

# Challenges of VRE and Nuclear Integration into Russian Power System: Current Status and Outlook

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Regional Meeting on Integrating Variable Renewable Energy Sources into Power Systems with a Focus on Nuclear Power (RER2018)

Dushanbe, Tajikistan, 7-11 April 2025



# Current Situation in Russian power sector



Kolskaya Wind Farm. World's largest wind farm above the Arctic circle (202 MW)



Kolskaya Nuclear Power Plant

# Russian Unified Power System (UPS)

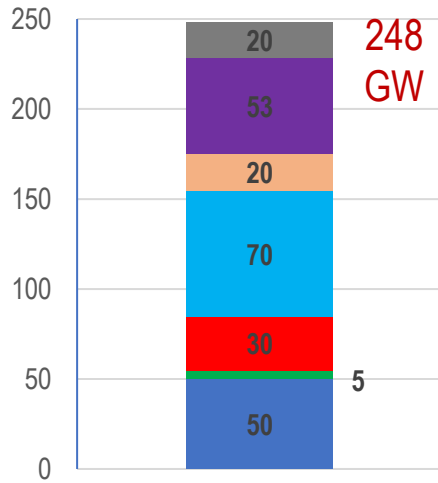
- 75 regional power systems spanning over 6000 km and 8 time zones
- 7 integrated power systems (IPS)
- > 600 power plants with installed capacity of around 250 GW
- > 3 200 000 km of power lines, of which 500 000 km of HV (110kV and higher) transmission lines
- > 1 000 000 MVA of transformers capacity
- Works in synchronous mode with power systems of 7 countries



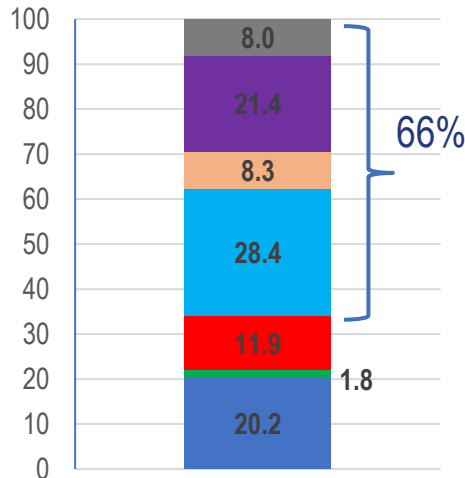
# Capacity and generation mix in Russian UPS in 2023

## Capacity mix

GW

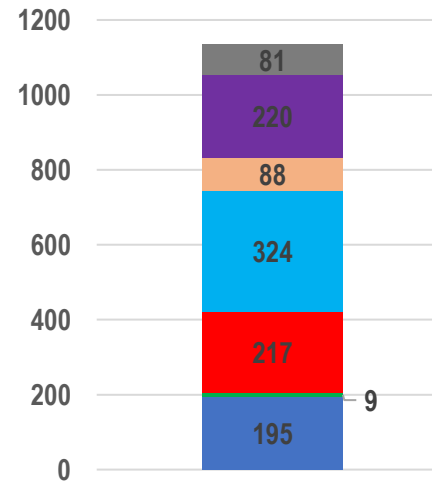


%

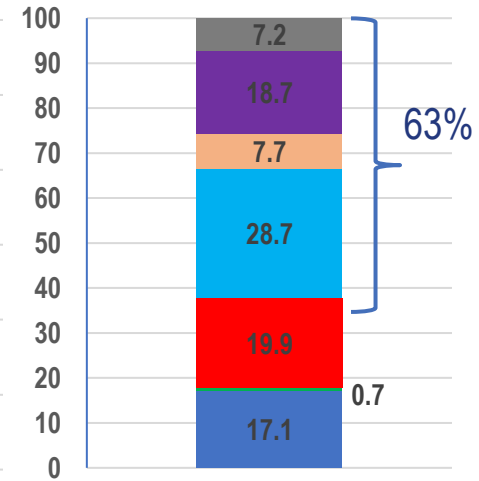


## Generation mix

TWh



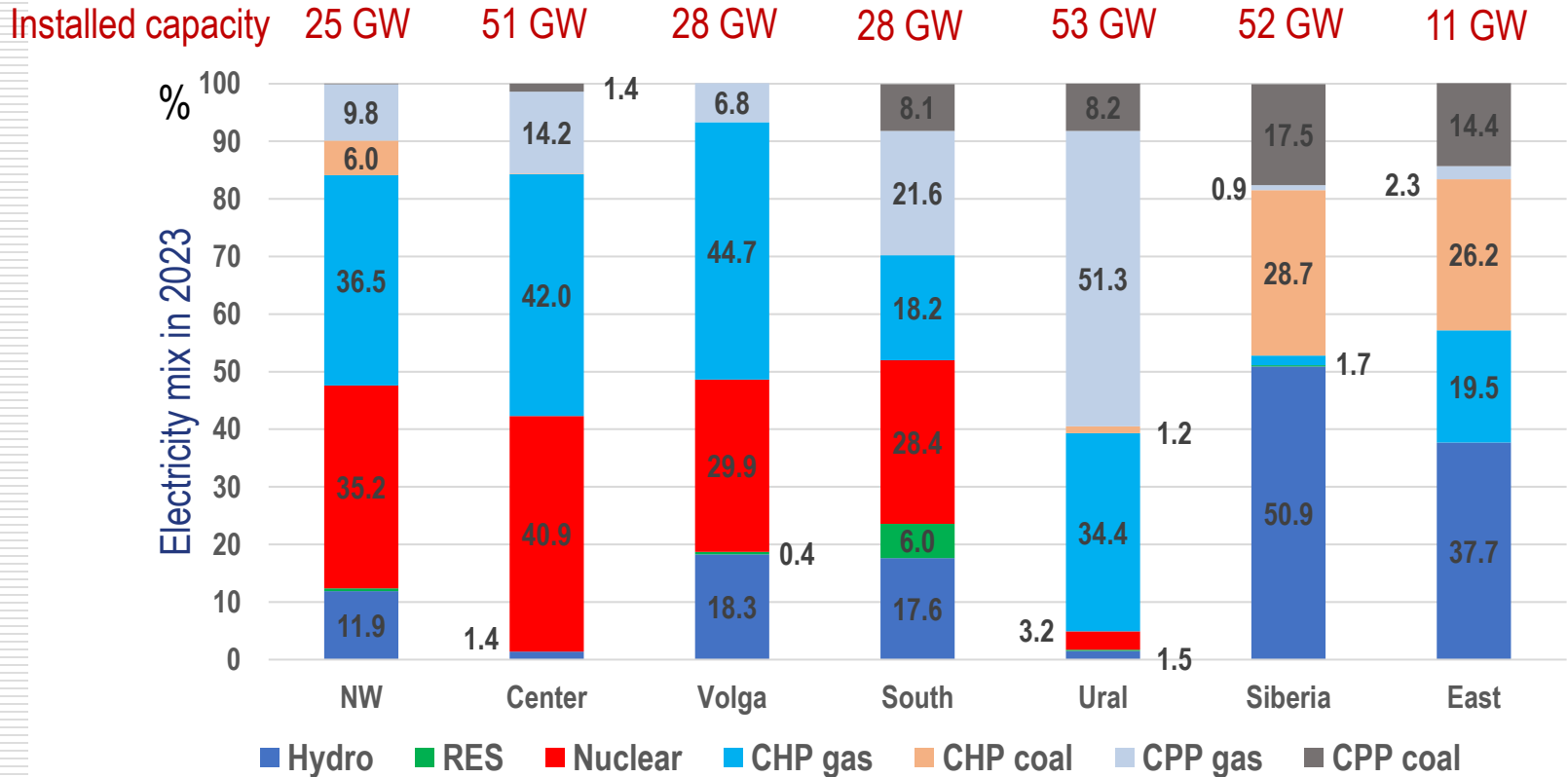
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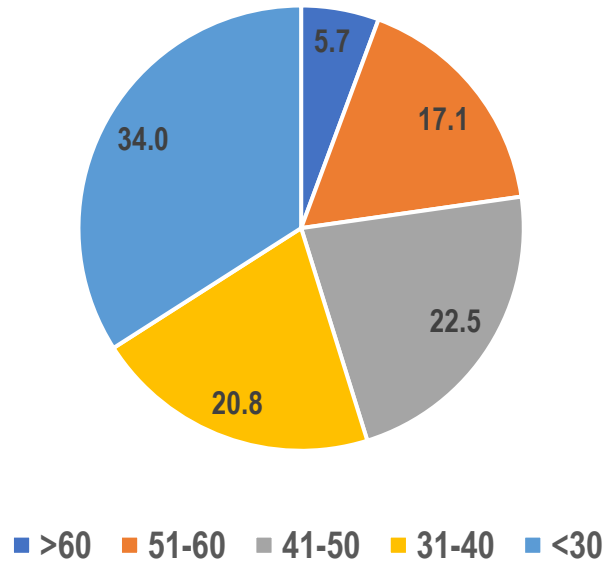
■ Hydro ■ RES ■ Nuclear ■ CHP gas ■ CHP coal ■ CPP gas ■ CPP coal

Maximum load – 171 GW. Electricity consumption – 1134 TWh

# Generation mix differs greatly over the regions



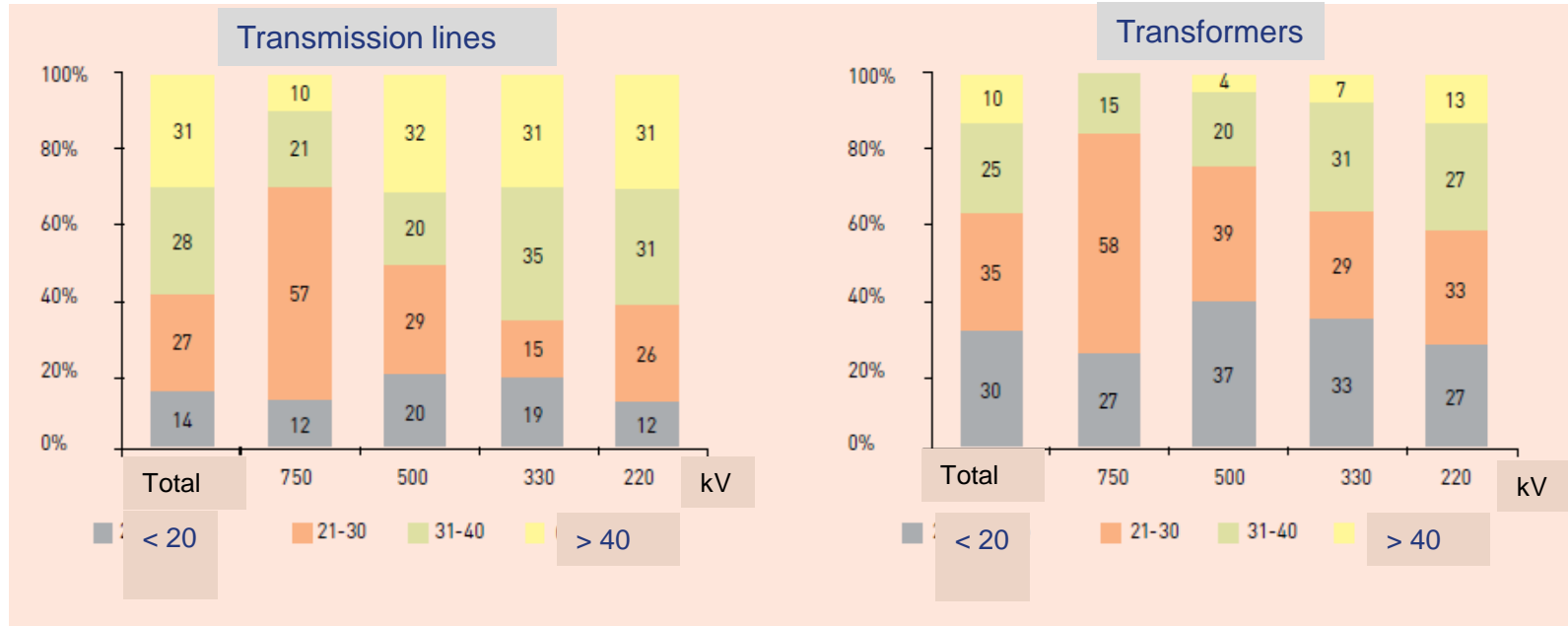
# Ageing generation capacities



***State Power Plant-1 in Moscow. Built in 1897***

Only 34% of the power plants are younger than 30 years. And only 55% – younger than 40.

# Ageing grid infrastructure



- Despite recent large investments in grid renovation about 1/3 of transmission lines and 10% of transformers are still in operation for more than 40 years.
- Situation in distribution grid is much worse



# Current and Planned Nuclear Power Development in Russia

11 nuclear  
power plants

36  
generating  
units

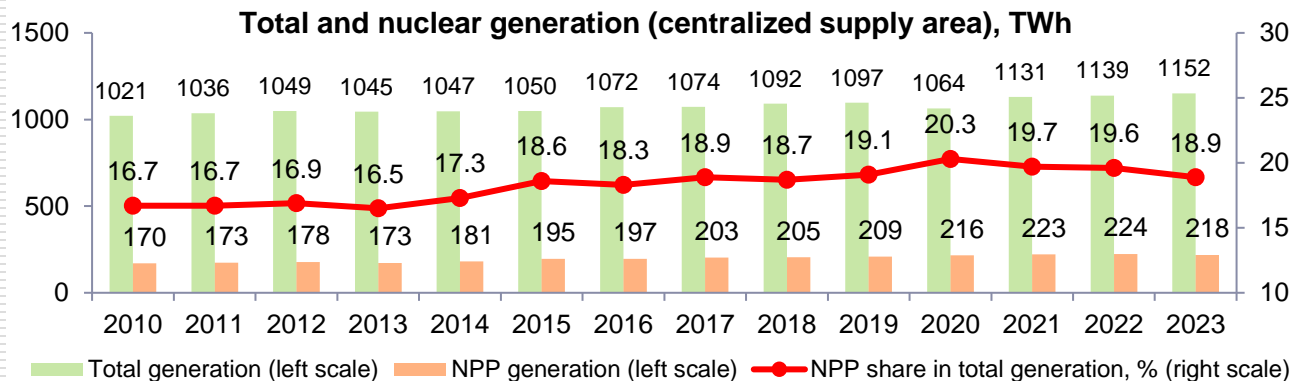
28,5 GWe



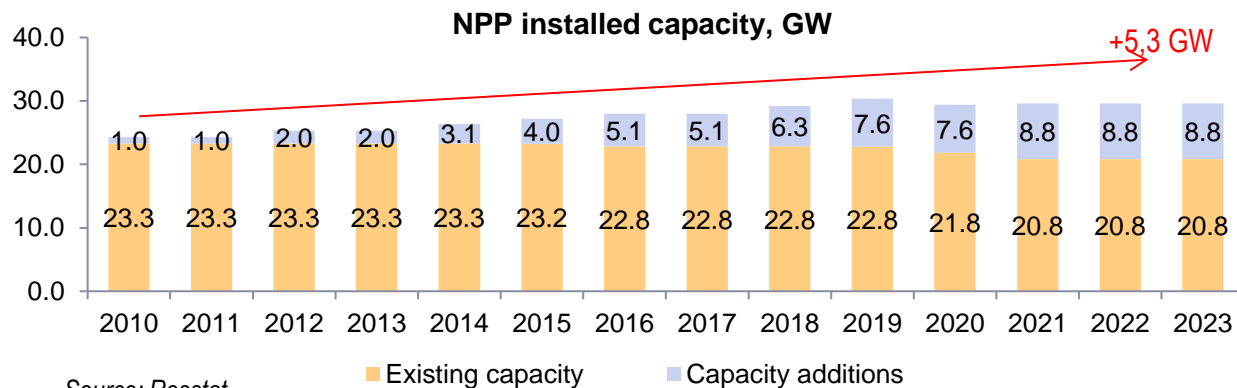
*Most of the Nuclear Power Plant are located in the European part of the Russia*



# Nuclear Power Has Been Growing but Not Very Fast



+ 4,24 GWh (or 15,6 PJ) of heat from NPP units in 2022



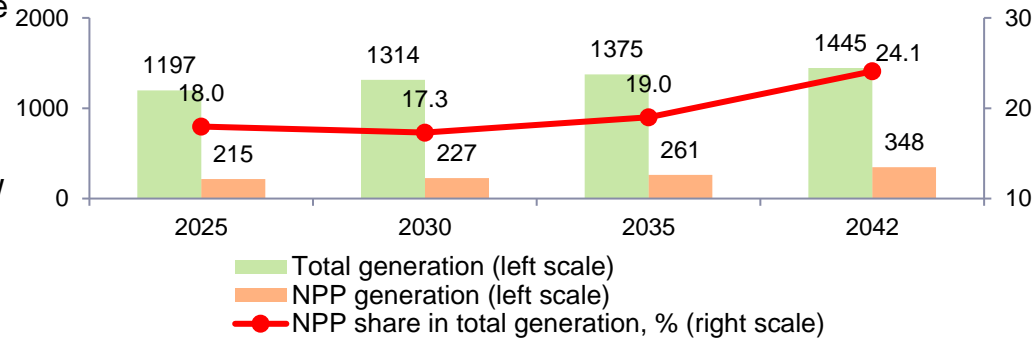
Less than one unit per year have been put online since 2010

Source: Rosstat

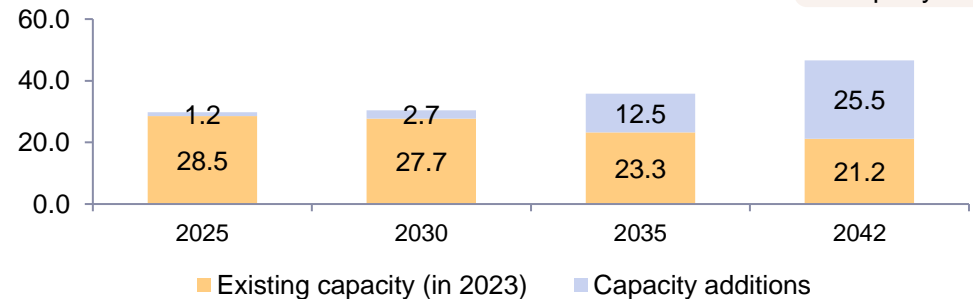
# Approved plans of NPP development in Russia

- In December 2024 RF Government approved the revised “Plan of power sector development up to 2042”
- To **2042**:
  - NPP installed capacity will reach 46,7 GW
  - Up to 25,5 GW of new nuclear capacities should be commissioned to replace the existing units and cover the increasing demand
  - PWR VVER-1200 (1200 MW) is going to be the main type of new units
  - 2 fast reactor units will be built also:
    - BN-1200 (1255 MW sodium-cooled)
    - BREST-OD-300 (300 MW lead-cooled)
- Strategic goal for **2045**: nuclear plants should produce >25% of electricity in Russia

Total and NPP generation (UPS of Russia), TWh



NPP installed capacity, GW



Almost 1,5  
GW per year

Source: RF Government/Ministry of Energy

# SMR development for Northern and Arctic regions

## Today in operation

Chukotka (Arctic) region:

- Bilibino NPP 3x12 MW (operating since 1974)
- Floating NPP “Academic Lomonosov” (PWR **KLT-40S**) 2x35 MW

## Up to 2035 Construction or design stage

Tomsk region (West Siberia)

- FBR **BREST-OD-300** (300 MW)

Yakutia (Arctic) region:

- Onshore NPP (PWR **RITM-200N**) 2x55 MW
- Onshore CHP (**ELENA** thermoelectric unit) 2x200kWe/7MWth

Chukotka (Arctic) region:

- 4 x Modernized floating NPP (PWR **RITM-200S** 2x53 MW each)
- Onshore **SHEL’F** PWR unit 1x10 MW

## Next 10 years Possible projects

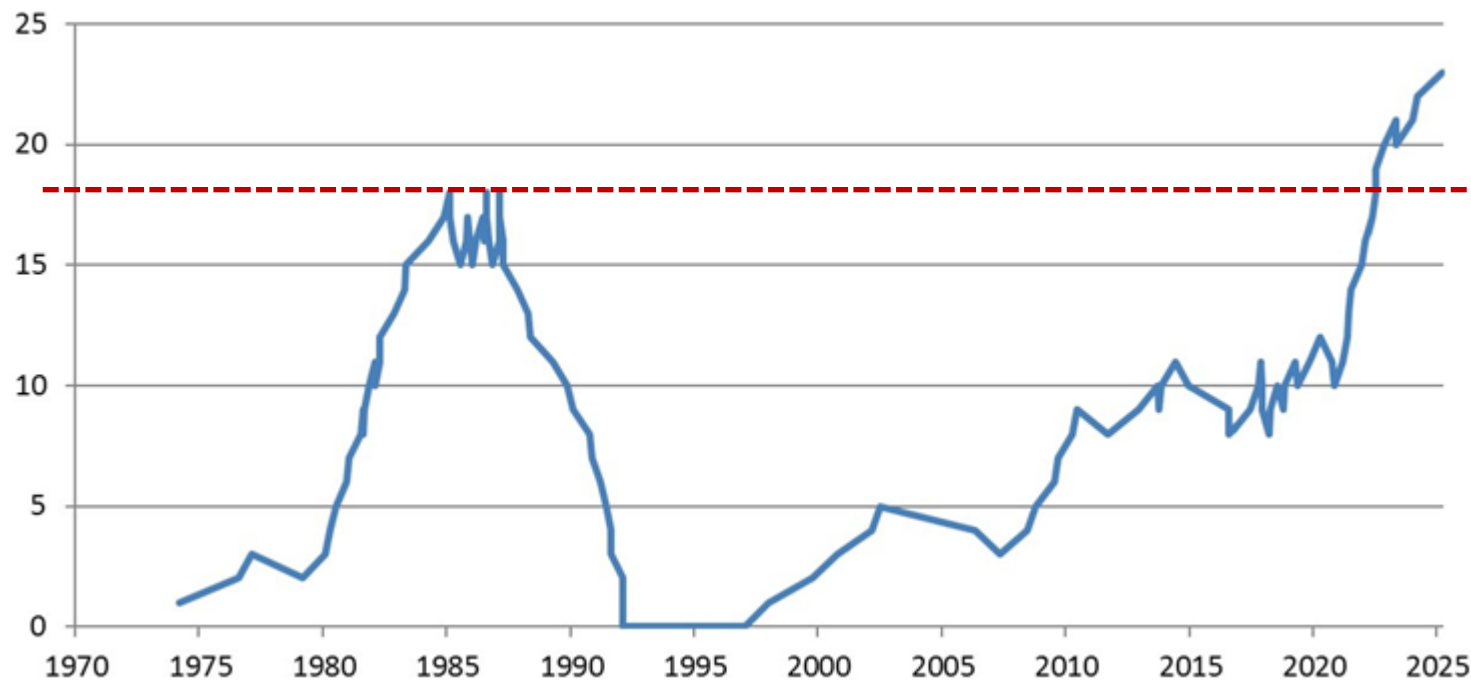
Noril’sk (Arctic) region:

- Onshore NPP (PWR **RITM-400**) 4x80 MW

Far East region:

- Up to 5 x Modernized floating NPP (PWR **RITM-200S** 2x55 MW)

## VVER-1000+ Reactors under Construction (Russia and Abroad)



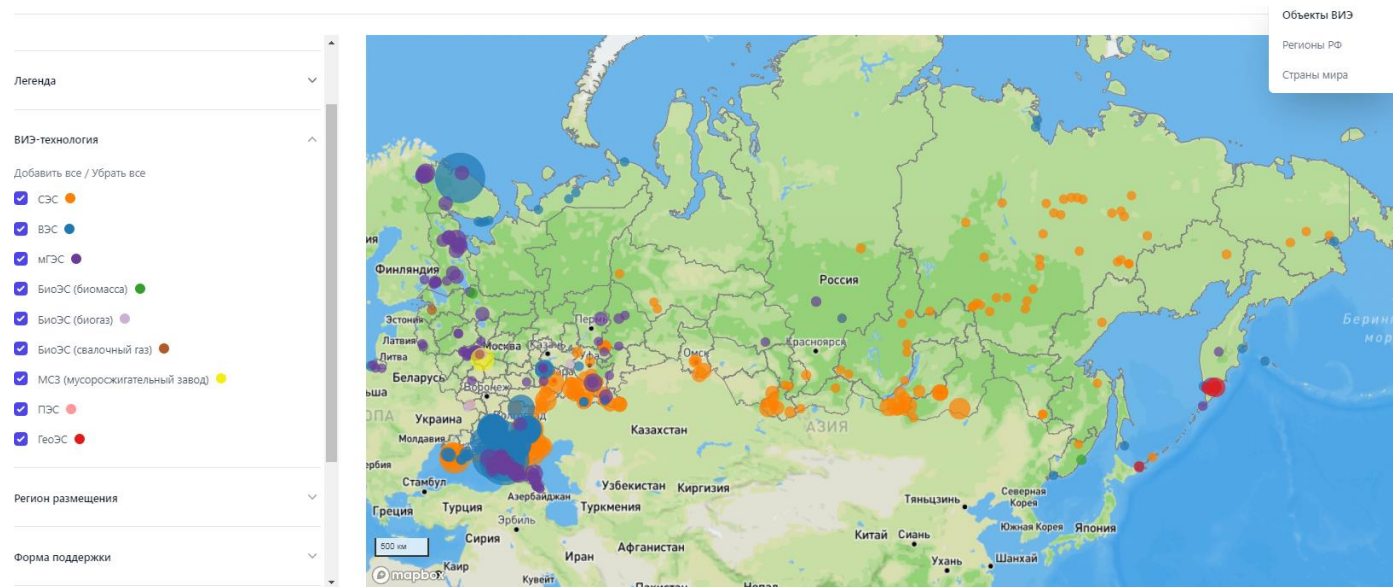
Currently, there are more VVER reactors under construction than there were during the heyday of the Soviet nuclear industry

# Current and Planned RE Power Development in Russia

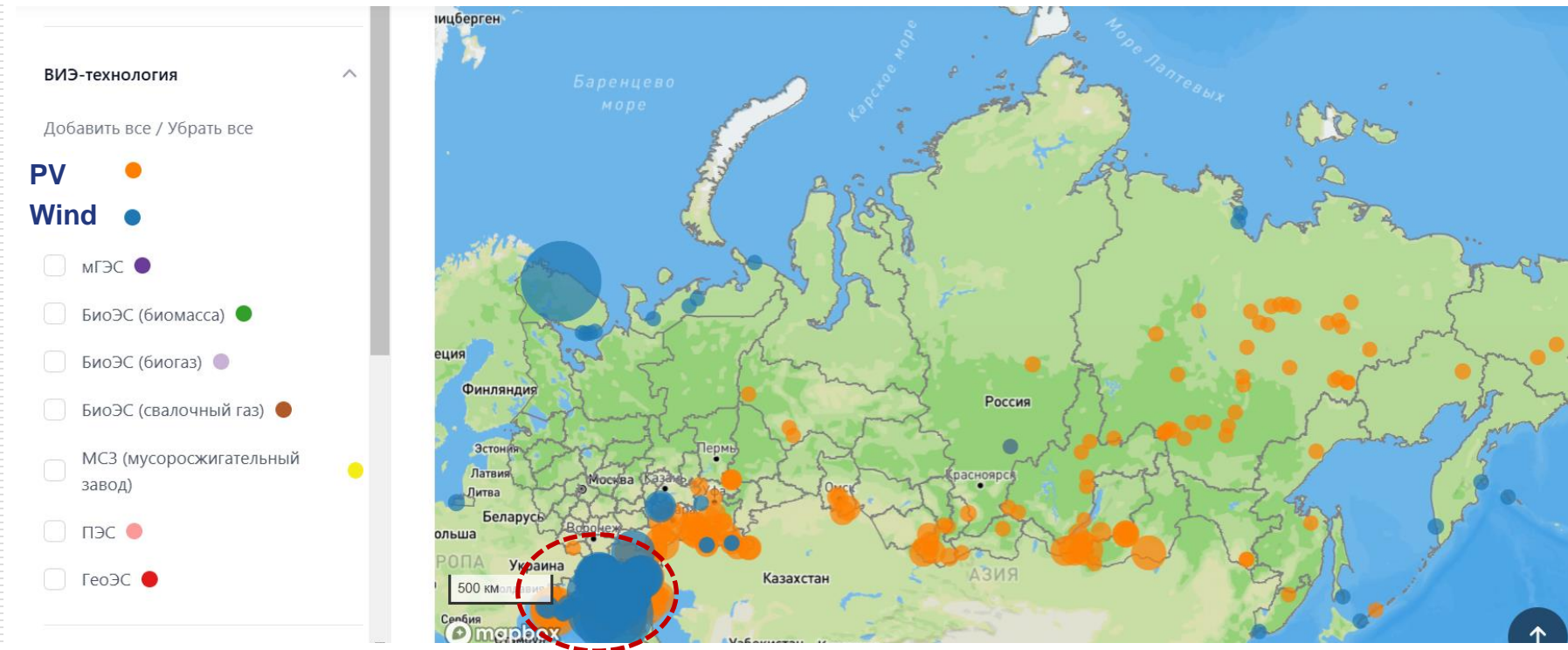
~120 RE  
power plants  
(VRE + small  
hydro + Geo)

6,5 GW  
(in 2024)

14,2 TWh  
(in 2024)



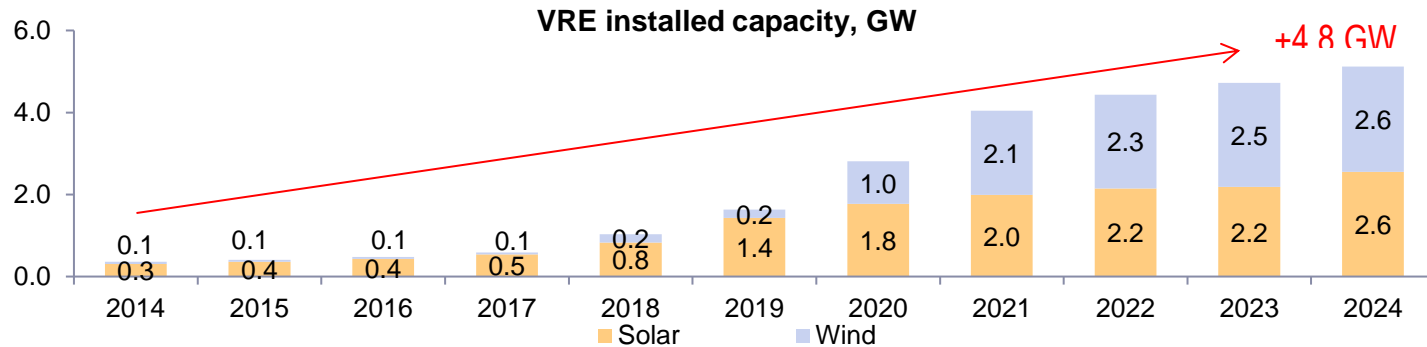
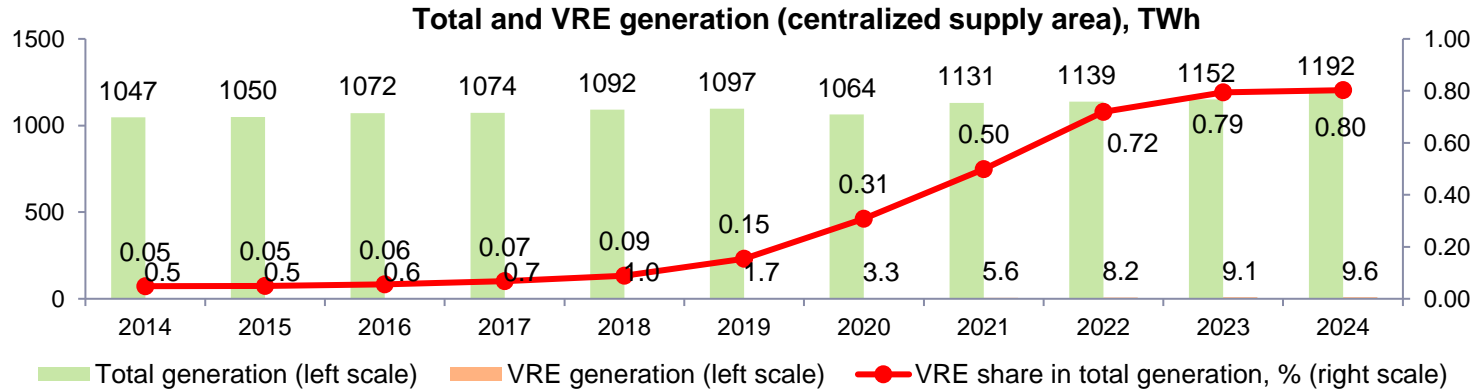
# Current and Planned RE Power Development in Russia



*Most of the VRE capacities are situated in IPS South with most favorable climatic conditions...  
but with quite limited demand*



# VRE Power Has Been Booming in 2018-2021, some projects were delayed since 2022

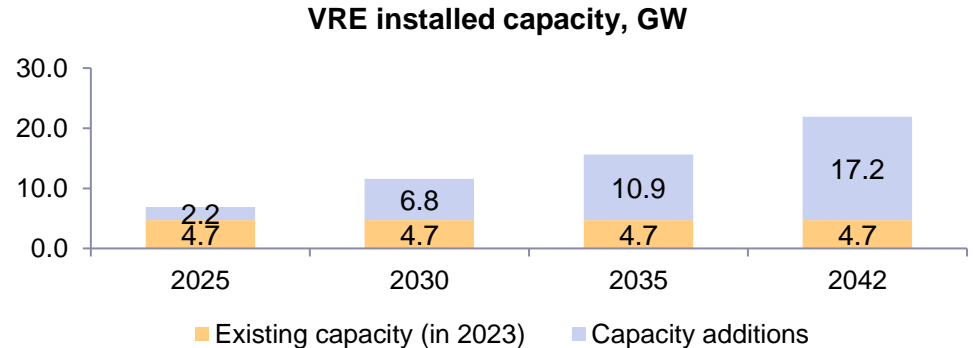
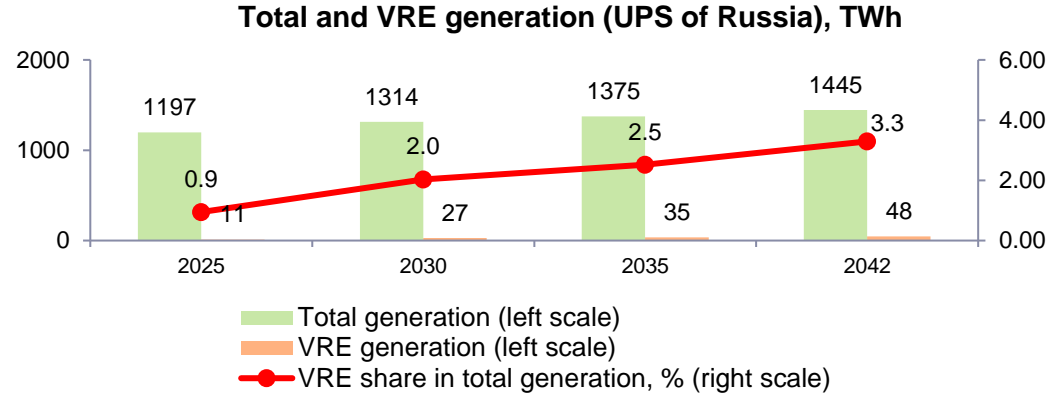


~700 MW per year in 2019 - 2022

Source: RREDA

## Approved plans of VRE development in Russia

- In December 2024 RF Government approved the revised “Plan of power sector development up to 2042”
- To **2042**:
  - VRE installed capacity will reach 21,9 GW
  - Up to 17,2 GW of new VRE capacities should be commissioned
  - Split between solar and wind is not fully decided
  - Further development of VREs in IPS South **should be limited due to integration issues**
  - Most of the VREs should be built in IPS Siberia and IPS East where faster demand growth is expected



Source: RF Government/Ministry of Energy

## Some VRE Integration Issues in Russia

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

RE Generation, GWh

Regional DSO	2020	2022
Kalmykia	0	1325
Rostov	663	1867
Volgograd	0	503

Network Losses, GWh

Regional DSO	1 <sup>st</sup> half 2020, GWh	1 <sup>st</sup> 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”

## Some VRE Integration Issues in Russia

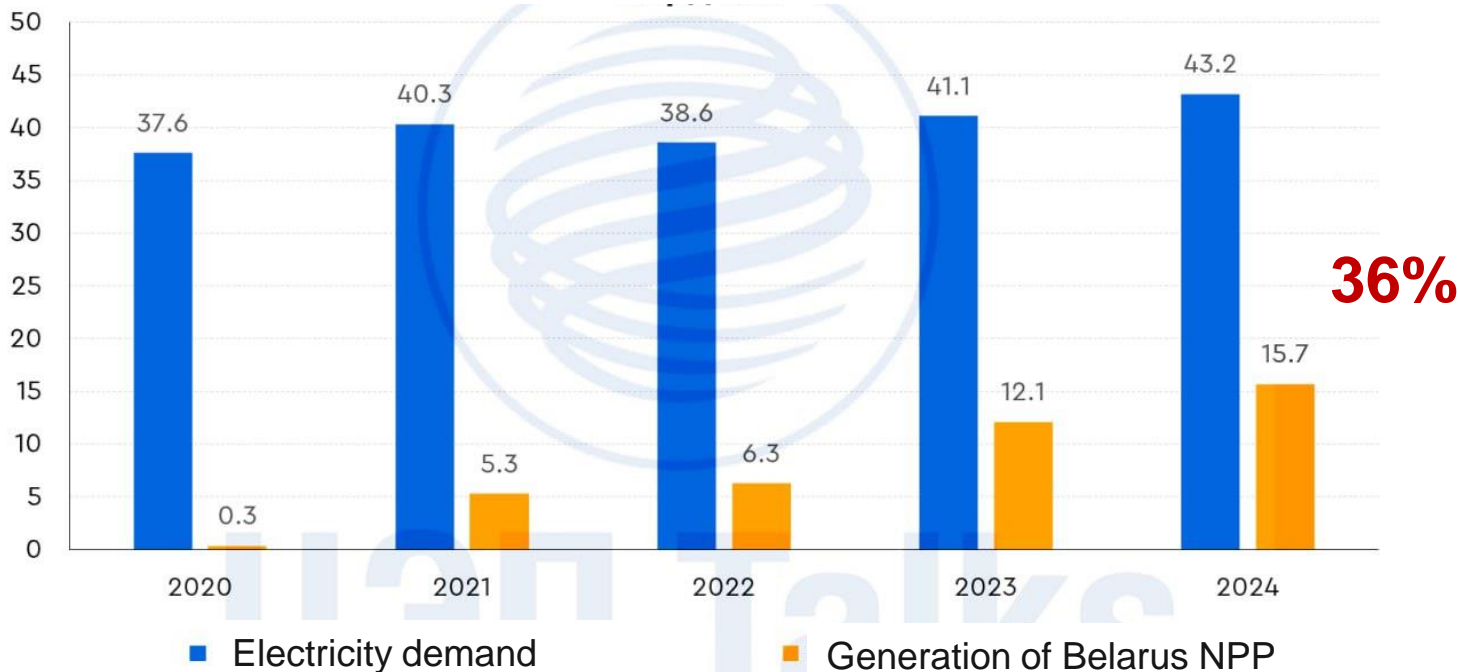
### VRE curtailment grows fast, especially for wind power plants...

	Number of hours with curtailment				Maximum curtailment, MW				Curtailment, GWh			
	2021	2022	2023	2024	2021	2022	2023	2024	2021	2022	2023	2024
Solar	0	20	15	60	0	26	52	477	Not disclosed by SO			
Wind	56	235	2150	3251	475	372	347	1341	Not disclosed by SO			

Mainly due to System operator commands and Automatic Power and Frequency Control devices

**Starting July 2024 all VRE sites should be approved by System operator**

## Electricity demand and Belarus NPP generation, TWh



Источник: оценка ЦЭП ГПБ

## Nuclear Integration Issues: Case of Belarus

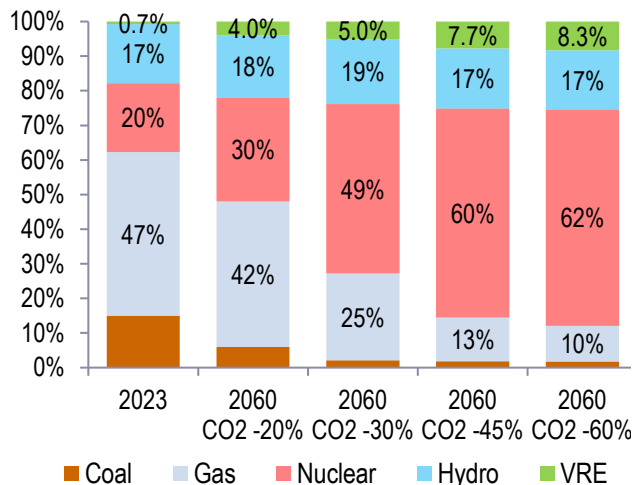
What was done to integrate NPP in Belarus power system:

- 1) **Power network upgrade:** 1000 km of new HV lines, 1 new 330 kV substation, 700 km of upgraded HV lines and 4 upgraded HV substations
  - 2) **Peaking and reserve power sources:** 800 MW of OCGTs at 4 different sites were build for this purpose. 400 MW were already in the system.
  - 3) **Large and flexible electricity consumers:** 916 MW of DH electric boilers (some with heat storages) at 20 sites were build to efficiently use of excess electricity (at night) and increase the flexibility of the power system
- ...and now they are thinking about another 2-unit NPP

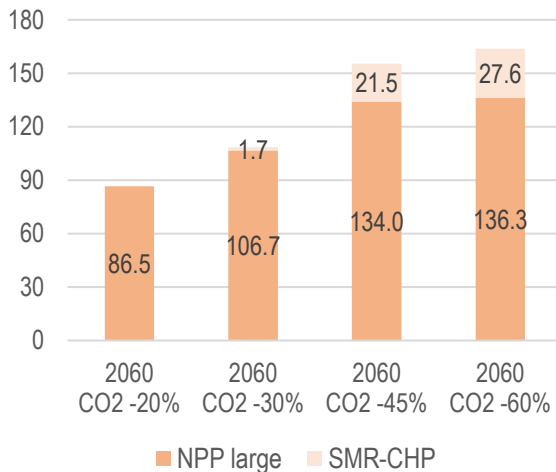


# Long-term projections to 2060. ERI RAS Modelling Results

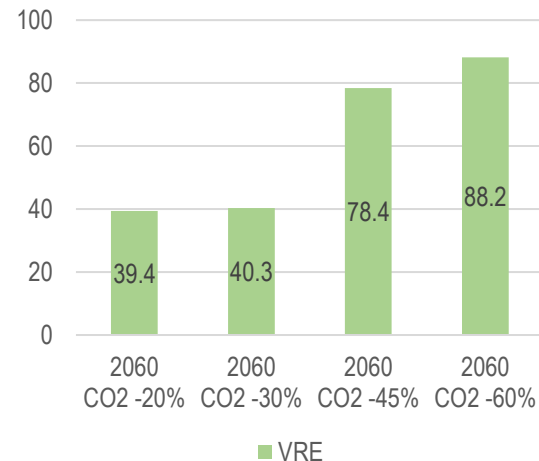
## Electricity production structure in 2060



## NPP Capacity, GW



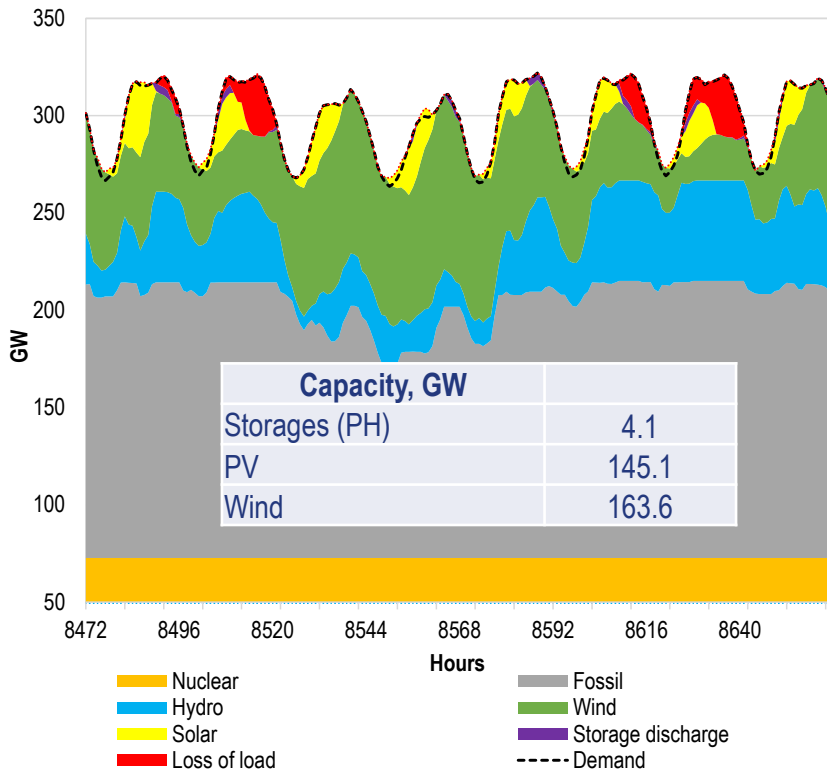
## VRE Capacity, GW



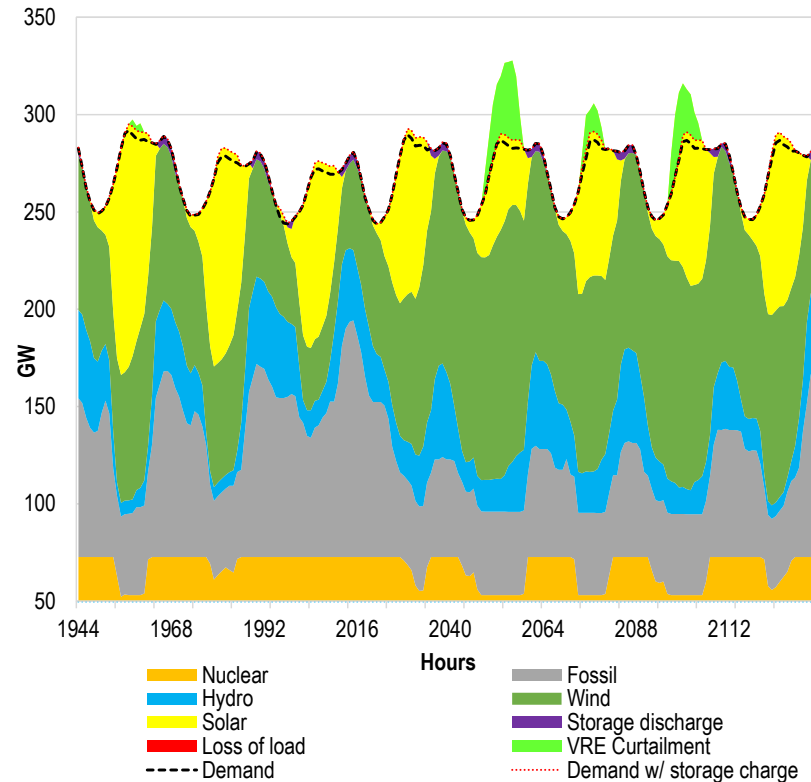
- Russia should focus on nuclear development in decarbonization scenarios.
- To meet most ambitious GHG targets, NPP capacity of large NPPs in 2060 should exceed 130 GW. In addition, up to 30 GW of CHP with SMR will be required. Total share of nuclear in electricity generation may reach 60%
- VRE development will be noticeable only in most ambitious scenarios, where their capacity will rise up to 90 GW in 2060. But VRE share in electricity production will be around 8%

# Long-term projections to 2060. ERI RAS Modelling Results

High VRE scenario, December 2060, no flexibility measures

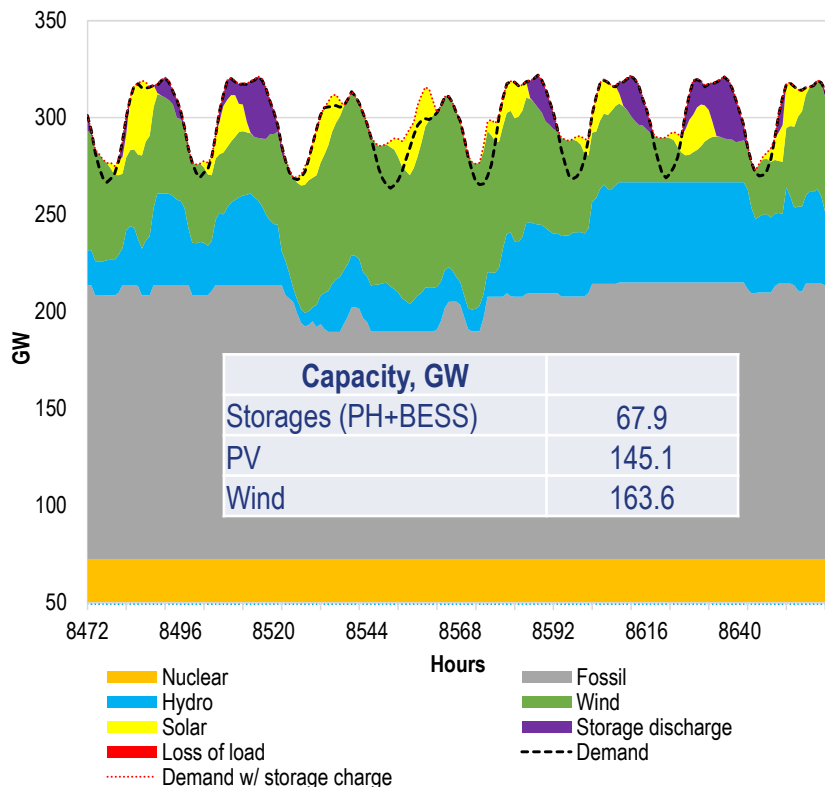


High VRE scenario, March 2060, no flexibility measures

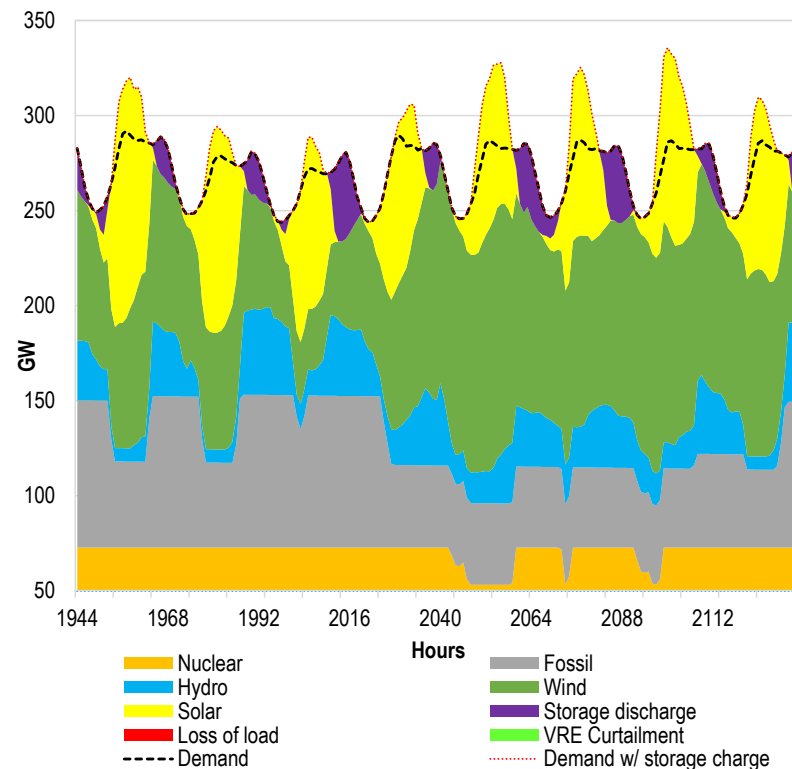


# Long-term projections to 2060. ERI RAS Modelling Results

High VRE scenario, December 2060, storages allowed



High VRE scenario, March 2060, storages allowed



# The Energy Research Institute of the Russian Academy of Sciences

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# Thank You for Attention!