Hydrogen for Decarbonization: is it real option?

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Governments invest a lot of resources in decarbonizing the economy. However, some fossil fuels economies are sceptics of these process due to beware of their rent income. Hydrogen is one of the possible options of win-win options: where fossil fuel economies replace structure of her exports, decarbonize their economy and make revenue from profitable commodity. Hydrogen combustion does not lead to harmful emissions and greenhouse gases in places of consumption. Hydrogen-powered cars do not require batteries with rare earth metals, are more resistant to temperature conditions, and can be refueled easily. On the other hand, the production and transportation of hydrogen requires a lot of energy, costs and, depending on the production process, can lead to emissions during the production of energy and rare earth metals.

For example, based on the law of conservation of mass, the production of 1 ton of hydrogen from natural gas requires at least 4 tons of natural gas, which leads to emissions of 11 tCO2. Is it a lot or a little? If all-natural gas consumed in Russia is converted, this will lead to an increase in emissions from natural gas combustion from 950 MtCO2 to 1600 MtCO2. Of course, up to 90% of these emissions can be disposed of. But this will require significant CO2 storage, and significant investment. Transportation, hydrogen, and final consumption are also problems: technologies are not yet fully developed and have significant costs.

The paper considers scenarios of “hydrogenation" of the Russian economy. In the scenarios, there are various options for the production of SMR (Steam Methane Reforming) with CCS, and electrolysis from green electricity sources: PV and wind farms, how much investment is needed for this, and what emissions will lead to. To develop these, we used a partial equilibrium optimization framework, the High-Resolution Renewable Energy System for Russia (HIRES-RUS). The framework consists of two models: a high frequency (hourly) power generation model (RUHOUR) and a representative energy model (RUTIMES), which covers the entire energy sector in Russia. The first model is necessary to analyze the possibility of constructing a power generation system that ensures a stable meeting of demand using intermittent alternative energy sources. The second (RUTIMES) is used for the construction of the transient dynamics up to 2050. RUTIMES includes renewables and fossil fuels, the heating and electricity generation sector, refineries, cement, iron and steel production, buildings, freight and passenger transport, pipeline distribution networks, and other industries, including non-energy use consumption

To construct a scenario for the development of energy, a model of the representative RUTIMES energy system was used. The RUTIMES model solves the task of the central planner to satisfy exogenously specified final demand, taking into account deposits and other sources of energy and materials, available technologies and existing, and possible technological options. Under some conditions, the task of the central planner is equivalent to the task in the market of perfect competition. The model is calibrated in the initial period, and build scenarios from 2012 to 2050. The model contains 8 regions: Northwestern, Central, Southern (contains the Southern and North Caucasian Federal Districts), Volga, Ural, Tyumen (Tyumen Region, together with two autonomous districts: Khanty-Mansi Autonomous Okrug and Yamalo-Nenets Autonomous Okrug), Siberian and Far Eastern. The RUTIMES model of Russian energy has been repeatedly tested in various studies, including in prestigious international journals Q1 Scopus & WoS (Golub, A., Lugovoy, O., Potashnikov, V. 2019) (Potashnikov, V., Golub, A., Brody, M., Lugovoy, O. 2022).

A significant modification is to take into account the availability factor, and additional balancing costs for building networks and saving energy, from solar and wind power plants, from the RUHOUR multi-regional hour model.

Three scenario was developed:

BAU: High growth of GDP 2-4% per year, no climate policy, Fossil fuel export goes to zero to 2050, Constant population, Available all BAT

Lost opportunity: BAU + Active climate policy, increase H2 export

Isolation: An extreme drop in GDP by 30% and a slow return to the same within 25 years, no climate policy, the export of fossil fuels will be reduced to zero by 2030, no BAT

These three-scenario provided completely different future options for Russia. If the “Lost opportunities” scenario provided Russia with a chance to replace hydrocarbon rents, which are subject to the risks of revenue reduction due to the active climate policy of the importing countries of Russian hydrocarbons, with hydrogen rents. Rent from hydrogen allowed to solve several tasks: Ensuring stable rent from hydrogen exports, diversification of hydrogen supplies through the development of maritime transport, reduction of negative environmental damage, and the possibility of increasing hydrocarbon exports in case of increased demand. In figure shown structure of energy export by Russia by scenarios.

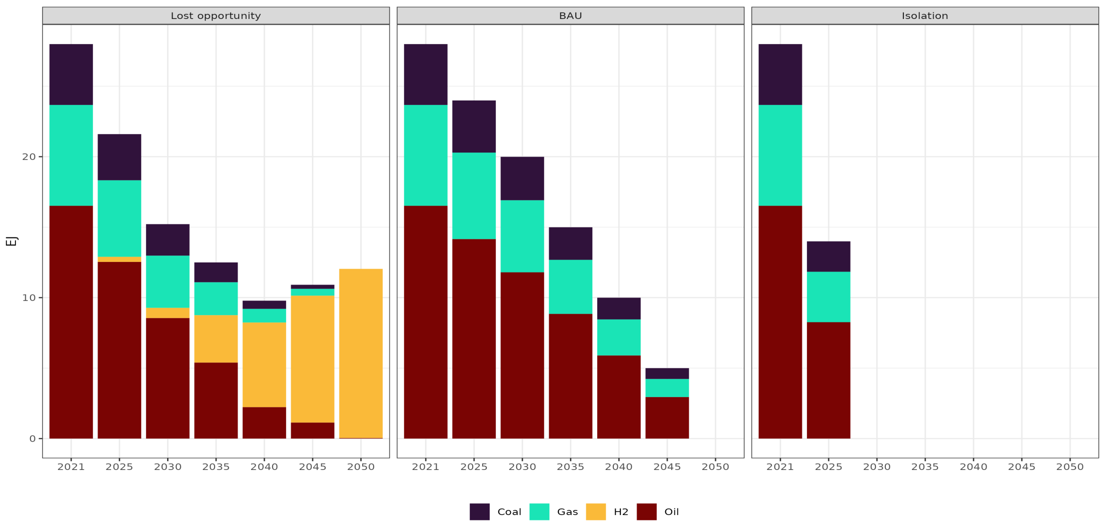

Figure 1. Structure of energy export by Russia by scenarios.

Revenue from scenario differ dramatically from 1.2 trln$ in scenario “Isolation”, to 7.2 trln.$ in scenario “Lost opportunities”. Change structure of energy exports, availability of modern technologies and target of climate policy lead, to different emissions paths (figure 2). If scenario “Lost opportunity” lead to:

1. Decrease emissions, including harmful emissions that increase average life expectations, and quality of life.
2. High level of economic development by revenue from hydrogen.

3. Low carbon technologies usually have better economic efficiency, that lead to higher TFP, and high GDP per capita.
4. Decreasing uncertainties from fossil fuel export have to lead to increase investment, rather than level of consumptions and export capital as it now.

Instead of scenario “Lost opportunities”, scenario “Isolation” lead to:

1. Technical degradations due to leakages of human capital and restrictions of high technology exports.
2. Tremendous decreasing revenue from fossil fuel exports.
3. Increasing uncertainty of economy perspective, due to lack of technologies, fossil fuel export perspective, and demotivation of human capital investment.
4. Reducing international collaborations, including science, will lead to decreasing quality of R&D, that critically important in autarky conditions.
5. Reducing possible partners for exports and imports will lead to Russian price discriminations, that lead worse balance of payments.

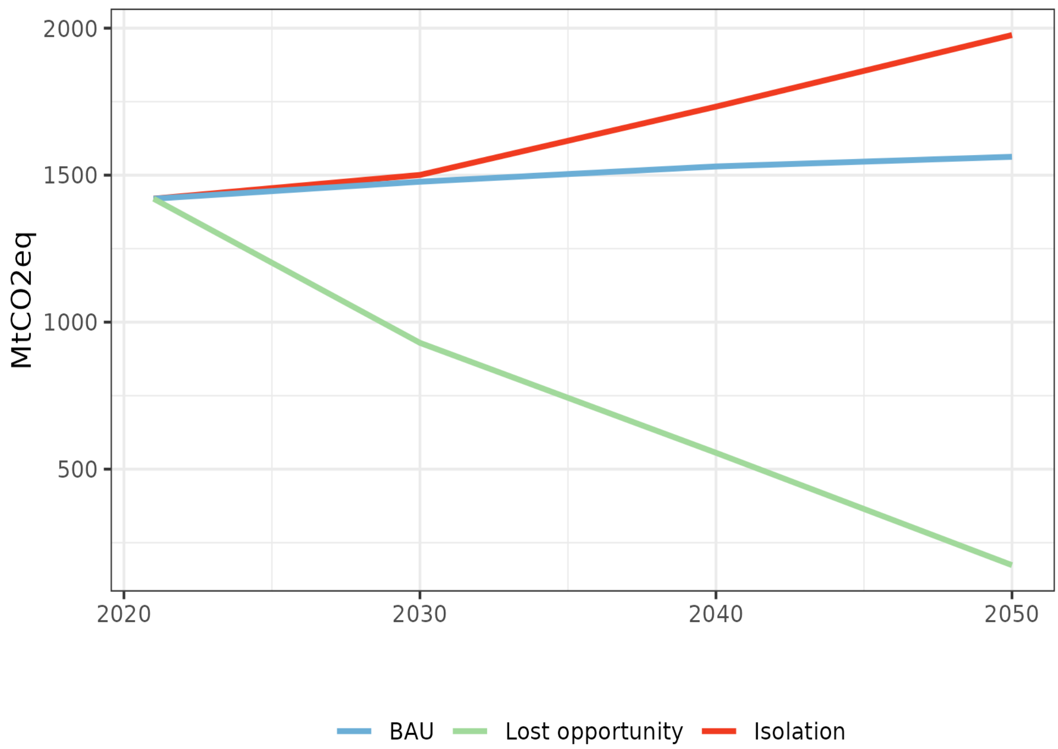

Figure 2. CO2 emissions from fossil fuel combustions.

All off these factors lead to different total primary energy supply (see fig. 3). Realization of “Isolation” scenario unfortunately reduce wind and solar power to extremely low share, even compare with BAU scenario, where wind electricity is sufficient part of electricity generation. Lost opportunity scenario use wind power for satisfy final energy demand and electricity generations for hydrogen production. Use mainly green hydrogen not only provide source of hydrogen for final demand and export, but also allow satisfy final demand for electricity with low cost for balancing. Where excessive capacity of wind generation satisfies final demand in any conditions and use residual capacity for hydrogen generations.

Conclusions

Russia had a considerable potential to deploy alternative energy production and consumption technologies. But Russia lost forever opportunity to become a leading supplier on the global hydrogen market. By the time Russia is reintegrated into the global economy, its potential nishe on the global market will be taken by other countries. Domestic climate policy will make a little difference in absence of new technologies and high cost of capital. Unfortunately, all of this factors will lead that Russia will remain in development trap.

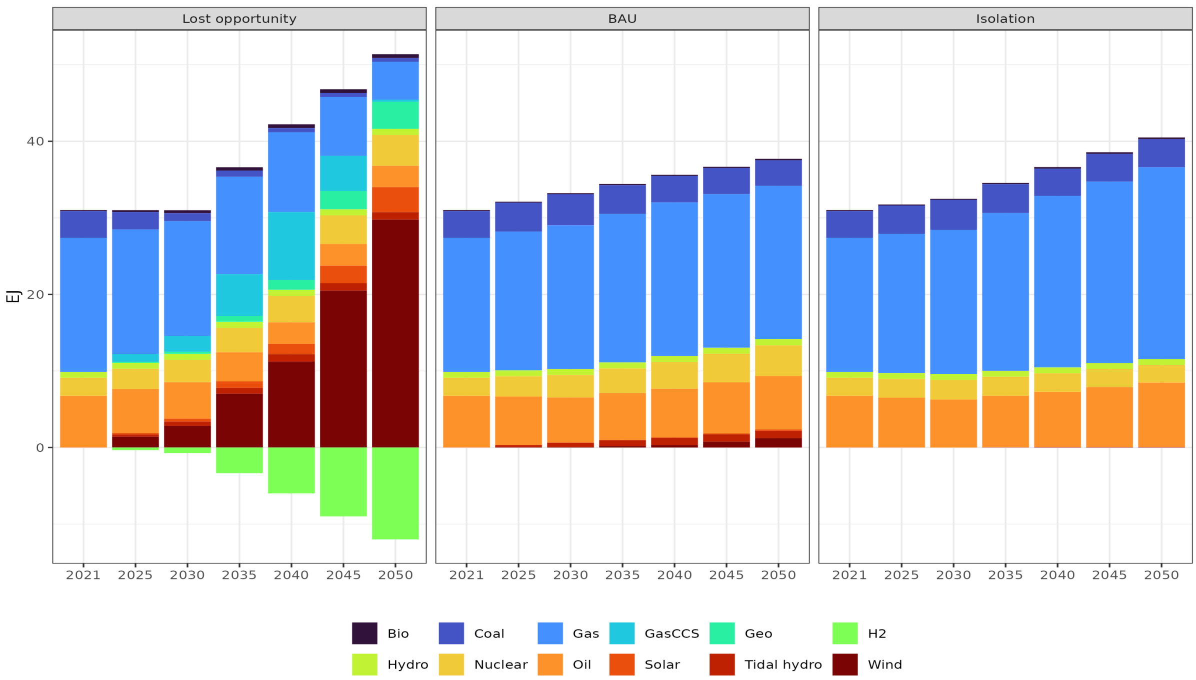

Figure 3. Total primary energy supply.

References

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