Carbon avoided costs for the low-carbon technologies in Russia and EU

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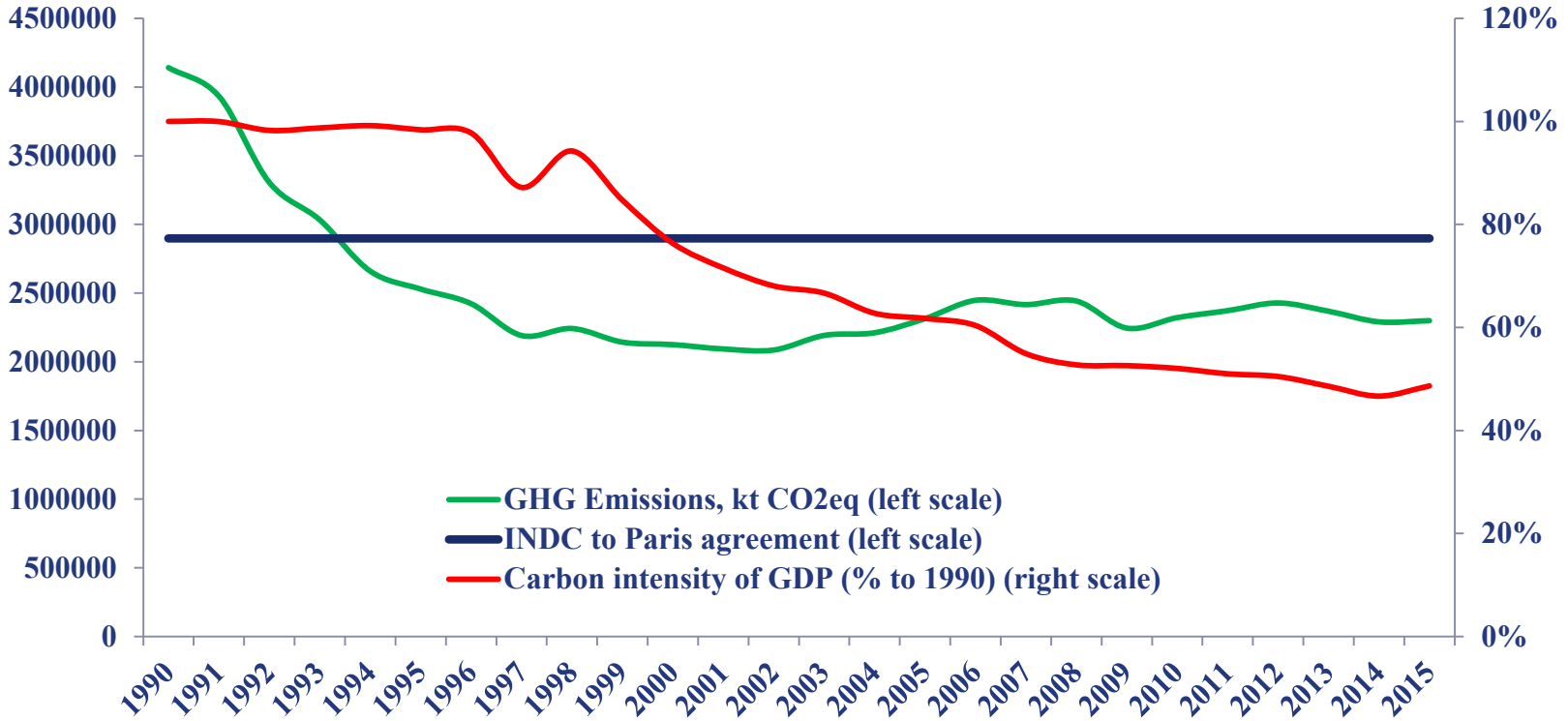
GHG Emissions in Russia



Источники: Второй двухгодичный доклад Российской Федерации, представленный в соответствии с Решением 1/CP.16 Конференции Сторон Рамочной Конвенции Организации Объединенных Наций об изменении климата. Москва, 2015 г. Обзор состояния и загрязнения окружающей среды в Российской Федерации за 2015 год. Росгидромет РФ. Москва, 2016.

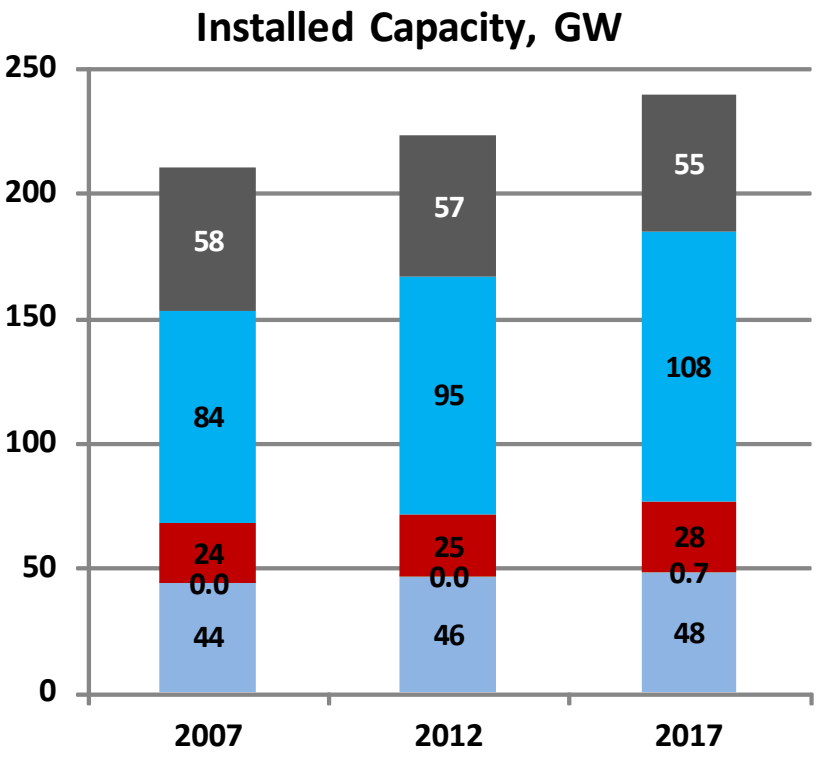
Russia has signed the Paris agreement but yet to ratify it. Even if Russia ratifies it with submitted INDC we will have the considerable positive gap between the actual emissions and possible limitation.

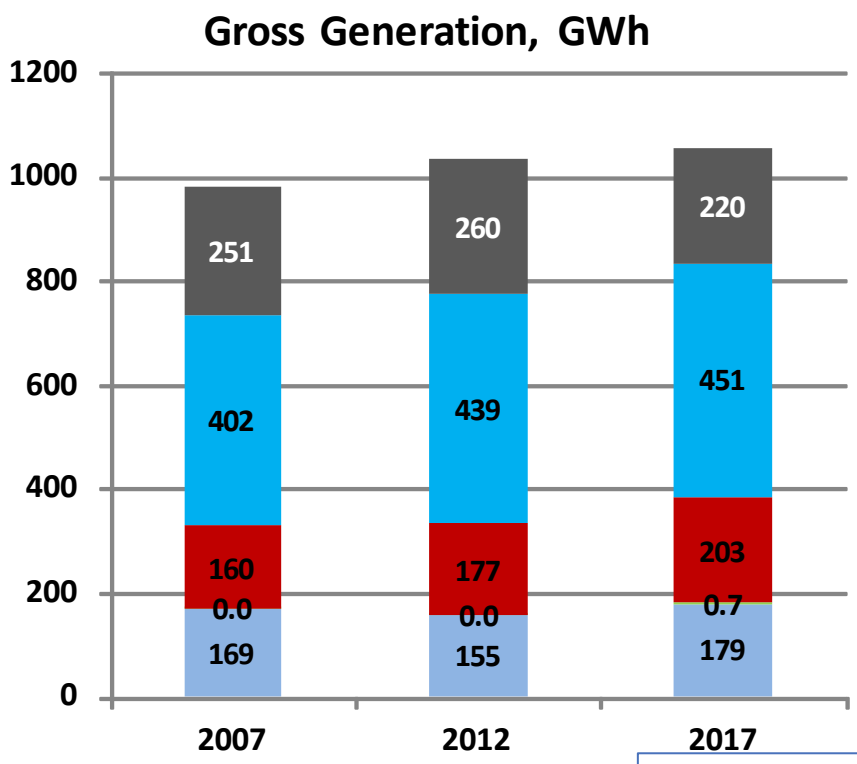
At present, mitigation of GHG emissions is NOT one of the main concerns for Russian Government.

Carbon avoided costs as a marker of carbon price

- Power sector forms >25% of GHG and >35% of national CO_2 emissions nowadays
- Power sector will be the main area of GHG mitigation through the unique technological opportunities for the inter-fuel competition and competition between fossil fuels and renewables
- Carbon avoided costs in electricity generation will form the long-term basis for carbon taxes and/or prices

Russian Power Sector at a Glance – Present



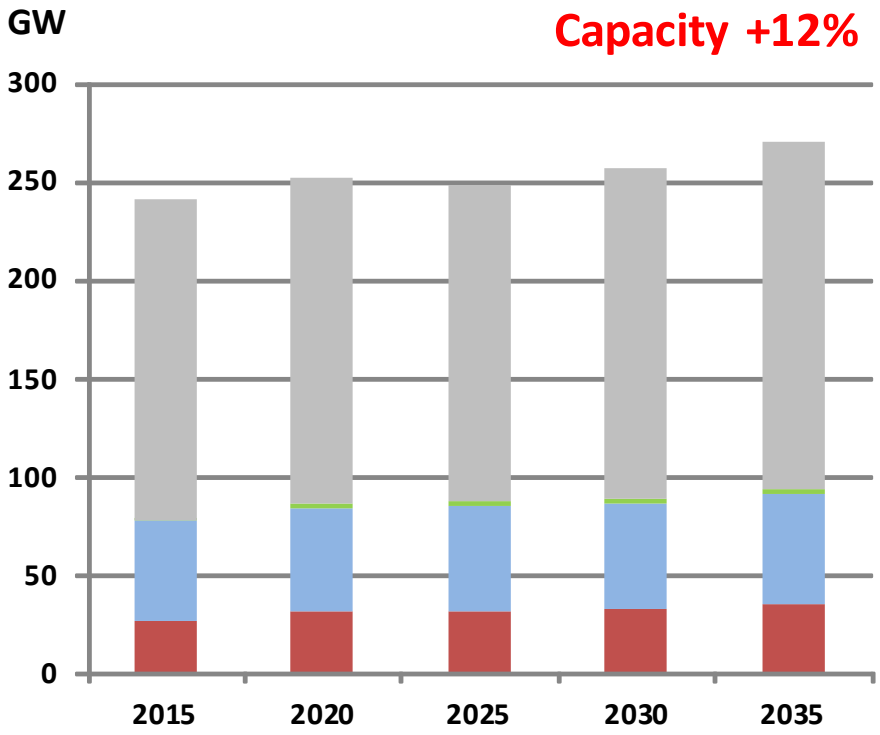


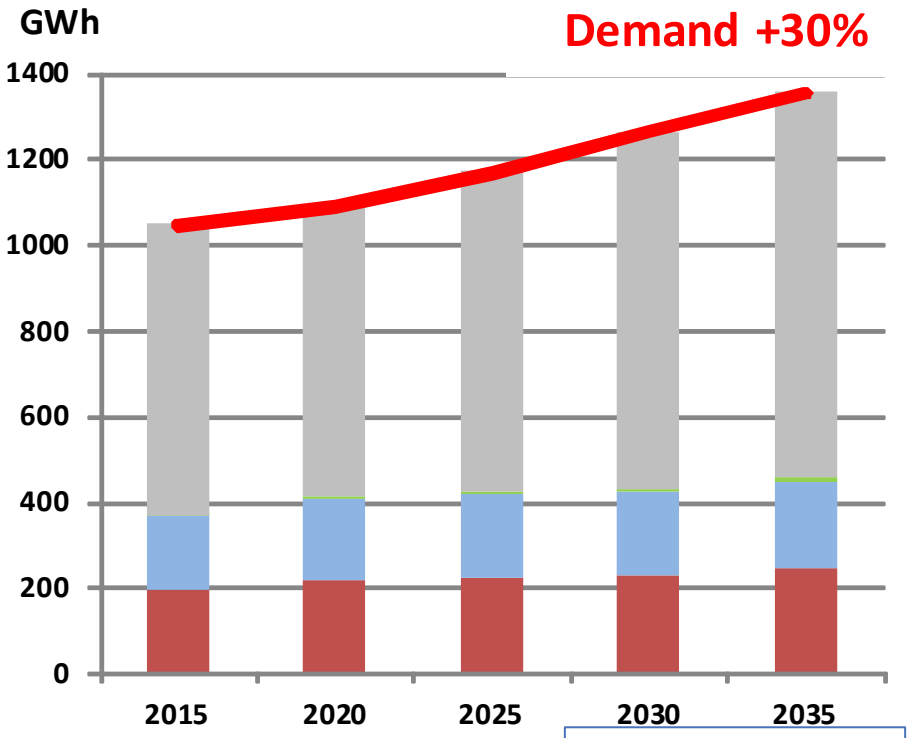
Hydro Solar+Wind Nuclear Gas Coal

*All data for IPS of Russia

- Slow growth of electricity demand (only +7% over 10 years), but 2x faster growth of available capacities (+14%) => big amount of spare capacities (≈30 GW)
- Mainstay of the power sector is GAS-fired generation–45% (of which 55% - CHP)
- Considerable share of non-carbon generation – 36%, but share of solar and wind is negligible (0,1%, 700 MW installed)
- Only 20% of TPPs has up-to-date equipment (efficient CCGT, OCGT)

Russian Power Sector at a Glance – Future: Latest General Scheme of Russian Power Sector Development





Nuclear Hydro RES Fossil Demand

*All data for IPS of Russia

Main Investment Priorities up to 2035:

- Modernization of existing TPPs (about 50 GW)
- New nuclear reactors (VVER-TOI, "Fast" Reactors) – up to 22 GW
- RES (Solar & Wind) – at least 3 GW (later increased to 5 GW)
- New effective Thermal Power Plants – CCGT (localized) + Coal USC
- Smart-grids and demand response

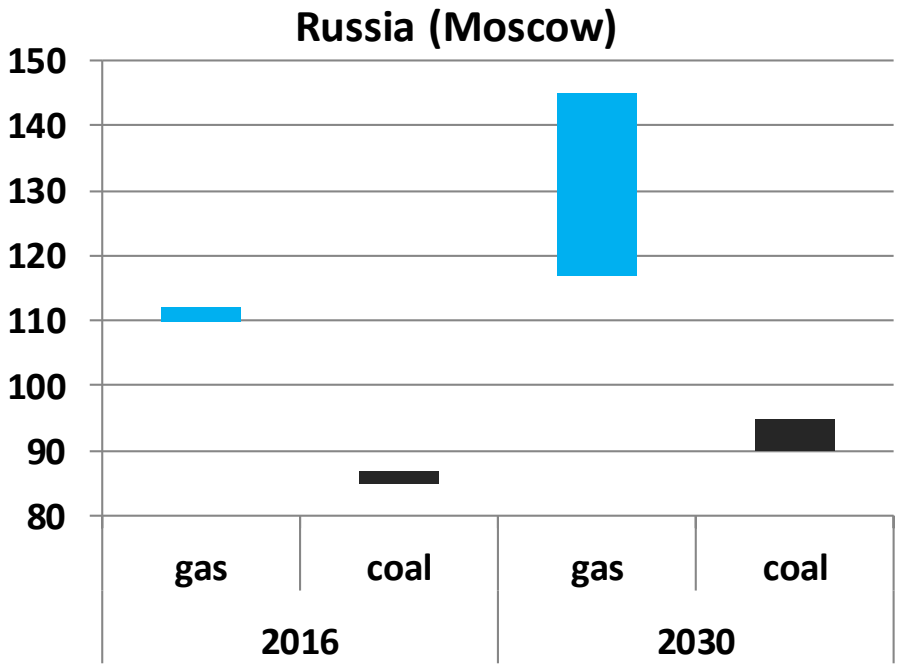
Methodology of CAC calculation

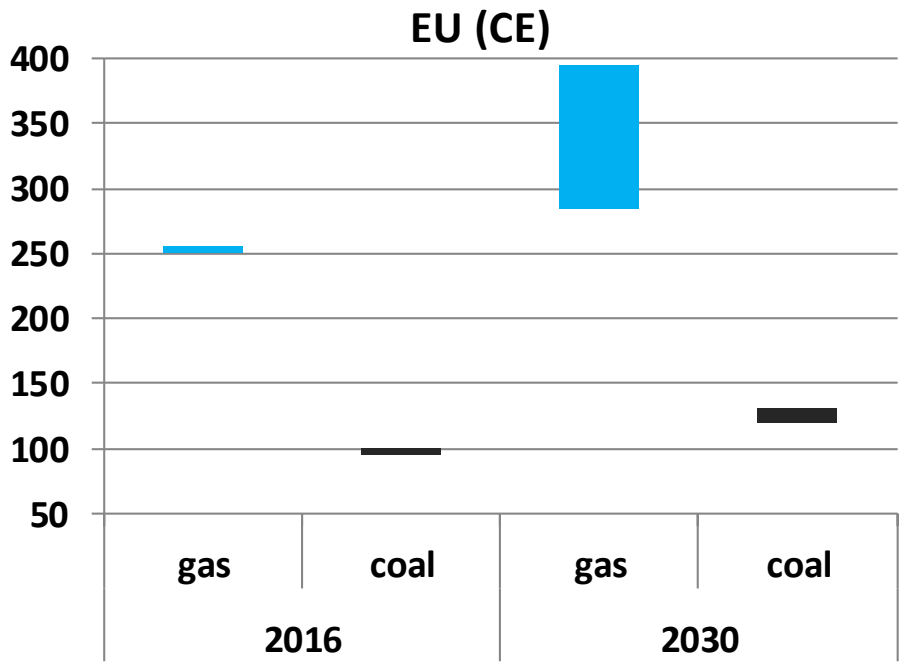
$$CarbonAvoidedCosts_{alt} = \frac{(LCOE_{alt} - LCOE_{ref})}{(Emission_{alt} - Emission_{ref})}$$

Main assumptions:

- Coal USC plant as a **REFERENCE** technology;
- LCOE calculations do **NOT** take into account:
  - EU ETS carbon prices;
  - tax, investment and other support measures for RES;
- Discount rate – **10%**;
- We assumed that all wind and solar capacity is unstable and must be **RESERVED** by:
  - existing thermal generation (+O&M costs to maintain the availability of existing gas/coal fired plants are included in LCOE) or;
  - new open cycle gas turbines (1-to-1) (+ capital costs of OCGT + O&M costs of OCGT) or;
  - new storage capacity (from 50% to 100%) (+ capital costs of storage + O&M costs of storage + additional losses due to the storage efficiency).

Assumed Fuel Prices in Russia and EU, $2016/toe

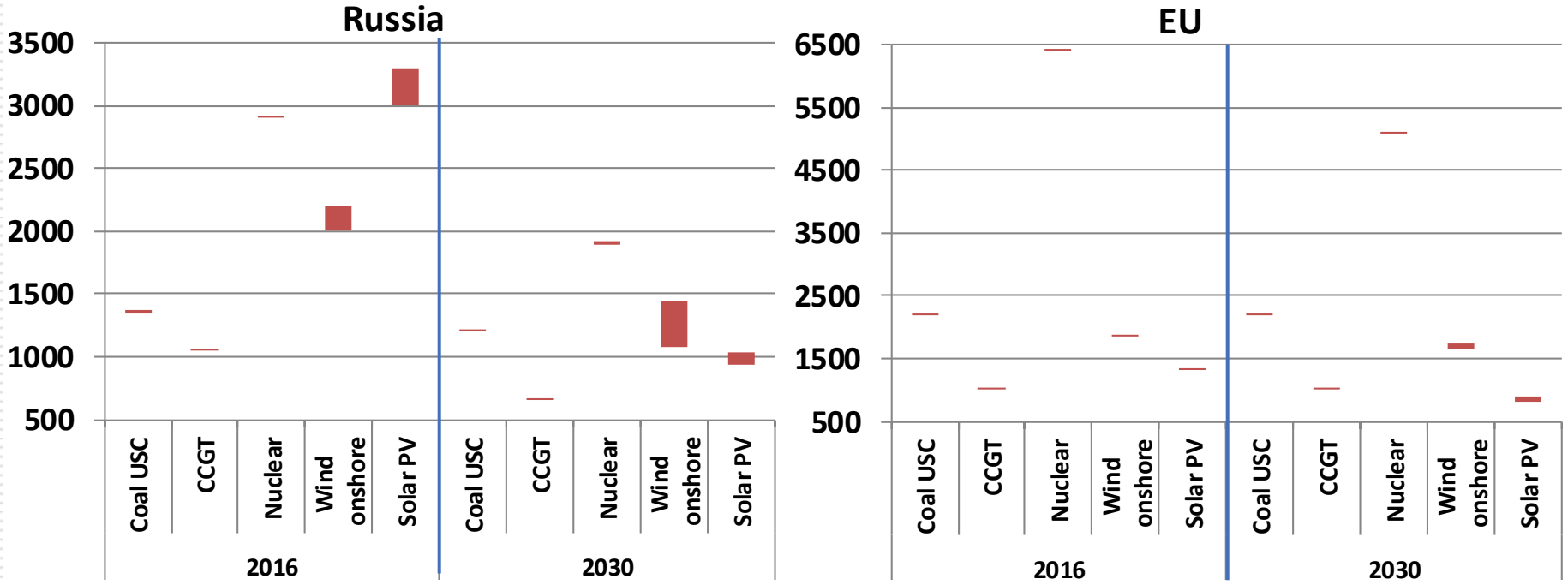




- Currently, Russia maintains regulation of domestic gas prices and their level is about 2.5 times lower than in EU
- It seems realistic that Russian policy of keeping the growth of gas prices around inflation will continue up to 2030. It will keep the 2-3 times gap between gas prices in Russia and the EU
- Despite the fact that coal prices in Russia are formed using market mechanisms, they still will be lower than in the EU by 20-30%

Source: for Russia – ERI RAS forecast, for EU – based on Columbia University (2018). The Role of Natural Gas in Europe's Electricity Sector Through 2030.

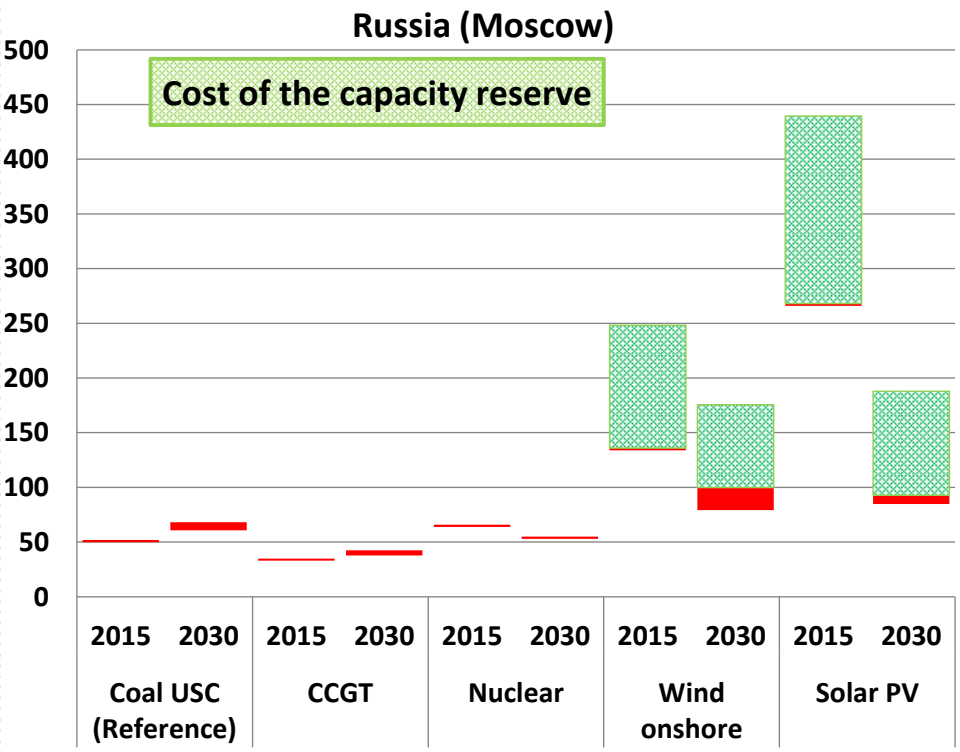
Assumed Capital Costs for Russia and EU, $2016/kW

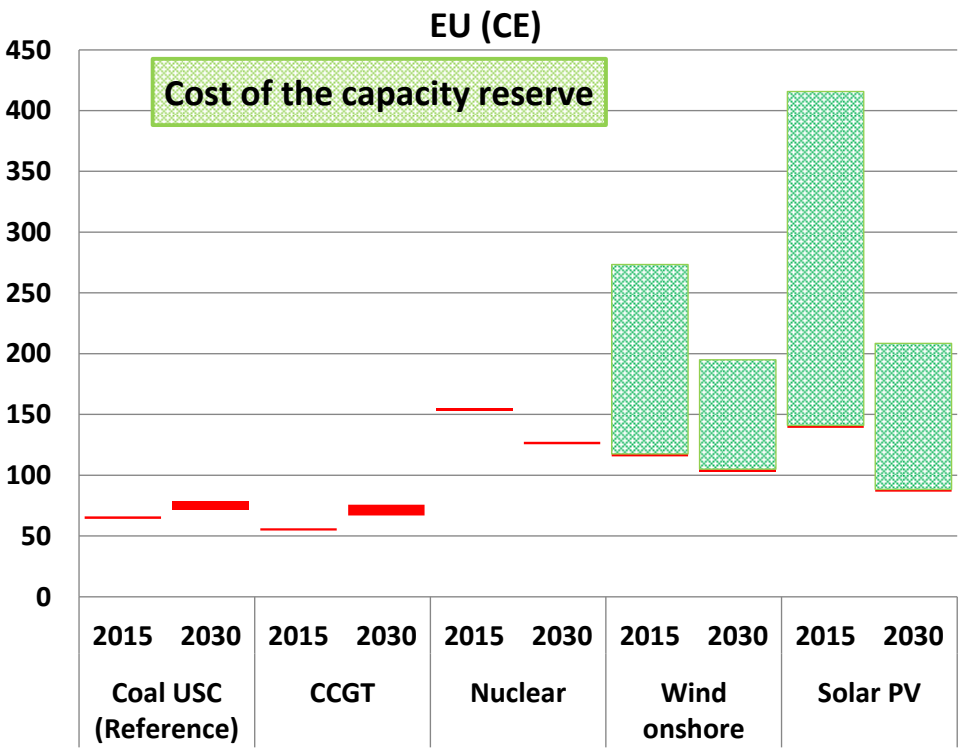


- Until recently, the development of large CCGT and RES in Russia was based on the imported equipment. This made their cost almost equal in Russia and the EU.
- However, a sharp drop in the ruble exchange rate and imposed sanctions made imported equipment too expensive or difficult to acquire. This led to the launch of a government localization program.
- Its implementation is already bringing results. At the 2018 auction for RES PPA capital costs of wind decreased 2 times, solar PV – almost 3 times (comparing with 2014-2016 auctions)
- There is a big difference in the cost of nuclear power plants in Russia and the EU. Mass construction of VVER-1200 units in recent years will keep their cost as low as 2200 $/kW. It's assumed that introduction of new VVER-TOI units after 2025 will reduce the cost for another 10-15% making nuclear very cost competitive in Russia

Source: for Russia – ERI RAS forecast, for EU – based on Columbia University (2018). The Role of Natural Gas in Europe's Electricity Sector Through 2030.

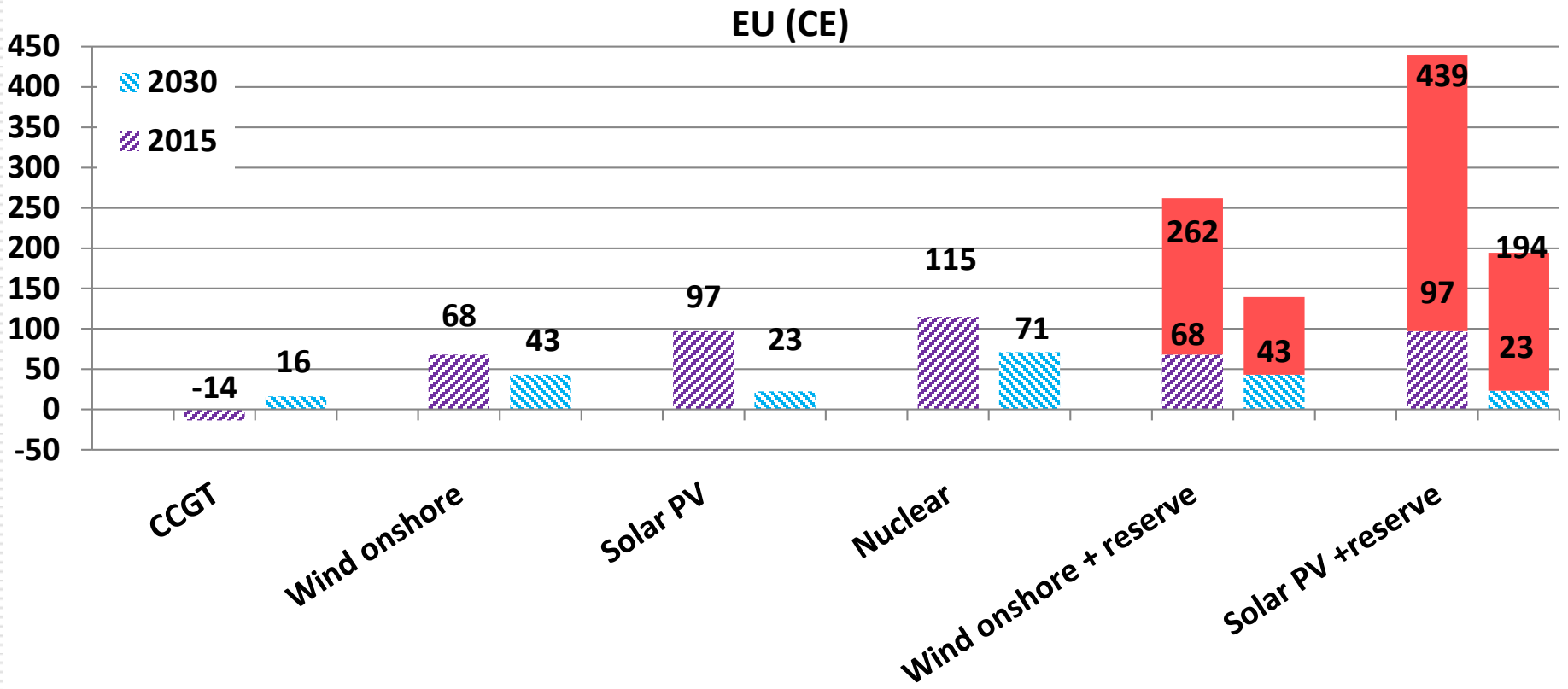
LCOE Ranges in Russia and EU, $2016/MWh





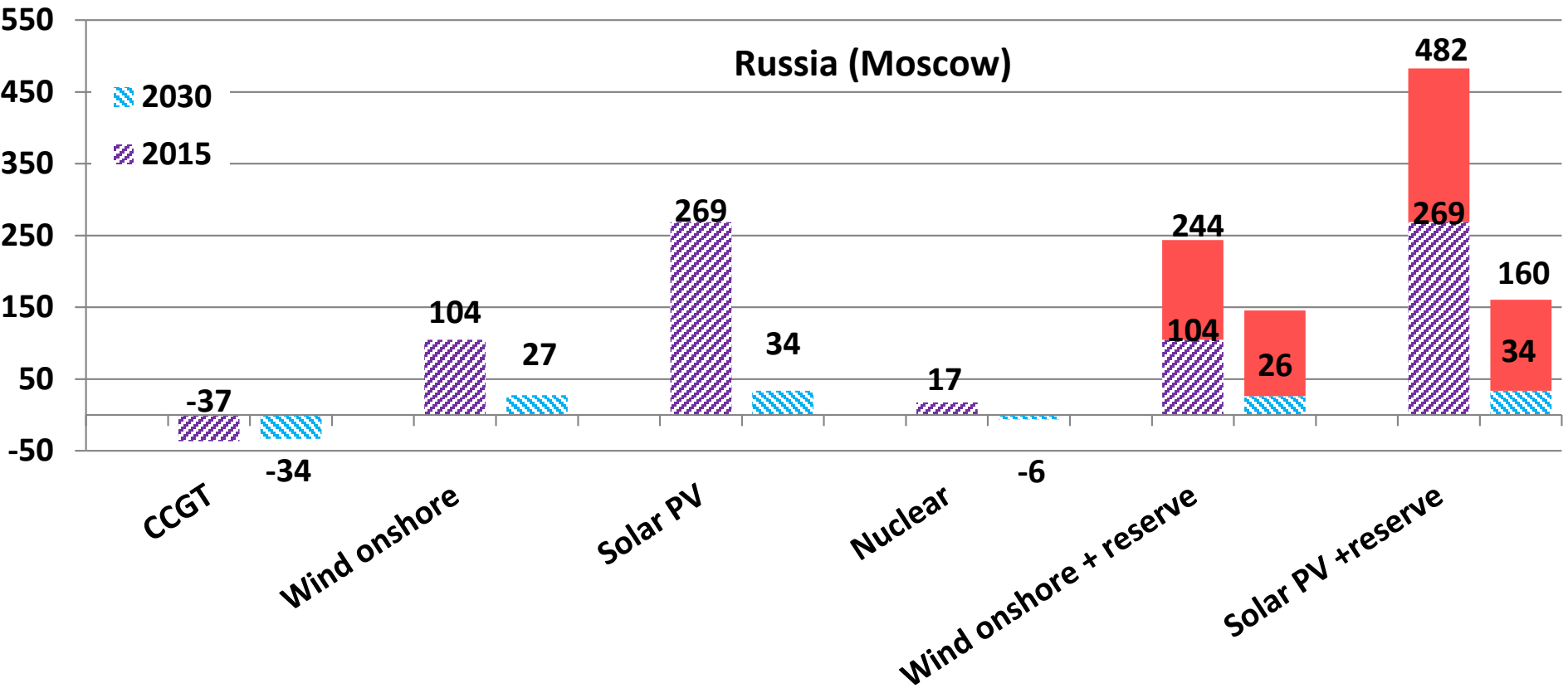
- At present, on average both in Russia and the EU most effective technology is CCGT, even considering long-term cost reduction of RES and the growth of gas prices.
- However, in Europe all non-carbon technologies remain more expensive, while in Russia, nuclear power plants, both now and in the future are competitive carbon-free sources of electricity.
- An important factor limiting the development of RES is the need for capacity reserve. Related costs are comparable to the actual LCOE values of these technologies even in the long-term.

Carbon Avoided Costs in EU, $2016/ t CO_2



- At present conditions best technology for carbon mitigation in the EU is CCGT. All other options need some support or carbon prices over 70$/t CO2
- In 2030 decrease in capital costs of RES will sharply decrease the amount of needed support. For example, at carbon price about 20$/t CO2 solar PV will be more effective than coal generation, at 40 $/t CO2 - onshore wind plants.
- When considering the cost of RES capacity reservation those types of plants will be significantly more expensive than any other option even with assumed decrease in cost of RES generation and storage

Carbon Avoided Costs in Russia, $2016/ t CO_2



- In Russia as well as in the EU most efficient way of cutting carbon emissions is to substitute coal plants with CCGTs.
- But unlike the EU nuclear generation could be a way to go, especially after 2030.
- It appears that by 2030 amount of needed support for RES in Russia will become comparable to the one in EU – at carbon price of about 30$/t CO_2 Solar and Wind could be effective sources of carbon mitigation

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Thank You for Your Attention