Modelling the scenarios of the low-carbon development of the Russian electricity and heat supply

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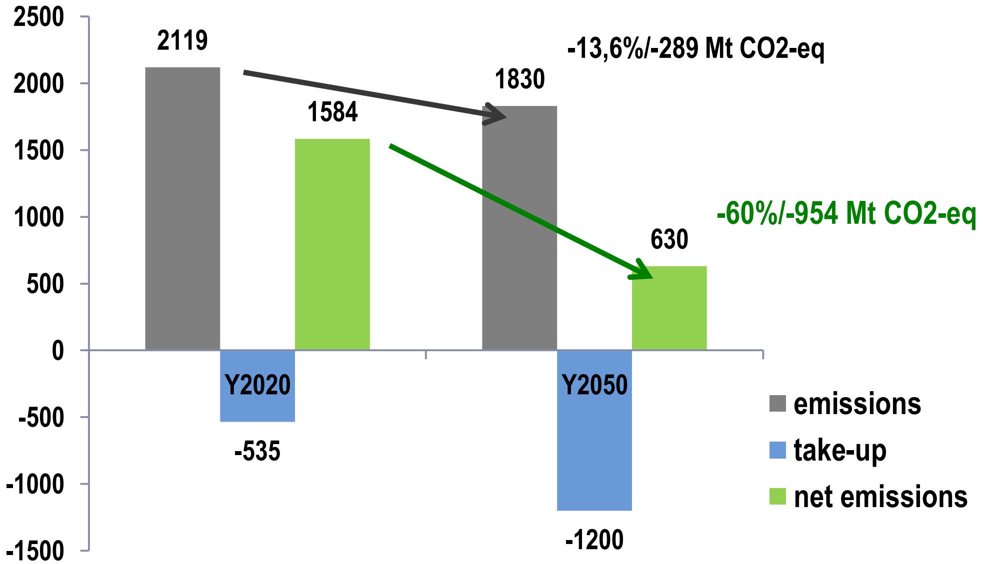
ИНЭИ РАН

Decarbonization of the Russian economy – targets and priorities

- Russia is a major GHG emitter and an important party to the Paris Agreement:
  - Updated NDC target – a **30% reduction below 1990 levels by 2030**
  - In 2021, the Government adopted «Strategy of socio-economic development of the Russian Federation with low greenhouse gas emissions by 2050» (SNUR-2050)
  - Long-term goal – **net zero by 2060**

Emissions and take-up of GHG (intensive scenario of SNUR-2050), Mt CO2-eq

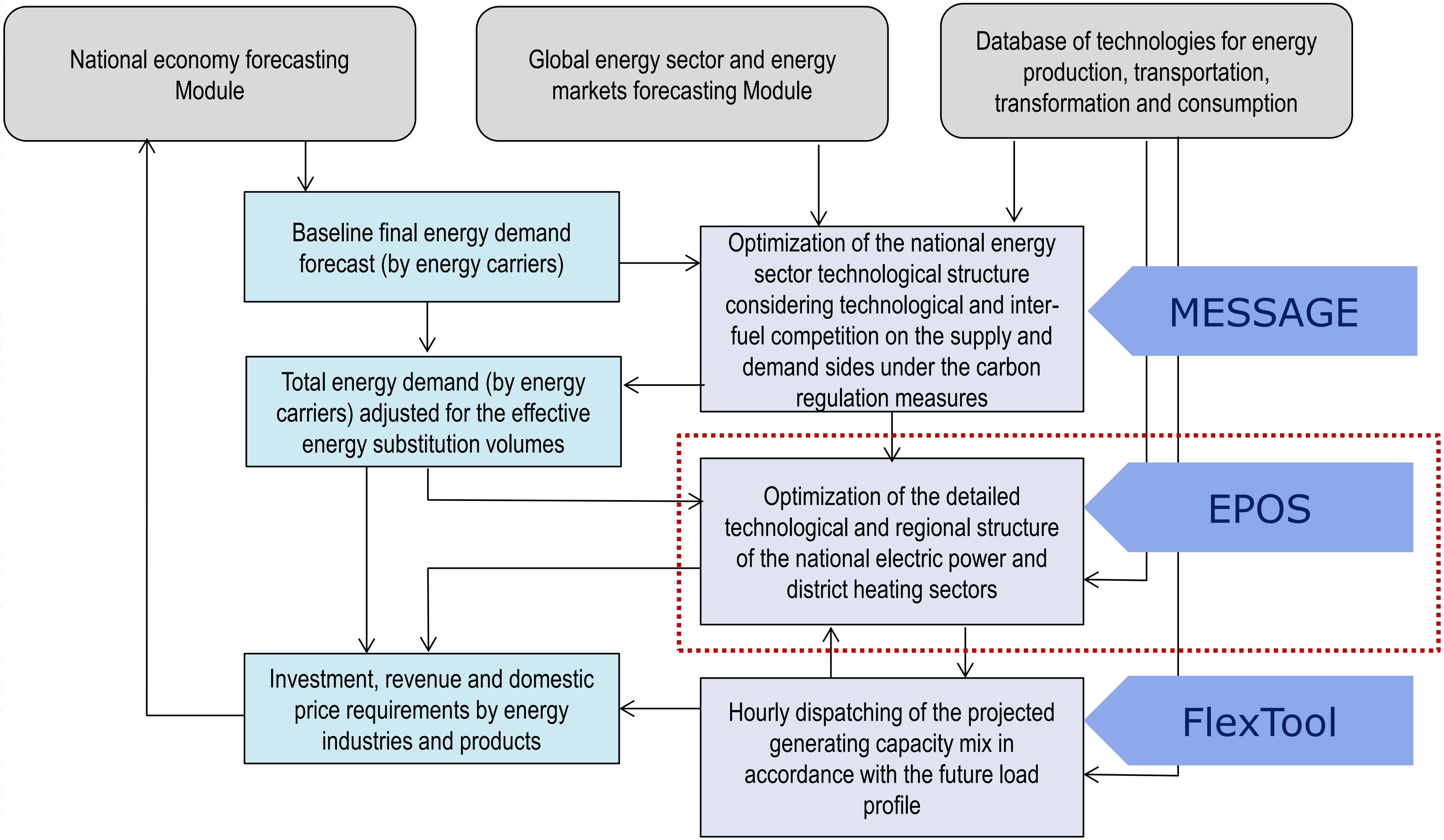


- Ambitious plans to reduce net GHG emissions by 2050 (by 60% or 954 million tons of CO2-eq) are mainly provided by a **multiple increase in the carbon take-up of forests**
- At the same time, the direct GHG emissions will be reduced only **by 14%** (289 million tons of CO2-eq)
- Net zero for the country ≠ net zero for power sector and/or other sectors
- The **optimal** contributions of the power and other sectors have not yet been determined

- In 2022, the Government of the Russian Federation launched a **multidisciplinary scientific project of the highest importance aimed at developing a National monitoring System for climatically active substances**. Within the framework of this project, it is planned to create a **forecasting system for elaborating the scenarios of the economy and the energy sector decarbonization** as well as for assessing the socio-economic consequences of the implementation of the low-carbon development policies.

Source: RF Government (SNUR-2050)

Forecasting module of the National energy sector decarbonization scenarios



Source: ERI RAS analysis

EPOS model structure

Carbon payments

Optimality criterion: the minimum cost of energy supply to the economy (total discounted costs) for the period under review and taking into account the costs of the aftereffect of decisions taken for another 30 years

- capacity balances for an hour of the annual maximum load and for an hour of the minimum load of the winter working day for energy zones, allowing to ensure minimum capacity requirements for the reliable operation of the UPS of Russia, including the mandatory level of the reserves and a sufficient level of intraday flexibility of the capacity mix

- annual electricity balances by energy zones with separate description of "retail" level to optimize the effective volumes of distributed generation

- annual balances of district heat supply from power plants and boilers in each administrative RF unit, differentiated by groups of heat consumers to optimize the effective scale and directions of DH development

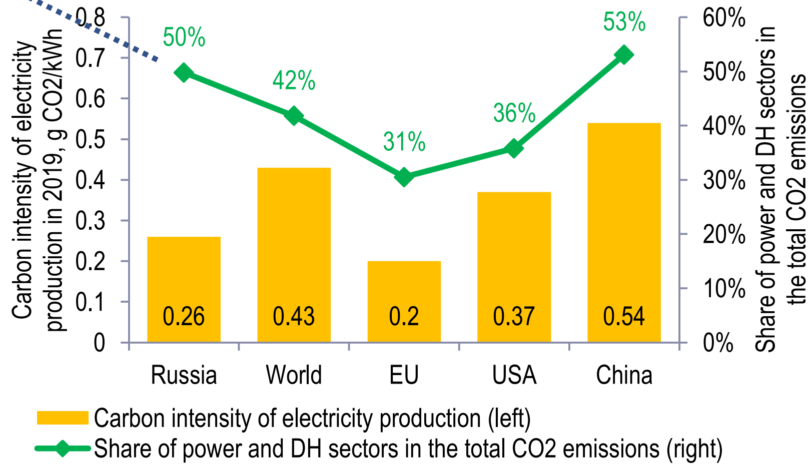
- annual fuel supply balances (by fuel types) for power plants and boilers, linking production volumes by main fuel deposits, aggregated transport flows (network for gas and radial for coal and fuel oil), consumption volumes optimized in the model at power plants and exogenously set demand forecasts of other domestic consumers and export dynamics

Quota on annual CO_2 emissions from power plants and DH boilers

The role of electric power and district heating in CO2 emissions

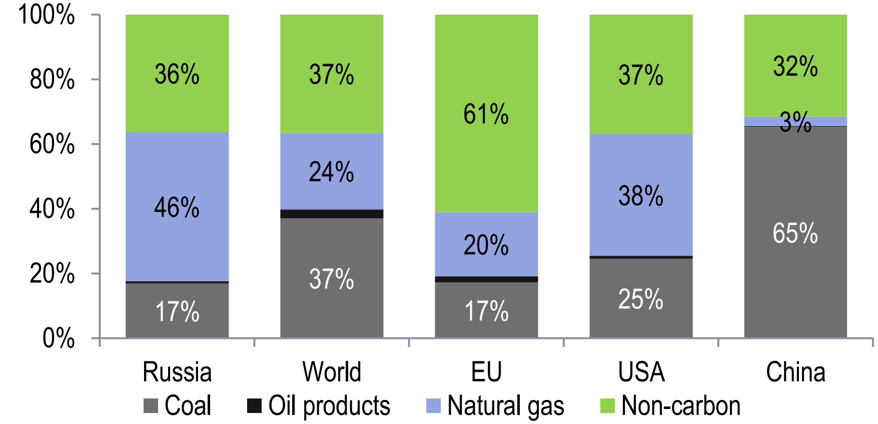
55% come from heat

The contribution of the power and DH sectors to CO_2 emissions in Russia and the world in 2019



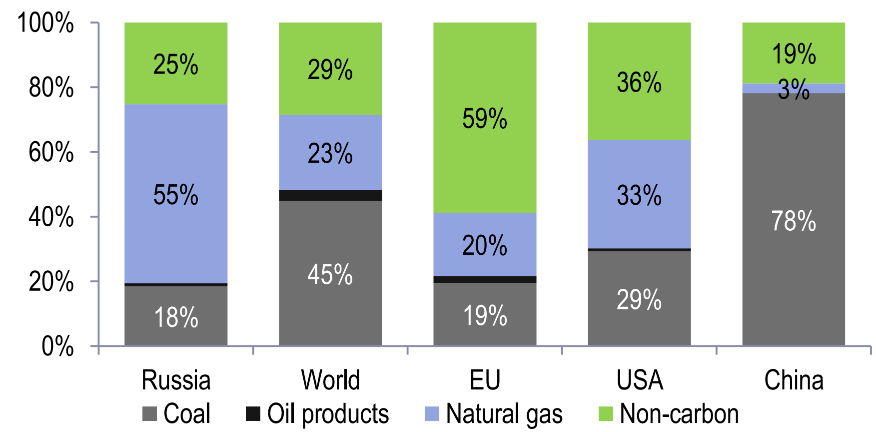
Source: ERI RAS analysis based on IEA data

Electricity production structure in 2019



Source: IEA data

Primary energy consumption for electricity production in 2019



Source: IEA data

- The Russian power and DH sectors are the largest GHG emitters in the country. 55% of emissions come from heat production, which is hard to decarbonize
- Unlike other countries, gas is the dominant resource for electricity and heat production
- A significant role is played by carbon-free sources – nuclear and hydropower plants.
- The RES development program has been active since 2010, but with limited financial support
- A lot of heat is produced in CHPs, which allows more efficient use of fossil fuels
- As a result, the specific carbon intensity of electricity production is well below the global average.

Reducing CO2 emissions from power plants becomes a non-trivial task in a broader context, taking into account decarbonization of other sectors

Electric power sector

- Reduction of CO2 emissions from power plants and carbon intensity of electricity production
- Various technological decarbonization strategies: nuclear power plants, RES, hydro plants, thermal power plants with CCS, biofuels, hydrogen

Restrictions on the CHP development

Hydrogen resources for electricity production

Additional electricity demand and requirements for generating capacities

District heating sector

- Reduction of CO2 emissions from DH systems
- Different technological priorities of decarbonization: Large CHPs with CCS, CHPs and boilers on biogas, pellets, **electric boilers, heat pumps** (not well suited for DH in Russia), etc.

Added into the model

Transport sector

- Reduction of CO2 emissions from various types of transport
- Various technological priorities of oil fuel substitution: gas, biodiesel, **electricity**, hydrogen, ammonia, methanol, etc.

Industrial energy facilities

- Reduction of CO2 emissions from the energy use of fuel in industry
- Various technological priorities of fuel substitution: gas, biofuels, **electricity**, hydrogen, etc.

Hydrogen industry

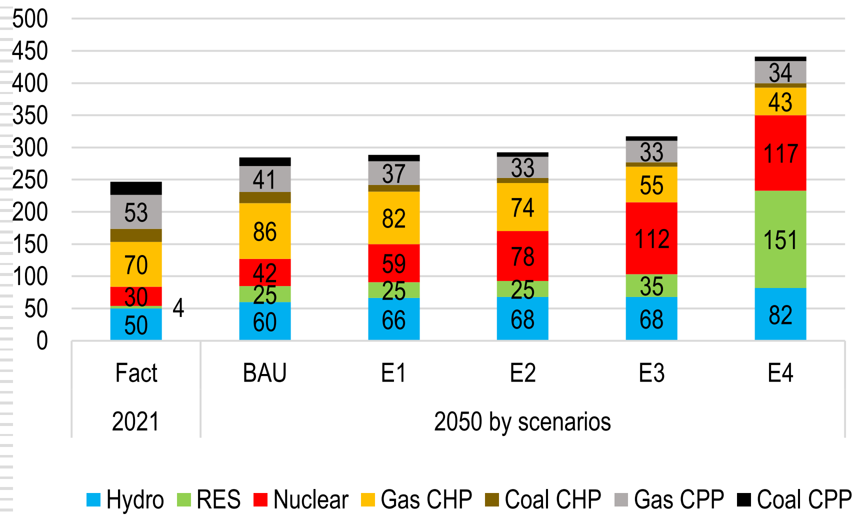
- Ensuring the demand for hydrogen as an energy carrier without CO_2 emissions
- Various technological possibilities of production using: gas, **electricity**, coal.

Source: ERI RAS analysis

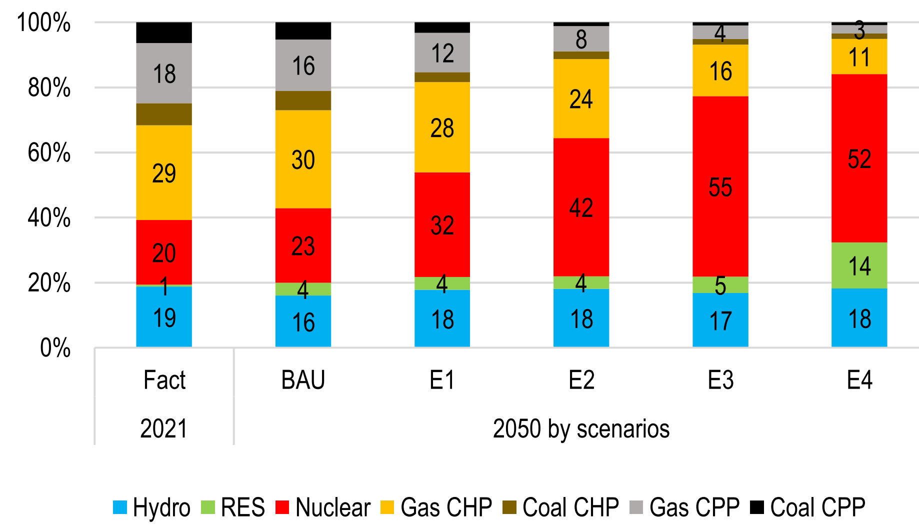
Scenarios with CO2 emission quotas

Scenarios	CO2 emissions quota, % to 2019			
	2035	2040	2045	2050
Base (BAU) – optimal CO2 emissions	108	106	103	102
E1 (SNUR scenario)	-	100	94	86
E2	-	95	87	75
E3	97	90	76	60
E4	97	78	62	50

Capacity mix, GW



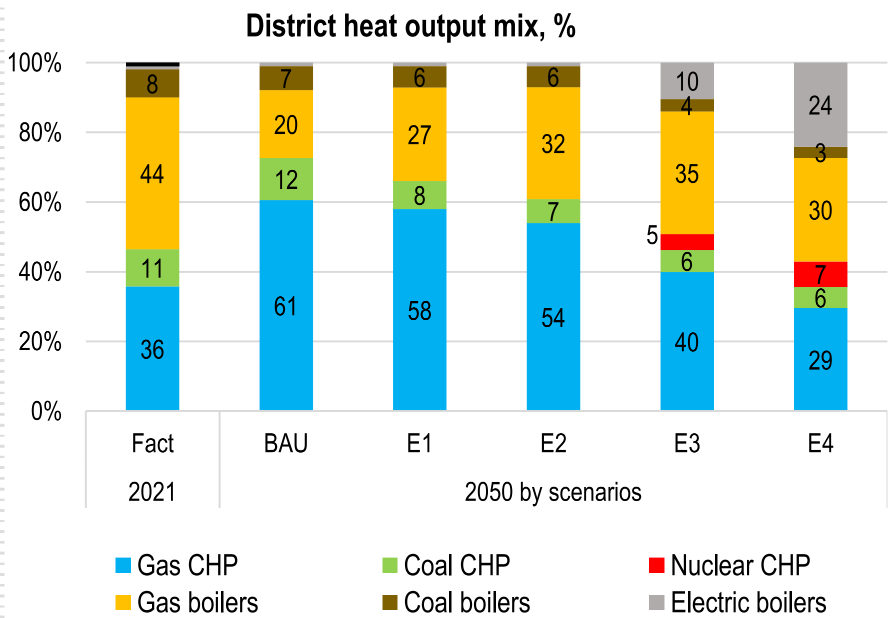
Electricity production mix, %

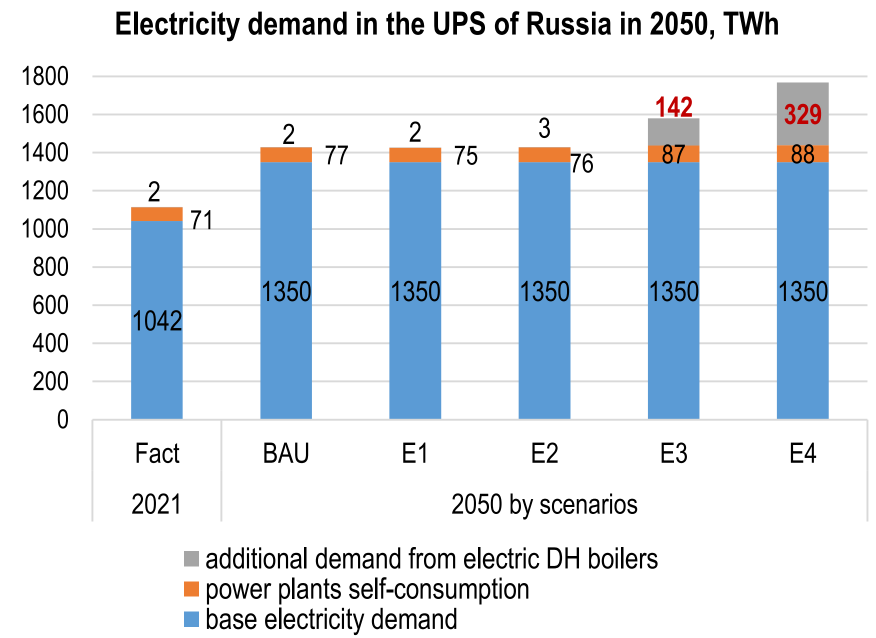


GW	2021	2050 by scenarios				
	Fact	BAU	E1	E2	E3	E4
Total installed capacity	247	284	288	293	317	441
Nuclear CHP (SMR)	-	-	-	-	9	15
RES with batteries	-	-	-	-	-	73
CCS	-	-	-	-	0.4	1.4

	2021	2050 by scenarios				
	Fact	BAU	E1	E2	E3	E4
Share of non-carbon	39.3	42.9	53.9	64.4	77.6	85.1
Share of coal	13.2	11.3	6.3	3.5	2.8	2.5
Share of gas	47.5	45.8	39.8	32.0	19.9	13.5
Share of CCS					0.3	1.0

Scenarios with CO2 emission quotas





%	2021	2050 by scenarios				
	Fact	BAU	E1	E2	E3	E4
Share of non-carbon	0.2	0.2	0.2	0.2	14.9	31.4
Share of coal	19.1	19.1	14.4	13.1	9.9	9.3
Share of gas	80.9	80.8	85.5	86.7	75.2	59.3

Source: ERI RAS forecast

Scenarios with CO_2 emission quotas

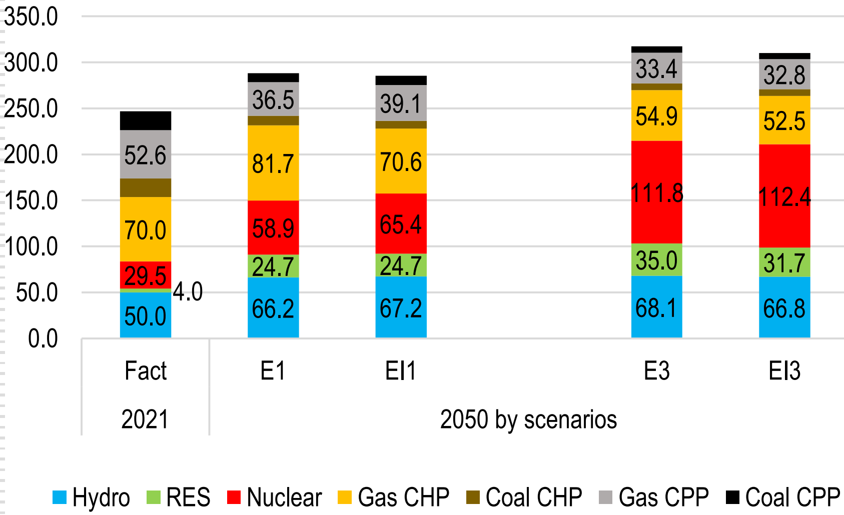
Comparison of the main characteristics of the scenarios with CO_2 emission quotas

	Scenarios				
	BAU	**E1**	**E2**	**E3**	**E4**
CO_2 emissions in 2050 г., % to 2019:	102	86	75	60	50
- thermal power plants	52	59	63	57	27
- DH boilers	121	96	79	61	58
Non-carbon share in electricity generation mix in 2050, %	42.9	53.9	64.4	77.6	85.1
Non-carbon share in DH output mix in 2050, %	0.1	0.2	0.2	14.9	31.4
Fossil fuel consumption in 2050, % to BAU:	-	-13.2	-25.0	-41.9	-54.4
- natural gas	-	-6.7	-16.9	-36.6	-52.8
- coal	-	-39.6	-59.6	-70.1	-71.6
Total capital requirements up to 2050, % to BAU	**-**	**+17.2**	**+33.6**	**+90.8**	**+170.8**
- nuclear	-	+74.9	+153.3	+346.6	+384.1
- RES and hydro	-	+29.2	+32.4	+55.5	+387.7
- fossil fuel power plants and boilers	-	-17.2	-28.2	-28.9	-21.0
Total discounted costs of electricity and heat supply (cost function value), % to BAU	**-**	**+0.5**	**+1.3**	**+4.9**	**+11.3**

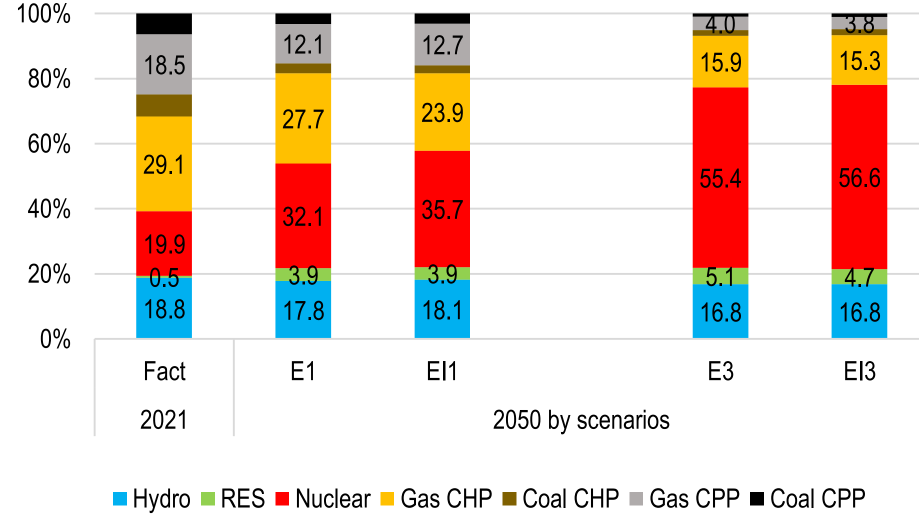
Source: ERI RAS forecast

CO2 emission quotas in power and district heating sectors: joint or individual?

Capacity mix, GW



Electricity production mix, %

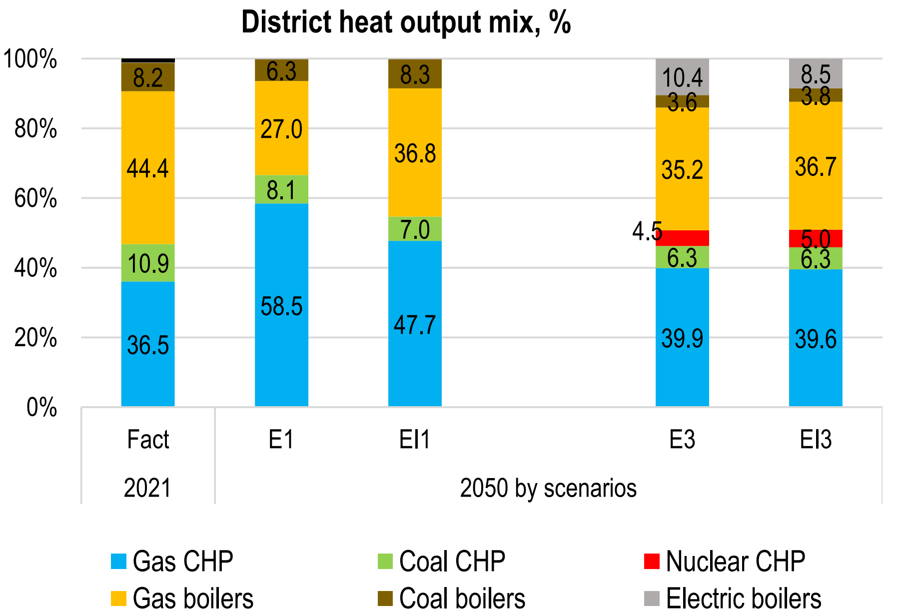


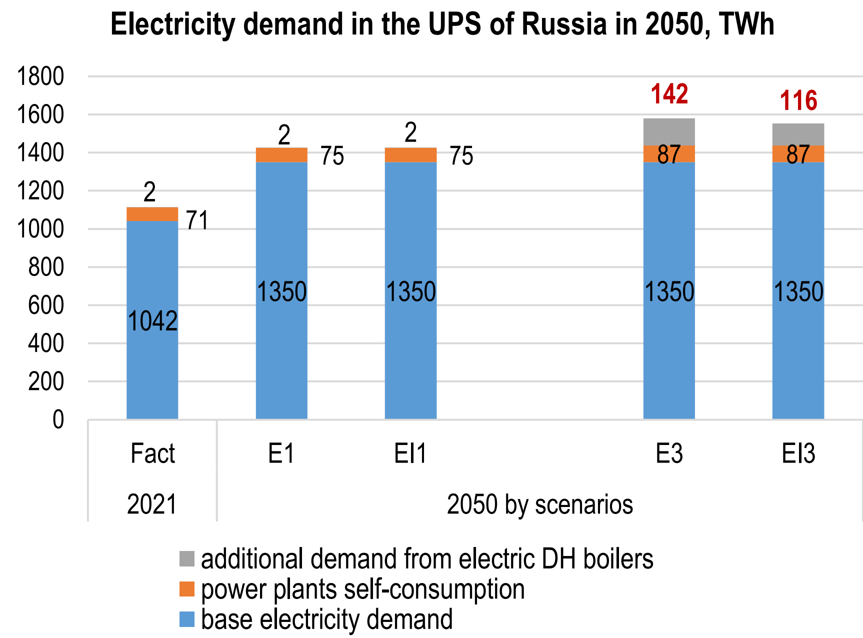
GW	2021	2050 by scenarios			
	Fact	E1	EI1	E3	EI3
Total installed capacity	246.7	288.3	285.4	317.3	310.2
Nuclear CHP (SMR)	-	-	-	9.1	10.1
CCS	-	-	-	0.4	0.5

	2021	2050 by scenarios			
	Fact	E1	EI1	E3	EI3
Share of non-carbon	39.3	53.9	57.8	77.6	78.4
Share of coal	13.2	6.3	5.6	2.8	2.9
Share of CCS				0.3	0.4

Source: ERI RAS forecast

CO2 emission quotas in power and district heating sectors: joint or individual?





%	2021	2050 by scenarios			
	Fact	E1	EI1	E3	EI3
Share of non-carbon	0.2	0.2	0.1	14.9	13.5
Share of coal	19.1	14.4	15.3	9.9	10.2
Share of gas	80.9	85.5	84.5	75.2	76.3

Source: ERI RAS forecast

CO2 emission quotas in power and district heating sectors: joint or individual?

Comparative analysis of the main characteristics of scenarios with joint and individual CO_2 emission quotas

	Scenarios			
	E1	EI1	E3	EI3
CO_2 emissions in 2050 г., % to 2019:	86	84	60	60
thermal power plants	59	79	57	60
DH boilers	96	86	61	60
Non-carbon share in electricity generation in 2050, %	53.9	57.8	77.6	78.0
Non-carbon share in DH generation in 2050, %	0.2	0.1	14.9	13.5
Fossil fuel consumption in 2050, % to corresponding scenario E:	-	-6.2	-	-0.1
natural gas	-	-7.4	-	-0.6
coal	-	-8.4	-	+2.5
Total capital requirements up to 2050, % to corresponding scenario E:	-	+4.7	-	+0.9
Nuclear	-	+13.7	-	+0.1
RES and hydro	-	+4.2	-	+6.2
Fossil power plants and boilers	-	-6.0	-	-1.4
Total discounted costs of electricity and heat supply (cost function value), % to corresponding scenario E	-	+0.3	-	+0.4

The difference between scenarios with joint or individual CO_2 emission quota is not very significant. The results show that the greatest differences in the technological structure of sectors are observed with fairly soft emission quotas. At the same time, the main economic indicators of the development of sectors do not change so obviously. However, in all considered scenarios, the transition from a joint quota to individual quotas leads to an increase in both capital and total discounted costs.

Source: ERI RAS forecast

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Thank you for attention!