissions are imposed. On the other hand, in the long-term perspective, more severe restrictions on CO_2 emissions may lead to a reduction in the role of all types of fossil fuel, including natural gas.
- The natural gas market may be subject to radical changes in the period through to 2050.

Role of natural gas. An important conclusion of the research carried out is the radical increase of the natural gas share indicated in the *Price* and *Regulatory* scenarios, i.e. by 40% and 30% respectively by the year 2050 (assuming a 20% level in 2005). The trend towards an increase in the gas share differs sharply from the conclusions, particularly those made by the International Energy Agency and especially upon comparing them with the environmentally-friendly "450" scenario produced by the IEA. Even more important is the fact that the assumptions of the MIT Price scenario and the IEA "450" scenario are very close in terms of the prices of quotas for greenhouse gas emissions in the USA (USD 100 and USD 110 per tonne by 2030). In many instances, the higher estimates of the role of gas indicated in the MIT research are determined by the deeper consideration of recent trends in the gas sector, i.e. the development of gas production from non-traditional sources. Certainly, increasing supply brings about a decrease in price, which leads to greater demand; however, in the long-term perspective, gas demonstratesits advantages against a background of toughened requirements for greenhouse emissions. In general, this leads to a growth in prices for energy resources.

Modelling approach. Unlike most other research that is based on a single model (as a maximum, the results of one or two models are used as input data for that model), the MIT report is built on the joint utilisation of seven different models. This fact may be viewed as a crucial advantage because any model has its own limitations in terms of utilisation (i.e. the impossibility of calculating a certain indicator, applying a certain approach, etc.). On the other hand, the joint application of many hybrid models requires extraordinary care because all of them should be compatible; in particular, every model should have consistent assumptions (i.e. if they are used successively, then the results of one model becomes the assumption of another one). If the models' assumptions conflict with each other (including unobvious assumptions which, in many cases, are not specified anywhere, which is why they are difficult to detect from the side and may be especially risky), then result of the joint utilisation will be methodologically incorrect.

1.2.8. The TIMES models

The results of the studies, carried out with TIMES models show that the so-called "20-20-20" targets can be reached via simultaneous increase in natural gas consumption and imports to the EU-

27 (even in the "high oil" scenarios). This appears to be contradicting to the results of the *Alternative* scenarios of the PRIMES model – currently the main model used by the European Commission for justifying the published energy policies. This evidence stipulates the necessity to compare the assumptions, implied modelling mechanisms and results of the PRIMES and TIMES scenarios.

Transparency. At the same time, it is necessary to highlight the contrast between the transparent model structure and scenario assumptions of the TIMES models and the closed-for-public scenario field and modelling environment of the PRIMES. The latter creates significant difficulties for the research work of the Thematic Group on Scenarios and Forecasts.

In the context of the EU-Russia Energy Dialogue, the REACCESS Project appears to be of particular interest, not only from the perspective of the modelling environment, which – according to project goals – is undergoing significant development on the basis of lessons learnt from the previous applications of TIMES models, but also from the substantial point of view. Assessment and modeling of energy corridors opens a new page in a series of integrated assessment of energy strategies, especially given that in this project particular attention is on factors of geopolitical and social risks.

In this connection, it would be important to facilitate participation of the Russian experts in the REACCESS projects (especially in part of the TIMES models) and to bring the issues of parameterizing the initial data (especially, risk indicators) related to Russia as model region to the discussion within the Thematic Group. It would be desirable to achieve progress in such knowledge exchange in the nearest future due to limited time frame of the REACCESS project.

1.2.9. ExxonMobil and Shell reports

The ExxonMobil and Shell scenarios represent a vision from the inside of the industry. In comparison with the other scenarios studied, the ExxonMobil one contains a scenario where natural gas plays the most crucial role in terms of its share of the world energy balance. At that, special attention is also awarded to renewable energy sources and nuclear energy. It is worth to note an interesting peculiarity: in contrast to the US market, renewable energy sources will not play an essential role on the European market even in the long-term perspective.

The Shell scenarios paint an alternative picture in many instances, i.e. special emphasis is placed on coal and RES, but the share of natural gas is rather low. Thus, within the oil and gas industry, even two super-major companies have diametrically opposed viewpoints on the future development of the world energy sector (i.e. at least in terms of gas). The above-mentioned fact may be considered as one indication of an existing significant degree of uncertainty with respect to the future development of world energy, which claims the attention of state authorities and companies in order to ensure a decision-making role in the energy and investment policy, correspondingly. Another piece of crucial evidence of such uncertainty is represented by the spread between forecasts in terms of gas consumption and imports in Europe, which differs by a two-fold margin.

Section 1.3. Quantitative comparison of energy scenarios and forecasts

1.3.1. Quantitative comparison of the results

The majority of actual scenarios on world energy shows that the primary energy consumption (PEC) would be about 16-17 gtoe in 2030 (Table 1) and 14-15 gtoe on 2020 (Table 2). Natural gas primary supply in 2030 is projected to be at the level of 3.1 gtoe in the scenario "450" compared to 4.1 gtoe in the forecast of ExxonMobil.

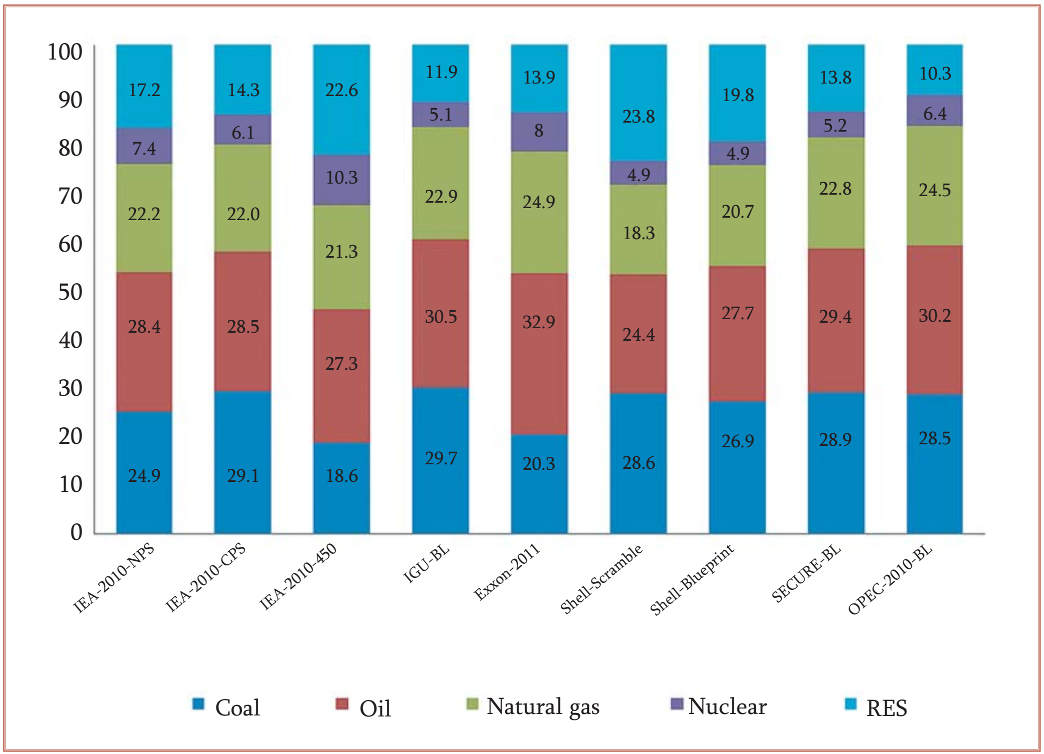

Figure 1. World PEC structure in 2030, %

Sources: IEA, IGU, ExxonMobil, Shell, SECURE, OPEC

The ExxonMobil report indicates the highest forecast (even higher than the figures cited in the International Gas Union report) regarding the consumption volume and overall share of natural gas (24.9%). In the scenario forecasts prepared by ExxonMobil, oil and nuclear energy also play more crucial roles than indicated in most other scenarios. The share of renewable energy resources amounts to 13.9%, which is close to the value specified for the CPS scenario of the International Energy Agency (14.3%). The share of coal in the energy balance, as estimated by Exxon, is considerably less than that which is indicated in most scenarios (with the exception of the alternative scenario prepared by the IEA).

In the *Scramble* scenario prepared by Shell, the total volume of primary consumption is significantly higher than that implied in the other scenarios, owing to the fact that no growth in energy efficiency is expected therein (determined by the scenario assumptions). This scenario supposes a higher-than-anticipated growth in coal consumption, but with respect to absolute and relative values, the coal consumption level specified in the *Scramble* scenario is at the same level specified in the scenarios prepared by the International Energy Agency, the International Gas Union and in POLES model. In comparison with other scenarios, the *Scramble* scenario also implies the lowest shares of natural gas, oil and nuclear energy in the energy balance and the highest share (even higher than the 450 scenario put forward by the International Energy Agency) of renewable energy resources. This means that the *Scramble* scenario appears to be the most extreme among the existing scenarios. This was most likely done intentionally in order to cast a shadow on the results of the *Blueprint* scenario.

It is worth noting that the *Blueprint* scenario greatly differs from other scenarios. The IEA 450 scenario and the *Scramble* scenario put forward by Shell itself are the closest existing ones to the *Blueprint* scenario. The share of natural gas in the *Blueprint* scenario is lower than the general level (20.7%). Similarly, the share of renewable energy resources is higher and the share of nuclear energy is lower than that for most other scenarios.

Table 1. World primary energy balance in 2030

Author	IEA-2010			IGU	Exxon	Shell		SECURE	OPEC	Factual 2008 (IEA data)
Scenario	NPS	CPS	450	BL	2011	Scramble	Blueprint	BL	BL	
PEC, gtoe	16.0	16.9	14.6	16.3	16.0	17.5	16.5	16.4	16.1	12.27
Coal	4.0	4.9	2.7	4.8	3.4	5	4.4	4.8	4.6	3.32
Oil	4.6	4.8	4.0	5	5.1	4.3	4.6	4.8	4.9	4.06
Natural Gas	3.6	3.7	3.1	3.7	4.1	3.2	3.4	3.7	3.9	2.60
Nuclear Energy	1.2	1.0	1.5	0.8	1.3	0.9	0.8	0.9	1.0	0.71
Renewables	2.8	2.4	3.3	1.9	2.1	4.2	3.3	2.3	1.7	1.59
Structure, %	100	100	100	100	100	100	100	100	100	100
Coal	24.9	29.1	18.6	29.7	20.3	28.6	26.9	28.9	28.5	27.0
Oil	28.4	28.5	27.3	30.5	32.9	24.4	27.7	29.4	30.2	33.1
Natural Gas	22.2	22.0	21.3	22.9	24.9	18.3	20.7	22.8	24.5	21.2
Nuclear Energy	7.4	6.1	10.3	5.1	8	4.9	4.9	5.2	6.4	5.8
Renewables	17.2	14.3	22.6	11.9	13.9	23.8	19.8	13.8	10.3	13.0

Sources: International Energy Agency, World Energy Outlook 2010; International Gas Union, Programme committee B: strategy, economics and regulation, 2006-2009 Triennium Work Report, 2009; Shell, Energy scenarios till 2050, 2009; ExxonMobil, 2010 The Outlook for energy: a view to 2030, 2011; OPEC, SECURE
Note: BL – baseline, NPS – new policy scenario, CPS – current policy scenario

Table 2. World primary energy balance in 2020

Author	IEA-2010			IGU	Exxon	Shell		SECURE	OPEC	Factual 2008 (IEA data)
Scenario	NPS	CPS	450	BL	2011	Scramble	Blueprint	BL	BL	
PEC, gtoe	14.6	14.9	14.1	14.7	14.5	15.5	15.0	14.3	13.7	12.3
Coal	4.0	4.3	3.7	4.4	3.4	4.8	4.1	4.0	4.0	3.3
Oil	4.3	4.4	4.2	4.6	4.8	4.4	4.6	4.6	4.5	4.1
Natural Gas	3.1	3.2	3.0	3.2	3.5	3.2	3.3	3.2	3.2	2.6
Nuclear Energy	1.0	0.9	1.0	0.8	1.0	0.8	0.7	0.7	0.8	0.7
Renewables	2.1	2.1	2.2	1.7	1.9	2.3	2.3	1.9	1.2	1.6
Structure, %	100	100	100	100	100	100	100	100	100	100
Coal	27.2	28.9	26.5	29.7	23.1	30.6	27.4	28.0	29.1	27.0
Oil	29.9	29.8	29.6	31.0	33.2	28.6	30.4	32.0	32.7	33.1
Natural Gas	21.5	21.3	21.0	22.1	24.0	20.5	22.1	22.3	23.5	21.2
Nuclear Energy	6.7	6.1	7.1	5.5	6.6	5.2	4.8	4.6	6.1	5.8
Renewables	14.7	13.9	15.9	11.7	13.0	15.1	15.3	13.1	8.5	13.0

Sources: International Energy Agency, World Energy Outlook 2010; International Gas Union, Programme committee B: strategy, economics and regulation, 2006-2009 Triennium Work Report, 2009; Shell, Energy scenarios till 2050, 2009; ExxonMobil, 2010 The Outlook for energy: a view to 2030, 2011

Table 3. EU-27 primary energy balance in 2020

Author	IEA-2010				PRIMES				SECURE-2010 (POLES)			Factual 2008 (IEA data)
Scenario	NPS-2010	CPS-2010	450-2010	Ref-2009	2007, BL	2009, BL	2009, Ref	2008, NEP, high prices	BL	EA	MT	
PEC, gtoe	1723	1753	1690	1723	1968	1823.9	1782.9	1672	1888.9	1716.3	1824.9	1749
Coal	220	268	213	260	342	287.3	261	253	333.3	181.4	276.5	304
Oil	544	566	523	557	702	627.2	604.7	567	666.7	572.1	663.6	606
Natural Gas	459	465	424	463	505	462.7	411.6	345	486.1	460.5	470	440
Nuclear Energy	244	211	257	202	221	237.7	226.6	233	180.6	195.3	193.6	244
Renewables	256	243	273	241	197	209	279	274	222.2	307	221.2	153
Structure, %	100	100	100	100	100	100	100	100	100	100	100	100
Coal	12.8	15.3	12.6	15.1	17.4	15.8	14.6	15.1	17.6	10.6	15.2	17.4
Oil	31.6	32.3	30.9	32.3	35.7	34.4	33.9	33.9	35.3	33.3	36.4	34.6
Natural Gas	26.6	26.5	25.1	26.9	25.7	25.4	23.1	20.6	25.7	26.8	25.8	25.2
Nuclear Energy	14.2	12.0	15.2	11.7	11.2	13.0	12.7	13.9	9.6	11.4	10.6	14.0
Renewables	14.9	13.9	16.2	14	10	11.5	15.6	16.4	11.8	17.9	12.1	8.7

Sources: International Energy Agency, World Energy Outlook 2009-2010; European Energy and Transport Trends to 2030 – update 2007, 2009; Second Strategic Energy Review: an EU Energy Security and Solidarity Action Plan, November 2008

Table 4. EU-27 primary energy balance in 2030

Author	IEA-2010				PRIMES		SECURE-2010 (POLES)			Factual 2008 (IEA data)
Scenario	NPS-2010	CPS-2010	450-2010	Ref-2009	2009, BL	2009, Ref	BL	EA	MT	
PEC, gtoe	1719	1802	1663	1781	1809	1755	2000	1730.2	1907.8	1749
Coal	168	231	115	233	260	253	402.7	167.4	304.1	304
Oil	483	547	435	545	579	560	652.8	460.5	622.1	606
Natural Gas	486	516	396	508	439	393	527.8	418.6	525.4	440
Nuclear Energy	237	204	307	192	268	244	166.7	237.2	207.4	244
Renewables	345	305	410	303	263	305	250	446.6	248.8	153
Structure, %	100	100	100	100	100	100	100	100	100	100
Coal	9.8	12.8	6.9	13.1	14.4	14.4	20.1	9.7	15.9	17.4
Oil	28.1	30.4	26.2	30.6	32.0	31.9	32.6	26.6	32.6	34.6
Natural Gas	28.3	28.6	23.8	28.5	24.3	22.4	26.4	24.2	27.5	25.2
Nuclear Energy	13.8	11.3	18.5	10.8	14.8	13.9	8.3	13.7	10.9	14.0
Renewables	20.1	16.9	24.7	17	14.5	17.4	12.5	25.8	13.0	8.7

Sources: International Energy Agency, World Energy Outlook 2009; European Energy and Transport Trends to 2030 - update 2009

At the same time it is necessary to mention that recently IEA in its forecasts exhibits a moderate trend in reducing the role of natural gas. This trend is most distinguishable in the European Commission forecasts. If to compare alternative scenarios of IEA ("450") and PRIMES results ("New energy policy" at high oil and gas prices) in part of the EU energy balance in 2020, one could notice that at the same level of total primary energy supply, PRIMES (and consequently EU) projects 84 mtoe less natural gas consumption, than IEA. Moreover, in PRIMES scenarios the reducing share of gas is compensated by oil and coal – quite a questionable trend for a low-carbon scenario.

It could be assumed that such tendency is the result of high gas prices in PRIMES assumptions. Note that give the same assumption for oil price – 100$/boe, gas price in PRIMES is 14 $/MBtu, whereas IEA projects it at 12$/MBtu.

Modern forecasts on gas consumption and import in EU in 2020 differ in 1.6 and 1.8 times correspondingly (**Table 5**). In 2030 divergence of scenarios decreases to 1.3 times for consumption and 1.5 times for import. The level of dependence on imported gas in the EU varies from 70% to 79.9% in 2020. It is worth noting that forecasts related to the EU differ more substantially than those for the world on the whole.

The average value of all of the forecasts outlined in Table 6 concerning gas consumption amounts to 465 mtoe and, with respect to net imports, it amounts to 354 mtoe, which is close to the International Energy Agency's forecast baseline scenario. The lowest forecasts for natural gas consumption were specified by the European Commission (the PRIMES model), while the highest results were suggested by the industry organisations Eurogas and ENTSOG.

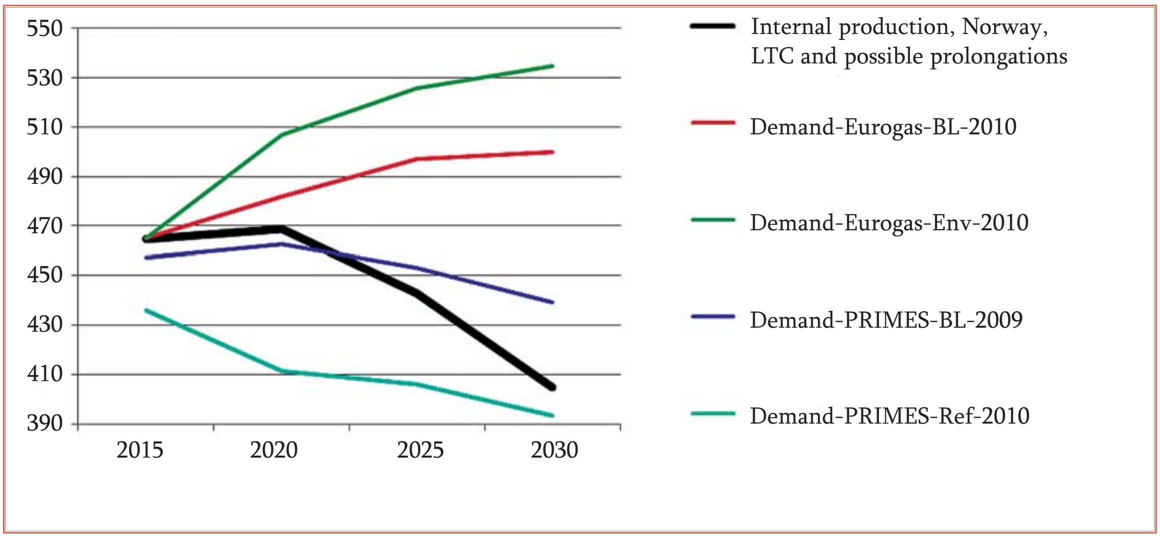

Figure 2. Potential of a new gas supply in EU-27 in 2015-2030 according to forecasts
Sources: Eurogas, 2010; EET-2030 update 2009
Note: LTC – long-term contracts

Table 5. EU-27 gas balance in 2020, mtoe

Model	PRIMES				SECURE (POLES)			
Scenarios	Reference-2009	BL-2009	No policy-2009	NEP-HOG-2008	BL	EA	MT	GR
Consumption	412	42	513	345	475	461	480	480
Net import	301	31	401	245	393	365	399	351
Import dependence, %	73	76	78.2	71	83	79	83	73
Model	RES-2020 (PET, TIMES)		ENTSOG*	Eurogas		IEA		
Scenarios	BL	BL, HOG	2009	BL-2010	Env-2010	NPS-2010	Ref-2009	450-2009
Consumption	429	539	556	482	507	459	463	429
Net import	332.2	425	438	380	405	329	349	321
Import dependence, %	77	79	79	79	80	72	75	75

Sources: ETT-2030 update 2007, 2009; SSER, 2008; IEA, 2009; Eurogas, 2010; ENTSOG, 2009
Note: For ENTSOG – 2019

Table 6. EU-27 gas balance in 2030, mtoe

Model	PRIMES			IEA		
Scenarios	Reference-2009	BL-2009	No policy-2009	NPS-2010	Ref-2009	450-2009
Consumption	393	439	500	486	508	418
Net import	319	364	424	394	424	351
Import dependence, %	81	83	85	81	83	84
Model	SECURE (POLES)				Eurogas	
Scenarios	BL	EA	MT	GR	BL-2010	Env-2010
Consumption	528	430	520	465	500	535
Net import	473	350	471	359	443	478
Import dependence, %	90	81	91	77	89	89

Sources: ET-2030 update 2009; IEA, 2009; Eurogas, 2010

The comparison of the forecasts for USA energy balance could be hampered by the fact that EIA provides forecasts for liquid types of fuel (mainly oil and biofuels) without differentiating between them. At the same time, the International Energy Agency (IEA) and MIT models include biofuels, as a rule, as renewable energy resources,

We note that, in terms of the share of natural gas in the primary energy balance of the USA, the MIT scenarios (the share in the fuel and energy balance is 25.7-26.2% in 2020, and 26.5-30.6% in 2030) are more optimistic than those presented by the IEA and EIA (21.8-23.9% in 2020 and 22.2-24.6% in 2030). In this case, in terms of absolute volumes of natural gas consumption, the MIT and EIA forecasts are rather close (in comparison, the IEA indicates considerably lower figures), but the EIA specifies the highest total level of primary energy consumption.

As for the share of coal in the energy balance, the baseline scenario of the IEA (23.7% and 24.2% in 2020 and 2030 respectively) is more optimistic. At the same time, MIT's Regulative scenario for the year 2020 indicates a lower share of coal in the energy balance, at 12.4%, while the Institute's Price-Based scenario for 2030 implies a share of 6.1%. In so doing, MIT researchers obtained a result that indicates radical change in the US energy balance structure with regard to coal.

Table 7. Primary energy balance of USA in 2020

Consumption, mtoe	EIA					Structure, %	EIA				
Scenario	Ref	HEG	LEG	HOP	LOP	Scenario	Ref	HEG	LEG	HOP	LOP
Coal	579.9	607.3	561.3	588.8	577.4	Coal	21.9	21.9	22.1	22.6	21.2
Liquids	991.8	1045.2	945.0	938.8	1067.5	Liquids	37.5	37.6	37.2	36.1	39.2
Natural gas	586.5	604.5	564.0	581.3	601.9	Natural gas	22.2	21.8	22.2	22.4	22.1
Nuclear	233.3	234.3	233.3	233.3	233.3	Nuclear	8.8	8.4	9.2	9.0	8.6
Other renewables	249.7	282.8	231.0	252.6	239.5	Other renewables	9.4	10.2	9.1	9.7	8.8
Others	5.0	5.1	4.8	5.1	4.9	Others	0.2	0.2	0.2	0.2	0.2
Total	2646.1	2779.2	2539.3	2599.9	2724.5	Total	100	100	100	100	100
Consumption, mtoe	IEA		MIT		Factual, 2007	Structure, %	IEA		MIT		Factual, 2007
Scenario	Ref	450	Pricing	Regulatory		Scenario	Ref	450	Pricing	Regulatory	
Coal	548	415	315	321.4	554	Coal	23.7	19.2	14.6	12.4	23.7
Oil	806	750	903	1129.0	910	Oil	34.8	34.6	41.7	43.5	38.9
Natural gas	522	517	567	666.4	538	Natural gas	22.5	23.9	26.2	25.7	23.0
Nuclear	231	260	189	219.5	218	Nuclear	10.0	12.0	8.7	8.5	9.3
Renewables	209	225	189	258.7	117	Renewables	9.0	10.4	8.7	10.0	5.0
Total	2316	2167	2163	2595.0	2337	Total	100	100	100	100	100

Sources: International Energy Agency, World Energy Outlook 2009; EIA, International Energy Outlook 2010; MIT, The Future of Natural Gas: Interim report, 2010

Table 8. Primary energy balance of USA in 2030

Consumption, mtoe	EIA					Structure, %	EIA				
Scenario	Ref	HEG	LEG	HOP	LOP	Scenario	Ref	HEG	LEG	HOP	LOP
Coal	611.2	641.5	575.7	646.7	594.9	Coal	21.8	21.1	22.3	23.0	20.6
Liquids	1035.2	1133.2	946.1	959.1	1152.1	Liquids	36.9	37.3	36.6	34.1	39.9
Natural gas	630.3	681.9	578.0	635.4	641.3	Natural gas	22.5	22.5	22.4	22.6	22.2
Nuclear	234.1	235.6	234.1	234.1	234.1	Nuclear	8.4	7.8	9.1	8.3	8.1
Other renewables	285.9	338.2	246.0	328.6	261.8	Other renewables	10.2	11.1	9.5	11.7	9.1
Others	5.0	6.7	4.6	5.3	5.0	Others	0.2	0.2	0.2	0.2	0.2
Total	2801.7	3037.1	2584.6	2809.3	2889.3	Total	100	100	100	100	100
Consumption, mtoe	IEA		MIT		Factual, 2007	Structure, %	IEA		MIT		Factual, 2007
Scenario	Ref	450	Pricing	Regulatory		Scenario	Ref	450	Pricing	Regulatory	
Coal	581	234	126	211.7	554	Coal	24.2	11.2	6.1	7.8	23.7
Oil	772	627	861	1191.7	910	Oil	32.2	30.0	41.8	43.8	38.9
Natural gas	533	515	630	721.3	538	Natural gas	22.2	24.6	30.6	26.5	23.0
Nuclear	248	316	231	235.2	218	Nuclear	10.4	15.1	11.2	8.6	9.3
Renewables	262	400	210	360.6	117	Renewables	10.9	19.1	10.2	13.3	5.0
Total	2396	2092	2058	2720.5	2337	Total	100	100	100	100	100

Sources: International Energy Agency, World Energy Outlook 2009; EIA, International Energy Outlook 2010; MIT, The Future of Natural Gas: Interim report, 2010

1.3.2. Prognostic power of energy scenarios

Such a considerable scenario results spread which is shown in the subsection 1.2.1 provides three important questions:

1. What are the reasons of this phenomenon? (subsection 1.3.3.)
2. Could we use these scenarios and forecasts? (section 1.1)
3. What is prognostic power of energy scenarios?

The answer at the last question allows us to determine the quality of the concrete scenarios and forecasts (which together determine the quality of the current scenario field). Let's consider the historical dynamic of the forecasts, and to compare the predicted and actual performance. The best opportunity to make such an analysis is the model of the International Energy Agency, as it has the longest history of all the models considered in this study. Take for example gas consumption in the Europe-OECD countries (Figures 3-7).

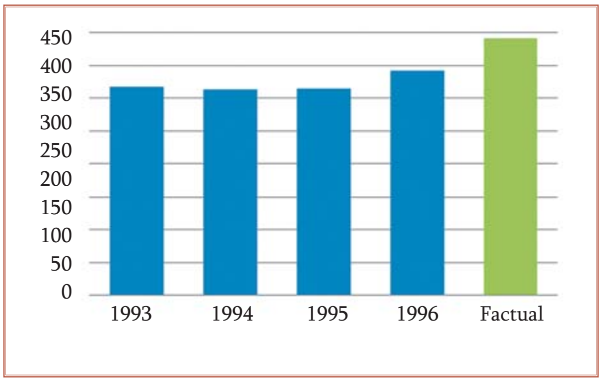

Figure 3. Projections of the IEA baseline scenario for gas consumption in Europe-OECD in 2000, mtoe/year

Sources: IEA, World Energy Outlook 1993-1996, Energy Balances OECD 2010

Note: the captions for the x-axis are the years that the relevant scenarios were published

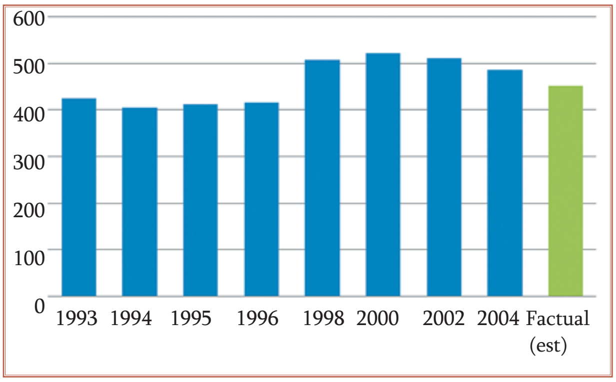

Figure 4. Projections of the IEA baseline scenario for gas consumption in Europe-OECD for 2010, mtoe/year

Sources: IEA, World Energy Outlook 1993-2004, Energy Balances OECD 2010, authors estimates

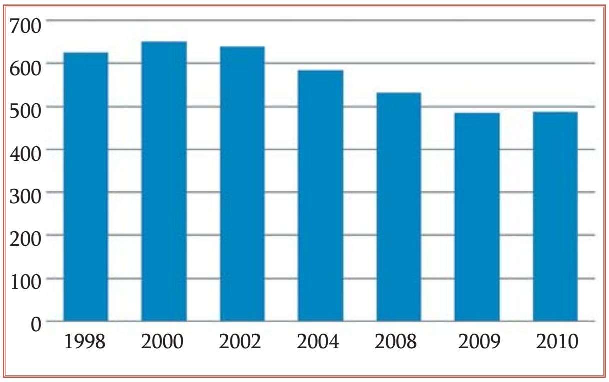

Figure 5. Projections of the IEA baseline scenario for gas consumption in Europe-OECD for 2020, mtoe/year

Sources: : IEA, World Energy Outlook 1998-2010

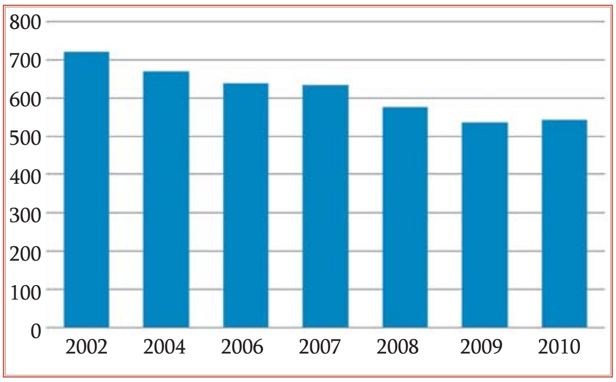

Figure 6. Projections of the IEA baseline scenario for gas consumption in Europe-OECD for 2030, million toe/year

Sources: IEA, World Energy Outlook 2002-2010

The deviation of the forecasts for 2000 with the actual 2000 figures ranges from 14% to 25%, with the closest prediction being the one made in 1996 – the last year in which predictions were made for 2000. Forecasts for 2010 have already proved to be much more precise: the discrepancy ranged from 6 to 16%. But the most accurate forecast turned out to be from 1993, so it seems incorrect to say that over the years forecast accuracy increases.

An analysis of the historical dynamics of projections may show changes in expectations for a particular indicator either due to changes in fundamental factors or for some political attitude towards it (for example, towards gas consumption) . In the reports from 1994 to 2000 the expectations for gas consumption grew (according to the projections made on all time points), while from 2000 to 2009 they fell. In the 2010 report expectations rose slightly, which may indicate a reversal of the trend for the 2000's.

Another interesting feature of the IEA forecasts is the disappearance of the forecast for the nearest date as it approaches. The last forecast for 2000 was presented in 1996, and the last forecast for 2010 in 2004. According to general logic, the closer the forecast horizon, the less uncertainty and the more accurate the forecast should be. It is also likely that the vast majority of users of the IEA model will not check how accurate the forecast was from 5-6 years previously. However, even if it is done, the authors of the model can quite reasonably note that over time things have changed (for example, there was the economic crisis, a sharp jump in oil prices or the shale oil evolution), which were not taken into account in the prediction and this is why there is difference between the forecast and fact.

However, the reality for every sufficiently long period of time (for example, five years) is that a few significant events are bound to occur that will have a significant impact on energy development. This means that the baseline scenarios, and all the other scenarios that have not precisely guessed these future radical changes (i.e., almost certainly all the scenarios) will be wrong. Obviously there can be no forecasts giving accurate predictions in the long term; the only question is about the magnitude of divergence. It should be noted that the IEA-2010 report expressly stated that the baseline (CPS) and one of the alternative scenarios (NPS) were not predictions.

Clearly, the IEA experts understand that a forecast published shortly before the relevant date is still "within earshot" and, accordingly, a significant divergence between the fact and the forecast will be easily detected. The IEA says that their model is long-term and not suited for forecasting short periods of time, but there is no reason to assume that a divergence from reality manifested by a certain date (for example, 2010) will be reduced in a more distant horizon. Taking into account the growing level of uncertainty, it is more likely that there will be a situation which will cause the error to grow.

At the same time, the new report from the PRIMES model (Energy Trends to 2030 update 2009) has forecasts for 2010, so after the appearance of statistics for 2010 (in the first half of 2011) it will be possible to compare them accurately. But even now it is possible to compare the actual figures for 2009 with the PRIMES forecast for 2010.[5] According to the report, PRIMES used the Eurostat statistics as a baseline, so it just necessary to compare it with the actual data from this source.

[5] Statistical data on 2010 was not presented in the Eurostat database by the time of the Report publication.

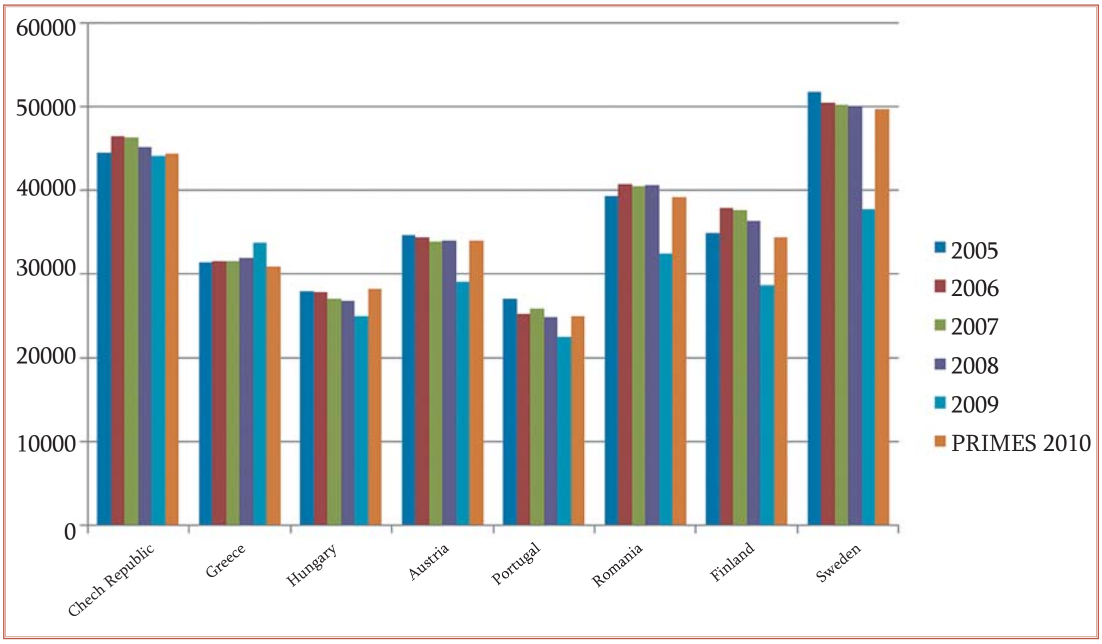

Figure 7. Comparison of actual data in 2005-2009 (Eurostat) and the forecast according to PRIMES baseline scenario for the consumption of primary energy in certain EU countries in 2010
Sources:Eurostat, European Energy Trends to 2030 update 2009

For a variety of countries (for example, Sweden, Finland, Romania, Austria) it is particularly easy to see that the forecast for 2010 is continuing the trend of the years 2005-2008, i.e. that it in fact does not take into account the effect of the crisis, although the report is positioned as having taken its influence into account. Discrepancies between the actual 2009 and the forecast for 2010 reach 32%. At the moment there is no reason to believe that in 2010 primary energy consumption in Sweden has increased by 32%, in Finland by 20%, in Slovenia by 21%, in Austria by 17%, while in Lithuania it has dropped by 9%. This error may also survive for forecasts at later time points – 2015, 2020, and 2030.

The early versions of the PRIMES model had another statistical base than in the new one so it would be incorrect to compare old results with factual data in the PRIMES reports.

This subsection analysis should not be seen as criticism of the two concrete models (you can find it in the Sections 4.1 and 3.1). WEM and PRIMES models are one of the most transparent and high-qualified models which have a long-duration history of development. A plenty of data on this models allows us to show its imperfection which is difficult to do for many other models and scenarios. Nevertheless even these models cannot be used as a source of exact quantitative information about the future development of energy sector.

1.3.3. Reasons for scenario results difference

Another important feature of the scenario field is the size of the spread of forecasts. And of particular importance here are the reasons for the discrepancies. Discrepancies in scenario results may be determined by the following reasons, which may be divided into two groups. Specifically, these are those of a conceptual and technical nature (refer to Figure 8).

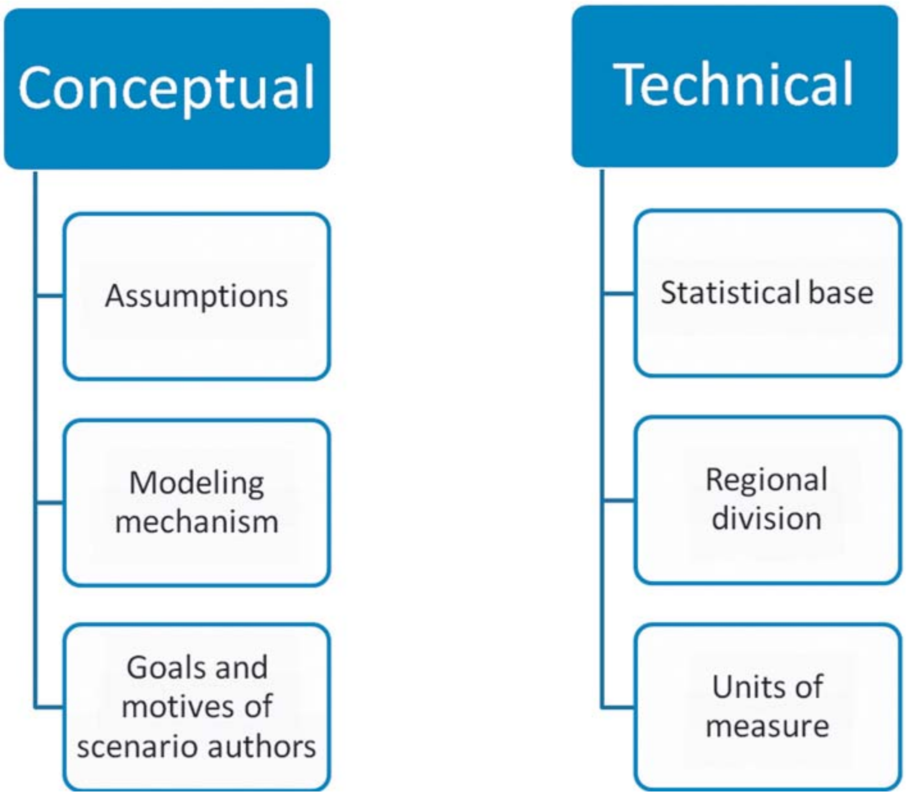

Figure 8. Reasons for the discrepancies in forecasts and the difficulties in comparing them

Conceptual reasons could not be avoided even theoretically because expert society is obliged to have different modelling tools with different assumptions to solve political and analytical tasks. Comparative analysis on assumptions and modelling mechanism could be founded in Section 2.2.

Trying to create possible or the most likely future in author's mind (vision scenario) or to find a pathway to the future described in a political document (policy scenario) you will get different results. It causes importance of the scenario goal in analysis and comparison. Classifications of scenarios by its goals could be founded in Figure 9.

Particularly in regard to the quality of the scenario field, it is crucial whether the differences in the scenarios is conditional on differences in the vision of the future by the authors of the scenarios (which is reflected through them in various other assumptions of the scenarios) or through a variety of motives of the authors, who for their own interests wish to obtain a certain definite result that can be achieved by "playing" with the assumptions, the simulation mechanism, the units of measure, the statistical base, etc.

It is also of great importance to be clear about what contribution to the divergence in the scenario results is due to technical reasons, since these can be relatively easily corrected. The key technical problem regards to the statistical base which includes:

- source of data (its own or some external source);
- methodology of data acquisition;
- methodology of indicator accounting (e.g. meaning of the terms "oil", "gas", "consumption", "import", etc).

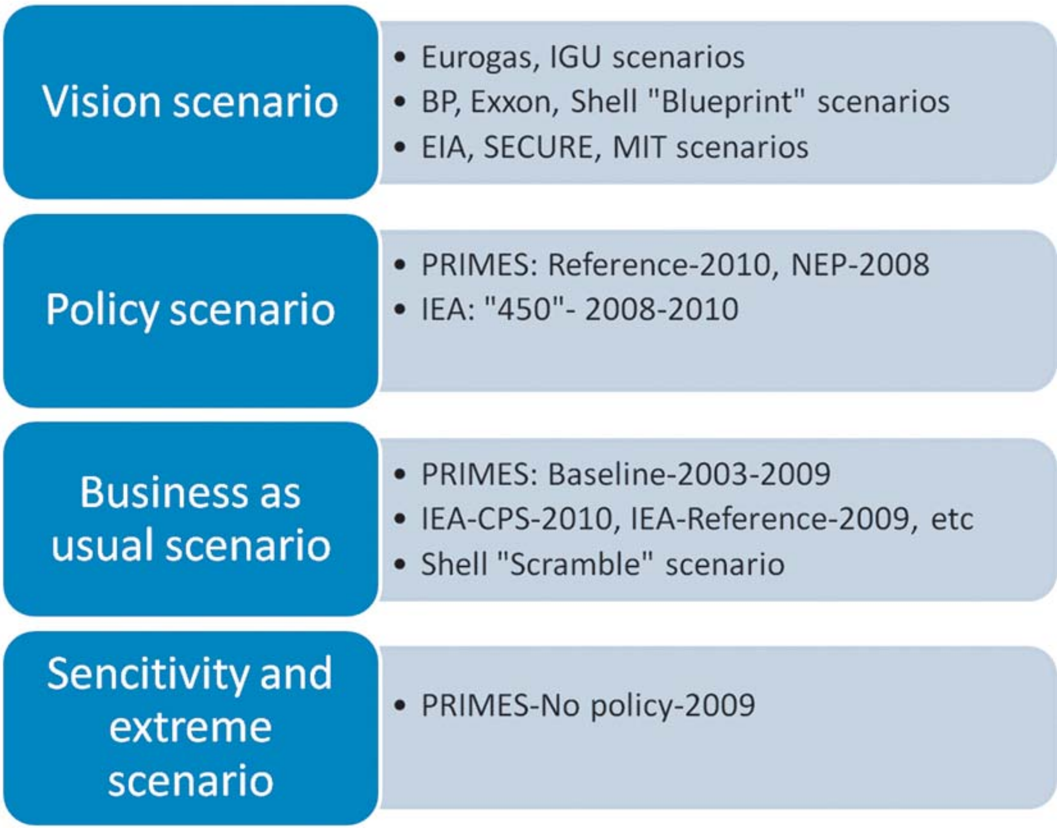

Figure 9. Scenario classification by its goal with examples

Table 9. Comparison of actual data on primary energy consumption in the world in 2007 employed by different models, gtoe

	IGU	IEA	OPEC	EIA	BP	Max/Min
Total	11.7	12.0	11.1	12.5	11.1	1.12
Coal	3.1	3.2	3.1	3.3	3.2	1.07
Oil	3.9	4.1	4.0	–	4.0	1.04
Natural Gas	2.7	2.5	2.5	2.8	2.7	1.14
Nuclear	0.7	0.7	0.7	0.7	0.6	1.18
Renewables	1.2	1.5	0.7	–	0.7	2.15
Structure, %						
Coal	26.8	26.5	28.2	26.7	28.6	1.08
Oil	33.7	34.1	36.4	–	35.7	1.08
Natural Gas	23.3	20.9	22.3	22.6	23.8	1.14
Nuclear	5.8	5.9	6.6	5.5	5.6	1.21
Renewables	10.4	12.6	6.5	–	6.3	2.01

Sources: : IGU, IEA, OPEC, EIA, BP
Note: the EIA data for oil and renewable energy are not presented because the organization keeps its own records of liquid fuel resources (petroleum and biofuels) and other renewables (excluding biofuels)

The discrepancy in relation to the actually-consumed total global primary energy resources across five models varies from 7 to 115%. The greatest discrepancy is observed for the statistics of renewable energy consumption by the IEA and BP – which are more than doubled in relative terms, and increased by 804 mtoe in absolute terms. Most likely this discrepancy is due to the fact that the IEA's statistics include their estimates for non-commercial firewood consumption (especially important for tropical countries). The problem is that all estimates in this area can only be very approximate. According to the IEA, in 2007 the world's households consumed 760 mtoe biomass and waste, which corresponds to the discrepancy between the statistics of the IEA and BP/ OPEC.

However, even for the other energy resources the statistics reveal discrepancies of up to 100-200 mtoe/year, which is a lot even on a global scale. At the level of specific regions, the discrepancies in relative terms may be even higher than shown in Table 10.

Of course, a discrepancy in the statistics will be shown by a significant scattering of the projections. For example, the IEA-2010 forecasts for renewable energy consumption in 2020 and 2030 (in the CPS scenario) are 2.1 and 2.4 gtoe/year, while OPEC forecasts 1.2 and 1.7 gtoe/year. Thus, the difference in the actual data is almost completely preserved in the projections (amounting to approximately the same size).

This means that a simple comparison of forecasts of energy consumption (and their share in the energy mix) for different scenarios may be incorrect due to employing a different statistical base. There are two possible solutions to this problem:

- through the introduction of amendments to the forecast indicators according to the size of the difference to the actual data (this approach requires an analysis of the causes of the discrepancies in the statistics);
- through an analysis of the growth rate of indicators (the rates calculated according to the forecast of the given model to its own actual data).

When comparing growth rates forecast in the IEA and OPEC models for the consumption of renewable energy, it turns out that OPEC assumes the highest growth rate of consumption of renewable energy among all the scenarios considered (although this is largely due to the effect of a low baseline), also in comparison to all IEA scenarios. At the same time, the analysis of a forecast growth in absolute values and a higher share in the energy mix shows the opposite (the weakest prospects for renewable energy, according to OPEC).

But the problem is compounded by the fact that it is far from the case that for all scenarios the indicators of their statistical base are known.

Growth rates analysis can show influence of motives of scenario author. Producing and consulting companies and gas industry organizations shows persistently higher forecasts on gas consumption (0.9% per year in 2010-2020) then governmental forecasts (0.2% per year in 2010-2020). Even the lowest estimates of companies are near to the highest governmental forecasts at 2010-2020. The PRIMES model shows the most pessimistic view on gas consumption in Europe in the nearest decade. For the 2020-2030 periods there are too much uncertainties but companies still presents stable positive forecasts on gas consumption.

Table 10 shows also the problem of regional division which complicates comparison of scenarios and forecasts.

Table 10. European gas consumption annual average growth rates, %

Author/model	Scenario	Growth rates, 2010-2020	Growth rates, 2020-2030	Region	Author/model	Scenario	Growth rates, 2010-2020	Growth rates, 2020-2030	Region
WEM (IEA)	NPS-2010	0.4	0.6	EU-27	EIA	Ref-2010	0.7	0.2	Europe-OECD
	CPS-2010	0.5	1.0			LOP-2010	0.6	0.2	
	450-2010	-0.4	-0.7			HOP-2010	0.9	0.4	
Eurogas	BL-2010	1.0	0.4			LEG-2010	0.4	-0.1	
	Env-2010	1.6	0.6			HEG-2010	0.9	0.5	
ENTSOG		1.4	–		Exxon	BL	1.2	0.7	
PRIMES	BL-2009	0.1	-0.5		Statoil		2.0	0.7	Europe
	Ref-2010	-0.9	-0.5		IGU		1.8	0.9	All Europe except CIS countries
IEC		0.7	–		CERA		1.0	0.6	Europe
		1.5	–		OMV		1.6	0.3	EU-27 + Turkey
Eni		1.5	–		Total		1.7	–	Europe
SECURE	BL	1.0	0.8		BP		1.8	0.7	Europe
	EA	0.4	-0.9		BG/Wood Mackenzie		0.8	–	Europe
	MT	0.3	1.1		LEA		1.2		Europe
	GR	0.3	-2.0				2.2		Europe
Averane EU-27		0.6	0.0		Average all Europes		0.9	0.2	

Sources: : scenario authors data, authors estimates

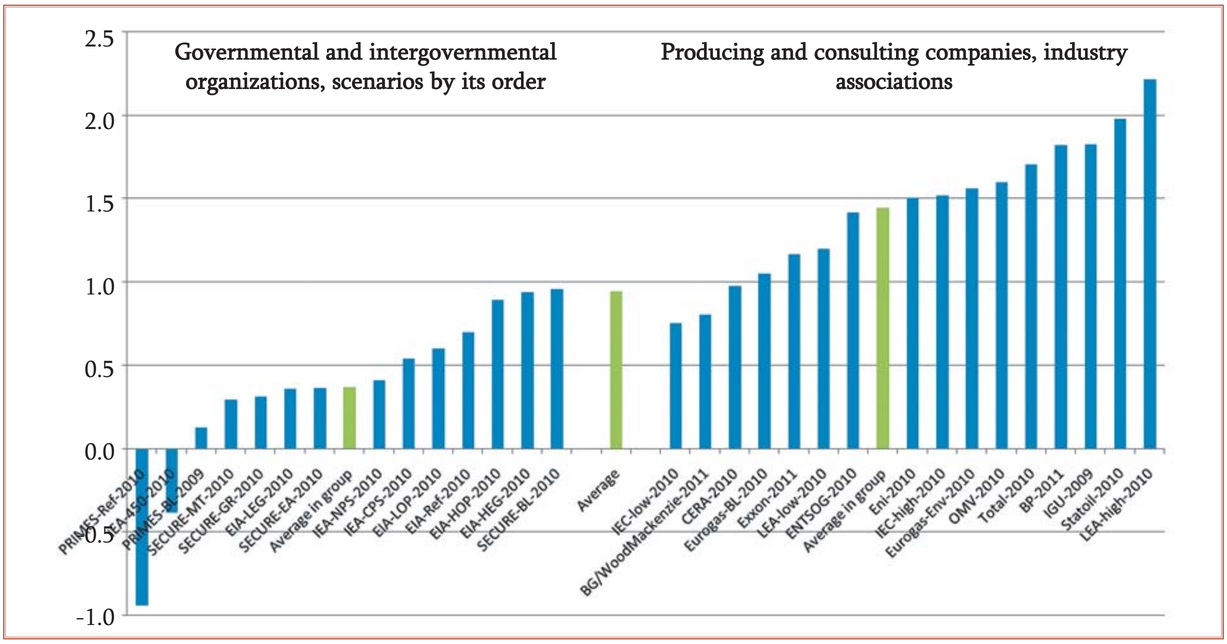

Figure 10. European gas consumption annual growth rates in 2010-2020 by different authors (2009-2011 scenarios), %

Sources:scenario authors, authors estimates

Note: Scenarios represent different regions (EU-27, Europe-OECD, EU-27 + Norway + Turkey + Switzerland), so comparison is not absolutely correct

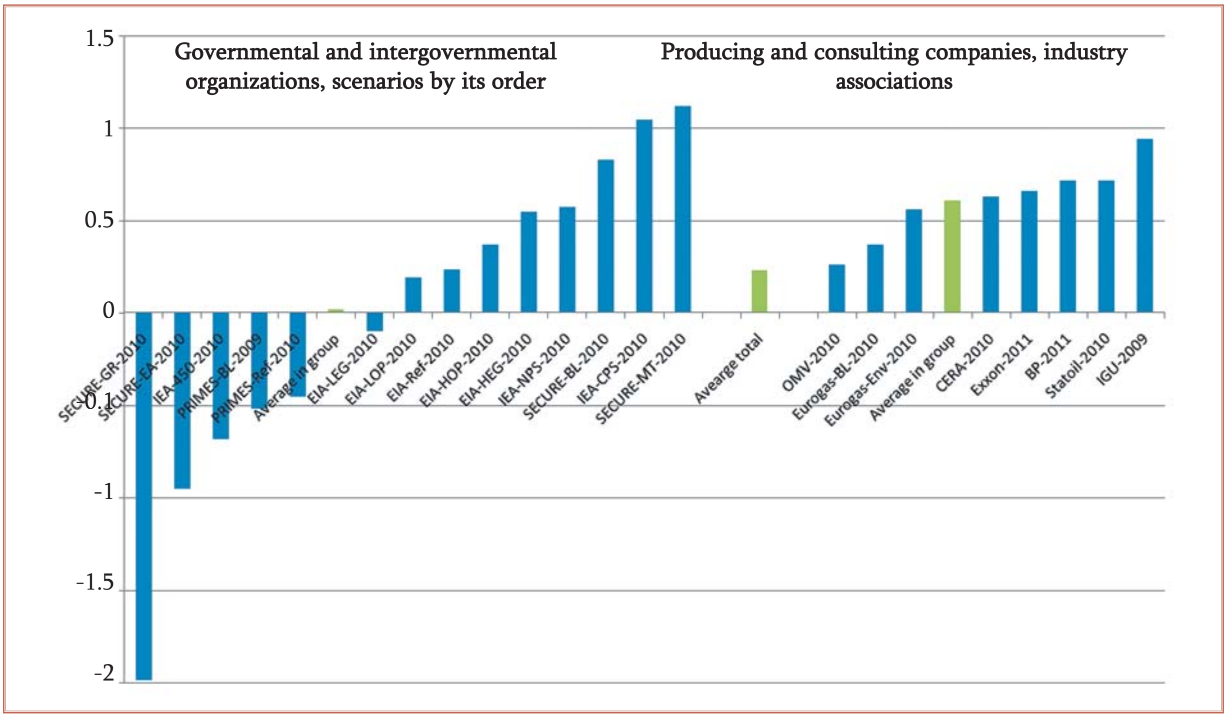

Figure 11. European gas consumption annual growth rates in 2020-2030 by different authors (2009-2011 scenarios), %

Sources:scenario authors, authors estimates

Emission of CO_2 plays a key role in the most of all modern models and scenarios. It causes importance of assumptions on CO_2 price and CCS perspectives.

Table 11. EU CO2 emissions and assumptions for ETS prices in PRIMES and WEM-2009

	PRIMES		IEA, WEO-2009	
Indicator	2007, Baseline	2008, New Energy Policy	BAU	"450"
EU ETS Price \$/tone CO_2	27.5	51.25	43	50
CO_2 emissions, mln. tones	4252.5	3232	3553	3109

Sources: International Energy Agency, World Energy Outlook 2009; Second Strategic Energy Review: an EU Energy Security and Solidarity Action Plan, November 2008
Note: ETS prices in PRIMES are in EUR; for conversion a rate of 1.25 USD/EUR was used (as assumed in the SSER report)

According to WEM-2009, CO_2 emissions in the EU will comprise 3.1 bln tones, which is 23% below the 1990 level. Thus, WEM-2009 projects an overshooting of the reduction target of 20%. At the same time ETS price, which would provide this target achievement is slightly lower than in the "New Energy Policy" scenario of PRIMES (the difference can be partly explained by exchange rate differences).

Table 12. Shifts of IEA views on coal share in energy balance and CCS perspectives

Scenario	IEA-2009-Ref	IEA-2009-450	IEA-2008-450	IEA-2007-450
Coal share in TPEC in 2030, %	29.1	18.2	16.6	n/d
CCS perspectives	After 2020, at a very small scale. 18 GW in 2020-2030	0,55% of electricity in 2020, 5,4% in 2030. 19 GW new capacities with CCS in 2008-2020, 213 GW in 2020-2030	350 GW capacities in 2030	500 GW capacities in 2030
CO_2 emission, Gt	40.2	26.4	25.7	n/d

Sources: IEA, World Energy Outlooks 2007-2009
Note: TPEC - total primary energy consumption. Gt - 10^9 ton

IEA's estimates of perspectives of CCS technology steadily decreased from 2007 report to 2009: generation capacity with CCS in 2030 in "450 scenario" decreased from 500 GW in 2007 to 350 GW on 2008 and 230 GW in 2009. It's ironic that lower estimates on CCS perspectives accompanies with higher role of coal (most of all CCS is assumed to use with coal power plants).

Shell and IGU show that relatively high use of CCS would increase future share of coal in primary energy supply. Shell is the most optimistic organization on perspectives of CCS, International Gas Union forecasts the highest share of coal (29.7% in 2030). On the other hand IEA supposes that high prices on CO_2 emission in "450 scenario" will stimulate companies to construct CCS but share of coal will dramatically decrease because only 15% of coal plants use CCS in 2030.

Table 13. Coal share in primary energy balance and CCS perspectives in the world

Scenario	IEA-2009-Ref	IEA-2009-450	Shell-2009-Blueprint	Exxon-2009	IGU-2009
Coal share in TPEC in 2030, %	29.1	18.2	26.9	20.3	29.7
CCS perspectives	After 2020, at a very small scale. 18 GW in 2020-2030	0,55% of electricity in 2020, 5,4% in 2030. 19 GW new capacities with CCS in 2008-2020, 213 GW in 2020-2030. (7% of all coal and gas capacities and 15% of all coal capacities)	20% of all coal and gas power plants equipped with CCS in 2030	CCS is not competitive without high CO_2 prices	In 2020 5% of coal plants has CCS, in 2030 - 20%
CO_2 emission, Gt	40.2	26.4	35	33	41

Sources: International Energy Agency, World Energy Outlook 2009; Shell, Energy scenarios till 2050, 2009; Exxon, Outlook for energy: a view to 2030, 2009; International Gas Union, PROGRAMME COMMITTEE B: STRATEGY, ECONOMICS AND REGULATION, 2006-2009 Triennium Work Report, 2009

Chapter 2. Methodological issues

Section 2.1. Harmonisation of analytical approaches and tools by the parties to the EU-Russia Energy Dialogue applied

Chapters 3 and 4 provide an in-depth analysis of existing materials on the models used for generating various scenarios of the EU and world energy sector development. Although there are extensive publications on the principles these models are built on, a number of their critical characteristics and mechanisms (i.e. energy price setting, elasticity factors, etc.) are unavailable and can only be assumed at the moment. A big scope of work has to be done in conjunction with the model developing for specifying these characteristics and the impact they have on the modeling results which, as it was mentioned above, raise a lot of questions.

Overall, it seems that the models under review correspond substantially to the modeling practices and methodologies typical for the 1990s and earlier elaborations. Currently, much attention is paid to the models built in the integrated language environment (e.g. TIMES models) enabling to systematize the model development and adjust process to make model descriptions more transparent for the users. Such upgrading of existing modeling tools is quite necessary.

At the meeting of the Sub-group on Energy Economics in Moscow in July 2009 Russian experts presented materials on the model systems that had been applied previously and are in use nowadays for analytical support of Russia's Energy Strategy development projection.

It should be noted that the experience and approaches of the Parties to the Energy Dialogue in applying analytical tools seem to differ considerably. This issue should be addressed more thoroughly.

In the EU, when generating concrete scenarios model developers use various economic and/or political assumptions and simulate the behavior of the market players and the EU Member States with incomplete interaction with both the Member States' researcher sand market players as well. Consolidated approach enables to perform a more integrated and "independent" analysis but simultaneously implies high confidence in the model assumptions and mechanisms applied.

Model developers in the EU also rely on various policy targets and programs (e.g. "20-20-20" initiative) which were engineered in parallel with modeling approaches adjustment.

In the Russian Federation, the Energy Strategy development is a complex process embracing interaction between ministries and departments, large companies, research centers and the expert society. Representatives from various organizations are brought together within the Inter-departmental Commission which for the sake of operating efficiency to set up energy sector working groups and to signify the basic aspects of the National Energy Strategy. Working group members often integrate their own projections and strategy scenarios (for example, development plans for companies, country regions, energy sectors, etc. inclusive.) and respective modeling accomplishments. The entire work is based on national socioeconomic development targets set in the State documents such as the Long-term Development Concept up to 2020 approved in 2008. The participants of this process are involved in adjusting energy development targets (both on a quantitative and qualitative basis) with the use of various analytical tools and based on integration of their experience and knowledge.

Modeling technique used in this process are largely aimed at determining inconsistency of various assumptions presumed and finding internal resources to coordinate individual decisions and comprehensively optimize the outcome.

Still, the basic aim of the researches is to form comprehensive and rational scenarios of regional and global energy development. Rational scenario may not be strictly to say optimal (i.e. such scenario may not comprise an extreme outcome meeting this or that economic objective). Nevertheless, under total objective uncertainty in determining a set of factors such scenario can prove to be as more adaptive and more secure within a wide range of factors to be involved in the analysis.

Moreover, "rational" scenario may be consistently structured (due to the expertise endeavors not modeling technique only) in terms of economic (energy price, new construction cost, etc.) and political (ecological, social and political tasks set, regulatory and institutional measures) factors integrations.

Amidst other features of the two approaches it should be noted that the EU's scenarios provide an in-depth description of the energy consumption sectors taking into account conventional energy consumption technique and energy conversion technologies, energy efficiency enhancement prospects and market penetration of new technologies. Issues related to energy supply, including from outside sources, seem to be analyzed far less scrupulously. The same refers to the complicated issues relating to the energy market formation and energy market reform mechanisms, including energy pricing, long-term energy supply contracts and short-term energy supply contracts profile, market competition factors, etc.

On the contrary, in the Russian Federation when developing the Energy Strategy greater attention is paid to issues related to the Russian energy resources exploitation and energy supply prospective, to the investment process, the implementation of conventional fuel and energy supply infrastructure development. The energy efficiency issues are to be addressed more properly as well. At the same time, Russia is certainly far less experienced compared to the EU in using the market-based demand analysis tools and has fewer data for analyzing consumer responses so far.

So, as it is clear from the above summary description, both the forecast development methodology and the role of modeling technique differ substantially in the EU and Russia. Historically, these processes in the EU and Russia have evolved independently with minimal cooperation. However, at present both Parties do need to enhance mutual awareness and promote deeper cooperation in the analysis of these issues due to intensification of energy trade and common investments in the energy sector and in past time - due to the considerably increased uncertainty about the energy prospects as it was shown in this study. It should be also noted that despite the publication of the fundamental materials on the energy strategies of the Parties involved, specialists and experts from the EU often express their willingness to expand information exchange.

An illustrative example of the difference in the Parties' approaches to building long- and mid-term scenarios for the energy systems development is a continuously changing forecast (on the EU's side) of the prospects for Russian gas imports to the EU. When constructing models and scenarios European study groups rely on gas production statistics and their perceptions of the technical potential for Russian gas exports over the past years (a trend is built on this basis). The wide-spread concerns of the Western countries about the insufficiency of Russia's upstream investments coupled with a negative evaluation of the recent gas transit crises effects and growing pressure with regard to a sharp reduction of GHG emissions lead to an "explosive mixture" which is detonated by the trend toward developing scenarios with increasingly less dependence on Russian supply. At the same time, both for Russia's gas industry and for domestic researchers the major basis for the gas production and gas transmission capacity development is a forecast of the gas market prospects, amidst which the European market is still a crucial one (if not in terms of gas volumes supplied, then in terms of gas sales revenues). Following the European downward gas consumption projections, it is quite natural that the Russian experts would have to adjust their own forecasts of investments and gas industry development growth rates in terms of gas production and gas exports. In the meantime, this process in Russia hasn't been so intensive as compared to the negative dynamics arising in the EU's scenarios. However, the situation might change and then one can expect that during the next revision of scenarios the European side will once again reduce the forecast of Russian gas imports for the reason of "the Russian side's inability to secure gas supply".

So, we are facing the commencement of a dangerous iterative process outbroken in the methodological and information spheres. Each Party's signals in this process may be interpreted inadequately and this may spell a serious imbalance in the energy policies and concrete investment decisions to be done.

Harmonizing the methodological approaches at least in the form of establishing internal links between the gas production & export and consumption models of both Parties is considered a paramount task.

What actions could be taken for solving the above tasks? Bearing in mind the complexity of the issue, a stage-by-stage and comprehensive approach should be maintained. There is a set of paramount actions to be taken below as follows:

Establishing a permanent community of experts of the two Parties in the energy forecasting and modeling area on the platform of the Sub-group on Energy Economics and under the auspices of the Energy Dialogue Thematic Group.

The community of experts could develop a forward-looking mid-term road map covering:

- Expansion of mutual awareness with regard to available energy forecasting approaches and methodology in order to reduce risks of incompleteness and incorrectness in energy projections results that might lead to unjustified implementation of the outcomes when strategic planning;
- Development of the uniform format for information and projection assumptions to be introduced in the modeling process exchange as well as the exchange with modeling results;
- Procedures for regular initial and prognostic information exchange with adjustment of the both Party's energy development prospects to be introduced;
- Discussion of the state of play and prospects for the development of forecasting and modeling methodology; formation of common modeling technique for the both Party's energy development outlooks, for the forecasting of global energy as well;
- Strengthening cooperation in research within the expert society of the both Parties involved, with prospects of common use of the projections of Russia's energy development (the CIS countries inclusive) when formulating strategic EU energy policy development as well as when formulating an individual EU country energy prospects to be integrated in the Russia's Energy Strategy documents preparation or other strategic documents of interest;
- Expansion of information and data exchange within the Energy Dialogue Initiative in such areas as the economics and development of perspective energy technologies, investment process development, correlations between plans and forecasts with their implementation prospective, etc.;
- Discussion of the establishment prospects for common modeling platforms of the both Parties' energy sector development potential;
- Promotion of cooperation with other forecasting and modeling centers beyond the EU and Russia.

If such efforts are considered eligible, then the form of financial support for these actions and their potential organizational reinforcement will have to be identified. It seems now that the EU and Russia are pioneers in raising the foregoing issues on a global scale and if these are dealt with proper diligence, the Parties will be capable of taking the position of world leaders in this area.

Section 2.2. Methodology of scenario comparison analysis by substantial aspects. Comparison of models and scenarios under investigation

Note that a comprehensive analysis of the models with taking into account of methodology applied, forecasting logic, set of assumptions is necessary. Special emphasis shall be given to achieving maximal understanding with respect to important question posed for the EU-Russia Energy Dialogue: "which assumptions and model mechanisms lead to certain conclusions about the perspectives of the Russian gas on European markets". In this regard, the central idea of the proposed concept is in the design of a comparative matrix consisting of scenarios and applied methods while taking model results as point of departure.

It is proposed therefore to divide the sources under study into three thematic areas: Entry (qualitative and quantitative assumptions, coefficients etc.), the Model and Exit (parameters, scenarios etc.)

Within the Entry area it is logical to pay special attention to the quantitative estimations - trends, elasticity coefficients etc. Within the Exit area - to preset trends and scenarios, first of all, to the role of natural gas in energy mix and on its dynamics, to the share of Russian (or CIS) gas in energy balance and also to the role of renewable. Comparison of the models and scenarios shall be carried out in accordance with the following scheme.

For example, if the Exits of the models are identical in their quantitative and qualitative results (trend of reducing share of natural gas in energy mix, more favorable position of the renewables etc.), it would be necessary to evaluate the Entry of the models. If input assumptions and basic model parameters are identical, then one can conclude that the description of the modeled processes in compared models is similar (even if methodological approach among models are radically different) or that the models are insignificantly sensitive against minor changes in the neighborhood of the preset values (of input parameters).

If a straight-forward comparison cannot be carried out (for example, in case of POLES, the output of which is at the same time used as the input to PRIMES model), it is possible to analyze groups of models and retrospective of their output parameters.

In order to systematize the study, during analysis and comparing on model forecasts, it is necessary to develop a complex mechanism, which would define their characteristics. The suggested set of such characteristics is listed below (5 groups):

- Model contents
- Basic assumptions
- Modeling mechanisms
- Captured production chain and energy markets
- Model results

The set of characteristics "Model contents" defines the place of the model against others and provides general definition throughout all areas. The set "Basic assumptions" lies within the Entry area, "Results" – Exit area and the "Modeling mechanisms" and "Production chain and energy markets" – within the Model area (see Figure 12).

In the first place, from the standpoint of analysis and comparison of models and forecasts, it is necessary to define parameters, which reflect the contents of the models. The following characteristics can be highlighted:

- Time horizon and resolution (periodicity)
- Geographical coverage – countries, world regions
- Capturing of the energy production/transformation chain: investments, mining, transport, distribution, consumers
- List of primary energy sources

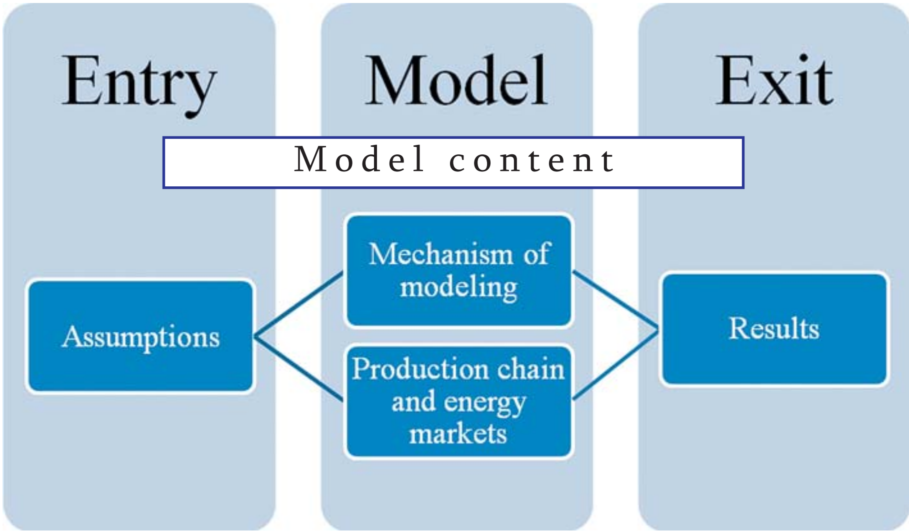

Figure 12. General scheme of analysis of energy scenarios and forecasts

After the characteristics of the first group have been identified, one can reveal the general context of the model; to define a space of results, which can be achieved with help of the model; identify the extent to which models are comparable.

Time horizon is the last date for which models can generate forecasts. Resolution/periodicity is description of time steps, into which the model horizon is partitioned.

Geographical coverage – is the characteristics describing countries and world regions, which are explicitly modeled in a scenario.

At the same time there is an essential methodological issue: almost every modeling group tends to introduce its own representation of the Europe region: for example, PRIMES analyses primarily energy system of EU-27 (in some scenarios – also of the accession countries), IEA model separately treats EU-27 and OECD-Europe (23 countries). POLES defines Europe as a 36-country region – in addition to EU-27 and other OECD-Europe countries it includes several countries of Southeast Europe. Similar "Europe" is considered in the WEM model by IEA.

In this connection comparison without additional corrections can be carried out among the results by WEM and PRIMES models, IGU and POLES models, but not among all of them. Corrections can be done on historical data, but it's difficult to apply the same to forecasts since it would imply making certain assumptions about the future development of the regions, which are not included in other models. For example, regions EU-27 and Europe in POLES differ in 9 countries, including Turkey – a large country with significant energy consumption and specific energy development path. Therefore, deviations in this case can be sensible.

While estimating the extent to which the energy production chain was captured, it is necessary to consider which process levels are modeled implicitly.

Table 14 features a brief comparison of the models against the first group of characteristics. The POLES model has the longest planning horizon. All models generate forecasts at least until 2030. Energy production chain is most described in the WEM model and least worked out in the IGU model, which also considers the least number of primary sources. In return, this model is rather particular with regard to natural gas (this can be explained by the nature of developing organization – International Gas Union).

Table 14. Comparative analysis of models and scenarios on the basis of their content

Model content	EIA (WEPS+)	MIT	PRIMES	Eurogas	Exxon	Shell	TIMES (PET)	WEM	IGU	POLES
Time horizon	Up to 2035, 5 year step	Up to 2050 (2100), 5 year step	Up to 2030, 5 year step	Up to 2030	Up to 2030	Up to 2050	Up to 2050, 1-5 year step	Up to 2030, 5 year step	Up to 2030, 5 year step	Up to 2050-2100, 10 year step
Geography	World: 8 regions	USA	EU-27	EU-27	World: 7 regions	World: 7 regions	EU-27 + IS, NO, CH	World: 24 regions	World: 7 regions	World: 47 regions
Production chain	Investments, production, export-import, consumption, CO_2 emission	Investments, production, import, consumption, CO_2 emission	Investments, production, import, consumption, CO_2 emission	Production, export-import, consumption	Investments, production, import, consumption, CO_2 emission	Investments, production, import, consumption, CO_2 emission	Investments, production, export-import, consumption, CO_2 emission, transport, storage	Investments, production, export-import, contribution, CO_2 emission	production, export-import, contribution	production, export-import, contribution, CO_2 emission
Number of primary energy sources	5 reported	7 reported	5 reported	natural gas	7 reported	7 reported	7 reported	7 reported (9 in the model)	5 reported	8 reported

Remark: a number of primary sources in the forecasts implies the number listed in the reported model results. For IEA indication of 9 primary sources analyzed is based on the OECD statistics standard. Information about 24 primary sources modeled in PRIMES refers to the model description (which, however, lacks the exact description of these sources). Investments and CO2 emissions can be also related to energy production chain. Investments proceed mining and CO2 emissions is the result of transformation.

Secondly, it is necessary to identify characteristics of the modeling process, namely:

- Applied modeling instruments: econometric, simulation, balance or gaming
- Modeling approach: top-down or bottom-up
- Input data and sources
- General structure of endogenous and exogenous indicators
- Possibility to forecast factors beyond economic demographic and regulation fields.

Bottom-up approach implies microeconomic analysis of agents behavior and of their harmonized decisions, which are often based on marginal cost estimation. Most engineering models refer to the bottom-up class. In contrast, top-down models pay more attention to macroeconomic feedbacks between and within regions and agents' decisions are stipulated from top to lower model levels.

Assessment of the input data requires data validation, for instance, by comparing historical data used in various models and scenarios. In some cases there can be deviations even within one scenario. Special emphasis shall be given to measurement units, types of resources and their calorific values. In particular, as this Study revealed, World Energy Outlook 2009 report (as well as earlier editions) figures for gas are reported in both calorific values: gross and net. Also these reports present results for lignite and other hard coal without informing the audience which exactly measurement units or parameters are used in a particular report section.

Analysis of general structure of endogenous/exogenous model parameters implies defining basic exogenous parameters and endogenous calculated modeled within the model. Here emphasis shall be on energy prices. In the context of energy modeling demographic indicators are almost always exogenous, thus they do not require specific attention.

At the same time, macroeconomic aspects, such as influence of the current economic and financial crisis or the growth perspectives with regard to basic economic sectors of the modeled region, have a strong influence on energy system development. Therefore it should be noted how these factors are included in the model - with respect to a specific scenario.

The following factors, which go beyond the economical, demographical and regulatory spheres can be highlighted: geopolitical, social and environmental. Separately the factor of energy security can be analyzed – this factor combines elements of economical and political nature (including geopolitics).

One of the most important stages of model analysis is the assessment of model/scenario assumptions. For the group of basic assumptions the following characteristics can be highlighted:

Foreseen global trends: world oil prices, natural gas market globalization due to LNG expansion, world economic and financial crisis etc. Influence of global trends on other characteristics of the model.

- Assumptions about new production and infrastructure objects and description of the existing.
- Coherence and consistency of scenario assumptions.
- Presentation of the pace and dynamics of new technology penetration, especially of the set of key technologies (e.g. CCS)
- Estimation of prices, macroeconomic, demographic and other assumptions.

Table 15. Comparative analysis of models and scenarios by the "modeling mechanism" parameter

Mechanism of modeling	EIA (WEPS+)	MIT	PRIMES	Eurogas	Exxon	Shell	TIMES (PET)	WEM (IEA)	IGU	POLES
Instruments	Econometrics, balance	Simulation, balance	Micro-economic foundation, individual optimisation of typical actors, market simulation	Balance, expert estimates	n/d	n/d	Partial equilibrium	Econometric, balance, simulation	balance	Econometric, balance, simulation
Approaches	top-down, bottom-up	top-down, bottom-up	top-down, bottom-up	top-down	top-down, bottom-up	top-down	bottom-up (основной), top-down (синергия)	top-down, bottom-up	top-down, bottom-up	top-down, bottom-up
Data	IEA, IHS	USGS, PGC, EIA, NPC, ICF, MIT	Prometheus for energy import prices and GEM-E3 for sectoral value added	Eurogas and its memebers	n/d	World Bank, UN, OECD, Oxford economics	Eurostat, IEA, EIA, UN, IIASA	OECD, UN, WB, IMF	IEA, DGTREN, EIA, expert estimates	UN, CEPII
General structure of exogenous and endogenous factors	Assumptions: international oil price, GDP growth, GDP energy intensity	Endogenous prices	International energy prices - assumption	Prices of oil, coal and CO_2 - assumptions	n/d	International prices - not assumption	International prices - assumption	International energy prices - assumption	International energy prices - assumption	International energy prices are model results (assumption of PRIMES)
Non-typical factors	Elasticity of energy consumption on GDP, energy security	Uncertainty, environment, elasticity	Environment, energy security	Contracts, ecology	Environment	Environment	E4-energy/ economy/ environment/ engineering	Environment, energy security	Energy security	Environment

Table 16. Comparative analysis of models and scenarios by assumptions

Assumptions	EIA (WEPS+)	MIT	PRIMES	Eurogas	Exxon	Shell	TIMES (PET)	WEM (IEA)	IGU	POLES
Global trends	Unconventionals	New role of gas, unconven-tionals, CO_2 emission decrease	Government energy policy (especially "20-20-20" program, renewables development)	RES and RES and nuclear, CO_2 emission reduction	unconven-tional gas, development of gas, nuclear and RES	renewables, shift to coal and biofuels	"20-20-20", renewables	Quick development of uncon-ventional gas, changes in LNG market structure, economic crisis influence	Unconven-tional gas, development of LNG market, government regulation of gas industry	Alternative energy sources, especially hydrogen. Outdated energy trends
Construction of new production and infrastructure objects	New capacities under costs	Potential analysis	Analysis of projects, endogenous power plant investments	n/d	No	No	Project analysis	Analysis of projects, investments, costs of production and transportation	Analysis of projects	No
Agreement, consistency and realism of assumptions	Set of models changes from one report to another	High CO_2 prices	PROMETHEUS modelling results in rather high gas and low coal prices. Prices on CO_2 emission endogenously determined	cconsistency and realism of assumptions	n/d	n/d	not enough data about hydrocar-bons	High prices on CO_2 emission	Assumptions are not agreed with each other. Information about assumptions is not sufficient	Data about assumptions is closed
Technologies	Partial analysis	Detailed analysis	Detailed analysis. CCS becoming available after 2020	Partial analysis	Partial analysis	Partial analysis, next generation biofuels in 2030, CCS in 2030	Detailed analysis	Detailed analysis. Rate of technology development is exogenous. CCS and advanced biofuel will be after 2020	Significant role of CCS (20% coal power plants) by 2030	Detailed analysis. Endogenous technological education
Value of price, macroeco-nomic, demographic and other assumptions	High oil price ($220/barr in 2035), old GDP growth fore-cast	No data on prices	High gas prices	postcrisis data, oil -$80-100/barr in 2030	n/d	n/d	Influence demand functions for energy services	High oil prices ($100/bbl), GDP growth assumptions take into account economic crisis	Moderate oil prices ($60-80/bbl)	GDP growth assumptions don't take into account economic crisis

The next important characteristics group refers to the modeling of the production chain and of the energy markets:

- Resource base with substantiation.
- Investments in energy sector by components, substantiation of specific and project indicators related to investments. Efficiency of investments in increasing the resource base with substantiation.
- Infrastructure restrictions, their flexibility and ways to overcome them.

- Energy markets, their organization, regulation, existing contracting practice (especially, volumes, timing and conditions of long-term-contracts).
- Structure of consuming sectors of economy – with detail by consumer groups and applied technology (equipment) type.
- Price formation (of international energy and end-user prices).
- Representation of price demand elasticity and rationale behind it.
- Factors influencing demand: subsidies and stimulation packages, taxes and other governmental initiatives.
- Environmental factors and emission abatement measures.

Results of particular models and scenarios conclude the list of groups of characteristics (Table 17):

- Primary and final energy mix.
- Final consumer prices.
- Socio-economical consequences for countries, companies and population after implementation of a particular scenario.
- Consumption and import of Russian gas

Depending on the authors and the goals of a particular study, some indicators might receive greater attention. Given that the current Study is in the context of the EU-Russia Energy dialogue, the indicator of Russian gas import in the EU has the most interest.

In general from the analyzed models one could highlight the IGU model, which is the simplest and in many aspects based on expert estimations. POLES, WEM and PRIMES models differ in many parameters. Each model has its strengths and weaknesses, which originate from the model goals and accents which were made in particular scenarios.

Analysis of scenario features allows us to classify it by dividing into three groups (Figure 13):

- Models (TIAM, PET, PRIMES, POLES, EIA and MIT modelling complex; ENTSOG, EWI/ERGEG);
- Expert estimates (Eurogas, IGU, Shell, ExxonMobil, producing and consulting companies);
- Strategies (Russian Energy Strategy till 2030 and ENTSOG in some extent).

Table 17. Comparative analysis of models and scenarios by the group "modeling of energy production chain and energy markets"

Production chain and energy markets	EIA (WEPS+)	MIT	PRIMES	Eurogas	Exxon	Shell	TIMES (PET)	WEM (IEA)	IGU	POLES
Reserves	Detailed analysis	Detailed analysis	Analysis from PROMETHEUS	n/d	n/d	n/d	Country analysis, OPEC-non-OPEC	Detailed analysis field by field	Analysis by countries and regions	Discovery and development of fields are modeled
Investments	Analysis	Analysis	Endogenous	No	Analysis	Analysis	Analysis	Detailed analysis	No	Modeling
Capacity limits	Included	Included	Flowing from detailed technology assumptions	No	No	No	Included	Analysis of capacity utilization level	Project analysis	No
Energy markets	Government regulation	Contracts are not included into model, Government regulation is in foundation of scenario analysis	Contracts are not included into model. Probably rejection of long-term contracts is proposed	No contracts	Contracts are government regulation are included	Contracts are not included, government regulation is important in Scramble scenario	No contracts	There is no exact information about inclusion of contracts into model. Government policy is analyzed	Analysis of contracts and government policy on gas markets	There is no exact information about inclusion of contracts into model. Government policy is analyzed
Composition of consumers	5 industry sectors, 5 household types, transport by fuel type	In interim report there is detailed analysis of transport and electricity	12 industry sectors (26 subsectors), 5 service sectors, 4 types of households, 4 types of transport, power plants	5 sectors	4 sectors	7 sectors	Detailed analysis	55 industry sectors, 5 household types,service sector, transport by type of fuel, power plants	Power plants, industry, households, transport and others	15 sectors of final consumption, power plants
Pricing	Iterative mechanism	Endogenous gas price	International prices for coal, oil and gas are assumptions. End-user prices are modeled	Prices of oil, coal - exogenous	n/d	n/d	Endogenous prices	International prices are defined by iterative procedure to equal demand and supply. End-user price are calculated through not clear mechanism from international prices	Oil price is assumption	Prices are modeled
Demand elasticity	Included	Elasticity of substitution	No	More sophisticated approach	No	No	Exogenous elasticity	Price elasticity of demand is not a point of a model. Income elasticity of demand is a regressor	No	No
Government policy	As assumption	Analysis	Government policy is analyzed, including subsidies	Government policy is included	Government policy is included	Government policy is included	Detailed analysis	Detailed analysis of government policy (3600 government policies). Subsidies are gradually reduced	Government policy and subsidies are analyzed	Government policy and subsidies aren't analyzed
Ecology, CO_2 emission	Emission is modeled	Emission is analysed	Emission is modeled. Detailed analysis especially for 20-20-20" program. Special module of a model	Role of gas in emission decrease	Emission is modeled	Emission is modeled	Emission is analysed	Emission is modeled. Detailed analysis especially in alternative scenario. Special module of a model	Emission is modeled	Influence of "climate strategies" is modeled

Table 18. Comparative analysis of models and scenarios by results

Results	EIA (WEPS+)	MIT	PRIMES	Eurogas	Exxon	Shell	TIMES (PET)	WEM (IEA)	IGU	POLES
Energy Balance Structure	Oil share decreases, share of RES, gas and nuclear rises, especially in high oil case	Gas share growth in long-term	Share of RES increases, fossil fuels share falls	Increasing role of gas	Growth of renewables, gas, nuclear	RES and coal share growth	RES and gas shares growth	Growth of RES share especially in 450 scenario. Small growth of gas in base scenario and decrease in alternative. Substantial growth of nuclear energy share in "450"	Increase of gas and coal shares, decrease of oil, nuclear and RES shares	Increase of RES, nuclear shares, decrease of oil and coal shares. Stability for natural gas
Values of end-user price	n/d	n/d	Determined in the model	n/d	n/d	n/d	Shadow prices	Unknown	Unknown	Unknown
Consequences of scenario realization	Not included	High CO_2 prices cause GDP decrease at 2% by 2030 and 3% by 2050	Not included	Not included	Not included	Partially included	Included	Are not taken into account	Are taken into account	Are taken into account
Import of natural gas from Russia to EU	No	In gas globalization scenario Russian share is less than in regional markets scenario	n/d	Russia is a main exporter	No	No	n/d	Increase of volumes and share in Reference scenario. Uncertainty in 450	It was taken into analysis, but forecast is not published	No

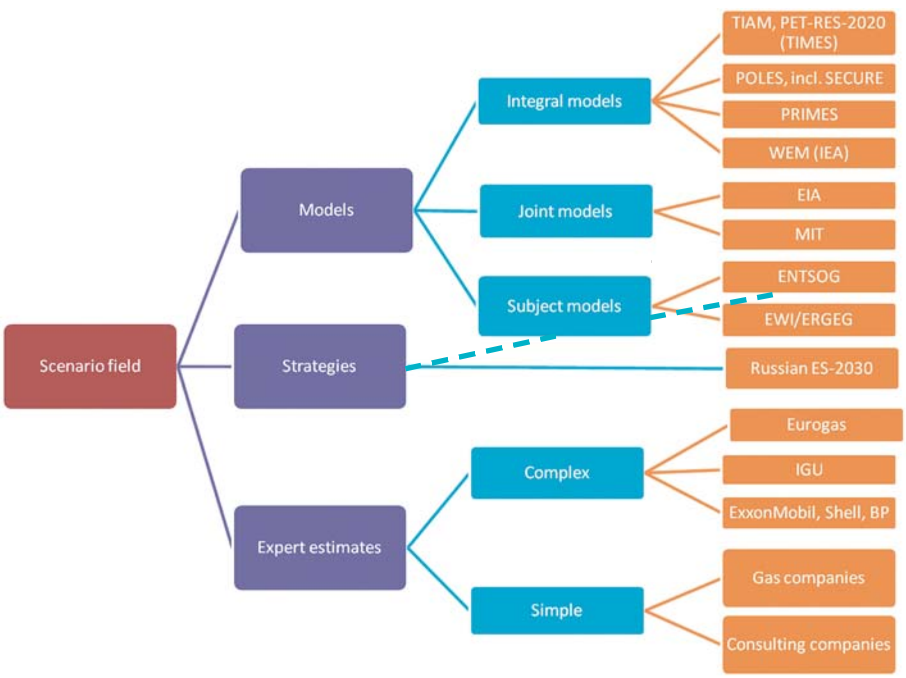

Figure 13. Scenario field

Chapter 3. European scenarios of energy development

Section 3.1. PRIMES Model Scenarios 2003-2010

The PRIMES model is considered as one of the main important tools for prediction the European energy future for the last decade. The European Commission has published "European Energy and Transport trends to 2030" based on the PRIMES model on 2003, 2007 and 2009 (the last calls "European Energy trends to 2030"), "European Energy and Transport. Scenarios on Key Drivers" on 2004. The Second Strategic Energy Review of the European Union was also created on a basis of the PRIMES scenarios. Almost all projections in the "Energy infrastructure priorities for 2020" were taken from the PRIMES scenario analysis.[6] The first documents on the EU Energy Roadmap to 2050[7] note also that scenario analysis will be based on the PRIMES model.

Thereby the PRIMES results have the strongest impact for decision making in energy by the European Union in comparison with any other scenario or forecast. It stipulates high costs of disadvantages and inaccuracies in the model for the European Union and thereafter importance of the PRIMES model analysis.

Note that official EU documents with the PRIMES scenarios contain indication that it represents only model author's views "on energy facts, figures and projections", which "have not been adopted or in any way approved by the Commission and should not be relied upon as a statement of the Commission's or the Directorate-General's views".[8]

3.1.1. General Overview of PRIMES Scenarios over 2003-2008

It should be specially mentioned that the National Technological University of Athens (NTUA) made a huge scope of high quality work. The PRIMES model is based on (these issues are in more detail in Appendix 1) the assumption that the market behavior of energy consumers, is in line with the maximization of energy consumption efficiency tasks, with due regard of legal environment (standards, equipment requirements, operating conditions of the GHG emission trading system, incentive system for renewable energy sources (RES) producers introduced) is presumed in an individual scenario. Therefore, economic assumptions play a critical role in such analysis.

It should be noted in this regard that over the past years the EU's scenario developments have showed a considerable shift from the forecasts based on the balanced growth of conventional energy sources consumption, primarily natural gas as an environmentally-friendly and efficient energy, together with RES, to a substantially corrected downwards conventional energy consumption growth rates (in some scenarios – to a decrease in its consumption even in absolute terms) and to a dramatic dominance of the RES share in energy mix, and in a number of scenarios – to predominant consumption of coal over natural gas. This trend is characteristic for the Baseline scenarios as well, where economic factors are critical for the behavior of consumers' models.

In addition to the economic factors, in the Alternative scenarios, significance is attached, as the developers of such scenarios mention, to the energy saving factors and increased utilization of RES. Such assumptions are not always explicitly substantiated by the developers' in their conclusions. In order to get a full picture, it may be recommended to the authors to more precisely indicate all possible stimulation measures to be taken, their potential impact (in scale and in monetary terms) case by case.

Let's note that the forecasts made in 2004[9] describe the Baseline scenario as a scenario whereby gas consumption in the EU-25 grows by 40% by 2030 compared to 2005 – to the level of 628.2

[6] European Commission, Energy infrastructure priorities for 2020 and beyond – A Blueprint for an integrated European energy network. COM(2010) 677 final.
[7] European Commission, Public consultation on Energy Roadmap 2050, 2010.
[8] European Commission, European Energy Trends to 2030 – update 2009.
[9] European Energy and Transport. Scenarios on Key Drivers, 2004.

mtoe (in the PRIMES-2003 projections gas consumption equals 629.8 in 2030).[10] Approximately 60% of this natural gas consumption growth (over 2005) was projected in power generation and 40% – in final consumption. At the same time, gas-fired generating capacity was projected to account for above 40% of the total capacity (some 380 GW of such capacity projected to be operational) by 2030.

In the 2004 Alternative scenario total energy consumption decreases by 10% versus the Baseline scenario, the RES share grows to 15% and gas consumption falls by 20% by 2030 versus the Baseline scenario. That is quite paradoxical, as in the third scenario – Extended Policy scenario (which presumed stimulating RES consumption growth, tightening energy efficiency standards and other measures, nuclear energy development) – gas consumption fell by only 5% versus the Baseline scenario. The authors point out in this context that the demand for gas is inelastic versus the factors under review.[11]

It's noteworthy to mention that the objective to cut by 20% GHG emissions by 2030 was achieved in scenario ETT-2030 due to high marginal costs – 130 €/t and led to an increase in energy tariffs by 1.5 times. The data presented in this scenario showed that respective measures undertaken in the marginal costs of around 40 €/t environment doesn't have substantial effect in terms of emissions reduction. The authors stated that "it seems unlikely that in the period to 2030 accelerated introduction of RES in energy mix only could ensure the attainment of the EU's goals". All these results differ from those obtained by the authors in subsequent conclusions (see details below) and these discrepancies need to be further analyzed and interpreted since they may have negative effect on the strategic decisions to be taken by the Parties to the Energy Dialogue.

According to the researchers, the main reason for the considerable changes in the conventional energy consumption outlooks in the EU, which followed after the publication of paper ETT-2030, is steep oil and gas price rise, as well as the gas supply security problems mounted since 2006. These issues are highlighted in "Hydrocarbons Outlook and Implications for Modeling and Analysis of Energy Prospects" dated autumn 2006.

The analysis undertaken by the authors hasn't revealed any serious global oil and gas resources threats. The authors point out that there are strong arguments in favour of the oil and gas price linkage to be in effect in the future. Since, according to the authors, gas consumption in the EU's residential sector is inelastic and in the industrial sector is characterized by low gas price elasticity, the main effect of higher gas prices will have strong effect in power generation as well as heat and steam production. At the same time, the new price behaviour forecasts are based on the sufficient stability of coal prices and on the assumption that the gas price will exceed the coal price by 2.7 and more times (in equal thermal units).[12] As a result, in the new Baseline scenario gas consumption in the EU decreases considerably versus the Baseline scenario of 2005 - to 587-573 bcm.[13]

A certain contradiction in such forecasts represents an assertions in "Hydrocarbons Outlook and Implications for Modeling and Analysis of Energy Prospects" that in the mid-term natural gas is to be the cheapest choice for limiting GHG emissions and maintaining the competitiveness of the EU energy sector (as far as in the Baseline scenario the economic factors are predominant, such assertion seems rather contradictory with sharp decrease of the natural gas consumption in the new scenario). At the same time, the factors of high gas prices and external gas supply vulnerability are stressed in the paper.

It should be noted that, according to the assumptions made in 2007-2008 PRIMES scenarios, gas prices will grow faster than even oil prices. In particular, in the Second Strategic Energy Review (SSER) natural gas prices in real terms grow in 2005-2020 by 33-124% while oil prices – only by 12-

[10] European Energy and Transport Trends to 2030, 2003.
[11] European Energy and Transport. Scenarios on Key Drivers, 2004.
[12] Capros P. Hydrocarbons Outlook and Implications for Modeling and Analysis of Energy Prospects, Sept.6-7, 2006.
[13] Ibid.

84% (in the moderate oil & gas prices sub-scenario or high oil & gas prices sub-scenario).[14] At the same time, according to historical price dynamics, in general, oil price grew faster than gas price. Taking into account that gas prices in Europe are generally determined by the long-term contracts prices, where there is gas price linkage to crude and its products price, forecasts with the gas price growth exceeding oil price rise should be substantiated additionally.

Table 19. Comparative characteristics of price assumptions in various documents under PRIMES

Second Strategic Energy Review		2010		2020	
$'2005/boe	2005	MOG	HOG	MOG	HOG
Oil	54.5	54.5	69.7	61.1	100.1
Gas	34.6	41.5	46.3	46	77.5
Coal	14.8	13.7	15.8	14.7	24.2
Oil/gas	1.58	1.31	1.51	1.33	1.29
Oil/coal	3.68	3.98	4.41	4.16	4.14
Gas/coal	2.34	3.03	2.93	3.13	3.20
Model-based Analysis of the 2008 EU Policy Package		2010		2020	
€ '2005/boe	2005	MOG	HOG	MOG	HOG
Oil	43.6	45.4	55.7	53	82.5
Gas	32.1	36.1	40.3	42.4	62.9
Coal	11.9	11.5	13.0	12.7	18.0
Oil/gas	1.36	1.26	1.38	1.25	1.31
Oil/coal	3.66	3.95	4.28	4.17	4.58
Gas price vs coal price	2.70	3.14	3.10	3.34	3.49
Price correlation in terms of SSER data / Model-based Analysis of the 2008 EU Policy Package data ratio		2010		2020	
	2005	MOG	HOG	MOG	HOG
Oil	1.25	1.20	1.25	1.15	1.21
Gas	1.08	1.15	1.15	1.08	1.23
Coal	1.24	1.19	1.22	1.16	1.34
Oil/gas	1.16	1.04	1.09	1.06	0.98
Oil/coal	1.01	1.01	1.03	1.00	0.90
Gas/coal	0.87	0.96	0.95	0.94	0.92

Sources: Second Strategic Energy Review: an EU Energy Security and Solidarity Action Plan, November 2008, Capros P., Mantzos L., Papandreou V., Model-based Analysis of the 2008 EU Policy Package on Climate Change and Renewables, June 2008.
Note: MOG - sub-scenario with moderate oil & gas prices, HOG - sub-scenario with high oil & gas prices

In the 2009 World Energy Outlook published by the International Energy Agency assumption of 100 USD/b oil price in 2020 presume European gas imported price by 15% lower than in the PRIMES scenario.

In addition, it is not clear why in various documents with adequate price assumptions in the Baseline scenario the developers obtain common results. In particular, as shown in Table 19 above, the price assumptions differ in the Second Strategic Energy Review and in the Model-based Analysis

[14] Second Strategic Energy Review: an EU Energy Security and Solidarity Action Plan, November 2008.

of the 2008 EU Policy Package on Climate Change and Renewables. In the first document the oil to gas price ratio in 2005 equals 1.58 and in the second document – 1.36 (a 16% difference). Moreover, by the time both documents had been published, the actual data for 2005 was in place already and couldn't diverge. The gas to coal price ratio by 2020 differs by 6-8% in the two documents. At the same time, the outcomes of the Baseline scenarios in both documents (energy consumption, production, imports, etc.) are similar. Regretfully, no indications have been found related to any changes in the methodology or the adjustment of any other assumptions undertaken in the period between June and November 2008. The origination of initial data discrepancy for 2005 is unclear either.

The Baseline scenario published by the authors in late 2007 is presented in detail in "European Energy and Transport Trends to 2030 – update 2007". The major indicators implied in the Baseline scenario are the economics of consumer uses of various fuels, energy appliances and energy technologies introduced. From this standpoint it is critical that based on the oil price growth factors shown during the paper ETT-2030 update 2007 preparation, the authors made the long-term conclusions that gas would be relatively expensive energy resource and lose its competitiveness. The external factors for such a conclusion was based on the projected long-term relationship between gas and coal prices (per toe) set at the 3.2 level (while, in the 1990s this price correlation ratio stood at around 1.5 and reached the 2.3 level only by 2005).[15]

These conclusions were presented by the developers in late 2007. It should be stressed that during that period and subsequently oil price growth has driven coal prices globally, and coal price started rapid growth. So, the authors' hypothesis about the "breakaway" of rapidly growing oil prices from "stable" coal prices hasn't been confirmed by the reality.

The authors have also developed and presented a considerable number of Alternative scenarios. The Alternative development scenarios for the European energy sector[16] have been generated analyzing the effects of various mechanisms for the tasks set by the European Commission ("20-20-20" implementation) as well as for describing conditions making the "20-20-20" targets actual.

In contrast to the Baseline scenarios based on global energy consumption optimization, the Alternative scenarios are based on finding a local optimum taking into account the introduction of measures leading to GHG emissions decrease (by 20% less than the 1990 level), the RES share in energy mix growth (to 20% in energy mix) as well as the biofuel share in liquid fuel consumption by the transport sector growth (to 10% in energy mix).

The most important considerations in relation to the conclusions made by the authors when modelling the Alternative scenarios are listed below:

- A drastic decrease in the conventional energy demand in these scenarios versus the Baseline scenarios is achieved provide for the GHG emission price set at up to 41 €/t. Previously, the authors pointed out that these price level is not enough to substantially reduce emissions. It is not always clear in the document whether additional mechanisms of the Guarantees of Origin (GO) are in place, and if the GOs are in place, one cannot find indication on their role in achieving the goals set. In particular, it is not obvious that wide RES technologies introduction in one EU country will be as efficient in another EU country. One cannot come to a conclusion that GOs practices implementation will result in a respective energy bill decrease in the EU countries.
- There is uncertainty about the scale of subsidies, primarily needed to provide RES development. These are needed for the various market players in order to reach energy supply stability, in these scenarios presumably high.

[15] European Energy and Transport Trends to 2030 – update 2007.
[16] Second Strategic Energy Review: an EU Energy Security and Solidarity Action Plan, November 2008. Capros P., Mantzos L., Papandreou V., Model-based Analysis of the 2008 EU Policy Package on Climate Change and Renewables, June 2008. Capros P., Overview of Energy Economic Analysis for the EC, 2009.

The difficulty of analyzing all the documents lies in actually absence of complete information on data and the assumptions used in a concrete scenario formulation. As a rule, Baseline scenarios are described in more detail, though they also imply a number of uncertainties.

The macroeconomic and demographic model assumptions are less questionable. Still, for example, in the Capros, Mantzos (2008) there are no data presented on the concrete economic growth or population growth parameters used in the model. It is also has to be clarified how the economic structure changes scenario by scenario.

None of the scenarios under review provides a full list of the state policy measures assumed. There are general indications only ("measures adopted in the EU before a certain date" or "all measures projected to be on stage to attain the 20-20-20 goals"). Such information leaves much room for suggestions on whether a concrete measure is included in a scenario or not.

As mentioned above, there is inconsistency in the energy price assumptions used in the model. In various model scenarios there are suggestions about substantial changes in energy price relationships, which is not supplied by certain explanations. Furthermore, energy prices may differ in the same scenario published in various documents.

Taking the model outcomes one can presume that there is a number of implicit assumptions that are not described in any of the documents. In particular, the fact that the volumes of the long-term for gas supply to Europe covenants existing exceed the import volumes projected in accordance with the New Energy Policy (NEP) scenario. It means that the model results simply are based with no regard to the long-term contracts for gas supply to Europe existing. That is to say, there is an inexplicit supposition of the cancellation of many long-term contracts signed, which seems highly improbable even in the long-term perspective. That is why all that raises questions on the adequacy of the model results.

The discrepancy between resulting parameters of the EU's energy demand projections, fuel by fuel, and the demand for fuel imports is rather high in all of the scenarios under review.
Even the results of the Baseline scenarios differ quite substantially. For example, global gas consumption by 2020 in the Baseline scenario prepared in 2007 versus the Baseline scenarios prepared in 2003 and 2005 decreases by 19% (by 115 mtoe) and consumption of RES and coal is more by 25 and 31% respectively.

The difference in energy consumption projections for 2020 in the scenarios published in 2007 and in 2008 reaches 58% (for coal consumption in the 2007 Baseline scenario and NEP scenario with moderate energy prices). For the 2020 natural gas consumption projections the maximum discrepancy amounts to 46%, for RES – to 33%.

In the 2007-2008 Alternative scenarios the difference in the coal and natural gas consumption is 32 % and 37% respectively. At the same time, even in scenarios with the adequate assumptions integrated (SOs trade introduction, but in the absence of CDM, the 20-20-20 targets policy in place, similar energy prices) – NEP[17] and the NSAT[18] scenario – the demand for natural gas differs by almost 7%).

Comparison of the Energy Strategy parameters, PRIMES scenarios as well as the IEA and Eurogas forecasts are presented in Tables 20 and 21 (for 2030 and 2020 respectively). These tables show a difference between scenarios results which existed at the middle of 2009.

Natural gas imports to the EU-27 (by 2020) in the 2007 Baseline scenario is less versus the 2005 scenario by 15.6% (by 72 mtoe). In the NEP Alternative scenario with high hydrocarbon prices gas imports are less even by 37.2% (by 145 mtoe).

[17] Second Strategic Energy Review: an EU Energy Security and Solidarity Action Plan, November 2008.
[18] Capros P., Mantzos L., Papandreou V., Model-based Analysis of the 2008 EU Policy Package on Climate Change and Renewables, June 2008.

Regretfully, gas imports to the EU on a country by country basis are not given in any of the Alternative scenarios presented. However, the natural gas source structure in the EU by 2030 is described in Capros (2009). With assumption that the Russia's gas share in total imports of gas under all scenarios will be consistent with this work (share accounts for 27% by 2030), the volumes of gas imports from Russia to the EU according to the PRIMES may be comparable with that of in The Russia's Energy Strategy by 2030 published. Another benchmark for comparisons is the calculation based on the assumption that the share of Russia's gas in total gas imports to Europe will remain at the pre-economic crisis level – some 45% on average.

In the lack of data on gas imports by 2030 in the NEP scenario, analysis of the NEP scenario can be only for 2020. Gas imports to the EU-27 according to the NEP will be at 245 to 291 mtoe due to different energy prices. Provide for the Russia's gas share set at 27%,[19] gas imports from Russia to the EU-27 will be at 66-79 mtoe, which is twice as less as stated in the Russia's Energy Strategy by 2030 (150-154 mtoe). Even with a 45% share of Russian gas imports from Russia to the EU will account for 98-116 mtoe, which is by 13-27% less than the Energy Strategy target.

These major parameters seem contradictory and stand far from the reality taking into account the long-term contracts signed, intentions of the parties to extend some of them pending prolongation, etc. Nevertheless, these are the conclusions arising from the scenarios presented by the EU analysts. So, it is clear that some cooperative work has to be done so as to reduce the degree of uncertainty in the relationships between Russia and the EU in the gas sector, within the frames of the Energy Dialogue inclusive.

It should be noted that with a 27% share of Russia in the European gas imports any scenario (even the Baseline scenario for 2005) shows a smaller value of gas imports from Russia by 2030 as compared to the Russia's Energy Strategy by 2030. Under the most pessimistic scenarios (for example, CES-HOG – energy efficiency scenario with high oil & gas prices) gas imports from Russia is projected by 2.5 times less than that in the forecast placed in the Russia's Energy Strategy by 2030.[20]

With a more reasonable assumption about Russia's share in gas imports to Europe at a roughly stable level of 45%, the Baseline scenarios enable to implement the projections of the Energy Strategy until 2030 on gas exports in the westward direction. In a number of Alternative scenarios (RSAT, NSAT) the values of gas imports from Russia are close to those indicated in the Energy Strategy (by 5 and 7% less respectively). However in the most radical scenarios (for example, CES-HOG) imports from Russia even with a 45% share are less by one-third versus the Energy Strategy until 2030.

It should be emphasized that the forecasts of natural gas imports to the EU according to the 2008-2009 PRIMES scenarios cardinally differ not only from Russia's projections under the Russia's Energy Strategy and the forecasts published by the International Energy Agency and Eurogas, but from the PRIMES scenarios published earlier as well. In conclusion, provide for the Russia's current share in gas imports to the EU to be projected for the future, the targets set in the Russia's Energy Strategy by 2030 will be more in line with the Baseline scenarios of PRIMES and the forecasts published by the IEA and Eurogas.

[19] Capros P., Overview of Energy Economic Analysis for the EC, 2009.
[20] With assumption of the Russia's gas share in overall European gas imports at 27%.

Table 20. Gas consumption and imports in the EU-27 by 2030 according to various scenarios, mtoe

Scenarios	PRIMES scenarios					IEA	Eurogas	
	BL 2005	BL 2007	RSAT	NSAT	CES-HOG	WEO 2008	Brussels 2009	ES 2030
Consumption	653.54	516.2	421.6	412.4	325.3	559	625	–
Imports	527	431	339	331	244	477.7	462.5	–
Imports from Russia (27% share)	142.3	116.5	91.5	89.4	65.9	129.0	124.9	160
Imports from Russia (45% share)	237.15	193.95	152.55	148.95	109.8	215.0	208.1	160

Sources: Capros P., Mantzos L., Papandreou V., Model-based Analysis of the 2008 EU Policy Package on Climate Change and Renewables, June 2008 Capros P., Overview of Energy Economic Analysis for the EC, 2009, European Energy and Transport Trends to 2030, 2003, Russian Energy Strategy until 2030, Eurogas, EU-Russia Energy Dialogue, 2009, IEA, World Energy Outlook 2008.
Note: a 27% share is taken from the presentation by Prof. Capros in May 2009 in Brussels. A 45% share is consistent with the historical trends of Russian gas supply to the EU.

Table 21. Gas consumption and imports in the EU-27 by 2020 according to various scenarios, mtoe

Scenarios	PRIMES scenarios							IEA	Eurogas	
	BL 2005	BL 2007	RSAT	NSAT	CES-HOG	NEP	NEP-HOG	WEO 2008	Brussels 2009	ES 2030
Consumption	620.2	505	438	427.9	362.5	399	345	517	578	–
Imports	461.9	390	328.6	318.8	260.9	291	245	393.9	393.04	–
Imports from Russia (27% share)	124.7	105.3	88.7	86.1	70.4	78.6	66.2	106.4	106.1	150-154
Imports from Russia (45% share)	207.9	175.5	147.9	143.5	117.4	116	98	177.3	176.9	150-154

Sources: Capros P., Mantzos L., Papandreou V., Model-based Analysis of the 2008 EU Policy Package on Climate Change and Renewables, June 2008 Capros P., Overview of Energy Economic Analysis for the EC, 2009, European Energy and Transport Trends to 2030, 2003, Russian Energy Strategy by 2030, Eurogas, EU-Russia Energy Dialogue, 2009, IEA, World Energy Outlook 2008.

3.1.2. The Comparison of Various Baseline and Alternative Scenarios 2003-2008

This analysis shows all the Baseline and Alternative scenarios published in the papers with the PRIMES model implemented. Alternative scenarios were presented for various periods and with a range of assumptions. Some of them were elaborated to prove the "20-20-20" goal reality, some was specified for finding optimal governmental policy direction to promote these goals. Early Alternative scenarios show what might happen in the European energy scene in case of external changes that are beyond the EU control (oil prices, economic growth).

Due to a wide scope of materials on the matter published, there are only general trends and highlights of such scenarios characterized below.

Baseline scenarios of 2003 through 2007 are prepared under essentially different economic conditions meaning energy price rise: in a later scenario the oil price by 2020 is 2.57 times higher, the gas price is 2.23 times higher, and the coal price – 2.1 times higher than in earlier publication. With due regard to the fact that both scenarios do not provide an exact list of governmental policy measures taken as basic assumption, it is quite difficult to evaluate to what extent government policy has changed. We may only expect that certain governmental decisions if made in the respective years were taken into account in the 2003 scenario or 2007 scenario.

Assumptions introduced in the Alternative scenarios published in SSER (NEP and NEP-HOG) and in (Capros, Mantzos, 2008) may have some differences as follows below:

- Prices for energy (described below);

- Government policy and measures taken as assumption;
- Macroeconomic and demographic assumptions;
- Implementation of the JI/CDM mechanisms and Guarantees of Origin (GO).

For both Alternative scenario groups (2003 and 2007), the exact state policy measures undertaken as assumptions are not specified, which makes direct comparison of these difficult. All the Alternative scenarios presume the "20-20-20" goals to be achieved. Meanwhile, it was specified that goals of individual countries will be put into calculations, but in the SSER publication it was not mentioned.[21]

Table 22. Comparison of assumptions in various scenarios of the PRIMES model introduced (for the EU-27)

Assumptions	BL 2003	BL 2007	BL 2008-HOG	NEP	NEP-HOG	RSAT
Government policy	Policy adopted as of late 2001	Policy adopted as of late 2006	Policy adopted as of late 2006	New policy – for 20-20-20	New policy – for 20-20-20	Policy aimed at achieving countries' goals**
Oil price by 2020, $/boe	23.8	61.1	100.1	61.1	100.1	66*
Gas price by 2020, $/boe	20.6	46	77.5	46	77.5	53*
GDP growth rates in 2000-2020, %	2.45	2.3	2.3	2.3	2.3	n/a
Population growth in 2000-2020, %	0.10	0.2	0.2	0.2	0.2	n/a
GO trading between countries	No	No	No	Yes	Yes	No
JI/CDM mechanism	No	No	No	No	No	No
Model peculiarities	–	–	-	RES and Carbon Value, marginal costs of energy efficiency are introduced	RES and Carbon Value, marginal costs of energy efficiency are introduced	RES and Carbon Value are introduced
Assumptions	RSAT-CDM	NSAT	NSAT-CDM	CES	CES-CDM	CES-HOG
Government policy	Policy aimed at achieving countries' goals**	Policy aimed at achieving countries' goals**	Policy aimed at achieving countries' goals**	Policy aimed at achieving countries' goals**	Policy aimed at achieving countries' goals**	Policy aimed at achieving countries' goals**
Oil price by 2020, $/boe	66*	66*	66*	66*	66*	103*
Gas price by 2020, $/boe	53*	53*	53*	53*	53*	79*
GDP growth rates in 2000-2020, %	n/a	n/a	n/a	n/a	n/a	n/a
Population growth in 2000-2020, %	n/a	n/a	n/a	n/a	n/a	n/a
GO trading between countries	No	Yes	Yes	No	No	No
JI/CDM mechanism	Yes	No	Yes	No	Yes	No
Model peculiarities	RES and Carbon Value are introduced	RES and Carbon Value are introduced	RES and Carbon Value are introduced	RES and Carbon Value are introduced	RES and Carbon Value are introduced	RES and Carbon Value are introduced

Sources: : Second Strategic Energy Review: an EU Energy Security and Solidarity Action Plan, November 2008; Capros P., Mantzos L., Papandreou V., Model-based Analysis of the 2008 EU Policy Package on Climate Change and Renewables, June 2008.
Note:*calculated at €= 1.25 $ (at exchange rate).
** each EU Member State is assumed to pursue the policy aimed at achieving its individual goals in relation to GHG emissions reduction and to the share of RES in ultimate energy consumption mix. BL - Baseline scenario (2005/2007 - year of publication of respective scenario), HOG - high oil and gas prices. The NEP and the NEP-HOG scenarios are taken from the work [4], other Alternative scenarios – from the work [5].

[21] Capros P., Mantzos L., Papandreou V., Model-based Analysis of the 2008 EU Policy Package on Climate Change and Renewables, June 2008.

It should be noted that the most adequate assumptions introduced in the scenarios described in SSER and ETT-2030 update 2007, are observed in the NEP and NSAT scenarios. These scenarios do not explore the CDM mechanisms, but allow for universal GO trading system, with marginal costs of energy efficiency varying within the margin of 10%.

Table 23. Key indicators implied for achieving the "20-20-20" goals by 2020

Indicators	BL 2007	NEP	RSAT	RSAT-CDM	NSAT	NSAT-CDM	CES	CES-CDM
Carbon value for ETS, €/t CO_2	22	41	47	30	42.7	30	39.2	30
Carbon value for non ETS, €/t CO_2	–	–	35.2	20.9	37.2	22.2	39.2	30
RES value – energy supply, €/toe	–	474	576.9	616.5	517.6	575.8	521.1	560.7
RES value – energy demand, €/toe	–	474	580.4	607.2	517.6	575.8	521.1	560.7
RES value – biofuel, €/toe	–	474	808.4	964.3	517.6	575.8	521.1	560.7
Efficiency value for non ETS, €/toe	–	220	–	–	–	–	–	–

Sources: Second Strategic Energy Review: an EU Energy Security and Solidarity Action Plan, November 2008; Capros P., Mantzos L., Papandreou V., Model-based Analysis of the 2008 EU Policy Package on Climate Change and Renewables, June 2008.

Data in Table 23 shows that once GO trading is launched, marginal costs of the increased biofuel consumption become equal to the marginal costs for building up the RES consumption, since the differences between these parameters are available in the RSAT and RSAT-CDM scenarios only, which do not imply the assumptions for Guarantees of origin trading introduction. It is still unknown own where there is real mechanism underlying such significant discrepancies in biofuel marginal costs: in the RSAT scenarios they are some one-third higher than in the RES scenario generally.

Primary Energy Resources Consumption Pattern for the EU under various scenarios 2005-2008

The energy resource patterns are compared in Tables 24 and 25 below.

Baseline scenarios were revised in 2004 and 2007. BL 2003 and BL 2004 and in every position of the primary energy consumption pattern these differ by more than 1%. At the same time the BL 2007 version is essentially far from previous versions. In the total primary energy consumption mix, oil and nuclear energy consumption percentage varies within margin of 0.7%. Simultaneously, gas consumption by 2020 in BL 2007 projections is 19% lower (by some 115 mtoe) than in the BL 2004 version. This was compensated with a rise in the RES (by 25%) and coal (by 31%) consumption projections. Thus, coal consumption increase in absolute terms is twice higher than that of RES (80 mtoe versus 40 mtoe).

It should be noted that the NEP and NSAT scenarios, with practically similar assumptions introduced, differ significantly in the outcomes. In particular, the aggregate demand for energy in the NEP is 3.4% lower than in NSAT projections. Demand for natural gas in NEP scenario is 6.8% (29 mtoe) lower than in the NSAT scenario. At the same time coal consumption in both versions differs only by 0.3%. Meanwhile, gas price in the NSAT is higher than in the NEP scenario.

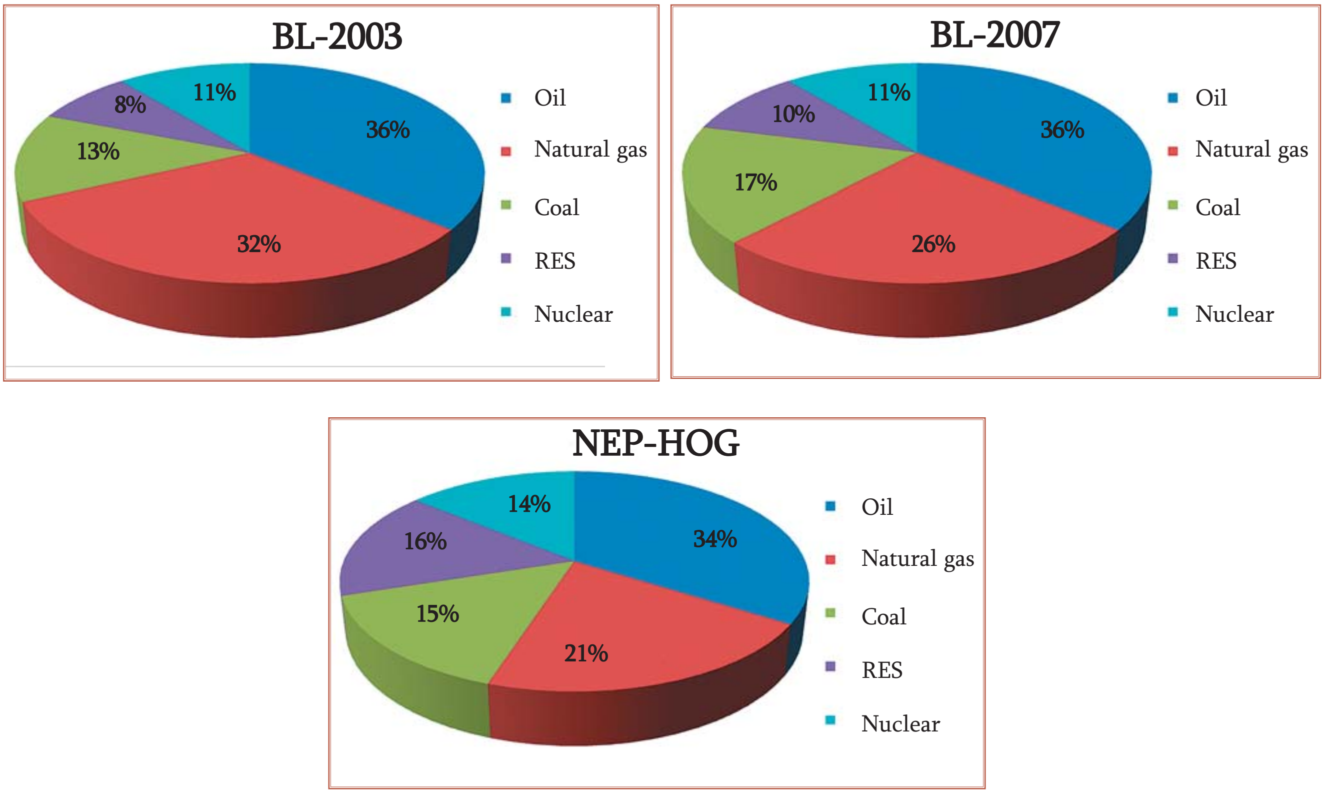

Figure 14. Comparison of 2020 for primary energy consumption patterns in the BL 2003, BL 2007 and NEP-HOG scenarios

Sources: European Energy and Transport Trends to 2030, 2003; European Energy and Transport Trends to 2030 - update 2007; Second Strategic Energy Review: an EU Energy Security and Solidarity Action Plan, November 2008

It should be noted that the NEP and NSAT scenarios, with practically similar assumptions introduced, differ significantly in the outcomes. In particular, the aggregate demand for energy in the NEP is 3.4% lower than in NSAT projections. Demand for natural gas in NEP scenario is 6.8% (29 mtoe) lower than in the NSAT scenario. At the same time coal consumption in both versions differs only by 0.3%. Meanwhile, gas price in the NSAT is higher than in the NEP scenario.

The major reason in the origin of such discrepancy may lie the two Alternative scenarios due to different political measures to be taken as assumed, which is not revealed in any of these documents published. So, the Second Strategic Review was elaborated with such package of political measures (unavailable to the public) as assumed, which help significantly reduce gas consumption with no influence on coal demand projections (when compared with the same forecast of June 2008).

Table 24. Primary energy consumption in EU-27 by 2020 under the Baseline and Alternative scenarios published from 2004 to 2009, mtoe

Balance item	2005 actual	BL 2004	BL 2007	BL 2008 HOG	NEP	NEP-HOG	RSAT	RSAT-CDM	NSAT	NSAT-CDM	CES	CES-CDM	CES-HOG
Primary energy demand	1811	1957.87	1967	1901.5	1711	1672	1771.3	1844.6	1770.9	1840.3	1777.1	1819.1	1759.6
Oil	666	699.26	702	648.1	608	567	617.3	633.3	623.5	642.4	625.4	635.7	588.9
Gas	445	620.19	505	442.5	399	345	438	433.3	427.9	430	420.9	422.7	362.5
Coal	320	261.78	342	340.4	216	253	215.3	267.7	216.7	257.1	228.3	253.8	285.1
RES	123	157.08	197	221.3	270	274	281.9	293.3	284.2	293.8	283.6	289.5	276.3
Nuclear energy	257	219.56	221	249.2	218	233	218.8	217	218.6	217	218.9	217.4	246.8
Share in the balance	100	100	100	100	100	100	100	100	100	100	100	100	100
Oil	36.78	35.72	35.69	34.08	35.53	33.91	34.85	34.33	35.21	34.91	35.19	34.95	33.47
Gas	24.57	31.68	25.67	23.27	23.32	20.63	24.73	23.49	24.16	23.37	23.68	23.24	20.60
Coal	17.67	13.37	17.39	17.90	12.62	15.13	12.15	14.51	12.24	13.97	12.85	13.95	16.20
RES	6.79	8.02	10.02	11.64	15.78	16.39	15.91	15.90	16.05	15.96	15.96	15.91	15.70
Nuclear energy	14.19	11.21	11.24	13.11	12.74	13.94	12.35	11.76	12.34	11.79	12.32	11.95	14.03

Sources: Second Strategic Energy Review: an EU Energy Security and Solidarity Action Plan, November 2008; Capros P., Mantzos L., Papandreou V., Model-based Analysis of the 2008 EU Policy Package on Climate Change and Renewables, June 2008.

Table 25. Primary energy consumption by 2030 in EU-27 under Baseline and Alternative scenarios published from 2004 to 2009, mtoe

Balance item	2005 actual	BL 2004	BL 2007	BL 2007 HOG	NEP	NEP-HOG	RSAT	RSAT-CDM	NSAT	NSAT-CDM	CES	CES-HOG
Primary energy demand	1811	2035.22	2003.7	1927.5	1652.2	1809.9	1865	1799.7	1857.2	1790	1835.6	1781.3
Oil	666	710.27	708.2	626.7	582.8	601.5	619.7	603.5	622.5	599.3	613.8	558.7
Gas	445	653.54	516.2	416.8	369.1	423	421.6	413.4	412.4	403	404.9	325.3
Coal	320	306.2	335.6	328.5	181.2	218.4	259.5	210.4	244.6	216.3	242.6	261.6
RES	123	175.77	237.3	275.3	346.5	355	369.3	365.8	377.1	363.4	371.6	350.4
Nuclear energy	257	189.44	206.4	280.2	172.6	212	194.9	206.6	200.6	208	202.7	285.3
Share in the balance	100	100	100	100	100	100	100	100	100	100	100	100
Oil	36.78	34.90	35.34	32.51	35.28	33.23	33.23	33.53	33.52	33.48	33.44	31.36
Gas	24.57	32.11	25.76	21.62	22.34	23.37	22.61	22.97	22.21	22.51	22.06	18.26
Coal	17.67	15.05	16.75	17.04	10.97	12.07	13.91	11.69	13.17	12.08	13.22	14.69
RES	6.79	8.64	11.84	14.28	20.97	19.61	19.80	20.33	20.30	20.30	20.24	19.67
Nuclear energy	14.19	9.31	10.30	14.54	10.44	11.71	10.45	11.48	10.80	11.62	11.04	16.02

Sources: Second Strategic Energy Review: an EU Energy Security and Solidarity Action Plan, November 2008; Capros P., Mantzos L., Papandreou V., Model-based Analysis of the 2008 EU Policy Package on Climate Change and Renewables, June 2008.

3.1.3. New PRIMES-2009 and 2010 Scenarios

The developers at the National Technical University of Athens, who conduct the modelling work for the Commission services, presented three scenarios using the PRIMES model. These are as follows: the *Baseline* Scenario, the *Reference* Scenario and the *No Policy* Scenario (the latter scenario not having been defined with the involvement of the Energy Directorate General of the European Commission). As in the case of the other scenarios, the *No Policy Scenario* (assuming the absence of the EU state policy measures in the energy sphere) is not used for forecasting, but for estimating the impact of political measures.

In the year 2009, a new Baseline scenario using the PRIMES models was produced. The first results produced by this scenario were presented at the February 2010 meeting of the Thematic Group on Scenarios and Forecasts of the EU-Russia Energy Dialogue in Moscow and at the April 2010 meeting of the Sub-Group on Energy Economy in Paris. The Baseline-2009 scenario shows the EU energy system development under current trends and policies which were implemented until April 2009.

The Reference-2010 scenario is a "benchmark for policy scenarios" which assumes achievement of the national targets under the Renewables and GHG directives. So that the PRIMES-Reference scenario assumes that "20-20-20" program would be achieved.

The European Commission notes that the PRIMES projections have been established by independent consultants for the European Commission services, who might use the insights gained through this modelling and scenario for their subsequent energy and environment policy analyses. The European Commission shares the results of the modelling and the description of scenario with stakeholders in order to help enlightening the policy debate. Meanwhile the report on "Energy Trends to 2030 update 2009" has been published on 14 September 2010.[22]

It is worth noting that Eurelectric, the association of European electricity companies, has also commissioned scenarios with the National Technical University using the PRIMES model.[23] These scenarios differ from the projections established for the European Commission services and are subject to a separate analysis.

It should be noted that the projections were consulted with experts from all Member States governments in August 2009 and that, taking account of Member States comments, the model was rerun over the following months. The figures for all energy sources, sectors and Member States up to 2030 do not represent forecasts of what will happen or should happen, but take stock of energy developments under the assumption that there will be no additional policies implemented in the Member States (after April 2009). The Reference scenario assumes that the legally binding targets for 20% renewables and 20% greenhouse gas reduction in 2020 will be achieved without specifying how exactly Member States will reach their respective targets. The cut-off point for implemented policies to be considered in the Reference case was the end of 2009.

The new PRIMES scenarios are being extended to 2050, but projections so far are only available up to 2030. In the recent post crisis modelling with PRIMES, the period through to 2030 is divided into three stages: the recession stage (from 2008 to 2012), the recovery stage (from 2013 to 2022), and the growth stage (after 2022). It should be noted that this approach is rather close to that used in the Russian Energy Strategy to 2030; in the latter case, the forecast indicators are given for the periods through to 2013-2015, 2015-2020 and 2020-2030 (such a breakdown is determined by the impact of the crisis).

GDP growth in the EU is forecast at 2% per annum in the period 2010-2030. Demographic and macro-economic assumptions are based on the DG ECFIN's Ageing 2009 report, which was established jointly with the Economic Policy Committee, i.e. with close involvement of experts from the EU Member States.

[22] The report is available via Internet from the Europa-website:
http://ec.europa.eu/energy/observatory/trends_2030/doc/trends_to_2030_update_2009.pdf
[23] Eurelectric, Power choices: pathways to carbon-neutral electricity in Europe by 2050, 2009.

Baseline-2009 Assumptions

The Baseline scenario is a scenario, which projects into the future ongoing market and policy trends; i.e. market forces drive the system within the framework of policies implemented so far including their long term effects. The main particularities of the Baseline-2009 scenario are as follows:

- All measures of EU state policy incorporated up to April 2009, including measures with respect to the "20-20-20" programme and the Third Energy Package are considered, but it is not assumed that such targets will be necessarily achieved under current policies;
- The impact of the economic crisis is taken into account.

This scenario considers the influence of the following state policy measures of EU member countries on the indicators under consideration:

- Directives and Regulations on energy efficiency, including those with respect to energy using products, buildings, heating appliances, combined heat and power and markets (e.g. labelling, energy services).
- Regulation on the characteristics of new automobiles setting strict limits on CO_2 emitted per km and stipulating penalties to be phased in (taking account of transition measures, the baseline modelling includes the following benchmarks: 2015 – 135 grams of CO_2 emissions per km; in 2020 – 115 grams per km; and in 2025 – 95 grams per km).
- Targeted support for RES, but without the obligatory attainment of a 20% share of gross final consumption by 2020 (the latter is one of the objectives of the "20-20-20" programme).
- Directives on cogeneration, and emissions from large combustion plants including large thermal power stations.
- The construction of Demonstration plants for CCS technologies.
- Rehabilitation of the nuclear energy sector in some countries (i.e. in Italy), while upholding prohibitions on constructing new nuclear power stations and phase-out of existing ones in other countries (i.e. Germany and Belgium).
- Directives on the European Emission Trading System with respect to greenhouse gas emissions.
- The Third Energy Package.

Note that "European Energy trends to 2030 update 2009" has much more detailed description of policy assumptions then in the previous reports.

The assumptions for this scenario in terms of prices are taken from the Prometheus model and are outlined in Table below.

Table 26. Price assumptions in PRIMES-2009

	Prices, euro 08/boe			Growth rates, %/year		
	2010	2020	2030	2010-2020	2020-2030	2010-2030
Oil	50.19	72.93	90.83	3.8	2.2	3.0
Gas	30.85	51.24	65.71	5.2	2.5	3.9
Coal	12.03	21.29	25.18	5.9	1.7	3.8

Sources: European Energy Trends to 2030 - update 2009

The Baseline scenario indicates that "gas prices are following prices for oil". While in fact, gas prices are actually growing somewhat faster than those for oil – by 3.9% per year in the period 2010-2030 in comparison with 3% for oil, the gap in favour of gas between oil and gas prices remains broadly constant. It is worth noting that the difference between the growth rate of oil and gas prices in the projections 2009 is less than that indicated in the PRIMES scenarios for 2007-2008. In particular, the coefficient between oil and gas prices in 2020, indicated in the forecasts for 2007-2008, varied within the range of 1.25 to 1.33, while this coefficient amounts to 1.42 in 2020 according to the Baseline scenario.

In general, coal prices are growing slightly slower than the price of gas, but faster than oil prices. The coefficient of gas and coal prices in 2020 specified in *BL-2009* is equal to 2.4, but in previous forecasts, it varied from 2.4 to 3.5. Nevertheless, it is worth noting that gas prices remain at a relatively low level in comparison with those for other hydrocarbons. At that, in the period from 2020 to 2030, the growth of coal prices should essentially slow down in comparison with those of other traditional energy resources. The recently published report on the "EU Energy Trends to 2030" highlights the importance of this gas to coal ratio by stating on page 16: "The evolution of the ratio of gas and coal prices can to a great extent influence the investment choices taken by investors in the power sector. A relatively low gas to coal price ratio up to the year 2000, together with the emergence of the gas turbine combined cycle technology, led to investments in gas fired power plants. The investments decreased afterwards due to significant gas price increases. As the gas to coal price ratio is projected to remain rather stable (around 2.5), the investment decision will highly depend on the carbon price. Any volatility in the carbon price will lead to high uncertainty for investors in the power sector."

Emerging climate policies - even under conservative Baseline conditions – are one reason for stronger global gas prices compared with global coal prices. Gas is a low carbon fuel that following environmental concerns – both on carbon and more traditional pollutants – finds its way into power generation and other uses, whereas coal encounters more difficulties. Relatively low capital costs for gas in comparison with those for coal reinforce such trends towards increasing demand for gas, which may have effects on prices in the global markets. This modelling logic was used in the PRIMES-2009 scenarios. In this case it should be noted three important facts:

- Now gas import prices in the European Union mostly depends on oil and oil products prices and in less extent on coal and electricity prices because of links in the long-term supply contracts. Current long-term gas supply contracts will provide more than 230 mtoe in 2020 and 90 mtoe in 2030. Moreover the NTUA modelling shows that even without oil-link in the long-term contacts oil and gas prices will strongly correlate with each other. It means that in mid-term or even in long-term gas import prices would not be fully defined by demand-supply balance.
- Spot import gas prices and end-user gas prices in the European Union has small relation to gas prices on other major gas markets (North America and Asia Pacific). IEA analysis shows that gas prices on the main markets would not substantially converge to each other.
- In the PRIMES-2009 scenarios EU gas demand in 2030 is less than in 2010 at 18-64 mtoe.

Thereby increase of global gas demand in comparison with global coal demand provides higher global gas prices (in PROMETHEUS), which stipulate decrease of comparative competitiveness of natural gas in the EU (in PRIMES). From the point of view of part of our experts it allows to speak about a contradiction in PRIMES modelling logic. Creating of new scenarios with different price assumptions or making a sensitivity analysis on energy prices may provide new fruitful results for the PRIMES modelling.

The prices on the ETS market indicated in this scenario are EUR 25 per tonne by 2020 and EUR 39 per tonne by 2030. It is worth noting that these indicators are higher than those specified in the Baseline scenario-2007, but lower than those given in the baseline forecast IEA-2009 (at. USD 43 and USD 54 per tonne respectively). The ETS prices in the PRIMES 2009 and 2010 modelling have been determined endogenously by considering the ETS cap and the possibilities for JI/CDM credits, on the one hand, and emission developments stemming from energy consumption and transformation patterns on the other, taking account of interdependencies, i.e. the effect of the carbon price on the level and structure of energy consumption and power plant input. In the previous 2007 exercise, ETS prices had been exogenously defined, given the still prevailing allocation of allowances by national governments at that time (the ETS Directive with an EU cap was adopted only in 2009). NTUA notes that volatility in the CO_2 price "will lead to high uncertainty for investors in the power sector".

Results of the Baseline-2009 Scenario

The stocktaking of the Baseline 2009 shows that the objectives of the 20-20-20 programme will not be attained completely by 2020, nor will this be done by 2030. Thus, the share of renewable energy sources in gross final energy consumption would amount to 14.8% in 2020 and 18.4% in 2030 (it should reach 20% in 2020). The objective of reducing greenhouse gas emissions by 20% in comparison with 1990 will be attained by 2030 (in 2020, the decrease will only amount to 8% for CO_2, but to 14 % for all greenhouse gases).

Table 27. Structure of energy sources for electricity sector in Baseline scenarios 2007 and 2009, %

	2005	2010	2020	2030
BL 2009				
Nuclear	30.5	28	24.5	25.9
Coal	30	26.9	24.9	22.2
Gas	**21.2**	**23.9**	**22.8**	**18.7**
Oil products	4.1	2	1.8	1.2
Renewables	14.3	19.2	26.0	32.1
BL 2007				
Nuclear	30.5	26.7	21.2	19.8
Coal	28	28.8	30.4	31.2
Gas	**21.2**	**24.2**	**26.2**	**24.6**
Oil products	4	2.9	2	1.6
Renewables	14.9	17.4	20.2	22.8

Sources: European Energy and Transport Trends to 2030 – update 2007, 2009

We note that the BL-2007 shows a growth in the share of gas in the electricity sector (i.e. the most prospective sector in terms of growth in demand) in the period through to 2020, and a declining share in the following 10 years. The 2009 revision of the Baseline has lower gas shares in power generation, which peak in 2020. The gas share in the year 2030 declines to 18.8%, which is even lower than the level observed in 2005. It is important to note that the share of coal should also considerably drop from 30% to 22.2% in the 2009 Baseline, while the BL-2007 indicates it would remain approximately steady. According to BL-2009, not only the role of RES increases in the energy sector (i.e. from 14.3% to 32% in 2030) but the share of nuclear energy also increases in comparison with BL-2009. In general, the share of nuclear energy drops, but this occurs more slowly than in BL-2007 (i.e. in BL-2009, it is 6 percentage points higher).

It is noteworthy that essential changes have occurred in terms of the renewable energy sources utilised. The share of biomass in RES-based power generation by the year 2030 has decreased in the BL-2009, in comparison with the projection in the BL-2007, representing a drop from 32% to 22%. At the same time, the role of wind energy in RES in 2030 should grow sharply from 34% to 48% (the volume of generated wind power should increase by 88%). Such important change in the projections undertaken for European Commission services is most probably caused by an updated understanding of the existing natural restrictions in the context of a re-evaluation of modelling parameters. The level of biomass use in previous PRIMES scenarios was criticised in the Report on the First Stage. Earlier, in the course of the discussions, EC exports promised to carry out a fundamental analysis of issues related to biomass utilisation in order to increase its justification. Apparently that analysis confirmed the existence of serious problems and restrictions, including those related to strong sustainability requirements, associated with the utilisation of this resource.

The greatest upward revision has been observed for offshore wind power stations, as power generation by these stations in 2030 should grow from 46 TWh in Baseline-2007 to 276 TWh in the most recent one, i.e. by exactly six times; however, in comparison with 2010, this represents a 20-fold increase in offshore wind power generation. It should be recognised that wind energy also has its natural limitations. Besides, a growth in the share of wind energy means an increase in the share of reserve generating capacities, in which gas power stations are the most effective. Consequently, the total installed capacity of gas power stations, according to this scenario, will permanently grow (i.e. from 167 GW in 2005 to 269 GW in 2030); however, their level of utilisation will decrease.

In terms of the utilisation of CCS technology, this scenario produces the following result: in the year 2020, the share of electric power generated in the EU using CCS technology will be 1.4% in 2025 and 8.7% in 2030 (which enables capturing 23% of all power plant emissions by 2030). In total, according to the BL-2009 scenario, 35 GW of capacities will be connected to the CCS system by 2030.

In accordance with the BL-2009, the net import of gas in the EU-27 countries in 2020 should amount to 351 mtoe. In the year 2030, it should amount to 364 mtoe (i.e. about 460 bcm), which supposes substantial growth in gas import in the EU compared to the current level.

The primary energy balance, according to the BL-2009, should be as follows (refer to Figure 15). In the long term, total energy consumption by the EU countries should continue to be approximately constant.

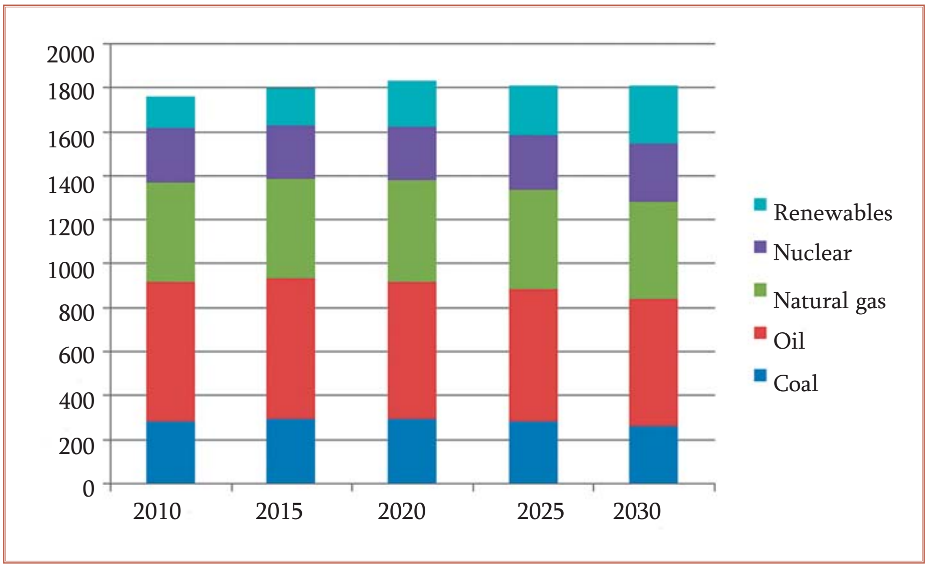

Figure 15. Primary energy balance in EU-27, Baseline scenario, mtoe
Sources: European Energy Trends to 2030 - update 2009

The share of renewable energy sources in the EU primary energy balance is continuously growing but, by 2030, it will only have reached 15%. The share of natural gas remains approximately constant, varying from 25.9% to 24.9% in the period 2010-2025, although it had an increase from 24.4% in 2005 and should decrease to 24.3% by 2030. In general, we see a tendency towards a very slow decline in the significance of natural gas in the energy sector under this scenario. The significance of nuclear power also changes insignificantly, but in an upward direction (i.e. from 14% to 15%). The share of oil falls from 36% to 32% and that of solid fuels drops from 16% to 14%.

Assumptions and Results of the Reference Scenario

For the time being, much less information on this *Reference* scenario (i.e. the scenario reflecting the achievement of the legally binding part of current policy ambitions) is available than is the case for the Baseline scenario. What is known is that it stipulates that, by 2020, two objectives of the *20-20-20* programme will be achieved in terms of renewable energy sources (i.e. a 20% share of final consumption by 2020 and 10% utilisation of RES in the transport sector) and greenhouse gas emissions (i.e. by the year 2020, greenhouse gas emissions should decrease by 20% in comparison with 1990 to be brought about by ETS and the Effort Sharing Decision on non ETS). Flexibility in achieving national target values in terms of the share of RES in the energy balance is allowed, in accordance with the Directive.

The scenario also includes state policy measures that have been introduced by the end of 2009. In other words, its difference from the *Baseline* scenario with respect to assumptions, i.e. state policy measures that were introduced in May-December 2009, particularly a great number of new measures in terms of eco-design and an updated version of the Directive on Buildings. The other assumptions of this scenario should comply with the *Baseline* scenario.

The primary energy balance of the Reference scenario rather strongly differs from the Baseline scenario.

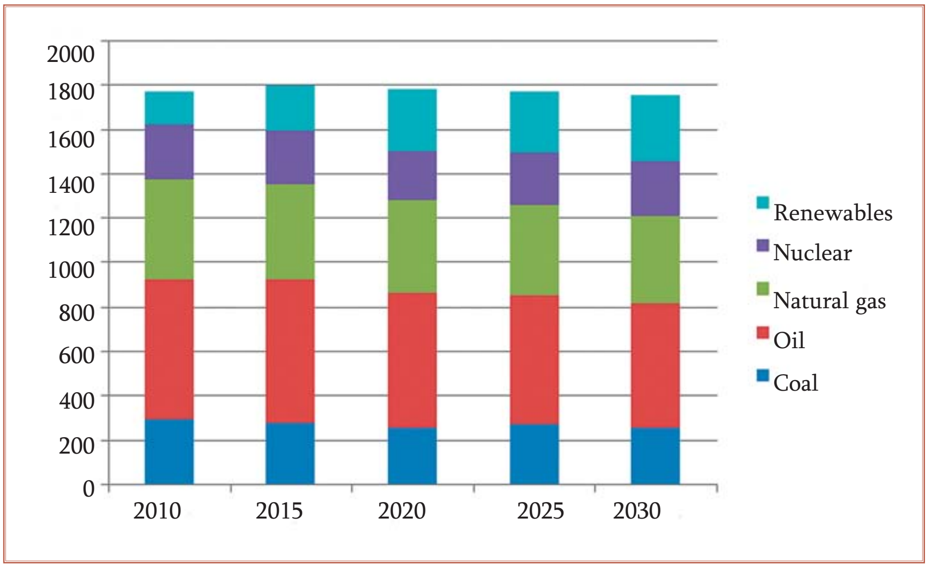

Figure 16. Primary energy balance in EU-27, Reference scenario, mtoe
Sources: European Energy Trends to 2030 - update 2009

With respect to absolute values of primary consumption in the period 2010-2015, the two scenarios coincide. In the period 2020-2030, the consumption level defined in the *Reference* scenario is approximately 3% less. The energy balance structure was subjected to more substantial changes. The natural gas share turns out to be considerably less in the *Reference* scenario, lower by 2.3 and 1.9 percentage points respectively, in 2020 and 2030. The share of nuclear energy in the *Reference* scenario is 1.4 and 1 percentage points less in 2020 and 2030 respectively, while the share of oil is less by 0.3 and 0.9 percentage points for those same years. It is worth noting that the share of solid fuels in the *Reference* scenario by 2020 is 1.1 percentage points less than in the baseline scenario but, by 2030, these shares are the same, which is related to the lower ETS price in the reference case following more energy (electricity) efficiency measures and a greater contribution of RES. The renewable energy sources' share in the reference case – reflecting the policy thrust that is examined in the refrerence case – is much more important. RES increase their significance compared with baseline by 4.2 percentage points by 2020, and by 2.9 percentage points by 2030 in terms of primary energy. In terms of gross final energy consumption, in which the RES share is measured in the RES Directive, the Reference case RES share exceeds that of the Baseline by 5.2 and 3.8 percentage points in 2020 and 2030, respectively. It may be easily seen that, due to the established limitations on attaining a certain share of RES by 2020, the difference between the *Baseline* scenario from the *Reference* scenario is greatest precisely upon reaching the levels expected in 2020. After that, economic mechanisms will begin to act in a greater degree as a consequence of the period 2020-2030. The Reference scenario comes closer to the Baseline version, as market and technology developments, starting from currently implemented policies (Baseline), would be catching up some of the RES policy push induced RES penetration (Reference case) after 2020.

It is important to note that the Reference scenario results (in particular, the rather low share of gas in the energy balance) are, to a far greater degree, caused by the assumption therein regarding the attainment of political objectives, which have been enshrined in EU law (RES and ETS Directive, Effort Sharing Descision). Thus far, not all policies needed for achieving these targets have already been implemented in the Member States. In order to ensure their timily realisation, it is necessary to provide for a marked turning point in established trends. This is especially difficult to ensure under the circumstances of a serious economic crisis, when resources are rather limited, including state support. As the strategy relies on energy markets (e.g. ETS and RES promotion systems where electricity consumers pay for greater RES use (as with feed-in tariffs), additional resouce needs from governments are limited. On the contrary, governments receive substantial revenues from auctioning of ETS allowances, which should be used also for facilitating the transition to more RES and GHG abatement to achieve the targets.

The fact that the share of natural gas in the *Reference* scenario should decrease more than the share of coal, given the assumptions that CO_2 emissions will significantly decline, would seem strange. On the other hand existing/depreciated coal fired power plants, even with ETS caps, have an economic advantage over new constructions of gas power plants. The latter new builds would need to earn also their capital costs, which is not the case for depreciated coal plants, which are still very widespread in the EU. This effect is however moderated by higher requirements for ETS allowances for a power plant that is using coal (given the higher CO_2 content of coal).

Probably, the above-mentioned situation is determined by the following factors (based on the earlier analysis of model runs with the PRIMES model):

- Substantially lower prices for coal in comparison to those for natural gas, while for capital costs the reverse is true. As a result, coal power stations are used as basic capacities but gas stations are used at lower loads and as reserve capacities.
- The utilisation of CCS technologies, which becomes especially significant by the year 2030.

The "No Policy" Scenario

The *No Policy* scenario, established by the NTUA according to their own assumptions and on their initiative (not the European Commission principal assumptions as for Baseline and Reference scenario), is a kind of baseline scenario, which does not entail assumptions in terms of state policy measures. Thus, this scenario permits estimating their effect on the energy sector. In the absence of related state policy, gas consumption in the EU-27 countries should be 11% higher in 2020 and 14% higher in 2030. At the same time, it appears that natural gas imports in the EU will be higher, by 14% and 16% in 2020 and 2030 respectively, in the absence of state policy. In absolute values, the "cost" of state policy measures for gas import amounts to 50 million and 60 million tonnes of oil equivalent in 2020 and 2030 respectively (according to the scenarios, the domestic production of gas does not change). At the same time, as noted by the authors of this model, the PRIMES scenarios contain no special policy on ensuring energy security but the advantage is achieved owing to policies directed at improving energy efficiency and increasing the share of RES in the energy balance. In this context, the authors have already noted that, nevertheless, there are no sufficiently consistent explanations (except that which is deducted from the economic indicators selected by the authors). Thus, is namely natural gas, which will become the first victim of the energy policy measures being applied.

Section 3.2. The 10-Year Plan for Developing the EU Gas Transportation System (first revision, end of 2009)

The authors, i.e. the management of ENTSOG and the management of Gas Transportation Europe, have noted that although the means of transportation and utilisation of primary energy resources in the world are changing rapidly, natural gas is playing a growing role with respect to its importance in the EU energy supply. The above-mentioned parties have emphasised a number of priorities for the near future, which are outlined as follows:

The reduction in volumes of equity production and growing demand for gas in the EU means the emergence of new requirements of the gas transport system with respect to the reception and transportation of new and more diversified gas sources from their supply point to the consumers.

Since Europe exerts significant effort in order to expand the scope of utilisation of cleaner forms of energy, natural gas will be a key element in a process directed at replacing forms of energy production associated with large carbon emissions in Europe. In this regard, gas-fuelled power stations will account for the largest part of the electric power deficit (moreover, rather rapidly) and will provide the necessary electric power reserve during periods when renewable energy sources, such as wind turbines, are not capable of providing power supplies.

The first Plan covers the period from 2010 to 2019. The second Plan for the period 2010-2020 was published on February 2011.

It is noteworthy that the Plan 2010-2019 represents the first pan-European vision on the development of supplies, demand and capabilities in terms of the prospects for the operation of the European gas transport network.

Within the framework of this document, the Peak Demand Scenario and the Potential Supplies Scenario were developed. The latter model includes existing facilities, facilities for which the final investment decisions have been taken, and facilities for projects that are in the developed stage of realisation. The Scenarios should lead to the following results in the period 2010-2019:

- Growth in import pipeline capabilities by 19%.
- An increase in liquefied natural gas (LNG) terminal capacities by 47%.
- A reduction in the equity production of gas by 24%.

- The expansion of underground gas storages capabilities for gas extraction by 34%.
- An increase in aggregate peak demand by 12%.
- An improvement in the interconnecting capabilities development index by 11%.
- An increase of the "sum of import pipeline capacity, LNG import capacity, scenarios of equity production and scenarios of gas extraction from LNG" index by 17%.

In the authors' understanding, these two scenarios are intended to demonstrate compliance of peak demand indices and supplies with the levels of gas supply capacities.

Simultaneously, the Average Annual Scenarios of Demand and Potential Supplies were developed, which led to the following results for the period 2010-2019:

- A reduction in the equity production of gas by 32%.
- An 8% increase of the total annual level of potential supplies by the year 2019 with growth in the period until 2015 up to 680 bcm per annum, followed by a decrease of as much as 656 bcm per annum.
- An increase in the level of annual demand by 14%.
- A lessening of the difference between the annual level of potential supplies and demand from 88 bcm per annum in 2010 to 62 bcm per annum in 2019. In this regard, the level of potential supplies may be defined only by the availability of the respective infrastructural capacities rather than by the actual amount of gas supplies.

When taking a number of known infrastructural projects into account, then the above-mentioned difference, on the contrary, should grow to as much as 166 bcm per annum.[24]

3.2.1. Scenarios of Peak Demand and Supply

These particular scenarios are developed on the basis of scenarios concerning the development of capacities, supplies and demand presented by the respective ministries or natural gas transport system operators of EU member countries.

In these scenarios, along with the projects that have been already realized and the projects about which the final investment decisions have already been taken, the following additional capacities are also taken into consideration:

The *Nord Stream* pipeline's capacity will amount to 84 mcm/day beginning in 2012 and 188 mcm/day as of 2013.

The combined capacity of the LNG terminals in France is up 40 mcm per day. In Italy, they can handle up to 15 mcm per day.

The combined capacity of underground gas storage facilities in France is up 40 mcm per day. In the Netherlands, it is up to 40 mcm per day and in Great Britain, it is up to 104 mcm per day.

The large-scale deployment of the storage facilities in Great Britain is worthy of attention; the capacities projected for deployment will amount to as much as 30% of daily gas consumption in the country and will probably enable an abrupt levelling-out of seasonal and peak price jumps on the British gas market.

Import pipeline capacities are expanding from 1156 to 1381 mcm per day, including an increase by 188 mcm per day owing to the *Nord Stream* and by 23 mcm per day owing to the Turkey-Greece gas pipeline.

The import capacities of LNG terminals are growing from 473 to 695 mcm per day, or by 47%. In this regard, the most remarkable increase is expected to be seen in France, where growth should amount to 59 mcm per day – an increase of almost two times. In the Netherlands, capacities should grow by 33 mcm per day, in Poland by 23 mcm per day, and in Spain by 60 mcm per day.

[24] The unit of measurement used is the cubic meter at 0 °C and at 1 atmosphere.

In the EU countries, the maximum equity production of gas should reach its maximum level at 894 mcm per day in 2011, after which it should gradually decrease by 28% or 659 mcm per day. It is important to note that there will be a considerable decrease, by about 104 mcm per day, from the Netherlands' peak capacity, which traditionally provides approximately 60% of the peak capacity of the EU on the whole. The capacities in Great Britain with regard to daily supplies will drop in the same abrupt manner, by approximately 88 cubic meters by day.

LNG capacity should grow from 993 mcm per day to 1333 mcm per day, representing an increase of 34%.

At the same time, as stated earlier, LNG capacity should experience sharp growth, by 163 mcm per day.

The peak level of demand for gas should grow by only 12% or by 360 mcm per day. As for other countries, it is worth noting a growth in demand in Austria by 31 mcm per day or by 55%. In Belgium, demand should increase by 32% or 46 mcm per day, while, in Spain, it should amount to 70 mcm per day, which is up 31%.

At the 'balance level', the peak scenario is characterised by the following indices:

Table 28. Gas balance in Europe in 2010-2019, mcm/day

Mln. cubic meters/day	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Pipeline import	1156	1154	1265	1358	1358	1381	1381	1381	1381	1381
Storage	993	1043	1086	1118	1145	1241	1295	1323	1329	1333
Production	863	894	884	850	818	774	743	719	687	650
Total supply	3485	3585	3789	3909	3939	4068	4101	4110	4092	4068
Total demand	3115	3188	3253	3308	3356	3399	3432	3448	3463	3475
Difference between supply and demand (%)	111.9	112.5	116.5	118.2	116.5	119.7	119.5	119.2	118.2	117.1

Sources: ENTSOG, European ten year network development plan 2010-2019

We draw attention to the consistent lowering of the role of equity production in supporting peak demand in the EU countries and enhancement of the role of other sources of coverage. In general, the role of domestic sources (with respect to extraction and LNG) should grow from 53.2% in 2010 to 57.3% in 2019. In other words, the above-mentioned sources will ensure the increased security of supplies. Additionally, supporting peak demand for gas through use of varied sources should also grow from 11.9% in 2010 to 117.1% by 2019. Thus, objective figures do not provide grounds for the alarming popular sentiment in Europe with respect to an increasing risk of dependence on external gas supplies and unreliable gas supplies to Europe in future.

3.2.2. Scenarios Concerning Annual Average Demand and Supplies

Within the framework of these particular scenarios, the possibilities regarding import supplies of pipeline gas have been estimated on the basis of scenarios concerning daily average supplies, which apply the annual average utilisation coefficient equal to 0.8. These scenarios were presented by operators of the respective pipeline systems. In this regard, the calculation was based on the analysis of infrastructural capacities rather than the volumes of imported gas.

The major growth in these volumes will occur for those volumes directly supplied from Russia (i.e. an increase of 55 bcm per annum, a volume corresponding to two lines of the *Nord Stream*). In total, the import pipeline capacities should grow by 65 bcm per annum to reach 403 bcm per annum.

At the same time, the total capabilities of supplies coming directly from Russia and through Ukraine and Belarus should grow to 243 bcm per annum.

LNG receiving capacities are estimated on the basis of the average daily figures presented by the operators, with a utilisation coefficient equal to 0.5. Here the utilisation coefficient is considerably lower than that of the pipeline supplies, because it is associated with the obvious excessiveness of capacities intended for LNG regasification, which have either been constructed already or are planned for construction.

Although, in relative terms, the growth of LNG receiving capacities are forecasted at a higher level than those for pipeline gas, in absolute terms, this capacity will increase by only 41 bcm per annum, which is less than for pipeline capacity. Thus, the allocation of increments corresponds to those identified above for the peak period.

According to this scenario, the equity gas production by EC countries, in annualised terms, will decrease by 32% – from 184 bcm per annum to 126 bcm per annum. At that, the capacity of the Netherlands will decrease from 84 bcm per annum to 57 bcm per annum, which is only by 11 bcm per annum will exceed domestic demand for gas therein. Gas production in Great Britain will drop from 50 bcm per annum to 29 bcm per annum. Finally, in Denmark, gas production will decrease from 6 bcm per annum to 2 bcm per annum. The above-mentioned forecasts show that, in practice, there will be no longer be any domestic gas exporters in the EC (the Netherlands will only carry out that role owing to the re-export and seasonal structuring of supplies, albeit in considerably decreased volumes in comparison to those levels that were previously recorded).

As for the scenario concerning annual gas demand, the forecasts are made, in part, on the basis of the PRIME model. In general, the scenario provides for a growth in demand by 14% – from 520 bcm per annum to 594 bcm per annum. It is important to note that demand in Austria should increase from 9 to 13 bcm per annum, while demand in Belgium should grow from 18 to 26 bcm per annum, in the Czech Republic from 9 to13 bcm, in Greece from 4 to 7 bcm per annum, in Hungary from 14 to 21 bcm per annum, in Italy from 85 to 102 bcm per annum, in Poland from 16 to 19 bcm per annum, in Portugal from 5 to 8 bcm per annum, in Spain from 45 to 56 bcm per annum, in Great Britain from 86 to 90 bcm per annum, and in France from 48 to 53 bcm per annum.

A comparison of the scenario concerning the development of gas demand with that concerning gas supplies, which was prepared by ENSOG, indicates the following developments. The potential supplies, in accordance with already existing and new, confirmed projects that are included into the capacities taken into consideration, exceed demand by 88 bcm per annum in 2010 and by 52 bcm per annum in 2019. The above-mentioned figures do not include the potential capabilities specified in the ENTSOG document which are here indicated according to the respective projects, as follows: *Nabucco* (16 bcm per annum), *South Stream* (63 bcm per annum), the *ITGI* interconnection between Greece and Italy (9 bcm per annum), the *Galsi* Algeria-Italy gas pipeline through Sardinia (8 bcm per annum), and the potential *White Stream* gas pipeline (8 bcm per annum). The incorporation of these additional facilities into the calculation will increase the capacity reserve with respect to supplies carried out in 2019 – up to 166 bcm per annum or to 28% of the demand level.

3.2.3. Comparison with Other Forecasts and Scenarios

The figures related to equity production, in comparison with those specified by the International Energy Agency (IEA) in the "World Energy Outlook 2009", indicate a rather steady downward inclination of the IEA figures relative to the ENTSOG figures – by 12 bcm per annum in 2010 and by 19 bcm per annum in 2019. Thus, the ENTSOG data presented by gas transport system operators indicate a rather higher rate of decline in production, at 32% in comparison with the 26%

suggested by the IEA. The difference between the initial figures for 2010 may be partially explained by an inaccuracy in the measurement units used by the IEA, which were subsequently noted in the report on the second Stage.

The ENTSOG document presents a comparison of its scenarios with the materials presented in the Energy Strategy-2030. According to ENTSOG, the potential pipeline gas export from the Russian Federation to the EC may grow from 184 to 244 bcm per annum. The figures provided in the Energy Strategy do not differentiate between forecast export volumes with respect to their directions, but they do separately define LNG share in export supplies. Accordingly, pipeline exports should grow from 251 to 295 bcm per annum. We believe that, taking into account a certain decrease in export levels to Ukraine and the improbable launch of large-scale exports of pipeline gas eastward during the period under consideration, the above-mentioned estimates are indeed comparable.

As for pipeline gas imported from Norway to the EU, the ENTSOG scenario stipulates a virtually steady level of from 97 to 98 bcm per annum, which seems to be quite unjustified. The IEA scenarios predict growth in Norway's total exports (inclusive of LNG) up to 126 bcm per annum (from 103 bcm per annum in 2010). At the same time, data from the Norwegian Petroleum Directorate indicates exports of 107 bcm per annum in 2010, which should increase to 112 bcm per annum by 2013. It is obvious that a clarification needs to be made about the units used and the forecasts for the development of LNG supplies from Norway. It is worth noting that different conversion coefficients cannot be the sole cause for these differences due to the fact that the forecasts prepared by ENTSOG, the IEA and the Petroleum Directorate all demonstrate different dynamics.

The most interesting data presented is a comparison of the ENTSOG scenarios concerning demand in the EU-27 according to the different sources.

The authors define the existence of three separate groups of forecasts, which are as follows:

The Eurogas-2007, Cedigaz-2009 and ENTSOG-2009, which predict considerable increases in gas consumption volumes in the EC, by approximately 15%, and these should have initial and final volumes that are very similar.

The PRIMES-2007 baseline scenario, which indicates that there will be moderate growth in gas consumption in the EC in 2019, by only 8%, and the recent IEA-2009 baseline scenario, indicating that gas consumption will increase by 5.5% (in addition to the nearly complete absence of growth in the period until 2015, which the IEA explains as an outcome of the world crisis).

All other PRIMES scenarios point to the stabilisation of or a reduction in gas consumption volumes.

ENTSOG has noted that a number of gas supply operators have not yet managed to analyse the impact of the economic crisis on their own scenarios with respect to demand for gas.

The following table contains a summary of the basic demand forecasts, adjusted in order to exhibit comparable units, i.e. bln kWh/year, with conversion figures of 11.63 bln kWh/mtoe and 10.83 kWh/cubic meters. It should be noted that the latter figure produces a difference of more than 13% towards inflation, in comparison to the Russian measurement units.

It is worth noting that such a considerable difference between the forecasts may also be determined by the different levels of calorific efficiency of natural gas implied in the different scenarios, as well as by the distinct initial statistic base. In particular, the conversion coefficient provided in the ten-year plan (conversion from *million tonnes of oil equivalent to billion kWh*) complies with that used by the IEA; however, another conversion coefficient (conversion from *bcm to billion kWh*) differs from the IEA in some cases by about 20%.

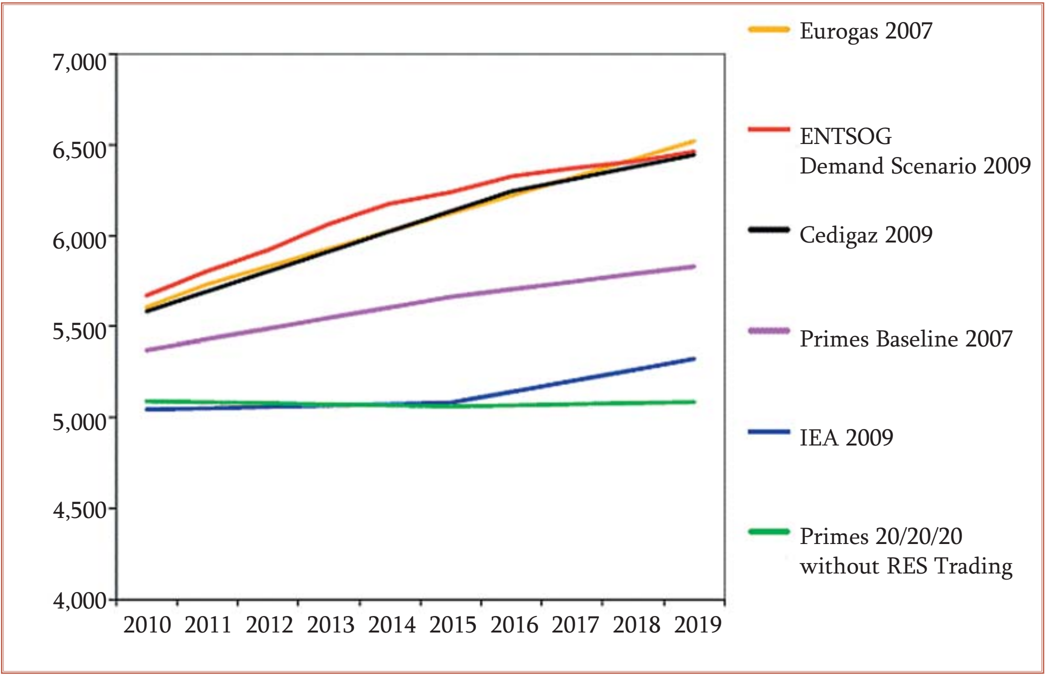

Figure 17. Gas consumption in EU-27 by different scenarios, billions kilowatt-hour
Sources: ENTSOG, European ten year network development plan 2010-2019

Table 29. Energy demand in EU-27 by different scenarios, billions kilowatt-hour

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Baseline PRIMES-2007	5372	5430	5488	5546	5605	5663	5705	5746	5788	5830
PRIMES 20/20/20 without RES	5090	5085	5079	5074	5068	5063	5069	5075	5081	5087
Eurogas-2007	5605	5732	5830	5928	6026	6123	6221	6321	6421	6521
Cedigaz-2009	5583	5693	5803	5914	6024	6134	6244	6312	6379	6446
ENTSOG-2009	5670	5805	5920	6064	6177	6239	6327	6371	6409	6463
Baseline IEA-2009	5046	5053	5061	5068	5075	5082	5143	5203	5264	5324

Sources: ENTSOG, European ten year network development plan 2010-2019

3.2.4. Questions and Remarks on the Ten-Year Development Plan

The sum of the daily potential supply is not comparable with the sum of the daily potential demand with respect to the EU for two key reasons:

The impossibility of supplying natural gas from every country to most other countries, taking into account the existence of bottlenecks (both trans-border and internal) and the lack of reverse capabilities (basically in the west to east direction).

The unequal distribution of excessive capacities and the different location of gas supply and gas demand centres across the EU.

For instance, the considerable excessive LNG capacities in Spain or the underground gas storage facilities in the Netherlands could not be used to satisfy demand for natural gas in Eastern Europe. Likewise, the capacities of the underground gas storages in Latvia are also useless in terms of increasing gas supplies to other EU countries.

Providing a summation of the peak possibilities of gas storage facilities' output, along with potential peak production and import levels appears to be the methodologically wrong approach. If domestic and inter-country capabilities are used to the maximum for transporting imported gas, then supplies from underground gas storage facilities should not be realised to their maximum capacity (with the exception of those countries with very high level of excessive capabilities). In addition, to realise gas extraction from underground gas storage facilities at their maximum possible level, they should be filled to ensure the appropriate pressure, and this fact is not obvious.

In the course of analysing the ENTSOG Ten-Year Plan, a number of questions arise that are not highlighted in the document. They are as follows:

- Did the analysis take into account the domestic gas line capacities, which may turn out to be less than import or inter-country capabilities? If this is not the case, the volume of capacities with respect to imports and inter-country capabilities should be reduced.
- Did the analysis consider the possibility that gas pipelines that are capable of supplying gas in both direct and reverse directions may be used to deliver supplies in different directions throughout the year? One example of such a pipeline is the Interconnector gas pipeline between Belgium and Great Britain.
- Did the analysis take into consideration that actual gas pipeline capacity may be less than its designed capacity, owing to depreciation? (i.e. as in the case with Ukraine's Gas Transportation System)
- Did the analysis consider that peak demand may continue for more than one day? How long can the peak supply be maintained (particularly given the gradual reduction in pressure in the underground storage facilities).
- Were seasonal fluctuation taken into account in the analysis?
- What is the mechanism for calculating the pan-European values with regard to country-specific data?

Section 3.3. The Eurogas report

In May 2010, Eurogas (i.e. the European Union of the Natural Gas Industry) published its vision of the long-term development of the EU gas market, covering the period until the year 2030.

The Report indicates that the current decline in demand for gas in Europe, which is occurring simultaneously with an increase in gas supply, has led to the formation of gas surpluses on the European market. However, most experts predict that such a situation will not maintain itself in the long-term perspective. This will be determined by the general trends towards growth in demand for gas in Europe and a decline in domestic production. Consequently, after the year 2015, demand for sizeable additional gas supplies should emerge. Eurogas notes that the European gas industry is capable of ensuring reliable and diversified gas supplies at competitive prices. There exists an opinion that any pragmatic way to a sustainable future entails an increase in the role of gas. At the same time, the Eurogas forecast does not assume the substantial development of gas generation from non-traditional sources in Europe. Thus, the gas production should not exceed 20-25 million tonnes of oil equivalent per annum.

The previous long-term forecast by Eurogas was prepared in 2007. The new forecast, in contrast to the old one, considers the impact of the economic crisis and the introduction of the 20-20-20 programme. The Report represents two following scenarios: the Baseline scenario and the **Environmental** scenario.

3.3.1. Methodology and Assumptions

In the summer of 2009, a questionnaire with the general assumptions of the analysis was sent to all members of Eurogas, so that they present their forecasts for gas demands and supplies for their own respective national markets. The questionnaire included the following assumptions from the Baseline scenario:

- Upon the end of the crisis, the economic growth rate will amount to about 2% per annum.
- The primary energy consumption in the EU will grow by 0.1% per annum.
- Pressure from EU regulators will continue and it will be directed at stepping up competition in the gas industry and electric energy sector.
- An economically-justified gas infrastructure will continue to grow.
- New supply of gas resources may obtain access to the market.
- In most countries, long-term contracts will continue to be the basis for gas supplies.
- Prices for oil will continue to be the main indicator of the energy market.
- Different types of fuel will compete with each other.
- Gas supply contracts will entail pegging to oil prices.
- Development of the greenhouse emission trade system (ETS) in Europe will continue; complete transition to an auction system will occur by the year 2012.
- The realisation of existing state policy in the context of the energy sector and its development will continue.
- A certain level of prices for oil, coal and CO_2 emission quotas (refer to Table 30) is forecasted.
- The EU population will be more or less steady.
- We may expect growing anxiety of the politicians and communities with respect to environmental issues.
- The tendency towards growth in the energy efficiency of the EU economy will continue.
- The intentions to develop nuclear energy and to expand the utilisation of renewable energy sources at the national level are taken into account.

Table 30. Assumptions on oil, coal and CO2 prices

	2009	2015	2030
Oil, $/barrel	50	60-70	80-100
Coal, euro/t	60	60-70	70-90
CO_2, euro/t	15	20-30	40-50

Sources: Eurogas, Long-term outlook for gas demand and supply 2007-2030, 2010

According to the Baseline scenario, the EU energy efficiency will grow by 31% by the year 2030 compared to 2007, taking into account the pre-determined growth rates of GDP and energy resource consumption.

The following assumptions are also made for the Environmental scenario, as follows:

- Higher rates of economic growth and pulling out of the crisis (however, the growth rate indicators are not actually defined).
- More favourable state policy in terms of natural gas.
- The guaranteed competitive ability of natural gas.
- Prices for CO_2 emissions are at the upper limit of the supposed range.

3.3.2. Results

According to all scenarios, the share of natural gas in the EU primary consumption will grow. However, it is worth noting that, in the scenario from 2007, the forecasts in terms of gas were more optimistic. At the same time, the difference between these forecasts should gradually increase through to 2030. In the forecast for 2015, the difference between the baseline forecasts from 2007 and 2010 amount to 1.7 percentage points, but by the year 2030, this should increase to 3.4 percentage points.

Table 31. Share of natural gas in EU-27 primary energy consumption, %

Scenario	2007	2015	2020	2025	2030
Eurogas, BL-2010	24	25.7	26.4	26.9	26.7
Eurogas, Env-2010	24	25.7	27.8	28.4	28.7
Eurogas, BL-2007	24	27.4	28.8	29.7	30.1

Sources: Eurogas, Natural gas demand and supply: long-term outlook to 2030, 2007; Eurogas, Long-term outlook for gas demand and supply 2007-2030, 2010

As per the Eurogas estimates, EU gas consumption in 2009 fell by 6.4% in comparison with 2008. It was caused by a drop of industrial production (heavy industry accounts for one-third of gas consumption in the EU) and a subsequent decline in gas consumption in the electric energy sector due to lowered demand for electric power and relatively high gas prices.

According to estimates made by Eurogas, in recent years, the economic crisis and EU policy has led to a 15-20% decline in the potential of long-term demand for natural gas in comparison with the 2007 estimates. Nevertheless, demand for natural gas will grow. Natural gas is advantageous compared with other energy sources due to its environmental friendliness and efficiency. Therefore, according to Eurogas, natural gas will be the fuel of choice for consumers.

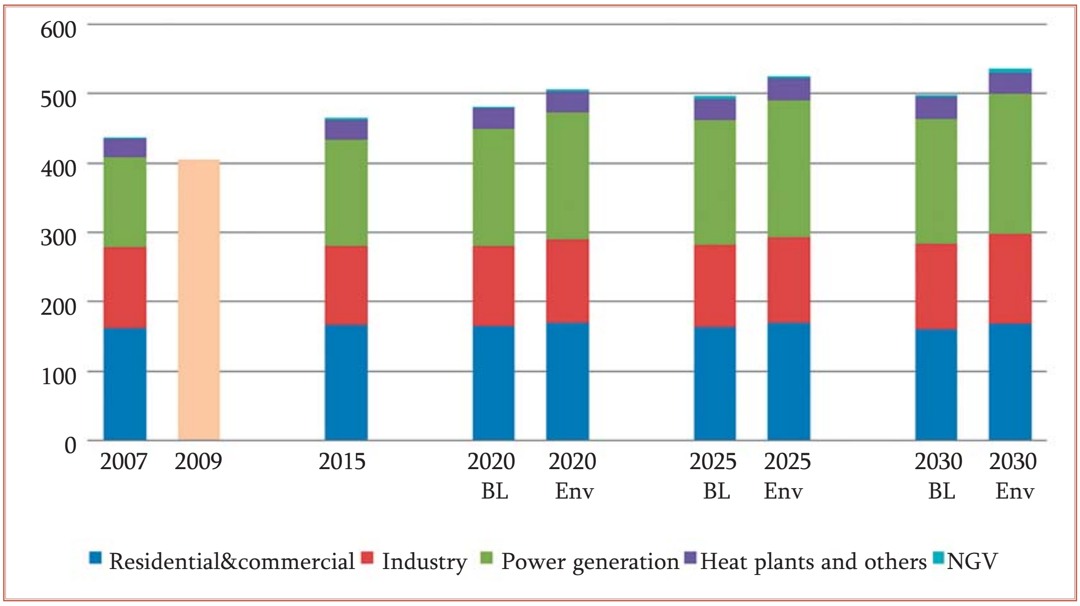

Figure 18. Natural gas consumption in EU-27, mtoe
Sources: Eurogas, Long-term outlook for gas demand and supply 2007-2030, 2010

In accordance with the baseline forecast, the average rates of natural gas consumption growth in the EC in the period 2010-2030 should amount to about 1% per annum. In the Environmental scenario, the average grow rates should reach 1.4%.

According to the Baseline Scenario-2010, in sectoral terms, the share of the commercial and household sector, and of industry, in the gas consumption structure will decline (though the share of the industry will see minor growth in the period 2025-2030). In the pre-crisis period, growth in gas consumption in the commercial and household sector was caused by population growth and the expansion of gas infrastructure. However, in the long-term perspective, it will undergo a moderate decrease for to the following reasons:

- Moderate population growth or even a decrease will be observed in the EU countries;
- The penetration of gas networks in private households is already at a rather high level in many EU countries;
- In a numbers of countries, the population density is low; the structure of settlements and the landscape conditions create economic limitations on the development of gas networks;
- The improvement of buildings' energy efficiency is currently happening.

Table 32. Forecasts of natural gas consumption in EU-27, mtoe

	Consumption, mtoe					Structure, %				
BL-2010	2007	2015	2020	2025	2030	2007	2015	2020	2025	2030
Residential&commercial	161	167	164	163	160	36.8	35.9	34.0	32.9	32.0
Industry	117	113	116	119	123	26.8	24.3	24.1	24.0	24.6
Power generation	131	154	169	180	181	30.0	33.1	35.1	36.3	36.2
Heat plants and others	27	29	30	31	31	6.2	6.2	6.2	6.3	6.2
NGV	1	2	3	4	4	0.2	0.4	0.6	0.8	0.8
Total	437	465	482	496	500	100	100	100	100	100
Env-2010	2007	2015	2020	2025	2030	2007	2015	2020	2025	2030
Residential&commercial	161	167	170	170	168	36.8	35.9	33.5	32.3	31.3
Industry	117	113	120	123	129	26.8	24.3	23.7	23.4	24.1
Power generation	131	154	184	198	203	30.0	33.1	36.3	37.6	37.9
Heat plants and others	27	29	30	31	31	6.2	6.2	5.9	5.9	5.8
NGV	1	2	3	4	5	0.2	0.4	0.6	0.8	0.9
Total	437	465	507	526	536	100	100	100	100	100
BL-2007	2010	2015	2020	2025	2030	2010	2015	2020	2025	2030
Residential&commercial	180	187	181	193	194	36.5	35.0	31.3	32.0	31.0
Industry	128	137	145	150	156	26.0	25.6	25.1	24.9	25.0
Power generation	158	181	209	226	239	32.0	33.8	36.2	37.5	38.2
Heat plants, NGV and others	27	30	43	34	36	5.5	5.6	7.4	5.6	5.8
Total	493	535	578	603	625	100	100	100	100	100

Sources: Eurogas, Natural gas demand and supply: long-term outlook to 2030, 2007; Eurogas, Long-term outlook for gas demand and supply 2007-2030, 2010

According to the Environmental scenario, gas consumption in the commercial and household sector will stabilise at 170 mtoe per annum owing to the development of new effective technologies, such as condensation heaters connected with solar batteries, micro-cogeneration, gas heating pumps, and fuel elements.

In industry, growing consumption owing to the expansion of production will be compensated by the increased energy efficiency of new plants. The price competitiveness of natural gas, in comparison with coal and oil, will ultimately be the principal influence on gas consumption levels.

The main increase in gas consumption should be seen for the electric power sector. According to the Baseline scenario, its share will grow from 30% to 36.2% from 2007 to 2030. Gas ensures the possibility to reduce carbon dioxide emissions at a relatively low price. On average, when utilising natural gas, the volume of CO_2 emissions is approximately 50-60% less than that of conventional coal power stations. The combined cycle gas turbine (CCGT) may be built rather quickly and cheaply. Gas power stations are very flexible in terms of operational activity. That, in particular, allows utilising gas power stations as reserve capacities for power stations that use RES (such as wind and solar energy).

Gas consumption for the purposes of heat generation should be approximately constant. While the share of gas consumption in the motor transport sector in the period 2007-2030 will increase by 4 to 5 times, in absolute figures, it will remain at a rather insignificant level – about 4-5 mtoe in 2030. The consumption growth potential in this sector will depend on EU countries' policy and the availability of coordinated support on their part.

The alternative scenario defines the same tendencies in the consumption structure than those outlined in the Baseline scenario, with the exception of the share of heating and other sectors, which should decrease from 6.2 to 5.8%.

Table 33. Sources of natural gas supply of EU-27, mtoe/year

	2007	2015	2020	2025	2030
Internal production	177	140	102	76	57
Norway	71	85	97	93	88
Contracted imports and possible prolongations from outside Europe	189	240	270	274	260
Additional supply to be defined, BL	0	0	13	54	95
Additional supply to be defined, Env	0	0	38	83	130

Sources: Eurogas, Long-term outlook for gas demand and supply 2007-2030, 2010

It is worth noting that, in comparison with the forecast from 2007, the prospects of building up import supplies in Europe have decreased, especially for the year 2015. Volumes in terms of long-term contracts for the year 2015, taking into account probable prolongations, fell from 270 to 240 mtoe per annum. At that, volumes of the necessary additional gas supplies declined from 50 mtoe per annum to zero. According to the forecast from 2010, total production of the EU-27 region and Norway in 2015 will grow from 215 to 225 mtoe per annum.

However, in the long-term perspective, the situation on the European gas market should improve. By the year 2020, supplies owing to existing long-term contracts amount to 270 mtoe, which is higher than the level indicated in the 2007 report (i.e. 266 mtoe). In addition, the potential of additional supply in 2020 should be from 13 to 51 mtoe, depending on the scenario applied. By the year 2030, the potential of an additional increase in supplies to the EU-27 should reach 95 mtoe or 225 mtoe, as indicated in the Baseline and alternative scenarios, respectively. It is worth noting that, even in the alternative scenario, demand for additional gas supplies for 2030 is less than that specified in the baseline forecast from 2007 (i.e. 241 mtoe).

Despite the relative worsening of forecasts in terms of gas imports, the main trend towards their substantial increase is also apparent in the new Eurogas forecasts. Consequently, the import dependence of the EU-27 (taking into consideration import supplies from Norway) should grow from 59% in 2007 to 78.8-79.9% in 2020 and to 88.6-89.4% in 2030.

Section 3.4. Analysis of Scenarios by POLES Model Used in Long-Term Energy Strategy of the EU

In the context of the presented here study, the POLES model poses high interest. Not only the model plays a role of methodological basis for several publications, but also it is a "suppler" of input data for other models, the resulting forecasts of which are included in the EU energy strategy. In particular, global and regional energy prices in PRIMES are the results of the POLES simulations.

The POLES model was applied in a number of international studies; in particular it is widely used in the research framework of the EU's Directorate General (DG) for the research on energy, transport and the environment. Besides the EU studies, the model was used to prepare scenarios for UNFCCC, in particular for the Conference of Parties (CoP) and for several interagency international studies on technology and energy development.

Among other examples of PRIMES application one could highlight the "World Energy, Technology and climate policy Outlook-2030" (WETO), published in 2003; its update with an emphasis on the transition to hydrogen economy – "World Energy, Technology and climate policy Outlook - 2050" (WETO-H2), issued in 2007. The further review will be based on the results of these aforementioned studies.

3.4.1. WETO-2030 Scenario

The centerpiece of the WETO-2030 study is the Baseline scenario, assumes that the development of the world energy system will follow the current trends and the structural changes in the world economy (business and technology as usual), which have already taken place. The indicators of this scenario are considered as a point of departure for the assessment of the alternative energy sources and of the strategies, targeted at technological development and climate change prevention. Thus, the Baseline scenario can be considered as a benchmark of the energy system (in a broad sense), which can be improved by implementing various energy policies.

In WETO-2030, growth of the world energy consumption is projected to comprise 1.8% per annum in the period from 2000 to 2030. Economic and population growth (3.1% and 1% per annum correspondingly) shall be compensated by reducing energy intensity of GDP at 1.2% per annum as a result of structural changes in the economy, technological progress and increase of energy prices. Energy demand – according to WETO-2030 scenario – shall be decreasing in the developed countries, in particular in the EU – by 0.4% per annum. On the other hand, energy demand in the developing countries is projected to rapidly grow: by 2030 their share in world energy demand is assumed to go over 50%.

Basic primary energy sources – according to study results – will be the fossil fuels – up to 90% in 2030, in particular oil (34%), coal (28%) and gas (25%).

In the EU energy mix, natural gas is projected to take the second place yielding to oil, while nuclear and renewable energy would comprise 20% of total primary energy supply.

Main results of WETO-2040 study for the "Western Europe"[25] region are presented in Figure 19, Figure 20 and Table 34.

[25] Western Europe: Western Europe: Austria, Belgium, Cyprus, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Malta, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, United Kingdom

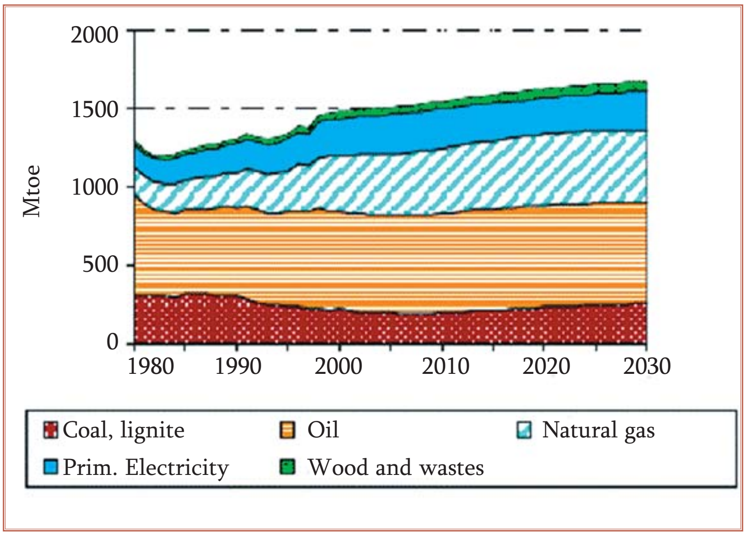

Figure 19. **Primary Energy consumption in Western Europe region according to WETO-2030 scenario**
Sources: Directorate-General for Research Energy, European Commission, World energy, technology and climate policy outlook - 2030 (WETO), 2003

Table 34. Basic economic and energy indicators in scenario WETO-2030

	1990	2000	2010	2020	2030	1990/00	2000/10	2010/30
Population (mln)	434	456	467	470	468	0.5%	0.2%	0.0%
GDP (bln EUR'99 PPP)	7536	9225	11517	14226	16706	2.0%	2.2%	1.9%
GDP per capita 1000 EUR'99/person)	17.4	20.2	24.7	30.2	35.7	1.5%	2.0%	1.9%
Primary energy consumption/GDP (toe/1000 EUR'99)	190	174	148	129	116	-0.9%	-1.6%	-1.2%
% of Renewables in primary energy consumption	6%	6%	7%	7%	7%	0.3%	1.0%	0.6%
Electricity consumption per capita (kWh/person)	4.7	5.4	6.1	7.2	8.4	1.4%	1.2%	1.6%
CO_2 emissions per capita (ton CO_2/person)	7.8	7.9	8.0	8.8	9.3	0.1%	0.2%	0.8%
Transport fuel per capita (ton/person)	0.64	0.71	0.73	0.77	0.79	1.0%	0.4%	0.4%
Primary energy production (mln toe), in particular	863	1045	926	809	752	1.9%	-1.2%	-1.0%
Lignite	224	134	107	108	110	-5.0%	-2.2%	0.1%
Oil	212	339	217	129	82	4.8%	-4.4%	-4.7%
Natural gas	156	252	261	220	178	4.9%	0.4%	-1.9%
Nuclear	188	223	227	218	238	1.7%	0.2%	0.2%
Hydro and geothermal	40	44	48	51	54	1.0%	0.9%	0.6%
Waste wood	41	48	54	65	71	1.5%	1.3%	1.4%
Wind, solar and small hydro	3	5	11	18	20	7.2%	8.1%	2.9%
TPES (mln toe)	1430	1604	1705	1839	1936	1.2%	0.6%	0.6%
Lignite	320	246	224	269	315	-2.6%	-0.9%	1.7%
Oil	615	667	688	716	722	0.8%	0.3%	0.2%
Natural gas	227	379	464	521	537	5.2%	2.0%	0.7%
Electricity	227	264	274	269	291	1.5%	0.4%	0.3%
Waste wood	41	48	54	65	71	1.5%	1.3%	1.4%
Import (mln toe)								
Oil	403	328	471	587	640	-18.6%	43.6%	35.9%
Gas	71	127	203	203	359	78.9%	59.8%	48.3%

Sources: Directorate-General for Research Energy, European Commission, World energy, technology and climate policy outlook - 2030 (WETO), 2003

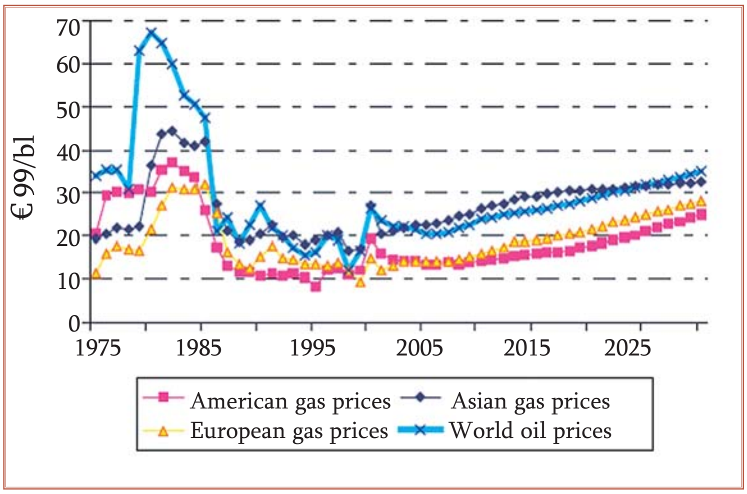

Figure 20. Basic energy source prices according to WETO-2030 scenario
Sources: Directorate-General for Research Energy, European Commission, World energy, technology and climate policy outlook - 2030 (WETO), 2003

As observed in the resulting forecasts, an upward trend will be observed in oil and gas prices as of 2003. In 2030 oil price is projected to reach 35 EUR/bbl, gas – 28 EUR/bbl (in energy content equivalent) in Europe and 25 EUR/bbl in the USA. Regional oil indexes (gas price differentials) shall significantly lower and follow market clearing.

Given that the study used EUR'99 as a basis currency and that the average yearly exchange rate corresponded 1,066 during that year, the diagrams in Figure 20 seem to stand far from reality as of 2009.

EU gas market perspectives in the global context

According to WETO-2030, the EU gas market will be expanding in the next 20 years driven by driven by the power generation sector. At the same time, in the context of the world gas consumption, the share of the EU will be decreasing.

It was revealed that the world gas reserves are abundant, but concentrated in two regions: CIS and Middle East, where – according to study results – gas production will significantly increase by 2030. EU gas reserves are estimated as limited and the decline in production and respectively increasing dependence on import is seen as inevitable.

Moreover it was defined that in the global context demand for gas will be growing in all other world regions and those, where a production decline is expected, will change their status to netto-importers. This evidence will results in a change of the current gas trade scheme. For example, it was noted that the rapid growth of gas demand in Asia was expected to have some influence on the EU gas supply pattern in 2030: while Asia was projected to rely predominantly on gas supplies from the Middle East, the EU and Accession countries may import more than half their natural gas needs from the CIS.

Natural gas supply projections in the Baseline scenario show that EU external gas supplies should continue to arrive primarily from the CIS, Norway and North Africa (Algeria and Libya). Other sources of imports into the EU were the Middle East (mainly pipeline gas via Turkey) and LNG from Nigeria but their cumulative share was not expected to exceed 10% in 2020 and 5% in 2030 of imports.

The relative contribution of these core gas suppliers to the EU is however projected to change in the next thirty years. Starting from 28% in 2000, the share of the CIS is expected to increase steadily up to 54% of gas requirements in the model regions "Western Europe" and "CEEC". This increase translates into a tripling of the currently traded volumes with the CIS countries over the projection period. The share of gas supplies from Africa and Middle East would peak at 22% in 2020 and then decline to 15% of the European gas demand in 2030. The decline is mainly driven by the diverted supplies from the Middle East, which will be rerouted towards Asia after 2020. On the contrary, the share of gas imports from Africa (mainly Algeria and Nigeria) is expected to remain stable up to 2030, ranging from 10 to 15% of European gas requirements. In absolute terms, the volumes of gas imported to Europe from Africa and Middle East will be doubled by 2030.

It is worthwhile mentioning an excerpt from the WETO-2030 report in relation to the EU dependency on CIS gas: "…such dependency may translate into higher supply risks for the EU. These risks could however be limited through different actions as outlined in the EC Green Paper, like the multiplication of gas transport routes, the further integration of the European gas network, and a continuous dialogue with gas producing countries."

Section 3.5. The SECURE Project

The three-year research project SECURE (Security of Energy Considering its Uncertainty, Risks, and Economic implications) is currently nearing completion. This project has been carried out for the European Commission by a number of groups from EU countries, and with the participation of the Energy Research Institute of the Russian Academy of Sciences (ERI RAS). The project aims to analyze a range of issues concerning EU energy security and includes an analysis of relevant factors and possible development scenarios for energy supplies, with an assessment of the security considerations of their implementation. The project started in 2008. The tools, models and policy recommendations developed in the project are intended to lay the groundwork for the formation of European energy policy.

The project aims to address issues of energy security in a wide-ranging manner, encompassing aspects of geopolitics, pricing, and the economic and technological mechanisms of energy markets in the EU and beyond. All major energy carriers (oil, natural gas, coal, nuclear energy, plus renewable supplies of energy and electricity) and technologies are included in the analysis, as well as all the links in the production chain from exploration and production to processing and marketing. The project is also developing mechanisms, methods and models for the measurement and evaluation of the reliability of EU energy supplies.

The SECURE project is being carried out by a consortium of 15 research centers. The goal of this consortium is to bring together data, information and the opinions of representatives of the EU and its partners – the provider countries.

The SECURE project expands existing research in the field of energy security into the following areas:

(i) The integration of medium-term econometric models with indicators of energy security and social well-being; the modeling of risk and the use of methods developed to assess the feasibility and effectiveness of political measures designed to increase the reliability of energy supplies.

(ii) Assessing "willingness to pay", exploring the risk factors of energy supply in relation to households and industry. Developing a strategy to improve the reliability of energy supplies involves an assessment of measures that can be proposed to the public to cover the risks. The collected data helps determine which areas are considered high priority by end-users and provides necessary information for qualitative analysis (such as how sensitive the preferences of end-users are to the reliability of energy systems and how best to develop corresponding measures in the political arena).

(iii) Developing high-quality long-term energy scenarios and simulation models. The link between political debate and simulation is an important step forward in terms of the reliability analysis of energy supplies. Previous large-scale energy research by the European Commission was used to study energy scenarios for the period up to 2050, subject to restrictions on greenhouse gas emissions. SECURE goes one step further, taking into account the effects of uncertainty and strategies for the reliability of energy supplies. The POLES model describes the oil market as "one huge joint pool", and is very detailed with respect to the natural gas market with a clear description of the various transportation possibilities in the different regions. SECURE combines the large-scale POLES model with the ERA model (model for the evaluation of energy risks), which was developed during the project work. The ERA model provides evaluation of the effectiveness of different scenarios regarding the uncertainties of demand and the supply of energy. It incorporates elements of subjective benefit, or "willingness to pay" for the reliability of energy supplies. Thus, the model considers a number of social consequences of the different scenarios.

And finally, SECURE investigates a number of relevant areas, such as:

i) the role of energy efficiency and demand management in electricity markets in order to improve the reliability of supply,
ii) the role of serious accidents and the terrorist threat in the basic energy supply chains,
iii) specific problems and threats for each of the major sources of energy and technologies (oil, natural gas, coal, nuclear energy, and renewable sources of energy and electricity).

The results of the SECURE project include a methodology for a qualitative and quantitative evaluation measuring the reliability of energy supplies, scenarios for the reliability of energy supplies for the period up to 2030 and recommendations for energy policy/regulatory legislation aimed at improving the reliability of energy supplies. These recommendations will take into account the cost, effectiveness and risks of various legislative solutions. It is assumed that the results of the SECURE project will help the European Union develop strategic measures to reduce threats to energy security.

3.5.1. First generation scenarios

Table 35 shows scenarios used in the implementation of the SECURE project with deviations from the baseline conditions. The arrows indicate the path of formation of five scenarios from the matrix. The calculations for these scenarios were carried out in the POLES model.

Table 36 presents a brief comparison of the conditions laid down in the scenarios of the SECURE project.

Table 35. SECURE scenario matrix

EU Energy policy	Liberalisation, Competition (L)				State Intervention (I)			
EU climate policy	Technology-Based (T)		Hard Cap on Emissions (C)		Technology-Based (T)		Hard Cap on Emissions (C)	
World energy market	Smooth Path, stable prices (S)	Rough Ride, high prices (R)	Smooth Path, stable prices (S)	Rough Ride, high prices (R)	Smooth Path, stable prices (S)	Rough Ride, high prices (R)	Smooth Path, stable prices (S)	Rough Ride, high prices (R)
Scenario	LTS	LTR	LCS		ITS	ITR		

Table 36. Main scenario characteristics

Scenario	LTS	LTR	LCS		ITS	ITR		
EU discount rate	16%	16%	16%		4%	4%		
Technology development	Optimistic	Optimistic	Normal		Optimistic	Optimistic		
Oil and gas reserves	Normal	-20%	Normal		-20%	Normal		

Table 37. CO2 emission price, euro/ tone

	2005	2010	2020	2050
Europe	5	10	15	25
Other countries from appendix B (Kyoto protocol)	0	5	10	20
Other countries	0	0	5	15

The baseline scenario

The baseline scenario is created in order to provide a comparison with forecasts of world energy development at different rates of development and the introduction of modern technologies, as well as to verify the effectiveness of environmental policies and reductions in CO_2 emissions.

The baseline scenario uses exogenous projections for population growth and economic growth in various regions of the world. In order to take into account the current financial crisis, SECURE's baseline scenario envisages a 20% reduction in the rate of growth of gross domestic product for the period from 2008 to 2015, compared with the previous ADAM project. This corresponds to global gross domestic product in 2015 being more than 6% lower in the field of energy than in previous forecasts of the POLES model, but may, nevertheless, be regarded as optimistic in the context of the ability of the global economy to recover in the short and medium term. It is assumed that other hypotheses about growth in the world can be explored in future deployment of the model.

In general, the baseline forecast is based on assumptions about the limited availability of fossil energy resources, as well as the costs and effectiveness of new technologies. It uses the POLES system for simulation of the global energy sector in order to describe the development of national and regional energy systems up until 2050 and their interactions through the international energy markets, under the constraints of resources and environmental policies. This scenario – without much liberalization of the energy markets – suggests a normal discount rate on investments of 8%. Figure 21 shows the results of modeling the global and European energy markets with the baseline scenario.

The key results of the baseline scenario are a doubling of world energy consumption from 2000 to 2050 with a stabilisation of global oil and gas production after 2030. Despite the noticeable development of nuclear energy, biomass and other renewable energy sources, which in 2050 amounts to more than a quarter of the world's gross energy consumption, it is coal consumption which is most significant in terms of its contribution to the absolute increase in energy consumption, and it increases three-fold over the period 2000 to 2050

As for Europe, the dynamics of gross energy consumption is much less clear, with an increase from 1.7 to 2.3 billion toe (tonnes of oil equivalent) over the period 2000 to 2050. It will be observed that there is a leveling in the future consumption of oil and gas (to a lesser extent, this tendency is also characteristic of the world as a whole), an increased use of renewable energy and increasing consumption of coal, although in a more modest scale than on the global level.

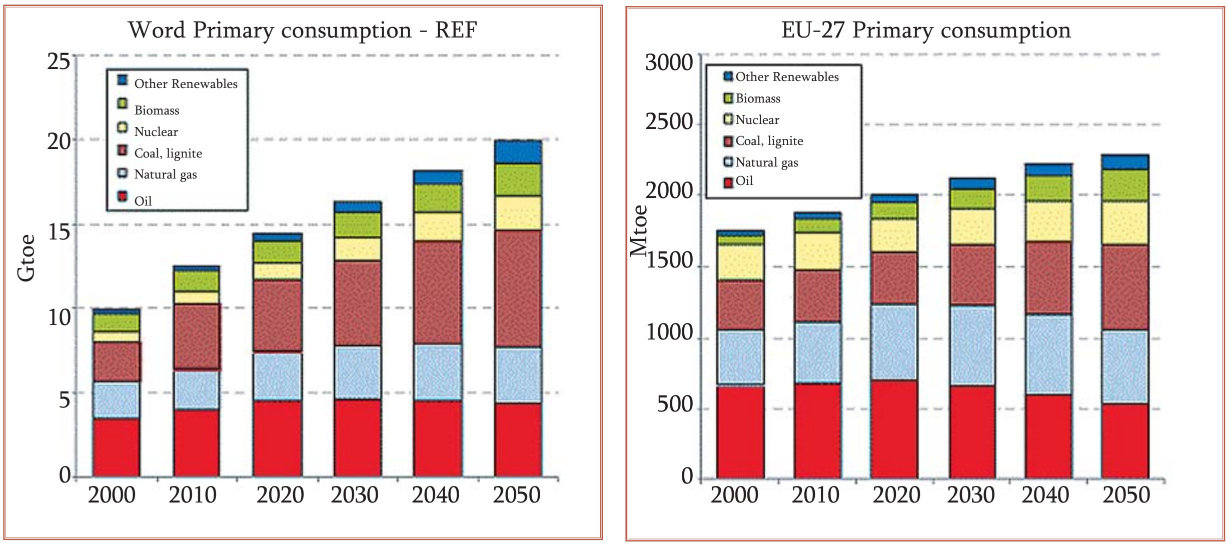

Figure 21. Results of modeling according to the baseline scenario

LTS Scenario: Liberalisation – Technology-based - Smooth prices

The projection for the global energy system in the LTS scenario must first of all take into account "minimal" environmental policies (although this is taken into account in the baseline scenario, developments in this direction are taken to be very slow). The policy of containment of greenhouse gases is reflected in fines for emissions or "carbon factor", which is regionally differentiated, with these fines being higher in industrialized countries, for example, than in developing regions. The system assumes that Europe will be the leader in climate protection and ecology. Figure 22 shows: emission charges exogenously entered into the system and prices for basic fuels calculated within the system.

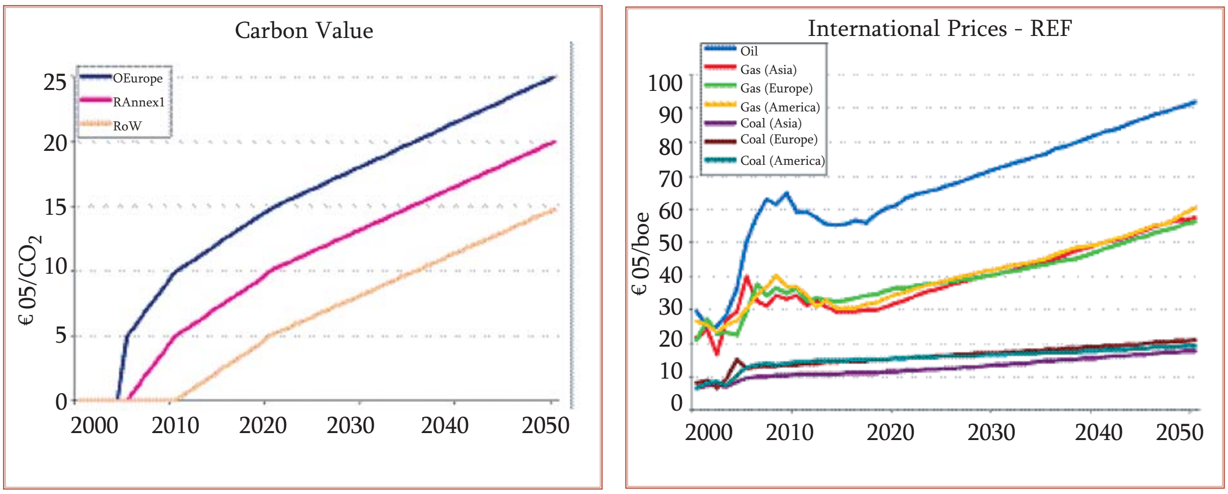

Figure 22. Emission charges and global energy prices

One important hypothesis of all energy scenarios based on liberalization is that the discount rate in Europe is higher than in usual forecasts. In this case, the selected discount rate is 16% instead of 8%, which reflects not only higher capital costs in the energy sector, but also the structural preference of energy companies for investment decisions with a short payback period. This hypothesis also includes an expectation of high competition in the external environment and the desire of companies to receive high returns on investment.

One important feature of forecasts based on the POLES model is that they rely on continual competition between technologies with dynamically changing characteristic features. The expected cost (investment) and operating costs for each critical technology is collected and analyzed using the TECHPOLES database adapted to user requirements. The LTS scenario considers alternative technological paths reflecting the possible ways of development of the European energy system. It assumes the accelerated development of all low-carbon energy technologies: capture and burial of CO_2 emissions, nuclear power, renewable energy sources and energy-efficient technologies for the end user. In fact, these hypotheses are not purely economic in nature, and reflect both the politics in this area, as well as expectations of its high efficiency.

The combination of these hypotheses explains the main results of the scenario, with a slightly lower gross consumption and global emissions of CO_2, compared with the baseline scenario. In EU-27 the total energy consumption is also lower than in the baseline case, but the most important difference between LTS and the baseline scenario REF is the development of nuclear energy: it is clear that these hypotheses, made primarily about the discount rate and for the determination the relative value of other energy technologies, will affect the development of nuclear energy in Europe. In the context of liberalization with a shorter forecasting horizon for investment decisions, nuclear technology clearly loses out to the other options for electricity generation, beginning with an approximate volume of production of 250 million toe in 2005: the output of nuclear energy in the LTS version will be 170 mtoe by 2050, compared to 300 mtoe in the baseline scenario. This change indicates a loss of competitiveness of nuclear technology given the assumptions entered into the LTS scenario.

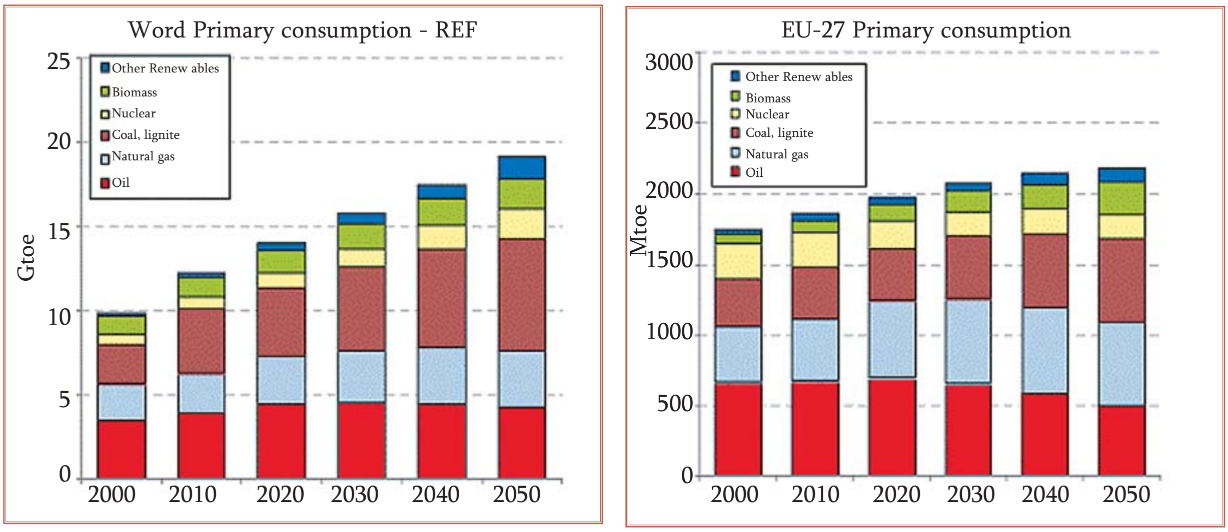

Figure 23. The results of the forecast in the LTS scenario

It is important to note that the assumptions of the LTS scenario lead to an increase in the future role of natural gas compared with the baseline scenario. This is evident from a comparison of Fig. 21 and Fig. 23.

LTR Scenario: Liberalisation – Technology-based – High prices

Assumptions about the availability of oil and gas resources are critical for POLES, since the current market conditions and a number of recent studies indicate that access to resources to meet growing demand may be problematic. Any long-term forecast of energy must be able to take into account the probability of oil or gas "peaks" (that is, the achievement of maximum levels for the global supply of these resources, followed by a drop in supply), which some geologists expect in the near future. The subsequent price increases could seriously influence the development of competing energy technologies, and change the future shape of the energy system.

Given these factors, the SECURE-LTR scenario pays special attention to the evaluation of oil and gas reserves. This scenario includes assumptions about the maximum recoverable reserves at a level of -20% of that of the baseline scenario and LTS.

This scenario also assumes shock price changes. It anticipates a doubling of prices for oil and gas by 2015 (Figure 24) compared with the price profile in the LTS scenario. This allows us to analyze the impact of sudden price changes on the stability of energy systems for the period until 2020.

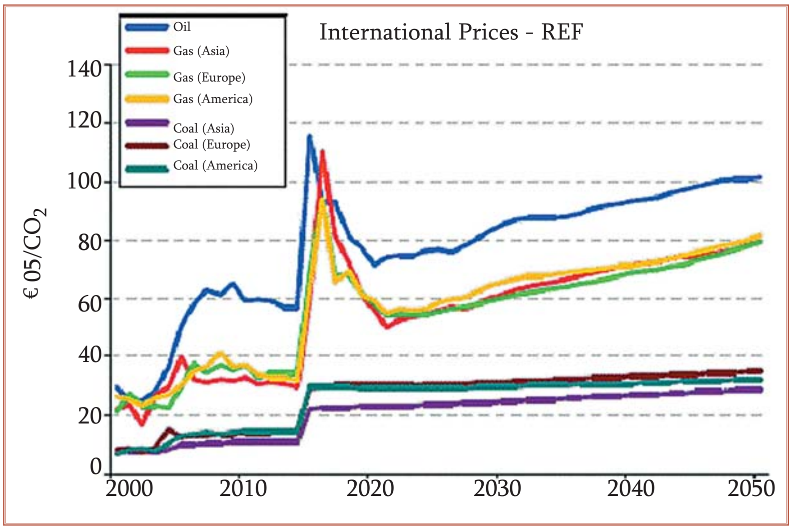

Figure 24. Prices for basic energy resources in the LTS scenario

The effects of exposure to price shocks in the global fuel-energy mix are very noticeable. The rise in prices is reflected in lower gross energy consumption compared with other scenarios, both in the EU and across the whole world, as well as a reduced demand for oil.

The most striking result of this scenario is that the oil and gas deficit will have a more deleterious effect on natural gas, development of the usage of which in the electricity sector becomes inefficient compared to coal and even more so when compared to nuclear energy and renewables. The reason for this is the high price of gas in a situation of competition between fuels, which is particularly acute in the electricity generating industry.

It should be noted that these results are obtained with additional assumptions of the weak reaction of coal prices to the energy price shock and the hypothesis of a disproportionately high jump in gas prices in North America and especially Asia.

In this scenario, the greatest negative impact will in general be on global gas consumption. Note that the expectation of "peak gas" in the reasonably near future is unrealistic, and its inclusion in the model calculations reflects an attempt to indirectly take into account political factors rather than the factors associated with natural gas reserves.

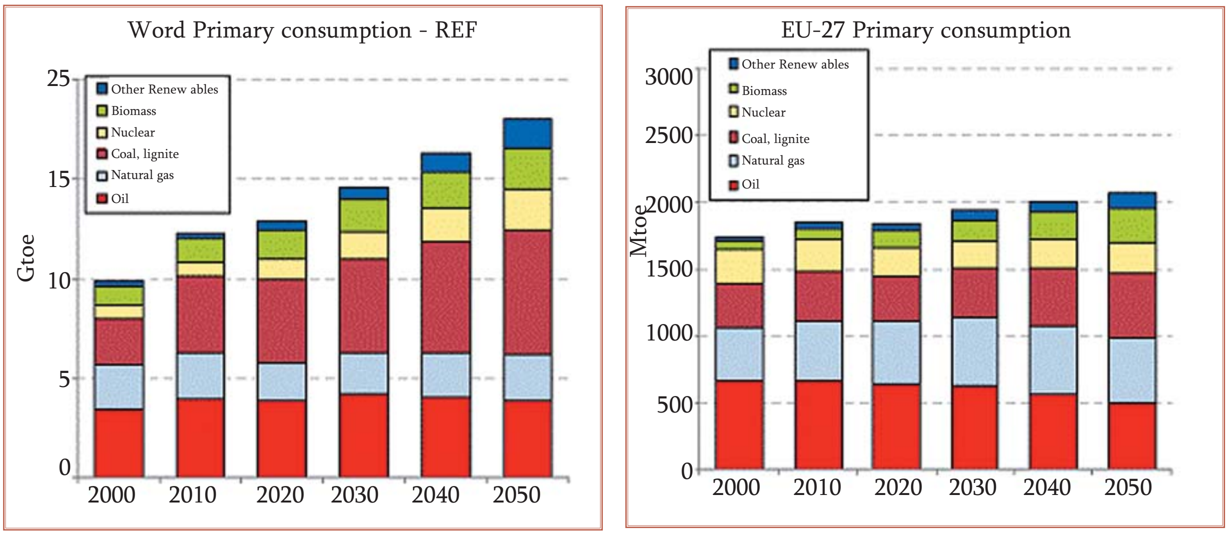

Figure 25. **The results of the calculation according to the LTS scenario**

LCS scenario: Liberalisation – Controls on emissions – Smooth prices

The main feature of this scenario is the introduction of emission controls. The scenario with a limit on CO_2 emissions reflects the state of the world with ambitious goals for reducing and determining the profile of emissions, which is compatible in the long term with a level of CO_2 concentrations at roughly 450 ppm (which corresponds to the alternative scenario of the IEA in its 2009 Review). This scenario should reflect the EU's policy on climate protection, which is currently under development, in its "moderate" version: -20% for emissions in Europe by 2020 relative to 1990 and -50% by 2050

The liberalization of energy markets presented here, as in previous scenarios, gives a higher discount rate for investment costs in comparison to the baseline scenario. The assumptions about the relative effectiveness of technologies and resources are identical. This scenario shows the expected structural changes and the direction of the development of the global energy system in the context of strict legislative limits on greenhouse gas emissions.

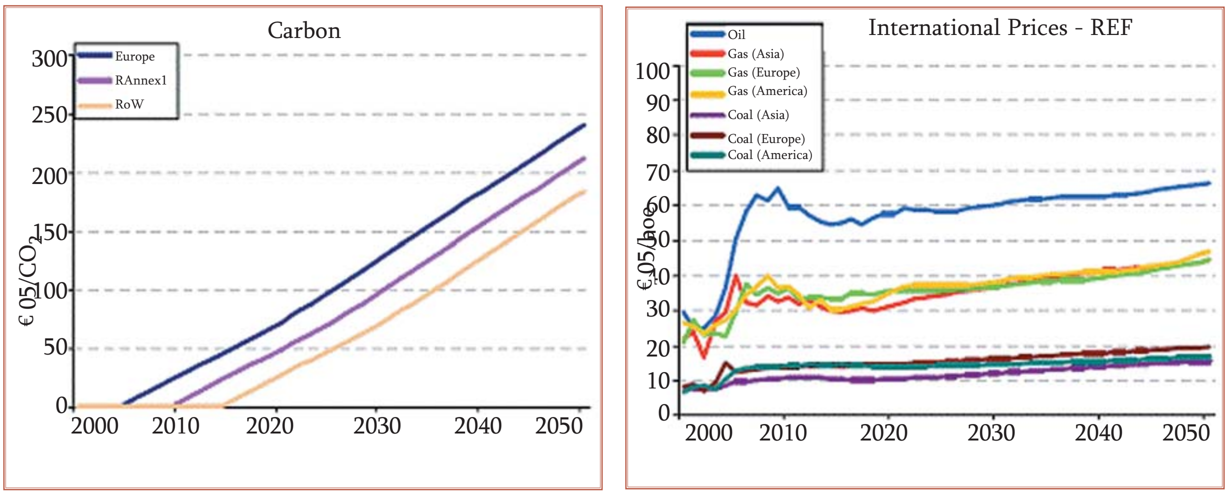

Figure 26. **Emission charges and energy prices in the LCS scenario**

In this scenario, CO_2 emission charges are set at a significantly higher level than in previous scenarios (Figure 26).

Such levels of payment for emissions are reflected in two major ways: the total domestic consumption and the structure of the fuel-energy mix in Europe and the world differs significantly from data obtained in the LTS scenario. In the new scenario there is a lower gross energy demand, a much lower consumption of coal and oil, and higher consumption of energy from nuclear power plants and renewable sources. In Europe, the total energy consumption is almost stable.

It is interesting that in this scenario, gas consumption in the EU up until 2020 does not change significantly compared to the previous scenarios. This is positive information for exporters supplying gas to Europe. However, prices for oil and gas in this scenario are much lower than in the LTS, as high demands on carbon emissions, which in this scenario are put into effect all over the world, force a severe reduction in the consumption of coal, oil and gas. As a result, the endogenous pricing mechanisms of the POLES model result in global energy prices being stable at a level slightly below their current values.

Note that a practically synchronous and sharp increase in the levels of emission charges worldwide, including the developing countries, is hard to achieve, as was shown by the experience of Copenhagen and the subsequent negotiations.

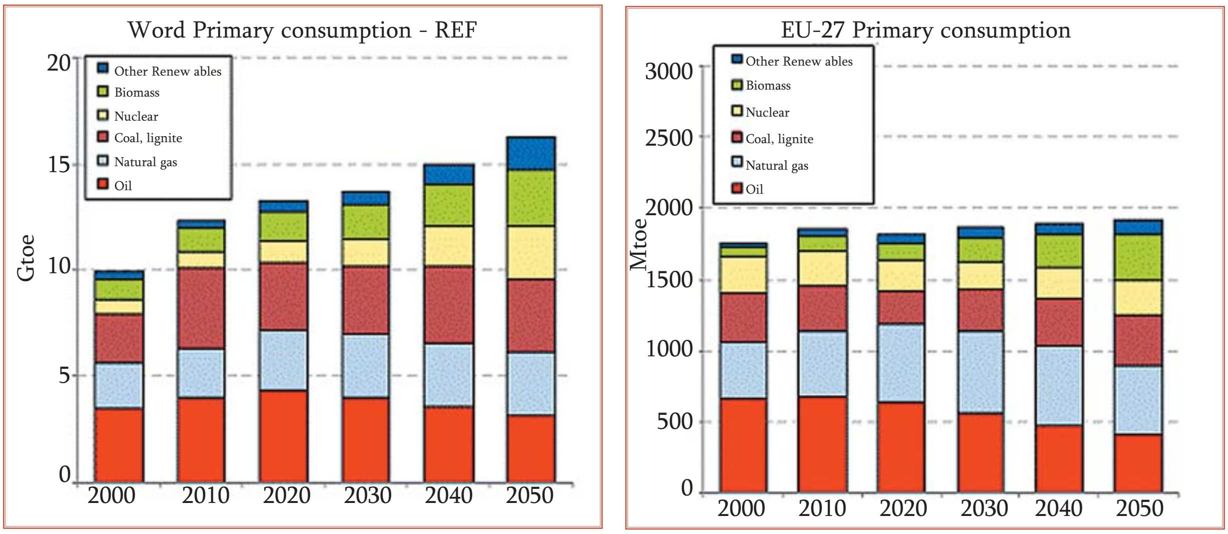

Figure 27. The results of calculations in the LCS scenario

This scenario is similar to the LTR scenario apart from the assumptions about the discount rate used for investment decisions in Europe, which is much lower (4%), reflecting a lower degree of market liberalization, greater state intervention and a longer planning horizon being taken into account when taking investment decisions in the energy sector. This has profound implications for all capital-intensive projects, particularly for low-emission technologies, and nuclear power is especially affected as far as it does not run up against possible limitations on the returns of investment. As a result, the development of nuclear energy in Europe is significantly different, with the overall consumption of nuclear energy in 2050 being 360 million toe, which is more than twice higher than in the LTS scenario.

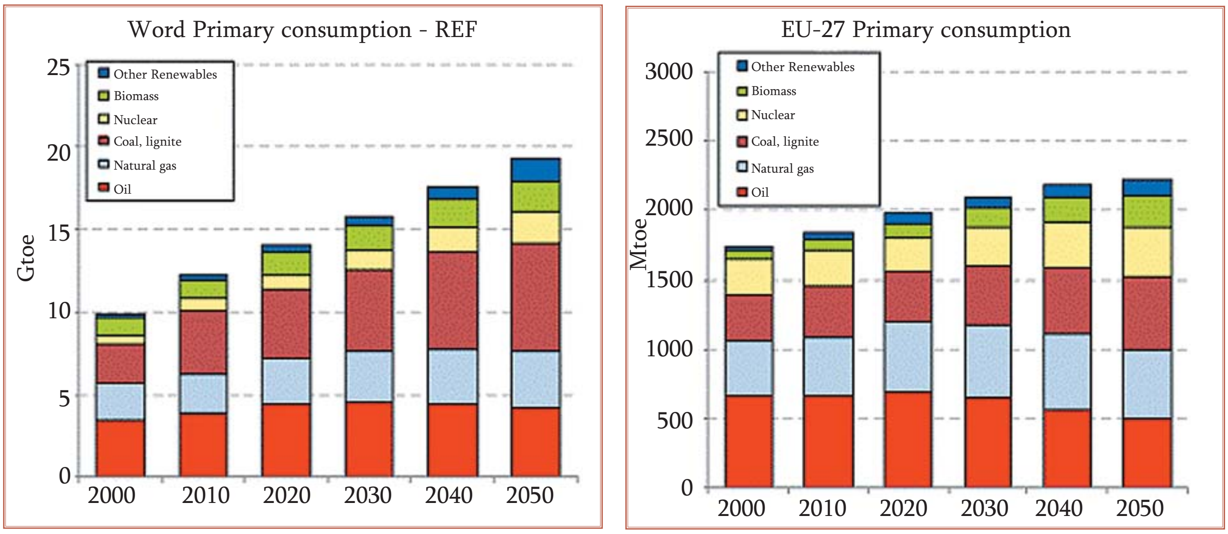

Figure 28. **Results of the calculation for the ITS scenario**

As a consequence, in this scenario EU-27 emissions are dramatically reduced. By 2050, without any substantial increases in environmental taxes, emissions in Europe will be at 1990 levels.

ITR scenario: Intervention by government in the economy – Technology-based – High prices
This scenario also corresponds to the LTR scenario, with an identical international context of oil and gas shortages and price volatility, but the main change is the assumptions about discount rates in Europe, which are set much lower (4%).

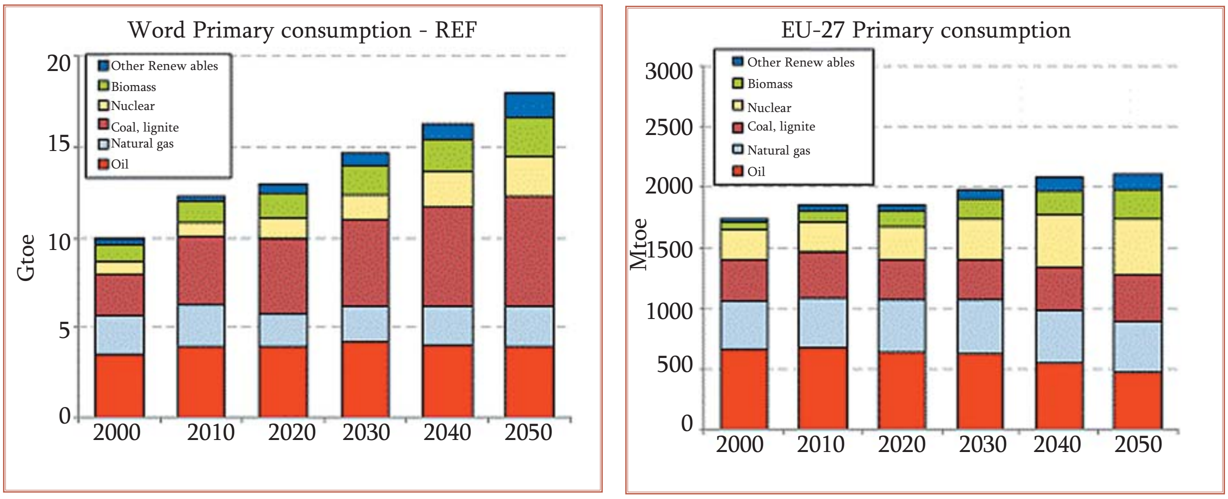

Figure 29. **Results of the calculation for the ITR scenario**

Because of higher international energy prices and lower discount rates in Europe, energy consumption is limited, while decisions about investment in capital-intensive projects (renewable sources of energy and nuclear energy) are actively stimulated. As a result, this is the scenario with the highest share of renewable energy and the lowest CO_2 emissions of all the options that do not foresee strict legislative limits on greenhouse gas emissions. In this scenario, by 2050 CO_2 emissions in the European energy sector will be 90% of 1990 levels.

3.5.2. Second Generation Scenarios

In the process of the development of the SECURE project it was decided to revise the previously developed scenarios and create a new range of scenarios for the project. The experts considered it unacceptable that only one of the five scenarios reflects the strategic objectives of Europe in the areas of energy efficiency and reduction of CO_2 emissions. The new range of scenarios takes into account the comments of the experts and includes a description of the historic process at the root of each of the scenarios.

Three new scenarios will be further discussed, but it is also necessary to calculate a hypothetical scenario – the baseline, i.e. the development of world energy supplies without any policy to reduce emissions of greenhouse gases. This scenario is not realistic, because some sort of policy, however uncoordinated and insufficiently rigorous, is already being conducted by a number of countries. So such a scenario is principally created for comparison with the other energy options.

Hypothetical variant – Baseline scenario

As already mentioned, the baseline scenario has been developed under the condition that up until 2050 no environmental-protection policies will be carried out. Taking into account the fact that some environmental policy is already a reality, this scenario is only used for comparison with the other development options.

In the baseline scenario, world population increases from 7 billion in 2010 to 9 billion in 2050, the world's GDP triples and the consumption of primary energy resources increases by 70%. Fossil fuels account for 83% of total consumption in 2010, but despite continuous growth in their consumption by 2050 this proportion will fall to 76%. Coal consumption in 2050 is doubled, oil consumption grows and reaches a peak in 2030, and the consumption of natural gas also increases. The share of renewable energy sources in the total energy mix will remain fairly modest and will increase from 12% in 2010 to 17% by 2050.

With regard to Europe, total energy consumption here will grow by 16% during the period 2010 to 2050. The share of oil in total energy consumption over the period drops from 37% to 25%, while the share of coal increases from 17% to 25%. The share of renewable energy sources will only increase to 17% by 2050.

EU dependence on energy supplies from third countries increases. In 2010, the EU imported 53% of its total consumption of energy resources, and by 2050 the proportion of imports will increase to 58%.

On the supply side, a significant increase in world oil demand puts pressure on its reserves. Up until 2030 the oil companies will continue to develop the major oil fields in the Middle East, accessible fields in North Africa, as well as cost-effective fields in the North Sea. Many other rich hydrocarbon regions will remain unexplored, as access is difficult for international oil companies (IOC). A strengthening of energy "radicalism" in Russia and Latin America will create an unfavorable investment climate for the IOC, which will further reduce the extent of its exploration of potential regions.

The desire of the major energy companies to operate in reliable and familiar regions leads to a low interest in unconventional oil resources. Thus, companies will not be ready for the oil crisis in 2030 when world oil production peaks, and the reduction in reserves will lead to a decrease in production volumes by 0.3% per annum in the period from 2030 to 2050.

The transition to less accessible oil reserves will demand that companies increase investment and operating costs, which will lead to significant price increases to more than $130 per barrel in 2050.

In this scenario, CO_2 emissions worldwide will increase more than 2-fold by 2050 compared with 1990, while the average temperature will increase by 5-6 degrees by the end of the 21st century.

In addition to the normal course of each scenario, three additional possible cases were tested for their development. Each case begins in 2015, after which there is an analysis of its impact on each of the scenarios.

Oil and gas shock implies a tripling of oil and gas prices as a result of tensions in the market. This shock leads to a reduction in primary energy consumption in the EU by 8% in the short term (until 2020) and by 7% up until 2050, relative to the levels of consumption without the price shock. For power generation there will be a replacement of fossil fuels by nuclear energy, which will reduce emissions by 17% by 2050 compared with the variant without the shock.

In contrast to the first shock, the second – an accident at a nuclear power plant – will halt the construction of new plants after 2015 and lead to the phasing out of existing ones. To compensate for the reduction in the use of nuclear energy, the EU energy mix will see an increased share of fossil fuels.

A third variant of the scenario involves a halt in the development of technologies for capturing greenhouse gases, due to issues of safety and economic efficiency. In the baseline scenario, environmental policy plays no role so the shock does not have an affect in either the short or long term.

Scenario 1: Copenhagen forever (Global disagreement)

Despite decades of talk about the need for collective international action to prevent climate change, national authorities decide to provide their own energy security in the short term, rather than creating a stable global system of cooperation. The first missed opportunity to negotiate – the meeting in Copenhagen in 2009, where under pressure from the US Congress and some developing countries it proved impossible to establish a goal of reducing emissions by 50% by 2050 relative to the 1990 level.

An era of energy "nationalism" begins, which leads to instability in the global energy sphere. In such a world, countries focus on their own well-being, ignoring the creation of a stable international community, which leads to a boomerang effect and negative consequences for all countries. Due to the low efficiency of national energy policies, the energy dependence of Europe and other consuming countries increases and their economy falls into dependence on decisions made in the Middle East, Africa and the Caspian region.

In order to support economic growth, countries such as the United States, Japan, China, India and Brazil take the decision to reduce support for costly and unpopular policies for the development of energy efficient and environmentally friendly technology. As a result, the world production of fossil fuels is increased by 22% by 2030 compared with 2010. This leads to an irrational utilization of resources and the early achievement of peak oil production in 2030.

The most worrying thing in this world of energy nationalism is the rapid growth in coal consumption, especially noticeable in countries which have large coal reserves (for example, the U.S. and China). In this scenario, world coal consumption increases by 5 times by 2050 compared to 2010, this being due to efforts by countries to reduce energy dependence, as well as to its low cost of production.

Also due to the low emissions charges (40 €/tonne CO_2 in the EU and 32 €/tonne CO_2 in other countries) the pace of the development and implementation of technologies to capture and reduce greenhouse gas emissions remains very low. By 2050, only 10% of electricity generation from coal will be using carbon capture and storage (CCS) technologies.

Despite the significant increase in coal consumption, growth in the share of fossil fuels in total energy consumption will be provided chiefly by the increase in gas consumption (62% in 2050 compared with 2010).

World production of renewable fuels will almost triple by 2050 relative to 2010, and they will account for 20% of total energy production in 2050. At the same time, the share of installed capacity of power plants running on renewable energy sources increases from 24% in 2010 to 46% in 2050. In large part this growth is due to the development of solar energy and energy from biomass.

Installed capacity using wind energy will also increase and by 2050 will exceed in volume the capacity of large hydroelectric power stations.

The absence of an agreed international policy on climate change and the dominance of nationalist energy policies in the major regions producing greenhouse gases will have a negative impact on achieving EU goals for energy efficiency and climate change.

On the one hand, low emission targets around the world will keep emission charges in the EU at a low level, making it unattractive for investors in low-emission technologies. In the longer term, this increases the cost of reducing emissions for enterprises and power stations in the European Community. On the other hand, despite the goal of the EU member states to stabilize the global temperature rise to 2 degrees compared with the pre-industrial period, it soon becomes apparent that this is unattainable without international agreement. Caught in an awkward position and conscious of the significant impact on emissions from China and India, instead of taking a more assertive stance in international negotiations, the EU also adopts a nationalist stance, linking energy policy with other issues of world trade and mutual relations. The EU therefore weakens its domestic policies aimed at reducing emissions. As a result, there is an irreversible cycle of global inaction.

Despite the fact that by 2020 the EU will achieve reductions in CO_2 emissions of only 4% (compared to the 1990 level), its policies will however be aimed at the target of 20%. This will lead to a reduction in coal consumption in the EU by 7% by 2020 relative to 2010. Similar dynamics for oil will lead to a fall in oil consumption by 2050 of 28% relative to the level in 2020. To compensate for the decrease in consumption of coal and oil up until 2030, there will be an increase in the consumption of natural gas, but subsequently this volume will also be reduced along with a decrease in total primary energy consumption.

EU countries will not achieve the goal of increasing the share of renewables in total energy consumption to 20% by 2020, this goal only being achieved in 2050.

As it was in the baseline scenario, the influence of the three shocks to energy development is also investigated in the Global Disagreement scenario. The first shock – oil and gas – reflects the effect of tripling the price of oil and gas on the energy mix. For the EU, the reduction in the total primary energy consumption, compared with the scenario without the shock, will be 8% in 2020 and 5% in 2050. A reduction in the volume of CO_2 emissions by 10% in 2020 and 14% in 2050 will mainly be due to the rapid increase of nuclear generation in the energy mix.

The second shock is an accident at a nuclear power plant. According to the estimates, this shock will lead to a reduction in nuclear energy production by 2050 to 70% of the originally planned level. Thus, an increase in the share of fossil fuels in the energy mix of EU countries will lead to an increase in emissions of 7%.

The third shock – restriction of the development and deployment of CCS technologies – will lead in this scenario to some changes in the balance of fuels for power generation. There will be a reduction in the share of fossil fuels, with an increase in nuclear energy and an unchanged share of renewable sources. As a result of this shock, CO_2 emissions from power generation will be 14% higher in 2050, while total emissions will grow by 5%.

Scenario 2. EU aims for 30% (Europe goes it alone)

Despite the fact that an international climate change agreement has not been reached, the EU does not change its strategic objectives in energy efficiency and environmental protection. EU countries not only keep to their established course of 20-20-20 by 2020, but they also strive to achieve emission reductions of 60% by 2050 relative to 1990 levels. In this case, of course, the influence of EU policy on global CO_2 emissions will not be large. The EU's aspirations will be offset by the emissions of countries such as USA, China, India and Brazil.

In this scenario, it is a benefit for the EU that through sustainable policies for energy efficiency and alternative energy it is able to significantly increase energy security and reduce dependence on energy imports from third countries. The development of renewable energy technologies would create 3 million jobs by 2020, mainly in the production of biomass, wind and hydropower.

The EU's aspiration to achieve its set goals will reduce primary energy consumption by 2050 to below 2000 levels. The main reductions will be in the transport and industry sectors. By 2050, primary consumption of coal and oil will be reduced by 48% and 50% respectively compared to the 2010 level. The situation will be different for the consumption of natural gas, where the volume will not decline until 2030.

Renewable energy sources will increase their share of total energy consumption in Europe to 47% by 2050. In power generation, the share of renewable energy could reach 34% by 2020 and 52% by 2050. The main growth is provided by solar energy, with significant increases also in the production of wind energy and biomass.

Despite the fact that nuclear energy is environmentally attractive, its share of electricity production is reduced from 27% in 2010 to 21% in 2050.

The results of the analysis of the impact of shocks on this scenario differ little from the previous scenarios. Thus a threefold increase in prices for oil and gas in 2015 will reduce energy consumption in the EU, compared with the variant without the shock, by 6% in 2020 and 3% in 2050. CO_2 emissions in the EU will also decline (by 8% in 2020 and 6% in 2050) due to the increased share of nuclear energy in the total energy mix.

Just as in previous variants, an accident at a nuclear power plant leads to a significant reduction in the share of nuclear energy. The replacement of nuclear power by fossil fuels will increase emissions of CO_2, despite the available CCS technologies.

In the absence of CCS technologies, nuclear power will increases its share in the overall energy mix. This is due to the fact that the use of fossil fuels becomes too expensive. Despite the change in the energy mix, total emissions from the remaining consumption of coal, oil and gas in 2050 will be 11% higher than in the version without the shock.

Scenario 3. Agreement in Johannesburg (Global regulation)

The world powers manage to reach an agreement on climate change, whereby the global temperature increase will amount to no more than 2°C compared to pre-industrial levels. In this scenario, CO_2 emissions would peak in 2020 and then begin gradually to decline.

Public opinion exerts a significant pressure on governments in both Europe and Asia, demanding that sustainable energy policies are followed, ensuring quality of life for current and future generations. The global energy mix changes with countries reducing their consumption of fossil fuels and switching to environmentally friendly ones – renewables and nuclear energy.

This scenario assumes that two markets for emissions will be formed: the countries of Annex 1 (industrialized) and other (developing) countries. Nevertheless, one variant was considered where a single global market for emissions trading is created.

After a peak in oil consumption in 2020, there will be a period of reduction in demand for this type of fuel, so that by 2050 consumption will be reduced by 27% (compared to the 2010 level), and global oil prices will fall to $58 per barrel in 2050. Coal consumption diminishes rapidly after 2010. Due to high CO_2 emission tariffs (180 €/tonne in 2030 and 392 €/tonne in 2050 for Annex 1 countries, and 43 €/tonne in 2030 and 257 €/tonne in 2050 for other countries), CCS technologies will become very profitable, with their use increasing rapidly after 2030. By 2050, 90% of all electricity generated from coal will be produced with the use of CCS technologies. Natural gas will remain an important source of global energy and consumption will only show a gradual decline after 2030.

The share of renewable energy sources in total electricity production will reach 30% by 2030 and grow to 40% by 2050. The main growth will be provided by solar energy and biomass. Electricity generation from wind energy will also grow, but by 2050 the amount of biomass consumption will surpass wind energy and will take second place among renewable sources after hydropower. Also, the share of nuclear energy will also increase thanks to higher CO_2 emission charges.

Against this background of a global trend to reduce CO_2 emissions, the EU decides to set itself a goal of an 80% cut in emissions by 2050 compared to 1990. The only way to achieve this goal is the development the European emissions trading system which was established in 1995. The EU will achieve this goal thanks to an increase in the share of renewables in the total energy mix to 47% in 2050. The most noticeable shift to renewable energy will be seen in power generation – by 2050 more than 50% of electricity will be produced from renewable energy sources, 23% from nuclear energy, and 22% from fossil fuels. This change in the mix significantly reduces the EU's dependence on energy imports from third countries, so if in 2010 more than 50% of all primary energy comes from other countries, by 2050 this will drop to 30%.

Just as in the other scenarios, the three shocks are also applied here. The influence of nuclear energy and CCS technologies on this scenario is so large that the reaction to an accident at a nuclear power or the absence of CCS technologies will be more severe than in the previous scenarios. At the same time, the economy's low level of dependence on fossil fuels will provide a softer reaction to the tripling of oil and gas prices.

Analysis of energy security for the EU-27 countries in the POLES model according to the SECURE scenarios

Modeling the scenarios described above in the POLES systems allows us to evaluate the dependence of the economies of the EU-27 countries on energy imports as a whole and for individual fuels (Table 38). From scenario to scenario, the level of dependence of the economy on imports of a particular energy resource shows only insignificant differences. More representative in this case is the analysis of the economy's overall dependence on imports, which varies significantly in the different scenarios.

Analysis shows that with a tightening of EU and global policies for reducing emissions and developing energy-saving methods, the dependence of the EU on energy imports is also reduced. This is accompanied by an increase in its energy security. In scenarios with lower energy consumption, an increase in nuclear energy production is observed and an increase in its share in the energy mix, with a reduced production of fossil fuels.

Analysis of the data presented in Table 38 does not allow us to evaluate security using the absolute values of consumption. Table 39 shows the level of total energy consumption in the EU-27 countries and the amount of energy they will have to import from third countries.

The results of the SECURE project include a methodology for a qualitative and quantitative evaluation measuring the reliability of energy supplies, scenarios for the reliability of energy supplies for the period up to 2030 and recommendations for energy policy/regulatory legislation, which aims to improve the reliability of energy supplies. These recommendations will take into account the cost, effectiveness and risks of various legislative solutions. It is assumed that the results of the SECURE project will help the European Union to develop strategic measures to reduce threats to energy security.

Table 38. The share of import dependence on energy resources in the EU-27, %

Scenario	Energy source	2010	2020	2030	2040	2050
Baseline	**Total**	**53**	**58**	**61**	**61**	**58**
	Coal	33	39	48	53	56
	Oil	81	84	87	87	86
	Natural gas	69	83	90	94	96
Muddling Through	**Total**	**53**	**57**	**60**	**57**	**53**
	Coal	32	35	44	48	50
	Oil	81	83	86	86	85
	Natural gas	69	83	91	94	96
Europe Alone	**Total**	**52**	**51**	**45**	**38**	**31**
	Coal	31	28	35	39	42
	Oil	81	81	82	81	78
	Natural gas	69	79	81	79	76
Global regime (2 emission markets)	**Total**	**50**	**48**	**39**	**32**	**26**
	Coal	31	28	37	41	47
	Oil	81	81	80	81	82
	Natural gas	62	72	73	71	70
Global regime (international emission market)	**Total**	**50**	**51**	**47**	**37**	**29**
	Coal	32	33	39	43	45
	Oil	81	82	85	84	83
	Natural gas	61	73	77	75	73

Table 39. Total EU-27 energy consumption and energy imports, mtoe

Scenario	Energy source	2010	2020	2030	2040	2050
Baseline	**PEC**	**1 764**	**1 883**	**2 004**	**2 041**	**2 053**
	Import by fuel type:					
	Coal	102	130	191	246	285
	Oil	532	560	564	511	440
	Natural gas	293	393	473	490	475
Muddling Through	**PEC**	**1 759**	**1 820**	**1 911**	**1 909**	**1 881**
	Import by fuel type:					
	Coal	95	96	132	144	146
	Oil	532	543	537	475	399
	Natural gas	298	399	471	473	448
Europe Alone	**PEC**	**1 741**	**1 723**	**1 731**	**1 737**	**1 724**
	Import by fuel type:					
	Coal	88	50	58	61	61
	Oil	524	466	378	304	235
	Natural gas	292	365	350	288	245
Global regime (2 emission markets)	**PEC**	**1 742**	**1 707**	**1 694**	**1 708**	**1 700**
	Import by fuel type:					
	Coal	86	48	60	62	51
	Oil	525	446	317	252	198
	Natural gas	264	327	282	226	184
Global regime (international emission market)	**PEC**	**1 748**	**1 802**	**1 845**	**1 795**	**1 723**
	Import by fuel type:					
	Coal	91	76	80	76	73
	Oil	526	497	428	320	216
	Natural gas	260	351	359	276	206

We note the following general conclusions:

- the analyses presented in the study, as well as other efforts aimed at long-term analysis of world energy development, show that it is extremely difficult, if not impossible, to achieving the declared objectives of a sharp reduction in global greenhouse gas emissions in the coming decades;
- a detailed analysis is required of the optimistic prospects for energy technologies incorporated into the scenarios;
- the submitted material does not reflect the work carried out in the project on a risk analysis of the various options for EU energy supplies, which was reported by the project developers at a seminar in Moscow in the summer of 2010. The options presented there include the possibility of a sharp decline in the volume of gas imports, including those from Russia, to levels well below those of existing long-term contracts.

The SECURE project and its methodology is undoubtedly of great interest, and therefore it is important during this final phase to increase interaction with its developers in the Energy Dialog framework. This is especially important because the findings from the project will be analyzed in the EU at the political level.

Chapter 4. World scenarios of energy development

Section 4.1. International Energy Agency

World Energy Outlook (WEO) is based on the updated 14th version of World Energy Model. It covers 24 world regions. The analysis includes about 3600 governmental policy measures of all the reviewed countries of the world. All the measures are listed and briefly described. However, it is not specified how these measures are incorporated in the model.

4.1.1. World Energy Outlook-2009 – Reference Scenario

WEO-2009 report features two scenarios: Reference and "450" (low-carbon) scenario. The Reference Scenario assumes the governments will not take any other state policy measures except for those implemented by mid-2009.

Assumptions

Detailed methodology description and assumption classification are presented in the "WEM Model General Description" section below. The following section is dedicated to specific numeric values of the assumptions as well as to the factors that influenced them according to the IEA report.

Table 40. GDP growth forecasts in the regions of the IEA of 2008 and 2009

WEO-2009	2007-2015	2015-2030	2007-2030
OECD	1.4	1.9	1.8
non-OECD	5.7	4.1	4.6
EU	1.1	1.8	1.5
USA	1.8	2.2	2
Russia	3.3	3.4	3.4
China	8.8	4.4	5.9
World	3.3	3	3.1
WEO-2008	**2006-2015**	**2015-2030**	**2006-2030**
OECD	2.3	1.8	2
non-OECD	6.7	3.7	4.8
EU	2.2	1.6	1.8
USA	2.1	2.1	2.1
Russia	5.7	2.4	3.6
China	9.2	4.3	6.1
World	4.2	2.8	3.3

Sources: IEA, World Energy Outlook 2008, 2009

The World Energy Outlook 2009 states that WEM model forecasts are highly sensitive to the adopted economic growth assumptions. Thus, a 1% world GDP growth (PPP real) increases the primary energy resources consumption by 0.7%. Meanwhile, the demand for electricity and diesel fuel in WEM has almost single correlation with the GDP.

As seen in Table 40, the economic downturn has led to a drop in WEO-2009 forecasts of economic growth rates in the world. Generally the growth rates forecasts by 2030 declined by 0.1-0.3% compared to the 2008 forecast. By 2015 economic growth rates in all regions are considerably lower than pre-crisis forecasts. One of the most significant forecast declines is observed in Russia – from 5.7% to 3.3% annually.

Within the period of 2015-2030 the GDP growth rates are expected to exceed the pre-crisis forecasts and that will allow to partially making up the drop caused by the crisis.

Table 41. Assumptions for real prices of energy sources in the Reference scenario of WEO-2009

Energy source	2000	2008	2015	2020	2025	2030
OECD oil import, $/bbl	34.3	97.19	86.67	100	107.5	115
Natural gas import, $/MBtu						
USA	4.74	8.25	7.29	8.87	10.04	11.36
Europe	3.46	10.32	10.46	12.1	13.09	14.02
Japan (LNG)	5.79	12.64	11.91	13.75	14.83	15.87
OECD import of steam coal, $/tone	41.22	120.59	91.05	104.16	107.12	109.4

Sources: IEA, World Energy Outlook 2009

The WEO-2009 report itself does not specify the coal energy equivalent the price assumptions are based on. Assuming that the nominal level of prices for power-generating coal in 2000 and 2008 matches with the IEA Energy Prices&Taxes reports, it is reasonable to assume that these materials are based on the same energy equivalent. However, Energy Prices&Taxes reports again do not specify the exact calorific capacity of the average import prices; it's only indicated that this value is the weighted average of all OECD countries. Due to the fact that the ratio of the volume of supply from each country, as well as the average calorific value of coal supplied are constantly changing, it is impossible to determine the energy value of coal in the price assumptions for 2015-2030 based on the data published by the IEA. Since this indicator is important for comparing different scenarios, it should be specified by the IEA.

Introduced as a assumption for the WEM model the import prices for energy have been taken in accordance with the authors' estimate of the price levels necessary to ensure the required level of investment to meet the demand in the forecast period (by 2030). Assumptions on energy resource prices were obtained through an iterative procedure to balance supply and demand in the forecast period. Therefore, these prices are not a forecast, but a trajectory, around which the actual prices should fluctuate in accordance with the IEA model.

Table 42. Price growth rates in Reference scenario, % per annum

Energy source	2000-2008	2008-2015	2015-2020	2020-2025	2025-2030
OECD oil import, $/bbl	13.9	-1.6	2.9	1.5	1.4
Natural gas import $/MBtu					
USA	7.2	-1.8	4.0	2.5	2.5
Europe	14.6	0.2	3.0	1.6	1.4
Japan (LNG)	10.3	-0.8	2.9	1.5	1.4
OECD import of steam coal, $/tone	14.4	-3.9	2.7	0.6	0.4

Sources: IEA, World Energy Outlook 2009

WEO authors note that the assumption of a gradual recovery in oil prices by 2015 is based on IEA expectations about strengthening the international oil markets combined with the revival of the global economy. Oil prices in 2000-2008 grew faster than gas prices (higher gas prices growth rates in Europe account for the fact they are mainly determined in accordance with long-term contracts that are tied to oil prices and oil with a lag, and the fall in oil prices in Sep -Dec 2008, didn't affect gas prices in 2008).

In addition, IEA-forecasted oil price fall in the world and gas price fall in the US and throughout Europe in 2008-2015 are accompanied by the increase of gas prices in Europe in IEA assumptions. Considering the prices tied in the long-term gas supply contracts to oil, a significant increase in spot prices for natural gas imports in Europe will be necessary to achieve the required values for these assumptions (+0.2% per year in Europe in 2008-2015.). Meanwhile the situation on the EU spot market does not give any grounds for such assumptions. IEA forecast developers attribute this effect to the anticipated convergence of gas prices in regional markets in the course of the global gas market development. As a result, in the period from 2008 to 2015 European import gas prices will approximate the Japanese prices (that is, LNG prices in the Pacific region).

Similarly, in the IEA scenario, in the period from 2015 to 2030 the US gas prices increase at an outstripping growth rate, gradually catching up with European and Japanese levels. Meanwhile the gas prices in Europe and Japan are growing at the same rates as the oil prices.

International prices for energy resources are used in the IEA forecast in order to receive the final prices of gas, oil and coal in every sector of consumption and in each region being analyzed in the WEM. But in a number of regions the domestic prices are not tied to the given import prices, but depend either on domestic production or imports from other regions (not in the form of LNG). This applies, in particular, to domestic natural gas market in Latin America, Russia, Africa, Australia, the Middle East and the coal market in some regions. It is therefore important to understand how the forecasts of the ultimate prices for energy resources are built. The IEA states that the model takes into account the current pricing policies and market reforms in the energy sector, as well as the corresponding subsidies. However, this information is not enough to build a long-term forecast of gas prices in the final market, more assumptions are required (for example, about the rate of price increases or their pegging to some factors, dependence on production costs, etc.). In particular, it is known that the IEA expects Russia to achieve export parity of gas prices by 2020. However, even in this case it is necessary to include assumptions about the cost of transportation and the difference between Russian export prices and the average price of exports to Europe (the IEA assumes that taxes, including export duty remain constant). Yearly price growth rates by 2020 are unclear. However, according to the report, for a number of other regions such assumptions about the mechanism of home price modelling cannot be made.

The report's authors note that the rates of decrease in the energy subsidies are different for each region, but their values are also unknown.

WEM-2009, unlike its previous version, includes a number of new state policy measures in the energy sector. The most important ones are presented in Table 43.

At the time of writing WEO-2009 only the EU has implemented a system that sets prices for carbon dioxide emission quotas – EU Emissions Trading System (EU ETS). Therefore, in the reference scenario the pricing for quotas on greenhouse gas emissions is limited to electric power and industry in the EU. ETS market prices are expected to amount to 43 dollars / ton in 2020 and 54 dollars / ton in 2030.

The demographic assumptions also include the forecast that in 2007-2030 the world population world will grow on average at a rate of 1% per year, while in OECD countries it will grow by 0.4% per year, and in non-OECD countries – by 1.1% per year.

Table 43. New governmental measures introduced in the Reference scenario of WEO-2009

Country	Program/regulation measure	Brief description
USA	New standards of the Corporate Average Fuel Economy (CAFE)	Sales-weighted fuel economy for light-duty vehicles capped at 39 mpg in 2016, 35.5 mpg for cars
China	"Golden sun" program	Subsidies 50% of investment cost for on-grid solar-power projects (over 500 MW) and 70% for off-grid projects, 2009-2011
	Entry tariff for wind electricity	Four categories of on-grid tariffs for new wind projects, based on regions of varying wind conditions.
	Nuclear development program	Planned expansion of nuclear capacity to 2020
EU	"20-20-20" Program	Cap on overall greenhouse-gas emissions of 20% below 1990 levels by 2020. National renewable energy targets for emission reductions and to reduce energy imports. Include a minimum 10% share for alternative fuels in gasoline and diesel by 2020. Revised guidelines on state aid for environmental protection to support development and safe use of carbon capture and storage (CCS).
Japan	Photovoltaic subsidies and an entry tariff for households	Subsidy: JPY 70 000/kW with a total budget of JPY 20 billion (April 2009 to January 2010). Feed-in tariff: surplus electricity to be purchased by electric utilities at twice retail price (JPY 48/kWh)

Sources: IEA, World Energy Outlook 2009

In terms of methodology the following innovations were added into the 2009 version of the model (compared to the 2008 version):

- Modules for power generation and supply of natural gas have been completely redesigned.
- Modules on Transport and carbon dioxide emissions have been improved.
- New module for desalination was introduced for the countries of Middle East and North Africa.
- The number of regions increased from 21 to 24, within the ASEAN region a country analysis was carried out for Thailand, Malaysia and the Philippines.

Natural gas

Compared to the 2008 report there was a decrease of forecasts on the consumption of natural gas, which was largely due to economic crisis (and decrease of forecasts on GDP growth in the future). According to the WEO-2008 reference scenario the EU demand for natural gas by 2030 should reach 681 bcm, while in WEO-2009, it equals to 619 bcm. In addition, according to the new forecast the demand growth rates for natural gas in the EU in 2015-2030 is even higher than in 2008 document. The main effect of demand growth rate reduction takes place in the period to 2015 (Figure 30).

Such conclusions seem quite disputable. Clearly, in the first half of 2009 the levels of gas consumption were combined with several factors: economic crisis building up (which particularly affected the consumption of gas in Russia, Ukraine and, to some extent in the EU), high gas prices on long-term contracts amid the sharp fall in oil prices, problems of gas transit through Ukraine, warm winter in 2009. It is clear that while WEO-2009 report was being prepared (mainly during the first half of 2009), these factors might seem crucial for the prospects of the next few years. But things with the demand began to improve in the second half of 2009.

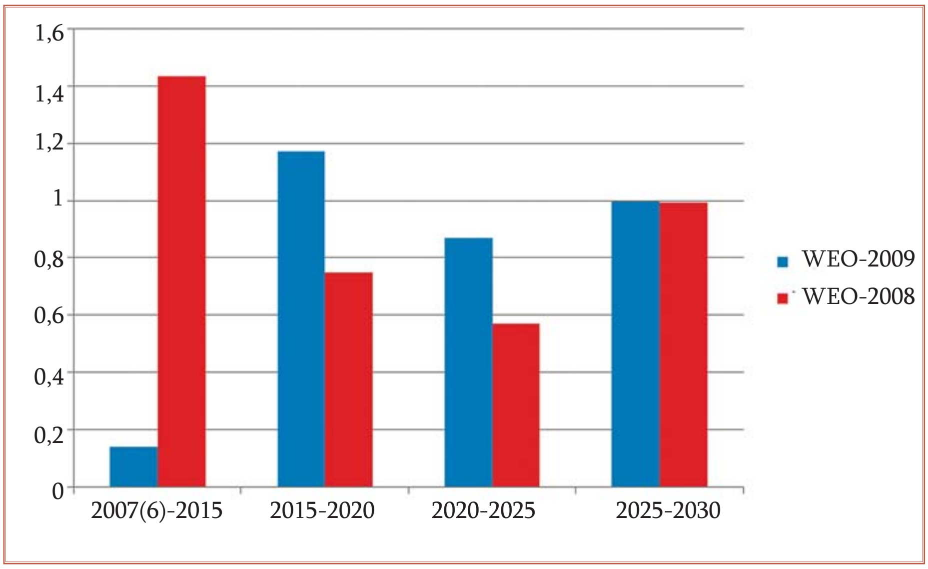

Figure 30. Average yearly gas demand growth rates in EU according to BaU scenario IEA 2008 and IEA 2009
Sources: IEA, World Energy Outlook 2008, 2009

Concurrently additional questions are raised by the combination of the following conclusions in the WEO-2009:

- significant excess capacity is created or will be created in the near term in pipeline gas transporting and in liquefying natural gas (up to 200 bcm per year);
- the development of emission reduction policies will increase the unit price of emissions that will increase the relative competitiveness of gas (compared to oil and coal);
- natural gas resources (commercially recoverable) are enormous – potentially more than 850 tcm;
- it is clear that in the near term it will be impossible to widely apply the new alternative energy technologies;
- high concentration of natural gas reserves in three countries – Russia, Qatar and Iran constitutes danger to the security of gas supplies;
- in addition, only on the basis of the last factor - the conclusion that demand for gas in the following years should cease to grow.

In the Reference Scenario, natural gas demand in Europe continues to grow, although at a lower rate than projected in 2008. For example, for the EU-27 the rates of gas consumption growth in the new forecast have decreased from 1% annually to 0.7%. Detailed forecasts for gas in Europe are presented in Table 44.

Under the Reference scenario, gas production in Russia will grow from 646 bcm in 2007 to 655 bcm in 2015 and 760 bcm in 2030. Moreover, the IEA forecast on gas production in Russia by 2015, falls within the range defined by Energy Strategy by 2030 (685-745 bcm of gas according to Russian standards), and the forecast for 2030 is significantly lower than Energy Strategy indicators (885-940 bcm of gas according to Russian standards).

In accordance with the IEA forecast on gas exports from Russia to Europe, by 2020 it will reach 210 bcm (Figure 31), which is significantly higher than Energy Strategy indicators (189-194 bcm in a western direction).

Table 44. EU gas balance forecast according to WEO-2009

bcm	2007	2015	2020	2025	2030	2007-2030 annual growth rates, %
OECD Europe, BaU scenario						
Demand	544	552	590	617	651	0.8
Indigenous production	294	279	260	239	222	-1.2
Net import	250	273	330	379	428	2.4
OECD Europe, "450" scenario						
Demand	544	527	541	550	525	-0.2
Indigenous production	294	268	245	210	171	-2.3
Net import	250	259	295	430	354	1.5
EU, BaU						
Demand	526	532	564	589	619	0.7
Indigenous production	214	167	139	116	103	-3.1
Net import	312	365	425	473	516	2.2
EU, "450" scenario						
Demand	526	512	523	533	509	-0.1
Indigenous production	214	162	132	103	81	-4.2
Net import	312	350	391	430	428	1.4

Sources: IEA, World Energy Outlook 2009

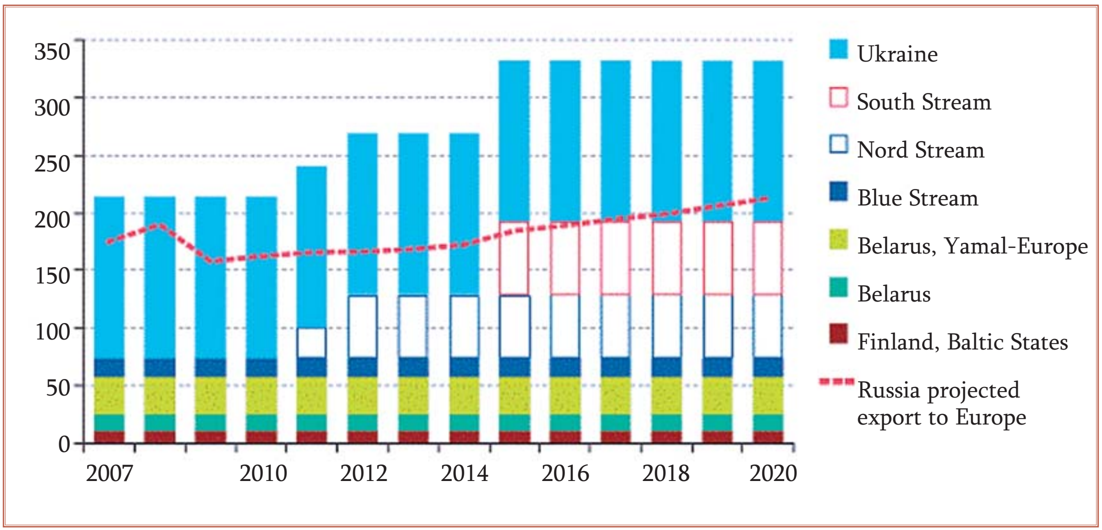

Figure 31. Export of gas from Russia to Europe and export infrastructure capacity in 2007-2020 according to BaU scenario, bcm

Sources: IEA, World Energy Outlook 2009

Inconsistency in measurement units

It should be noted that the WEO-2009 report does not specify the calorific value, which sets the values for natural gas and that complicates the possibility to compare IEA data with other sources, including the Russian Energy Strategy to 2030. On one hand, in other IEA reports (e.g. Natural Gas Information) a relevant coefficient is introduced: 1.047 bcm in 1 mtoe. On the other hand, based on the evidence presented in the WEO-2009, the actual conversion factor can be calculated. It differs from the 1.16 for the Indian gas balance to 1.24 for the Russia at least (According to balance sheets presented both in bcm and in mtoe). Last ratio is close to bcm of gas according to Russian standards. On average coefficient is equal to about 1.217 bcm in 1 mtoe.

IEA experts note that they use its own calorific values for natural gas for each region because of factual differences in calorific value of natural gas which were produced or consumed in these regions. Most of all gas data on the majority of countries (except the biggest one) has shown in WEO reports only in billion cubic meters without any guidelines on its calorific values.

Forecasts of Russian gas exports

Significant volumes of already concluded long-term contracts, in particular, count in favor of preserving Russia's share in natural gas imports by European consumers. On the other hand, the IEA notes the increase in the cost of extracting and transporting gas from Russia, which could negatively affect the competitiveness of Russian gas on European markets as compared to gas from North Africa, North Sea and the Middle East (Fig. 32, Tab. 45).

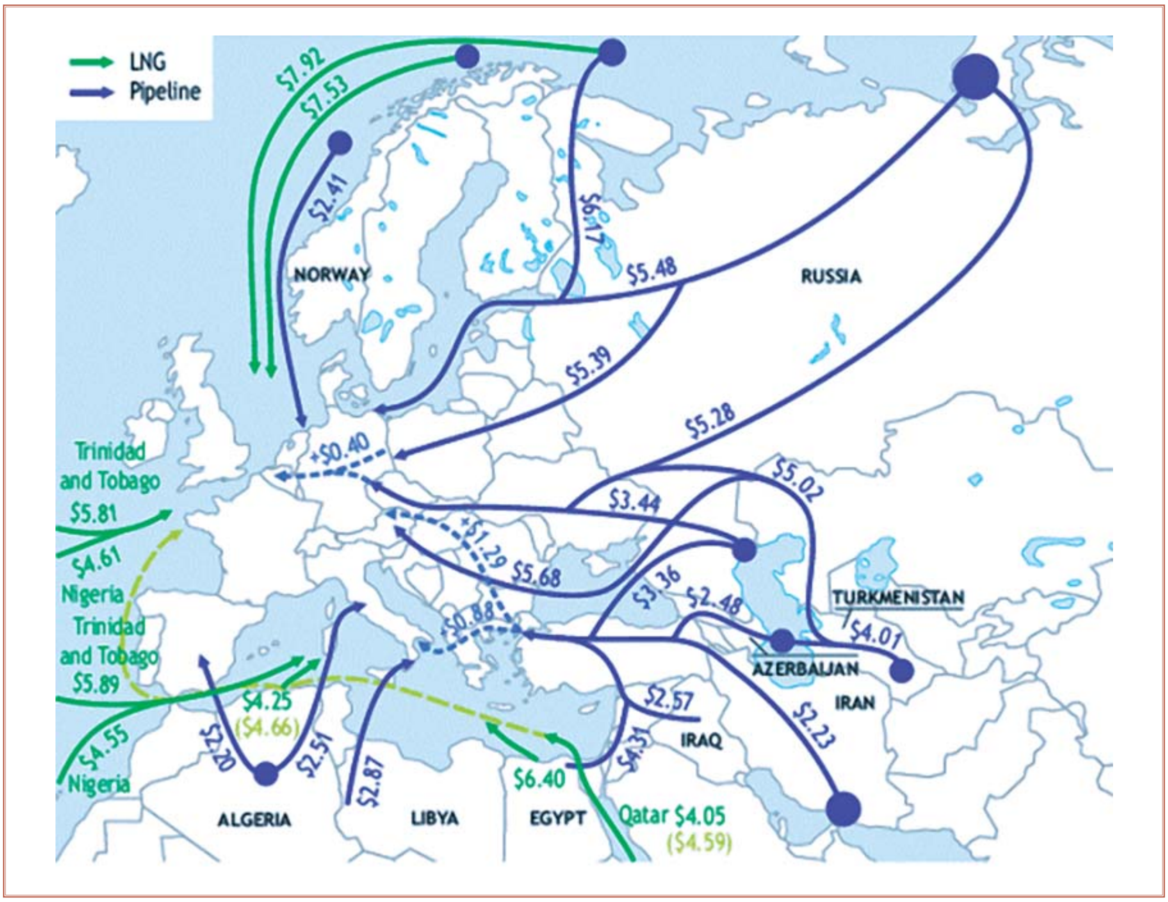

Figure 32. **Approximate gas transportation cost from different sources to EU by 2020, $/MBtu**

Sources: World Energy Outlook 2009

Note: The export duties shall not be taken into account, the value of the costs of production and transportation from Russia are calculated based on Shtokman gas condensate deposit, deposits of Yamal peninsula and the Astrakhan field.

Table 45. Gas transportation costs to Europe by 2020, $/MBtu

Gas source and route	Consumer	Production	Transport and transit	Total
Iran	Turkey	0-0.5	1.98	1.98-2.48
Caspian offshore via South Caucasus	Turkey	1.2-1.8	0.98	2.18-2.78
Russia – "Blue Stream"	Turkey	0.75-1.45	1.47	2.22-2.92
Turkmenistan via South Caucasus	Turkey	1.9-2.4	1.21	3.11-3.61
Egypt - Arabian pipeline	Turkey	2.2-2.8	1.51	3.71-4.31
Russia via Ukraine (Astrakhanskoe)	Germany	1.9-2.4	1.29	3.19-3.69
Turkmenistan via Ukraine	Germany	2.2-2.8	2.52	4.72-5.32
Russia via Ukraine (Yamal)	Germany	3.6-4.0	1.48	5.08-5.48
Russia via Belarus (Yamal)	Germany	3.6-4.0	1.59	5.19-5.59
Russia – "Nord Stream" (Yamal)	Germany	3.6-4.0	1.68	5.28-5.68
Turkmenistan via Black Sea to Bulgaria	Germany	2.2-2.8	3.18	5.38-5.98
Russia – "Nord Stream" (Shtokman)	Germany	4-4.5	1.92	5.92-6.42
Algeria	Mediterranean/Spain	0-1.8	1.3	1.3-3.1
Norway (Norwegian sea)	Germany	1.2-1.55	1.04	2.24-2.59
Algeria	Mediterranean/Italy	0-1.8	1.61	1.61-3.41
Libya	Mediterranean/Italy	0.9-1.35	1.24	2.14-3.59

Note: The calculations assume that the costs of extraction and transportation take into account distribution of capital investments in the development of the new fields and construction of new pipelines. High values of costs for Russia are caused by the fact that the supply will be performed mainly due to new projects. Cost calculation does not include export duties. Supply from Turkmenistan via the Black Sea to Bulgaria means the "South Stream" project. However, according to project documentation, the main source of gas for the "South Stream" is Yamal deposits

These figures are subject to comparison with the results of the analysis previously carried out by the authors of research on pricing for GECF (Energy Markets, TENI, Institute for Energy and Finance), who analyzed the maximum possible future levels of expenditure on gas supplies from various sources, came up with lower estimates. For example, according to the given research, costs for gas supplies from Russia to Germany across the Baltic Sea in 2025 are within 6.5 - 8.0 USD / MBTU including the export duty (on two options for the routes). At the same time, according to IEA estimates, these costs without export duties included vary in the range of 5.28-6.42 USD / MBTU. Given that the average real export price for gas in Europe by 2020, according to the assumptions of the IEA amounts to 12.1 USD / MBTU, then 30% of Russian export duty will be equal to approximately 3.63 USD / MBTU. In this case, the total cost of supplies from Russia through the Baltic Sea from the Yamal and Shtokman gas condensate fields, according to the IEA will amount to 8.91-10.05 USD / MBTU, which is about a third more than the estimates of the highest possible level of costs in the research for the GECF.

However, as seen from the table, the cost of gas supply in the new projects from the Yamal Peninsula is quite competitive with the supply of Turkmen gas via the new routes. The cost of LNG supply from Shtokman gas condensate field, specified by the IEA, seems too high, but it is commensurate to the cost of LNG supply from the new Norwegian fields. The high price of gas imports to Europe, even at considerable expenses ensures Gazprom gets not only the return on investment (incorporated in the costs of extraction and transportation), but also "excess profits" amounting to 2.05-3.19 USD / MBTU for "Nord Stream" supplies (in case the calculation is based on the average import price in Europe).

It should be noted that the price of Russian gas in Europe is not determined on the basis of cost-plus, but according to formulas in the long-term contracts. Therefore, the costs of extraction and transporting gas from Russia to Europe may affect the profitability of these operations for Gazprom (and, respectively, the projects' investment potential), but not the price of gas or its competitiveness. According to IEA estimates the new Russian gas extraction and transportation projects will not only pay off, but will provide additional revenue for expanded investment. The IEA report doesn't show the clear extent to which the data is included in the WEM model taking into account the European market pricing peculiarities.

It should also be noted that, according to the IEA analysis one of the most important factors influencing the level of gas production in Russia is the level of prices in the domestic market, in defining which the terms of introduction of Russian export parity gas prices should be considered. The IEA assumes that the export parity will have been introduced by 2020. At the same time, Gazprom expects to achieve its introduction much earlier. If the Russian Government decides that the export parity will be introduced in Russia before 2020 (and the assumption will be incorporated into the IEA model), this can obviously lead to a significant change in the results on extraction, domestic consumption and exports of Russian gas.

Investments

In its calculations the IEA pays great attention to investments of energy industry companies, as they influence the forecast level of energy supply.

In its report, the IEA said that amid the crisis oil and gas companies have reduced their investments in the upstream sector by 19% compared with 2008 (by 90 billion dollars). Over 20 projects with a total planned capacity of 2 million barrels per day have been cancelled, and the development of 29 projects with a planned capacity of 3.8 million barrels per day was delayed for at least 18 months. Total capital expenditure of oil and gas companies (according to the data of 50 companies) in 2009 fell by 15.6% compared to 2008 and by 16.3% compared to the pre-crisis plans. According to the IEA this may even lead to oil shortages on the world market in the medium term.

The IEA comments that insufficient investment in energy infrastructure lead to security violation of importing countries.

Investment in the coal industry decreased even more – they approximately halved as compared to 2008. This is caused by higher debt load of the respective manufacturers and a significant decline in prices for thermal coal (by 70% of the peak level). At the same time, a number of companies have maintained their investments in coal industry at the same level because most of the produced coal is consumed at other enterprises of the same group (Sasol, RWE), or because of low production costs (Indonesian companies).

As for the electric power industry, the companies' investment may fall by 30-50%. Biofuel industry experiences a significant drop in investment.

The IEA has carried out a very time-consuming investment analysis of specific companies and projects. However, it proves to have several apparent inaccuracies and tendentious approaches.

In particular, the IEA's analysis considers only the nominal dollar investments. On the basis of changes of these investments in 2009 (with respect to investment plans), as compared to 2008 conclusions are made about the impact of economic crisis on the production of hydrocarbons, whereas the following factors are neglected:

- Reducing the cost of investment projects because of falling prices for metals, energy, service companies' work, equipment rental, etc. In particular, the WEO-2009 indicates that the cost of investment projects in exploration and development in the first half of 2009 is 9% lower than in 2008. Therefore, for the nominal investment in 2009 it is necessary to make an adjustment for the decline in value of projects, thus obtaining real investments in 2009, which will be substantially higher than the figures given in the IEA report.
- A significant proportion of investments in oil and gas sectors are made in the national currency rather than in dollars or euros. Devaluation of national currencies of developing countries in relation to dollar amid the crisis (in some cases by more than 30%) means that

although the capital investments remain on the same level or increase, because they are denominated in national currency, according to the IEA analysis in dollar terms they still significantly drop.

- Each company has its own individual investment cycle, which can be independent on the economic crisis. In particular, a number of companies planned to reduce investment in 2009 and in subsequent years in accordance with their production programs and existing projects before they even knew about the crisis.
- Comparing figures for only two years is not enough to get a complete picture of the investment dynamics and identify the causes of the current changes. The analysis requires the consideration of longer time series. It should be noted that in 2008 – the "reference" year for the IEA analysis, a surge of investment caused by a sharp rise in energy prices and expectations of further stable growth in energy demand was indicated. Therefore, even by the IEA estimates falling nominal volume of investment in 2009, simply means their return to the 2007 level, which was not considered by analysts as insufficient.

Thus, the fact that IEA neglected a number of important aspects in its analysis led to a substantial overstatement of the investment drop in 2009 and the reassessment of this factor's influence on the prospects of world energy supplies.

It should also be noted that some mistakes were made by IEA during the collection of information on companies' investment plans. In particular, it was stated that China's CNOOC plans to increase its investments by 11.8%: from 5.1 billion in 2008 to 5.7 billion dollars in 2009. In fact, CNOOC increases the actual investments from 13.1 to 16.5 billion dollars, i.e. by 26%. Thus, a total increase in investment (for national and other oil companies) specified by IEA, amounts only to 0.6 billion dollars instead of 3.4 billion. According to IEA, the BP company plans to reduce their investments in 2009 to 19 billion dollars, while in reality, the company issued a plan to reduce investment to 20-21 billion dollars. The Total reduces its investments not from 20.5 to 18 billion dollars, but from 18.3 to 18 billion dollars. The IEA stated that Petrobras plans 28 billion dollars of capital investments in 2009, but this information is outdated. As early as in summer Petrobras announced that the company will invest 28.6 billion dollars. ExxonMobil increases its investments not from 23.9 to 24.9 billion (an increase of 4.3%), but from 26.1 to 29 billion dollars (an increase of 10.9%). Shell, instead of the 31-32 billion interval investment plan for 2009, takes the lower limit – 31 billion dollars, etc.

Thus, there is a tendency in the IEA report to a systematic understatement of the companies' plans for 2009, and in some cases, overstatement as regards to 2008. As a result the rates of nominal investment reduction in 25 oil and gas companies the IEA describes in its report, are overstated by more than 20 billion dollars, or 6% of the value of investments of these 25 companies in 2008. That is, the reduction of nominal dollar investments of the specified 25 companies in 2009 is 9.2%, and not 15.2%.

IEA states that the majority of national oil companies reduce their investments. But according to the experts, the following companies have increased their investment programs: Saudi Aramco, CNPC, Sinopec, CNOOC, Pemex, Ecopetrol, Petronas, Sonatrach, KOC, Pertamina, DONG, ENAP, TPAO, Indian Oil Corporation. Such companies have reduced their investments: PdVSA, StatoilHydro, ONGC, Rosneft, Gazprom, Gazprom Neft. Petrobras' dollar investments decreased by 1.6%, but in the national currency they have increased by 25%, at the same time the company has increased its medium-term investment program in dollar terms. On a number of other companies the investment information is not available. But, in general, even those nominal dollar investments of national oil companies, on which the information is available, in 2009 rose by more than 4%.

The report of the IEA states that such national companies as Petrobras, Chinese national companies and Gazprom have given up (compared to what might be) in their investment programs, particularly due to the decrease of value of their market capitalization, making it impossible for them to raise capital by selling shares. On the other hand, financing investment projects through the sale of treasury shares is rarely used by large oil and gas companies, one of the reasons is that it costs relatively more cost than debt financing (amid the crisis borrowing money is still advantageous for the oil companies).

Also, IEA notes the slowdown of investment in the biofuel development, as well as delay or cancellation of some of biofuel production projects. 29% out of 135 projects of construction of biofuel production plants were cancelled or delayed, the implementation of another 23% had been suspended. The IEA report stated that it would lead to a decrease in the production of biofuels in the short and medium term. It was natural to expect that IEA would reduce levels of medium-term forecasts of biofuel consumption, but it didn't.

4.1.2. WEO-2009 Alternative Scenario

"450" Scenario suggests that, due to more active state policy the level of carbon dioxide in the atmosphere will be reduced to 450 parts per million. In this case, with a probability of 50% the average temperature on Earth will rise by no more than 2 °C, but not by 6 °C as it was stated in the Reference Scenario.

Assumptions

The alternative scenario is based on the same macro-economic and demographic assumptions that were introduced in the Reference Scenario.

According to "450" scenario until 2015 the actual international oil prices will be moving along the same trajectory as they do in the Reference Scenario, while in 2015-2030 they will constantly remain at the level of 2015. The report's authors attribute the difference in prices (10% lower by 2020 and 22% lower by 2030) between the reference and alternative scenarios to oil demand weakening in the latter.

If the Alternative Scenario uses the same mechanism for obtaining price assumptions as the Reference Scenario, the constant level of oil prices means that in 2015-2030, when the real level of oil prices amounts to $87 per barrel, oil production and consumption will be fully balanced (except for stock variations). This statement (and, accordingly, the assumption of price stability) is expected to be very strong and requires more substantial grounding than just talks about demand reduction. Especially considering that the authors themselves report about very low price elasticity of oil demand and supply, which, in particular, could mean strong and unexpected changes in price, even if demand or supply variations are insignificant.

It should be noted that in Europe and Japan, natural gas prices in the Alternative Scenario differ from the basic ones by the same amount in 2020 and in 2030. The authors explain this by saying that gas prices in Europe and Japan significantly correlate because of their connection to oil prices and the gradual globalization of gas markets. However, historically, as well as in the Reference Scenario forecasts, prices on European and Japanese gas markets vary at different rates. It is unclear why the transition to a "450" scenario leads to identical changes on dissimilar gas markets in Europe and Japan.

At the same time gas prices in the U.S. move along other trajectories due to the fact that their natural gas market is largely dependent on domestic supply and thus its prices in the Alternative scenario do not decrease considerably as compared to other regions.

Table 46. Comparison of the assumptions for world gas prices in Reference and Alternative scenarios, $/MBTU

	2008	2015	2020	2025	2030
Reference					
USA	8.25	7.29	8.87	10.04	11.36
Europe	10.32	10.46	12.1	13.09	14.02
Japan (LNG)	12.64	11.91	13.75	14.83	15.87
"450"					
USA	8.25	7.29	8.15	9.11	10.18
Europe	10.32	10.46	11.04	11.04	11.04
Japan (LNG)	12.64	11.91	12.46	12.46	12.46
Relative price change in "450" scenario compared to Reference scenario, %					
USA	0	0	-8.12	-9.26	-10.39
Europe	0	0	-8.76	-15.66	-21.26
Japan (LNG)	0	0	-9.38	-15.98	-21.49

Sources: IEA, World Energy Outlook 2009

"450" Scenario assumes that the quota trading system will be implemented in all OECD countries and the EU (OECD +) by 2013, and in other large economies (China, Russia, Brazil, South Africa and the Middle East) by 2021. Another assumption is introduced about dividing the quota trading market into two parts: in OECD + and in other major economies.

Quota prices in OECD + price should reach 50 USD / ton by 2020, and 110 USD / ton by 2030. It is expected that in other major economies, the cost of quotas by 2030 will amount to 65 USD / ton. It should be noted that all these levels are extremely high and even prohibitive for traditional energy sources; indeed, burning these energy sources makes payments for emissions quite comparable to the cost of energy sources themselves. At the same time the ETS price levels are incomparably lower than these levels.

Natural gas

It should be noted that the volume of gas consumption in Europe, according to the "450" scenario decrease in 2007-2030 and the growth rates of gas imports slow down significantly. This may adversely affect the exports of Russian gas to Europe. In many ways, reducing gas consumption in the "450" scenario is attributed to relatively high price for carbon emissions: 50 USD/ ton of CO_2 in the OECD countries by 2020. At that price, according to the IEA analysis, gas is far behind renewable and nuclear energy sources (these findings require further detailed analysis). According to the same analysis, after 2020, given that CCS are widely used gas in electric power industry will be replaced even by coal.

4.1.3. WEO-2010

In November 2010, World Energy Outlook 2010 was released. Generally, the model section has not undergone significant changes compared with 2009. In WEO-2010 some of the modules are worked out in more detail and country models have been added for the states of the Caspian region. Also, the time horizon has been extended to 2035 (in WEO-2009, it was 2030).

In the new report, there are three scenarios, two corresponding to those in 2008-2009 reports, and one new one:

- The Current Policy Scenario (CPS) corresponds to the Reference scenario of 2009. The CPS scenario assumes that all government policies adopted by the middle of 2010 will be carried out, and that no new ones will be imposed. The difference between CPS-2010 and Reference-2009 is that it takes into account government programs announced in the second half of 2009 and the first half of 2010.

- The "450" scenario supposes, as in the 2009 report, that government measures will be introduced to restrict the content of greenhouse gases in the atmosphere to "450" parts per million in the ultralong-term (see figure below). According to the IEA, this will limit the increase in average global temperatures to 2 °C.
- The New Policy Scenario (NPS).

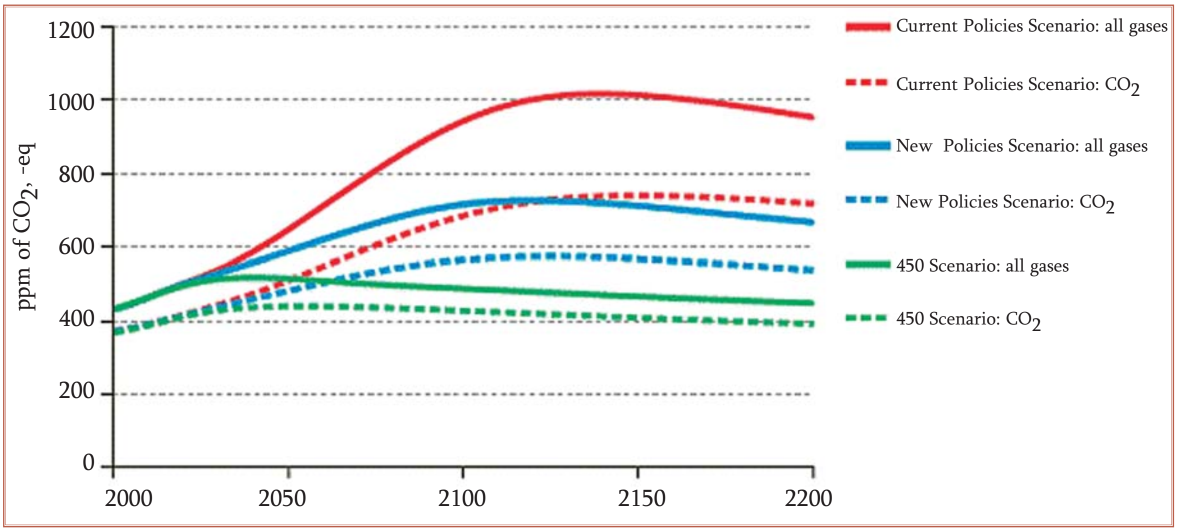

Figure 33. Changes in the concentration of carbon dioxide and other greenhouse gases in the atmosphere according to the IEA-2010 scenarios
Sources: IEA, World Energy Outlook 2010

The principal feature of the new IEA report is that it plainly states that **the scenarios for the new and current state policies are not forecasts and cannot be used as such** (pp. 62-63 of the report). This follows from an entirely correct argument, which our experts also used in its criticism of existing energy scenarios and projections, including those involving the IEA. It shows that the CPS scenario cannot be taken as a forecast as it is obvious that government policy will change with respect to the status quo in mid-2010. It should be noted that this is a problem for all business-as-usual scenarios in all models. Although the NPS scenario indicates that government policy over the world will change, it definitely will not change to exactly the same extent as is assumed in the NPS scenario.

This clear demonstration of the impossibility of using the CPS and NPS scenarios as forecasts is a significant step forward in terms of the objective presentation of information in the IEA report. However, it is important to understand that this does not necessarily mean an improvement in the quality of forecasts or a rejection of their role in presenting society with a vision of the future of world energy. In the presentation of the new IEA report, for example, there is no indication that the NPS and CPS scenarios are not forecasts. In contrast, data is provided for the NPS scenario according to the basic indicators up until 2035, which is likely to be perceived by society, business and government (and even a majority of the expert community) as indeed being a forecast. Similarly, the WEO-2010 report generally provides specific values for all indicators of energy in the future for all three scenarios (with an emphasis on the NPS scenario), although in reality it can only objectively provide the major trends in the IEA's understanding and analysis of the sensitivity of future energy indicators to the adoption of the corresponding government policy.

The "450"scenario is a forecast in the true sense of the word, based on the text of the report.

Assumptions

The demographic assumptions are practically unchanged in the new report, which logically is also conditional on the inertia of demographic processes.

As for the macroeconomic assumptions, it should be noted that they are constant in all three scenarios, which seems rather strange. It is clear that the decision about the implementation of government policies (especially in the '450' scenario) will have a significant impact on the growth of GDP.

Of greatest interest are the assumptions concerning prices, government policy and technology.

According to the IEA's assumptions, gas prices will rise in nominal and real terms. The differentiation of gas prices on major markets is preserved, although the prices on the U.S. market will gradually converge to the level of Europe and Asia. The highest gas prices are projected to be in the Asian market.

Compared to the assumptions of the 2009 report, prices for oil and coal are increased, while gas prices are only slightly reduced. This makes the proposed price ratio between oil and gas more plausible than before. However, coal prices are still extremely low.

As regards the technological assumptions in the report, a fairly general description is presented of the principles for their introduction. It shows that the most rapid development of technology (primarily, energy efficiency, and the reduction of CO_2 emissions) is seen in the '450' scenario. The lowest rate of development is in the CPS scenario, although here it is still large enough in the context of high oil prices. The rate of change in the NPS scenario is in the range between the rates for CPS and '450'.

It should be noted that there is a lack of clarity concerning the data on the technological assumptions. Their validity would have been much easier to verify if tables were provided showing the parts of the utilization of key technologies, such as carbon capture and storage (CCS), for the main dates of the scenarios.

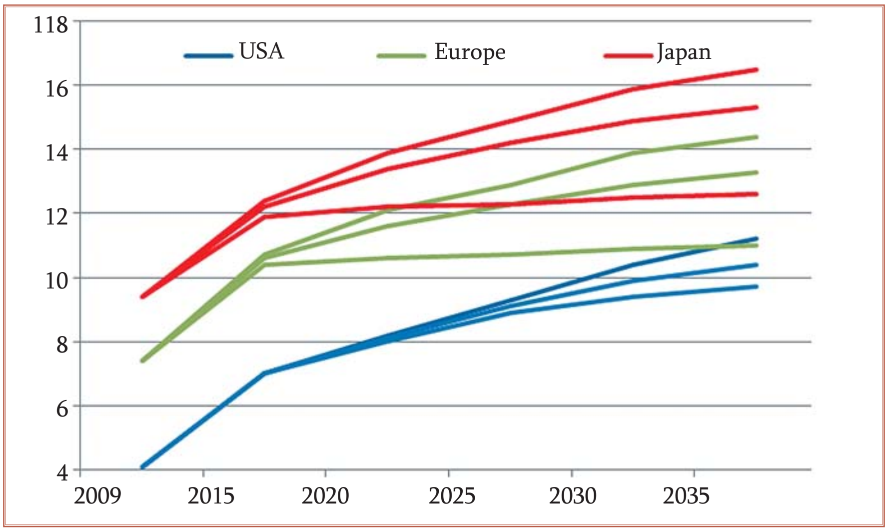

Figure 34. Natural gas price assumptions, $'2009/MBtu

Sources: IEA, World Energy Outlook 2010

Table 47. Assumptions for energy prices in WEO-2010 at 2009 prices

WEO-2010	NPS						CPS					450				
	2009	2015	2020	2025	2030	2035	2015	2020	2025	2030	2035	2015	2020	2025	2030	2035
IEA crude oil imports, $/barrel	60.4	90.4	99	105	110	113	94	110	120	130	135	87.9	90	90	90	90
Natural gas imports, $/MBtu																
USA	4.1	7	8.1	9.1	9.9	10.4	7	8.2	9.3	10.4	11.2	7	8	8.9	9.4	9.7
Europe	7.4	10.6	11.6	12.3	12.9	13.3	10.7	12.1	12.9	13.9	14.4	10.4	10.6	10.7	10.9	11
Japan	9.4	12.2	13.4	14.2	14.9	15.3	12.4	13.9	14.9	15.9	16.5	11.9	12.2	12.3	12.5	12.6
OECD steam coal imports, $/tonne	97.3	97.7	101.7	104.1	105.6	106.5	97.8	105.8	109.5	112.5	115	92.5	85.8	75.8	66.3	62.1

Source: IEA, World Energy Outlook 2010

Table 48. Assumptions for energy prices in WEO-2009 at 2009 prices

WEO-2009	Reference				450			
	2015	2020	2025	2030	2015	2020	2025	2030
IEA crude oil imports, $/barrel	86.4	99.7	107.2	114.6	86.4	89.7	89.7	89.7
Natural gas imports, $/MBtu								
USA	7.3	8.8	10.0	11.3	7.3	8.8	10.0	11.3
Europe	10.4	12.1	13.0	14.0	10.4	12.1	13.0	14.0
Japan	11.9	13.7	14.8	15.8	11.9	13.7	14.8	15.8
OECD steam coal imports, $/tonne	90.8	103.8	106.8	109.0	85.3	79.8	72.2	64.6

Source: IEA, World Energy Outlook 2009

Table 49. Assumptions for prices of CO2 emissions quotas (USD 2009/tonne)

Scenario	Region	2009	2020	2030	2035
NPS	EU	22	38	46	50
	Japan	n/d	20	40	50
	Other OECD	n/d	–	40	50
CPS	EU	22	30	37	42
450	OECD+	n/d	45	105	120
	Other Major Economies	n/d	–	63	90

Source: IEA, World Energy Outlook 2010

The assumptions concerning prices remain about the same as in the 2009 report. As already mentioned previously in the WEO-2009 analysis, the "450" scenario involves an increase in the level of emission prices that would lead to a significant increase in prices for end-consumers and a reduction in prosperity.

Note that in some regions, the differences in government policy assumptions in the NPS and "450" scenarios are relatively small (Brazil, India), while in other regions the differences are much more noticeable (Russia, China). For Russia, the assumption of reducing emissions in the "450" scenario is apparently a goal that has already been set by President Medvedev in 2009.

Table 50. Principal policy assumptions for 2020

Region	NPS	"450"
USA	15% share of renewables in power generation, push for domestic supplies, including gas and biofuels	17% reduction in GHG emissions compared with 2005
Japan	Implementation of the Basic Energy Plan	25% reduction in GHG emissions compared with 1990
EU	25% reduction in GHG emissions compared with 1990	30% reduction in GHG emissions compared with 1990
Russia	15% reduction in GHG emissions compared with 1990	25% reduction in GHG emissions compared with 1990
China	40% reduction in CO_2 intensity compared with 2005	45% reduction in CO2 intensity compared with 2005; 15% share of renewables and nuclear power in primary demand
India	20% reduction in CO_2 intensity compared with 2005	25% reduction in CO2 intensity compared with 2005
Brazil	36% reduction in GHG emissions compared with business-as-usual	39% reduction in GHG emissions compared with business-as-usual

Source: IEA, World Energy Outlook 2010

For the EU, the assumption has already been made of a 25% reduction of emissions in the NPS scenario, and 30% in the "450" scenario. It can be seen that the CPS scenario assumes a 20% reduction in emissions by 2020 compared with 1990, i.e. it is in compliance with the "20-20-20" program. It should be noted that even a 20% reduction is an extremely ambitious task, which according to the European Commission's 2009 Energy Trends to 2030 update (the PRIMES model) cannot be achieved by 2020 under current EU government policies (by 2020 the fall will only be 13.9%). Even in the most radical scenario (Reference) of PRIMES-2009, an emissions reduction of only 20.3% is achieved by 2020. Thus, the IEA assumptions concerning EU emissions reductions seem too high, which distorts the results of the scenarios, particularly the role of natural gas.

It is not enough information in the Report to completely estimate adequacy of policy assumption (e.g. assumption for 2030 or 2035, other policy assumptions except GHG emission).

Results

We will also consider the results of the report, including data for the scenarios which are not predictions (CPS and NPS), paying most attention to the gas markets.

Energy Balance

Consider the results of the major changes in WEO-2010 compared to WEO-2009.

The most obvious change in the energy mix across all the regions in the 2010 report is a decrease in oil consumption in absolute terms and also as a proportion of the energy mix. In particular, world oil consumption in 2030 is reduced by 170-330 mtoe per annum. Given the growth in total primary energy consumption, the share of oil in the energy mix in 2030 decreased by 1.3 and 2.2 percentage points in the CPS and "450"scenarios, respectively.

The biggest change of all in the 2010 scenarios compared to 2009 was the increase in natural gas. Its consumption increases by 120-210 mtoe by 2030, while its share in the global energy mix increases by 0.8-0.9%. The share of natural gas in the IEA-2010 scenarios ranges from 21.3-22.2%. Despite a significant increase in gas consumption compared with the 2009 forecast, overall its share does not grow strongly with respect to the 2008 level, which amounted to 21.2%. In absolute terms, consumption of gas over 2008-2030 increases by 20-37% in the various scenarios.

In comparison with 2009, the 2010 scenarios also see an increased consumption of coal, nuclear energy and renewable energy, although this is less than for gas consumption. In absolute terms, in the "450" scenario the strongest increase was for coal, while in the CPS scenario it was for atomic energy. In the composition of the energy mix, in the "450" scenario the share of renewable energy showed the biggest increase, while for CPS it was the share of nuclear energy that increased the most.

Table 51. Mix of global primary energy consumption in 2030 in the IEA 2010 and 2009 scenarios, gtoe/year

	WEO-2010			WEO-2009		Comparison of the 2010 and 2009 scenarios		
Scenarios	NPS	CPS	"450"	Ref	"450"	"450"	CPS-Ref	Factual 2008-2007
Total	16.0	16.9	14.6	16.8	14.4	0.2	0.1	0.3
Coal	4.0	4.9	2.7	4.9	2.6	0.1	0.0	0.1
Oil	4.6	4.8	4.0	5	4.3	-0.3	-0.2	0.0
Natural Gas	3.6	3.7	3.1	3.6	2.9	0.2	0.1	0.1
Nuclear	1.2	1.0	1.5	1	1.4	0.1	0.0	0.0
Renewables	2.8	2.4	3.3	2.4	3.2	0.1	0.0	0.1
Structure	100	100	100	100	100	–	–	–
Coal	24.9	29.1	18.6	29.1	18.2	0.41	0.01	0.51
Oil	28.4	28.5	27.3	29.8	29.5	-2.24	-1.31	-1.02
Natural Gas	22.2	22.0	21.3	21.2	20.4	0.90	0.77	0.26
Nuclear	7.4	6.1	10.3	5.7	9.9	0.35	0.44	-0.10
Renewables	17.2	14.3	22.6	14.2	22	0.59	0.09	0.36

Sources: IEA, 2009, 2010
Note: In the columns "Comparison of the 2010 and 2009 scenarios", the divergence between the indicators for the 2010 scenarios is shown, along with the same indicators for the 2009 scenarios. The comparison was performed for scenarios with similar assumptions: between the 2010 and 2009 '450' scenarios, and between the 2010 CPS scenario and the 2009 Reference scenario. In the 2009 report, statistics from 2007 were used as a baseline, while in the 2010 report statistics from 2008 were used, so their comparison also allows us to understand the factors influencing the IEA's change of position

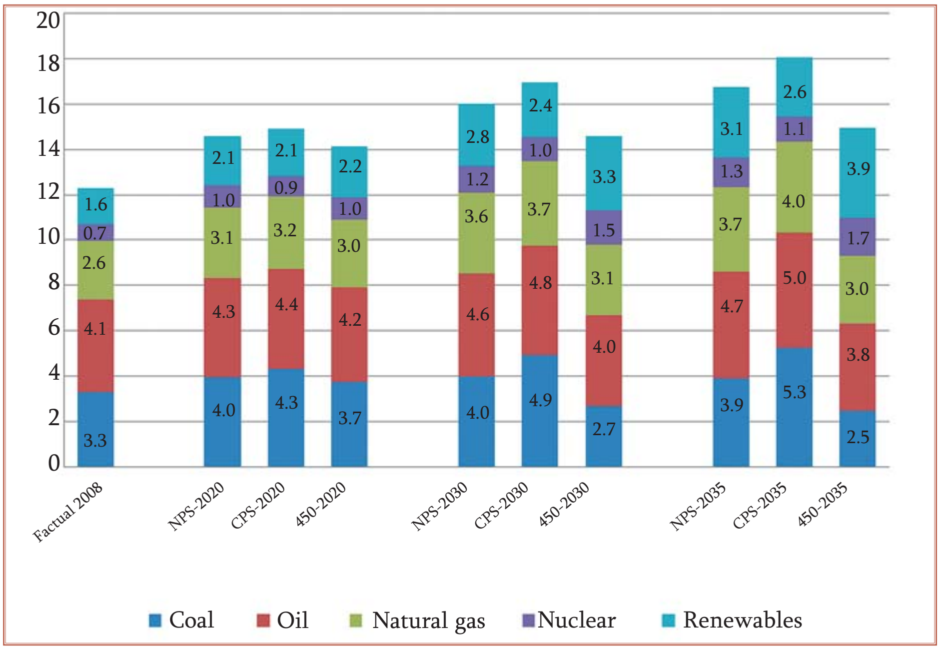

Figure 35. Global energy mix for the WEO-2010 scenarios, gtoe/year
Sources: IEA, World Energy Outlook 2010

As already noted above, the CPS and NPS scenarios are not forecasts, but from a comparison of the data they contain concerning the global energy sector we may arrive at the following conclusions:

- The adoption of government policies aimed at reducing CO_2 emissions and increasing energy efficiency leads to a fall in absolute terms in primary energy consumption and the consumption of oil, coal and gas (in NPS the corresponding government policies are greater than in CPS, and in '450' even greater), and the growth in demand for nuclear power and renewable energy.

- Moderate adoption of government policies with respect to the current levels (the NPS scenario compared with CPS) leads to an increase in the share of gas consumption throughout the forecast horizon, while the application of more drastic measures (the "450" scenario compared to the NPS) results in a significant drop in the share of gas, especially in the long term.
- For all other energy sources besides gas, their share in consumption patterns showed the same dynamics across the scenarios, as did the absolute values.

Table 52. Mix of primary energy consumption in the EU-27 in 2030 according to the IEA 2010 and 2009 scenarios, mtoe/year

	WEO-2010			WEO-2009		Comparison of the 2010 and 2009 scenarios		
Scenarios	NPS	CPS	"450"	Ref	"450"	"450"	CPS-Ref	Factual 2008-2007
Total	1719	1802	1663	1781	1682	-19	21	-8
Coal	168	231	115	233	103	12	-2	-26
Oil	483	547	435	545	448	-13	2	-1
Natural Gas	486	516	396	508	418	-22	8	8
Nuclear	237	204	307	192	297	10	12	0
Renewables	345	305	410	303	415	-5	2	9
Structure	100	100	100	100	100	–	–	–
Coal	9.8	12.8	6.9	13.1	6.1	0.82	-0.28	-1.42
Oil	28.1	30.4	26.2	30.6	26.6	-0.44	-0.24	0.15
Natural Gas	28.3	28.6	23.8	28.5	24.9	-1.09	0.13	0.56
Nuclear	13.8	11.3	18.5	10.8	17.7	0.76	0.52	0.05
Renewables	20.1	16.9	24.7	17	24.7	-0.05	-0.07	0.55

Sources: IEA, 2009, 2010

Note that the future consumption dynamics in Europe differ from the global ones. In the WEO-2010 "450" scenario, compared with WEO-2009 there is a decrease in total primary energy consumption and the consumption (and share in the energy mix) of oil, gas, and even renewable energy sources. At the same time, a significant increase is observed for coal and nuclear power. It should be noted that nuclear energy is the only energy source whose consumption in the EU-27 grew in both scenarios. Clearly, this is due to the review of plans regarding nuclear energy by a number of European countries. For the remaining energy resources, in a comparison of the CPS-2010 and baseline-2009 scenarios the dynamic is the opposite: gas increases and oil rises slightly, while renewable energy and coal both fall.

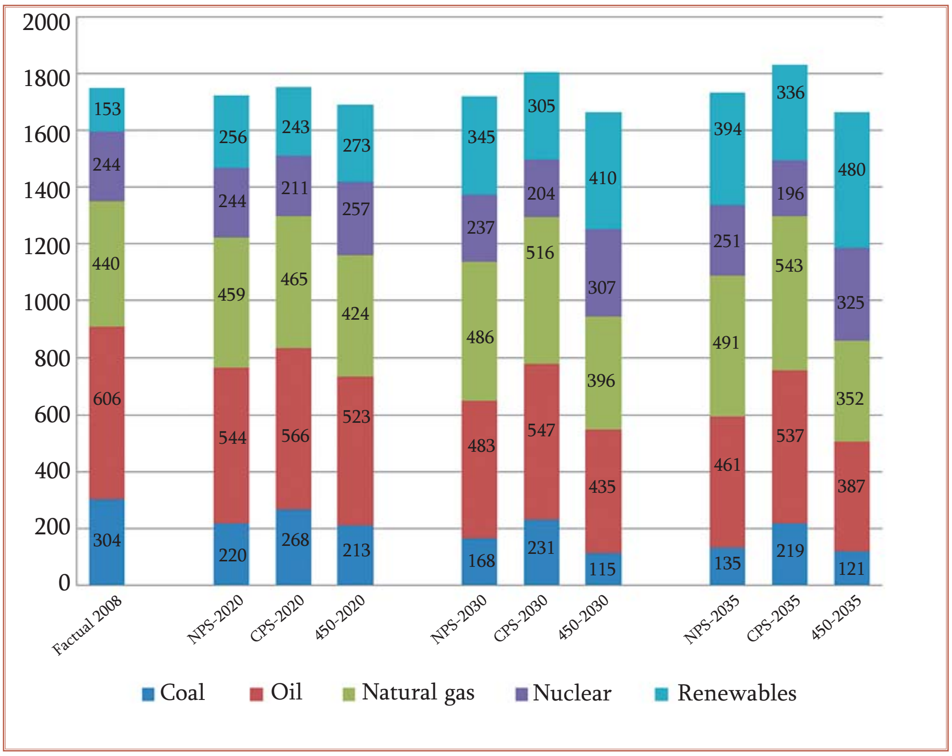

Figure 36. Energy mix in the EU-27 for the WEO-2010 scenarios, mtoe/year
Sources: IEA, World Energy Outlook 2010

The only difference in the comparison of scenarios in Europe with the above analysis given for the world as a whole is that the share of gas in the EU energy mix in the transition from the current policy to the new policy increases only slightly (by 0.1 percentage points) by 2020, and by 2030 there is already a decline in the role of gas by 0.3 percentage points.

Table 53. Mix of primary energy consumption in the U.S. in 2030 in the IEA 2010 and 2009 scenarios, mtoe/year

	WEO-2010			WEO-2009		Comparison of the 2010 and 2009 scenarios		
Scenarios	NPS	CPS	"450"	Ref	"450"	"450"	CPS-Ref	Factual 2008-2007
Total	2288	2353	2101	2396	2092	9	-43	-56
Coal	454	543	204	581	234	-30	-38	-8
Oil	723	757	616	772	627	-11	-15	-58
Natural Gas	537	542	541	533	515	26	9	5
Nuclear	259	241	317	248	316	1	-7	0
Renewables	315	270	423	262	400	23	8	5
Structure	100	100	100	100	100	–	–	–
Coal	19.8	23.1	9.7	24.2	11.2	-1.5	-1.2	0.2
Oil	31.6	32.2	29.3	32.2	30.0	-0.7	0.0	-1.6
Natural Gas	23.5	23.0	25.7	22.2	24.6	1.1	0.8	0.8
Nuclear	11.3	10.2	15.1	10.4	15.1	0.0	-0.1	0.2
Renewables	13.8	11.5	20.1	10.9	19.1	1.0	0.5	0.3

Sources: IEA, 2009, 2010

The dynamics of the indicators in the U.S. in WEO-2010 compared to the WEO-2009 is similar to the global picture. But unlike the world as a whole, the role of nuclear energy is re-assessed downwards. At the same time, the CPS scenario shows a significant reduction in expectations for total energy consumption. This can largely be attributed to a drop of a similar magnitude in primary energy consumption in 2008 compared with 2007 (in 2009 the fall in primary energy consumption in the U.S. continued, which could also be taken into account). In the 2010 '450' scenario there is a marked increase in gas consumption – by 26 mtoe/year in 2030. However, in the CPS scenarios the increase in gas consumption is relatively small – only 9 mtoe/year.

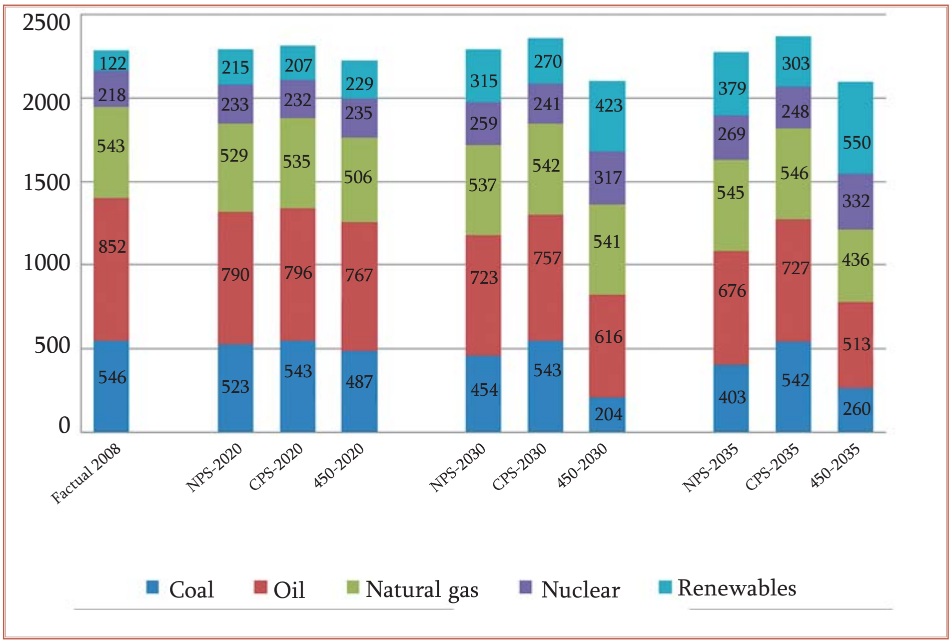

Figure 37. U.S. energy mix in the WEO-2010 scenarios, mtoe/year
Sources: IEA, World Energy Outlook 2010

U.S. oil consumption in the transition from CPS to NPS decreases slightly (by 6 million tonnes/year or 0.8%), but the share of oil in the energy mix actually increases by 0.1 percentage points. In the transition to the "450" scenario, the share of oil in the energy mix in 2020 remains unchanged. In 2030 the standard dynamic is re-established: the transition to more active government policies leads to the share of oil in the energy mix being significantly reduced.

Attention should be given to the dynamics of energy consumption in 2035 compared to 2030 in the "450" scenario. In just five years, gas consumption falls to 105 mtoe/year (19%) and oil to 103 mtoe/year (17%). With an almost stable total energy consumption there is a significant increase in the use of renewable energy – to 127 million mtoe/year (30%), and coal – to 56 mtoe/year (27%). The increase in coal consumption is most likely due to the rapid increase in the use of CCS in the U.S. in this long-term projection.

Table 54. Mix of primary energy consumption in China in 2030 in the IEA 2010 and 2009 scenarios, mtoe/year

	WEO-2010			WEO-2009		Comparison of the 2010 and 2009 scenarios		
Scenarios	NPS	CPS	"450"	Ref	"450"	"450"	CPS-Ref	Factual 2008-2007
Total	3568	3907	3094	3827	2934	160	80	161
Coal	1990	2422	1398	2397	1370	28	25	120
Oil	675	698	605	758	664	-59	-60	11
Natural Gas	277	270	266	202	166	100	68	10
Nuclear	210	174	288	127	249	39	47	2
Renewables	416	343	537	343	485	52	0	18
Structure	100	100	100	100	100	–	–	–
Coal	55.8	62.0	45.2	62.6	46.7	-1.5	-0.6	0.7
Oil	18.9	17.9	19.6	19.8	22.6	-3.1	-1.9	-0.9
Natural Gas	7.8	6.9	8.6	5.3	5.7	2.9	1.6	0.2
Nuclear	5.9	4.5	9.3	3.3	8.5	0.8	1.1	0.0
Renewables	11.7	8.8	17.4	9.0	16.5	0.8	-0.2	-0.1

Sources: IEA, 2009, 2010

The volume of primary energy consumption in China increased significantly in the 2010 report – by 80-160 mtoe/year in 2030 (although in relative terms, this amounts to only 2-5% growth). It is interesting to note that the increase in the "450" scenario was exactly the value of the growth in consumption in 2008 compared with 2007. It should also be noted that the entire global primary energy demand in the "450" scenario in 2030 increased to 184 mtoe/year. That is, to a large extent this is due to growth in China (this is also a significant influence in the CPS scenario, but less than in "450").

In the 2010 scenarios, the biggest change was the increase in gas consumption – by 68-100 mtoe/year (1.6-2.9 percentage points, respectively). According to the IEA, there will be 32-42 mtoe/year of additional consumption by 2020. Despite the small increase in coal consumption by 2030, its share in the 2010 scenarios is falling.

What looks very strange is the almost complete agreement concerning gas consumption in China, regardless of the scenario for each of the time points. The differences in gas consumption between the scenarios do not amount to more than 4%. At the same time, as is the case even for oil, where consumption is generally inelastic, the spread across the scenarios reaches more than 22%. And the data on coal consumption in China in 2035 between the CPS and "450" scenarios differs by 2.2 times. Natural gas and coal are interchangeable (with allowance for technological limitations) in the electricity industry, which according to the IEA report is the main driver of increases in energy consumption in the country.

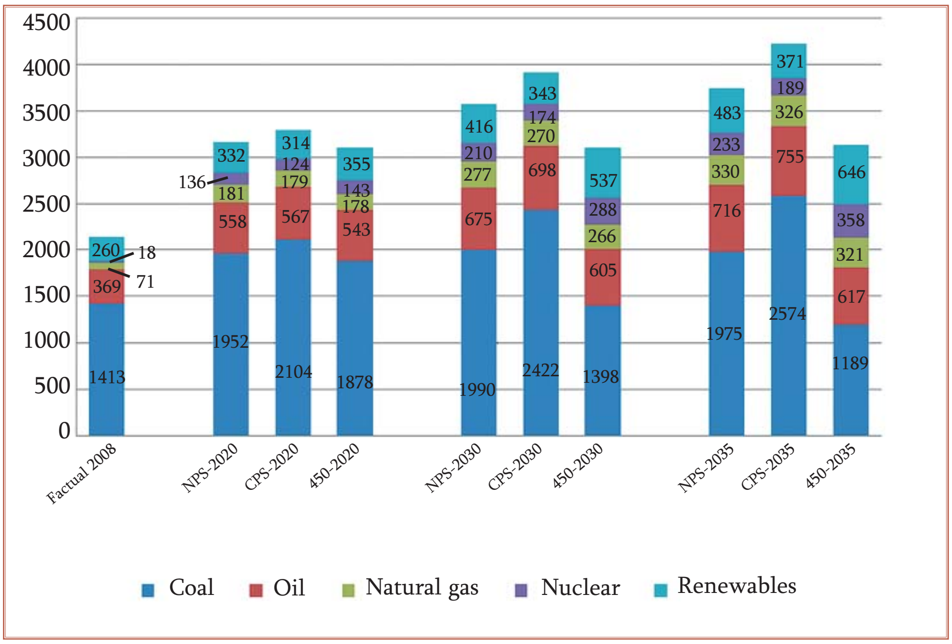

Figure 38. China energy mix in the WEO-2010 scenarios, mtoe/year
Sources: IEA, World Energy Outlook 2010

The gas industry

The IEA notes that natural gas will play a central role in ensuring global energy needs, at least until 2035. This statement may be interpreted as a change in the position of the IEA on gas compared to the 2009 report. This may in many ways be due to a general change of attitude to gas in the world and especially in the U.S. after the "shale revolution".

One extremely important conclusion by the IEA is that despite the rising price of natural gas, its use in combined cycle gas turbines (CCGT) will largely be preferable for the following reasons:

- the significant benefits of gas compared to coal in terms of its impact on the environment;
- higher efficiency;
- the relatively low investment costs;
- the relatively short time needed to construct power plants based on gas;
- greater operational flexibility.

The IEA also notes that the spread of CO_2 emissions trading quotas and the rising prices for these will lead to an increase in the relative competitiveness of gas over coal (although the competitiveness of nuclear energy and renewable energy will grow even more strongly). With prices for CO_2 emissions at more than $100 per ton, preferred alternatives will be nuclear power and renewables, while with moderate (not low or high) price levels for CO_2 emissions, natural gas will be cheapest in terms of operational costs for the electricity sector.

The IEA predicts the existence of a significant excess of natural gas in the world, which is measured as the difference between the sum capacity of inter-regional gas pipelines and LNG plants and the volume of inter-regional gas trading. This difference in 2009 was 130 bcm (80 bcm in 2007), and in 2011 this should rise to 200 bcm, after which it will decline. The greatest excess in gas at this time will be seen in Europe. It is noted that even if no new pipelines or LNG projects other than those which have already undergone a final investment decision (i.e., South Stream and Nabucco should not be taken into account) are not brought into operation in Europe until 2020, the unused capacity will be more than 150 bcm/year, and the level of use of export infrastructure will be below 80%.

A number of shortcomings should be noted in relation to this reasoning. First, the presence of 150 bcm unused capacity does not mean that it would be used to deliver natural gas to create an excess supply of gas in Europe, putting pressure on prices in this market. In this regard the volume of unused gas export capacity in Europe in recent years cannot be counted. A substantial portion of this unused capacity will be in the Ukrainian gas transportation system, which for many years has been at no more than two-thirds capacity. A part of the Ukrainian gas transportation streams can be redirected, for example to the second branch of the Nord Stream (for the first branch, in general, there will be new contracts). Furthermore, never in European history has the LNG regasification terminal capacity been used at 100%. Pressure on the European market due to LNG, primarily from Qatar, may in the medium term cease due to the recovery of gas demand in Asia at a higher level of prices in the region (higher prices in Asia are also suggested by the IEA). Declarations about the presence in the medium term and beyond of the gas glut are based on only a very approximate infrastructure analysis and appear to be unfounded.

According to the IEA data, the share of LNG in the international gas trade will grow, albeit at a moderate pace: from 31% in 2008 to 35% in 2020 and 42% in 2035 (in the NPS scenario). As of summer 2010, the total capacity of LNG plants in the world amounted to 360 bcm, while 8 plants presently being built and expected to be operational before 2015 will add another 77 bcm.

Gas production is growing rapidly in the Middle East, but about two-thirds of production growth in the NPS scenario will be used for domestic consumption in the region. The rapid growth in gas consumption in the Middle East will be largely due to its substitution for petroleum products in the electricity industry in order to free up additional volumes of crude oil and petroleum products for export.

In OECD countries, there will be fairly moderate growth in gas consumption due to several factors:

- the saturation effect in the domestic sector;
- the decline in industrial production in developed countries;
- increasing energy efficiency;
- competition in the electricity industry with other energy sources, especially renewable energy, the use of which will be prioritized by decision-makers.

In the NPS scenario, the proportion of GECF countries in total world gas production will grow moderately, from 36% in 2008 to 40% in 2035.

In the U.S., gas consumption in the long term remains unchanged or even declines (in the "450" scenario), which is in contradiction with a number of other scenarios (especially the MIT scenarios, but also the plans of the U.S. government). In 2008-2020, gas consumption in the United States falls by 2-7% depending on which of the IEA scenarios is taken. In this case, the projected levels of gas prices in the country will be very low, which should greatly stimulate the demand for natural gas. Even in the IEA report it is noted that: "In some cases, gas is able to increase its share in the structure of fuels for electricity, particularly in the U.S., usually due to competitive pricing."[26]

The relation of the consumption indicators in the various WEO-2010 scenarios for the United States also raises questions. For the CPS and NPS scenarios, there is practically no difference in the volume of natural gas consumption for all dates (by 2035 the difference between them is reduced to just 1 million toe/year, which is 0.2% of consumption). In terms of consumption patterns: in 2020 the share of gas in both scenarios is almost identical, while in 2030 for NPS the share of gas is higher by 0.5 percentage points, and in 2035 higher by 0.9 percentage points. It seems rather strange that additional government policies have practically no impact on gas consumption in the U.S.

For the "450" scenario, in 2020 there is a significant difference in the volume of gas consumption in the CPS and NPS scenarios (23-29 mtoe/year), but in 2030 it almost disappears (1-4 mtoe/year), and in 2035 abruptly increases to 109-110 mtoe/year. Moreover, in 2030 gas consumption in the "450" scenario is higher than in the NPS scenario by 4 mtoe, although it is slightly lower than in the CPS

[26] IEA, World Energy Outlook 2010, p. 181.

scenario. That is, additional government measures in 2030 lead to a slight decrease in gas consumption relative to the current policy, but the tightening leads again to an increase in gas consumption. In the "450" scenario, the fall in gas consumption by 20% in 2035 compared to 2030 requires further explanation.

Note that gas consumption in China according to IEA-2010 is much lower than the last national forecasts which propose that it could reach even 230-260 bcm in 2015 and 300 bcm in 2020. Probably national Chinese forecasts are too optimistic but it demands more IEA attention.

Thanks to the construction boom in China, about a third of global growth in gas consumption in the residential sector will be accounted for in this country.

According to the IEA data, about a third of the total increase in gas production in the world in the long term will come from unconventional sources of gas (in the NPS scenario). The share of coal-bed methane, shale gas and tight gas reservoirs in total natural gas production is expected to increase from 12% in 2008 to 19% in 2035. IEA experts also note the possible risk that investments will be directed towards unconventional gas resources whose development potential is overestimated, leading to under-investment in traditional resources and consequently to a temporary acceleration in the growth of gas prices.

Also of considerable interest are the IEA estimates of the required investment in the gas sector (in the NPS scenario), primarily for Russia.

Table 55. Comparison of the volume of investment required in the Russian gas industry in the IEA's NPS scenario and the Russian Energy Strategy to 2030, the General Scheme for Gas Sector Development, billion $'2009

Sector	Exploration and development	Transmission and distribution	LNG	Total	Average amount per year
IEA-2010-NPS (2010-2035)	525	234	33	792	30.5
Sector	Exploration and development	Transportation	UGS, processing, others	Total	Average amount per year
ES-2030 (2009-2030)	192-201	287-299	107-111	586-611	26.6-27.8
General scheme (2010-2030)	203-272	208-258	47-64	477-572	22.7-27.2

Sources: IEA, World Energy Outlook 2010, Russian Energy Strategy to 2030, project of the General scheme of the gas industry development, author's calculations

The total annual amount of investment required by the IEA and the Energy Strategy do not differ (on the average interval) by so much – only by $3 billion per year or 12%, but the IEA estimates do not seem to include the need to build gas processing facilities and storage facilities. The discrepancies between IEA and the General Scheme data are larger (on the average interval) – 5.5 billion dollars of annual investment, or 22%. The evaluations of investments in gas transportation infrastructure are higher in the ES-2030: the average annual investment in Russia's view should be 13-13.6 billion dollars, and in the IEA's view – 10.3 billion dollars (including LNG infrastructure). The fundamental difference is seen with regard to investment in exploration and development: 525 billion dollars (for the period 2010-2035) by the IEA, and 192-201 billion dollars (for the period 2009-2030 in USD 2009) in ES-2030. The average annual amount of required investment in gas exploration and exploitation, according to IEA, is approximately 2.3 times higher than is assumed in Russia. The General Scheme rates are higher than those in the Energy Strategy, but still they are almost two times less than those of the IEA. In the NPS scenario, gas production in Russia in 2030 should reach 772 mtoe/year, whereas in the ES-2030 it is assumed that production levels will be 710-

755 mtoe/year. But even if we correct for different amounts of future gas production, the amount of investment required for gas production in Russia is still twice as high in the IEA as in the Energy Strategy.

In principle, this may reflect an underestimate of the amount of investment required in the Russian gas sector by the Energy Strategy and the General Scheme for Gas Sector Development. The latter is not very likely, as these indicators generally are based on industry estimates, principally those of Gazprom, and its interest in playing down the volume of investment is illogical.

On the other hand, this difference may also reflect a revaluation of the IEA investments that are required to ensure a certain level of production. If this is the case, we should perhaps take a more sceptical view of the estimates of the required investments in other regions (note that the IEA's "increased" attention to investments in countries exporting oil and gas is also noted by the IEF in the IEA analysis of the effect of reducing investment in times of crisis in the 2009 report).

The discrepancy may also partly be explained by the high marginal cost of production capacity in Russia beyond a certain level, which at a higher level of production in the IEA significantly increases the size of the average investment required. The overall effect may be explained by a combination of all three reasons.

Section 4.2. Modelling Tools of the Energy Information Administration of the US Department of Energy (EIA DOE)

Along with the prospects of global energy development that are published by the International Energy Agency or by major energy companies, the forecasts prepared by the Energy Information Administration of the US Department of Energy (EIA DOE, hereafter referred to as "the EI Administration") enjoy wide popularity in the expert community. In contrast to other bodies, the EI Administration stimulates the evolution of tools that can be applied; to be more precise, it stimulates their replacement, updating and symbiosis for the purpose of ensuring compliance with increasingly complicated business processes in the context of global energy.

The modelling tool of the EI Administration was initially developed for evaluating the prospects of the US energy system's development and it was applied for that purpose until the mid-1990s. In 1990, the IFFS (Future Forecasting System) model was replaced by not only a single model but a modelling approach known as NEMS (National Energy Modelling System). As was the case with the previous models, the main purpose of this tool consisted of developing medium-term forecasts for the development of the US energy system. Subsequently, the scope of the modelling analysis was expanded to include the possibility of evaluating various ecological and regulatory measures, and the geographical scope expanded to become a global energy model.

Since 1994, the main purpose of the NEMS model has been to render assistance in the preparation of scenarios for the Annual Energy Outlook, which is published by the EI Administration's Department of Integrated Analysis and Forecasting.

Among other things, the NEMS model is utilised by the US Energy Department to evaluate alternative energy sources and different assumptions concerning the economic aspects of energy markets, the environmental impacts, and security aspects. The planning horizon covers a period of about 25 years from the current date. According to the model's authors, the main economic, demographic and technological assumptions for modelling may be sufficiently justified by the existing vision of development in this period.

Beginning from the year 1992, work on producing a more aggregated model of world development – the WEPS (World Energy Projection System) – was being carried out in parallel. In 1997, the final version of this system was completed; that version was used for preparing the

Information Energy Outlook (IEO) in the period from 1998 (the first issue) to 2002. In the following years, until 2007, the WEPS model was updated and the new version took on the suffix *Plus* (abbreviated as WEPS+).

The more complicated mechanisms of the world energy markets have necessitated the production of additional instruments. Thus, in the period from 2002 to 2006, calculations for an IEO review were carried out by means of the SAGE model (System for the Analysis of Global Energy Markets), developed in 2003 within the framework of the ETSAP (Energy Technology Systems Analysis Programme, the programme for researching energy technologies according to the canons of system analysis - this activity is coordinated by the International Energy Agency (IEA) within the framework of the Implementation Agreements). At the same time, the part of the forecasts that could not be covered by SAGE (due to the upgrading of the WEPS) was carried out on the basis of the international energy module of the NEMS approach.

According to IEO-2008, the GWOB (Generate World Oil Balance Model) oil sector model was added to the tools used (WEPS+ and SAGE).

Beginning from the year 2009, the WEPS+ model has again become positioned by the Energy Information Administration as the main tool for making forecasts. The model symbiosis at this point in time is seen as follows:

- The WEPS+ model is the main model. After the model's upgrade, it includes a detailed module of the International Gas Sector (linked with the interface of the Oil and Gas Supply module of the NEMS model), the Transport module, and the Electric Energy Sector module (beginning from 2009);
- For estimating the demand for energy (by region and economic sector), the SAGE model was used prior to 2009;[27]
- For estimating the prospects for the production of liquid types of fuel[28], the GWOB model is used on the basis of available data on the active and prospective production and processing capacities.

It is worth noting that such an evolution of the models used cannot but affect the consistency of the Energy Information Administration's forecasts. Upon comparing reports from different periods, the observed volatility of both the main input data (mainly oil prices) and results differs in terms of their severity (in the case of the IE Agency's model, smoother transitions may be noted).

4.2.1. Results of Applying the WEPS+ Model According to the IEO-2010 Data

This subsection will cover the results of the EIA models. The main accent within the framework of this document will be placed on natural gas in the regions of the Organisation for Economic Cooperation and Development (OECD) and Russia. The Reference case and the *high oil prices* scenario were selected for analysis within the framework of this paper.

Reference case

This scenario assumes that the established technological trends and energy strategies will remain unchanged over the whole observation period, i.e. in the period through to 2035. According to this scenario, world consumption of primary energy will grow by 49% in the period 2007-2035. Total consumption of primary energy in the world will grow from 12.5 million tonnes of oil equiv-

[27] It is worth noting that the SAGE model is not mentioned in the description of the modelling tools defined in the IEO-2009. The IEO-2010 report does not contain a Section specifying the methods used.

[28] Beginning from 2008, the EIA incorporated a new system for categorising energy sources, in accordance with which the latter are sub-divided into solid, liquid and natural gas. Liquid fuels include oil and condensate, LNG, petroleum derivatives, oil-bearing sands, heavy still bottoms, coal processed into liquid fuels, gas processed into liquid fuels, shale oils and biofuels.

alent in 2007 to 18.6 million tonnes of oil equivalent in 2035 (Table 40 illustrates the consumption forecast, broken down in terms of fuel types).

The global economic recession, which began in 2008 and continued throughout 2009, has had a considerable effect on energy consumption in the short-term period. The total consumption of energy resources decreased by 1.2% in 2008 and is estimated to have fallen by 2.2% in 2009 owing to a drop in consumer demand. Despite the fact that external data indicate that the global economy has emerged from the crisis, the rate of recovery varies in different countries. For instance, China and India are the leaders in terms of this process, while Japan and the EC are among the countries that are lagging behind.

Nevertheless, for many regions of the world reviewed in the Reference scenario, patterns of Gross Domestic Product (GDP) growth corresponding to pre-crisis forecasts were employed. The greatest growth in energy consumption is expected in the non-OECD countries, where the total energy consumption should grow by 84%. For purposes of comparison, it is noteworthy that this indicator in OECD countries should only grow by 14%. Such development is determined by GDP growth in these regions. Thus, GDP growth, on average, is expected at the rate of 4.4% per annum in non-OECD countries, while this indicator will amount to 2% per annum in OECD countries.

The basic input data and assumptions in the WEPS+ model are GDP growth rates and oil prices. Table 56 illustrates the main economic and demographic assumptions for the world on the whole, for the OECD-Europe region and for Russia.

Table 56. Main economic and demographic assumptions

	2007	2015	2020	2025	2030	2035	Annual change 2007-2035 %
GDP, World, billion 2005'$	49 106	59 136	66 140	76 277	90 181	102 057	2.6
GDP, OECD Europe, billion 2005'$	15 594	16 889	18 665	20 453	22 319	24 306	1.6
GDP, Russia, billion 2005'$	889	1 053	1 234	1 436	1 653	1 894	2.7
Population, World, million people	6 650	7 256	7 610	7 932	8 217	8 469	0.9
Population, OECD Europe, million people	541	558	565	571	575	577	0.2
Population, Russia, million people	142	138	135	132	129	125	-0.4

As indicated in Table, Russia stands out from the list of forecast indicators, primarily in terms of the trend of a declining population. At the same time, GDP growth conforms to the global level, at 2.7% per annum, which points to a gradual increase in per capita GDP. It should be noted that the GDP indicators for Russia provided in Table 1 lag behind the actual figures.

The oil price forecast has changed slightly from the time of the IEO-2009 publication. The curve corresponding to the Reference scenario may be observed in Figure 39.

The different agencies (e.g. IEA, EIA, etc.) repeatedly re-adjusted oil price growth patterns in the period 2006-2010 with the publication of every new Outlook, owing to radical changes in price trends in around 2008. The forms of the forecasts for the different scenarios on oil price growth were established by 2008 and, since then, they have only been updated in terms of the currency exchange rate and calibration in terms of new retrospective values.

At this point in time, the patterns outlined in Figure 39 are similar to those specified in the IEA reports or in the forecasts produced using the TIMES model (with the exception of the fact that linear trends are applied in many forecasts).

Following tables show the results of the WEPS+ model for the Reference scenario. In order to convert quadrillion British Thermal Units to million tonnes of oil equivalent, the coefficient $2.52*10^{-8}$ was applied.

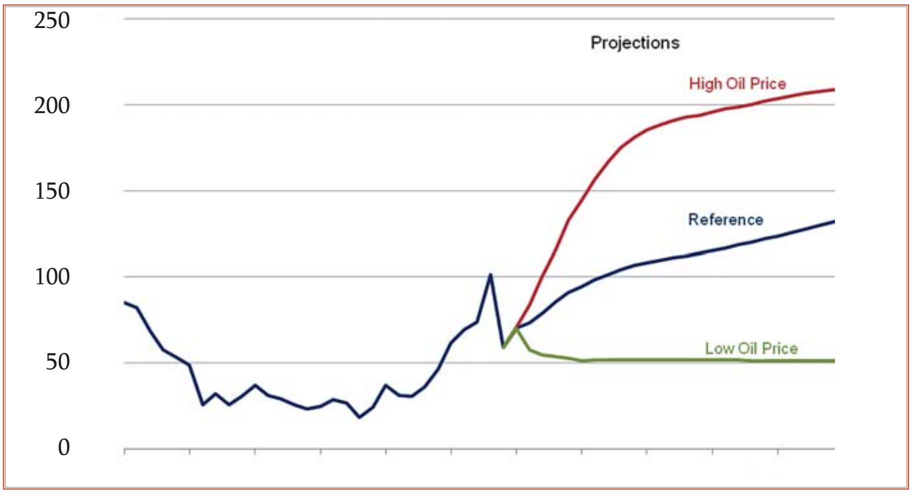

Figure 39. **Average annual world oil prices in three cases, 2005-2035**

Table 57. World energy balance. Reference case

Mtoe	2007	2015	2020	2025	2030	2035	Annual change, % 2007-2035
Liquids	4402.4	4518.4	4687.2	4969.4	5292.0	5634.7	0.9
Natural gas	2824.9	3253.3	3558.2	3785.0	3926.2	4082.4	1.3
Coal	3336.5	3505.3	3840.5	4228.6	4677.1	5198.8	1.6
Nuclear	682.9	811.4	942.5	1035.7	1106.3	1186.9	2.0
Others	1229.8	1607.8	1849.7	2076.5	2298.2	2515.0	2.6
Total	12479.0	13696.2	14880.6	16095.2	17299.8	18615.2	1.4
CO_2 emission, mln t	29694.0	31509.0	33812.0	36460.0	39268.0	42392.0	1.3

According to the Reference scenario, the greatest consumption growth with respect to renewable energy sources and other types of energy, as well as nuclear energy, is expected in the period from 2007 to 2035. We draw attention to the rather high indicator for coal consumption (1.6% per annum), which is higher than the growth rate of total energy consumption. It is also worth noting the growth rate for CO_2 emissions, which is comparable to that for total energy consumption (which, given a GDP growth rate of 2.6% per annum, indicates a gradual decarbonisation of GDP), as well as the conditional consistency in the coefficient of energy intensity and carbon intensity to GDP. The lowest growth rates are seen for liquid types of fuel, which is determined, first and foremost, by a deceleration of oil consumption growth.

In the European energy balance, two components may simultaneously be noted: a drop in consumption of coal and liquid types of fuel against the background of a worldwide growth trend. However, it is also noteworthy that the forecast indicates a slight increase in total energy consumption in Europe. At a time when GDP growth is at 1.6% per annum, it is clear that new energy saving technologies have played a role herein. An accent on renewable energy is also apparent here (the highest growth indicator). CO_2 emissions are declining but much slower than the rate specified in the European Commission's plans. The energy intensity and carbon intensity of the GDP in the countries of the OECD-Europe region will substantially decrease in the period until 2035.

Table 58. OECD Europe energy balance. Reference case

Mtoe	2007	2015	2020	2025	2030	2035	Annual change, % 2007-2035
Liquids	796.3	730.8	698.0	698.0	705.6	713.2	-0.4
Natural gas	499.0	524.2	546.8	556.9	559.4	569.5	0.5
Coal	332.6	289.8	282.2	274.7	272.2	277.2	-0.6
Nuclear	229.3	244.4	252.0	264.6	274.7	282.2	0.8
Others	219.2	277.2	312.5	347.8	365.4	380.5	2.0
Total	2074.0	2066.4	2091.6	2142.0	2179.8	2222.6	0.2
CO_2 emission, mln t	4386.0	4110.0	4042.0	4037.0	4052.0	4107.0	-0.2

Table 59. Forecasts of gas production and export

Mtoe	2007	2008	2015	2020	2025	2030	2035	Annual change, % 2007-2035
Russia, production	654.2	662.6	651.3	688.1	716.5	750.4	773.1	0.6
Russia, export	178.4	186.9	175.6	203.9	226.5	252.0	274.7	1.5
Central Asia, production	172.7	186.9	220.9	229.4	232.2	229.4	232.2	1
Central Asia, export	56.6	65.1	85.0	90.6	87.8	85.0	93.5	1.8
Middle East, production	356.8	382.3	591.9	696.6	753.3	787.2	804.2	2.9
Middle East, export	53.8	53.8	127.4	175.6	212.4	218.1	226.5	5.2

As illustrated in Table, it is worth noting the considerable increase (by 2.25 times) in gas production in the Middle East, which will result in an abrupt increase (by 4.2 times) of exports in comparison to the levels observed in 2007 (including increases by 3.1 and 4 times, respectively, in the period until 2025). Also noteworthy is the application of the potential of Central Asian producers, which will enable increasing gas production by 1.5 times in those countries by the year 2035 and boosting gas exports by 1.65 times in the same period.

In general, the favourable climate with stable moderate growth is expected for the world's major natural gas producers.

Table 60. OECD Europe gas balance

bcm	2007	2008	2015	2020	2025	2030	2035	Annual change, % 2007-2035
Production	288.8	303.0	271.9	254.9	243.5	235.0	226.5	-0.9
Net import	254.9	252.0	303.0	345.5	365.3	382.3	399.3	1.6
Consumption	543.7	–	572.0	594.7	608.8	608.8	620.2	0.5

The forecasts outlined in Table fall within the range of the forecast researched earlier (in the IEA, TIMES, PRIMES models). The rate of production decline is a notably moderate one, which is most probably due to the rather high price for oil, even according to the Reference scenario.

High oil price scenario

The difference of this scenario consists of application of the pattern for price fluctuations for oil, which accords with the *High Oil* scenario.

Table 61. World energy balance. High oil case

Mtoe	2007	2015	2020	2025	2030	2035	Annual change, % 2007-2035
Liquids	4402.4	4238.6	4168.1	4342.0	4581.4	4843.4	0.3
Natural gas	2824.9	3258.4	3603.6	3858.1	4024.4	4208.4	1.4
Coal	3336.5	3515.4	3870.7	4301.6	4800.6	5367.6	1.7
Nuclear	682.9	814.0	942.5	1035.7	1106.3	1186.9	2.0
Others	1229.8	1605.2	1852.2	2101.7	2356.2	2578.0	2.7
Total	12479.0	13429.1	14437.1	15636.6	16868.9	18184.3	1.4
CO_2 emission, mln t	29694.0	30819.0	32626.0	35162.0	37959.0	41111.0	1.2

It is possible to draw the conclusion that, in the case that oil prices are high, only oil consumption will decline at the global level (as oil is the main component of the category *liquid types of fuel*). Moreover, this effect will be observed in the period until 2020, after which the economy should adapt to the continuing growth in oil prices and positive oil consumption dynamics will resume.

Table 62. OECD Europe energy balance. High oil case

Mtoe	2007	2015	2020	2025	2030	2035	Annual change, % 2007-2035
Liquids	796.3	675.4	604.8	594.7	594.7	597,2	-1.0
Natural gas	499.0	531.7	556.9	574.6	577.1	589.7	0.6
Coal	332.6	292.3	284.8	277.2	279.7	292.3	-0.5
Nuclear	229.3	244.4	252.0	264.6	274.7	282.2	0.8
Others	219.2	274.7	312.5	347.8	367.9	383.0	2.0
Total	2074.0	2016.0	2013.5	2058.8	2096.6	2144.5	0.1
CO_2 emission, mln t	4386.0	3985.0	3829.0	3811.0	3829.0	3903.0	-0.4

High oil prices should have an insignificant impact on the total volume of energy consumption, and the stabilisation of oil consumption levels on the entire planning horizon should be compensated by a minor increase in the consumption of gas, coal and renewable energy sources.

In the OECD-Europe region, high oil prices should also not have impact significantly on the total energy consumption level. It is quite predictable that the greatest decrease in consumption will be observed in the oil sector. To maintain the total level, the above-mentioned reduction is compensated by a minor growth in gas consumption and a deceleration in the reduction of the use of coal. Additional coal consumption should lead to a reduction in CO_2 emissions, which may be explained by the lower consumption of oil products.

As indicated in Table below, in the case of high oil prices, gas production in Russia remains at the same level, while exports should increase. The Middle East is defined separately in both Table 59 and Table 63 – it is likely that this model has factored in assumptions about low production costs and transport, as well as the high potential of reserves and possibility for economically-efficient gas production in that region. In the *high oil prices* scenario, the greatest increase in gas production and export levels is also observed in this region.

One factor worthy of attention is an insignificant reduction in gas exports from Central Asia (87.6 bcm in 2035 are specified in this scenario, in comparison with the 93.5 bcm indicated in the Reference scenario). It is possible that competition will occur with gas from the Middle East.

Table 63. Forecasts of gas production and export in high oil case

Mtoe	2007	2008	2015	2020	2025	2030	2035	Annual change, % 2007-2035
Russia, production	654.2	662.6	651.3	691.0	733.4	761.8	778.8	0.6
Russia, export	178.4	186.9	175.6	215.2	252.0	277.5	288.8	1.7
Central Asia, production	172.7	186.9	220.9	232.2	232.2	226.5	226.5	1
Central Asia, export	56.6	65.1	87.8	93.5	90.6	87.8	87.8	1.7
Middle East, production	356.8	382.3	591.9	705.1	775.9	821.2	877.9	3.3
Middle East, export	53.8	53.8	127.4	172.7	209.6	232.2	252.0	5.6

Table 64. OECD Europe gas balance in high oil case

bcm	2007	2008	2015	2020	2025	2030	2035	Annual change, % 2007-2035
Production	288.8	303.0	271.9	254.9	237.9	229.4	220.9	-0.9
Net import	254.9	252.0	308.7	351.1	385.1	399.3	413.4	1.8
Consumption	543.7	–	577.7	606.0	625.8	628.7	640.0	0.6

As was noted earlier, gas consumption in the OECD-Europe region will grow at a high rate, owing to a drop in consumption of liquid types of fuel. As indicated in Table 64, that is possibly due to an increase in imports (by 1.8% per annum in the *high oil prices* scenario in comparison with 1.6% per annum in the Reference scenario).

4.2.2. Questions and Remarks with Respect to EIA Modelling Tools

In general, the context of the modelling instruments produced by the Energy Information Agency of the US Energy Department is not sufficiently clear. The models have virtually not been documented. Moreover, in order to understand the pattern of the models used, as well as their chronology (evolution), the authors had to appeal to their colleagues from the EI Agency for further information.

Despite the negative feature specified in article 1, in comparison with the other models analysed in this document, the greatest progress herein was attained in terms of the intensiveness of the analysis of the EI Administration models. In particular, the authors of this document have access to the complete WEPS 2002 model (set of Excel files), a fact that has greatly compensated for the lack of literature enabling this subject to be studied in practice. This fact may also assist in terms of mastering one of the objectives of the Thematic Sub-group of the Russia-EC Energy Dialogue – namely, the coordination of analytical and forecasting approaches in the energy sector between Russian and western research centres. Taking into account that the main Russian forecasts in the energy sphere are built on the basis of balance models, which are realised in Excel, such an experience could prove to be very useful.

Since the initial publication of the International Energy Outlook (IEO-1998), the EI Agency has constantly changed the set of models used, i.e. from the joint application of balance models (WEPS and other conjugate models) to the exclusive application of iterative models of the SAGE type (see section 1 for a detailed chronology). Of course, this leads to the question about the consistency of the forecasts pertaining to the different years it was issued. In particular, some expert circles regularly criticise the constant changes in the main assumptions in the model in recent years, i.e. oil price patterns, which are also a product of one of the Agency's models.

The main WEPS model was realised in MS Excel in the form of electronic tables. Such practice was widely used at the end of the 1990s; however, the current requirements of modelling tools are not so much expressed in terms of data storage and ease of access (according to information available to the authors of this paper, these aspects were updated in the WEPS+ model) as they are in terms of functionality. The above-mentioned aspects form a severe barrier to the further expansion of the model. In comparison with the dynamic models considered earlier, the WEPS model represents a rather simple model for covering the global challenges that are resolved by the Energy Information Agency.

Section 4.3. The MIT Research

On June 23, 2010, the research centre Massachusetts Institute of Technology (MIT) Energy Initiative issued a preliminary report with respect to research it had conducted on the role of gas in the energy sector. The report was titled *The Future of Natural Gas*. The final report on the research should be published by the end of 2010. While the research was intended for use by the USA, the authors believe that many of its conclusions may be applied in the wider global context. The time horizon covers until 2050, though some of the indicators cover the period through to 2100. The Project does not intend to produce long-term periods in terms of energy resources' volumes and prices; rather, it is focused on detecting the long-term consequences of restricting carbon dioxide emissions.

The research reviews three scenarios, namely:

- *The Business-as-usual (BaU)* scenario considers the maintenance of current tendencies without the imposition of restrictions for greenhouse gas emissions.
- According to the Price Scenario, the incorporation of price formation for CO_2 emissions leads to a 50% reduction in emissions by the year 2050 (in comparison with the year 2005).
- T*he Regulatory Scenario* provides for a drop in CO_2 emissions without incorporating price formation for emissions; emission reductions are achieved by means of state policy measures that are focused on increasing the role of renewable energy sources (RES) and decommissioning coal power stations.

Two probable scenarios reviewing the development of the gas market in the worldwide context are also provided:

- maintenance of the regional division of the gas market;
- globalisation of the gas market in a similar way to that of the oil market.

4.3.1. Methodology and Assumptions of the Research

The following methodology was applied when analysing natural gas supply. The gas supply curves were developed in the first stage, reflecting the dependence of recoverable gas reserve volumes on the price of gas. The ICF Hydrocarbon Supply Model and the ICF World Assessment Unit Model were used to produce the above-mentioned curves. The input data for the integrated economic modelling are calculated by means of the obtained curves.

In the second stage, the uncertainty factors of natural gas supply were defined. At the same time, the gas supply distribution curve is determined according to probability.

Integrated economic modelling was carried out by means of the MIT EPPA and U.S. Regional Energy Policy (USREP) models, which are multi-sector economic models for the world and the USA respectively.

Assumptions in terms of the amount of unit costs for electric power generation are based on the coefficient of the sum of all operational and capital investments to the total volume of electric power generated.

Table 65. Levelized Cost of Electricity (2005 cents/kWh)

	Reference	Sensitivity
Coal	5.4	
Advanced Natural Gas (NGCC)	5.6	
Advanced Nuclear	8.8	7.3
Coal/Gas with CCS	9.2/8.5	6.9/6.6
Renewables		
Wind	6.0	
Biomass	8.5	
Solar	19.3	
Substitution elasticity (Wind, Biomass, Solar)	1.0	3.0
Wind+Gas Backup	10.0	

Sources: MIT, The Future of Natural Gas: Interim report, 2010

Assumptions in terms of economic growth in the USA are as follows: 0.9% per annum from 2005 to 2010; 3.1% from 2010 to 2020; and 2.4% in the period from 2020 to 2050.

The sources of input data for the models are as follows: USGS, the Potential Gas Committee (PGC), the Energy Information Administration (EIA), the National Petroleum Council (NPC), ICF International ICF and MIT.

Three models were applied for the purposes of estimating the potential demand for natural gas in the electric power sector. They are as follows:

The MARKAL model (the preceding generation with regard to models of TIMES type; details are given in the Third Stage report), which is related to electric power sector in the USA.

The Renewable Energy Deployment System (ReEDS) model is intended for forecasting the expansion of generation capacities, taking into account the impact of electric networks and the reliability of supplies and synergy on the part of power stations. This model is also used for considering the stochastic nature of "intermittent" energy sources (such as wind and sun).

The Memphis model is intended for modelling the hourly generation of electric power given substantial volumes of "intermittent" power generation.

4.3.2. Results of the Research

The first section (General Context) considers the physical properties of natural gas, its advantages and disadvantages in comparison with other types of fossil fuel, as well as the history of the development of the US gas sector. It is noteworthy that, owing to the natural gas specifics and development of the sector, this analysis should consider a number of uncertainties, as follows:

The future conditions for controlling carbon dioxide emissions;

Overhead costs for applying different technologies in the energy sector (depending on the Research and Development Works Programme, the cost of emissions quotas;

The volume of reserves and production costs of extracting gas, as well as the feasibility of production in terms of the impact on the environment;

The development of the international gas market (this takes into consideration that, in the future the USA, despite the production of its own non-conventional gas, may return to international gas markets).

Gas Supply

The authors have noted that current world gas reserves are estimated in the range of 12.4 to 20.8 quadrillion cubic feet - an average of 150 years at current consumption levels (non-conventional gas sources are not included in that amount, with the exception of those in the USA and Canada). In this case, 70% of gas reserves are concentrated in three regions: Russia, the Middle East (mainly in Qatar and Iran), and North America. Economically recoverable gas reserves at the export price of 4 USD/MBTU amount to 9 quadrillion cubic feet of gas.

The recoverable reserves of non-conventional gas sources in the USA are estimated as ranging between 420 to 870 billion cubic feet. At the wellhead price of 6 USD/MBTU, the economically recoverable reserves amount to about 400 billion cubic feet. The MIT research indicates that shale gas reserves greatly differ in terms of different fields and even within fields with respect to the well production rate. In general, shale resources are not sufficiently studied even in the USA, in comparison with conventional gas, which makes it difficult to develop optimal programmes for gas production. The research also implies that the problem associated with the environmental impact of gas production using unconventional sources may be resolved.

The total reserves of unconventional gas sources in the world is estimated at 24 quadrillion cubic feet; however, the extremely low level of reliability of such estimates reliability has been noted. It is probably for this reason that gas supplies from unconventional sources (with the exception of the USA and Canada) were not included when calculating the global gas supply curves (refer to Figure 18).

The authors have noted the crucial difference between conventional and unconventional gas reserves in terms of the gas recovery coefficient, which amounts to 80% for the former and from 15% to 30% for the latter type of reserves.

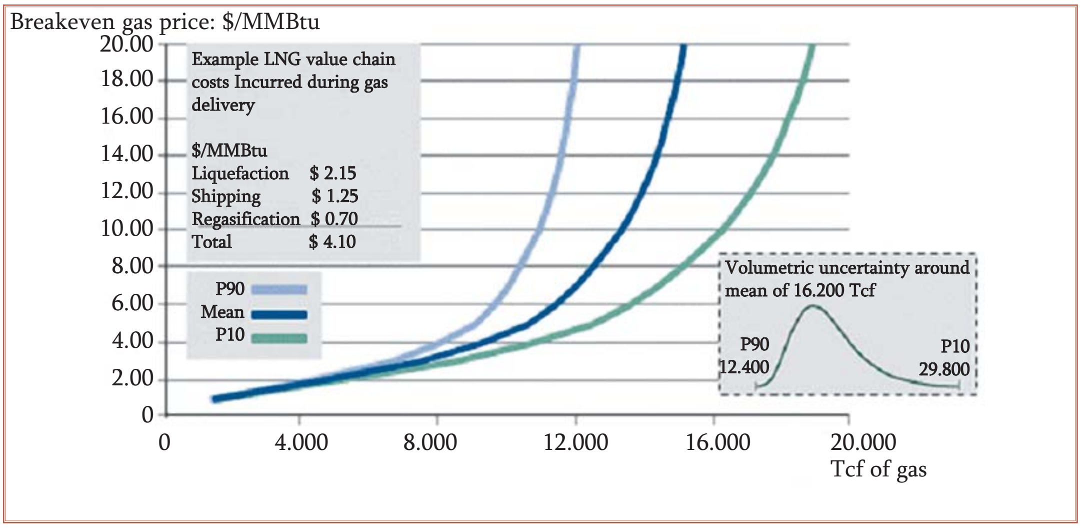

Figure 40. **Global Gas Supply Cost Curve, with Uncertainty; 2007 Cost Base**
Sources: MIT, The Future of Natural Gas: Interim report, 2010

An analysis of the supply curves related to the different gas resources indicates that they have different elasticity in terms of the price (refer to Figure 40). The diagram reflects the limitations of the unconventional gas resources capacities at any gas price. It is worth noting that two points are noticeable on the shale gas curve and, upon passing through them, price elasticity increases considerably.

The development of gas production using unconventional sources in those areas of the USA where it has never previously been utilised stipulates the necessity to construct powerful infrastructure for gas transportation, storage and processing.

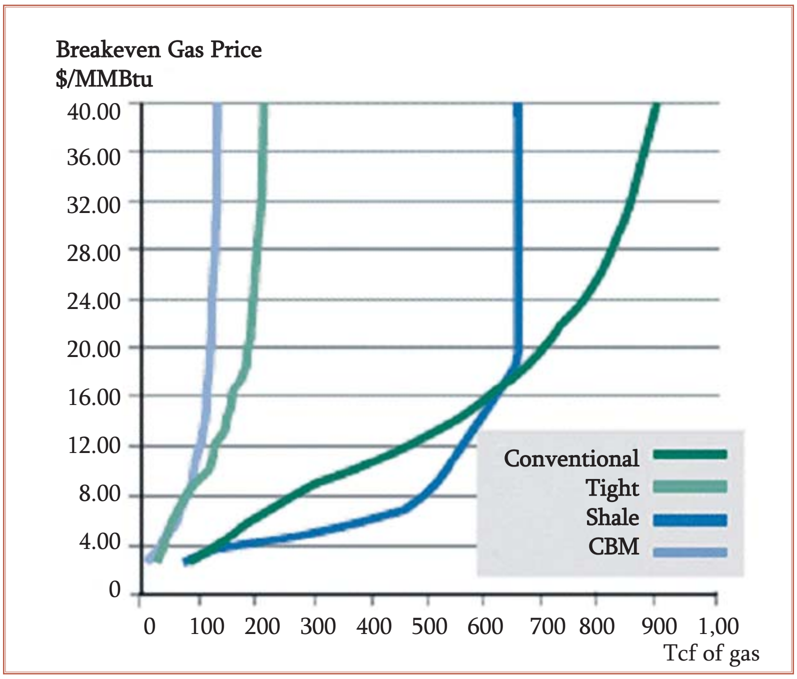

Figure 41. Breakdown of Mean U.S. Gas Supply Curve by Type; 2007 Cost Base
Sources: MIT, The Future of Natural Gas: Interim report, 2010

Gas Production, Consumption and Trading in the USA

The main factors affecting the development of the gas sector are as follows:

- Policy focused on limiting greenhouse gas emissions;
- Technological developments;
- The volume of gas reserves;
- The development of the world gas market.

The BaU scenario (which does not entail imposing emission restrictions) indicates that the average level of gas production in the USA should increase by 40% in the period from 2005 to 2050. Gas prices on the domestic market should turn out to be at USD 10.4 per thousand cubic feet. At the same time, both gas import to the USA (mainly from Canada) and gas exports (mainly to Mexico) should take place. It is worth noting that, in the pessimistic case, gas consumption in 2050 should decrease to the level observed in 2020, but prices should end up being 50% higher than the average values. According to the BaU scenario, coal will continue to dominate in the energy sector (though the use of gas in electric energy generation should increase by 70% in the period 2010-2050); nuclear and renewable energy sectors will develop slowly. In this case, SO2 emissions should increase by 40% in the period from 2005 to 2050.

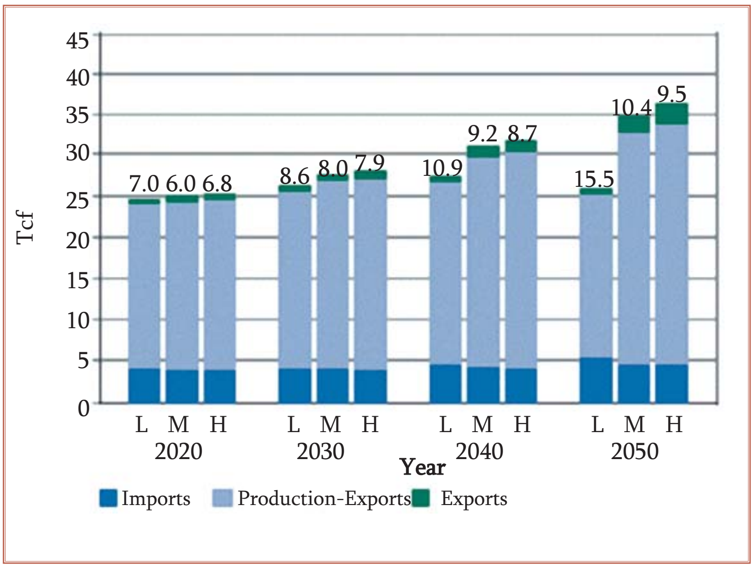

Figure 42. **US. Gas Use, Production and Imports & Exports (Tcf), and U.S. Gas Prices above Bars ($/1000 cf) for Low (L), Mean (M) and High (H) U.S. Resources. No Climate Policy and Regional International Gas Markets**

Sources: The Future of Natural Gas: Interim report, 2010

In scenarios providing for the limitation of CO_2 emissions through price formation, natural gas is the most advantageous type of fuel. In this scenario, due to the high prices of CO_2 emissions, demand for energy resources is declining and coal displacement by natural gas is occurring in the energy sector. The only factor that may change the latter tendency is an improvement in the efficiency of CCS technologies.

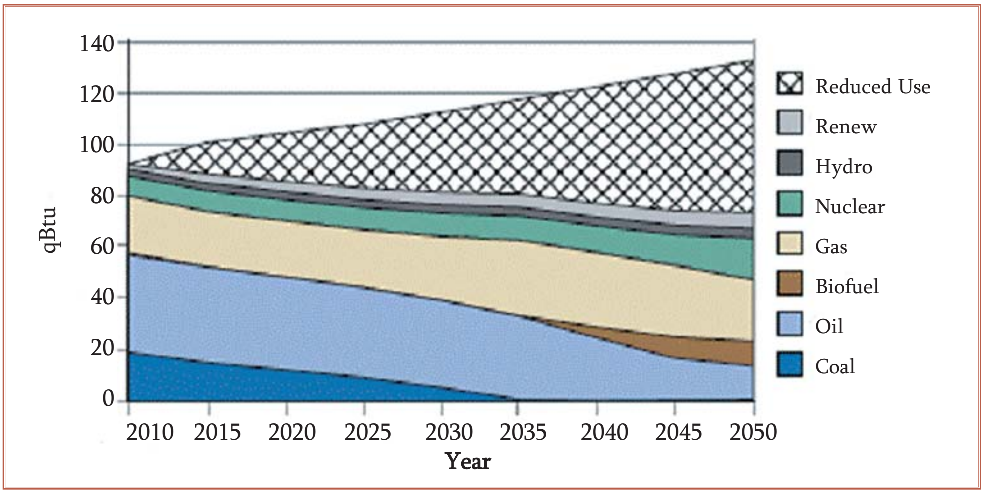

Figure 43. **Energy Mix under Climate Policy**

Sources: MIT, The Future of Natural Gas: Interim report, 2010

As a result, owing to a reduction in total energy consumption, the share of gas in primary energy consumption will grow from the current value of 20% to 40% by 2040. Then, in the period

2040-2050, there should be a minor decrease in gas consumption (refer to Fig. 5). It should be noted that, according to this scenario, gas consumption will drop to practically zero by 2035. A radical re-arrangement of the energy balance should take place. It is also worth noting that such an effect is attained in the case of extremely high prices for emission quotas, i.e. at USD 100 per tonne of CO_2 in 2030 and USD 240 per tonne of CO_2 in 2050. The price for quotas in 2030 should be close to the level specified in the 450 scenario, i.e. USD 110 per tonne. The MIT report indicates that such high prices for emissions will have a relatively minor effect on the economy, with the USA's GDP in 2030 declining by 2% and by about 3% in 2050. This conclusion appears overly optimistic. According to the *Price-Based Climate Policy* scenario, CO_2 emissions in 2050 should drop by 50% in comparison with 2005 levels.

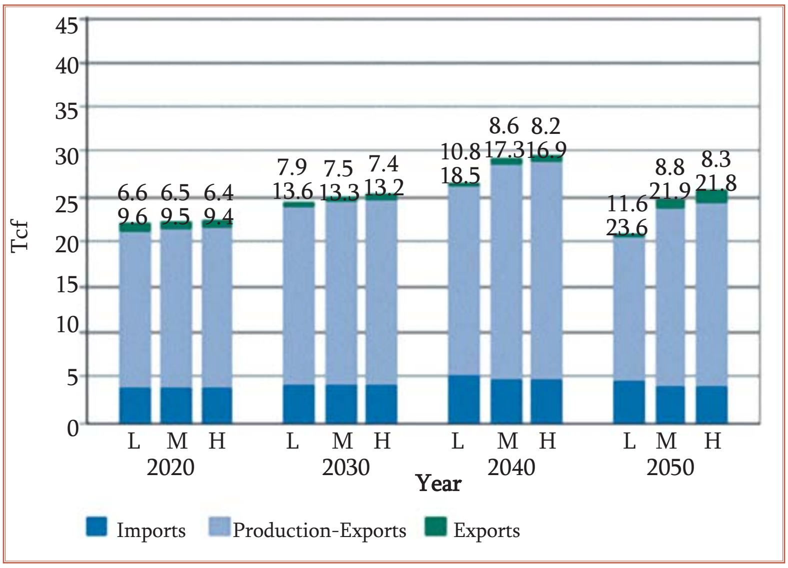

Figure 44. **U.S. Gas Use, Production and Imports & Exports (Tcf), and U.S. Gas Prices ($/1000 cf) for Low (L), Mean (M) and High (H) U.S. Resources, Price-Based Climate Policy**

Sources: MIT, The Future of Natural Gas: Interim report, 2010

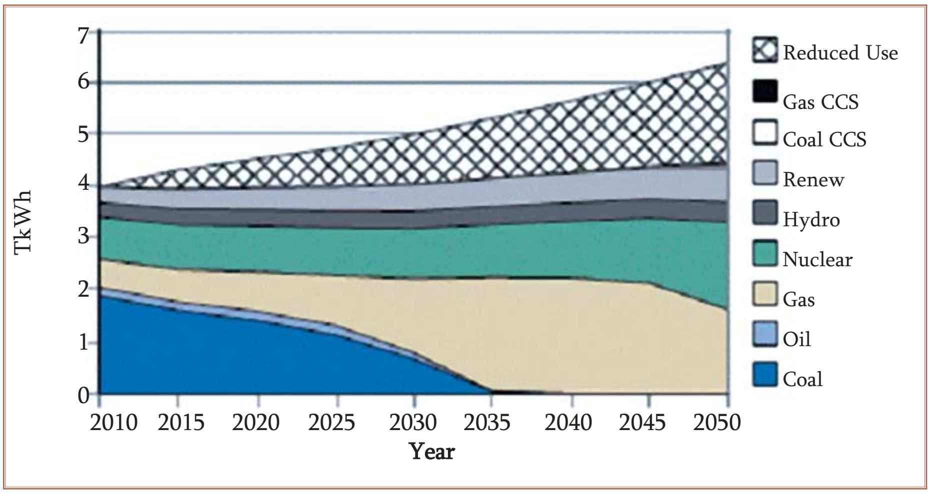

Figure 45. **Energy mix in electric sector under Price scenario**

Sources: MIT, The Future of Natural Gas: Interim report, 2010

The *Regulatory* scenario supposes that the share of RES in electric energy will be maintained at 25% in the period from 2030 to 2050 by special use of state policy. Taking into account that such measures are not supposed to be applied beyond the energy sector, according to this scenario, CO_2 emission levels in 2050 will remain at the same level recorded in 2005.

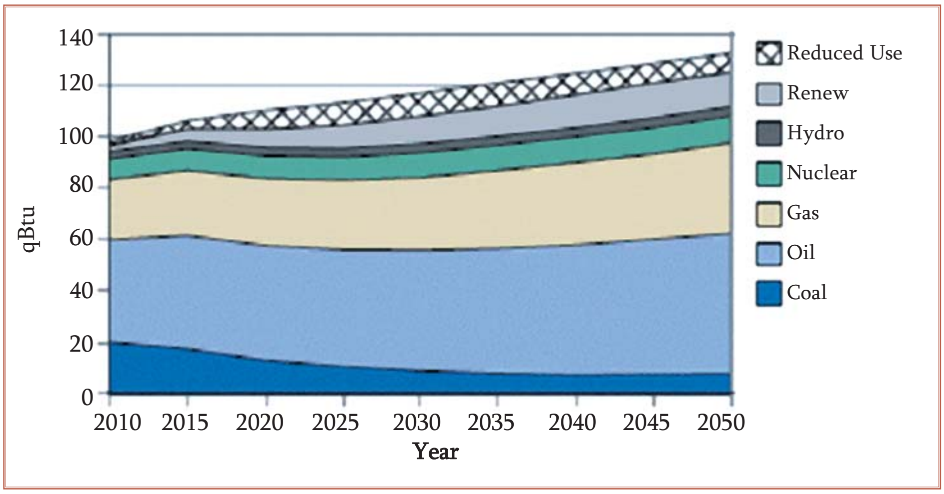

Figure 46. Energy Mix under Regulatory scenario
Sources: MIT, The Future of Natural Gas: Interim report, 2010

It is worth noting that, according to the *Regulatory* scenario, the utilisation of oil will grow substantially by 2050, which hardly may be considered as a sustainable prospect given a general understanding of oil supply restraints in the middle of the 21st century and the anticipated growth in demand for oil in the developing countries.

According to the *Regulatory* scenario, gas consumption will grow. However, against the background of general growth in the energy consumption, the share of gas should increase by less than that specified in the previous scenario - approximately up to 30% by the year 2050.

The incorporation of price formation policy and regulatory policy focused on limiting emissions will have tremendous affect on natural gas prices and on the USA energy sector in general.

The authors of this research also note that while investment and political decisions are oriented to the relatively short-term horizon, decisions on the stabilisation of greenhouse gas emissions in the atmosphere cannot be justified without considering the long-term perspective. For this purpose, the forecasting horizon used in the research was extended to the year 2100 while adding the assumption that CO_2 emissions will be reduced by 80% by that year relative to 2005. To achieve the above-specified objective, a complete de-carbonisation of the electric energy sector will be required. After the year 2065 (refer to the *Price* scenario), natural gas will not be used in the electric energy sector, with the exception of CCS technologies. That stipulates the significance of the development of expensive CCS technologies even given the presence of a substantial natural gas supply capable of displacing coal.

It is worth noting that, during preparations for the Copenhagen Conference and the Climate Change Summits, the objective of reducing greenhouse gas emissions by 80% in the developing countries by the year 2050 was specified. The MIT analysis confirms that it is impossible to attain full decarbonisation of the energy sector by that year due to the unavailability of CCS technologies and the sluggishness of such large-scale developments in the energy sector, not to mention the magnitude of costs required to realise the above-mentioned objective.

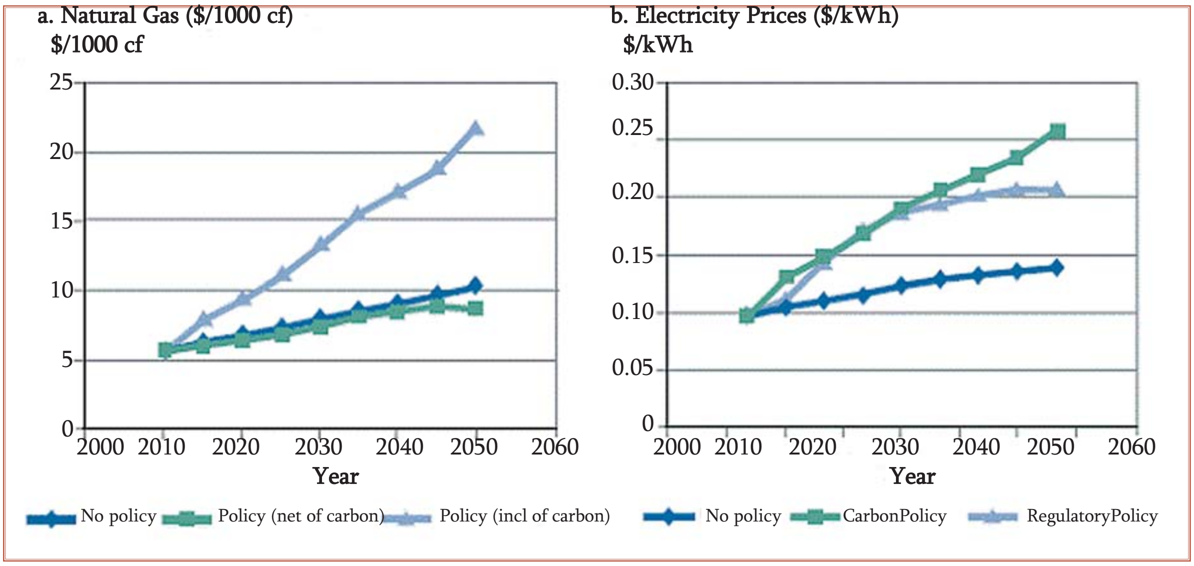

Figure 47. U.S. Natural Gas and Electricity Prices in different scenarios
Sources: MIT, The Future of Natural Gas: Interim report, 2010

It is worth noting that the *Price* scenario indicates that fossil fuels will be replaced with nuclear energy after 2050 rather than RES (as determined by the assumptions about overhead costs). Thus, natural gas will not turn out to be a panacea for reducing greenhouse gas emissions in the long-term horizon, but rather a bridge to a low-carbon future.

The Power Energy Sector

The previous report analyses the electric power and transport sectors (as natural gas consumers). The complete report also includes other sectors (the preliminary report contains a brief description of industry and the commercial and household sector.

The authors note that the USA's gas-fired power plants (384 GW of the installed facilities[29] at the date of the research) are divided into three types in terms of level and usage mode in terms of energy efficiency. These groups are as follows:

- combined cycle power plants (CCGT) (190 GW), which are relatively new power stations (86% of them are less than 13 years old) and have high energy efficiency and relatively high utilisation rate;
- old steam-driven power stations, which, from the outset were designed to utilise oil products or on a dual-fuel basis (80 GW);
- power stations equipped with single-cycle gas turbines (112 GW), which are generally used as peak capacitance.

Coal-powered and nuclear power stations have relatively low variable costs and thus, are used more often as the basic production capacities. The power stations utilising RES have virtually zero variable costs because they have no fuel costs; therefore they are also used as basic capacities. However their specific feature is the irregularity of energy generation, which is dependent on weather conditions.

Increasing "intermittent" energy resources (such as wind and sun) in the electric energy sector will lead to the following consequences:

[29] It is worth noting that the sum of 190, 80 и 112 GW does not come to 384 GW (thus 2 GW is lost). This is probably due to rounding or a lack of information on the types of some power stations.

In the short-term perspective, energy generation with the greatest operational costs will be displaced; in the majority of the US market, this refers to gas-fired power plants;

In the long-term perspective, two effects will be observable – an increase in the rated capacity of the more flexible power plants (basically, those that utilise gas) along with a reduction in their utilisation level and their displacement from the facilities for basic capacity utilisation (this will differ by region).

Figure 48 demonstrates the capacity utilisation levels of different types of generating capacities.

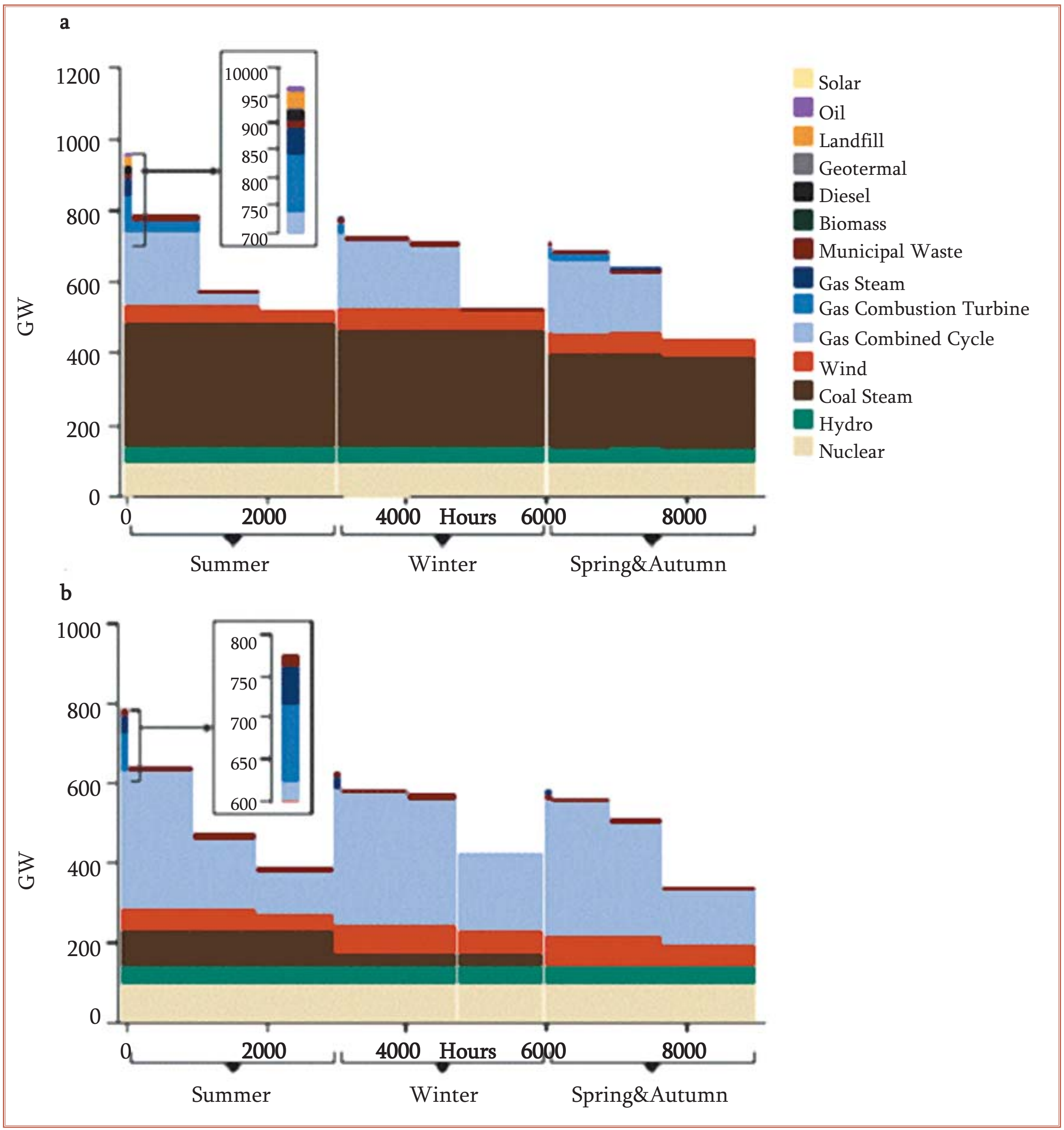

Figure 48. Load Duration Curve for the (a) No Policy and (b) 50% Carbon Reduction Policy Scenarios in 2030

Sources: MIT, The Future of Natural Gas: Interim report, 2010

The research analysed seasonal and daily variations of utilising different kinds of generating capacities, which enabled carrying out a rather interesting analysis to determine the sensitivity (the short-term effect) of a given technology's utilisation with an eye to increasing the utilisation of a certain type of production capacities (wind or solar capacities). In particular, it was proven that an increase in energy generation using wind energy by 1 GWhr effectively reduces gas energy generation by 0.65 Gwhr; the respective indicator for solar energy amounts to 0.9 GWhr.

An evaluation of the potential of coal power station substitution was also carried out according to US region (refer to Fig. 26). The substitution will become profitable in the case that they incorporate prices for CO_2 emissions. The optimal utilisation for CCGT stations is 85%. Having calculated the energy volume that could be generated by existing gas-fired capacities at 85% capacity and having subtracted from this the volume of energy actually produced (all data as of the year 2008), the authors obtained the current potential of increasing power generation on the basis of gas. Upon conducting a comparison with power volumes generated in coal-fired power stations, divided in terms of generation efficiency, it is possible to evaluate the potential of substituting coal with gas in the electric sector. Such states as Texas, Louisiana, Mississippi, Alabama and Florida have the greatest substantiation potential. The lowest substantiation potential is observed in the Mid West, particularly in Illinois and Ohio.

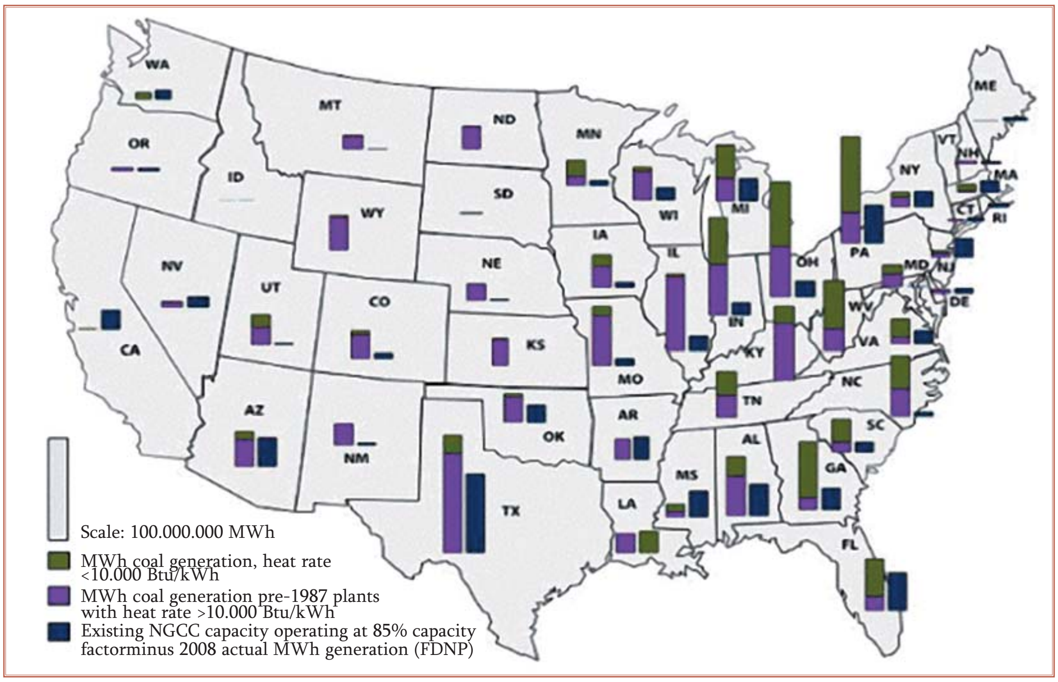

Figure 49. Scale and Location of Fully Dispatched NGCC Potential and Coal Generation (MWh, 2008)

Sources: MIT, The Future of Natural Gas: Interim report, 2010

The Transport Sector

The development of compressed natural gas (CNG) utilisation in the US transport sector will lead to a reduction in CO_2 emissions in the country. The conversion of automobiles to CNG should permit reducing emissions by 25% in comparison with benzene (gasoline) and besides, CNG is substantially cheaper than this fuel. The accumulative consumption potential of the two most prospective market segments in terms of gas (i.e. passenger vehicles and long-haul trucks) amounts to 3 billion cubic feet per year. Nevertheless, it is unlikely that the engine fuel market will become crucial in terms of natural gas consumption in the near future. At the same time, the authors assume that CNG will not be utilised as engine fuel due to the high overheads associated with its utilisation. However, according to the *Price* scenario, by 2040-2050, CNG may occupy about 20% of the engine-fuel market, owing to additional savings from lower CO_2 emissions.

Markets and Geopolitics

The report's authors have noted that the global gas market is currently in the development stage and, at this point in time, there are three major gas consumption markets in the world, i.e. North America, Europe and Asia. It is assumed that the volume of the global gas trade will grow. If that occurs, the USA may begin to realise the export of CNG in the future.

Inter-regional gas flows will greatly depend on the realisation of the scenarios of international gas markets' development. In the case of the globalisation of markets, the flows will expand significantly.

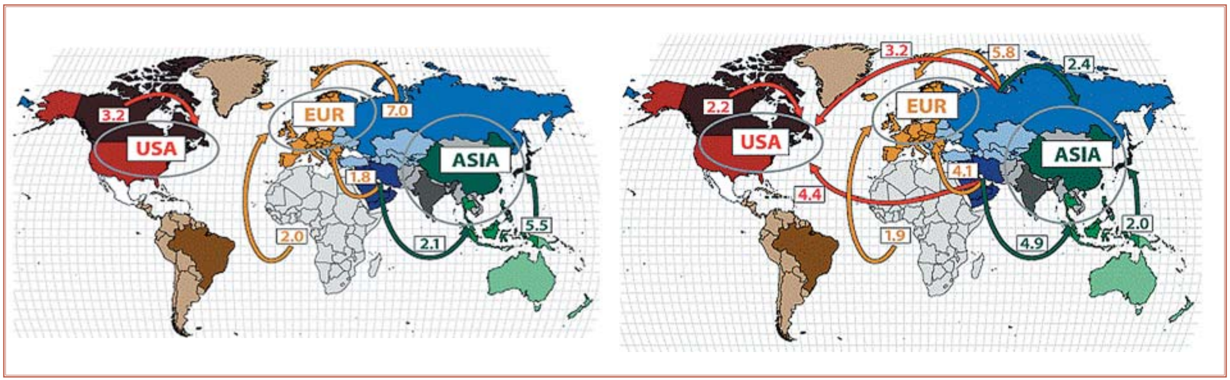

Figure 50. Interregional gas flows in 2030 under two scenarios, trillion cubic feet/year
Sources: MIT, The Future of Natural Gas: Interim report, 2010

It should be noted, as a rather strange circumstance, that eastward gas flows from the Russian Federation are not indicated at all in the first scenario, which does not correspond with currently available plans or the actual business situation.

Owing to the substantial concentration of conventional gas reserves, geopolitics and state policy play a crucial role in the development of the global gas market. Taking into consideration the growing role of natural gas in the country and in the world energy sector, the authors of this research assume that issues with respect to natural gas will appear on the agenda of US policy with increasing frequency. The critical issues associated with energy security are as follows:

The USA's and its allies' dependence on natural gas may ultimately restrict the country's foreign state policy capabilities, especially considering the unique volume of American international security obligations.

New players acting on the gas market may introduce barriers against market transparency (i.e. by concluding bilateral non-market long-term agreements, which is typical for China, for instance). Competition for control over gas pipelines and gas mainline routes in key regions will be intensified. Long supply chains increase the vulnerability of gas infrastructure.

Research, Development and Demonstration Installations (RD&D)

New technologies may change the relative competitiveness of domestic production in comparison with imports due to improvements in the efficiency of resources utilisation, reductions in overhead costs, and the lessened impact on the environment.

Some national and quasi-national RD&D programmes may be successful in developing non-traditional gas sources. Coupled with short-term tax incentives, this should have a significant impact on the non-traditional gas production business.

The most prospective programmes noted in the research are as follows: the analysis and modelling of shale formations, natural protection of the environment in the case of shale gas production, gas hydrates, and CCS.

4.3.3. Conclusions and Recommendations

The main conclusions drawn from the research are as follows:

- The existence of enormous natural gas reserves has led to a considerable increase in its utilisation, especially in the energy sector.
- The role of natural gas in the US energy balance will grow in the next few decades and, as part of that trend, unconventional gas sources will play a key role.
- The share of natural gas in the energy balance will be even greater once restrictions on CO_2 emissions are imposed. On the other hand, in the long-term perspective, more severe restrictions on CO_2 emissions may lead to a reduction in the role of all types of fossil fuel, including natural gas.
- The natural gas market may be subject to radical changes in the period through to 2050.

The MIT report indicates the following crucial factors, which should determine the future of natural gas as a peculiar kind of bridge to a low-carbonic future:

- Substantially lower level of greenhouse gas emissions from natural gas utilisation in comparison with other types of fossil fuel;
- The development of non-traditional gas production in North America;
- High overheads and slow development rates in terms of low-carbon alternative sources of energy.

The authors of this research suggest the following recommendations for the US government:

Policy aimed at reducing CO_2 emissions should establish a level playing field, in which all existing energy technologies would have the same conditions for competition (i.e. the absence of long-term subsidies or special state policy measures regarding separate types of fuel).

In the absence of the above-mentioned special measures, current state energy policy should try to reflect the main consequences of forming a unified competition field. This should lead, at minimum, to a reduction in overall energy consumption and the substitution of coal by gas in the energy sector in the near term.

Nevertheless, it should be necessary to realise short-term policy (i.e. targeted subsidies for limited time periods, RD&D programmes) directed at supporting key low-carbon technologies (e.g. renewable energy sources and CCS).

The displacement of coal production by that of gas should be considered as one of the opportunities for reducing CO_2 emissions in the short-term perspective.

In the case that energy generation from intermittent energy resources is substantially developed, state policy measures aimed at maintaining investment in gas generation at a sufficient level should be taken.

The administrative and regulatory barriers to the utilisation of gas as engine fuel should be eliminated.

In using its foreign policy, the USA should support transparency and the diversity of the global gas market and further development of gas production from non-traditional sources in the world, especially in Europe and China.

Several measures of domestic and foreign state policy should be adopted, as follows: realising an integrated approach to all energy issues (cooperation of all Agencies under the President Administration's leadership); supporting the IEA's attempts to draw more attention to natural gas and to involve new countries, (i.e. major developing markets such as China, India, Brazil) to membership in that organisation; expanding technologies for generating energy from non-traditional sources; furthering the expansion and integration of gas mainline systems; promoting the effective utilisation of gas on the US domestic market and the domestic markets of gas producing countries.

To ensure the development of gas production from non-traditional sources, the following developments are necessary: to further fundamental research in this sphere; that the United States Geological Survey (USGS) accelerate the development of updated methodology for assessing non-traditional energy reserves; to direct the joint efforts of companies and state authorities at minimising the environmental impact of gas generation from non-traditional sources.

The Presidential Administration and Congress should support RD&D programmes for domestic gas production both through a new programme of the US Energy Department and through an extra-budgetary sectoral programme.

It is worth noting that Russia was not specified among the countries that should, first and foremost, be involved as participants in the IEA.

The latest research carried out by MIT may be considered as one of the first signals on an emerging new tendency in the world - understanding the importance of the role of natural gas in the energy sector in future (for example, natural gas may be serve as a "bridge" in converting to low-carbon energy). Certainly, similar conclusions have also been expressed by other researchers but in this case, sectoral organisations such as Eurogas and International Gas Union or producing companies (ExxonMobil), which could be accused of closed-mindedness, have supported these statements.

An extremely important conclusion of the research carried out is the radical increase of the natural gas share indicated in the *Price* and *Regulatory* scenarios, i.e. by 40% and 30% respectively by the year 2050 (assuming a 20% level in 2005). The trend towards an increase in the gas share differs sharply from the conclusions, particularly those made by the International Energy Agency and especially upon comparing them with the environmentally-friendly 450 scenario produced by the IEA. Even more important is the fact that the assumptions of the MIT *Price* scenario and the IEA 450 scenario are very close in terms of the prices of quotas for greenhouse gas emissions in the USA (USD 100 and USD 110 per tonne by 2030). In many instances, the higher estimates of the role of gas indicated in the MIT research are determined by the deeper consideration of recent trends in the gas sector, i.e. the development of gas production from non-traditional sources. Certainly, increasing supply brings about a decrease in price, which leads to greater demand; however, in the long-term perspective, gas demonstrates its advantages against a background of toughened requirements for greenhouse emissions. In general, this leads to a growth in prices for energy resources.

It is obvious that the research was carried out in specific reference to the USA market; however, many of its conclusions may also be applied to other regions.

A rather crucial aspect of the research carried out is understanding the necessity to consider the long-term perspective when analysing CO_2 emissions and their consequences, which is lacking, for example, in the International Energy Agency report.

Unlike most other research that is based on a single model (as a maximum, the results of one or two models are used as input data for that model), the MIT report is built on the joint utilisation of seven different models. This fact may be viewed as a crucial advantage because any model has its own limitations in terms of utilisation (i.e. the impossibility of calculating a certain indicator, applying a certain approach, etc.). On the other hand, the joint application of many hybrid models requires extraordinary care because all of them should be compatible; in particular, every model should have consistent assumptions (i.e. if they are used successively, then the results of one model becomes the assumption of another one). If the models' assumptions conflict with each other (including unobvious assumptions which, in many cases, are not specified anywhere, which is why they are difficult to detect from the side and may be especially risky), then result of the joint utilisation will be methodologically incorrect.

Section 4.4. The ExxonMobil Forecast

This material is built on the basis of the most recent issue (ExxonMobil, Outlook for energy: a view to 2030, 2009) of the long-term forecast for the world energy sector, prepared by ExxonMobil. The newest ExxonMobil report was presented on February 2011.

In to the company's opinion, the main future challenge in the energy sector consists of satisfying the demands for the energy required by the entire world population. At this point in time, about 1.5 billion people have no access to electric power and 2.5 billion people still do not have access to modern fuel for the purposes of heat and preparing food.

4.4.1. Assumptions

As specified in the report, the world's population in the period from 2005 to 2030 grows at a rate of 0.9% annually. It is assumed that the global economy, in this case, will grow by 2.7% annually in the same period (taking into consideration the fact that the world's Gross Domestic Product should slow down by approximately 2% in 2009 due to the economic crisis).

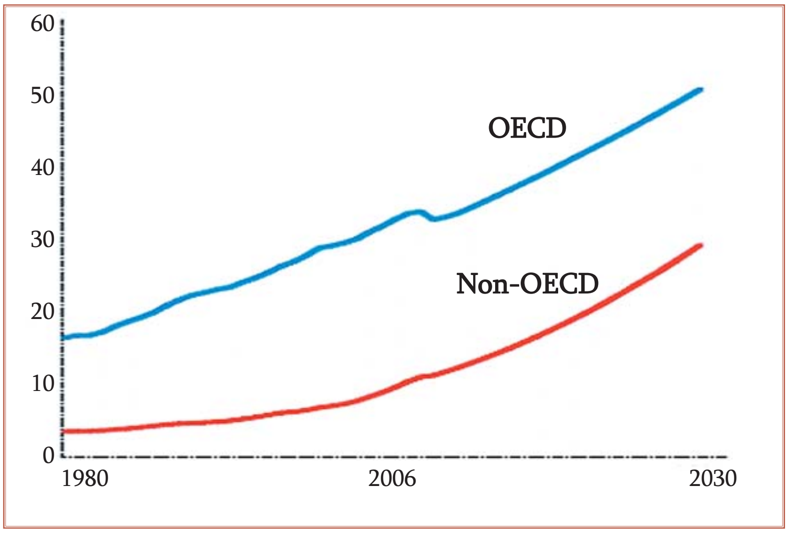

Figure 51. GDP in OECD and non-OECD countries, trillion dollars
Source: ExxonMobil, Outlook for energy: a view to 2030, 2009

The report assumes that the energy efficiency rate in the world will improve from 1.2% in the period 1980-2000 to 1.5% in the period 2005-2030.

4.4.2. The Modelling Mechanism

The ExxonMobil model does not contain detailed description of the calculation methodology, though some of the aspects are still indicated. In particular, an analysis of the overheads involved in power production under the different scenarios was carried out in order to determine the structure of energy resources consumption.

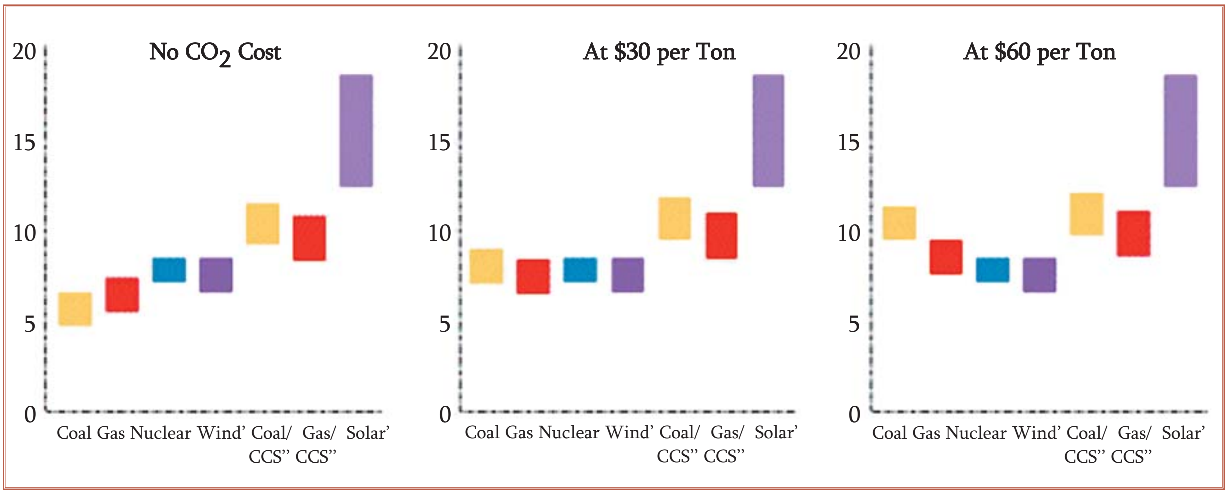

Figure 52. Cost per Kilowatt Hour U.S. baseload plants, startup 2025
Source: ExxonMobil, Outlook for energy: a view to 2030, 2009

The cost of one tonne of carbon dioxide emissions is taken as a main parameter for defining the scenarios, which is determined by the seriousness of the ecological aspects at this point of time and, moreover, in the long-term perspective.

The most profitable energy resources for the energy sector (without the US moving to implement a special policy on controlling carbon dioxide emissions) in the future are coal and natural gas.

Coal is the most sensitive energy resource to a change in the cost of CO_2 emissions. At 60 dollars per tonne and in the absence of the Carbon Capture and Storage technology (CCS), coal production becomes non-competitive relative to natural gas, nuclear energy and even compared to wind energy. At 30 dollars per tonne of emissions, energy production costs in the context of four main sources (coal, gas, nuclear energy, and wind energy) are at saleable levels but, on average, natural gas is still more attractive. The cost of producing electric power by solar power stations continues to be higher than the cost of other energy resources given any of the price levels for emission quotas that have been considered. Consequently, this will require subsidisation from the state.

Even at 60 dollars per tonne for carbon dioxide, the production cost of the electric power using CCS technology, is, on average, higher than that produced without using CCS technology. Thus, the prospects for applying CCS technology in future appear to be rather dim, according to ExxonMobil. This technology will be used only given the introduction of state subsidies.

It is worth noting an important particularity. This is, based on the above-mentioned analysis, ExxonMobil does not expect that there is any possibility for increasing the cost of quotas for emissions to 110 dollars per tonne, as it should be the case for the USA by the year 2030, according to the 450 scenario put forward by the International Energy Agency.

4.4.3. Results

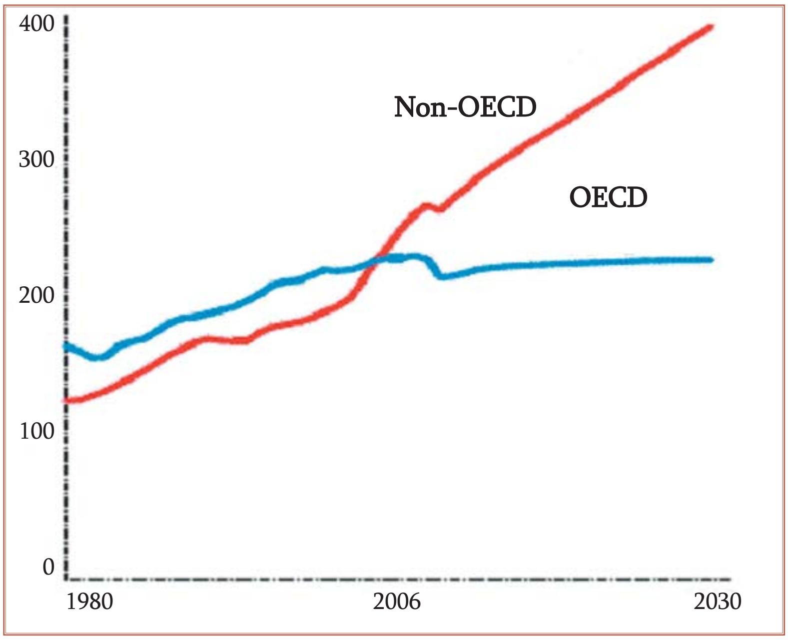

Figure 53. Energy demand, quadrillion BTU's
Source: ExxonMobil, Outlook for energy: a view to 2030, 2009

ExxonMobil expects that, in the period from 2005 to 2030, the average growth rate of world primary consumption of energy will amount to 1.2% (taking into consideration the impact of the crisis).

The geographical structure of energy resource consumption will change worldwide. While consumption in the member countries of the Organisation for Economic Cooperation and Development (OECD) is stabilising at a close-to-steady level in the medium- and long-term perspective, consumption in the non-OECD countries will grow at very intensive rates.

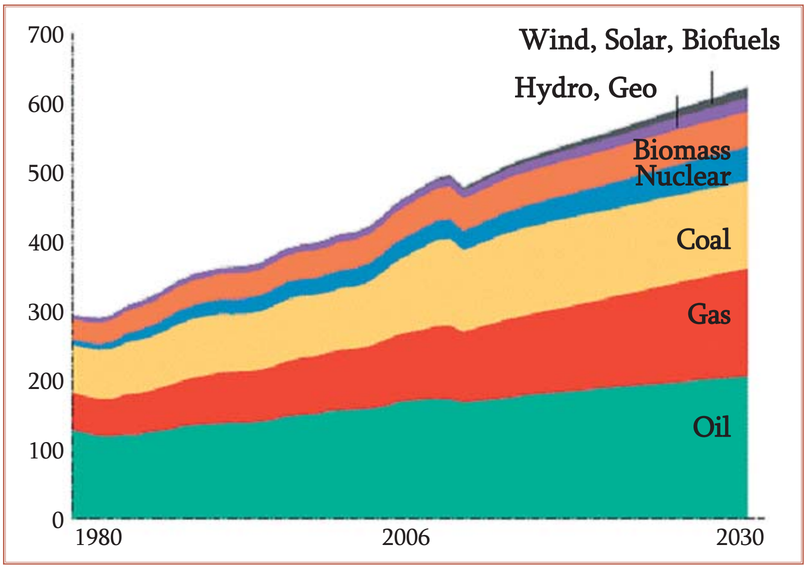

Figure 54. Global energy demand by fuel type, quadrillion BTUs
Source: ExxonMobil, Outlook for energy: a view to 2030, 2009

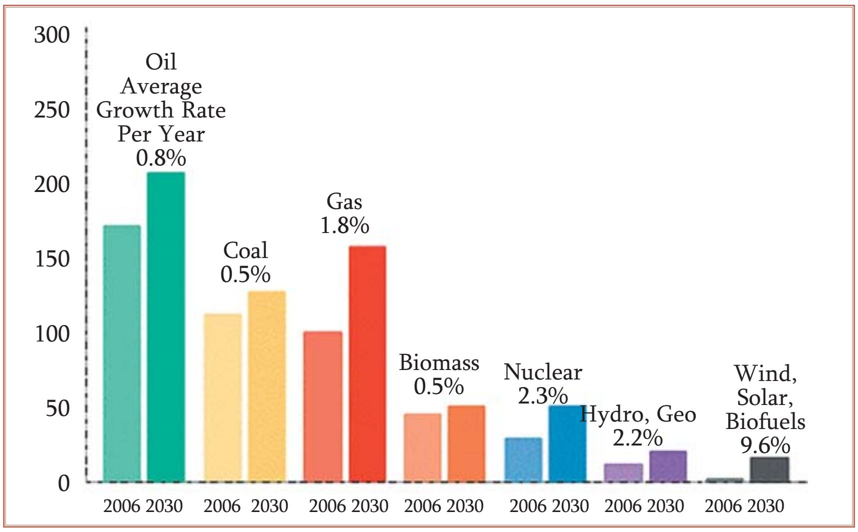

Figure 55. Global energy demand by fuel type in 2005 and 2030, quadrillion BTUs
Source: ExxonMobil, Outlook for energy: a view to 2030, 2009

The most intensive growth will be observed in the consumption rate for wind energy, solar energy and biofuels, increasing by 9.6% per year in the period through to 2030, which, in many ways, will be due to the baseline effect. High growth rates will also be seen in the field of nuclear energy (2.3%), hydro energy (2.2%), and natural gas (1.8%). Relatively low growth rates are expected for oil, coal and biomass. Thus, among the traditional energy sources, natural gas as the ecologically cleaner energy resource will undergo the most intensive growth rate. In general, the share of the traditional energy sources in the world energy balance will amount to 80% in the year 2030.

It is worth noting one particularity. Namely, Figures 54 and 55 indicate that biomass and biofuels are differentiated as types of the energy resources and that they demonstrate different dynamics. In the majority of forecasts, biofuels are considered as a kind of biomass. At the same time, the EC forecasts separately define biomass and predict intensive and large-scale growth in terms of the utilisation of that energy resource, so, in the Alternative scenarios associated with the relative or absolute reduction of natural gas utilisation, it is natural gas that will play a crucial role in the EC's energy supply. ExxonMobil predicts nothing of the kind, with an increase of biomass production in the world, on the whole, being minimal, i.e. by 0.5% per year.

According to the ExxonMobil forecast, energy resource consumption in the world will also change with respect to its composite sectors. Consumption will grow faster in the electric energy sector and that is largely determined by growth in the world's population that has access to electric energy and by an increase in electric energy consumption per capita in the developing countries. By the year 2030, electric energy will account for about 50% of global energy resource consumption. In this case, 80% of the growth in energy consumption will come from non-OECD countries.

A 90% increase in energy consumption by households in the period until 2030 should be derived from developing countries (non-OECD countries), owing to the intensive growth in the number of households therein (the higher population growth rate) against the background of enhancements in household energy efficiency in the developing countries. The share of natural gas and electric power will grow in terms of household consumption.

In the transport sector, energy consumption will grow most intensively on the part of the heavy motor transport (trucks and buses), which is determined by a good number of factors, the most crucial of which are economic growth and an increase in the scale of international trade.

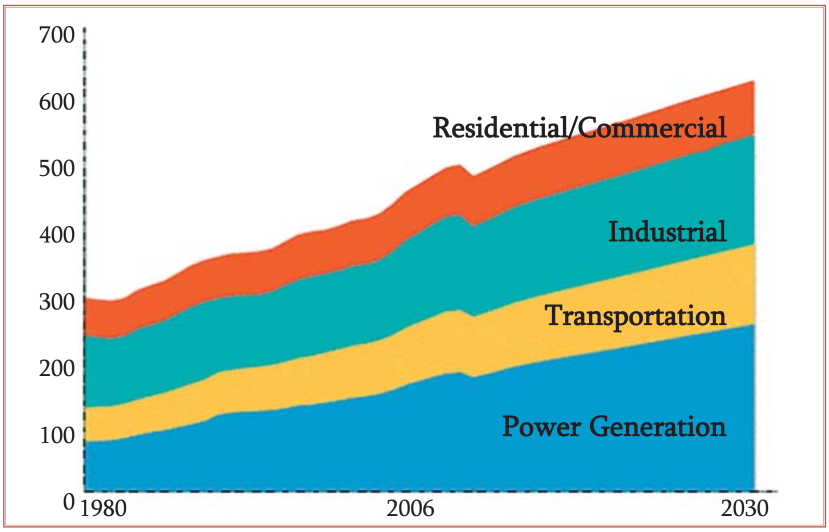

Figure 56. Structure of energy consumption by sector, quadrillion BTUs
Source: ExxonMobil, Outlook for energy: a view to 2030, 2009

By the year 2030, energy consumption on the part of private transport in the OECD countries should decrease by 25% in comparison with 2005 (owing to an increase in efficiency), while consumption in the non-OECD countries should increase more than twice due to improvements in material well-being and an increase in the number of private automobiles per capita (in OECD countries, that figure is already at a high level and will not grow significantly).

ExxonMobil has noted that the role of biofuels in the world energy balance will grow in the future, and the company is paying attention to the prospects of using photosynthetic algae. The choice of photosynthetic algae as a raw material for alternative fuel is determined by the following factors, specifically:

From certain types of algae, it is possible to produce oil that has similar properties as existing oil products. Therefore, there will be no need to create a new special transportation and distribution network for that fuel, which would be a requirement if utilising other alternative types of fuel.

Algae consume carbon dioxide and emit oxygen therewith. The development of algae production, as indicated by ExxonMobil, may lead to a reduction in carbon dioxide emissions.

Utilising algae instead of grain crops or sugar will not affect the world food market. The cultivation of algae will not require the allocation of ground space, nor will it require regular irrigation with potable water. Therefore, utilising algae as a raw material for producing alternative fuel enables avoiding a whole number of disadvantages for which the idea of increasing the role of biofuels in the energy balance is generally criticised.

It is worth noting that the fact that the ExxonMobil report indicated the prospectivity of photosynthetic algae may be determined by the fact that the Company is developing that trend intensively (in July 2009, a joint project was announced with Synthetic Genomics Inc., for which about 600 million dollars are expected to be allocated), and is interested in establishing a favourable impression thereof on the part of investors. Therefore, this estimation of the photosynthetic algae perspectives should be subject to critical scrutiny. In particular, upon burning the alternative fuel produced from algae, the carbon dioxide earlier consumed by the algae will be re-emitted into the atmosphere and oxygen will be burned up. Therefore, there is no indication that algae will help to solve the problem concerning the high concentration of greenhouse gases in the atmosphere. The Company itself has noted that the development of technologies focused on the utilisation of algae, and their implementation may require work over a period of several decades.

It is worth noting that there are similar issued to the ones above-mentioned with respect to biomass. The unconditional inclusion of such sources of biomass and such forms of their utilisation as gathering and incineration of such additional resources as wood tissue, waste materials and domestic waste do not lead to a reduction of greenhouse gas emissions. On the contrary, they only bring about an increase in emission levels.

In accordance with the ExxonMobil forecasts, more than 90% of energy consumption growth in the industry until 2030 will be accounted for by chemical and heavy industries, which will be stipulated by the considerable expansion of these sectors in the developing countries. Energy consumption by industries in the OECD countries will gradually decrease until the year 2030, but in non-OECD countries, consumption should increase by approximately 60% and of this amount, 35 percentage points will be associated with China alone. In the structure of the energy resources consumption by industry, the share of natural gas and electric power should increase but the share of coal should drop (owing to policy focused on reducing carbon dioxide emissions).

The share of electricity in the global consumption balance should increase from 36% in 2005 to 40% in 2030. At that, ExxonMobil indicates that there will be a shift from coal towards natural gas, nuclear energy and renewable fuels in the structure of energy resources used for electric power generation. It is assumed that, by the year 2030, about 40% of all electric energy will be generated by means of nuclear energy or renewable types of fuel.

By the year 2030, composite demand for liquid types of fuel will grow by 24% in comparison to 2005, amounting to 104 million barrels of oil equivalent per day. At the same time, oil supplies from the OPEC countries will act as the balancing figure between demand for liquid fuel and supply on the part of other producers (including biofuels, gas condensate, "gas-to-liquid" and "coal-to-liquid" plants). Consequently, supply from the OPEC countries should increase in the period 2010-2030 by one-third.

In the USA and Europe, natural gas consumption will grow slowly, by about 0.8% per year in the period 2005-2030 (taking into consideration the drop in consumption during the crisis). At the same time, the Asia-Pacific Region will become the most prospective gas market in the world, where consumption should grow by 4% annually. Consequently, the Asia-Pacific Region market will become larger than the US and European markets.

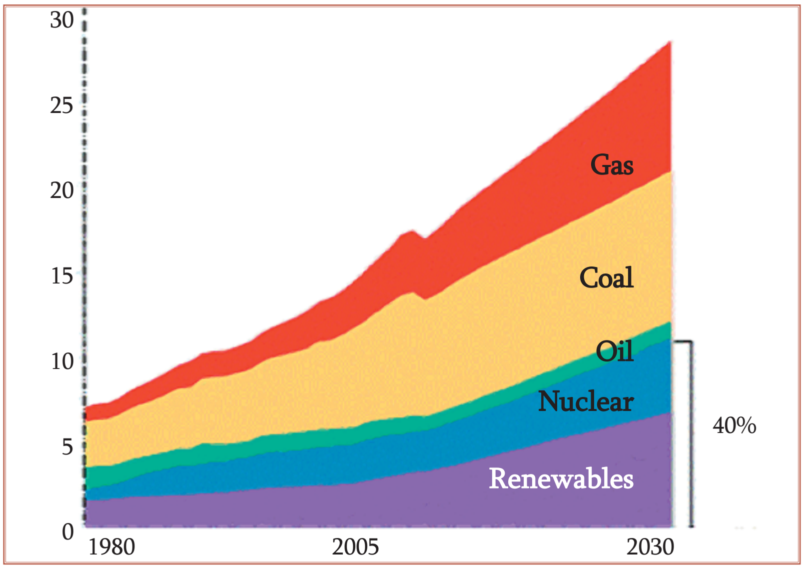

Figure 57. Structure of electricity generation

Source: ExxonMobil, Outlook for energy: a view to 2030, 2009

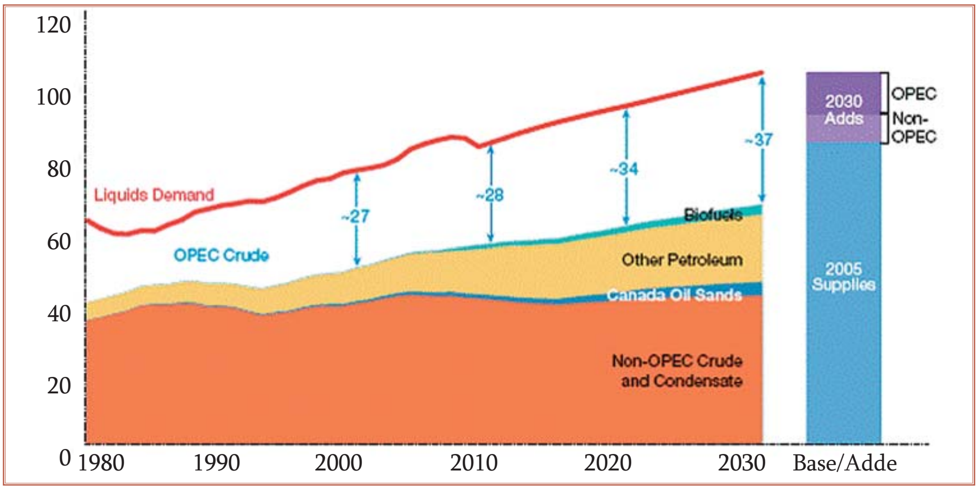

Figure 58. Structure of liquids supply
Source: ExxonMobil, Outlook for energy: a view to 2030, 2009

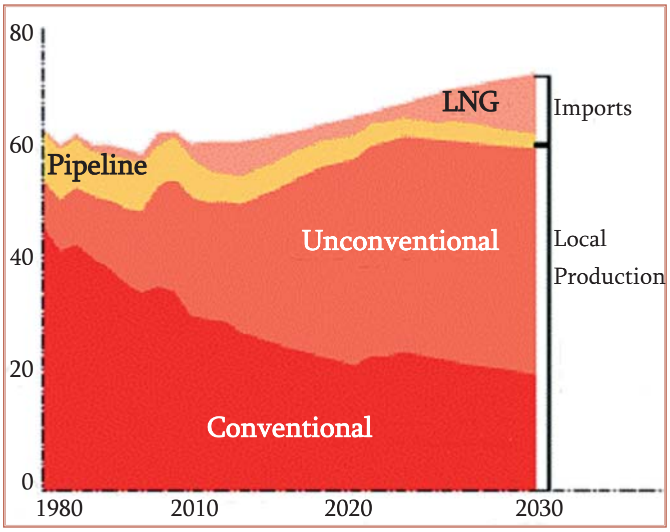

Figure 59. Structure of the US gas supply, bln. cubic feet/day
Source: ExxonMobil, Outlook for energy: a view to 2030, 2009

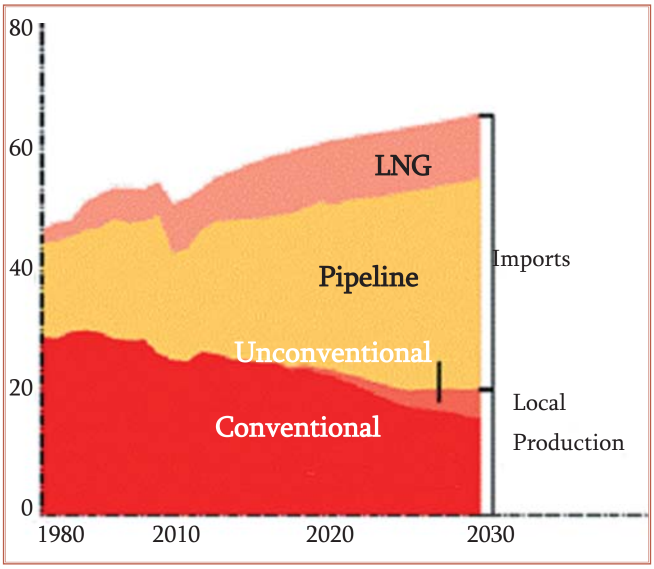

Figure 60. Structure of the European gas supply, bln. cubic feet/day
Source: ExxonMobil, Outlook for energy: a view to 2030, 2009

According to the ExxonMobil forecast, in the medium- and long-term perspective, non-conventional gas sources will become the most crucial sources of natural gas available on the US market. By the year 2030, they will account for more than half of all gas consumption in the country. Liquefied natural gas supplies will gradually decline in the medium-term, but should again grow after the year 2020, owing to a decline in domestic production.

In Europe, equity production of natural gas will decrease in the long-term perspective. It is worth noting that gas production using non-conventional gas sources will not permit overcoming this trend, as it will amount to a relatively small share in the total volume of consumption. The share of imported gas in European consumption should grow from 45% in 2005 to 70% in 2030. In this regard, the import of pipelined gas will continue to play the most crucial role.

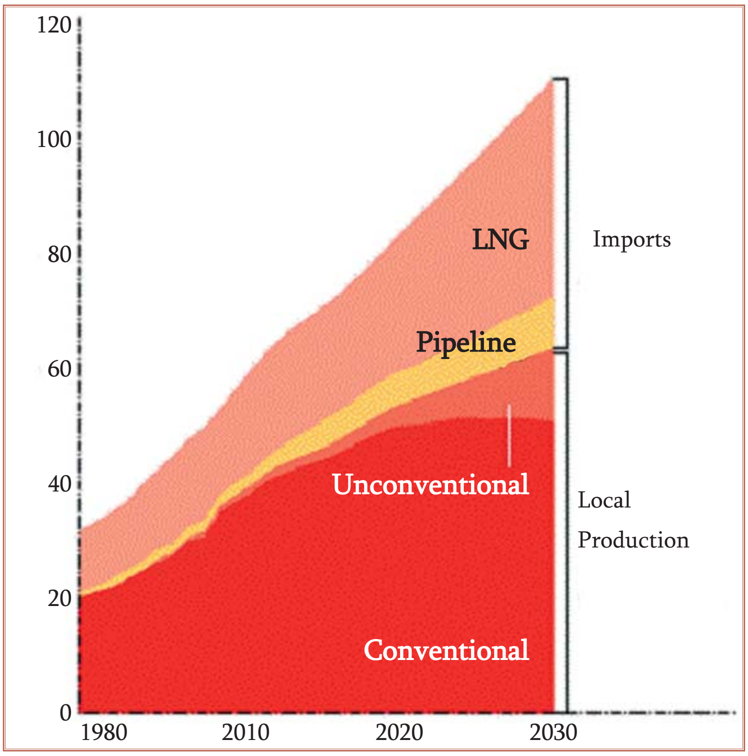

Figure 61. Structure of the Asia Pacific gas supply, bln. cubic feet/day
Source: ExxonMobil, Outlook for energy: a view to 2030, 2009

Gas production in the Asia-Pacific Region will also continue to grow. In the long-term perspective, stabilisation and a subsequent decline in gas production will be compensated, owing to non-conventional gas sources. In the Asia-Pacific Region, natural gas imports will grow intensively, mainly due to liquefied natural gas, which will account for one-third of gas consumption in the region by 2030.

Section 4.5. The Shell Forecast

This section is structured on the basis of an analysis of the latest long-term forecasts put forward by the Shell company (Shell, Energy scenarios till 2050, 2009).

In its report, Shell submitted two scenarios of its vision of the future development of world energy. The first model – the *Scramble* scenario – emphasises the issue of national energy security. It is assumed that national governments will pursue energy policy that is primarily focused on ensuring that internal demand for energy resources is satisfied. In this case, state authorities will place little attention on reducing greenhouse gases emission (until the occurrence of disastrous effects).

In accordance with the second model – the *Blueprint* scenario – vigorous public activity will allow for overcoming the obstacles encountered on the path of economic development, ensuring energy security while also reducing environment pollution. Shell considers the *Blueprint* scenario to be more preferable and sees it as complying with the concept of long-term sustainable development. The two scenarios cover the period through to the year 2050.

4.5.1. Assumptions

Shell has separately defined a number of trends in the world economy that are factored into the basis of the analysis to be carried out. However, it is not always clear which way it should be done at the model level and what the quantitative terms of the specified factors are.

Shell has indicated that the developing countries (especially China and India) are entering the most energy-intensive phase of their economic growth (industrialisation, infrastructure construction, and an increase in the volume of transported goods). Growth in demand on the part of developing countries will stimulate the use of alternative energy sources and energy savings, but that may be insufficient to completely satisfy demand.

By the year 2015, rates of growth of the easily extractable oil and gas reserves will lag behind the forecasted rate of growth in demand for the energy resources on the whole. There are still considerable coal reserves in the world but their utilisation is limited by difficulties associated with their transportation and a stiffening of ecological requirements. As a result, the share of alternative energy resources such as biofuels, in the energy balance could rise, but none of them could become a panacea for solving the problem of balancing global energy supply and demand.

The report's authors indicate that, in the future, the development of world energy will largely be defined by the necessity to reduce CO_2 emissions and the concentration of greenhouse gases in the atmosphere.

An important assumption in the analysis is as follows: by the year 2050, the world's population should grow by more than 40% and will amount to more than 9 trillion people. Developing countries will account for the greatest portion of the population.

4.5.2. Results

The *Scramble* Scenario

First and foremost, governments of the world should take national energy security interests into consideration, thereby decreasing the scope of international cooperation. As such, every country will use its own set of energy policy tools (uncoordinated with other countries). In general, the supplier and consumer countries will conclude bilateral agreements. Meanwhile, the purchasing countries will compete with each other to obtain access to resources and to gain more favourable conditions for their supplies. National energy companies will acquire special influence but, at the same time, they will be used as tools of national energy policy.

The policy of strengthening national energy security will include incentives to develop local energy sources. Consequently, coal and biofuels will gain the greatest importance. In particular, by the year 2030, coal consumption will grow 2.2 times compared to the year 2000, and, by the year 2050, coal consumption will grow by another 25%. The average growth rate of coal consumption in the period 2010-2050 will amount to 1.5% annually. The share of coal in primary consumption in the same period should grow from 27.2% to 29.9%.

At the same time, Shell experts note that, owing to the low ecological properties of coal, a rise in its consumption will raise strong protests on the part of the public and will worsen the ecological situation. In China, the existing railroad infrastructure does not permit any considerable increase in coal consumption and therefore, large-scale upgrades of the entire system would be required under consideration of this development scenario.

The Shell report indicates that some countries may use nuclear power stations in order to avoid the ecological problems associated with using coal as an energy source. However, Shell sees the prospects of nuclear energy development as low for the following reasons:

- Nuclear power stations' construction and the development of uranium deposits require much more time than that required for coal.
- There are substantial risks with respect to the global deficiency of uranium.

- The construction of nuclear power stations requires substantial support from the state owing to extremely high financial risks.
- The expansion of nuclear technologies in the world is limited for political reasons.

Consequently, it is forecast that nuclear energy consumption will grow relatively slowly, by just 0.8% annually in the period 2010-2050, and that its share in the primary balance will decrease from 5.8% to 4.9%.

It is worth noting that, in its report, Shell says nothing about the advantages of nuclear energy in comparison with other energy sources, and also does not mention plans by a good number of countries to construct new nuclear power stations.

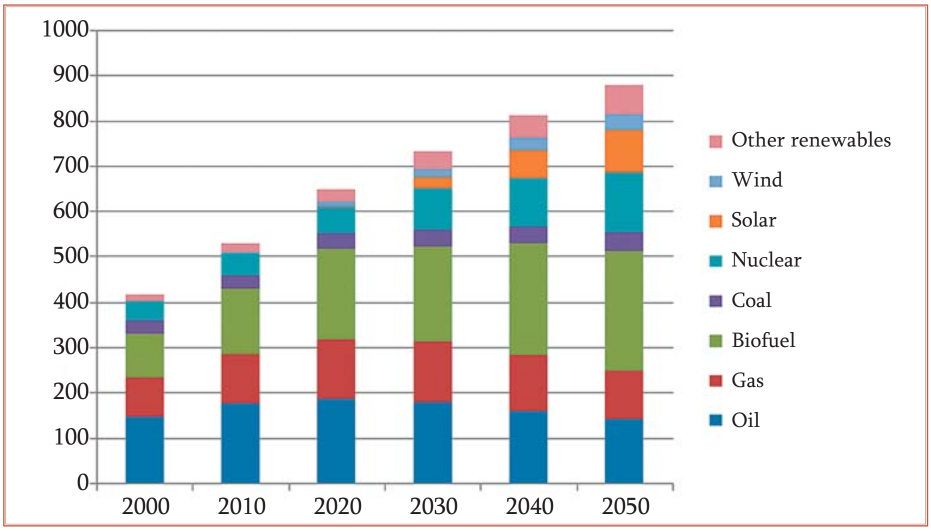

Figure 62. Primary world energy consumption, EJ
Source: Shell, Energy scenarios till 2050, 2009

In the Shell forecast for the long-term perspective, biomass should come to gain more significance (which, in this study, also includes biofuels; growth in consumption amounts to 2.5% per year in the period 2010-2050). At the same time, solar and wind energy consumption should reach 11% per year and other renewable energy sources should reach 3.1% per year. This forecast includes both independence on imported supplies and environmental friendliness. Consequently, the total share of renewable energy sources in the primary energy balance will grow from 13% in 2010 to 23.7% in 2030, and 37% in 2050.

Shell has indicated the disadvantages of first generation biofuels, particularly the negative impact on the pricing environment in the food market. The report assumes that, by the year 2020, second generation biofuels will come into use. By the year 2030, the consumption volume of second generation biofuels will be higher than that of first generation biofuels.

One of the main trends with respect to biofuels stipulates its utilisation as an engine fuel. Despite the considerable growth of biofuel consumption in the transport sector, liquid hydrocarbon fuels will dominate that sector even in 2050 (refer to Figure 64).

It is worth noting that in the *Scramble* scenario, the natural gas and electricity specified in the forecast amount to only an insignificant share of energy consumption by the transport sector in the long-term perspective.

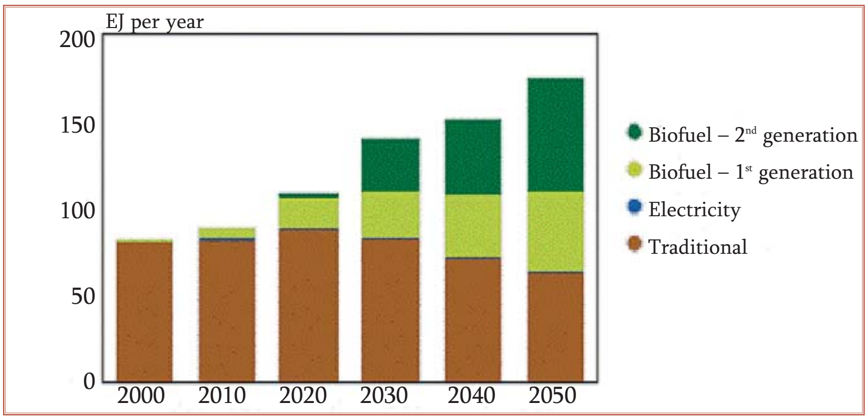

Figure 63. Biofuels structure, EJ
Source: Shell, Energy scenarios till 2050, 2009

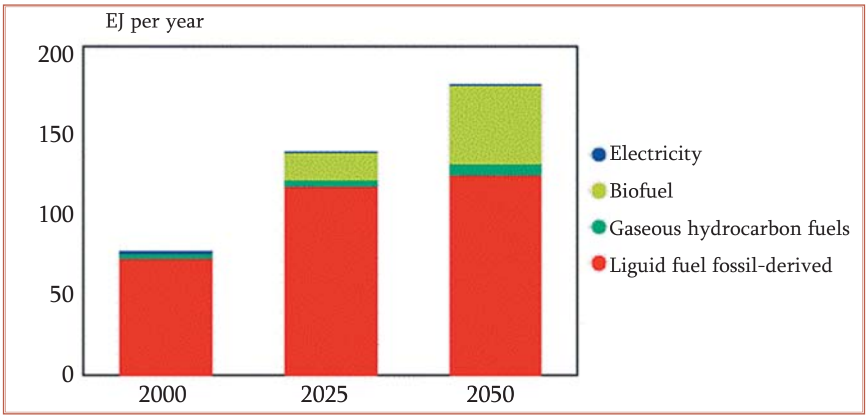

Figure 64. Energy consumption on transport, EJ
Source: Shell, Energy scenarios till 2050, 2009

According to the long-term outlook specified in the Scramble scenario, the natural gas share in the energy balance will decrease, owing to policy focused on reducing dependence on imports. In the period 2000-2020, gas consumption will grow at average rate of 2% annually; in the period 2020-2030, consumption will stabilise at a steady level, and after 2030 it will decline at an average rate of 1.1% annually. Consequently, the natural gas share in the primary energy balance should decrease from 20.8% in 2010 to 18.3% by 2030 and to nearly 12.3% by 2050. At the same time, in the period until 2020, this scenario implies that the volumes of natural gas consumption will grow, and then stabilise in the period until 2030.

Oil consumption will start to decrease after 2020 at an average rate of 0.9% per year. By the year 2050, the oil share in the primary world energy balance will decrease to 16%. The *Scramble* scenario indicates that one of the trends for ensuring energy security will include the utilisation of non-conventional energy sources. (Refer to Figure 65. Regional structure of primary energy consumption in 2010-2050, billion GJ).

The domination of developing countries in Asia in the regional consumption structure can already be observed in the medium-term perspective and their share should only increase in future.

Such policy will also result in an increase in price volatility for energy resources. Sharp jumps in the prices of energy resources, in turn, may lead to a temporary decline in economic growth rates. In the opinion of Shell experts, prices for energy resources in general should be high, not only due to pressure driven by demand, but also owing to OPEC countries' perception that the world can pay for energy hire price. In fact, as the price makers, manufactures themselves will determine the rules of the game on the market.

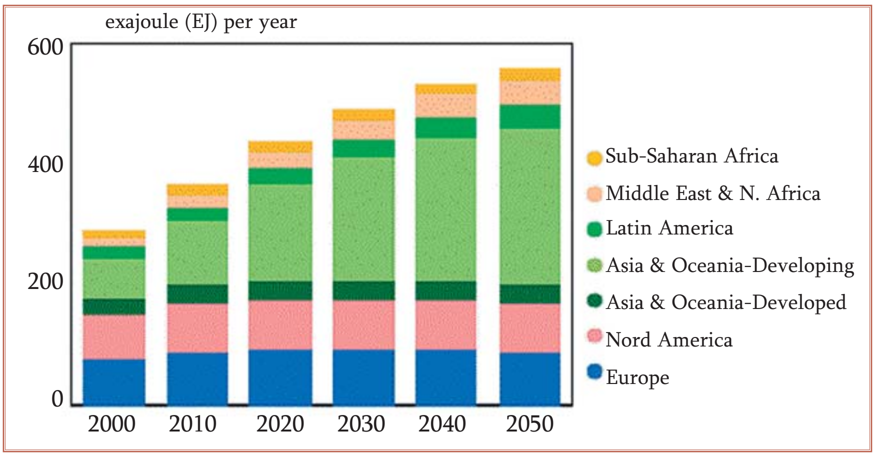

Figure 65. Regional structure of energy demand, EJ
Source: Shell, Energy scenarios till 2050, 2009

As a result of insufficient attention on environmental problems on the part of governments will result in the fact that the concentration of carbon dioxide in the atmosphere will maintain at the rather high level in the long term, i.e. 550 ppm (parts of CO_2 per million parts of air). In turn, this will negatively affect the climate.

In general, Shell has noted the negative consequences of realising the Scramble scenario. It supposes that, under such a model, countries will pass through three separate stages, which are as follows:

- The gradual transition to coal, biofuels and non-conventional energy sources will occur, ensuring that domestic demand for energy is satisfied.
- A crisis in the supplies of energy resources will occur once the growth of coal, oil and gas supplies have reached their limits.
- Governments will implement draconian measures that will lead to a reduction in economic growth rates.

It is worth noting that such developments are not clearly evident. For a good number of countries, it will be difficult to reach the limits of energy consumption growth given the substantial volume of reserves therein (including non-conventional reserves). In the age of globalisation, there are ample opportunities to cover national energy deficiencies via imports (increasing import dependence is somewhat better than having an energy balance deficit). Pursuing policy that is focused on the priority of national energy security does not mean the absence of measures directed at improving energy efficiency or misunderstanding (an absence of forecasts) concerning the probability of an energy crisis. The analysis provided here does not consider the existence and recently-established tendency of expanding the utilisation of non-conventional gas sources.

The *Blueprint* Scenario

This scenario suggests that "new unions" (i.e. industry associations, regional unions and citizen communities) will start to influence the energy sector in an aggressive way. As a result, energy efficiency will grow and carbon dioxide emissions will drop.

In particular, the authors assume that the mechanism of carbon dioxide emission trading will gradually extend from Europe (ETS market) to other countries, including the USA and China. The emission trading system will provide additional incentives for the development of non-conventional energy sources and the construction of CCS plants. According to this scenario, about 90% of all coal- and gas-powered stations in the OECD countries and 50% in non-OECD countries will be equipped with carbon dioxide capture and storage systems. This should enable reducing CO_2 emissions in the world by 15-20%.

In anticipation of competition on the part of oil substitutes (in first order, biofuels), OPEC should maintain oil prices at a low level (lower than the production cost for alternative fuels) by supplying considerable volumes of oil to the market. However, neither of the scenarios put forward by Shell provides a forecast regarding oil price levels.

India will invest considerable funds in wind power stations, while China should become the leader in terms of solar energy. The production plants designed by these countries should be exported to the West. Wind and solar plants for retrieving water from deep wells will be in place even in African villages.

Owing to a general increase in energy efficiency, the total primary consumption specified in the *Blueprint* scenario will grow by 1% per year vs. the 1.3% figure cited in the *Scramble* scenario. Consequently, by the year 2050, total primary consumption in the *Scramble* scenario will be lower by 13%.

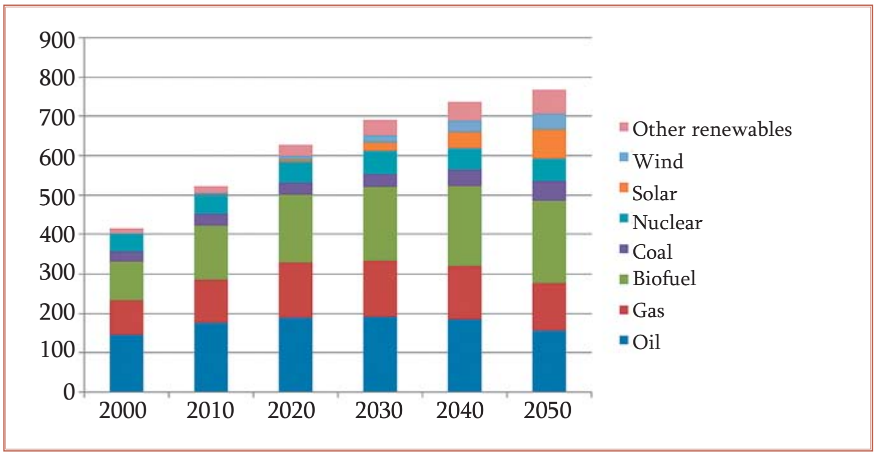

Figure 66. Primary world energy consumption, EJ
Source: Shell, Energy scenarios till 2050, 2009

Owing to the low oil prices and the absence of apprehensions about dependence on imports, the role of oil in the scenario under consideration will be more significant than that the level noted in the Scramble scenario. In the *Blueprint* scenario, oil consumption will decrease only after 2030, and its share in the primary energy balance will drop to 20.4%, which is by 4.4 percentage points higher than indicated in the first scenario.

The situation with natural gas is also more favourable. For instance, by the year 2020, its share of primary consumption will amount to 22.1%, after which it should decrease to 15.9% in 2050 (3.6 percentage points higher than indicated in the *Scrambl*e scenario).

In a situation where the price of oil is low, biomass will lose out to the competition, i.e. by the year 2050, its consumption will be 2.3 times lower than indicated in the *Scramble* scenario. After the year 2030, consumption will start to decline. The share of biomass in the energy balance by 2050 will amount to 7.4%, which is 7.5 percentage point lower.

Owing to the more extensive utilisation of oil and gas, the role of coal will decrease and its consumption should grow by only 1% per year in the period 2010-2050. By 2050, the share of coal is expected to amount to 27% (i.e. 2.9% lower than the level indicated in the *Scramble* scenario).

The share of solar, wind and other renewable energy sources will remain at approximately the same level than was noted in the previous scenario.

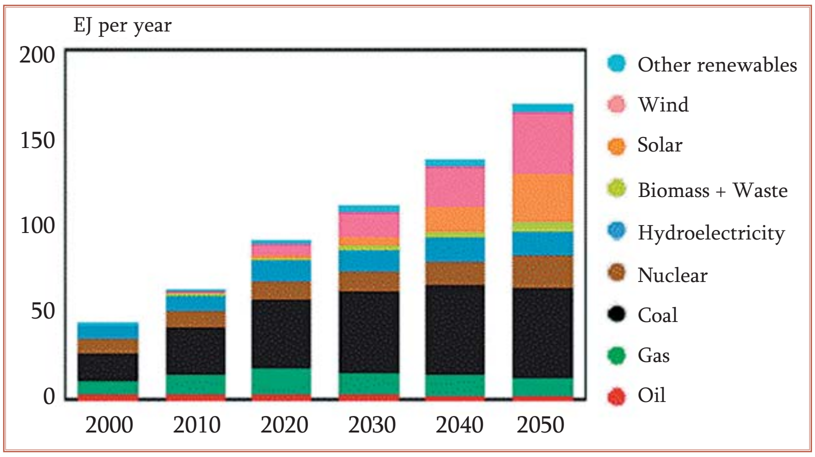

Figure 67. Electricity by energy source
Source: Shell, Energy scenarios till 2050, 2009

The domination of coal and renewable energy sources is notable in the energy sector. The role of natural gas is insignificant and will decrease in the long-term perspective.

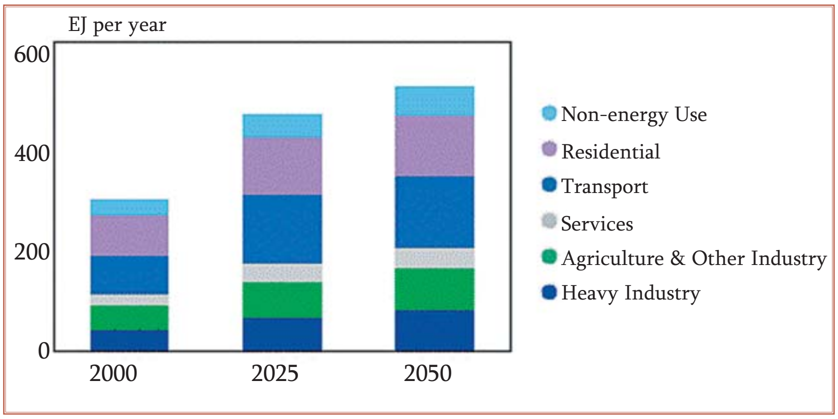

Figure 68. Structure of final consumption by energy source
Source: Shell, Energy scenarios till 2050, 2009

Households and the transport sector will make up the greatest share in final consumption.

State policy focused on reducing greenhouse emissions caused by transport should lead to a significant growth in motor transport that utilises electric power.

In general, the conditions set out for the execution of the *Blueprint* scenario seem to be too idealistic. Rather, it appears to be more of a call for public action than a scenario for the development of actual events.

4.5.3. Conclusions

In general, Shell suggests a sufficiently original approach for selecting the criteria for scenarios of the future development of world energy. Both the assumptions and the results of the scenarios outlined therein definitely differ from the forecasts prepared by other international organisations and companies. It is worth noting that the obvious partiality of the report's authors in the text, i.e. their negative attitude is observed with regard to the *Scramble* scenario and their apparent summoning of support for the *Blueprint* scenario (this is even apparent from its name). In essence, it appears that the *Scramble* scenario was prepared in order to contrapose its results against those of the Blueprint scenario.

The authors of the report have not take into account a number of the advantages of using nuclear energy and natural gas, resulting in an underestimation on their role in the world energy balance.

One of the more noteworthy disadvantages of the Shell report is as follows: this analysis in no way considers the impact of the economic crisis, despite the fact that this report was published in 2009.

Section 4.6. The TIMES Models

4.6.1. The TIMES Modelling Approach: the Basic Methodological Aspects

Among the other investigated models, which were specifically developed for the purpose of particular studies the TIMES (abbreviated from The Integrated MARKAL-EFOM System[30]) is rather a modelling environment, which allows for designing of national or multi-regional energy models in the long-term or for a multi-period planning horizon. In general, the TIMES approach is used in developing models for assessing integrated energy systems; however, it is also possible to assess individual sectors (for example, power sector or district heating system).

The TIMES modelling environment was designed and is being developed by the ETSAP framework (Energy Technology Systems Analysis – the programme for researching energy technologies in the spirit of systems analysis), which activities are coordinated by the International Energy Agency within the framework of its Implementation Agreements. The Programme benefits from contribution of the research groups from 16 IEA-countries, with support of invited groups of individual researchers. The Programme's aim is to support and develop a unified analytical potential in the field of systems analysis from the perspective of energy, environment and technologies (the so called 4E approach: energy-economy-environment-engineering).

The models created with the TIMES modelling environment found extensive application in several regional, national and global studies. Such popularity is explained, in particular, by universal structure of the System and by developers' support in form of trainings, which allow many research centres to absorb the know-how of TIMES modelling, accumulated during previous studies.

Among the models used in national studies, it is worth mentioning the TIMES-D model, created for Germany's energy system, as well as local models, built on its basis for municipal energy systems in different regions of the country. At the regional level one could highlight the sectoral TIMES-EG model, which covers EU's power and gas sectors, and the TIMES PAN-EU (PET) model, a model of the Pan-European energy system. Examples of global models include the integrated assessment ETSAP-TIAM and EFDA[31] models.

The typical structure of the TIMES models and the modelling environment were developing in parallel with the other energy models, such as MARKAL, PRIMES (National Technical University of Athens), MESSAGE (International Institute for Applied Systems Analysis, IIASA), and NEMS (Energy Information Administration DOE).The evolution of these models, including TIMES, was

[30] MARKAL (MARket ALlocation model) and EFOM are two bottom-up models, which formed the basis of which the TIMES structure was built.
[31] EFDA - European Fusion Development Agreement .

motivated by the developments in particular real-world sectors, in which each model was specialized (E2, energy-economy, E3, energy-economy-environment and further to E4).

The selective process resulted in a new model, which was indented to combine the main useful features of the MARKAL and EFOM-ENV models. The new model inherited their structure and was enhanced by required at that time modifications, targeted at flexibility and adaptability.

The reference case in TIMES is built on the basis of user-defined dynamics of useful energy for each model region (e.g. transportation in passenger-kilometres, room illumination in lux, utilisation of process steam in calories etc.) Additionally, each model region shall be described by (1) the installed generation capacity (2) characteristics of the existing and perspective (energy transformation) technologies; and (3) the existing and perspective primary energy sources.

On the basis of input data, generic TIMES model will be seeking for an optimal solution to satisfy the useful demand at minimal cost through simultaneous control of capacity building (long term) and operational mode (unit commitment, short term), as well as though decisions on primary energy supply and trade within a single region. During optimisation, the selection of the appropriate generation technology (type of equipment and type of fuel) is based on: (1) comparative advantages of technical and economical characteristics of the technologies available for a given period; (2) economic efficiency of energy supplies; and (3) environmental impacts.

Thus, the models created with TIMES (hereinafter referred as the TIMES models) are vertically integrated in the context of the (model-) global energy system.

The model scope goes beyond purely energy issues; it also includes consideration of environmental impacts and to a certain extent – consideration of materials, which productions affects energy demand (for instance, the energy-intensive production of aluminium).

In addition, the TIMES family models are well suited for the assessment of *energy – environment* interactions, which can be modelled at a high level of detail due to explicit formulation of technologies and energy sources in all sectors of the economy.

In the TIMES models, the volumes and prices for different commodities are in equilibrium, i.e. at every instant, the above-mentioned figures are sorted out in such a way that quantity of the commodity produced by the suppliers would be exactly the same as quantity of the commodity required by the end consumers. One of the properties of the aforementioned equilibrium is the maximisation of the cumulative value added.

The following features of TIMES models form its specific portrait:

- Explicit technology formulation.
- Global modelled Energy system is considered as a system of systems (regional models).
- Partial equilibrium model, what assumes:
  - Price elastic demand
  - competitive market with ...
  - ... perfect foresight (expressed in marginal price formation).

Solutions obtain though linear, non-linear and mixed-integer optimisation.

4.6.2. The European TIMES Model within the Scope of RES2020 Research

General

The RES2020 project was initiated in December 2006 with several purposes: (1) analysing the progress of implementation of the European Commission measures to facilitate dissemination of renewable energy sources (RES) (2) identifying the target share of RES in the EU energy mix, (3) assessing prospective strategies, which could lead to achieving the RES targets and finally, (4) evaluating the impacts after (hypothetical) achievement RES targets. The Project was completed in March 2009.

It was coordinated by the Centre for Renewable Energy Sources in Greece and it involved 14 participating teams from 13 countries of the EC.

Methodological and informational basis for the research were the European model and the TIMES scenarios (Pan-EU TIMES or PET), which have been developed in the course of the NEEDS project within the framework of the Sixth Framework Programme of the European Commission. Development of the PET model included detailed description of the energy system of each EC member state, and inclusion of such model regions, as Norway, Iceland and Switzerland. Coherence of the model was provided by incorporating intraregional trade mechanism.

The model inherited high level of detail of the economic sector within model regions: for demand – residential and commercial, agriculture, industry and transport sector; for supply – power and heat generation, processing of energy resources on the basis of a generalised structure. Energy resources were described with a supply curve (three cost grades).

The PET model was improved and amended in the course of the RES2020 Project, mainly with respect to the RES (for instance, the technological database was enhanced in part of wind, solar and biofuels potential)

In brief, the enhanced PET model can be characterised by the following aspects:

- 30 regions (the EU-27 + Norway, Iceland and Switzerland);
- Time horizon – from 2000 to 2050;
- 12 time slices (12 seasonal and 2 daily levels);
- Greenhouse gases include CO_2, CH4, N2O, SF6;
- Other emissions include SO2, NOx, CO, NMVOC, PM2.5, PM10;
- Technological database includes characteristics of losses (current interruptions and other types of damage) with the purpose of integrating external disturbances into the optimisation procedure.

Supply-side modelling (electricity only):

- Public power plants, CHP, combined cycle plants, autonomous power plants;
- RES potential is region-specific;
- Energy transformation technologies are region-specific (both, existing and perspective).

Demand-side modelling (was based on simulation of GEM-E3 and NEWAGE models):

- Agriculture;
- Industry: energy-intensive (steel and ferrous metals, aluminium, copper, etc.) and other;
- Residential and commercial: space heating/cooling, warm water, household appliances;
- Transport: passenger and freight (options: motor vehicles, buses, bicycles, trains, etc.), air transport;
- End-user technologies are region-specific.

Problem formulation and scenarios

As mentioned earlier, the goal of the RES202 project was to analyse attainability and potential impacts with respect to implementation of the EC targets on renewable energy sources (RES). Some of its points:

- GHG emission reduction in the scope of the EU Emission Trading Scheme (ETS) 21% compared to 2005 level by 2020;
- GHG emission reduction outside the ETS – 10% compared to 2005 level by 2020;

Share of renewable energy sources shall reach 20% of the final demand in 2020.

Basic assumptions for the reference scenario

The reference scenario in TIMES is constructed under assumption of realistic storyline, its reference point in time is the base year (corresponds to or precedes the beginning of planning horizon). Calibration of model assumptions is carried out on historical data. After the Reference Scenario has been constructed and calibrated, the alternative scenarios are derived from it by altering certain assumptions or input data.

In RES-2020, the main assumptions for the reference scenario were in line with the Baseline Scenario of the Directorate for Transport and Energy of the EC (DG TREN). Some of them are listed below.

Nuclear energy assumptions: no nuclear for: Austria, Cyprus, Denmark, Estonia, Greece, Italy, Ireland, Luxemburg, Malta, and Portugal. Nuclear phase out after the decided extension of lifetime for: Bulgaria, Germany, Sweden. Possible new nuclear (without lifetime extension for existing) for: Bulgaria, Czech Republic, France, Finland, Hungary, Lithuania, Poland, Romania, Slovakia, Spain, and Great Britain.

Renewable energy sources:

The support mechanisms that are modeled are investment subsidies and feed-in tariffs in the Member States that employ them

Biofuels Directive:

In the Reference Scenario the target for Biofuels for 2005 and 2010 is not imposed as a bound.

CO_2 tax:

In the Reference Scenario the Kyoto targets or the post-Kyoto targets set by the 2007 European Spring Council are not imposed as a bound. It is assumed that the current Emissions Trading Scheme (ETS) operates at a clearing price of 20 € (2005)/ton CO_2 in 2010. For the post-Kyoto period carbon prices increase smoothly to 24 € (2005)/ton CO_2 in 2030 and this price applies to the current ETS sectors.

RES Reference- scenario is a key alternative research scenario. It specifies the target shares of renewable energy sources for 2020 for each country, pursuant to the Directive EC 2009/28/EC. These targets are used as lower boundaries for optimisation at the country level.

Other assumptions that differ from the reference scenario are as follows:

Biofuels: biofuels targets are imposed in this scenario and used as the lower boundary in optimization for all model regions, which belong to EU. The targets correspond to 5.75% of final consumption in 2010 and 10% in 2020.

CO_2 emissions: Only CO_2 emissions are taken into account in the implementation of the emissions limits.The approach taken in the modelling is the following:

- ETS Sectors: Full trade of CO_2 emitted from the ETS sectors between the EU27.
- Non-ETS Sectors: An upper bound in the emissions of CO_2 from the non-ETS sectors is imposed according the Directive proposal for non- ETS emissions, per Member State.
- The total CO_2 both from the ETS and non-ETS sectors, has a reduction, of 18% from the 1990 level (following the results from GAINS model of IIASA).

The **RES-30 Reference scenario** differs from the above-mentioned scenario by a stricter CO_2 reduction target: the 2020 level of CO2 emissions should be reduced by 30% compared to 1990 level.

For ease of interpreting the graphical results, it is worth noting one particular case of the RES Reference RES scenario, that is the "BEST climate policy on global trade", in which it is assumed that after the 2020 the emission reduction rate will increase sustainably reaching 39% in 2050.

The source of data for calibrating the model with respect to volumes and prices was the Eurostat database. The GDP forecasts for different sectors of economy in model regions were made on the basis of the forecasts produced by the GEM-E3 model.

Fossil fuel prices are in line with the Baseline Scenario (BaU) of the World Energy Outlook-2008. Oil prices presented in Table 66, in barrel equivalent look as follows: 100 $(2007)/bbl in 2010, 110 $(2007)/bbl in 2020, and 116$(2007)/bbl in 2025.

Table 66. Price assumptions in Reference scenario of RES2020

€ 2000/GJ	2005	2010	2015	2020	2025
Oil	6.89	12.016	12.016	13.218	13.939
Gas	4.37	7.394	7.626	8.428	8.919
Coal	1.87	2.864	2.864	2.785	2.705

It is notable that coal prices exhibit stable and slightly declining dynamics.

The **Reference-High Oil** scenario was introduced with the purpose to carry out a sensitivity analysis. This scenario is deviates from the Reference scenario in part of the oil price forecast, which are based here on the Annual Energy Outlook of the Energy Information Administration (EIA, Annual Energy Outlook-2009). The oil prices provided in Table 67 in barrel equivalent are: 100 $(2007)/bbl in 2010, 185 $(2007)/bbl in 2020 and $193(2007)/bbl in 2025.

Table 67. Oil price assumptions in Reference-High Oil scenario

€ 2000/GJ	2005	2010	2015	2020	2025
Oil	6.89	12.016	18.889	13.218	23.167

Every model region can export and import oil, coal and natural gas from the global market at prices, indicated in Tables 66 and 67. At the same time, within the model export prices, are not slightly lower than the import prices. This restriction was incorporated with the purpose to prevent arbitrage. In addition to import costs, every model region (country) may introduce transport cost, which depends on geographic location of entry and exit points. For instance, an oil importing region, which has no access to open sea, will receive oil via a pipeline or freight transportation, which will result in additional costs.

Only some of the regions may import LNG, what is also determined by geographical location. These regions also have an option of investing in portside storage and regasification technologies.

Results

Due to the fact that the RES2020 study is mainly focusing on analysing the targets and the potential of RES (as well as alternative energy sources), the model output with regard to oil and gas (the key energy sources in this report) is rather limited. Table 68 summarizes the perspectives of natural gas production, import and export. The table presents the dynamics of the balance item according to period and features the total primary energy supply for comparison purposes.

According to the results of the PET model, the dynamics domestic gas production is pretty similar among the scenarios: it is peaking in 2020 with a subsequent decline to minimal level. As evidenced by the figures in Table 68, even the assumptions in the High Oil scenario (in which high gas prices should, in theory, stimulate domestic production), have no impact.

Export of gas is at its minimum level with insignificant increase in 2010 (which is facilitated by the increased production in this period should further gas exports). The RES-30 and High Oil scenarios result in slightly higher export levels compared to the other two scenarios.

The analysis of the natural gas imports is provided further.

Table 68. Natural gas balance in EU-27, mtoe

mtoe	2005	2010	2015	2020	2025
Baseline					
Export	29.8	52.1	42.9	42.5	33.3
Import	251.1	267.6	299.9	374.7	398.8
Production	196.1	222.0	202.8	96.8	75.3
Primary supply	1771.1	1811.5	1875.5	1897.3	1933.0
Baseline-RES					
Export	29.8	50.6	40.7	40.3	31.9
Import	251.1	268.2	307.6	358.4	377.1
Production	196.1	222.0	202.8	96.8	75.3
Primary supply	1771.09	1805.86	1850.1	1769.3	1807.5
Baseline-RES-30					
Export	29.8	40,2	36.8	38.9	29,2
Import	251.1	268,4	303.6	363.5	416,9
Production	196.1	208,8	191.5	139.4	94,0
Primary supply	1771.1	1804,3	1837.0	1729.1	1764,9
Baseline-High Oil					
Export	29.8	48.9	34.8	38.9	30.3
Import	251.1	298.2	361.2	464.3	511.2
Production	196.1	221.7	199.2	113.7	88.7
Primary supply	1771.1	1787.2	1792.7	1735.0	1765.1

Table 69. Oil balance in EU-27, mtoe

mtoe	2005	2010	2015	2020	2025
Baseline					
Export	131.8	153.6	144.7	155.6	162.6
Import	702.4	719.6	756.4	870.4	893.9
Production	130.2	152.1	129.1	25.2	20.3
Primary supply	1771.1	1811.5	1875.5	1897.3	1933.0
Baseline-RES					
Export	131.8	159.9	157.2	187.5	186.9
Import	702.4	716.1	748.0	489.1	875.3
Production	130.2	152.1	129.2	25.1	19.5
Primary supply	1771.1	1805.9	1850.1	1769.3	1807.5
Baseline-RES-30					
Export	131.8	161.2	158.0	190.4	201.4
Import	702.4	716.3	747.5	846.2	871.6
Production	130.2	152.1	129.2	24.4	19.2
Primary supply	1771.1	1804.3	1837.0	1729.1	1764.9
Baseline-High Oil					
Export	131.8	180.2	243.6	371.1	329.3
Import	702.4	802.9	734.3	695.5	809.2
Production	130.2	32.9	92.7	178.8	25.6
Primary supply	1771.1	1787.2	1792.7	1735.0	1765.1

According to PET model results, oil production in EU-27 drops significantly in all scenarios (with a comparable rate among the scenarios), except the High Oil scenario, according to which, a considerable production growth is expected by 2020 from rather low level of 2015. This level will again drop by 2025, though the dynamics of oil consumption correlate with the dynamics of TPES except for the High Oil scenario, in which the share of oil in energy mix is replaced by natural gas.

Figures in Table 66 allow to conclude that natural gas import dynamics is quite stable regardless of the scenario. Given that almost all TIMES scenario components (those are useful demand, primary energy, energy strategies and technologies) were altered in 4 considered scenarios, such robustness of the output dynamics justifies that the reference energy system and gas as a commodity were modelled appropriately.

It is notable that the High Oil scenario, against all expectations, does not result in a reduced gas consumption or gas import. On the contrary, net imports are higher in this scenario (for all periods), especially compared to the RES-20 scenario (which is the central alternative scenario). Also, the High Oil scenario exhibits the highest levels of gas import and consumption, the level of TPES is comparable with that of the RES-20 scenario. The increase of RES share takes place at account of oil share in the energy. It can be assumed that in this case the model takes into account the so-called "gas premium" in terms of environmental impact.

The results of the key alternative RES-2020 scenario – the RES Reference -(RES target of 20% in 2020) give grounds for several questions. First of all, the figures for 2020 deviate from the general trend over the periods (in terms of gas or oil imports, and in terms of consumption and TPES). It can be assumed that, in order to reach certain targets (primarily with regard to the share of RES), additional limitations have been imposed in the model for this particular period. After 2020, when the limitations are relaxed, the model continues to follow an "equilibrium" trend, which may be observed in several indicators. Moreover, according to the scenarios description, only the High Oil Scenario is built on the basis of the Reference scenario, which did not specify any clear target with regard to RES. Nevertheless, the dynamics that were observed, for instance, in the results of the RES-30 scenario indicate that a period of at least five years, for which 2020 falls in the middle, was described differently in the model.

Actually, if the RES-30 scenario only differs from the RES-20 scenario by its objective with regard to in 2020, then it would be possible to expect similar dynamics in the reduction of fossil fuel supplies.

The Baseline-High Oil scenario is also notable. Unlike the other models considered, in the TIMES approach, gas imports grow in proportion to growth (and quite significant growth) of prices for imported oil.

The following research results may be separately distinguished from other results as follows. First of all, for a comparison of CO_2 emissions at their pre-crisis level, the level suggested by the EC and the results of the Baseline-RES scenario of the PET model (Pan-European TIMES).

According to the results of the RES-2020 research, in practically all EC countries, it is possible to attain a more significant reduction of CO_2 emissions by the year 2020 than has been assumed by the European Commission. Italy and the Netherlands are exceptions – in these countries, on the contrary, higher emission volumes in comparison with the year 1990 are expected.

Target shares of RES that the EC has proposed in many countries are determined in a rather realistic way. Moreover, in some counties, this share may be greater. The results presented here comply with the BEST scenario, which differs from the RES-20 scenario in the fact that, after the year 2020, the share of RES should increase to 37% by the year 2050.

In the context of the results presented, it is necessary to carry out an additional comparison of the results and mechanisms of the PRIMES models (which constituted the basis for the 20-20-20 Programme as it noted in the analytical memo on the First Stage of the Energy Dialogue) and TIMES (the PET modification), owing to the fact that, even in the scenarios assuming high oil prices, the results of TIMES show that the objectives of the 20-20-20 Programme are achievable given a simultaneous increase in natural gas consumption and imports in the EC-27.

It is worth noting that the Internet portal (http://www.kanors.com/DCM/Default.aspx?Mod=RES2020) was established within the framework of the RES 2020 project, and it ensures interactive data communication. In particular, its users may build scenarios by themselves (in terms of target values with respect to emissions and RES) and request that the PET model be launched.

It is probable that such functionality is observed for the first time among the energy models that have previously been explored and the energy models in existence. In the case of successful work, this should allow for improving the transparency of the modelling mechanisms. Once again, it is necessary to note the devastating contrast of this approach with the closedness that, at least for the time being, characterises the developers of the PRIMES models. This situation creates actual difficulties in the work of the Energy Dialogue Subject Group.

4.6.3. TIAM Model for Integrated Estimation on the Basis of the TIMES Model

The previous sections considered the evolution and application of the TIMES modelling approach, intended for creating regional and global models of energy development. The text analysed the necessity for the exogenous definition of some scenario components and also reviewed the disadvantages of the TIMES models (in general and particularly the absence of an integrated approach in which macroeconomic "top down" models could harmonically cooperate with more technological "bottom up" models).

Taking into consideration the experience accumulated in implementing the TIMES family models, as well as the current modelling tendencies,

TIAM (the TIMES Integrated Assessment Model) was used in the course of the REACCESS Project (Risk of Energy Availability Common Corridors for Europe Supply Security) within the framework of the Seventh Framework Programme. The development of TIAM started in 2000, and the model has been used in many European and international projects, such as:

- Enhancing Robustness and Model integration for The Assessment of Global Environmental Change (ERMITAGE, to begin soon, 7th Framework Programme);
- Evaluation of Post-Kyoto climate negotiations (http://synscop15.ordecsys.com);
- Risk of Energy Availability, Common Corridors for Europe Supply Security (REACCESS, described below); Evaluation of emission scenarios (EMF24, IPCC-AR5, IPCC-SRRN, Asian Modelling Exercise);
- Evaluation of Renewable Energy Technology Deployment (RETD, International Energy Agency http://www.iea-retd.org/page.aspx?idsection=55); Probabilistic Long-Term Assessment of New Energy Technology Scenarios (PLANETS, http://www.feem-project.net/planets/);
- Technology-Oriented Cooperation and Strategies in India & China (TOCSIN, 6th FP).

This model is intended for describing the world energy system. Additionally it is planned to add the PET model, which was considered earlier, and to combine two models to create a unified modelling approach. The Project began in 2008 and, by the time that this analytical memo was being prepared, the developers had already prepared several reports on the development of the modelling component of the REACCESS concept.

Within the framework of the Russia-EC Energy Dialogue, certainly this Project is of special interest, not merely owing to the declared objective of creating a modelling approach in which the greatest disadvantages inherent to the other models will be taken into consideration, but also due to the content of this approach. Research on energy corridors opens a new page in a series of the integrated evaluation of energy strategies, especially in the case that the factors pertaining to the geopolitical and social risks are taken into account.

It is remarkable that the REACCESS Project team, which consists of 14 participants, includes partners from Russia (the Institute for the Economy in Transition, or IET) and Kazakhstan (the Coordinating Centre on Climate Change, CCC).

The Project is coordinated by the Politecnico di Torino[32], while the National Technical University of Athens is responsible for disseminating the results of and information on the Project.[33]

The objectives of the Project can be divided into two categories, those related to content and methodological ones. The content-related objectives may be formulated as follows:

- Determining the technological, economic and environmental characteristics of both existing and prospective energy corridors:
- within Europe; and
- between Europe and supplying regions,
- taking the following factors into account:
- The different topology of infrastructure and technologies (i.e. railroads, pipelines, etc.);
- Streams; and
- The distances involved.

The development of scenarios and the analysis of results will be based on the *European Decision-Making Triangular*:

- Security of supplies (i.e. stability of the world trade system, short-term reserve storage facilities).
- Objectives regarding environmental protection (i.e. the Kyoto Protocol in terms of renewable energy resources).
- Economic competition (innovations as a result of research, investments in technologies, the liberalisation of markets, the Lisbon strategies with respect to nuclear energy).

With respect to the methodological scope, the following activities are planned:

The creation of a modelling mechanism using the TIMES technological model and scenario generator, including the main centres of energy consumption and production, as well as the corridors for export supplies with the following specifics:

- The long-term planning horizon for constructing long-term strategies, given that the different standards of energy plants and technological development are taking into account.
- A high level of elaboration when describing the energy system with respect to supplies and the final consumption, including the training function at the regional and global levels.
- The evaluation of responses to new strategies involving an alternative equilibrium.
- The possibility of evaluating the accessibility and security of every supply region and corridor using the appropriate methodology.
- A breakdown of the demand curve into energy services (useful energy), each of which is a function of the price.
- The possibility of analysing the impact of different strategies and pricing mechanisms (for instance, taxation schemes or subsidisation with respect to energy products or technologies), as well as different schemes of energy supply chains.
- The evaluation of target strategies (the establishment of threshold limit values for CO_2 emissions).
- Demo scenarios for the EC-27 and other consumer regions.

[32] The Project coordinator is Professor Evasio Lavagno.
[33] The Department of Electronic and Computing Machinery, Laboratories for decision making support systems. The responsible person is Professor John Psarras.

Model symbiosis

Within the framework of the REACCESS Project, integration means the incorporation and modification of the following models:

The PET (Pan-European TIMES) model, which is intended for re-calibrating the models produced in the course of the NEEDS and RES-2020 projects (described above) on the basis of actual retrospective data.

The TIAM model, which describes the world energy system with regard to 16 countries.

The RECOR model (REACCESS Corridor Model), which was developed for the current project with the purpose of describing the mechanisms of the energy corridors.

The RECOR interconnecting module performs the function of a connector that works in a unified approach, and will ensure the endogenous management of energy resource streams, as well as investment in energy corridors' infrastructure. Owing to RECOR's incorporation, the problem of dynamic links to global and regional models is being addressed. Moreover, the global model is also incorporated into the integrated modelling approach, which leads us assuming the existence of full feedback (at least in an interactive form) between the three models. The structure of the TIAM energy system in this realisation is distinguished in that it excludes intra-module supply management of resources and withdrawal of this function into a separate block, thereby ensuring concurrence.

The RECOR model describes in detail the properties of the communication nodes and centres of global energy corridors (i.e. ports, railroads, pipelines, etc.).

Risk assessment

One of the critical supplementary features of the TIMES model is its risk assessment module and its consideration as part of the optimisation process. Risk assessment is carried out on the grounds of factor analysis, with the main categories (social, political, energy, and economic) for which points are given and consequently scored (translated on a scale from 1 to 100). The obtained values are then used in the PET/TIAM model.

An elemental risk parameter can be added to each process. A general risk indicator can be calculated for any predefined set of processes. Such indicator can become the objective function. Combined trade-off scenarios can be built, where the economic equilibrium is perturbed by the desired level of risk (or climate change mitigation).

The above-mentioned scope of work is now at the initial stage. According to the preliminary results, the index for Russia is 39.0, while it is 10.9 for the USA and 40.9 for Ukraine.

Risks for the population in terms of casualties or accidences (the number of victims per annum or the volume of damage, euros per annum, victims per Joul, damage in euros per Joul). The environmental risk in terms of casualties or accidents (damage in euros per Joul, damage in euros per annum). Inoperability is a probabilistic estimate of the average annual capacity loss of the system due to the recovery after service interruptions (% of operational capacity = idle hours/ expected activity hours).

The TIAM-World model

The TIAM model represents a global model, in which the world is divided into 16 regions such as: Russia, Central Asia and the Caucasus, other eastern countries, Africa, Australia and New Zealand, Canada, Central and South America, China, Eastern Europe, India, Japan, Mexico, the Middle East, other developing countries of Asia, South Korea, the USA, and Western Europe. Therein the upstream sectors of the energy producing regions are divided into the OPEC and non-OPEC countries. It is worth noting that the TIAM model is one of the few global energy models for which the regrouping of countries into regions – labelled as Russia, the Middle Asia, and the Caucasus as well as other eastern countries – was finally carried out following a 20-year period after the Soviet Union's USSR disintegration and substantial changes in the structure of regional economic integration.

The regional modules are linked amongst themselves with variables describing the main energy sources (coal, oil and gas) and permits for CO_2 emissions. In such a manner, the strategy is reflected in terms of environment protection impacts on the energy trade.

The model's time horizon corresponds to the period 2005-2100 and it is divided into several periods of different duration freely chosen by the user.

As is the case with the RET model, demand is described on the basis of the GEM-E3 model results in the form of the demand growth propellers (drivers) for 42 types of demand for useful power. In terms of price, demand elasticity varies from 0 to -0.6, with most figures in within the range from -0.2 to -0.3.

For every application of the TIAM-World model (similar to other TIMES models), the following is simultaneously calculates:

- The volume of energy produced
- Prices
- The acceptance and refusal of technologies
- The volume of the emission
- The cost of greenhouse gas emissions
- Variables for the climate model
- Demand for useful energy
- Moreover, this is done in such a way that prices and volumes will be in equilibrium:
- For all sectors, time periods and regions; and
- The equilibrium should maximise the cumulative added capital of the producers and suppliers by means of linear programming.

The following points may be noted with respect to price formation.

The oil market is non-competitive. The Cartel (OPEC) establishes fixed limits on production and other producers supplement supplies in order to satisfy demand. In general, the price formation mechanism using the TIAM model may be described in the following procedure:

Establish an upper limit for OPEC production.

Launch the TIAM model and consequently obtain data on the input of other producers, the reaction of consumers, and world prices for oil.

Update the upper limit of OPEC production.

Repeat steps 1 through 3 until the maximum profit of OPEC producers is known.

The natural gas markets are regional in scope. The TIAM model suggests that they are competitive, i.e. the price is equal to the maximum cost in every region. However, the market of the liquefied natural gas is global and the supply chain is fully represented in the model.

Results

Below are the preliminary results within the framework of the REACCESS research. First of all, calculations with respect to the new modelling region, i.e. Russia should be noted. Figure 69 indicates the dynamics of CO_2 emissions by economic sector for the Reference scenario.

Within the framework of this document, it will also be useful to estimate the impact of climate measures on the import structure and volume with respect to the main energy sources in the EU-27. The specifics of the given results consist of, as specified above, the fact that import potential is estimated in the integrated models approach, i.e. global, regional and transportation-related.

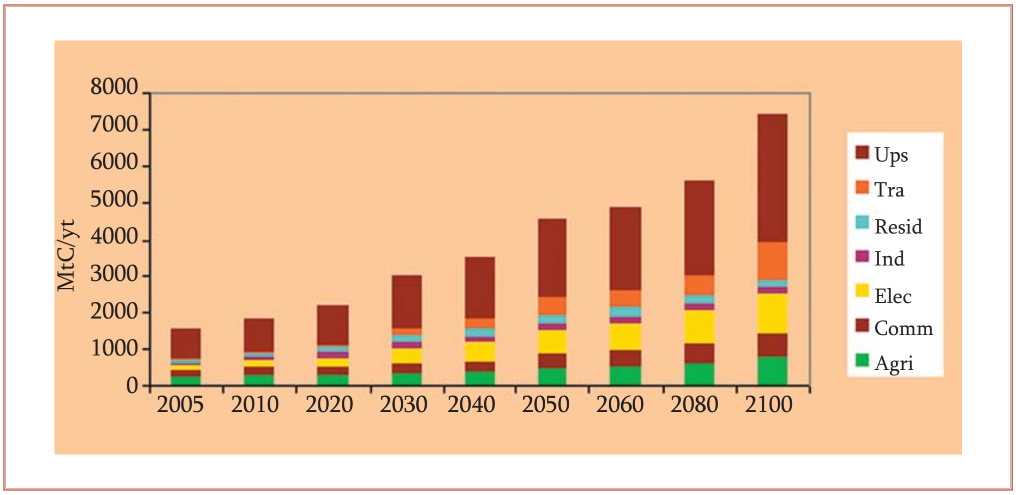

Figure 69. **CO_2 emission in Russia**

Note: Ups – upstream, Tra – transport sector, Resid – housing and public utilities sector, Ind – industry, Elec – electric energy sector, Comm – commercial sector, Agri – agriculture. MtC/yr - million metric tonnes of carbon equivalent per annum

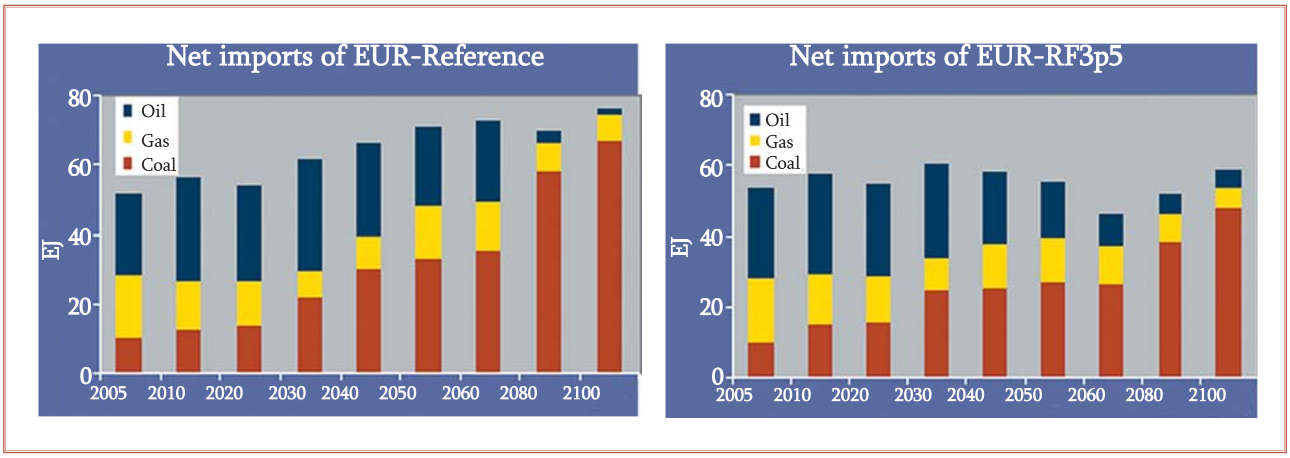

Figure 70. Comparison of import in reference and RF3p5 scenarios

Note: Net Imports of EUR – RF3p5 – Net import of primary energy sources in the EU-27 according to the Temperature Growth by 2 °C by the Year 2100 scenario (equivalently to RF3.5, meaning Radiative Force = 3.5 W/m²). EJ – exaJoul (10^{18} J)

It should be noted that, in Figure 70, despite the acceptance of the energy development scenario and climatic targets (the world temperature will increase by less than 2°C by 2100, which imposes strict limitations on the CO_2 concentration and, respectively, on emission quotas' temporal distribution), the dynamics and supply volumes of natural gas remain virtually unchanged.

In conclusion, it is worth noting that the REACCESS project is the most interesting in the framework of the EU-Russia Energy Dialogue. The Project represents the next step in the development of applying the TIMES methodology and the integration of the *bottom up* and *top down* models.

In addition to substantial growth in the volume of data and the clarification of some mechanisms (technology and price formation), as well as internal links, the following specifics are worth noting:

- The integration of the PET model (Pan-European Times) and the TIAM model, which allows, on the one hand, using a detailed description of the EC energy model and, on the other hand, reducing the number of exogenous variables through the parallel modelling of the world's centres of energy sources production and consumption. In order to build the feedback link between the models, among other things, the transport corridors expression is incorporated to ensure the modelling of the import/export of the main energy sources.

- The incorporation of the risk assessment module, including those of both a technological and social nature. As mentioned earlier, the TIMES models are probably ones of the few that would allow for a quick response to the current financial and economic crisis, as well as the development of additional scenarios that consider, on the one hand, the insufficiency of investments, and, on the other, the cheapening of investment projects. The creation of an additional module increases the possibilities for an integrated evaluation owing to the endogenous modelling of processes similar to those of the current crisis.

At the same time, it would be important to accelerate Russian participation in the Project and to consider, within the framework of the Thematic Group of the EU-Russia Energy Dialogue, those parameters of the initial data and the model descriptions that refer to the Russian Federation and that are applied within the framework of this Project, including the rather subjective parameters (like risk assessment). It is desirable that the above-mentioned steps be realised in the near future, taking into account the fact that the year 2010 was initially considered as the year of completion for this particular Project.

As the Project advances towards its completion, it may be possible to evaluate the results of the universal scheme for comparing the models that is suggested within the framework of this document.

Abbreviations and acronyms

bcm – billion cubic meters
BL – Baseline (about scenario)
boe – barrel of oil equivalent
CCGT – combined cycle gas turbine
CCS – carbon capture and storage
CNG – compressed natural gas
CPS – Current Policy Scenario (IEA scenario)
EIA DOE – Energy Information Administration Department of Energy
EU – European Union
GHG – greenhouse gases
GO – guarantees of origin
gtoe – billion tonnes oil equivalent
HOG – high oil and gas (about scenario)
IGU – International Gas Union
IEA – International Energy Agency
IPCC – Intergovernmental Panel on Climate Change
LNG – liquefied natural gas
LTC – long-term contracts
MBTU – million British termal units
mtoe – million tonnes of oil equivalent
NEP – New Energy Policy
NPS – New Policy Scenario (IEA scenario)
OPEC – Organization of Petroleum Exporting Countries
PEC – primary energy consumption
RES – renewable energy sources
RF – Russian Federation
SSER – Second Strategic Energy Review
tcf – trillion cubic feet
TYNDP – ten year network development plan
WEM – World Energy Model
WEO – World Energy Outlook

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Appendixes

Appendix 1. Summary Description of the E3M-Lab Modeling and Information Tools

A.1.1. Integrated Modeling and Information Environment

The basic tool for generating development scenarios and forecasts for the EU's energy sector is the PRIMES model developed by the E3M-Lab of the National Technical University of Athens (hereafter NTUA). During the generation of these scenarios the PRIMES model has been applied together with other global and regional models partially adapted to the needs of these studies. Among the major models (apart from PRIMES) are as follows:

- GEM E3 global macroeconomic model developed and supported by a consortium of European institutes (BUES, ERASME, NTUA, KUL, PSI, ZEW); the European version of the model is supported by NTUA;
- POLES – a large-scale world simulation model for the energy sector with endogenous international energy prices and lagged adjustments of supply and demand by world regions. POLES is developed by a laboratory in LEPII (Grenobel-2) and a commercial company Enerdata.
- Prometheus simulation energy model that is also used for setting global world and import energy prices;
- Assessment environmental impacts in PRIMES scenarios has been earlier conducted with help of GEM E3 model; at present, work is underway to identify a more detailed spectrum of their environmental impacts through the GAINS model developed by IIASA.

The scheme of model interaction is presented in Figure 49. The major models of the information and modeling complex will be addressed more in detail.

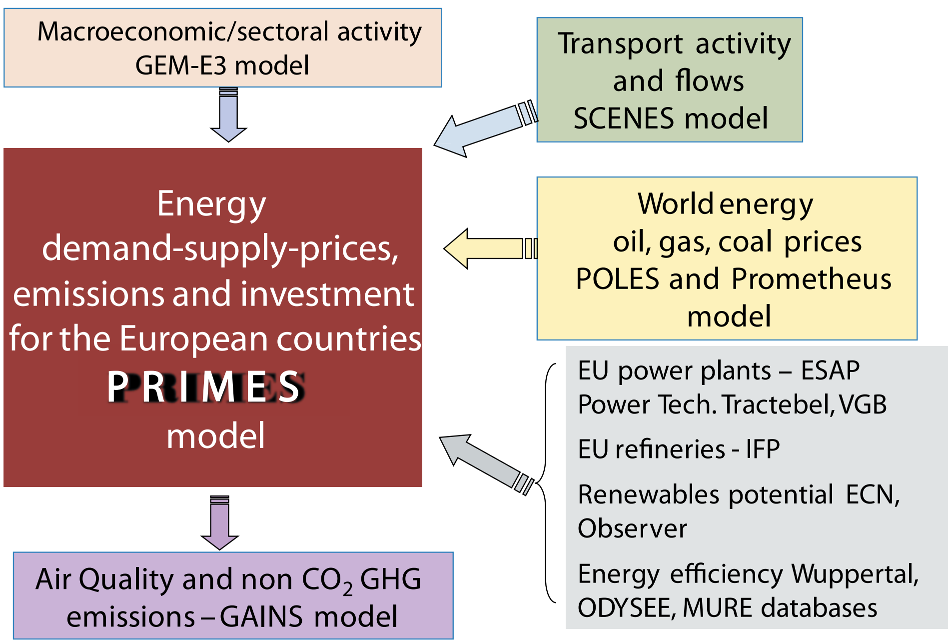

Figure 71. Integrated modeling and information flow environment implemented by E3M-Lab

Combined use of various models and approaches enables, on the one hand, provides a comprehensive assessment of the process under review, for example, by complementing a bottom-up concept in engineering models with a top-down macroeconomic concept. At the same time, it is clear that such symbiosis requires applying a smoothly running mechanism of interaction between the models (interface), which is supposed to evolve along with the development of the models. It is unclear to what extent the interaction shown in Figure 49 had been adjusted at earlier stages and to what extent it is implemented during its development up to date. Moreover, given that the models are based on different economic approach, it is critical to understand to what degree their feedback is included. The iteration is mentioned in a number of publications and presentations but there is no detailed information. We may assume a situation whereby, for example, a PRIMES generated scenario over determines macroeconomic development in GEM E3 and this is the case for next iteration. If the process diverges or runs into a cyclic path, a decision will have to be taken in favour of a certain option.

Another argument is about potential inconsistency of both final and interim operating results of the models in view of the heterogeneity of the modeling environment under review (for example, the system uses general equilibrium models along with simulation models and inputs from optimisation models). There are no materials to explain the development and implementation extent for the results validation mechanism.

These questions arise particularly due to the fact that the available documents on the models are very limited and there is no data on model interaction in the publications known to the experts.

A.1.2. PRIMES Model

PRIMES is the cornerstone of the scenario and forecast rendering process in the E3M-Lab.

The model describes the European energy system and markets in a great deal of detail. It features modular structure and covers the supply and demand sectors balanced through a price clearance mechanism. The model is reach with engineering and cost information and contains wide range of energy policy instruments.

PRIMES is a general purpose model. It was initially designated for forecasting, scenario rendering and analysing the impact of energy strategies/policies implementation. Forecast horizon varies from mid-term to long-term. Due to its modular structure, it is possible to use the model as a full package, or in separate modules, depending on requirements of a specific research.

The initial model design in 1995 was mainly driven by the need to complement the bottom-up engineering models with the processes of market liberalisation, market mechanisms and modes, as well as the pattern for consumer and producer behaviour. In such a form, models may endogenously include the energy policy instruments. Such models are called "new generation models" since they dominate the applied research in the field of energy policies and strategies. On the one hand, they are often referred to as partial equilibrium models due to the fact that they go beyond the energy sector. On the other hand, they are also referred to as complete equilibrium models since they may formulate behaviour patterns for economic agents with the help of mathematical formulations for sub-models, and provide market clearance modes.

In addition, the PRIMES model is attributed to hybrid models unifying the technical orientation and economic market-based assumptions.

PRIMES is in fact a system of models, which simulates market clearing by determining prices of each energy form so that the quantity the producers find best to supply at given price level matches the quantity the consumers wish to consume at this price. The equilibrium is static within each time period, but repeated in a time-forward path under dynamic relationships. Despite the fact that the model is behavioral, it contains explicit and detailed formulations for the available supply and demand energy technologies and for emission abatement. Moreover, the system reflects considerations about market economics, industry structure, energy and environmental strategies and regulation, which influence the market behaviour of the energy system agents.

One of the model peculiarities is the modular structure, which reflects distribution of the decision making process among the agents, which decide independently about their demand and supply parameters on the background of the global (in the model's context) prices, demand and supply. Global equilibrium is determined in the integrating module of the PRIMES model accumulating the informational flows from all sub-models and featuring the interface with external models.

While each module has its own pricing mechanism, certain prices are determined exogenously, i.e. externally. Among the latter, for example, are the import prices for energy sources (gas, coal, oil), which subsequently affect the preferences of end users through (as well) externally defined elasticity coefficients and endogenous cost curves (for example, for electricicty and heat generation). Since there is a large number of regions and, respectively, agents, sensitivity of the model with respect to exogenously determined prices may only be determined empirically (i.e. through model runs with various price indices).

The basic features of the PRIMES model, as stated by the developers, are as follows:

- Full description of the energy system on the demand side and the supply side;
- Integrated representation:
  - o Bottom-up (engineering model, technologies are defined explicitly); and
  - o Top-down (microeconomic behavior, economically coordinated decisions of the agents);
- Modular structure with separate sub-models for each sector of demand and supply with a separate decision making block;
- Decentralised decisions on the demand side and supply side in relation to a certain energy carrier;
- Market orientation: equilibrium prices are determine the demand-supply balance for a certain energy carrier;
- Gas and energy trading simulation both, within the EU market and beyond;
- A wide range of energy policy instruments: taxes, subsidies, market certificates and emission permits, strategies that promote technological development, environmental instruments, market intervention and regulatory instruments.

At the same time, for the description of the energy policy instruments as the authors allocated 1 page in a 250-page full version of the user manual. Unfortunately, neither the exact formulas, nor the data underlying the assumptions are provided. This was likely to be caused by low interest in this field during the compilation of a public description of the model (late 1990s). The authors, probably, didn't have enough time to prepare more detailed description. However, once the NEP и NAT CDM scenarios were released, it became evident that the mechanisms of the above mentioned instruments need to be revealed.

Geographic coverage:

Each of the EU-27 Member States is represented individually. The EU accession and partner countries are also represented, e.g. Norway, Switzerland, Turkey, countries of Southeast Europe.

Energy networks presentation:

Eurasian electricicity and gas networks are presented in general form. European electricity and gas markets can be modelled as a single interrelated system.

Core modules:

Sub-models of demand and supply sectors connected via integrating module, models of power generation and energy supply.

Additional modules (introduced after 2000):

Biomass supply, oil refineries, detailed transportation sector, gas module (Eurasia), hydrogen supply.

Time horizon:

2000-2030: reporting period, 2000 - 2050: modelling period with five-year intervals. The model is calibrated on the basis of the EUROSTAT data for the period from 1990 to 2005. Forecasts – from 2010.

Sectors and technologies:

- 12 industrial sectors divided into 26 sub-sectors by the form of energy use in 12 typical processes (air compression, furnaces, etc.);
- 5 service sectors with 6 typical processes of energy use (conditioning, equipment, etc.);
- 4 types of households with 5 typical processes of energy use and 12 types of equipment (TV set, refrigerator, etc.);
- 4 means of transportation, 10 kinds of transport and 10 vehicle technologies;
- 14 types of fossil fuels, new types of fuel (hydrogen, biofuel), 10 RES;
- Basic energy supply system: power generation with the use of over 150 generation and transmission technologies;
- 7 types of emissions in the energy sector.

It should be noted that due to heterogeneity of the energy markets, it is difficult to render a uniform methodology that would adequately describe the processes of supply and demand reaction to changes in relevant factors. Presentation of separate consumption sectors (households, industries, etc.), which feature specific economic behavior and forms of reaction, seems to be more realistic.

Therefore, the PRIMES model is based on the modular principle. The modules are featured with various detalisation of the structural representation level, therefore, the feature of modularity allows each sector (within the model) to meet its specifics. Moreover, this feature helps investigate a sector or a group of sectors separately from the general system of the PRIMES model modules.

The model is based on energy production sub-systems (oil derivatives, natural gas, coal, heat and power generation, etc.) of the demand side and on final consumption sectors of the supply side (households, commercial and transportation sectors, etc.)

It is important to note that a consumer may simultaneously act as a supplier. Various modules share information flows in the form of volume or price exchange via the integrating module. This brings the system to a general (price-based) equilibrium (see Figure 72).

Special attention in the updated version of PRIMES is paid to the natural gas module as a part of the process of a gradual transition from the "consumption model" to the model of the processes, which were formerly calculated with other models. This will definitely reduce the level of results disagreement.

Geographically, the module covers 55 countries including Russia, Europe, the Caspian region, North Africa, etc.

The module aggregates nodes of the import and export infrastructure: gas fields, transmission pipelines, storages, LNG terminals, etc.

As for the pricing, this market is modeled via oligopoly competition (among large companies, on the basis of the price elasticity of supply, with due regard to the share of regulated markets, as applicable).

In addition, the module incorporates exchange trading with the prices and volumes calculated endogenously.

The gas module implementation in the PRIMES model in terms of commercial and physical flows is shown in Figures 73 and 74.

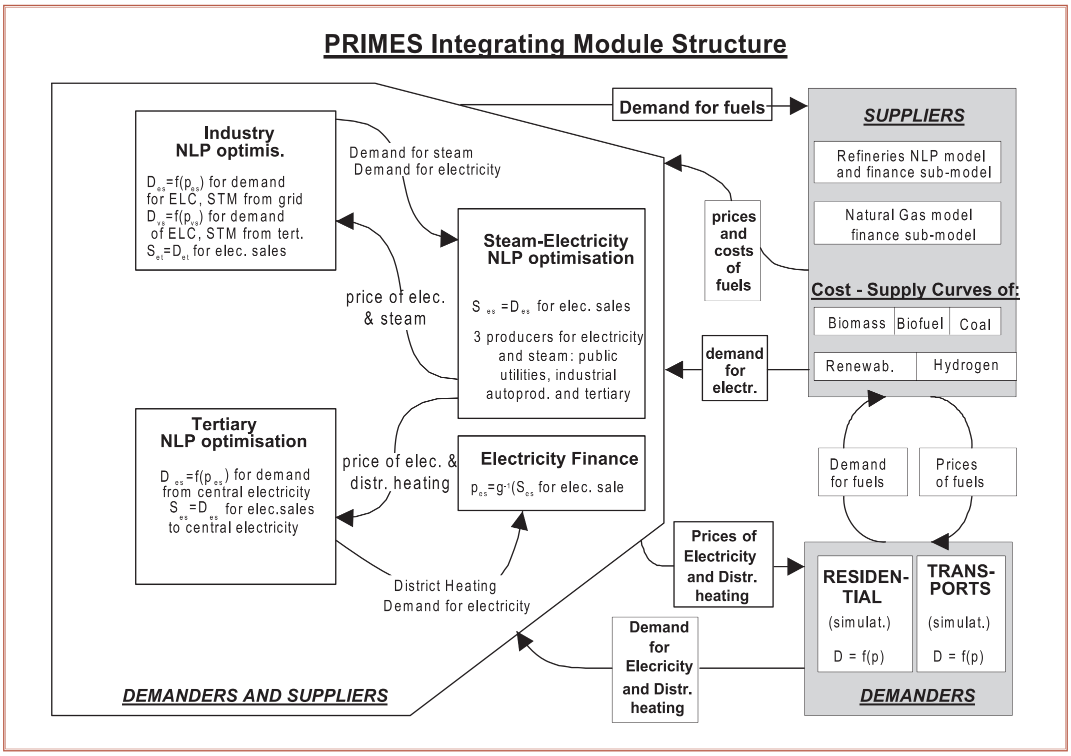

Figure 72. **PRIMES Integrating module structure**

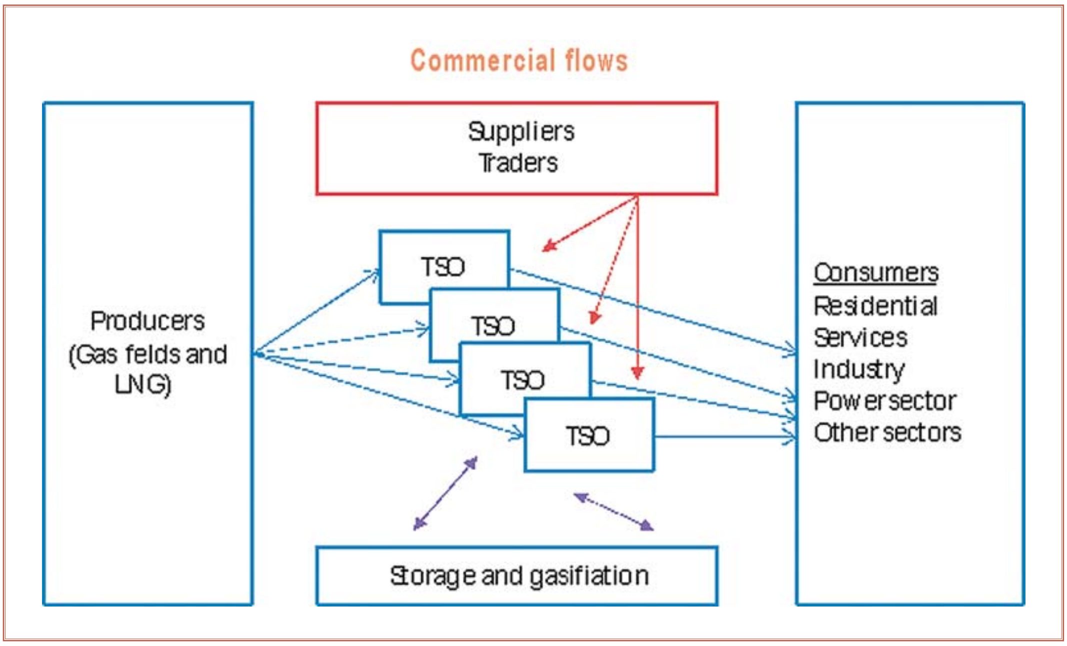

Figure 73. **Commercial flows in the Natural Gas module of PRIMES**

Speaking of the physical flows, it should be noted that network nodes have technical limits, and modelling of logistic flows is carried out on the basis of the supply pattern (reference day).

Each agent (a producer, consumer, operator or dealer) is represented as an independent decision maker. Pipeline gas and LNG are treated separately and are competitive products.

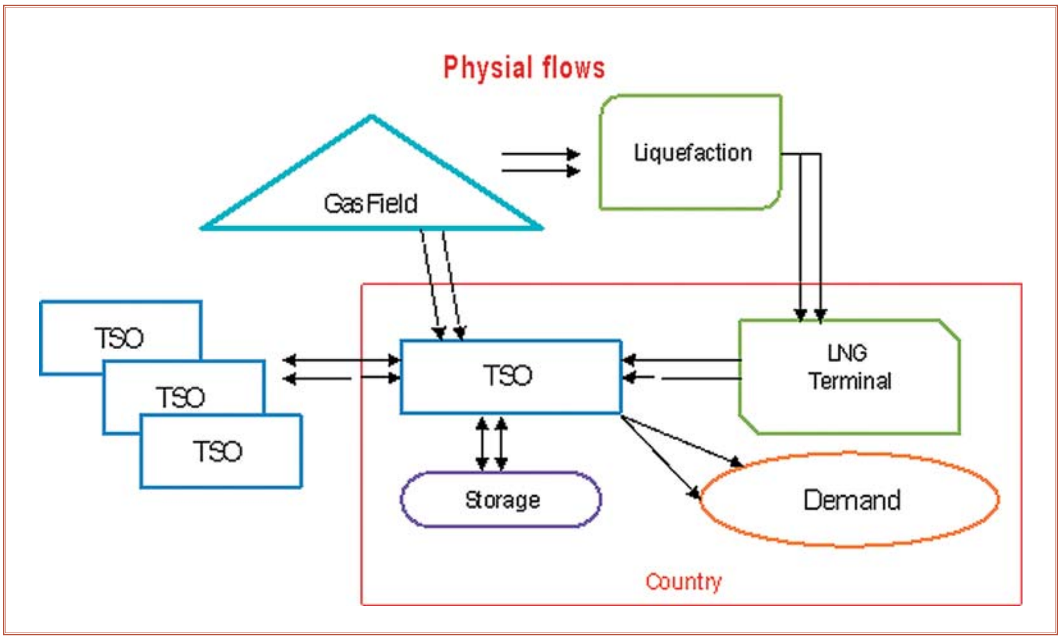

Figure 74. Physical flows in the Natural Gas module of the PRIMES model

The authors stress that market equilibrium is determined on the basis of the Cournot oligopoly, while the prices are identified endogenously (no pegging to oil prices). It is evident that these changes have been made in the most recent releases of the model. They are likely to diverge greatly from the present-day and future realities of the EU gas market dominated by long-term contracts at present. In addition, it may be assumed that due to unlinking the gas prices from oil prices they went up in the NEP scenario (probably, a natural gas module was included in this scenario only).

The authors identify the following major input (scenario) data:

- GDP level and growth for different sectors of economy.
- Global review of energy supply - world energy prices.
- Tax and subsidy policy.
- Interest rates, risk premiums, etc.
- Environmental policy and constraints.
- Technical and economic characteristics of future energy technologies.
- Energy consumption patterns, the parameters influencing the primary energy supply curve, potential sites for potential generation units.
- Parameters of the comfort demanded by consumers, rational energy use, preferences and habits of final consumers.
- Parameters for primary energy supply curves, energy saving, RES potential.

In the absence of the information relevant to PRIMES, it should be noted that consumer comfort and preferences are commonly determined at the level of useful energy. Thus, in MESSAGE[34] -type models these parameters are expressed in candle-meters for rooms, passenger-kilometers for private and public transport, heating parameters, etc. Moreover, on the basis of the ideas of future technology dynamics, these parameters may be projected (transferred) on the final consumption sphere. It may be assumed that PRIMES accounts for the above peculiarities in a similar manner. The only difference is that PRIMES does not support the level of useful energy leaving this responsibility to POLES and Prometheus models. In this case, the "habits" are likely to have been translated into the PRIMES model input in terms of final consumption (i.e. it is known how much gas, electric power, etc. will be required to sustain the lifestyle), while fully endogenous

[34] Global energy model developed at IIASA.

modelling would help select the appropriate energy form. Subsequently, this will determine the demand for final energy depending on the market conditions in a specific time instance.

These items are very important for understanding due to the fact that a recent independent study by A. Reuter (IRM at that time) carried out for the Austrian government has shown that Austria's targets to increase the share of RES in the energy balance are achievable only by changing the consumer behaviour (i.e. consuming less light, heat, etc.). There is an important question in this regard: what changes have been made in the NEP scenario in relation to the lifestyle of the end consumers.

The first four of the above mentioned groups of input parameters for the PRIMES model are obtained from the macroeconomic GEM E3 model.

A.1.3. GEM E3 Model

The GEM E3 model (global and European versions) is a global equilibrium model (GEM) covering 21 world regions and European countries interlinked via internal mechanism of bilateral trade. The European model is being constantly expanded through new member and accession states, as well as Switzerland.

The key mission of the model is to simulate interaction between energy, economy and environment (i.e. this model belongs to E3 class of models). At the same time, the model calculates the competitive equilibrium on the market according to the Walras law and determines the optimal demand-supply balance in the energy sector, as well as between emissions and emission abatement measures.

Basic characteristics of the GEM E3 model:

1. In general, the model embraces two features: it includes all the interrelated markets and at the same time the system is represented in a suitable way in terms of geography, in relation to the sub-systems (energy, economy, and environment) and dynamic mechanisms of the agents' behaviour.
2. Agents' behaviour is formulated separately for supply and demand: the agents optimise their respective (consumption/production) utility function, while the prices are cleared on the market to provide general equilibrium.
3. The market mechanism and respective pricing forms (in economy, energy and environment) are clearly described: the prices are defined as a result of market clearing. In addition to the assumption of perfect competition, alternative market mechanisms can be applied.
4. The model is both inter-regional (EU and the rest of the world) and regional (country/region). The general mechanism of the market equilibrium exists along with regional redistribution strategies and principles (goods and benefits).
5. Being a global model, GEM E3 provides sufficient level of discretion by sectors, structural features of the energy – environment link and by national strategy instruments (taxation, etc.). The model endogenously formulates production technologies making a price incentive to shape the intermediate consumption and services on the basis of capital and labor resources. In the electricity sector, production factors may be selected on the basis of an explicit technologies description (as model elements). On the consumption side, the model formulates the consumer behaviour and introduces clear distinction of the equipment, commodities and services.
6. The model dynamics is provided via time recursiveness. The main driver is accumulation of capital and production equipment. Technological advance is explicitly expressed in a production function (endogenous or exogenous) and depends on R&D costs in the commercial or public sectors taking into consideration the technology spillover effect.
7. The model describes emission permits and flexibility mechanisms that allow selecting one of the following options: distribution (auctioning, grandfathering, etc.), utilisation of the marketplaces defined by the customer, various schemes for disburdening or income redistribution.

The GEM E3 model general layout is shown in Figure 75.

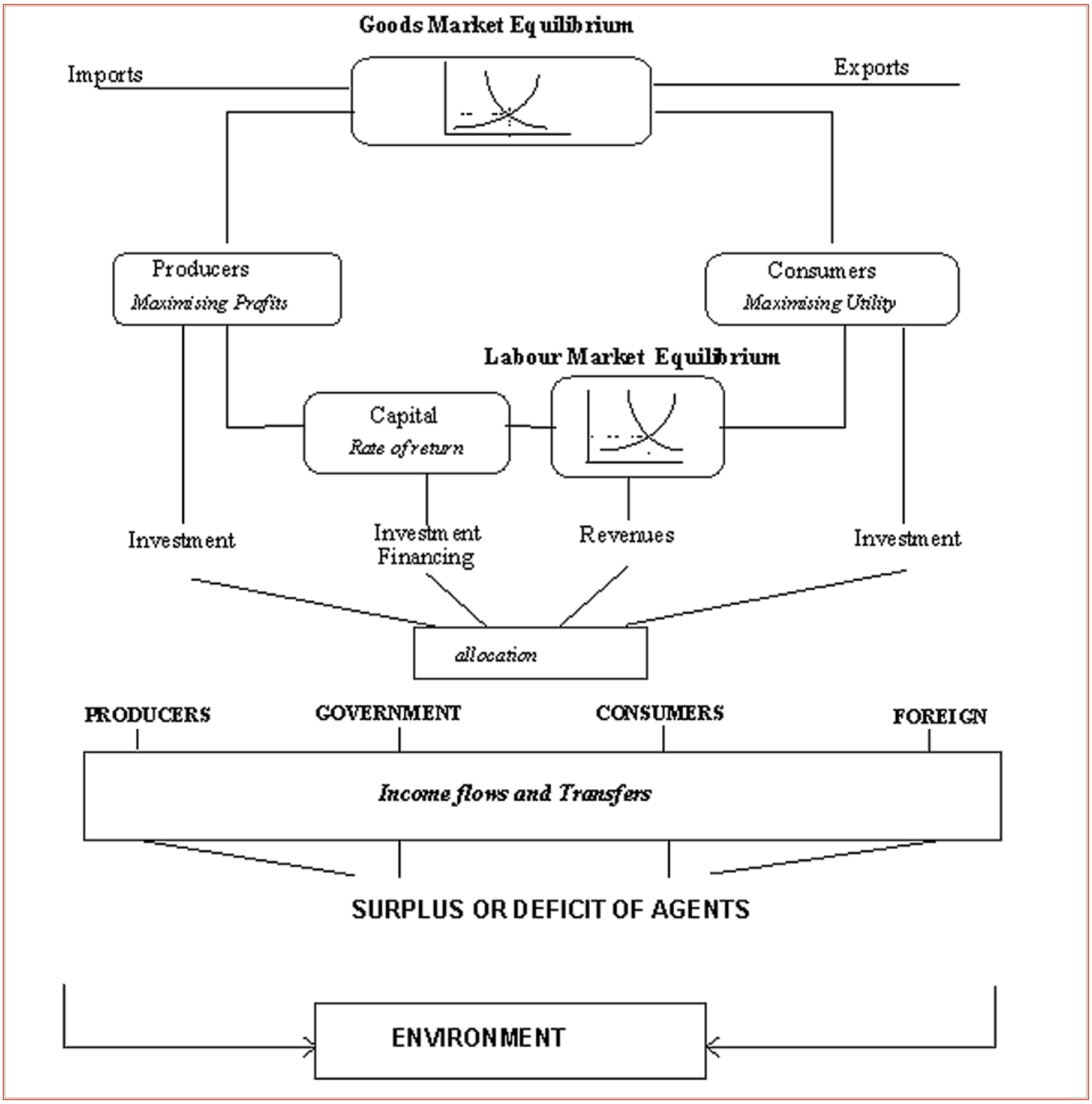

Figure 75. GEM E3 model general layout

The model was created in compliance with four major requirements:

1. The model structure based on the general equilibrium core with the use of modular structure so as to ensure that various modeling options, market regimes and position closure rules meet unified model specifications.
2. Fully adjustable (endogenous) demand factors of consumers and producers.
3. Calibration against the base year in the format of the System of National Accounts (SNA) applied in the EU along with specific features introduced in SNA.
4. Dynamic mechanisms through capital accumulation.

For the purpose of the current analysis, specific attention was paid to a set of input parameters of the GEM E3 model so as to ensure that these indicators simultaneously shape the basic package of macroeconomic assumptions for the scenarios modeled with the help of the PRIMES model.

Input Parameters of the Model

- Dynamic forecast of the economic indicators in absolute and relative units for each country. Input-output tables for each country and for the EU-15 in general by 18 sectors.
- Income distribution as a matrix of the System of National Accounts for a country. The level of employment, capital and investments for a country and by economy sectors. The state budget, tax and income distribution for a country, the current register for a country.
- Consumption matrix by products and the investment matrix by industries. A full matrix for the EU-15 and the rest of the world.
- GHG emissions, pollution abatement capital, costs for emission quota and environmental damage caused by the following six gases: CO_2, SO_2, NOx, VOC, PM and additionally O_3.

It should be noted that (Capros, Mantzos, 2008) and (Capros, 2009) provide input data for the PRIMES model as of 2005 including GDP distribution by economy sectors. However, similar data are not available for the NEP and NAT CDM scenarios. For the purpose of adequate analysis of the results, it is necessary to compare changes in macroeconomic scenario assumptions being the output of the GEM E3 model and, if required (in case the changes are difficult to explain or rapid), dip into the structure of the latter in order to investigate the nature of such changes.

It should be noted that the available materials on GEM E3 model do not provide the actual release date. The materials (obtained from the official website of the model developers) used for this report compilation are likely to date back to 2000. Regular reference to EU-15 and links to the projects dating back to the 1990s raise the issue of relevancy of the mechanisms/data and other factors underlying the model.

It is not clear how the mechanisms for establishing the market equilibrium in the PRIMES and GEM E3 models are linked, since their objects are partially overlapped. In addition, the indication that the mechanisms for economic evaluation of the GHG emission are formed in the GEM E3 model and the absence of similar information in relation to the integrating module of PRIMES also require clarification.

A.1.4. POLES Model

Within this analytical study, the POLES model seems to be one of the spotlights since the unreasonably high level of gas prices and parity with oil prices is determined in PRIMES on the basis of POLES (Prometheus model is just an additional cross-section due to a stochastic nature of the model and its results). However, both models are least documented in the available publications.
Nevertheless, this section provides basic features and some peculiarities of the modelling process.

The POLES model is a global general equilibrium econometric model (i.e. basic economic assumptions are set endogenously) covering 32 countries and 18 regions of the world (7 regions and 11 sub-regions).

Each region is described by 15 energy consumption sectors, 12 new (RES) technologies and 12 electric power generation technologies. The model is based on imitation of new discoveries of oil and gas fields and modeling of the dynamic oil and gas reserve by main producers (countries). The prices for energy carriers are modeled endogenously.

The model is hybrid to a certain extent and combines macro- and microeconomic approaches with the engineering ones (bottom-up). In order to demonstrate the specifics, we may consider two examples (under point 1 below).

1. Electric power consumption by households.

Econometric equation:

This example is based on the so called "top-down" macroeconomic approach. The demand function is the demand dependency on the electric power price (P) and on the level of its consumption by households (PC):

$E = k * PA * PC^b$, where

E - demand;

a: price elasticity of demand;

b: consumption elasticity of demand.

Engineering equiation:

This example is based on the "bottom-up" or engineering approach. In this case, demand is equal to the sum of the products of the number of equipment items (Eq) in a household and consumption per equipment unit (UC, kWh/equipment unit)

$E = \Sigma_i (Eq_i \cdot UC_i)$.

2. Elasticity in econometric models

Elasticity is a measure of demand vulnerability to negative zero. The equations are based on the theory and practice, and the elasticity coefficients are determined on the basis of regression.

$Ln(E) = a*Ln(P) + b*Ln(PC) + Ln(k)$.

3. Demand equation (ultimate consumption, FC)

Ln(FC) =	Linearised equation form; FC - ultimate consumption
RES + Ln(FC[-1])	Remainders (RES) and a lagged variable (FC[-1])
+ ES * f(FC,FC[-1],FC[-2])	Short-term price effect multiplier (ES) related to customer behaviour: changes in the current and previous periods
+ EL * g(FC[-2], FC [-3], …)	Long-term price effect multiplier related to investments
+ EY * Ln(FC/FC[-1])	Income multiplier / elasticity of consumers activity
+ Ln(1+Tr/100)	Autonomous energy efficiency indicator (sector-wide)