Nuclear Power in the Scenarios of the Low-Carbon Development of the Russian Electricity and Heat Supply

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Russian Unified Power System (UPS)

75 regional power systems spanning over 6000 km and 8 time zones

7 integrated power systems (IPS)

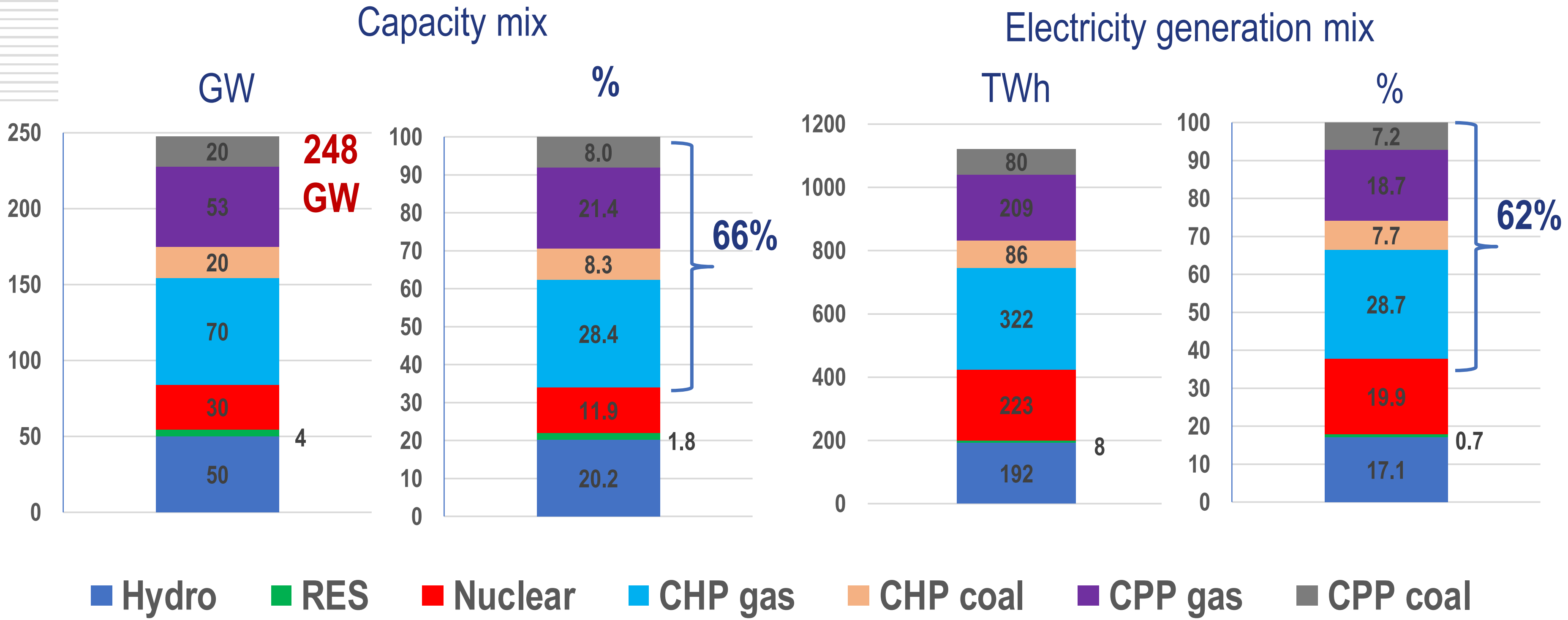
> 600 power plants with installed capacity of around 250 GW

> 3 200 000 km of power lines, of which 500 000 km of HV (110kV and higher) transmission lines

> 1 000 000 MVA of transformers capacity

Source: https://www.so-ups.ru/

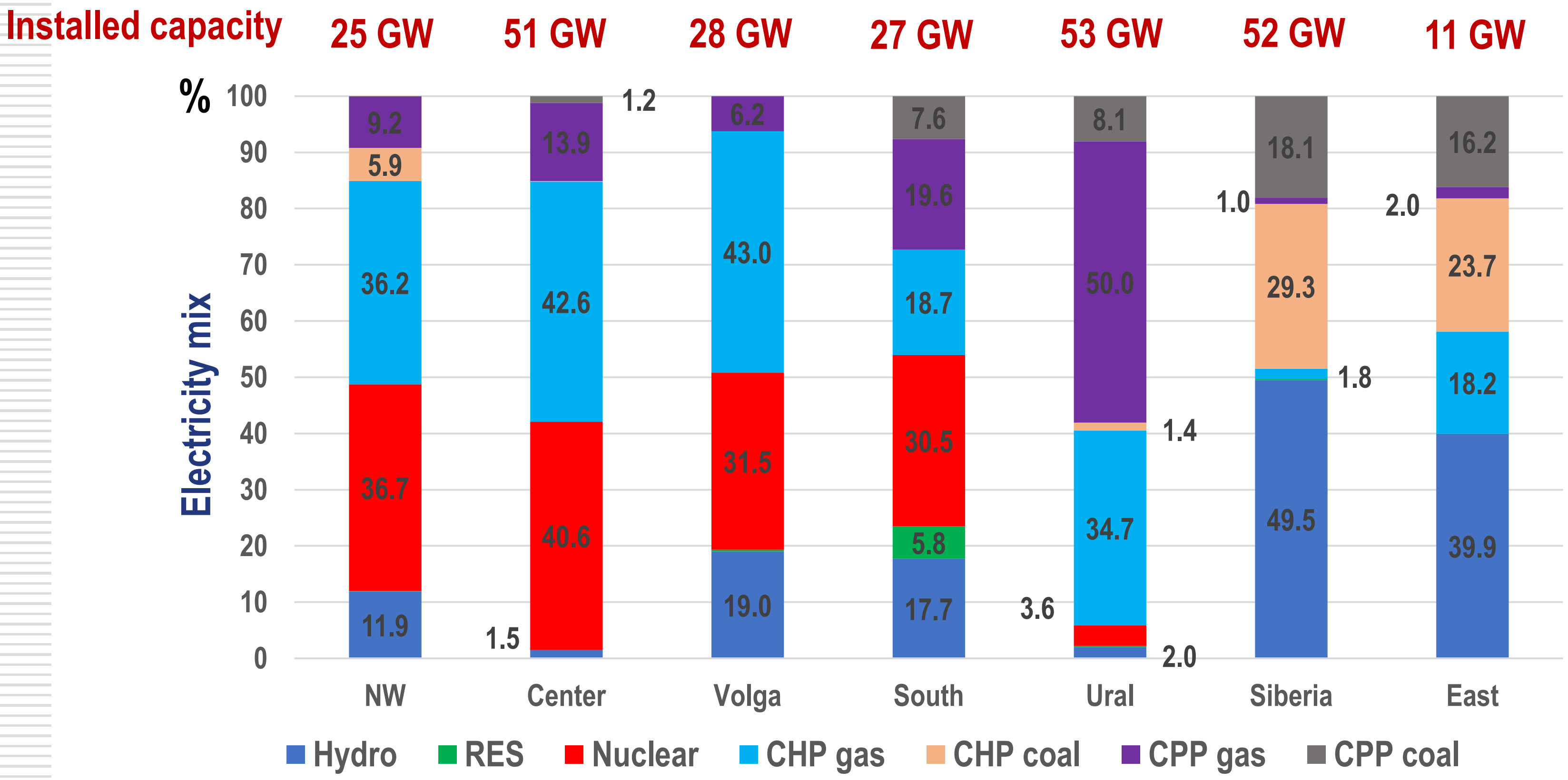
Capacity and generation mix in Russian UPS in 2022



Maximum load – 159 GW. Electricity consumption – 1122 TWh

Source: https://www.so-ups.ru/

Generation mix differs greatly over the regions



Source: https://www.so-ups.ru/

Key challenges for power sector development in Russia

Energy support of GDP growth

- According to the long-term Forecast of economic development, GDP should grow about 2,7-3% per year
  - It requires an increase in electricity production by 1,0-1,1% per year
- Geopolitical, technological, market challenges require much more intensive growth of the national economy, and GDP should grow by 3,5-4,5% per year
  - It requires an increase in electricity production by 1,6-2,0% per year

GHG mitigation

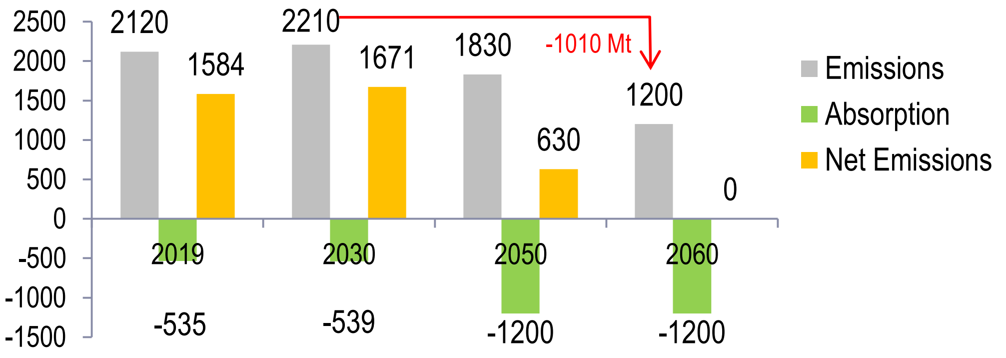
- According to the National Strategy for Development with Low Level of GHG Emissions (2021) by 2050:
  - Net emissions should be reduced by 60% compared to 2019 level, mainly due to the doubling of GHG absorption by LULUCF sector
  - At the same time, GHG emissions related to energy and industry should be only 13,6% lower than in 2019
- According to the National Climate Doctrine (2023), Russian economy should become carbon-neutral by 2060

Net Zero by 2060 – is it feasible?

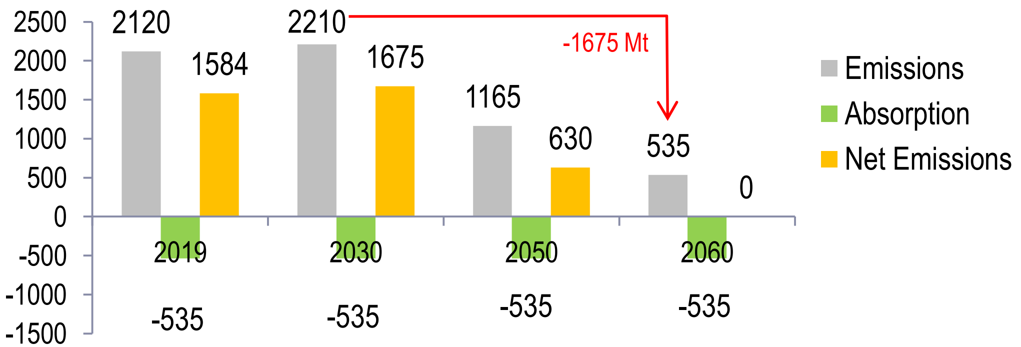
The climate doctrine of the Russian Federation aims to achieve carbon neutrality of the economy by 2060:

- Annual GHG emissions will continue to increase until 2030.
- From 2030 to 2060 over 30 years, annual gross emissions must decrease by:
  - 1000 Mton of CO2 with a doubling of the absorption capacity of ecosystems (as per National Strategy for Development with Low Level of GHG Emissions) which is questionable, to say the least
  - 1700 Mton of CO2 if current absorption capacity is maintained

GHG Emissions – doubling absorption capacity of ecosystems, Mt CO2-eq



GHG Emissions – current absorption capacity of ecosystems, Mt CO2-eq

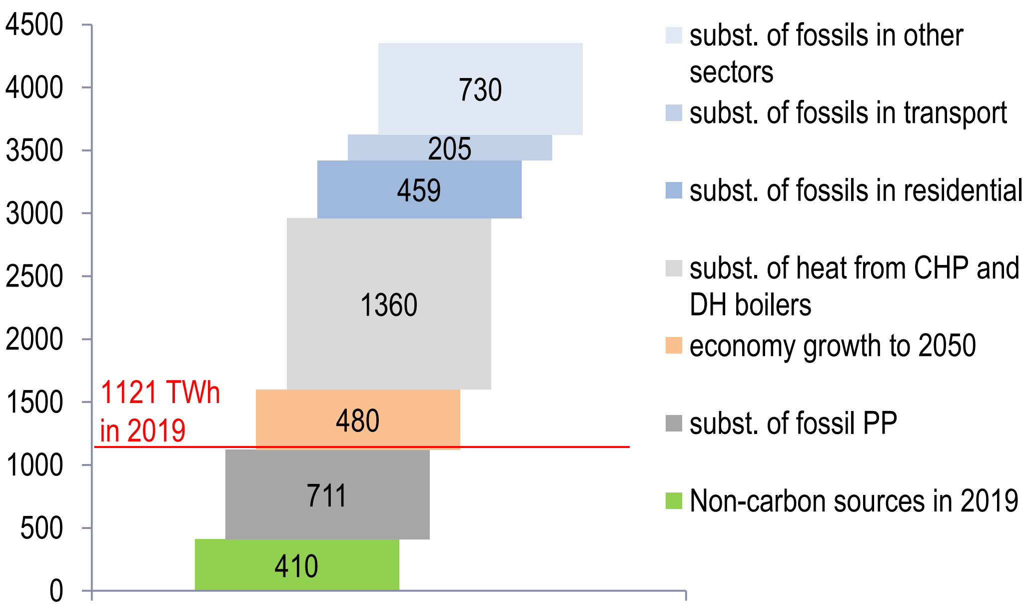


Source: ERI RAS analysis

Net Zero by 2060 – is it feasible?

- Annual emissions from power plants and DH boilers in 2019 totaled about **750 Mtons** of CO2, or 45% of total emissions from fuel combustion.
- Zeroing out these emissions **would not be enough to reach the Net Zero target** of 2060 without additional measures in other sectors (electrification, efficiency, H2, synfuels, etc.)
- For example, the transition to an "electric future" would require a **3x-4x increase** in electricity generation in just **30 years**, all of which should be non-carbon:
  - 500-600 GW of nuclear and/or CCS
  - 1400-2400 GW of RES + reserves/storages

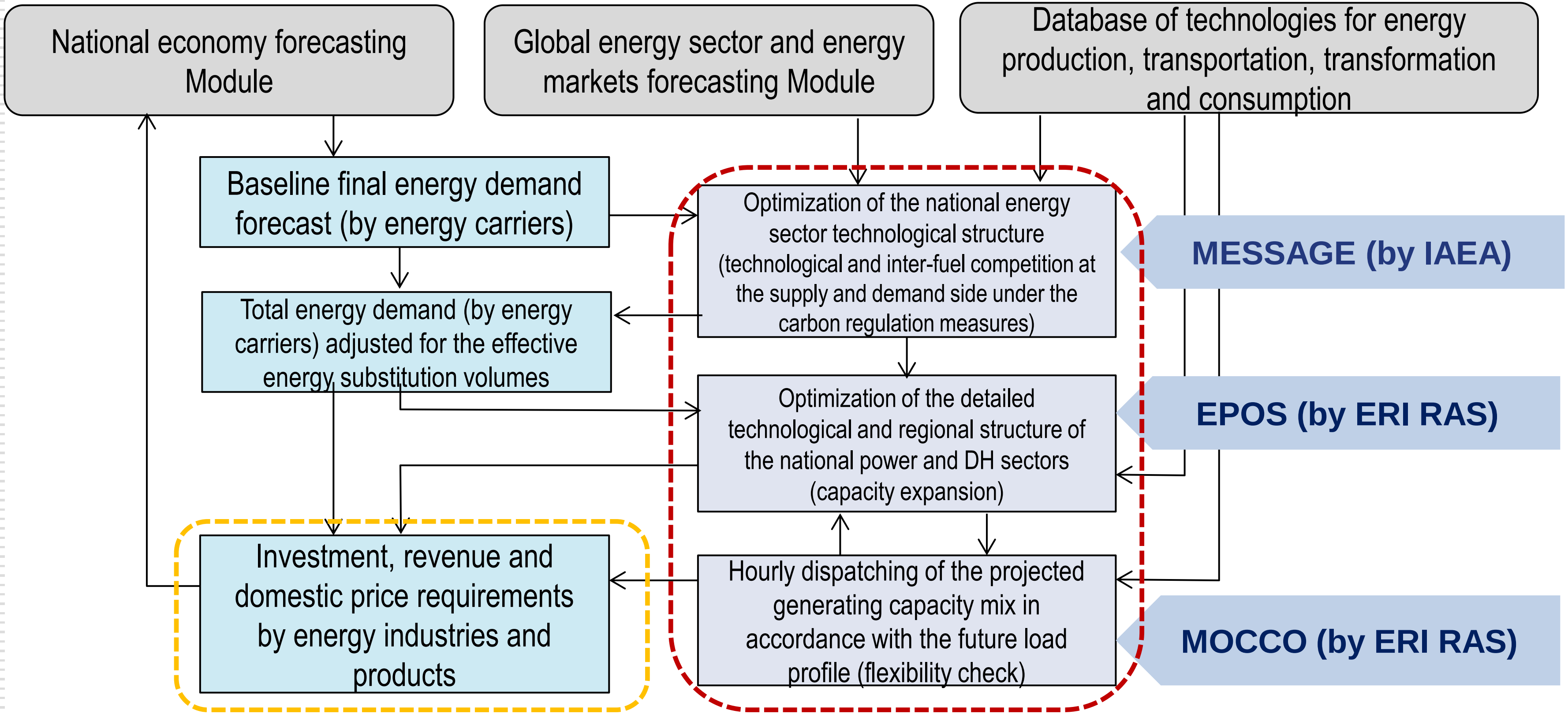
Electricity consumption in 2060 in "electric future", TWh



What kind of decarbonization can be feasible and beneficial for the Russian economy? We need to explore realistic options for reaching net zero by 2060, considering cross-sectoral and macroeconomic implications, including the costs of transitioning for the population, fuel and energy sectors, and economy as a whole

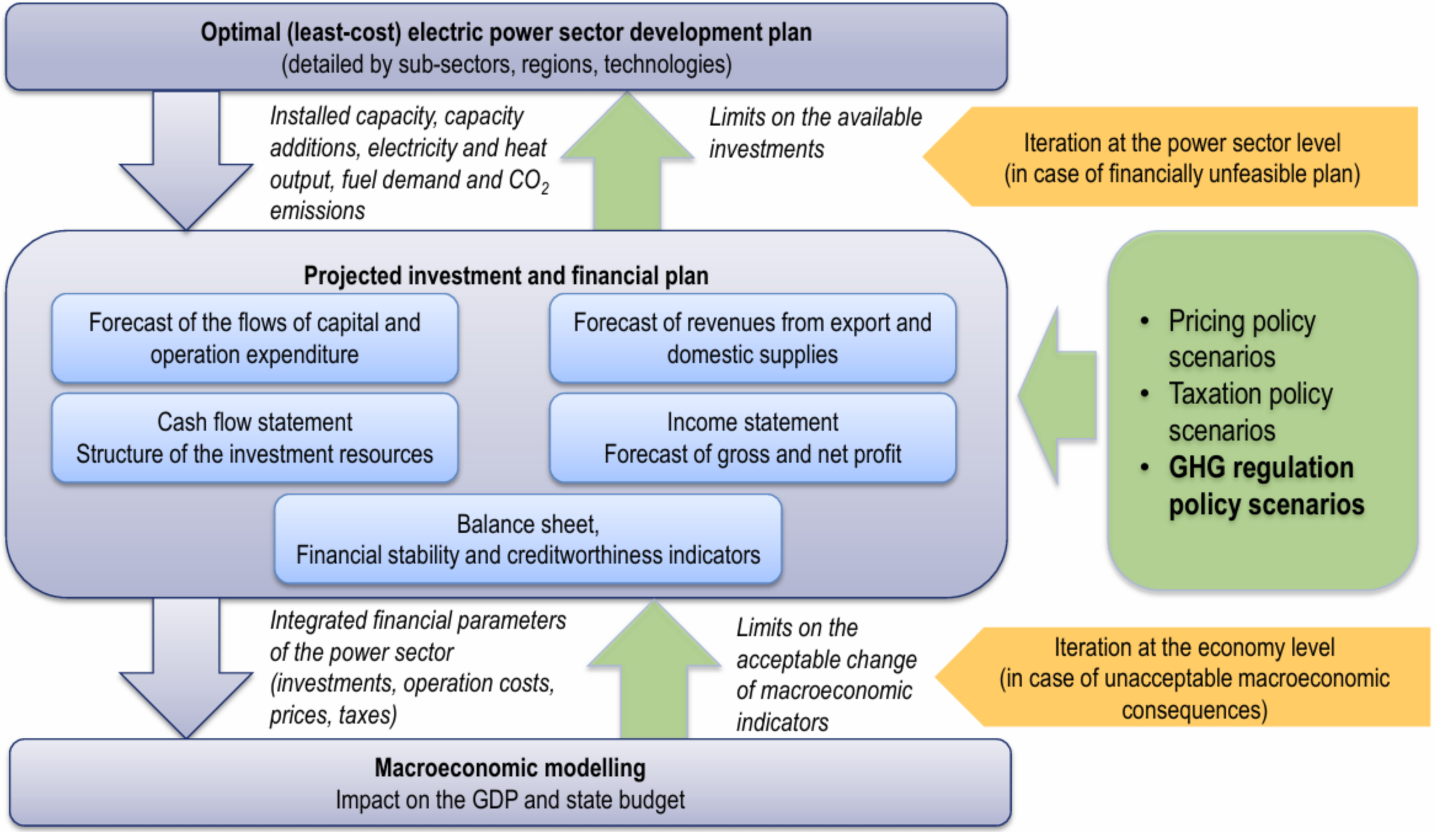
Source: ERI RAS analysis

Forecasting module of the National energy sector decarbonization scenarios



Source: ERI RAS analysis

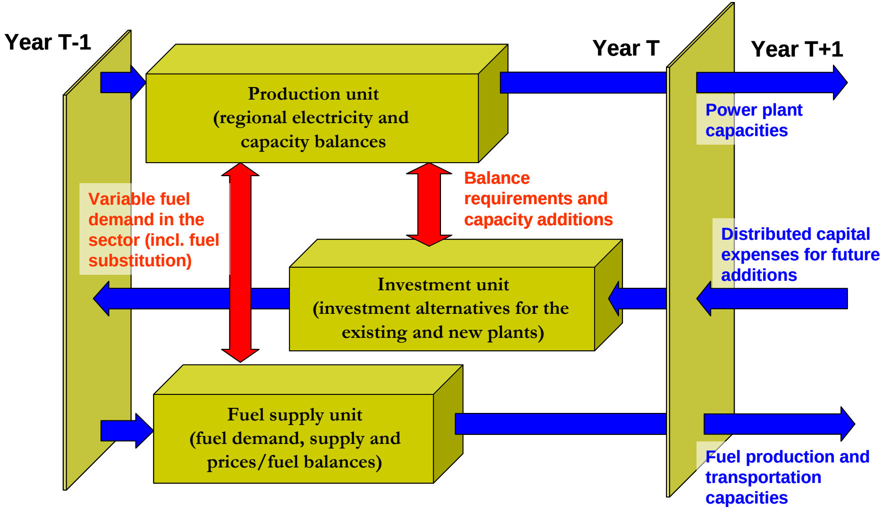
Economic and financial evaluation of the least-cost decarbonization plans



Main features of EPOS model

EPOS is the least-cost multi-year, multi-nodal modeling tool for the power and DH sectors expansion planning:

- 2050 planning horizon with perfect foresight (now extended to 2070)
- >400 major existing and planned power plants + >50 types of new generating technologies
- capacity (incl. reserve) and wholesale electricity balances by 42 nodes
- district heat and retail electricity balances by 80 regions
- only basic flexibility check and intra-year temporal resolution
- different emissions regulation measures
- can be expanded to cover gas and coal sectors

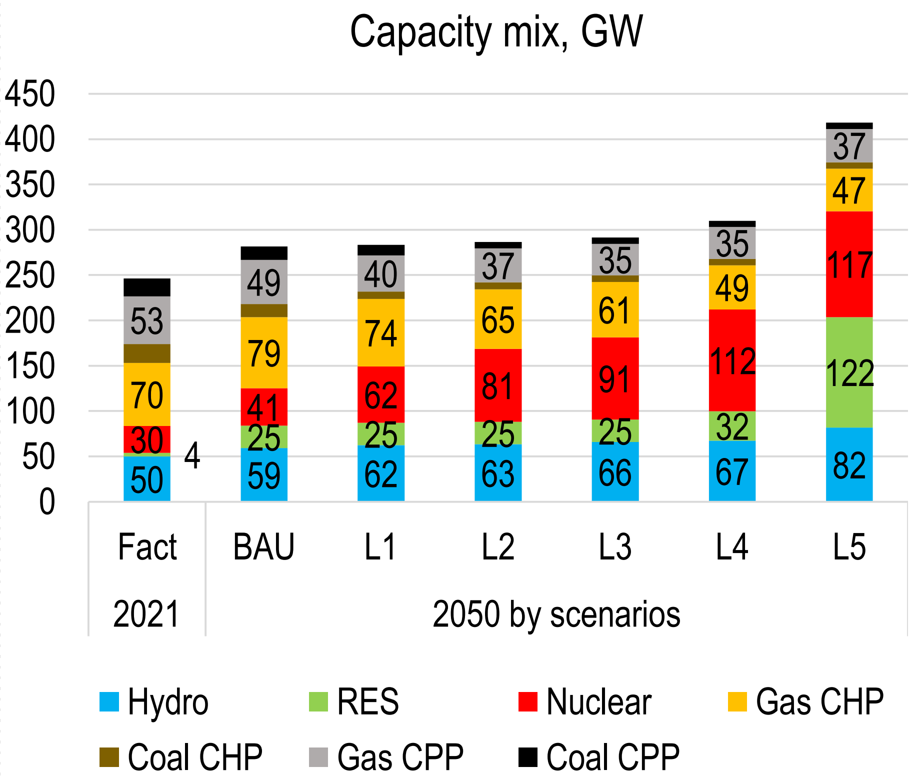


Scenarios with CO_2 emission quotas in power and DH sectors

Scenarios	CO_2 emission quota, % to 2019			
	2035	2040	2045	2050
Base (BAU) - no limits on emissions	108	105	103	103
L1	-	100	94	86
L2	-	95	86	75
L3	99	93	83	70
L4	97	90	76	60
L5	96	85	70	50

Source: ERI RAS modelling

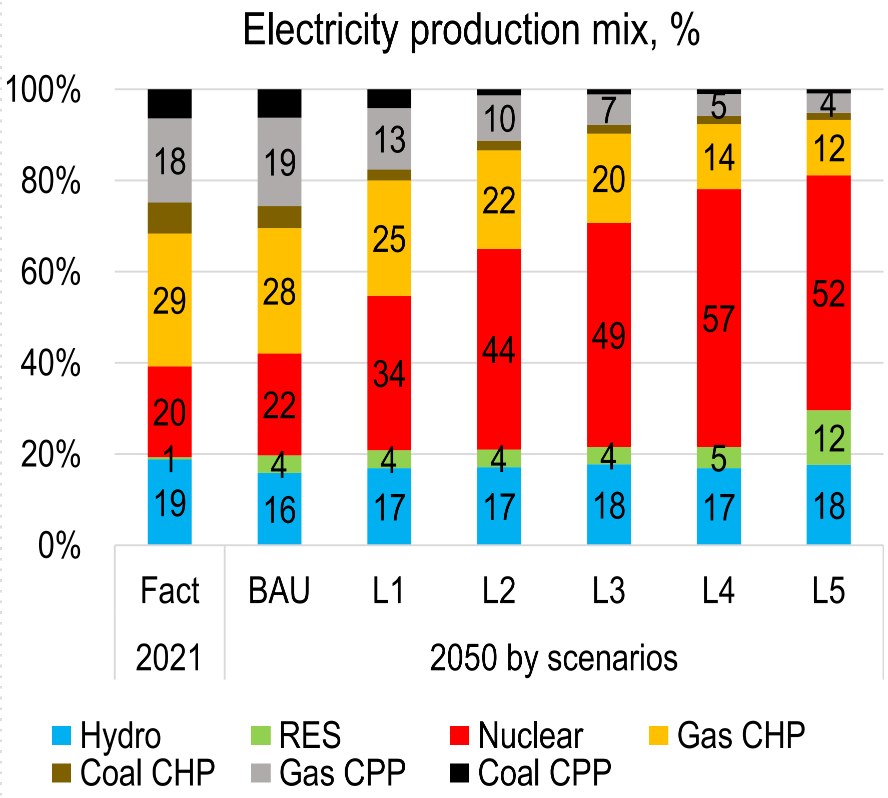
Scenarios with CO2 emission quotas in power and DH sectors – Power sector



GW	2021	2050 by scenarios					
	Fact	BAU	L1	L2	L3	L4	L5
Total installed capacity	246	281	283	286	291	310	418
Nuclear CHP (SMR)	-	-	-	-	-	10	15
RES with batteries	-	-	-	-	-	-	49
CCS	-	-	-	-	-	0.6	9.0

Source: ERI RAS modelling

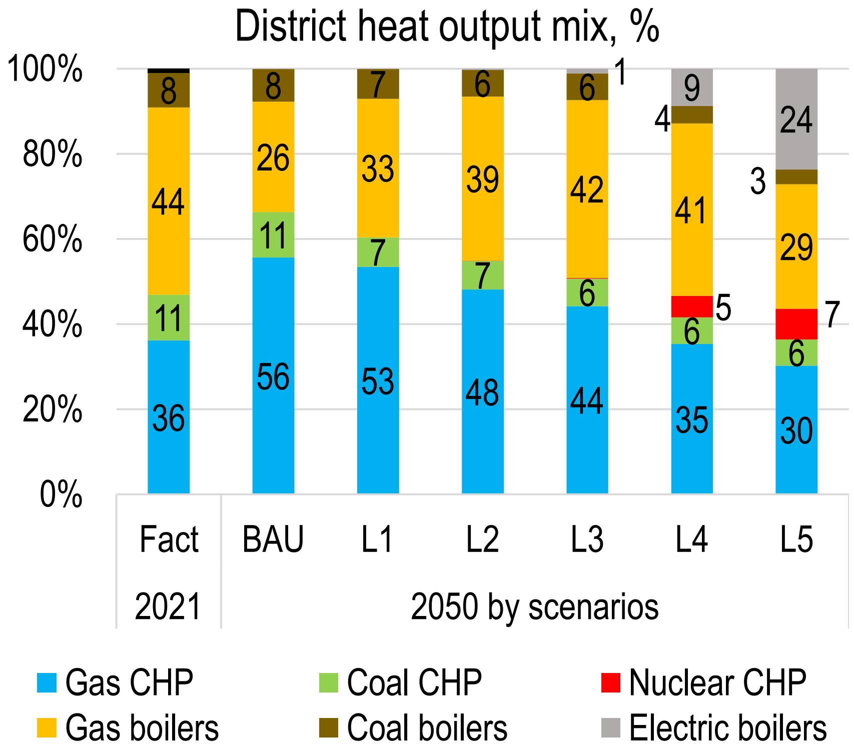
Scenarios with CO_2 emission quotas in power and DH sectors – Power sector



%	2021	2050 by scenarios					
	Fact	BAU	L1	L2	L3	L4	L5
Share of non-carbon	39.3	42.0	54.7	65.0	70.7	78.1	81.2
Share of coal	13.2	11.1	6.5	3.4	3.1	2.8	2.5
Share of gas	47.5	46.8	38.8	31.6	26.2	19.1	16.4
Share of CCS	-	-	-	-	-	0.2	2.6

Source: ERI RAS modelling

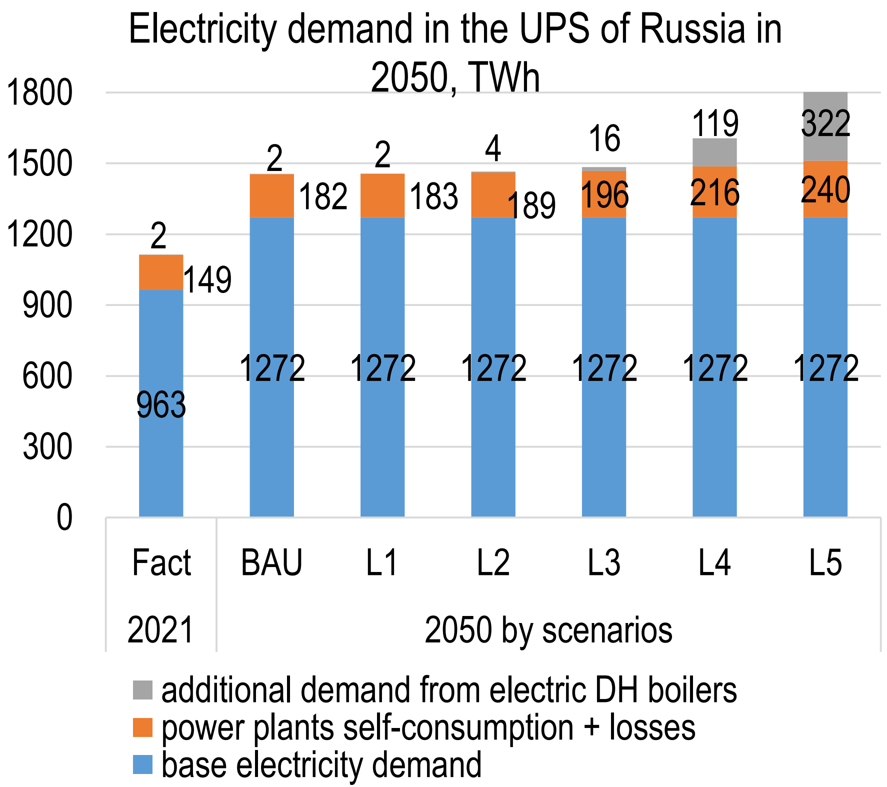
Scenarios with CO_2 emission quotas in power and DH sectors – DH sector



%	2021	2050 by scenarios					
	Fact	BAU	L1	L2	L3	L4	L5
Share of non-carbon	0.1	0.1	0.1	0.4	1.4	13.7	30.9
Share of coal	19.1	18.4	14.0	12.9	12.6	10.4	9.7
Share of gas	80.9	81.5	85.9	86.7	86.0	75.9	59.4

Source: ERI RAS modelling

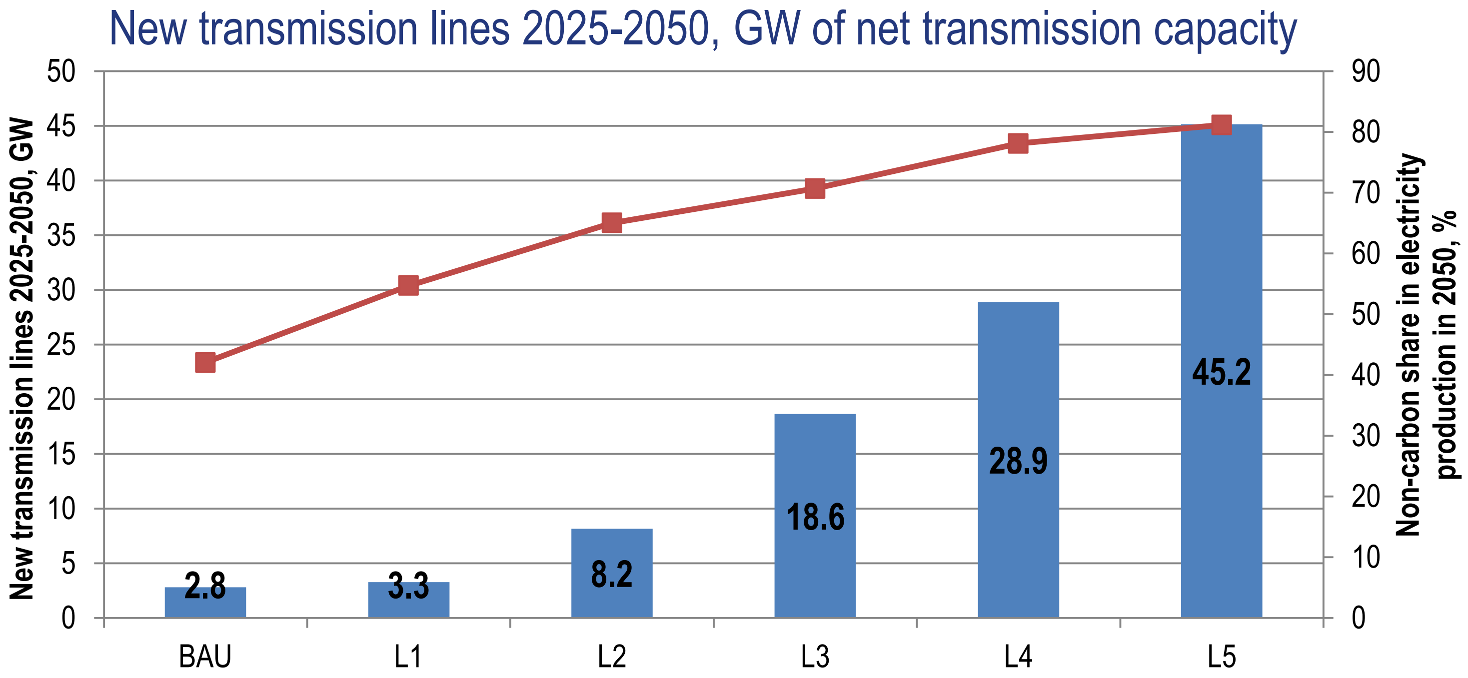
Scenarios with CO_2 emission quotas in power and DH sectors – Additional electricity demand



- Additional electricity demand from DH electrification
- Electricity grid losses are growing. Not only because of the increase of the demand. But also due to an increase of the non-carbon production

Source: ERI RAS modelling

Scenarios with CO2 emission quotas in power and DH sectors – Grid development

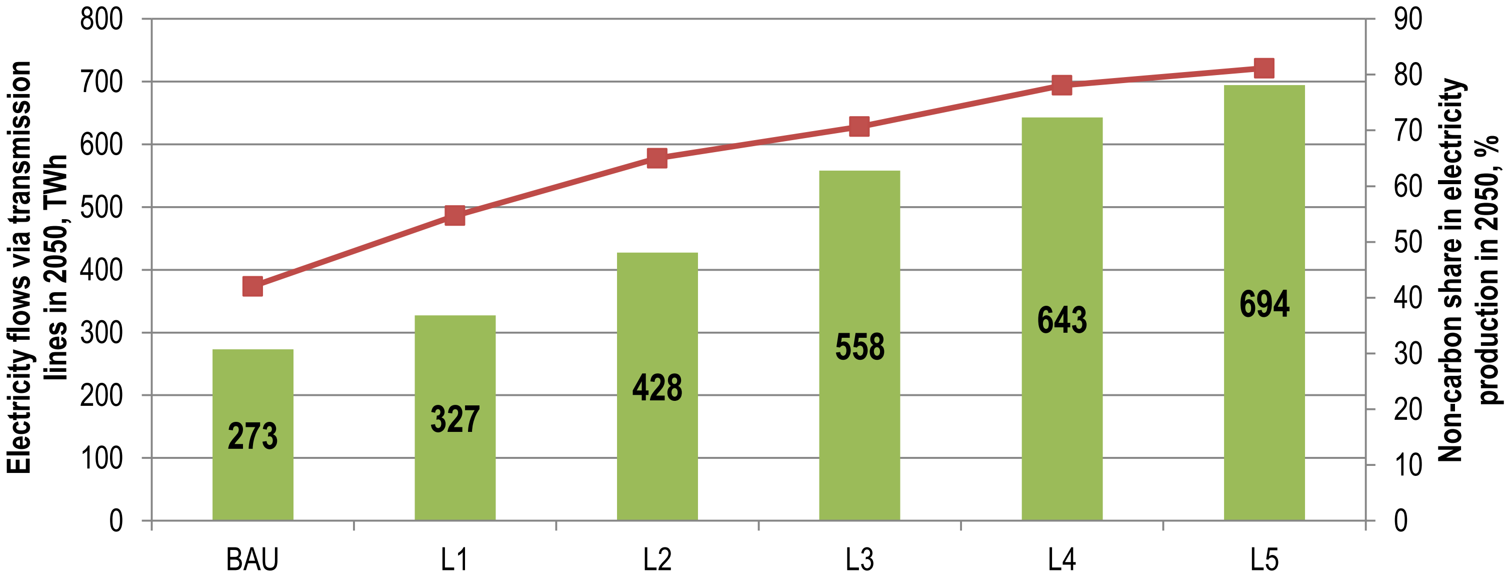


Fast development of new transmission lines is needed to accommodate growing capacity of non-carbon sources

Source: ERI RAS modelling

Scenarios with CO2 emission quotas in power and DH sectors – Grid development

Electricity flows via transmission lines in 2050, TWh



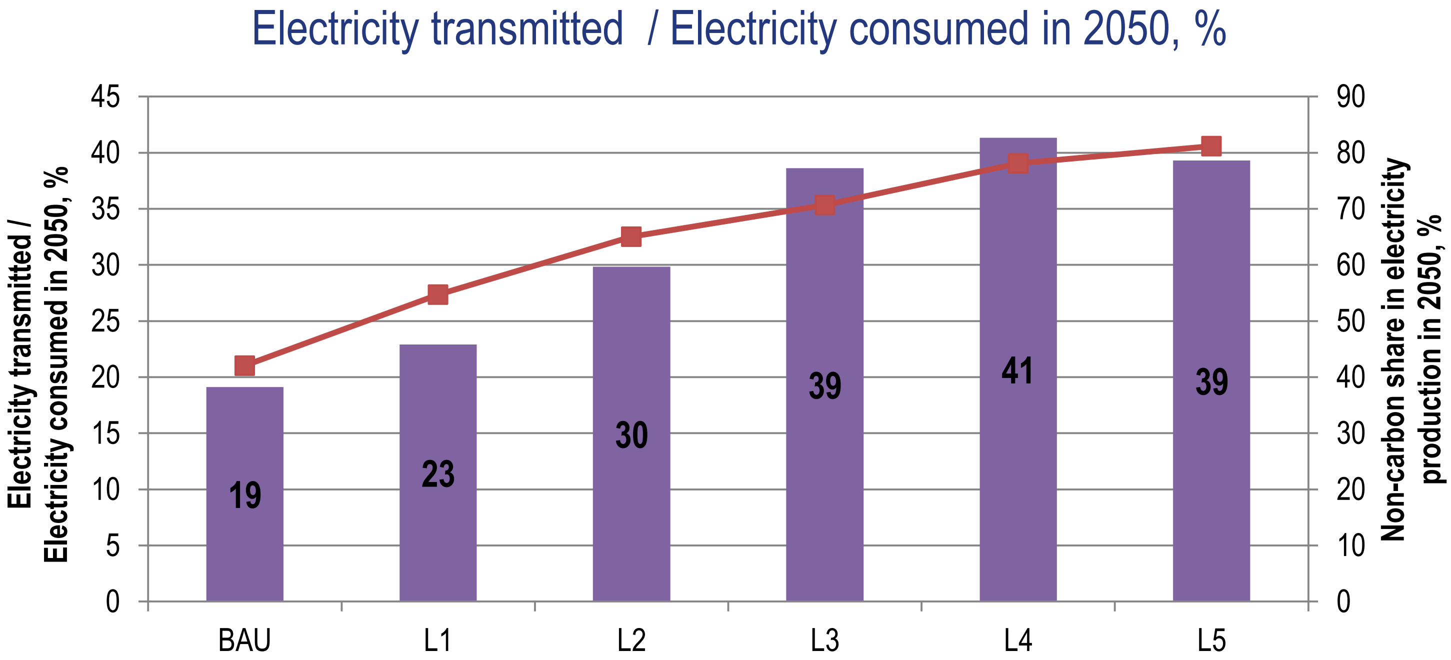
Electricity flows over transmission lines grow with an increase of non-carbon share, but not so fast as a capacity of new transmission lines

Source: ERI RAS modelling

Net annual electricity flows in 2050 – BAU Scenario, TWh

Net annual electricity flows in 2050 – L5 Scenario, TWh

Scenarios with CO2 emission quotas in power and DH sectors – Grid development



In decarbonizing scenarios almost 40% of consumed electricity is transmitted over the inter-regional power lines

All of this means that non-carbon power plants are not evenly distributed over the face of the Earth due to various reasons

The volume of losses after RES connection: Real-life example from Russia

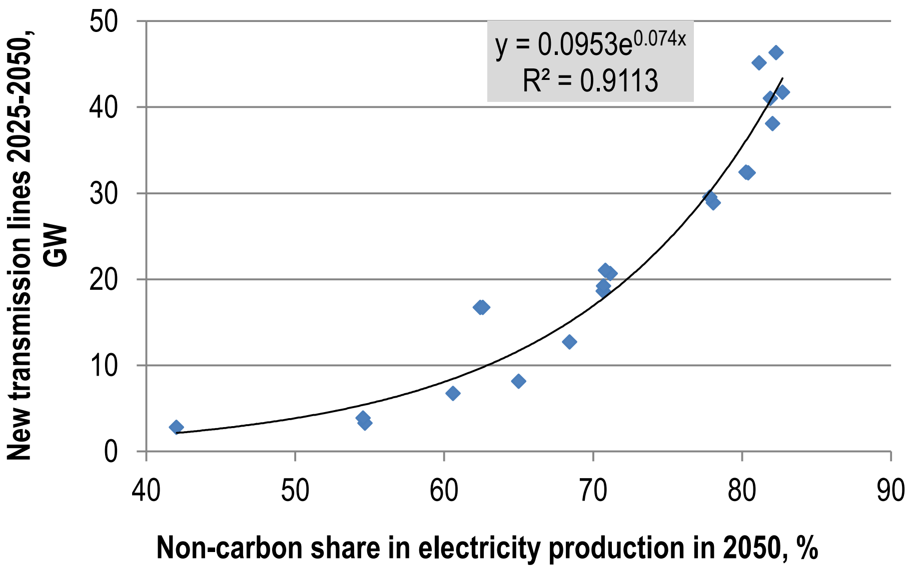
Филиал ПАО «Россети Юг»	1st half 2020, GWh	1st half 2022, GWh	Increase, %
Kalmykia	31,863	42,620	33
Rostov	107,807	136,629	26
Volgograd	32,430	36,323	12

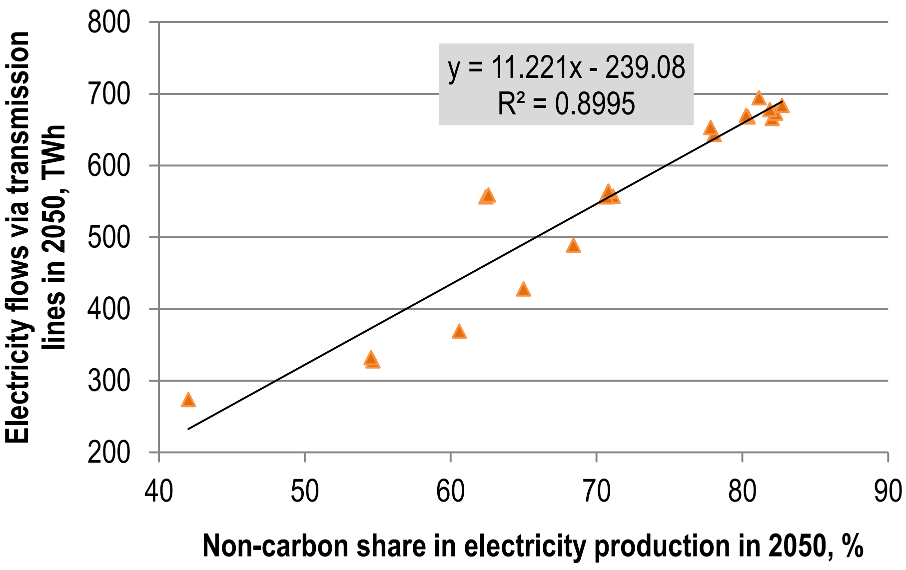
According to DSO “Rosseti South” it happens because “the generated electricity is not consumed locally due to the lack of consumers, but it is transmitted over long distances”

Source: ERI RAS forecast

Scenarios with CO2 emission quotas in power and DH sectors – Grid development

Correlation between grid development and share of non-carbon sources in electricity production mix

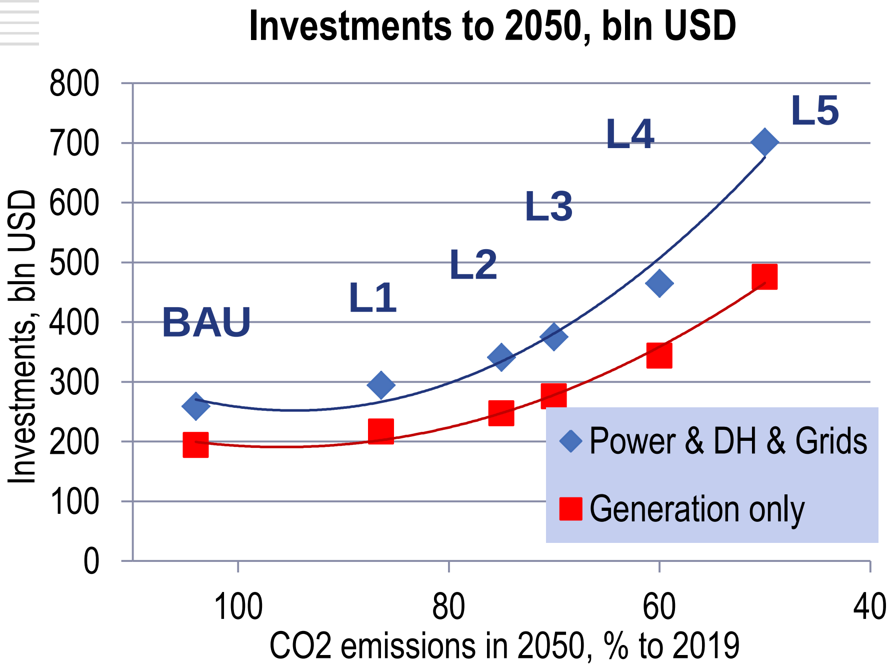


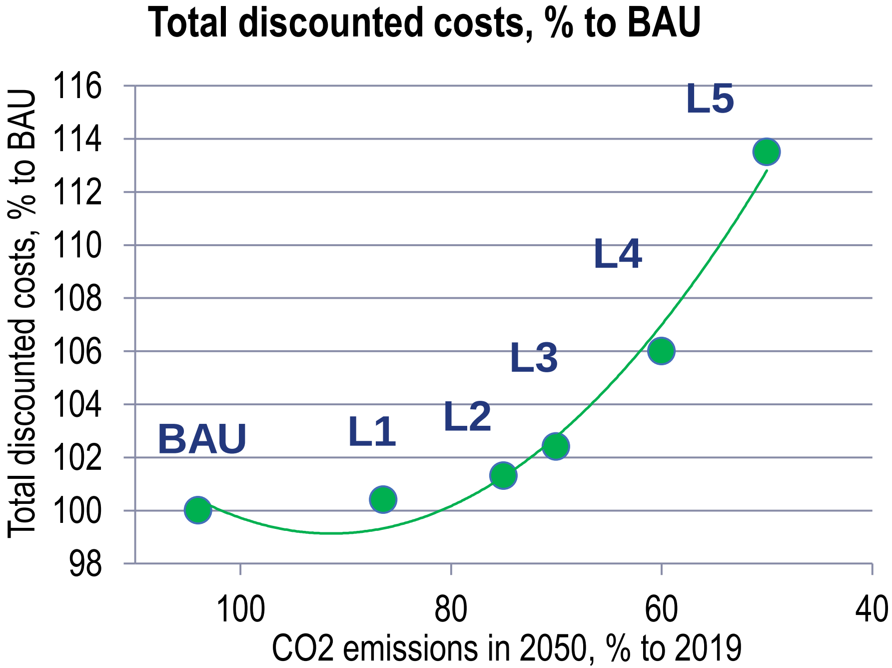


Obviously the investments into transmission grid will grow while decarbonization deepens.

The distribution grid could be another story depending on the type of dominating non-carbon source and the depth of electrification of final demand

Scenarios with CO_2 emission quotas in power and DH sectors – investments and total discounted costs of the system



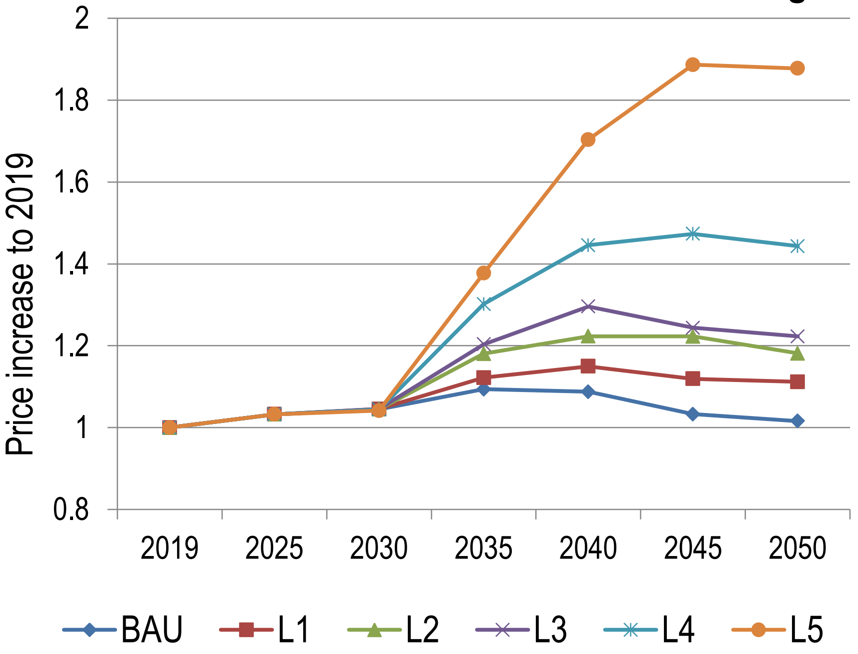


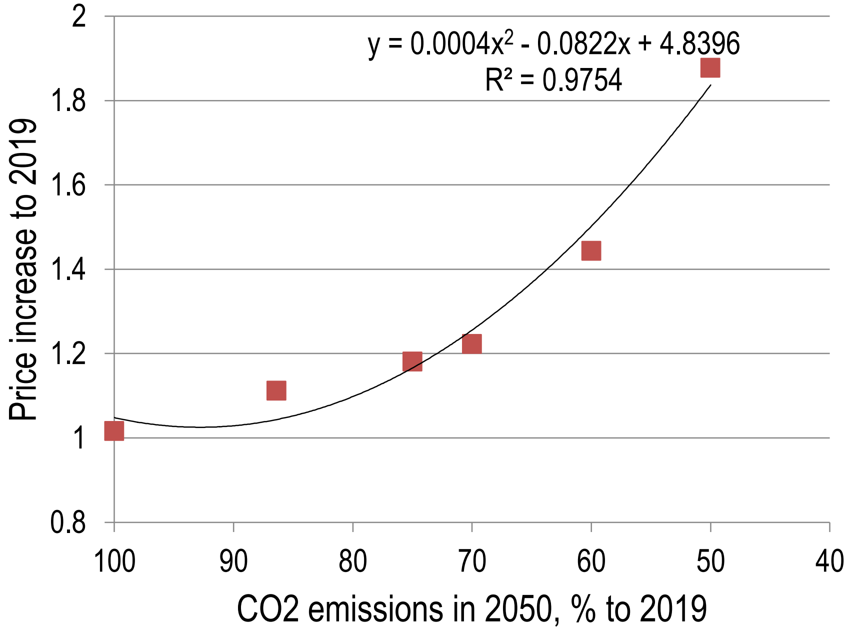
Investments and total discounted costs increase non-linearly as emissions restrictions become more stringent.

In the most ambitious scenarios, the grid investments are increasing much faster than investments in generation.

Scenarios with CO_2 emission quotas in power and DH sectors – price consequences

Average retail price (in real terms)

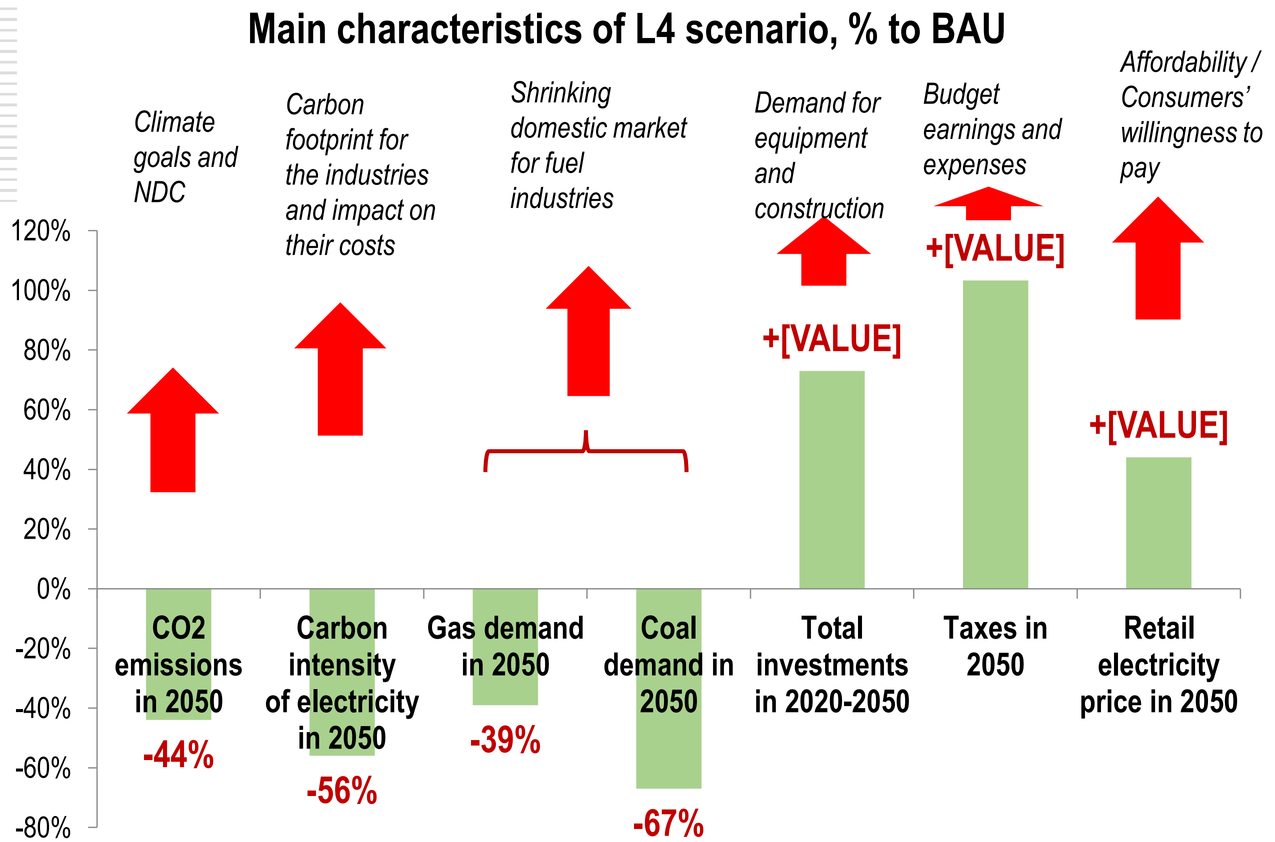




In BAU scenario, it is possible to ensure the stable level of CO_2 emissions with a quite stable price

CO_2 emissions reduction of 20-30% (L1-L3 scenarios) is achievable with reasonable price increase

Effects of the power and DH sectors decarbonization for the economy – example



These results show the importance of a more comprehensive, cross-sectoral analysis of the economy-wide impact of decarbonization in the power sector and optimizing the scale (and costs) of reducing CO2 emissions from power plants alongside with energy efficiency and decarbonization measures at demand side.

Takeaways

1). Modelling of the sector coupling is essential for understanding system costs and effects. In the Russian context, power and district heating coupling is most crucial for decarbonization efforts

2). Modelling enables us to evaluate not only the required reserves/storages for RES integration, but also the increase in power sector self-consumption, grid expansion investments and losses.

3) In models we can consider real constraints on the scale of technological development, such as the capacity of potential sites for nuclear and hydro power plants, the maximum rates of equipment supply and construction.

4) The least-cost optimization gives us an economic assessment of different scenarios (in terms of system discounted costs), but that is not what consumers are concerned about. It is crucial to make an accurate forecast of the financial plan for the sector, as well as to assess the necessary revenues and retail prices, based on the modelling results.

5) These prices and investments (which translate into demand for equipment and construction), as well as demand for fuel, can then be used as inputs into macroeconomic models to understand the effect on other sectors and the economy as a whole

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Thank You for Attention!