Technological priorities for the decarbonisation of the Russian power sector.

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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:

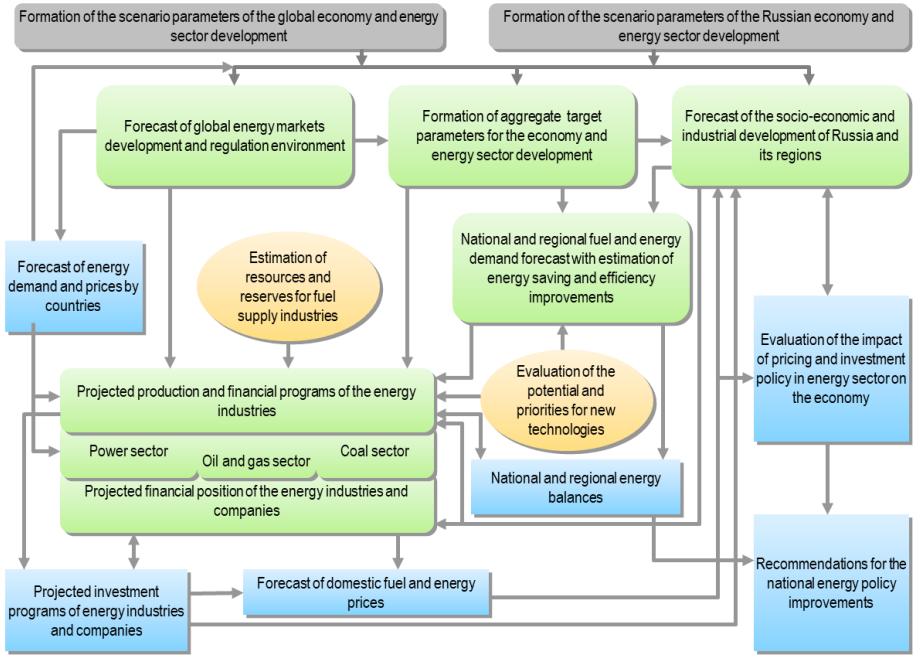
✓ international level – scientific and analytical co-operation with leading institutions and research teams in the area of global energy and technological forecasting, transformation of energy systems and energy markets, participation in the EU-Russia Energy Dialogue, BRICS Economic Partnership, Global Energy Interconnection Development and Cooperation Organization (GEIDCO), etc.

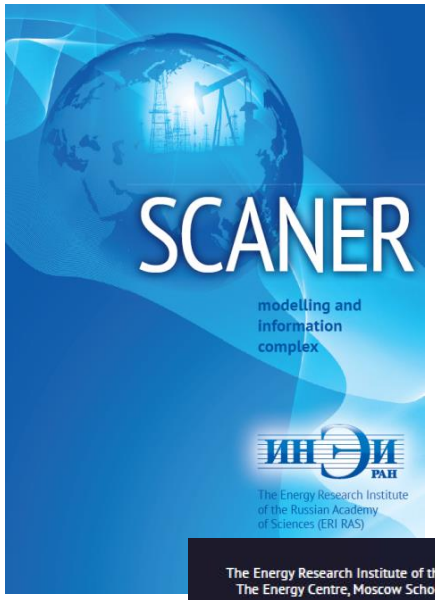
✓state level - methodological, modeling and analytical support for the energy policy priorities and implementation mechanisms (incl. macroeconomic, technological, pricing, environmental and other aspects), quantitative elaboration of the economy and energy sector scenarios, incl. decarbonisation options

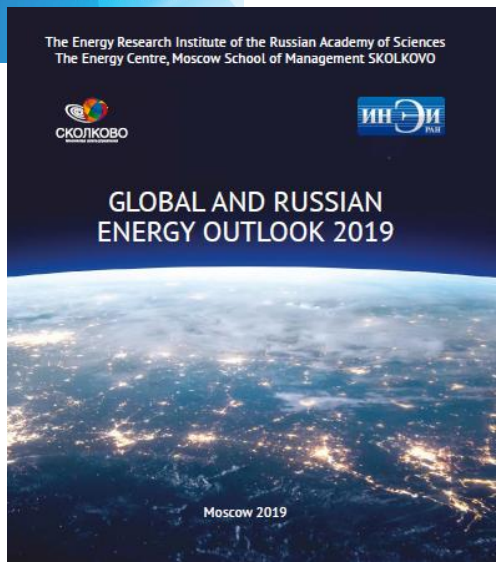
- *National Energy Strategy (multiple updates)*
- *Long-term Development Plan for the Gas Industry*
- *Long-term Development Plan for the Coal Industry*
- *Long-term Development Plan for the Electric Power Sector*
- *Energy Technologies Forecast to 2035*
- *Vision of the Smart Power System*
- *Vision, Scenarios and Roadmap of the Renewable Energy Sources Development*
- *Effects from digital transformation of Russian Energy Sector*

✓ 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

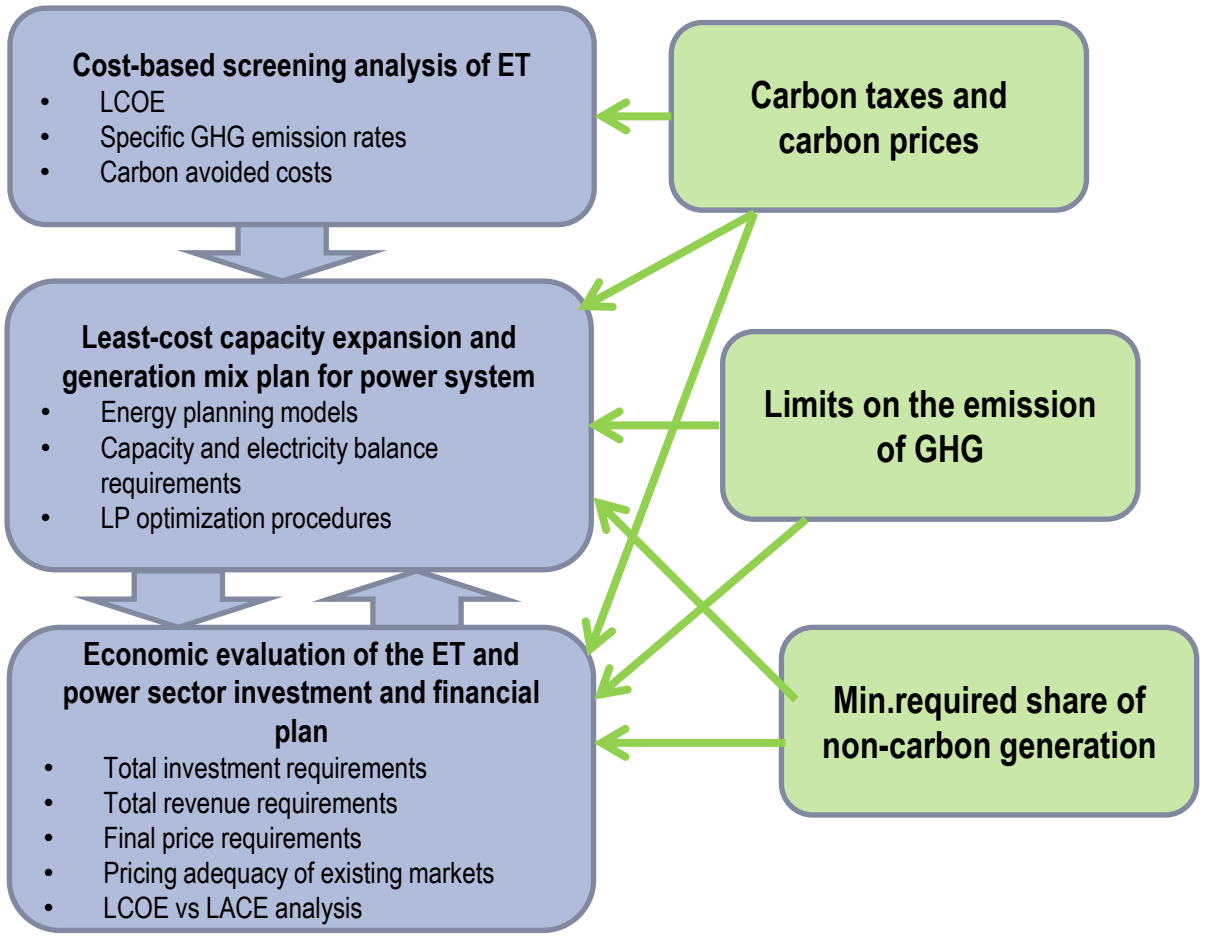
✓Huge flexibility and fast adaptation of the models and their calculation modes under the separate forecasting requirements

Energy planning procedure for the assessment of low carbon scenarios in the Russian power sector

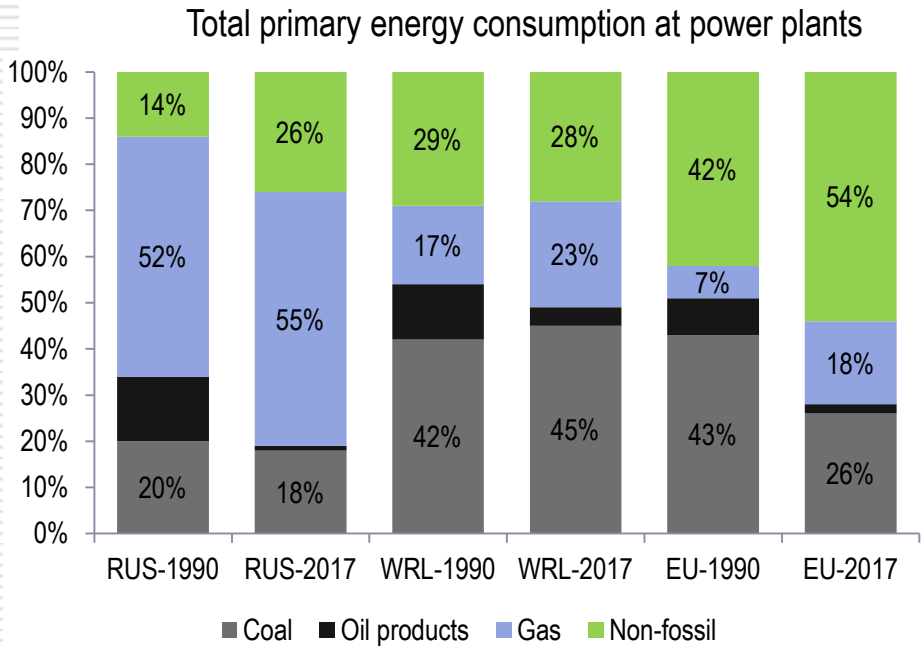
The range of low- and non-carbon energy technologies (ET)

Thermal plants	CCGT CCGT-CHP GT-CHP
	Thermal plants with CCS
	Biomass/biogas plants
Nuclear plants	VVER-TOI (PWR) Fast reactors Different SMRs
RES plants	Wind onshore (utility/non-utility scale) Solar PV (utility/non-utility scale)
Hydro plants	Reservoir and run-of-river plants
Storage	Pumped storage plants Battery storage facilities

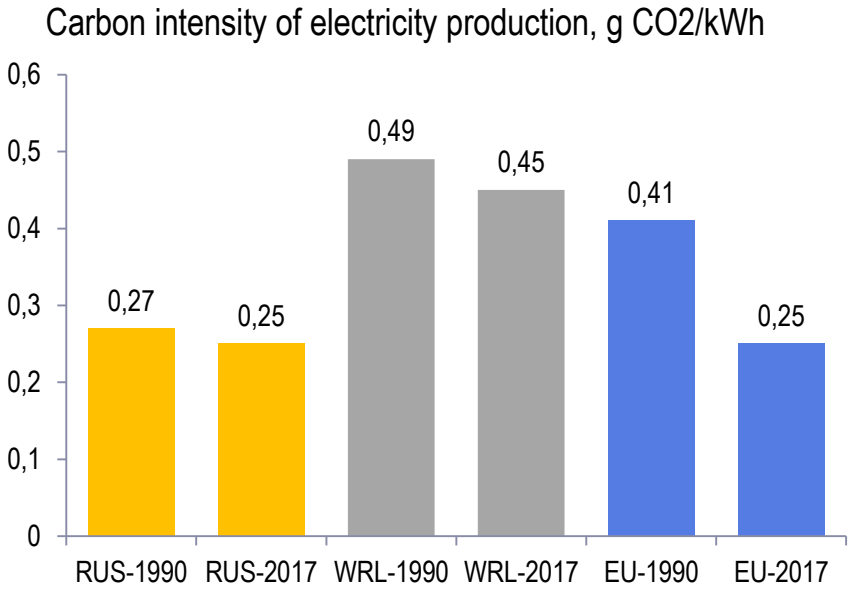
Multistage energy planning procedure with detailed carbon regulation options



Russian power sector has a relatively low carbon intensity as well as a huge potential for the further decarbonisation



Source: IEA data



Source: IEA data, ERI RAS analysis

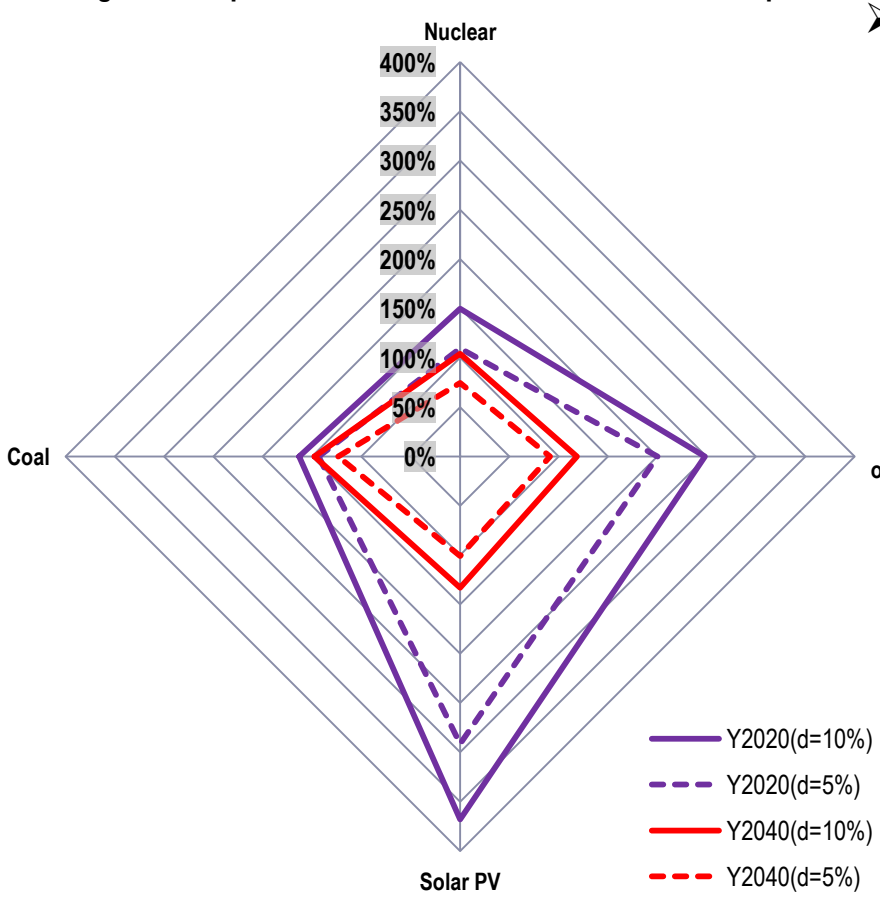
- Gas remains a dominating primary energy resource for electricity, but the average fuel efficiency of thermal plants is near 40%
- CHP represents >50% of total thermal plants capacity, but produce just near 40% of the centralized heat
- Growing share of non-fossil generation, mainly nuclear or hydro. RES development remains at the beginning stage

Strategic options to decrease GHG emissions in the electric power sector

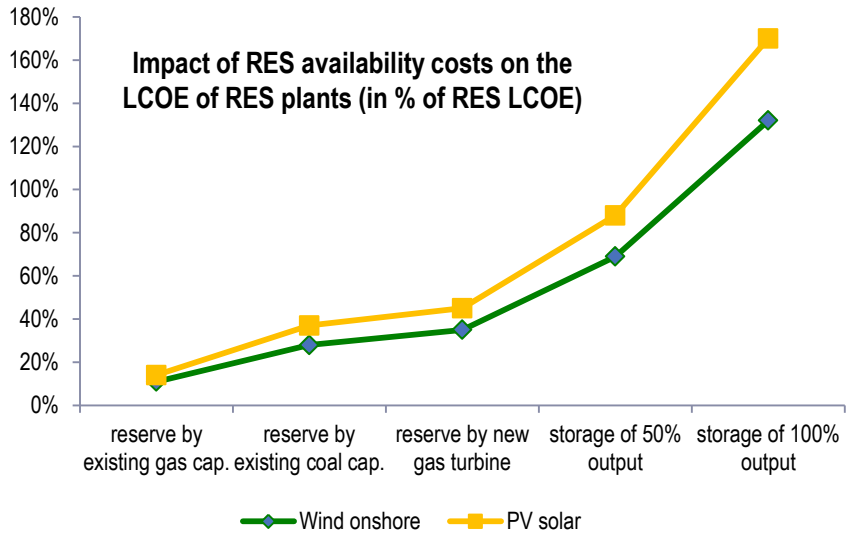
CCGT and co-generation technologies	• Huge potential for the substitution of existing fleet of steam-turbine units • Additional opportunities for CHPs to substitute boilers • LOW but not NON-carbon option - GHG emissions may be decreased but not eliminated • CCS are related with technological and cost improvements in CO_2 transport and storage/recycling
Nuclear power	• Well-developed domestic industry providing the full cycle of equipment production and construction of nuclear power plants as well as their fuel supply • Low CAPEX of 1200 MW units with VVER-type reactors (near 2000 USD/kW for NOAK units • Expected 15-20% decrease of CAPEX due to the technological learning and transition to the fast reactors in 2040+
Hydro power	• Most of hydro resources are located in the Eastern part of Russia and the CAPEX of new hydro plants is highly differentiated • Extremely long (x1000 km) HV transmission lines are required to transport electricity to the European part where 80% of electricity demand is located.
Renewable sources (wind and solar plants)	• Actual CAPEX near 1000 $/kW and further optimistic cost decrease trends • Domestic production of equipment is still limited • Low capacity factor and additional “system” costs to enhance the availability of variable RES capacity (additional capacity reserves or storage) • Most of resources with higher CF are located I the North and East of Russia far away from the load centers

Cost-based screening analysis of energy technologies

LCOE of greenfield plants in the Central Russia, in % of CCGT plant



- CCGT is the least-cost low-carbon technology today
  - Nuclear is the least-cost non-carbon technology
    - RES are the least cost-effective non-carbon technologies

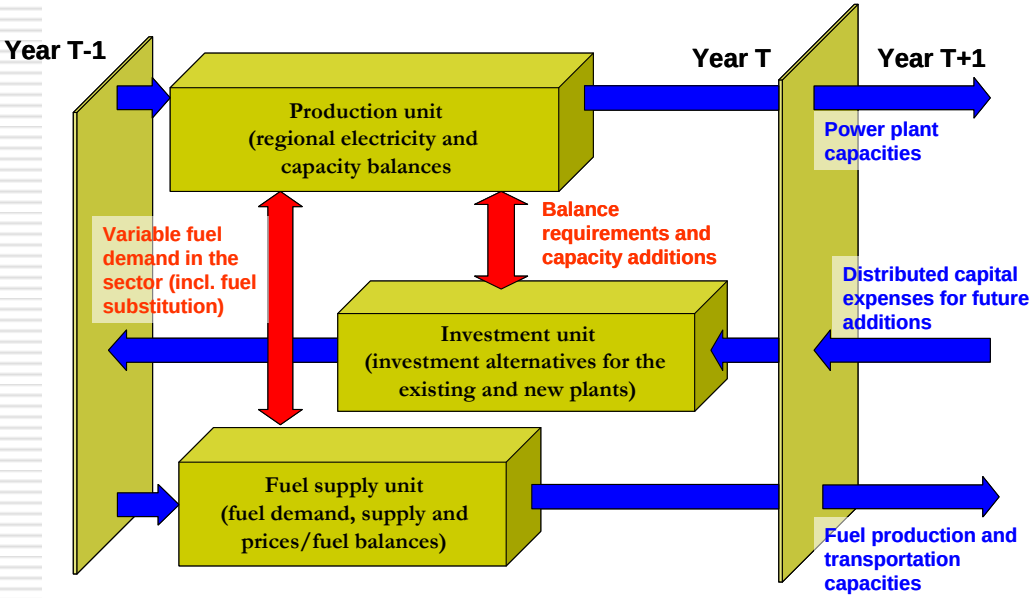


Source: ERI RAS analysis

Tools for 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 load curve
  - 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



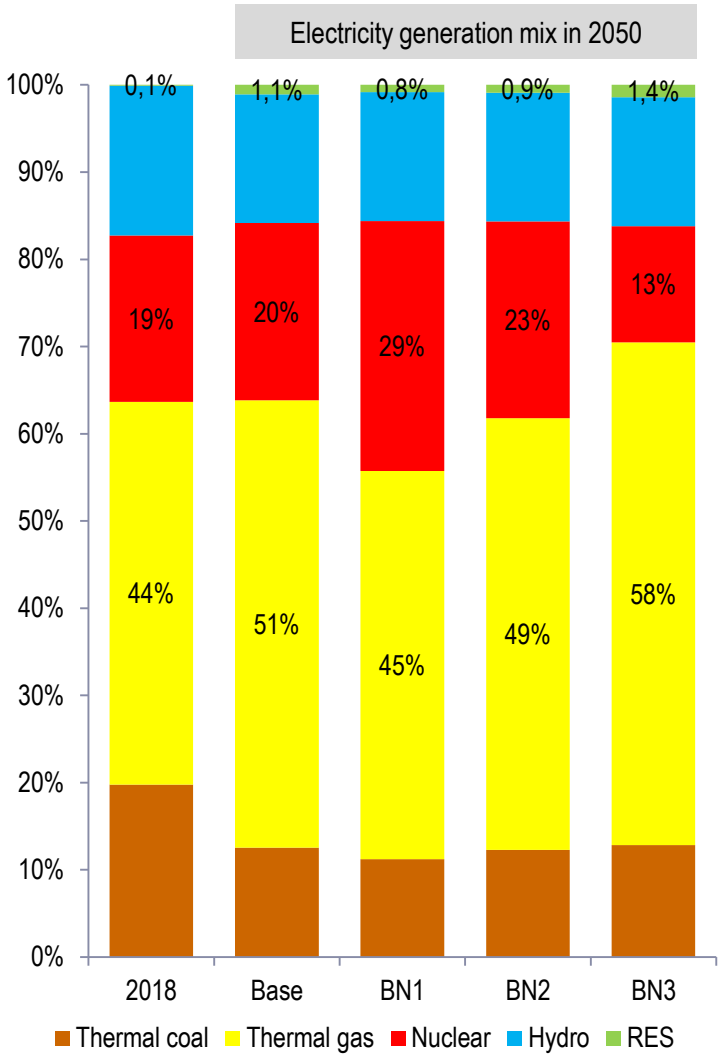
EPOS optimization model is the least-cost multi-year, multi-regional, multi-case, multi-product modeling tool for the power sector strategic planning

- 2040+ planning horizon
- capacity and wholesale electricity balances by 40+ nodes
- heat and retail electricity balances by 80+ regions
- rated capacity balances for min/max winter day load by 7 integrated power systems
- special simulation dispatching models are used for the detailed seasonal and daily adequacy of capacity mix
- limits on GHG emissions and availability of investments can be activated
- Optimization can be expanded to cover gas and coal sector (balance requirements can be activated)

Generation mix in 2050 w/o carbon regulation measures

	Base	BN1	BN2	BN3
Limits on NPP capacity	Y	N	N	N
CAPEX of NPP	min	min	avg	max
Limits on CO_2 emissions in 2050	N	N	N	N
Carbon prices in 2050, RUR/ t CO_2	N	N	N	N
CO_2 emissions in 2050 (% to 2018 level)	122%	112%	120%	130%
Changes by cases, % to the Base Case				
Fuel consumption in 2050	-	-9,0	-2,2	+7,0
Total capital costs	-	+6,6	+5,1	-0,4
Total discounted electricity supply costs	-	-0,15	+0,36	+1,04

- Without any carbon regulation measures the growth of electricity production at 54% to 2050 will be inevitably supplemented by the growth of CO_2 emissions at 12-30%
- Limits on the nuclear capacity or high NPP CAPEX will stimulate further expansion of gas-fired technologies
- RES will play the marginal role in optimal least-cost plan

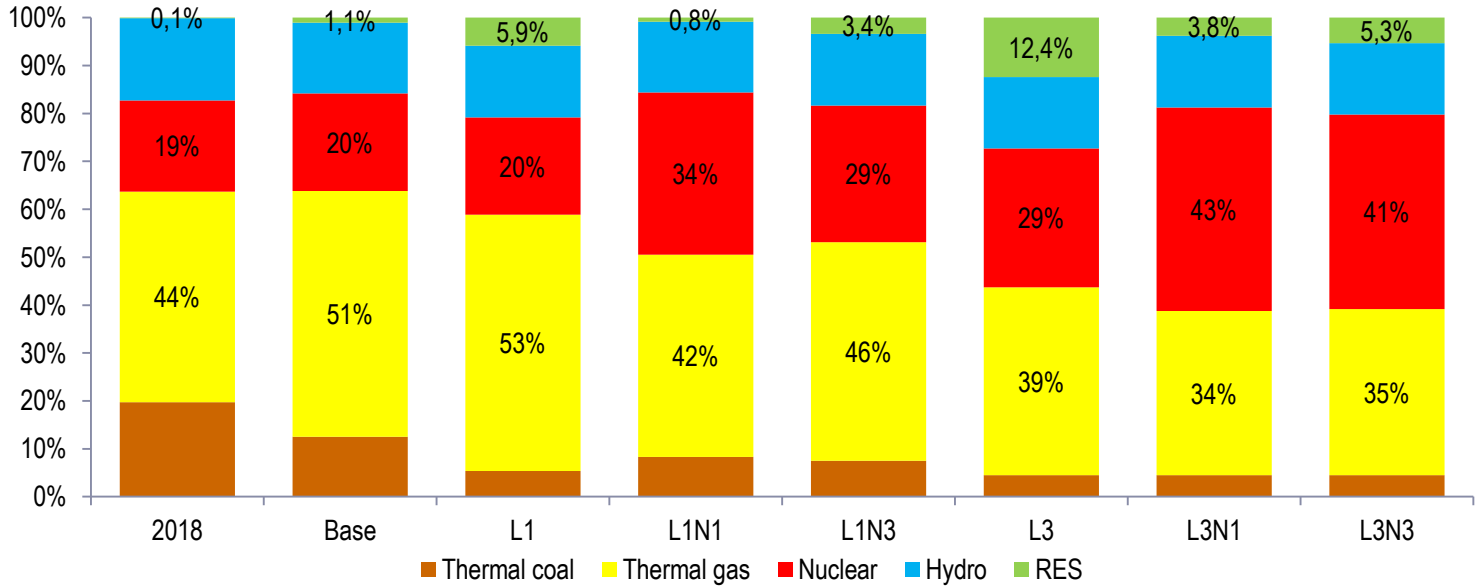


Source: ERI RAS analysis

Generation mix in 2050 with direct limits on CO_2 emissions

	Base	L1	L1N1	L1N3	L3	L3N1	L3N3
Limits on NPP capacity	Y	Y	N	N	Y	N	N
CAPEX of NPP	min	min	min	max	min	min	max
Limits on CO_2 emissions in 2050	N	Y	Y	Y	Y	Y	Y
Carbon prices in 2050, RUR/ t CO_2	N	N	N	N	N	N	N
CO_2 emissions in 2050 (% to 2018 level)	122%	100%	100%	100%	80%	80%	80%
Changes by cases, % to the Base Case							
Fuel consumption in 2050	-	-13,2	-18,1	-16,2	-30,9	-36,3	-35,6
Total capital costs	-	+21,2	+13,9	+28,7	+73,8	+39,8	+60,1
Total discounted electricity supply costs	-	+1,10	+0,30	+1,82	+4,60	+1,60	+3,49

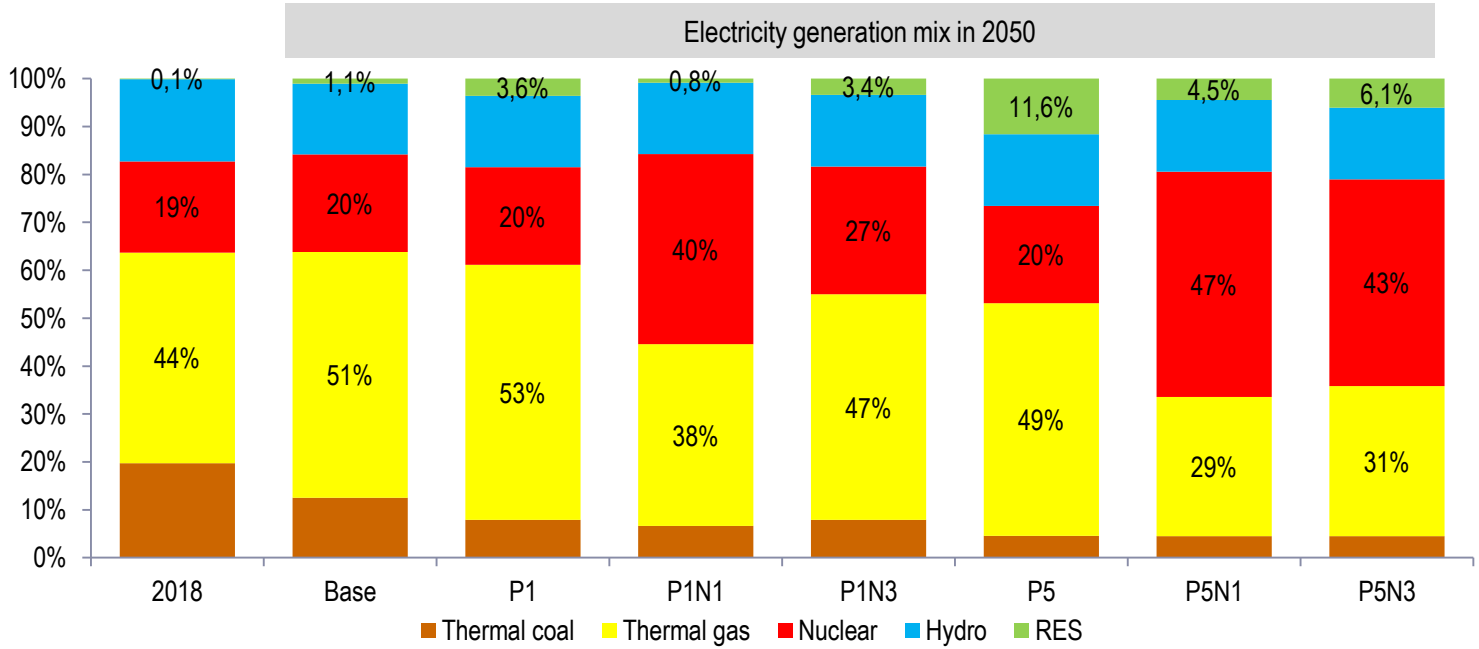
Electricity generation mix in 2050



Source: ERI RAS analysis

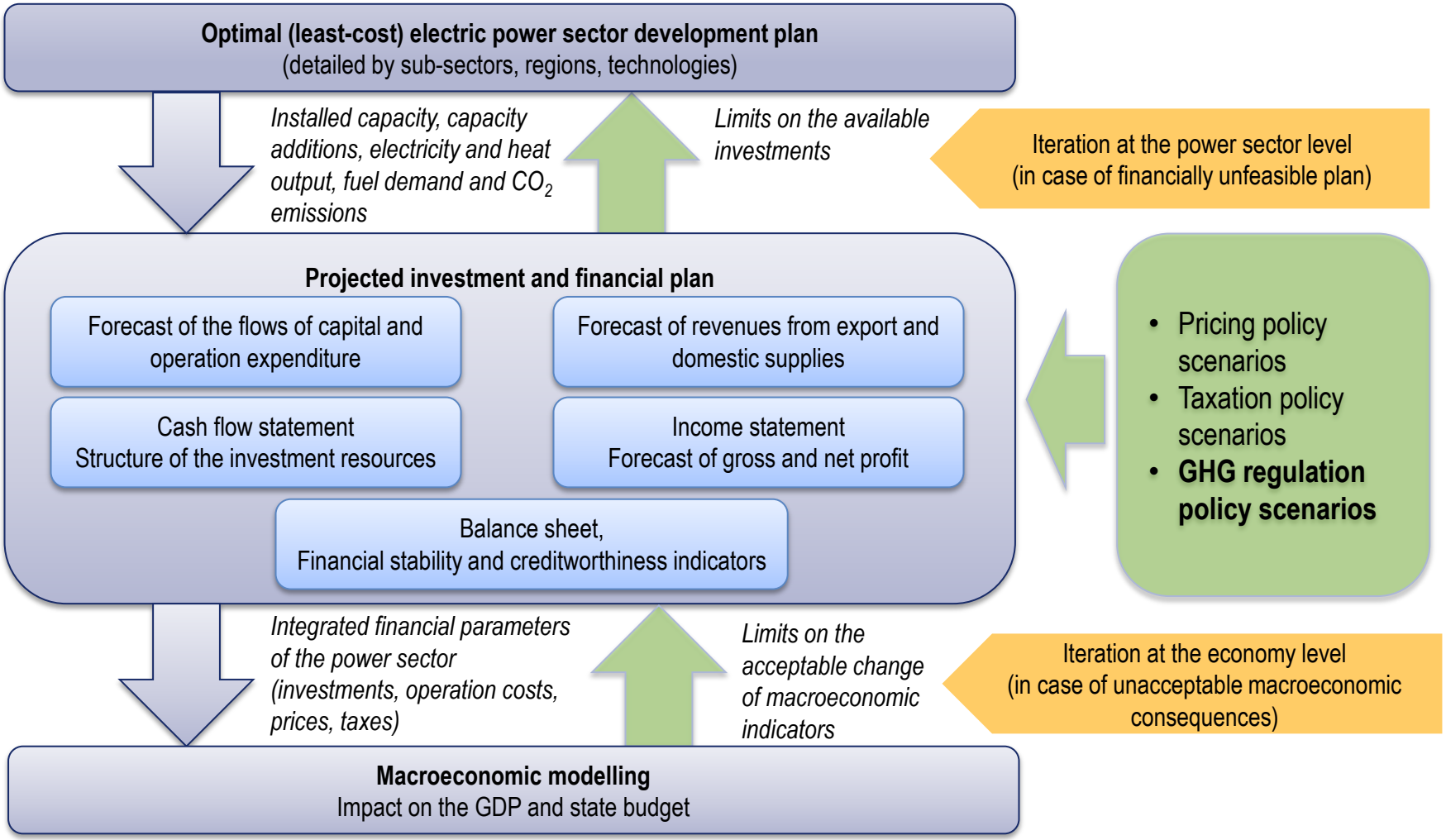
Generation mix in 2050 with carbon prices

	Base	P1	P1N1	P1N3	P5	P5N1	P5N3
Limits on NPP capacity	Y	Y	N	N	Y	N	N
CAPEX of NPP	min	min	min	max	min	min	max
Limits on CO_2 emissions in 2050	N	N	N	N	N	N	N
Carbon prices in 2050, RUR/ t CO_2	N	1300	1300	1300	6500	6500	6500
CO_2 emissions in 2050 (% to 2018 level)	122%	109%	91%	104%	92%	75%	77%
Changes by cases, % to the Base Case							
Fuel consumption in 2050	-	-7,3	-26,1	-13,0	-20,2	-42,8	-39,6
Total capital costs	-	+9,2	+20,6	+24,4	+44,0	+47,1	+65,7
Total disc. electricity supply costs (w/o carbon prices)	-	+0,29	+0,27	+1,57	+1,63	+1,54	+3,22



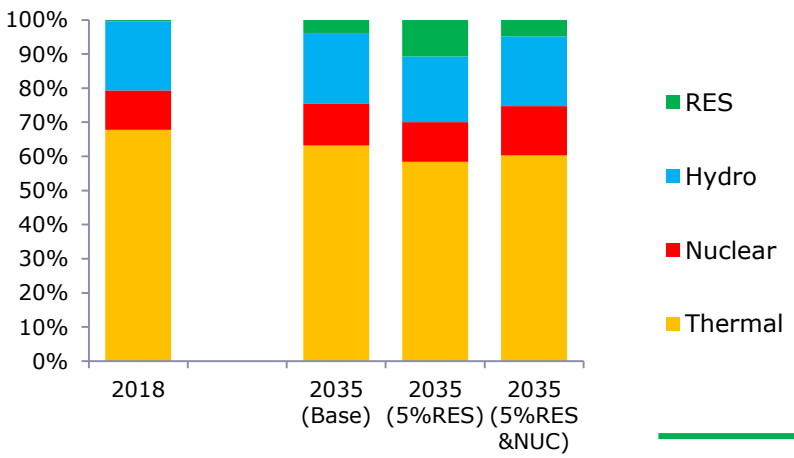
Source: ERI RAS analysis

Economic and financial evaluation of the least-cost decarbonisation plans

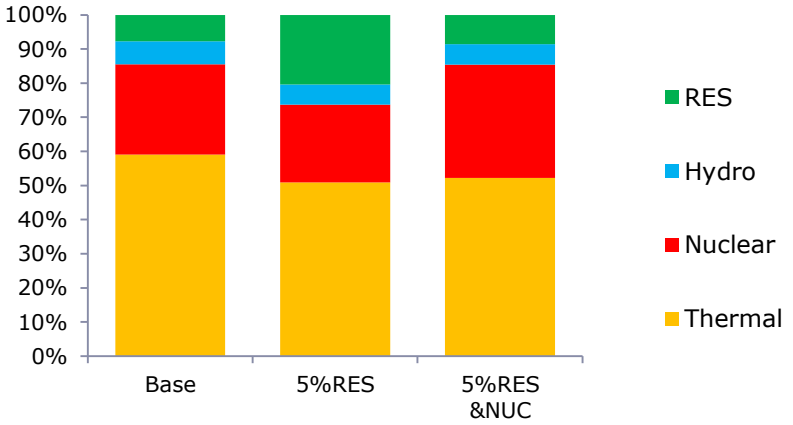


Economic and financial evaluation of the least-cost decarbonisation plans (example – case for 5% RES target in electricity generation mix to 2035)

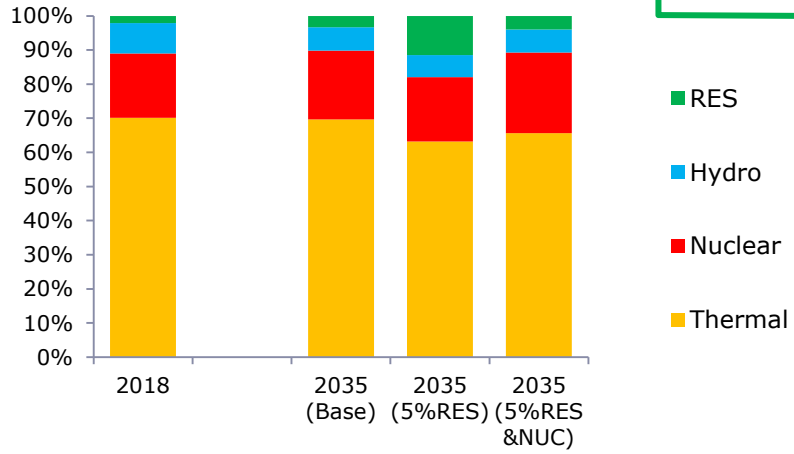
Generating capacity mix



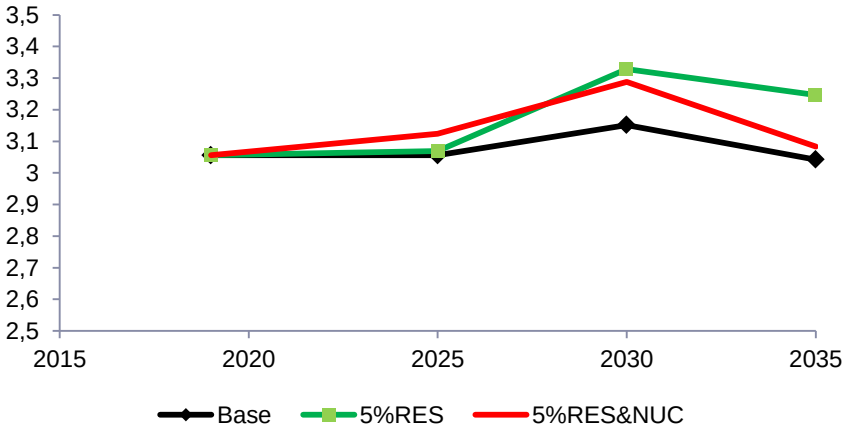
Cumulative investments structure to 2035



Revenue requirement structure



Electricity producer's price, 0.01 2019$/kWh



Source: ERI RAS analysis

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Thanks for attention