We inherited the planet from our ancestors, and should not borrow it from descendants

Modeling low carbon transitions

Igor Bashmakov

Center for Energy Efficiency - XXI

www.cenef.ru 8 (499) 120-9209

We spend our energy to save yours!

Long – term transition model is a time machine

- Model is just a sophisticated tool
- Each tool fits specific task or work
- Those who have never done similar work, have more trust to sophisticated tools. Modelers should not try to profit from this
- What is the task?
  - Forecasting (the departure point is known, while destinations in the distant future are different) - imitate future GHG emissions and socio-economic developments based on:
    - effects of no additional action (BAU) or
    - impacts of additional policies and actions
  - Backcasting (both departure and destination are known, while transition trajectories are not) – identify parameters and policies that allow it to reach the desired system status in the future

Required features of the long–term transition model set (1)

- *Adequate complexity* – all activities directly or indirectly impact GHG emissions. A set of integrated models is required to address this complexity
- *Adequate aggregation* level, coverage of major sectors and inclusion of major technologies and patterns within sectors with deep engineering resolution (bottom-up approach)
  - Physical parameters are needed, so IOT models do not really fit this well
- *Reflecting*
  - not marginal changes in a system with relatively stable parameters,
  - but *deep transitional processes* with substantial structural and technological shifts and with dynamic technological learning (LCOE reductions)
- Allowing to show how 'small' at a small scale becomes 'large' at a larger scale

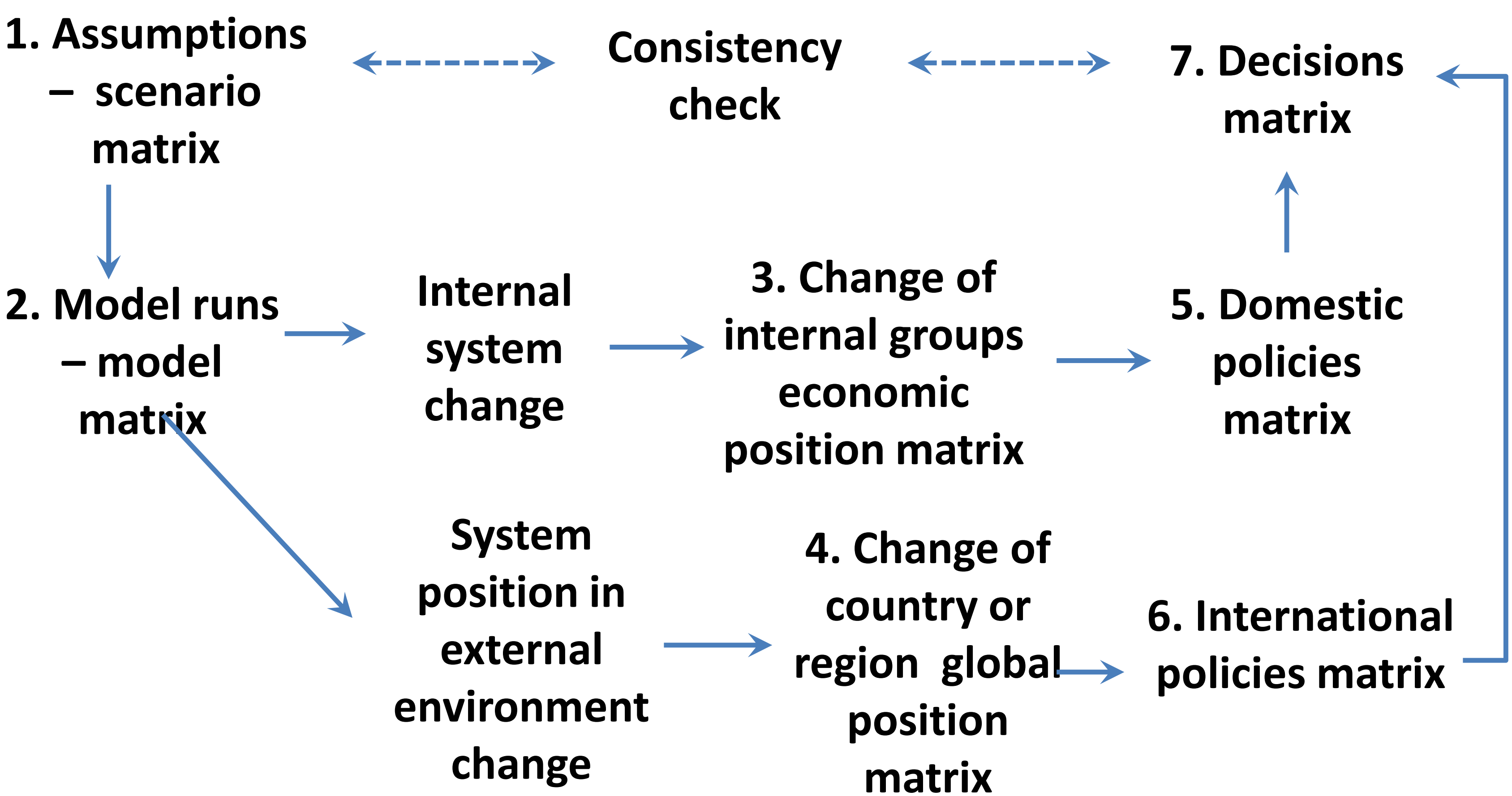
Required features of the long – term transition model set (2)

- ***Reflection and understanding of limits of change*** **and potential to change these limits**
- ***Reflect policies-parameters matrix*****. A model should include parameters to enable policy assumptions impact exogenous variables. CENEF-XXI has just developed an unique EE policy model for the RF Ministry of Economy**
- **In case price instruments effects are simulated, adjustment mechanisms that allow for cost reduction are to be integrated in the model - price elasticities. Some Russian studies fail to do so**
- **If the effects of high carbon prices are simulated, it should be also recognized that:**
  - **price elasticities are not constant – the higher the carbon price, the higher the elasticity**
  - **when energy cost share (ECS) exceeds the upper limit, economic growth rates decline (Ty and Pen are not independent anymore)**
  - **"Minus one" phenomena should be accounted for - in a 25-33 years cycle, prices can escalate only as much as the efficiency of resources use improves with ECS staying relatively stable**

Required features of the long-term transition model set (3)

- *Reflecting feedbacks and cross-sectorial effects* (less coal use – less rail freight turnover; more wind – more metals). Top-down approach. IOT models fit this well.
  - Economic growth, energy efficiency progress and energy prices are all interconnected
- *Reflection of external demand for major products*. Low-carbon 'vice' – shrinking demand and withdrawal of the oil and gas rent. Oil and gas revenues: big on small scale, but smaller on a bigger scale
- *Use of the most recent statistical data* to calibrate the model to better reflect the departure point. Data availability and quality finally set the limits to model sophistication. Only recently did the RF government get a sophisticated energy balance and energy efficiency accounting system (through the efforts of CENEf-XXI)
- *Use a time horizon sufficient for transition processes to manifest* (to 2050 and beyond)

Closing the analytical loop reduces uncertainty range. Seven matrixes method



Test assumptions to outcomes compliance for each scenario
Internal and external aspects are to be separated

IEF 'aggressive' scenario.
What is aggressive in fact: global or Russian low carbon policy?

Assumptions

- ***90% reduction in oil and gas exports by 2050***
- ***introduction of carbon price to reach 50$/t CO_2 by 2050***

Results

- ***Emission reduction – 83% down from 1990***
- ***GDP growth rates reduction from the base scenario - 1.8% down per year***
  - ***due to oil and gas exports revenues reduction - 1.4% down per year and***
  - ***due to carbon tax introduction - only 0.07% down per year***

IEF conclusion

- **"The unacceptability of an aggressive scenario is that, according to our calculations, it could cost the Russian economy loss of 1.8% of the average annual GDP growth rate until 2050"**

Some problems:

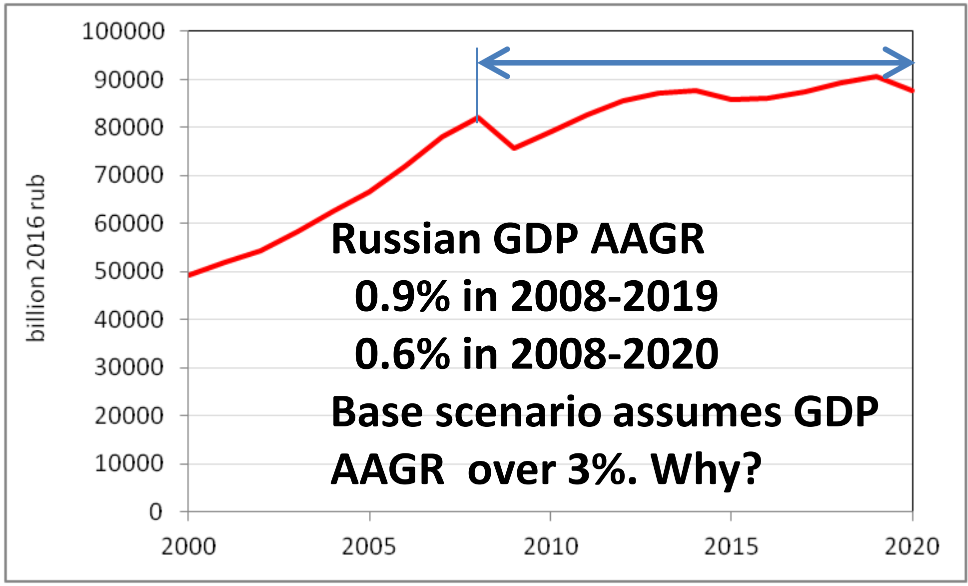
- **Not clear why assumptions on global low carbon transitions are combined with assumptions on RF low carbon policies**
- **IOT do not allow for demand and supply adjustments via price elasticity**
- **Not clear whether the model has a technological learning feature**

Dynamic economic growth in the BAU scenario is not what "is given". It is what "needs to be proved"

- In many instances, such as:
  - Russian long-term low carbon development strategy
  - Institute for Economic Forecasting' paper 'Low carbon development strategy: prospects for the Russian economy'

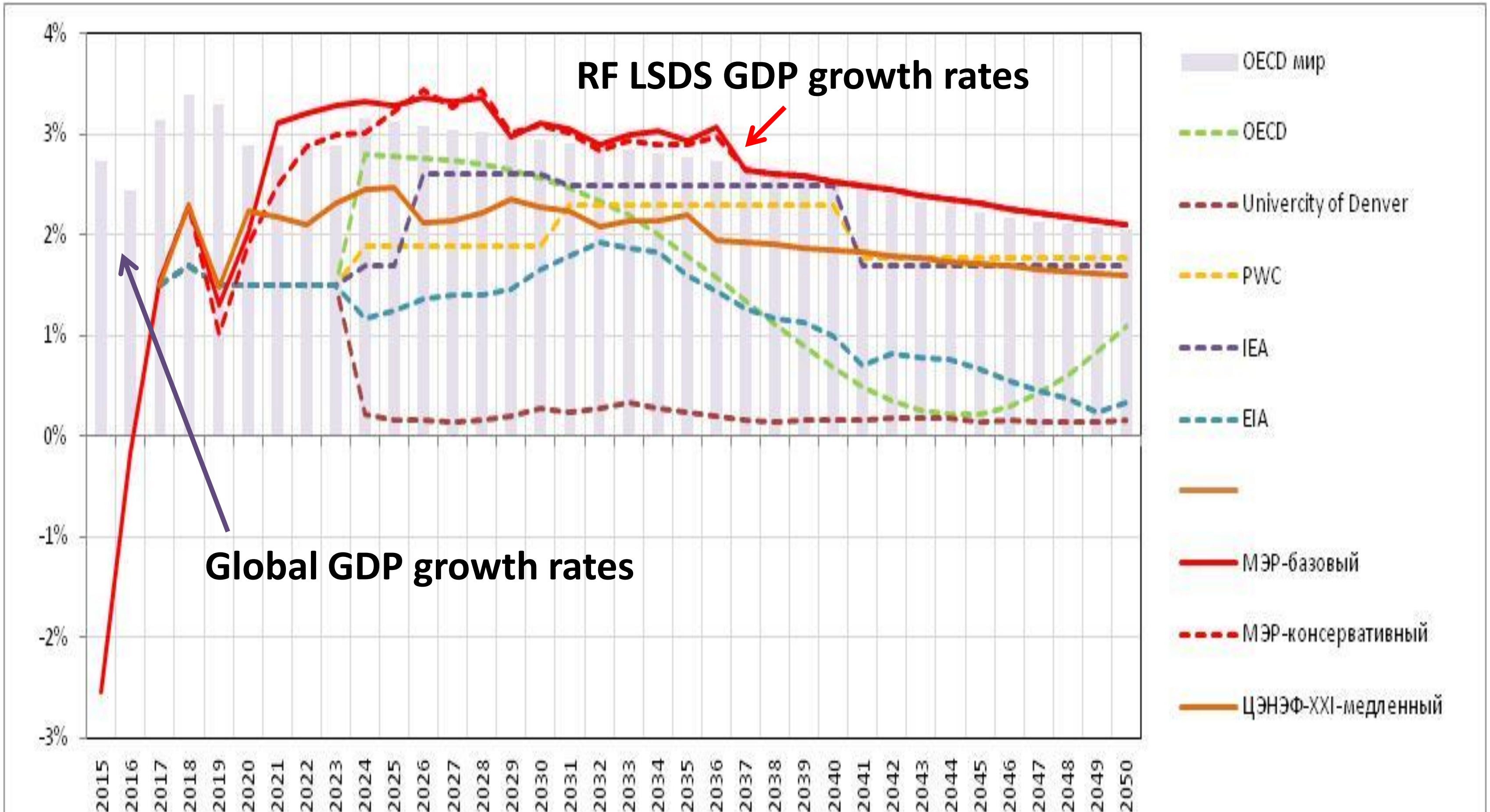
It is assumed as **given** that in the base scenario Russian economy can grow as fast as the global one

- In the IEF paper, some of the measures associated with low carbon transition are considered at the same time as slowing potential growth



- First, it should be **proved** that such dynamic growth is possible with current resource exports-oriented model with limited internal competition and therefore, lack of modernization drivers
- What is declared a possible loss, is not real, but rather assumed, "paper" growth

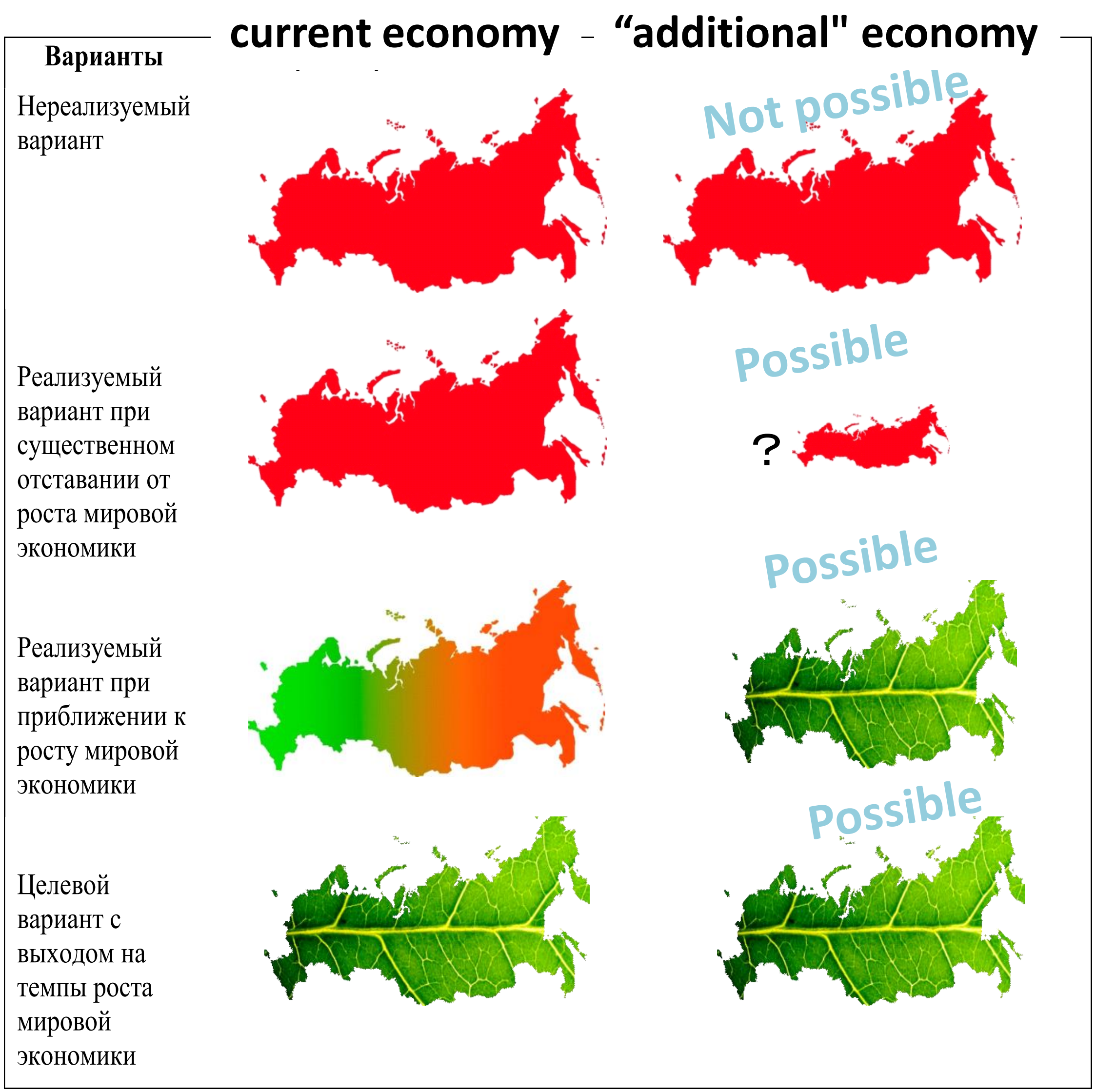
Russian GDP growth rates - long-term projections



Many projections are much less optimistic, than those assumed by the RF Ministry of Economy or IEF RAS

New drivers are needed to attain high growth rates

With a “Red economy” model, there is no chance of doubling Russian GDP by 2050!



- ‘Old’ markets (fossil fuels) can only ensure stagnation of the Russian economy by 2050
- If Russia’s GDP is doubled, but energy intensity is about stable (as it is in recent years), no fuels will be left for export by 2050
- Reliance on the “Red economy” model would make Russia’s share in global GDP shrink to below 1%

Источники: ЦЭНЭФ-XXI

The road to the future is paved with the ruins of projections!
But some projections made in the late 80-es are not that bad

Historical view: 1953-1990' projections versus reality (red lines)

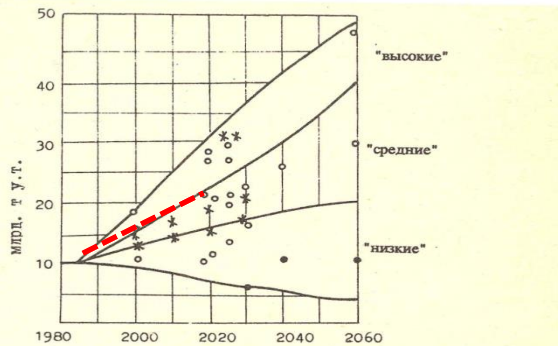


Рис. 1.3. Долгосрочные прогнозы мирового потребления первичной энергии, опубликованные в 80-х годах

Primary energy

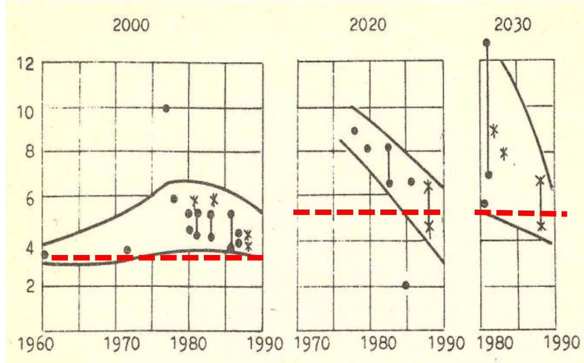


Рис. 1.4. Эволюция оценок мирового потребления твердого топлива

Solid fuels

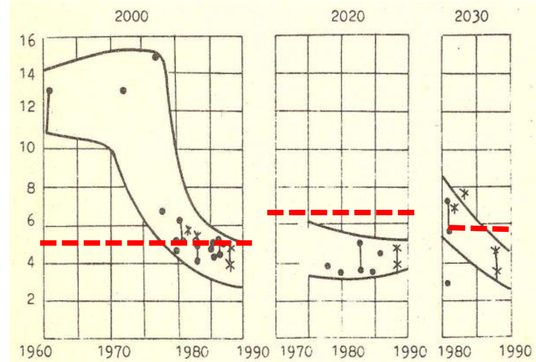


Рис. 1.5. Эволюция оценок мирового потребления жидкого топлива

Liquid fuels

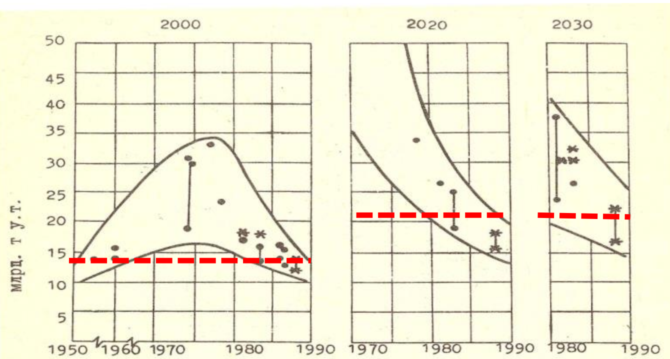


Рис. 1.2. Эволюция прогнозных оценок мирового потребления первичных энергоресурсов

Evolution of TPES projections

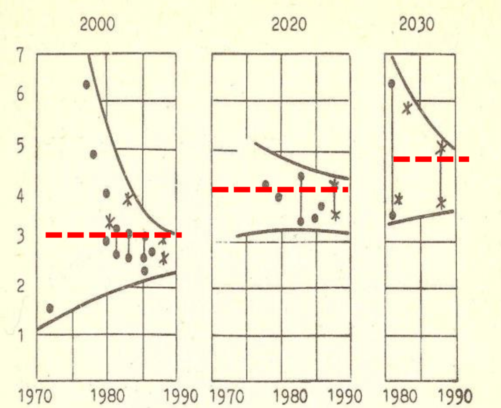


Рис. 1.6. Эволюция оценок мирового потребления природного газа

Natural gas

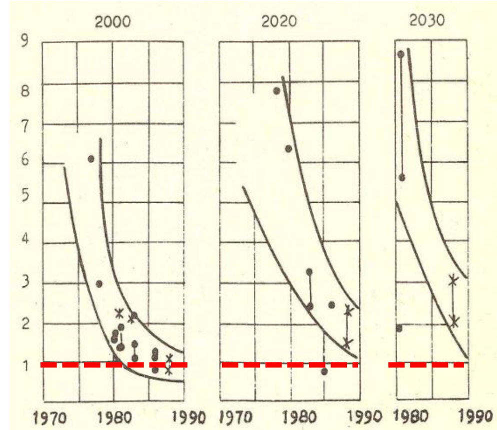


Рис. 1.7. Эволюция оценок мирового производства ядерной энергии

Nuclear

“Global energy: Lessons of the future”. Bashmakov Ed. 29 years after the publication (1992)

Primary energy

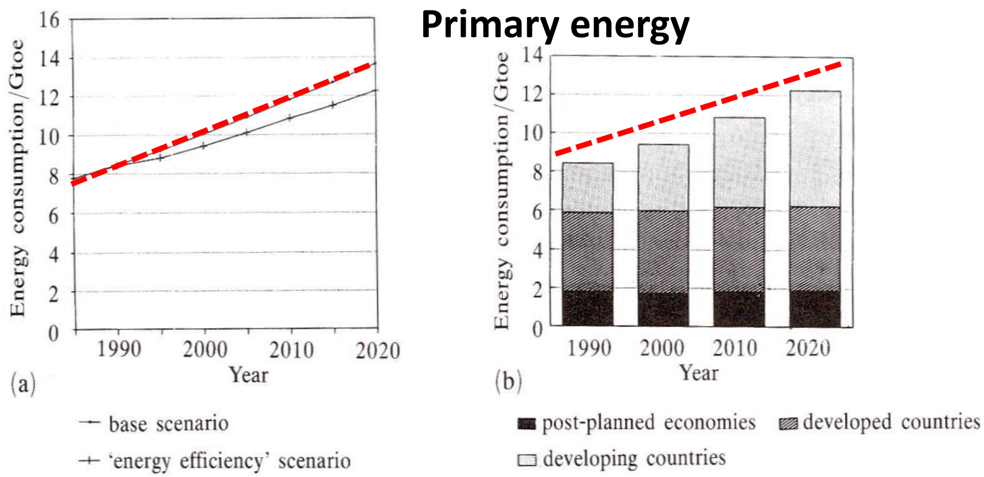
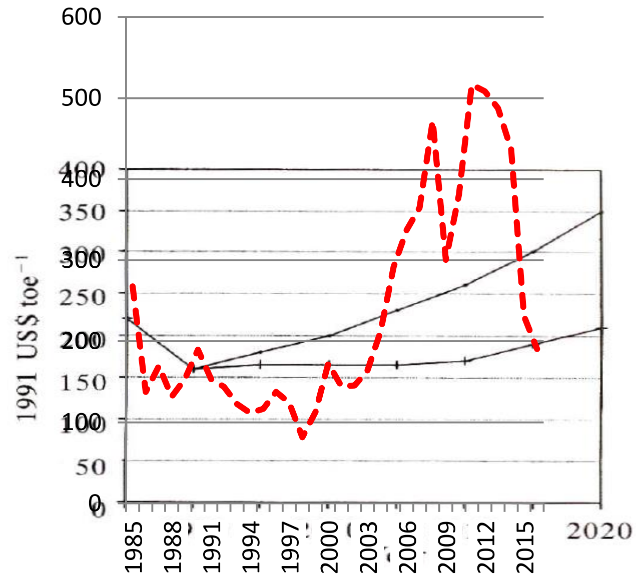


Figure 5. Predicted global primary energy consumption for; (a) the base scenario and the 'energy efficiency' scenario; (b) three regions ('energy efficiency' scenario).



Crude oil price $US1991/toe

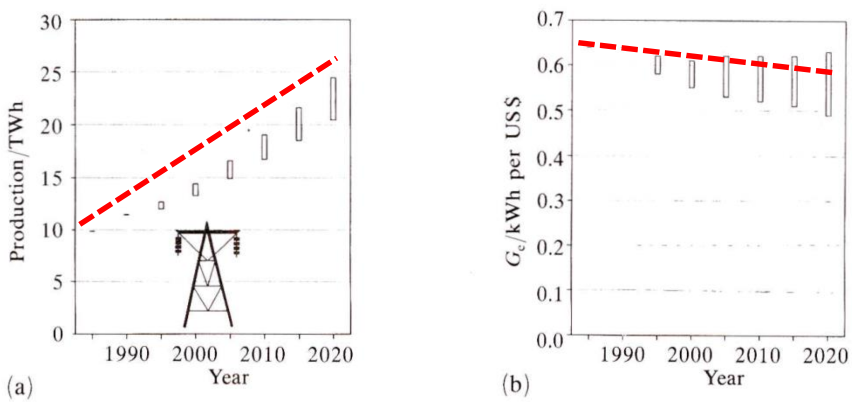


Figure 7. (a) Predicted global electricity production. (b) Predicted electricity-production–GDP ratio, G_e.

Electricity generation and electricity intensity

1988-1992. Key finding: oil prices will keep below the 1985 level until 2000 and will inevitably start growing thereafter

2006 -2007. Beyond 100$/barrel is not a sustainable range for oil prices. They will eventually drop to 30-40 $US and then will start growing again

“Global energy: Lessons of the future”. Bashmakov Ed. 29 years after the publication (1992)

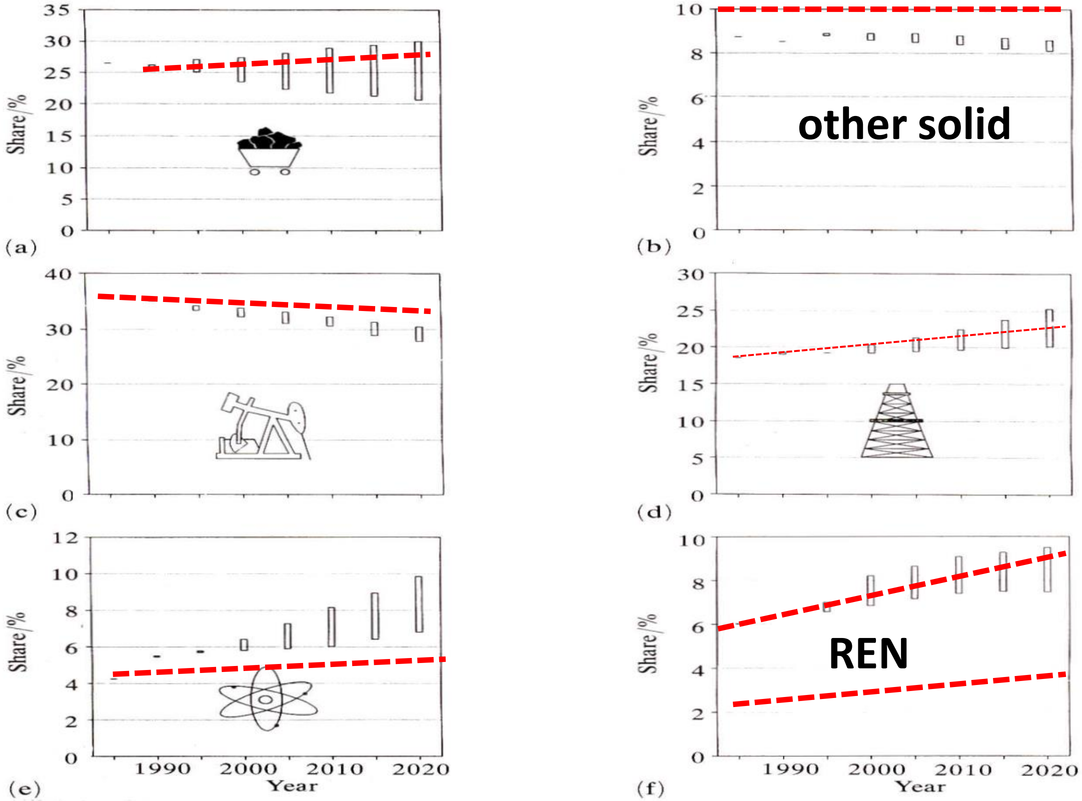


Figure 6. Predicted shares of various energy resources in future global primary energy consumption: (a) coal; (b) other solid fuels; (c) oil; (d) gas; (e) nuclear energy; (f) renewable energy.

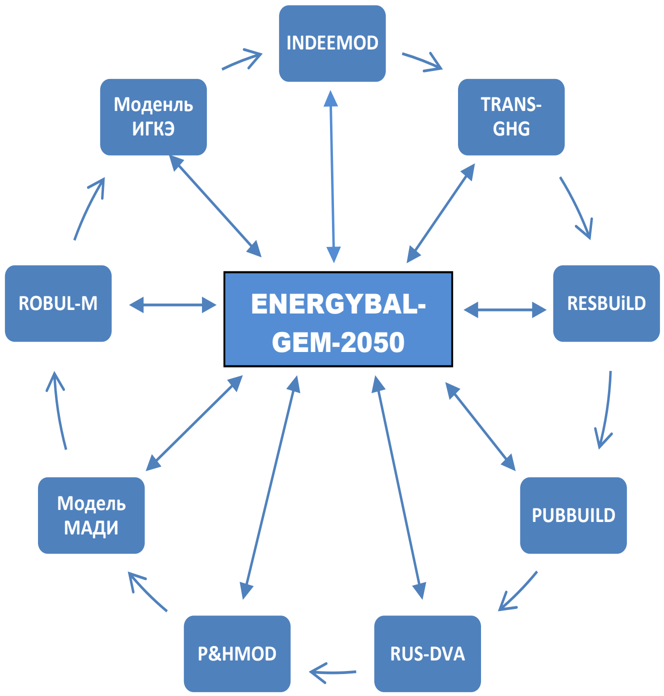
Can we learn the lessons of the future?

Yes, we can!

Another methodology to translate power to TPES
Multiply by 3

Projected shares of energy resources fit the reality quite well

Cloud (set) of 10 models used for Russia's long-term LCDS



Duplicate models were used to improve the reliability of results for several sectors (power and heat generation, transportation, AFOLU)

Global prospects are assessed using CENEf-XXI's global model MoG^{3}EM-21-50 (21 global regions)

The model set is built around the core multisectorial model –

ENERGYBAL-GEM-2050

The 'cloud' of models includes macroeconomic and sectorial models developed by CENEf-XXI:

- Macroeconomic model - RUS-DVA
- Model for power and heat sector - P&HMOD
- Model for industry - INDEE-MOD
- Model for transport - TRANS-GHG
- Models for residential sector REsBUILD and «Assistant of EE MFB rehabilitation»
- Model for public buildings - PUBBUILD

Models developed by other institutions:

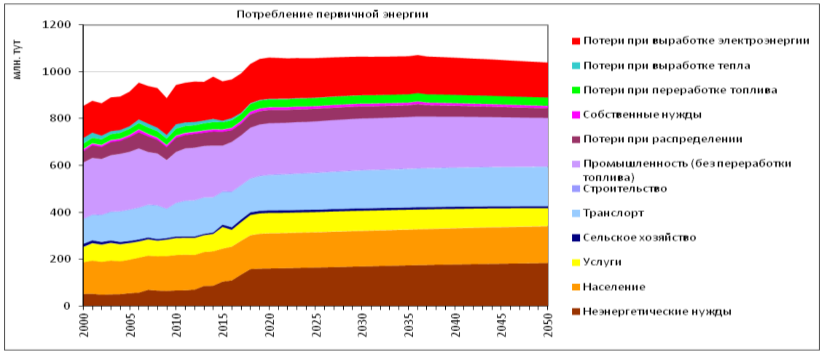
- Model for AFOLU sector – ROBUL-M (Center for Forest Ecology and Productivity of the Russian Academy of Sciences (CEPF RAS))
- AFOLU model (Institute of global climate and ecology RAS)
- Automobile transport model (Moscow Automobile and Road Construction State Technical University (MADI))

ENERGYBAL-GEM-2050 – core model

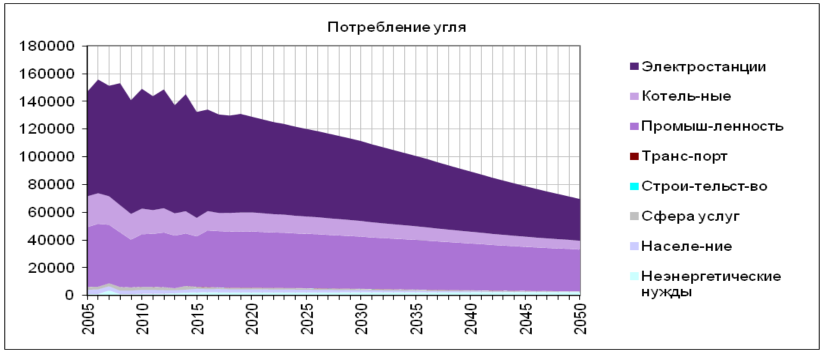
- **ENERGYBAL-GEM-2050** is a simulation model. It is based on the RF energy balance, but also includes emissions from industrial processes, waste, and agriculture
- Parameters are calibrated based on data for 2000-2019
- Includes 10 sectors and 40 activities within these sectors, 9 primary and secondary energy carriers plus some activities for waste and agriculture
- Assesses energy use by carriers, sectors and activities, GHG emissions, other atmospheric emissions, water pollution, and investments
- Allows it to identify the effects of multiple policies, including technological, structural, behavioral, carbon pricing and other pricing policies
- Combines top-down and bottom-up approaches, as many aggregated technology parameters are mostly imported from very detailed sectorial engineering models, while macro parameters to sectorial models are imported from ENERGYBAL-GEM-2050 and RUS-DVA
- Produces multiple tables and graphs allowing for effective visual control and presentation of results

Some illustrations of ENERGYBAL-GEM-2050 outputs

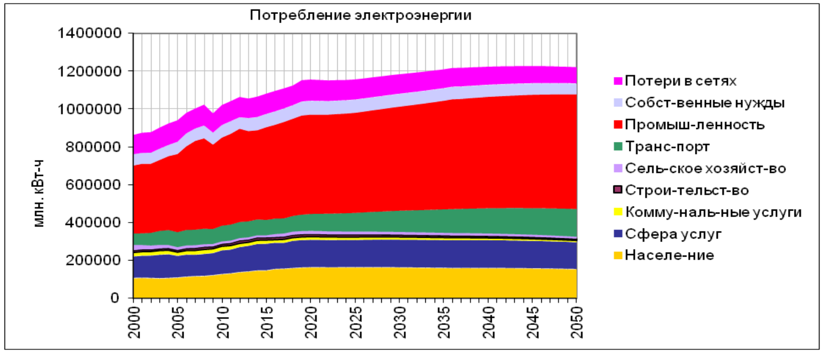
Primary energy consumption



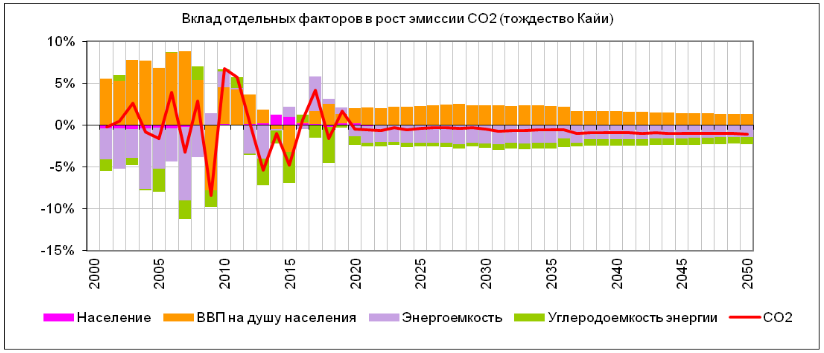
Coal consumption



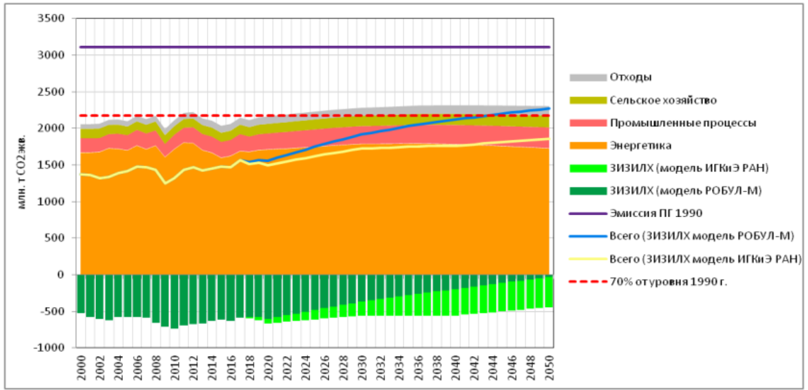
Electricity consumption



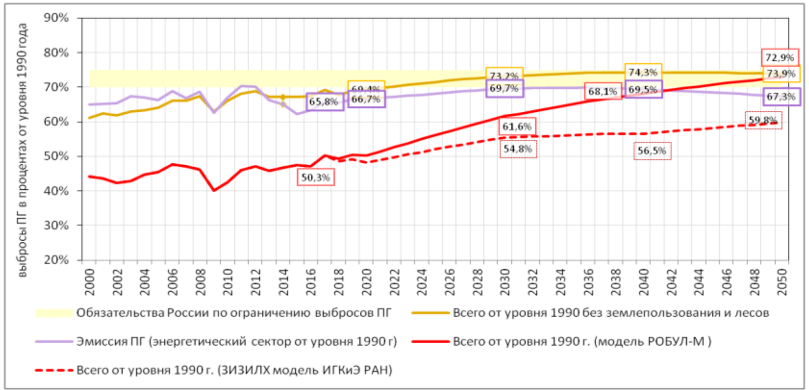
Kaya identity



GHG emissions by sector



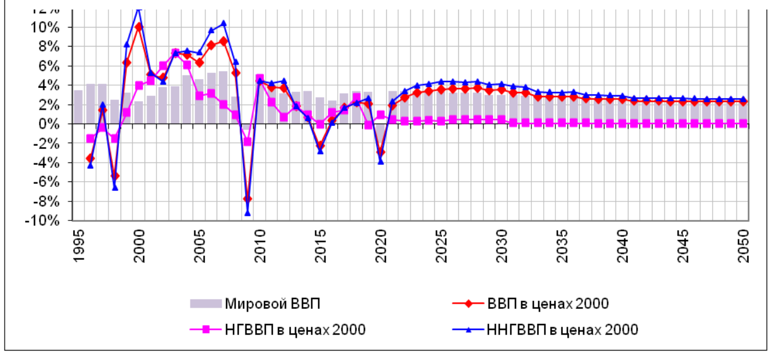
GHG emission compared to 1990 level

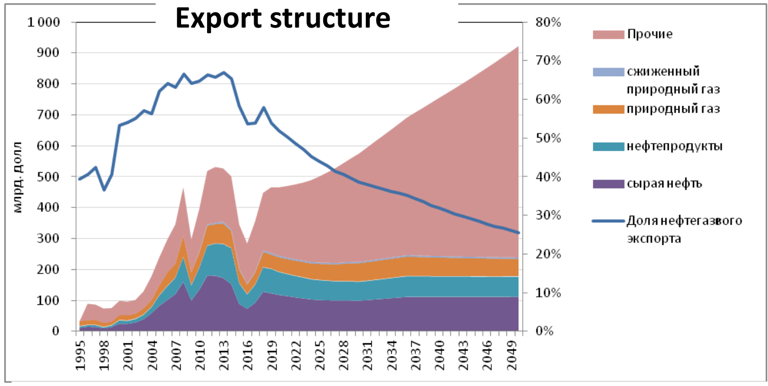


Macroeconomic model RUS-DVA

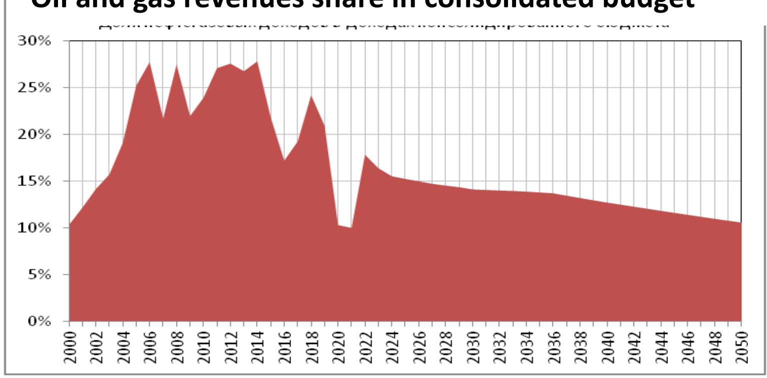
- RF Ministry of Economy only has projections to 2036
- Therefore, this model was needed to obtain projections to 2050
- **RUS-DVA** is a simulation model. Parameters are calibrated based on data for 1995-2019
- 5 blocks
  - GDP (supply and demand)
  - Prices and exchange rate
  - Investments
  - Balance of payments
  - Consolidated budget
- Oil and gas exports and export oil prices are exogenous
- Domestic fuel use comes from ENERGYBAL-GEM-2050

Growth rates: Global GDP; Russian GDP; Oil and gas GDP; Non OG GDP





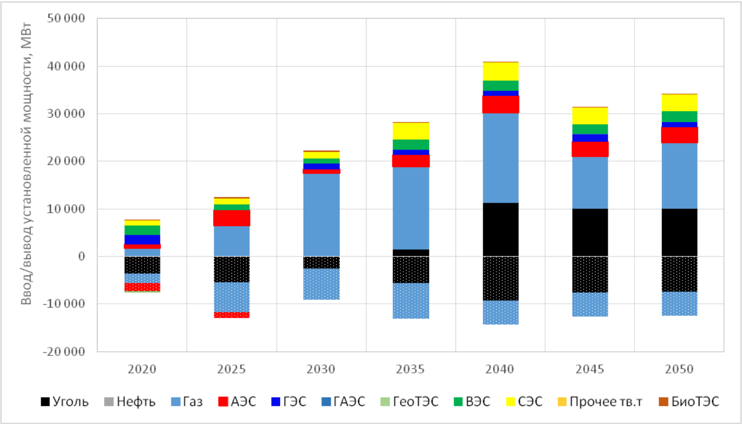
Oil and gas revenues share in consolidated budget



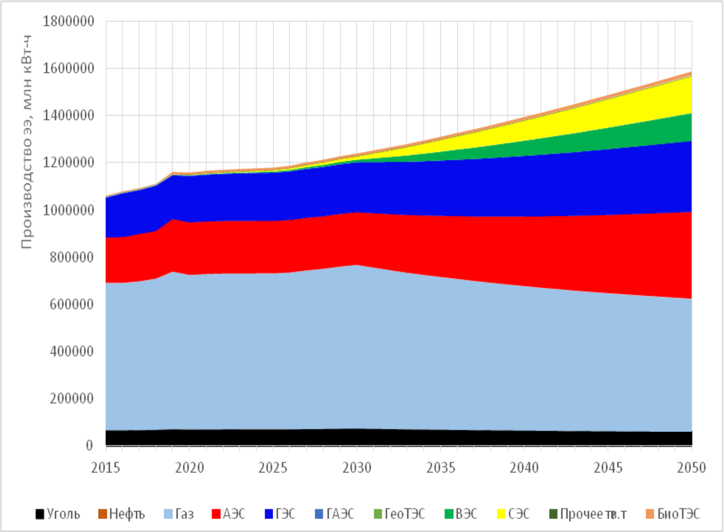
Model for Power and Heat sector - P&HMOD

- Engineering model
- Based on power demand evolution
- 9 power generation technologies
  - Coal
  - Liquid fuels
  - Natural gas
  - Nuclear
  - Large hydro
  - Renewable (wind, solar, geothermal, biomass)
- Accounts for retirement, modernization, and commissioning of new capacity, power factors, specific fuel use and fuels needs
- Estimates investment demand

Capacity additions



Power generation

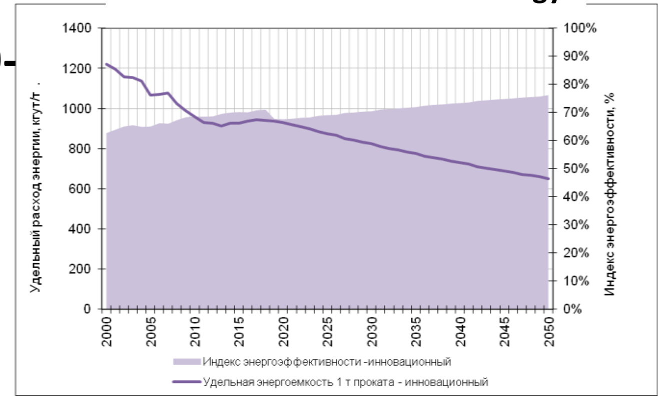


- Interfuel competition and carbon pricing effects are also taken care of in the ENERGYBAL-GEM-2050

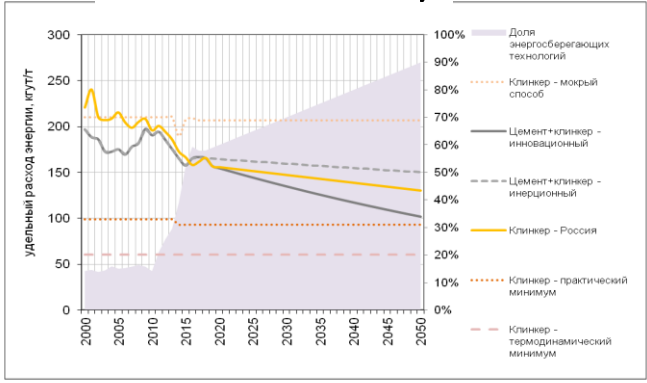
Model for industry - INDEE-MoD

- Detailed engineering simulation model. Parameters are calibrated based on data for 2000-2019
- Estimates production of energy intense industrial products and related specific energy use, as well as cross-cutting technologies depending on:
    - Interconnected evolution of technological structure for individual products
    - Selection of capacity modernization rate
    - Selection of BATs EE parameters for new capacity addtions
    - Circularity of economy - rate of secondary products use (scrap, waste paper, etc.)
- Projections of new capacity commissioning are based on products demand growth and old capacity retirement rates
- Macroeconomic inputs are from ENERGYBAL-GEM-2050
- INDEE-MoD outputs (production and SECs) are inputs to ENERGYBAL-GEM-2050

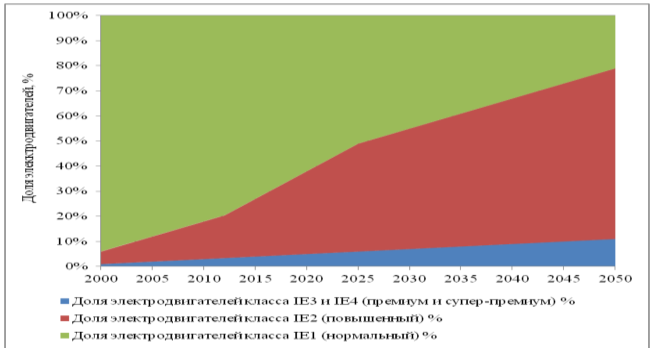
SEC and EEI in ferrous metallurgy



SECs in cement industry



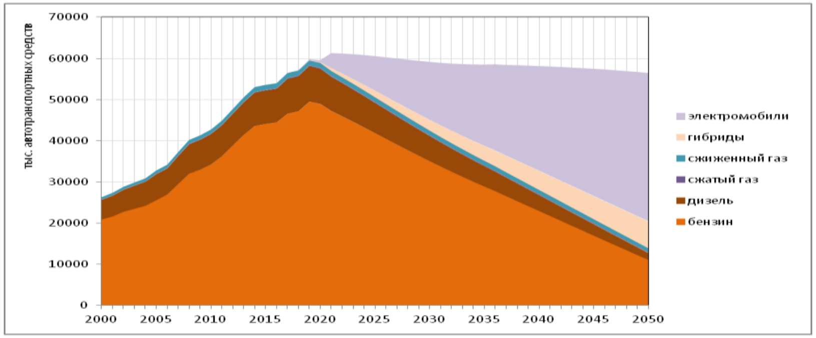
Electric drivers by efficiency rating



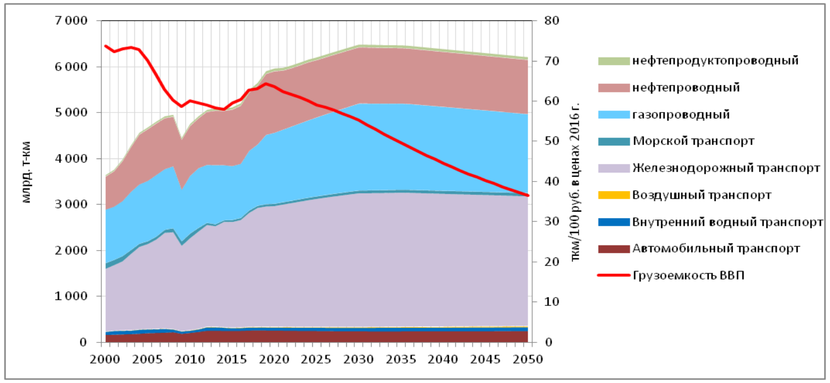
Model for transport - TRANS-GHG

- Detailed engineering simulation model. Parameters are calibrated based on data for 2000-2019
- Freight transport: 8 modes, including rail, oil and gas pipelines, water, trucks, air
- Passenger transport - 13 modes, including cars, buses, rail, light rail, water, air, bicycles
- Parameters modeled – freight and passenger turnover and structure, transportation infrastructure evolution, vehicle park dynamics and composition, fuel use, GHG emissions, other pollutants
- Macroeconomic inputs are from ENERGYBAL-GEM-2050 (for example freight turnover goes from INCEE-MOD to ENERGYBAL-GEM-2050 and TRANS-GHG)
- TRANS-GHG outputs are inputs to ENERGYBAL-GEM-2050

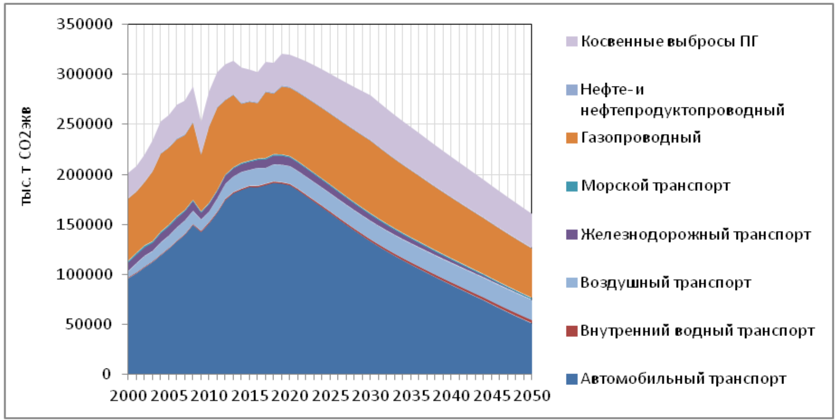
Vehicles park



Freight turnover

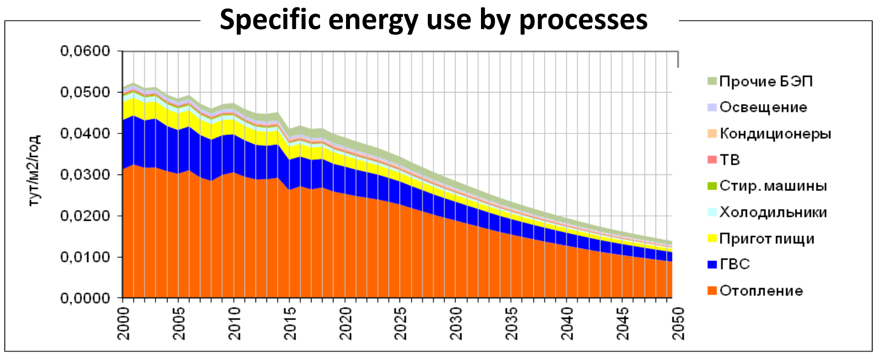


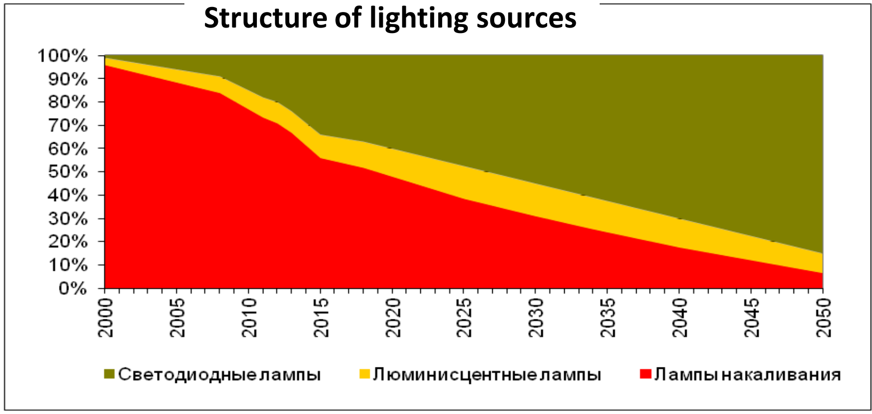
GHG emissions

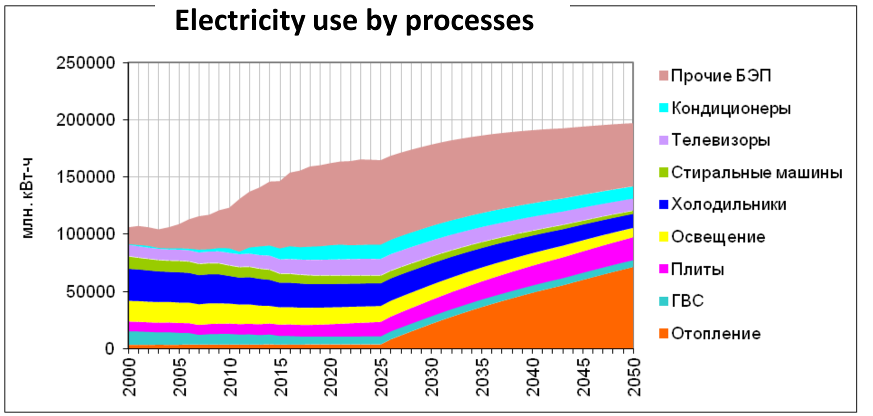


Model for residential sector REsBUILD and similar to it Model for Public buildings - PUBBUILD

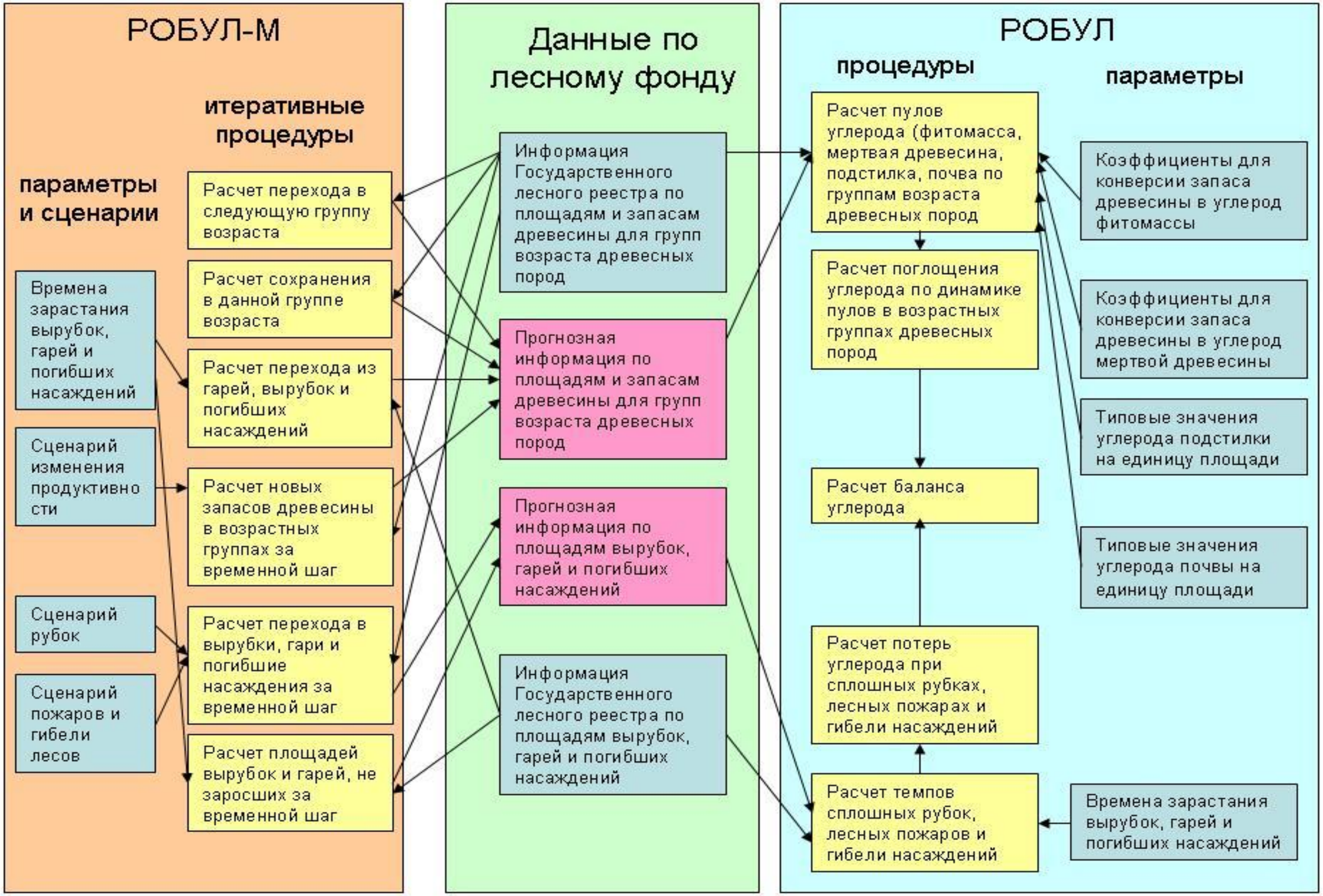
- Detailed engineering simulation model. Parameters are calibrated based on data for 2000-2019
- Two types of buildings – multifamily and individual
- 9 types of energy use – heating and ventilation, hot water, air conditioning, cooking, lighting, refrigeration, dishwashing, TVs and other appliances
- 7 energy carriers
- On-site (micro) power and heat generation
- Evolution of building stock and appliances is presented by annual age-cohorts
- Macroeconomic inputs are from ENERGYBAL-GEM-2050
- REsBUILD outputs are inputs to ENERGYBAL-GEM-2050





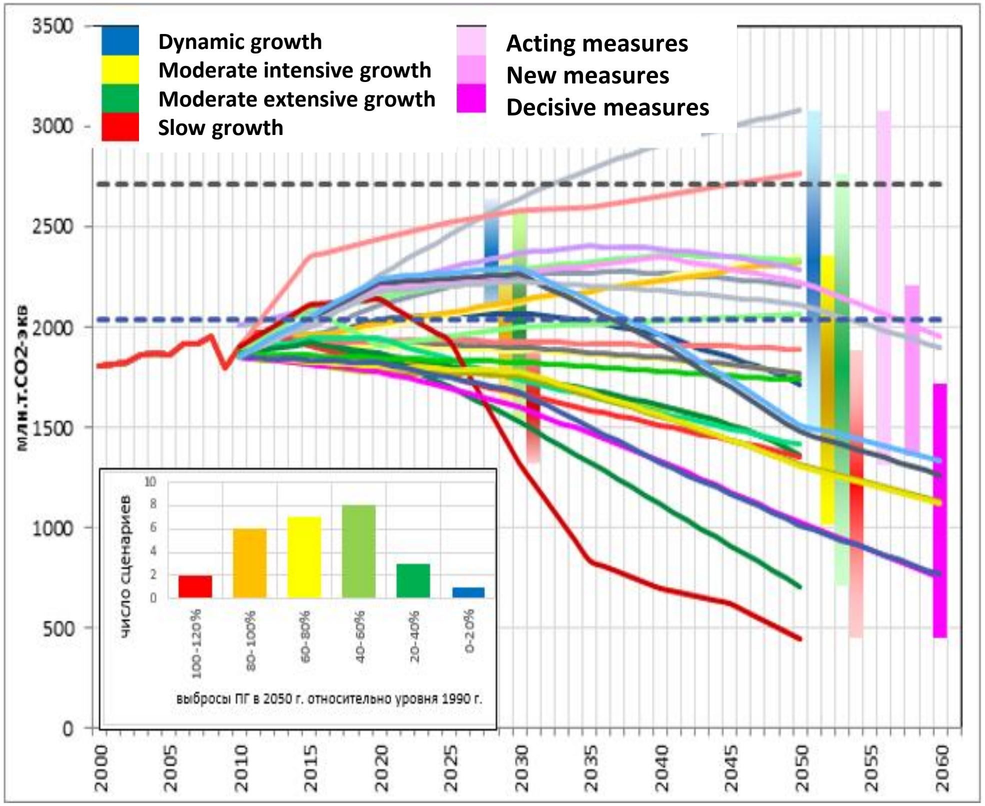


Model for AFOLU sector – ROBUL-M (Center for Forest Ecology and Productivity of the Russian Academy of Sciences (CEPF RAS))



There is a certain order in the very wide 'spaghetti' of energy projections. The chaos of 'spaghetti' can be well structured

RF energy related GHG emissions projections by 30 scenarios from 5 models (made in 2014)



Затраты и выгоды низкоуглеродной экономики и трансформации общества в России. Перспективы до и после 2050 г. CENEF. 2014

Projections can be organized in a data base according to assumptions and modeling techniques:

Assumptions:

- Economic and population growth rates
- Energy prices
- Energy policies
- Penetration of new technologies

Modeling and metrics:

- Energy balance accounting methods
- Top-down models
- General equilibrium or simulation models
- Bottom-up models (engineering modeling approaches)
- Combination of top-down and bottom-up models

Ensemble of models used to develop Russian long-term LCDS allows it to simulate vast sets of policies in all sectors with due consideration of their interactions

Thank you!

Igor Bashmakov
Center for energy efficiency -XXI
www.cenef.ru 8 (499) 120-9209
We spend our energy to save your's!