Overview of analytical work in the Global and Russian Energy Outlooks.

Fedor Veselov
ERI RAS – experience in system energy studies

Energy Research Institute of the Russian Academy of Sciences (ERI RAS) was established in 1985 for the fundamental studies in the area of national energy policy development and implementation:

✓ state level - methodological, modeling and analytical support for the energy policy priorities and implementation mechanisms (incl. macroeconomic, technological, pricing, environmental and other aspects), quantitative elaboration of the economy and energy sector scenarios, incl. decarbonisation options

- **National Energy Strategy to 2035**
- **Long-term Development Plan for the Gas Industry**
- **Long-term Development Plan for the Coal Industry**
- **Long-term Development Plan for the Electric Power Sector**
- **Energy Technologies Forecast to 2035**
- **Vision of the Smart Power System**
- **Vision, Scenarios and Roadmap of the Renewable Energy Sources Development**

✓ corporate level – capacity building, modeling and information support of the strategic planning system of leading Russian and foreign energy companies, justification of investment and market policy (at the domestic and global markets) under the energy markets transformation processes
SCANER – multi-functional system of models for the investigation of the global and Russian energy sector development

«SCANER» is a tool for the system analysis of the Russian energy sector development for the mid- and long-term prospects (to 2030-50) as an important part of national economy and global energy markets. Integrating the powerful modeling and informational resources, SCANER provides:

✓ Unique informational support to the analysis and forecasts (regularly updated databases on the national and regional economy, energy sector, energy balances and markets)

✓ Multi-level co-ordination system of energy forecasts focused on the formulation of rational scenarios of the economy, energy sector and energy companies’ development

✓ Huge flexibility and fast adaptation of the models and their calculation modes under the separate forecasting requirements
SCANER – multi-level co-ordination of energy forecasts

Formation of the scenario parameters of the global economy and energy sector development

Formation of the scenario parameters of the Russian economy and energy sector development

Forecast of global energy markets development and regulation environment

Formation of aggregate target parameters for the economy and energy sector development

Forecast of the socio-economic and industrial development of Russia and its regions

Forecast of global energy markets development and regulation environment

Estimation of resources and reserves for fuel supply industries

National and regional fuel and energy demand forecast with estimation of energy saving and efficiency improvements

Evaluation of the potential and priorities for new technologies

Evaluation of the impact of pricing and investment policy in energy sector on the economy

At the global level - co-ordination of the competitive export capabilities of the Russian energy industries with demand/prices trends at the global energy markets trends (on the basis of energy resources' supply/demand balances by regions and countries)

Recommendations for the national energy policy improvements
SCANER – multi-level co-ordination of energy forecasts

SCANER models for forecasting global energy sector development

- Retrospective indicators: GDP and population size, energy demand by fuel type and consumption sector
- Databases: resources, projects, contracts, investments, facilities, routes, costs etc.
- Scenario assumptions: population growth rate, GDP growth, energy and geopolitical policies, scientific and technological progress

Diagram showing the structure and modules of the SCANER models.
Global energy sector outlook. Different low carbon transformation (decarbonization) rates

Figure 2.4 – Scenario forecast of growth in world population, GDP and global world energy consumption

Figure 2.11 – Projected electricity consumption by region, TWh, by scenario

Figure 2.5 – Scenario forecast of primary energy consumption by region
Global energy sector outlook. Different low carbon transformation (decarbonization) rates

Figure 2.6 – Primary energy consumption by region, fuel type and scenario, mtoe
Global energy sector outlook.
Different low carbon transformation (decarbonization) rates

Transformation of the electricity production structure (C - Conservative and ET – Energy Transition scenarios)
Global energy sector outlook. Different low carbon transformation (decarbonization) rates
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At the economy level – co-ordination of national and regional economy and energy sector development forecasts in terms of domestic energy demand, fuel and energy prices, taxes, investments (on the basis of input-output and financial balances)

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Russian energy sector outlook. Macroeconomic and energy demand projections

Non-linear input-output model of the national economy (MENEK)

**Economic agents:**
25 types of economic activity (sectors and industries), *incl. 5 related to energy sector;* state institutions; aggregated households

**Products:**
30 goods and services, *incl. 9 related to the fuel and energy: oil, gas, coal, motor fuel, fuel oil, electricity, centralized heat, coke and other oil products*
Russian energy sector outlook. Macroeconomic and final energy demand projections

Socio-economic forecast (Ministry of Economic Development)

Database of actual large-scale energy consuming investment projects

Development of the disaggregated sectoral and regional macroeconomic forecasts (outputs and investments)

Projected energy intensities by energy carriers, sectors and regions

Projected final energy demand by energy carriers, sectors and regions

Projected final regional and national demand by energy carriers (fuels, electricity, heat)

Key results of the energy efficiency improvements and final energy demand transformation to 2040

Energy efficiency improvement is the most important part of decarbonisation scenarios. Energy, fuel and electricity demand trends are defined by the integrated effect, including:

- **structural impact** from the transformation of GDP structure, increase of the role of low energy consuming sectors/industries/products & services
- **technological impact** from the replacement/reconstruction of the existing and development of new equipment/buildings with the lower energy consumption
- **technological substitution of energy carriers** by the electricity in transport, heating, industry

Source: ERI RAS analysis
Russian energy sector outlook.
Harmonization of the economy and energy sector development

Russian economy and energy sector development indicators must be iteratively harmonized in the context of Energy Strategy elaboration.

**Integrated economy-energy development forecast simulation model**

**Regional final energy demand simulation model**

**Economy and energy sector interrelations forecasting system (MENEK)**

- Initial scenario of the economy development
- Adjustments of initial scenario of the economy development

**Fuel and energy prices growth rates**

- Final energy demand
- Fuel and energy wholesale prices growth rates
- World energy prices’ trends
- Limits for the availability of the capital for the energy sector investment
- GHG penalties or carbon prices

**Fuel and energy prices forecast**

- Taxes and duties
- Investments
- Fixed assets
- External financing requirements
- Budget subsidies and investments
- GHG emission in energy industries

**Energy industries’ development forecasting systems (production and financial models of industries and energy companies)**

Energy Research Institute RAS
Russian energy sector outlook. Impact of decarbonisation on the economy and energy sector development (2010 year study)

In 2010 ERI RAS made a special study to evaluate the impact of carbon taxation or limitation of GHG emissions in the electric power sector, energy sector and the whole Russian economy.

Carbon prices were considered in the wide range (up to 100 $/t) as well as limits on GHG emissions were considered up to 25%.
SCANER – multi-level co-ordination of energy forecasts

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At the energy sector level – co-ordination of the power sector and fuel supply industries development forecasts (on the basis of national and regional energy balances)

Projected production and financial programs of the energy industries

Power sector

Oil and gas sector

Coal sector

Projected financial position of the energy industries and companies

Forecast of domestic fuel and energy prices

National and regional fuel and energy demand forecast with estimation of energy saving and efficiency improvements

Evaluation of the potential and priorities for new technologies

Evaluation of the impact of pricing and investment policy in energy sector on the economy

Recommendations for the national energy policy improvements

Projected investment programs of energy industries and companies
Russian energy sector outlook. Transformation of energy balance

Primary energy supply and demand growth (% to 2015)

Energy export projections (% to 2015)

Total primary energy supply structure

Total final energy consumption structure
Russian energy sector outlook. Transformation of energy balance

GHG emissions from fuel combustion (% to 1990)

Emissions from fuel combustion by resources

Energy sector’s contribution to the macroeconomic parameters (% of total)

Energy Research Institute RAS
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At the energy industry level – co-ordination of the production and investment programs with financial stability requirements for the industries and separate energy companies (on the basis of financial balances)

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Projec...
Energy planning procedures

Cost-based screening analysis of ET
- LCOE
- Specific GHG emission rates
- Carbon avioded costs

Least-cost capacity expansion and generation mix plan for power system
- Energy planning models
- Capacity and electricity balance requirements
- LP optimization procedures

Economic evaluation of the ET and power sector plan
- Total investment requirements
- Total revenue requirements
- Final price requirements
- Pricing adequacy of existing markets
- LCOE vs LACE analysis

GHG abatement options

Carbon taxes and carbon prices

Limits (quotas) on GHG emissions

Min. required share of non-carbon generation

Russian energy sector outlook. Decarbonisation scenarios for the electric power sector
Discount rate can reverse the investment priorities for the future (esp. low-carbon) capacity mix

**LCOE of greenfield plants in the Central Russia, 0.01$/kWh**

- **2020**
  - **CCGT**
  - **Coal**
  - **Nuclear**
  - **Wind onshore**
  - **Solar PV**

- **2040**
  - **CCGT**
  - **Coal**
  - **Nuclear**
  - **Wind onshore**
  - **Solar PV**

**Carbon avoided costs, $/t CO₂**

**Impact of RES availability costs on the LCOE of RES plants (in % of RES LCOE)**

Source: ERI RAS analysis
Russian energy sector outlook. Least-cost capacity expansion and generation mix planning

Power system always includes different generating technologies to fit the set of requirements:

- **Security of energy supply**
  - capacity should cover the peak demand and reserve margin

- **Adequacy to the demand volume and profile**
  - the mix of technologies with different capacity factors should provide enough electricity and heat on an annual basis (key seasonal, weekly and daily load following requirements also should be checked)

- **Limitations on GHG emissions (volumes or growth/decrease rates)**

- **Introduction of carbon taxes/prices will change the previous structure**

- **Optimal (least-cost) economics**
  - operational and investment decisions should minimize the overall costs of energy supply

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<table>
<thead>
<tr>
<th>Gas balances</th>
<th>Coal balances</th>
<th>Fuel oil balances</th>
<th>Balances of electric power and capacity</th>
<th>Balances of centralised heat supply</th>
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<tbody>
<tr>
<td>Production and long distance transportation of gas</td>
<td>Production and transportation of coal</td>
<td>Production and transportation of fuel oil</td>
<td>CPP</td>
<td>Boiler houses</td>
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<tr>
<td>Consumption of fuel at thermal power plants and boiler houses</td>
<td>Domestic consumption (excluding thermal power plants and boiler houses) and export</td>
<td>Demand for electric power</td>
<td>Demand for electric power</td>
<td>Demand for heat</td>
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EPOS optimization model is the least-cost multi-year, multi-regional, multi-case, multi-product modeling tool for the power sector strategic planning:

- 2040+ planning horizon
- annual capacity, electricity and heat balances by 40+ nodes
- limitations on GHG emissions and availability of investments can be activated
- can be expanded to cover gas and coal sector (balance requirements can be activated)
- seasonal and daily adequacy of capacity mix is checked by special simulation models
Russian energy sector outlook.
Least-cost capacity expansion and generation mix planning

Conservative scenario
- low GDP and electricity demand growth rates
- low gas prices
- low (actual) technological transformation rates

Innovative (Energy Transition) scenario
- high GDP and electricity demand growth rates
- high (netback level) gas prices
- no special economic GHG abatement measures
- wide-scale replacement of existing thermal power plants:
  - CCGT and GT technologies for gas-fired steam plants
  - SC and USC units for coal-fired steam plants
  - increase of co-generation impact for heat supply, incl. distributed generation using gas or biomass
- intensive development of non-carbon generation:
  - increase of nuclear plants (PWR and breeders) with lower capex (up to 49 GW – 16% of total capacity)
  - increase of RES plants (up to 23GW in 2040 – 7,5% of total capacity)

Electricity generation mix

Key results of technological transformation of the power sector to 2040

Key energy efficiency and decarbonization indicators (in % to 2015)

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<th>Conservative</th>
<th>Innovative</th>
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<tbody>
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<td>Heat rate decrease</td>
<td>90,5%</td>
<td>81,8%</td>
</tr>
<tr>
<td>Carbon intensity of electricity</td>
<td>91%</td>
<td>75%</td>
</tr>
</tbody>
</table>

Source: ERI RAS analysis
Russian energy sector outlook.
Economic evaluation of the low carbon expansion plans

Cost-based screening analysis of ET
- Levelized cost of electricity – LCOE
- Carbon avoided costs

Power sector development plan
- Capacity expansion/energy flows models
- Capacity and generation mix
- Energy resource mix
- GHG emissions

Simulation of power markets
- Capacity dispatching models
- Spot electricity prices
- Capacity payments

Power sector/subsector investment plan
- Investment requirements for generation
- Investment requirements for transmission and distribution grid
- Available sources of investments

Pricing conditions for the ET
- Weighted average wholesale price (spot+capacity payments)
- Levelized avoided cost of electricity - LACE

Power sector/subsector financial plan
- Required revenue for the planned investments
- Final electricity price requirements
- Available revenue at the existing markets
- Revenue/price gaps

Macroeconomic assessment
- Input-output models
- Price acceptability
- Impact on GDP (cumulative impact from investments, operational costs and prices)
Russian energy sector outlook.
Economic evaluation of the ET and power sector plan

Generating capacity mix
- RES
- Hydro
- Nuclear
- Thermal gas
- Thermal coal

Total investments structure
- Hydro and RES
- Nuclear
- Thermal
- Grid

Revenue requirement structure
- Retail
- Grid
- Hydro+RES
- Nuclear
- Thermal (electro)
- Thermal (heat)

Average retail price, 0.01$/kWh

Source: ERI RAS analysis

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Thanks for attention