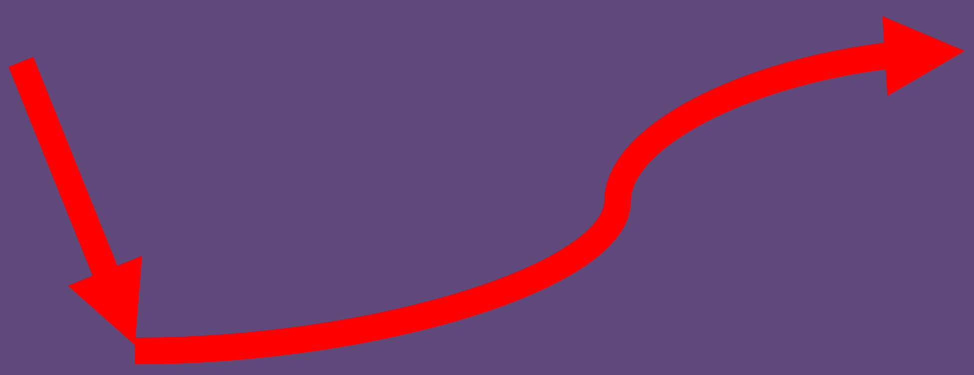
Igor Bashmakov

# The angle of incidence is not equal to the angle of reflection



# CONTENTS

## Abstract

Initial purpose of this chapter was to assess the impacts of the global economy low carbon transition on Russia's economic development. After February 24th, it was modified to reflect also long-term impacts of imposed sanctions. The analysis below shows that Russia may lose 10-11 years of economic growth. The 2021 GDP level is expected to be back only in 2031-2032. By 2050, Russia will have lost about 50% of the previously (late 2021) expected potential GDP. In 2060, Russia's GDP will be only 6-44% up from 2021. The share of Russia in the global GDP thus will be shrinking to 0.7-0.9% in 2060, when estimated in exchange rates, and to 1.3-1.7%, if estimated in PPP. This drives Russia out to the middle or to the end of the second dozen in the list of major economies, making it hardly visible in the global 2060 economic landscape, shadowed by such giants of the time as China, India, and USA. This will deeply undermine Russia's economic security, political role, and the military potential. The share of oil and gas GDP, after some temporal growth in 2022-2024, will be fast declining towards 2030 and stay low thereafter with a subsequent decline in the influence of the oil and gas elites, growing dependency of the state on other businesses, and gradually dissipating illusions of its omnipotence with a real democracy replacing the decorative one. All these processes are expected to be delayed, as the current elites will do anything to keep their power and influence.

# 3 Impacts of the global scale and of Russia's key trade partners' low carbon transition on Russia's economic development

## 3.1 Call for change

The purpose of this chapter is to assess the systemic impacts of the global scale and of Russia's key trade partners' low carbon transition on Russia's economic development depending on the selected decarbonization pathways. This assessment is broken down into exploring the effects on Russia's traditional exports (mostly fossil fuels and basic materials) and on the emerging low carbon markets. Russia's economy is raw materials-based. Fossil fuels and raw materials production contributes 28-30% to GDP, nearly two thirds to the industrial output, up to 40% to the federal budget, almost 25% to the consolidated budget, and nearly 75% to export revenues. Therefore, if the "old" model of economic growth persists, the economic progress will largely depend on the potential to supply fuels and basic materials to Russia's trade partners and to the domestic market in the decades to come. Since the expansion potential of both these markets is limited, new drivers are required to accelerate the economic growth, and so new low carbon products have to find market niches in the emerging markets. Global low carbon transition sets challenges, but also provides opportunities for Russia's economic future. The balance will largely depend on the ability of the Russian government to recognize the scale of the challenge and to address it via effective policy packages. Until very recently, all these three calls for significant transformation were poorly met.

The potential to reach such balance substantially shrank after the military operation of the Russian troops in Ukraine. Some countries announced their willingness to reduce imports from Russia as part of sanctions packages[1] and longer term energy security policy.[2] So short-term, as well as medium- and long-term export perspectives for the Russian fossil fuels and basic materials got much worse just overnight. Russian products are labeled as 'toxic', and many former trade partners have started to

[1] Oil Market and Russian Supply – Russian supplies to global energy markets – Analysis - IEA; Background Press Call by a Senior Administration Official on Announcement of U.S. Ban on Imports of Russian Oil, Liquefied Natural Gas, and Coal | The White House; Oil rallies as US and UK announce bans on Russian oil imports – business live | Business | The Guardian

[2] Joint Statement between the European Commission and the United States on European Energy Security Brussels, 25 March 2022. Statement between the Commission and the US on energy (europa.eu)

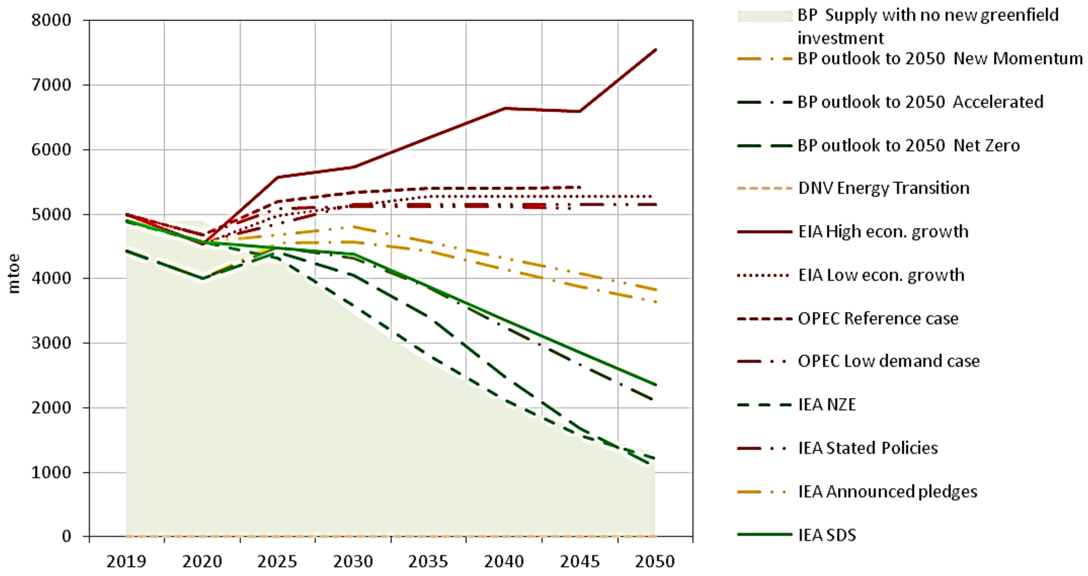
develop strategic goals to minimize their reliance on Russian products as their long-term policies. This may have severe effects for Russia's economic prospects.

## 3.2 Traditional markets

### 3.2.1 Crude oil and petroleum products

The future of markets for Russian crude oil and petroleum products depends on the evolution of the global oil market, the ability to maintain or expand Russia's market niches, and the evolution of Russia's domestic oil demand. Most projections agree, that the global liquid fuel supply will peak before 2050 (Fig. 3.1). The only exception is the projection by EIA, which anticipates high economic and oil demand growth. In the IEA's scenario with stated policies, global oil market will saturate close to 5000 mtoe in 2030-2050; however, in the announced pledges and low carbon scenarios, after a peak in 2030, oil supply is expected to be steadily shrinking. In the IEA or BP NZE scenarios, there is no need for additional investments in oil production, as demand follows the natural production decline in currently operating oil fields. The gap between supply with no new greenfield investments and any other pathway plotted in Fig. 3.1 indirectly indicates the huge need for investments to bridge the corresponding gap in oil demand.

**Figure 3.1. Projections of global oil and liquid fuels* production to 2050**




* Some sources report crude oil, while others show liquid fuels.

Sources: IEA. 2021. World Energy Outlook 2021; IEA. 2021. Net Zero by 2050. A Roadmap for the Global Energy Sector; BP Energy Outlook. 2022 Edition; DOE. 2021. International Energy Outlook 2021with projections to 2050. October 2021; OPEC. 2021. World oil outlook. 2045; DNV. 2021. Pathway to net zero emissions. Energy transition outlook 2021; estimates by CENEf-XXI and The Energy Strategy of the Russian Federation to 2035. Decree by the Government of the Russian Federation No. 1523-r of June 9, 2020.

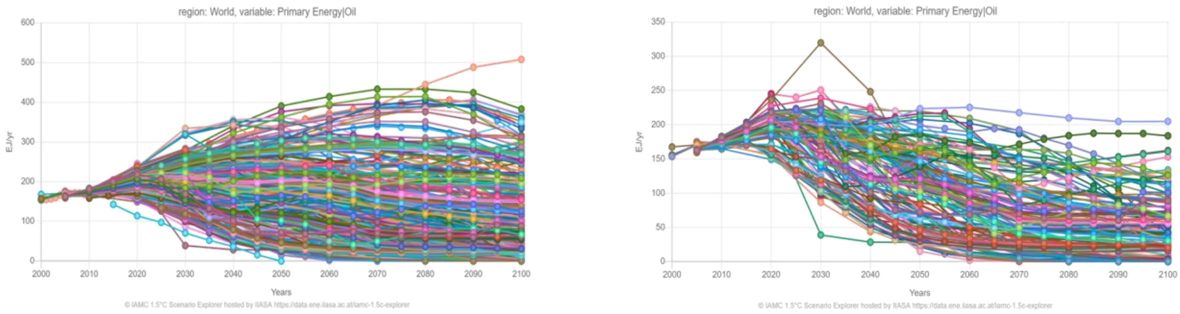
The analysis time span is to 2060. IAMs projections were explored to clarify, how oil supply may evolve beyond 2050 (Fig. 3.2). The evolution pattern beyond 2050 is similar. In low carbon scenarios, oil supply peaks before 2030 and then scales down with subsequent stabilization at a level below 2000 mtoe in most scenarios. For low carbon scenarios, declining trends plateau at a level nearly equal to the volumes of oil needed as chemicals feedstock. BP estimates feedstock oil demand by the chemical industry (plastics, fertilizers, fibers, etc.) at 360-765 mtoe.[3] IEA estimates it close to 750 mtoe in 2050.[4] Some of it can be substituted by liquid biofuels and synthetic oil. The current level is close to 500

[3] BP Energy Outlook 1995-2050, 2020 Edition.
[4] IEA. 2021. World Energy Outlook. 2021.

mtoe. Therefore, only moderate growth is expected for non-energy use liquids. The rest are combustible liquids with a quite substantial future demand uncertainty range.

Maintaining the current level of oil supply by 2100 will require 400 thousand mtoe of proven resources. BP reports them at 244 thousand[5] mtoe in 2021. So about as much additional resource will be required in the decades to come to meet such demand.

**Figure 3.2. IAMs projections of global oil and liquid fuels supply to 2100**



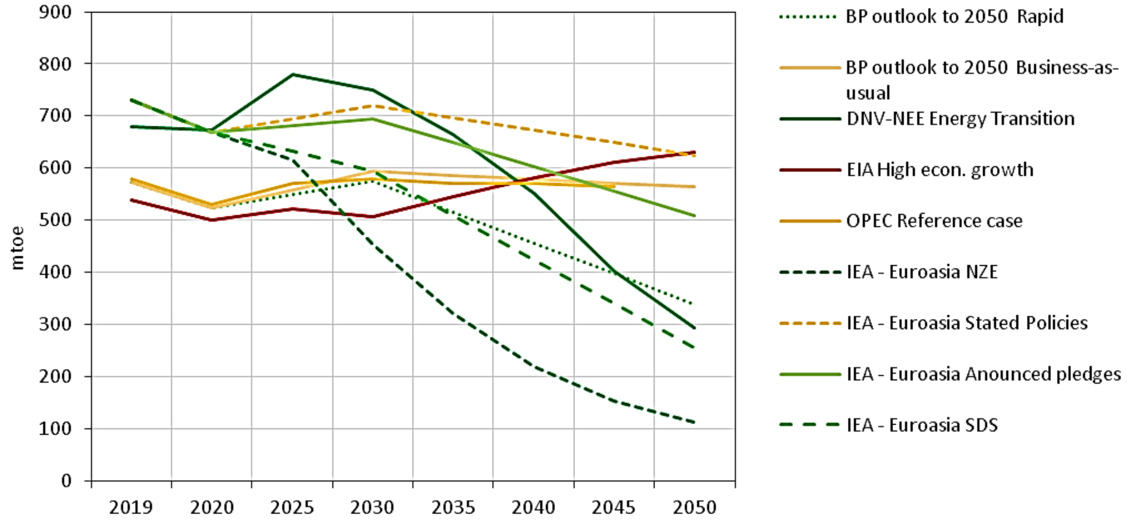

all scenarios | scenarios of less than 2ºC warming to 2100

Sources: [IAMC 1.5°C Scenario Explorer hosted by IIASA]

Russia contributes about 13% of global oil supply and is the world's third largest oil producer after the US and Saudi Arabia. Three quarters of produced oil and gas condensate are exported. The RF Customs Service reports 2021 crude oil and gas condensate exports from Russia at 230 mtoe and the exports of petroleum products at 144 mtoe[6]. Russia is (depending on the year) the largest or second largest oil and petroleum products exporter: 412, 381, and 383 mtoe in 2019, 2020, and 2021 respectively, which means Russia has a more than 10% share in the global liquid fuels international trade. This explains why oil and gas condensate production projections for Russia mirror the global market temporal patterns (Fig. 3.3). Until recently, only DOE had expected that Russian oil production could expand. All other projections either take production nearly constant or – for low carbon pathways – expect a deep decline by the mid-century. These pathways are based on the expected evolution of domestic demand and exports. The latter are projected by BP[7] for Russia to drop to 244 mtoe by 2050. OPEC[8] only expects a modest decline for Russia and Caspian: from 330 to 308 mtoe in 2020-2045.

[5] BP Statistical Review of World Energy, July 2021.
[6] RF customs service (customs.gov.ru)
[7] BP Energy Outlook 1995-2050, 2020 Edition.
[8] OPEC. 2021. World oil outlook. 2045.

**Figure 3.3. Projections of Russia's* oil production to 2050 made before March 2022**



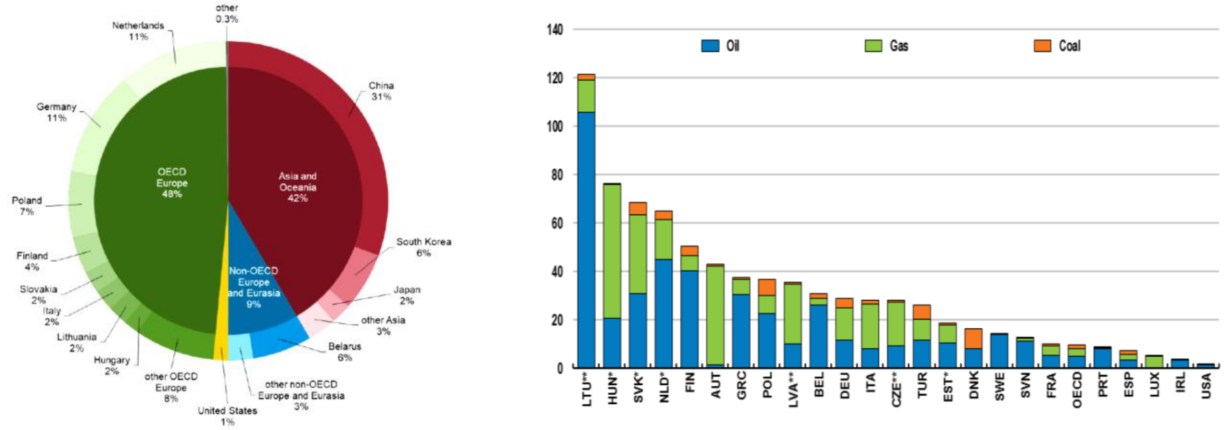

*

* Projections by DNV and IEA are provided for global subregions, which include Russia.

Sources: IEA. 2021. World Energy Outlook 2021; IEA. 2021. Net Zero by 2050. A Roadmap for the Global Energy Sector; BP. 2021. Energy Outlook 2050; BP. 2022. Energy Outlook: 2022 Edition; DOE. 2021. International Energy Outlook 2021with projections to 2050. October 2021; OPEC. 2021. World oil outlook. 2045; DNV. 2021. Pathway to net zero emissions. Energy transition outlook 2021.

All of the above projections had been developed before sanctions were announced. Some countries (USA, UK and Australia) have announced bans on the imports of Russian oil, liquefied natural gas, and coal by the end of 2022.[9] EU has proposed to phase out dependencies on Russian fossil fuels by 2027.[10] According to DOE, in November 2021 Russia was responsible for 26% of the OECD oil and petroleum imports: 17% of OECD-America; 34% of OECD-Europe; 3% of Japan and 9% of South Korea The share of external markets for the Russian oil, which may be affected by the sanctions, exceeds 55% (Fig. 3.4).

**Figure 3.4. Russia's crude oil and gas condensate exports by destination in 2020 (a) and Russian energy imports as a share in total energy supply, 2019 (b)**




a b

Sources: US EIA. Country Analysis Executive Summary: Russia. 2021; OECD Economic Outlook, Interim Report Economic and Social Impacts and Policy Implications of the War in Ukraine, March 2022.

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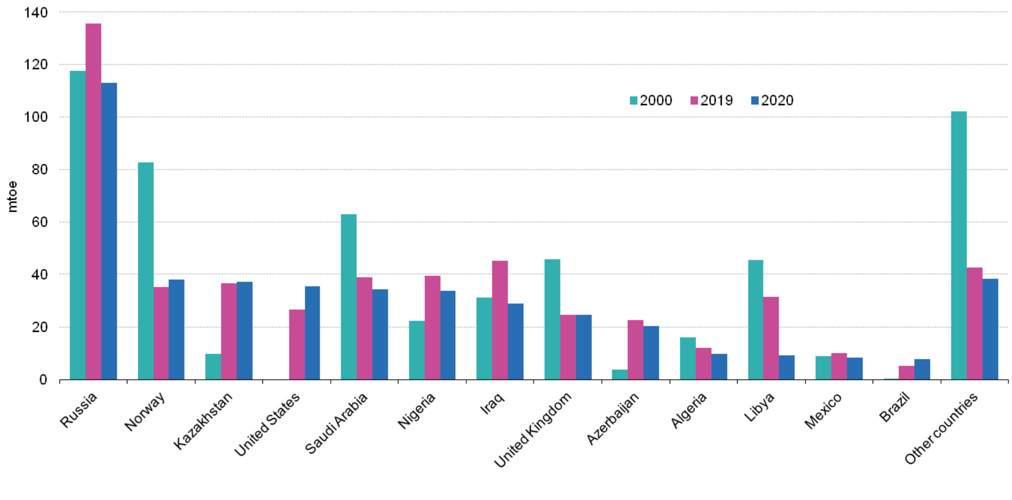
[9] Background Press Call by a Senior Administration Official on Announcement of U.S. Ban on Imports of Russian Oil, Liquefied Natural Gas, and Coal | The White House; Oil rallies as US and UK announce bans on Russian oil imports – business live | Business | The Guardian

[10] War in Ukraine: Von Der Leyen Eyes Ending EU's Russian Energy Reliance by 2027 - Bloomberg

In 2019-2021, EU imported 117-138 mtoe of crude oil from Russia (Fig. 3.5), which is 26-29% of the EU import. Additionally, EU imported from Russia 71-79 mtoe of petroleum products per year (nearly half of the EU import) in 2019 – first half 2021.[11] EU's petroleum exports and imports are more or less balanced, therefore the crude oil import reliance doesn't deviate much from the total oil import dependence.[12] The cut of supply from Russia needs to be followed by the reorientation of some EU petroleum exports to domestic uses. This would reduce the EU export to other markets, where it potentially can be substituted by some Russian refinery products. Such profound dependence on the oil imports – more than a quarter of crude oil demand and slightly below 40% of liquid fuels supply – explains why EU cannot quickly refuse the Russian oil.

If the EU embargo schedule is adopted and fully implemented, Russia will lose 188-217 mtoe of the EU petroleum market by 2027. In the IEA NZE scenario, oil demand in Europe is expected to decrease by 160 mtoe in 2020-2030. The major part of this decrease is attributed to the EU. In the IEA's announced pledges scenario, the EU oil demand decline is limited to 95 mtoe. Therefore, if the entire EU is politically determined to implement the whole demand reduction potential and the expected consumption decline is attributed entirely to the Russian oil supply cuts, still some additional amount (60-100 mtoe) will be required and can be obtained either by redirecting the EU exports of petroleum products to domestic use[13] or by turning to other regions for supply to substitute Russian imports. In this case, average annual decline in Russian imports in 2021-2027 will be 31-36 mtoe, which may be larger (35-45 mtoe) in 2022, if all of the announced measures are effectively adopted. Part of the 2022 EU consumption decline will originate from the economic slowdown in response to the energy price shock and resulting low energy affordability.

**Figure 3.5. EU crude oil imports by country of origin**




*Source:* Eurostat (online data code: nrg_ti_oil)

Source: [Table_and_figures_oil_and_petroleum_products_2020.xlsx (live.com)]

Russian crude oil exports to the US were below 5 mtoe in 2019, below 3 mtoe in 2020, and below 1.5 mtoe in 2021. For petroleum products the corresponding numbers are 11.4, 17.4 and below 4 mtoe. President Biden's Executive Order blocks new purchases of Russian crude oil and some of the petroleum products, LNG, and coal. UK imported 2.4 mtoe of crude oil in 2019, 3.1 mtoe in 2020, and 2.7 mtoe over three quarters of 2021, along with 3.9, 2.1 and 1.7 mtoe of petroleum products. So an embargo on oil and petroleum products supply will squeeze the external market for Russian oil by additional 11-15 mtoe. This effect may be distributed over two years with a cut of some 8-11 mtoe in 2022. Australian imports of Russian oil and refinery products in 2021 was only 0.06 mtoe, so an

[11] BP Statistical Review of World Energy July 2021; BP Statistical Review of World Energy July 2020; EU imports of energy products - recent developments - Statistics Explained
[12] Table_and_figures_oil_and_petroleum_products_2020.xlsx (live.com)
[13] There are some problems related to the different structure of petroleum products imports and exports.

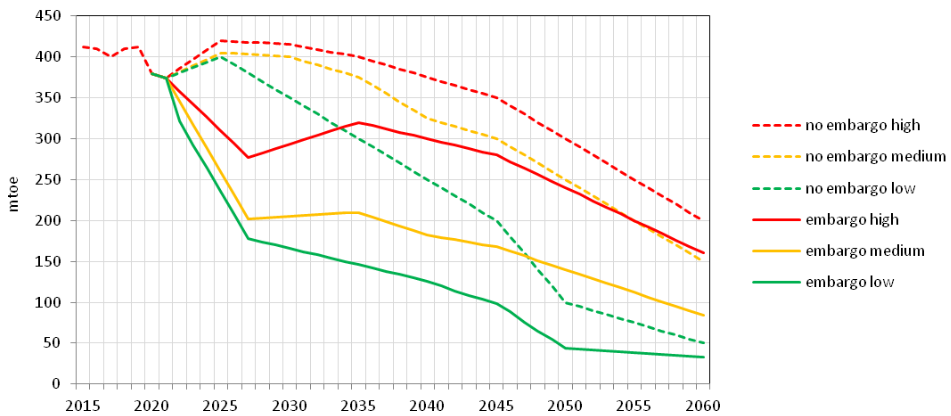
Australian embargo will have little impact. After the active phase of the invasion is over, these sanctions may persist depending on the outcome.

IEA has estimated, that 10 immediate steps taken by advanced economies can cut oil demand by 2.7 mbd in the next 4 months.[14] But many of these 10 actions (car-free Sundays in cities, or work from home up to three days a week, where possible) require a significant and sustainable behavioural change, which is hard to attain to the required level and to back up with necessary regulation in limited time. Therefore, only a fraction of this potential is practically available.

The total market loss for the Russian oil is estimated close to 200-230 mtoe by 2027, or 52-60% of 2021 exports (383 mtoe), or 38-44% of Russia's total production (524 mtoe). If about 1 mbd in 2022 and 4-5 mbd by 2027 are removed from the global market (which is about 100 mbd) at the ascending stage of the cyclical energy price evolution, oil prices might grow up to US$/b 100-150 or even higher, while the average annual price may reach US$/b 100-120 in 2022, up by 50-80% from US$/b 67 in 2021. In this case, despite the embargo in 2022 and a few subsequent years, Russia's oil revenues may not drop, but increase compared to 2021. The embargo effects might become painful for Russia only after the oil prices fall down substantially along with a supply decline closer to 2027. An additional short-term reduction in Russia's oil production will result from a deep recession in the Russian economy.

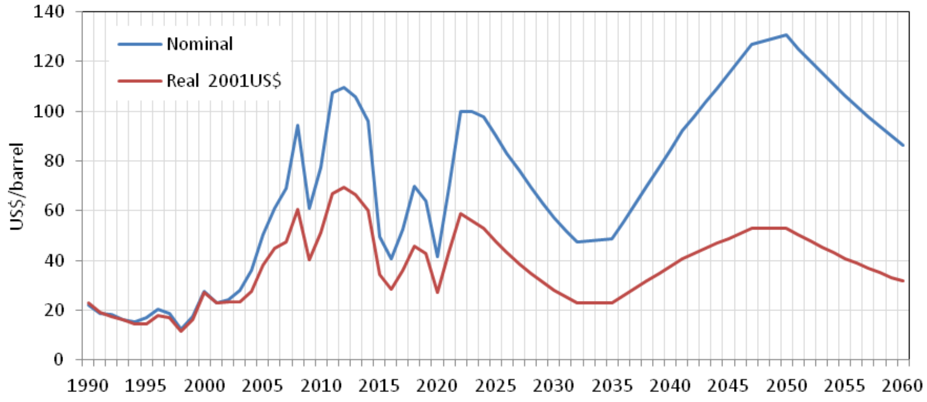
In a longer term, the global switch from fossil fuels and oil will accelerate as a result of both political determination to reduce the energy dependence on Russia and a greater uptake of alternative technologies as these become more competitive. Russian oil will be viewed as 'toxic' for a long time, unless this label is removed after a change of the regime. Therefore, pathways that are based on the stabilization in Russia's oil production are becoming unfeasible. After a significant decline in 2022-2027, Russian oil exports may somewhat rebound in the mid-term, but in a longer term they will "highly likely" decline faster, than expected before February 24th (Fig. 3.6a). Reduction in foreign investment and limited access to new technologies and financing would additionally limit the ability of Russian oil companies to scale up production in a longer term. As to the alternative markets for Russian oil, there is some potential for additional supply by 2030 to China, India, Africa, and Southeast Asia to meet their respective demands projected by the IEA stated policies and announced pledges scenarios, but this potential will expire by 2050 (and it is non-existent in the NZE scenario).

**Figure 3.6. Russian oil and petroleum products exports, export prices and export revenues with an account of the embargo effects**

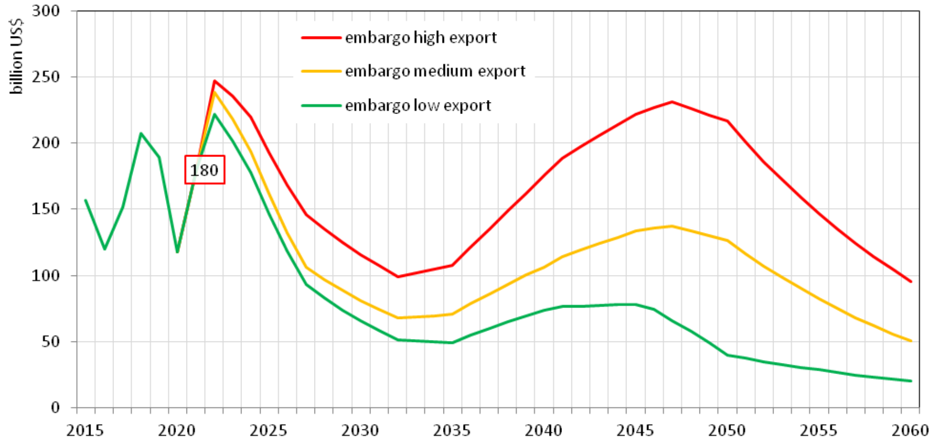



(a) Russian oil and petroleum products exports

[14] IEA. 2022. A 10-Point Plan to Cut Oil Use, 18 March 2022. A 10-Point Plan to Cut Oil Use (windows.net)




(b) oil export prices




(c) oil export revenues

Source: CENEf-XXI.

Oil price predictions are risky both in the short and long-term. The logic of oil price projection shown in Fig. 3.6b is based on the observed cyclical evolution of energy prices (and energy costs shares in the income) with some 25-30-year cycles. The cyclical nature of energy price dynamics has manifested for five centuries and experienced multiple technological transitions and changes in the energy mix.[15] Energy costs constants, i.e. stable over long time energy costs to income ratios, are the center of ‘economic gravitation’. Energy affordability thresholds are found in all major final energy use sectors manifesting the ‘minus one’ phenomenon, which shows that cycle-long real energy prices may only grow by as much as energy intensity declines.[16] Energy affordability thresholds and asymmetric price elasticities are important factors that determine the existence of the turning points towards the center of ‘economic gravitation’ in the cyclic evolution of the energy costs shares.

Despite a deep reduction in Russian oil and petroleum imports by 2025, Russia’s oil export revenues will exceed the 2021 level for a while (Fig. 3.6c). A severe impact of sanctions will only be felt thereafter. In the strong decarbonization pathway, beyond 2027 oil revenues will stay below US$ 100 billion in current prices, which is just a half of the US$ 204 billion average in 2010-2021. Russian oil revenues in 2022 will exceed the 2021 level, unless the average annual oil price stays below 70US$/b.

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[15] Bashmakov I. “Economics of the constants” and long cycles of energy prices dynamics. *Voprosy Ekonomiki*. 2016;(7):36-63. (In Russ.) https://doi.org/10.32609/0042-8736-2016-7-36-63

[16] Bashmakov I. 2007. Three laws of energy transitions. *Energy Policy*, Vol. 35, No. 7, pp. 3583–3594; Bashmakov I. 2017. The first law of energy transitions and carbon pricing. *International Journal of Energy, Environment, and Economics*, Vol. 25, No. 1, pp. 1–42; Bashmakov I., Myshak A. 2018. ‘Minus 1’ and energy costs constants: Sectorial implications. Journal of Energy, Vol. 2018, Article ID 8962437. https://doi.org/10.1155/2018/8962437.

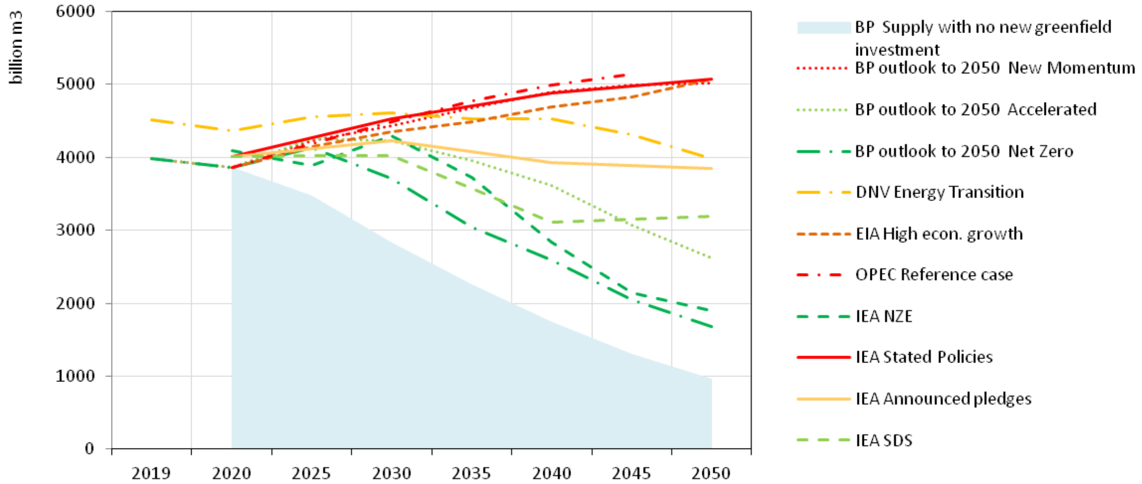
For oil, the key findings are as follows:

- Foreign markets will be steadily shrinking at a pace determined by the progress in low carbon transition and -- at least for some time -- by the political unwillingness to purchase the ‘politically toxic’ Russian oil;
- It is highly unlikely that Russia will ever be close to 400 mtoe in oil and petroleum exports registered back in 2018-2019;
- Oil prices growth in 2022-2024 will overcompensate (for a few years) the revenue loss associated with the sanctions announced for Russian oil. The effect of both decarbonization and sanctions will become severer after 2025. Extra revenues obtained in 2022-2024, if not fully spent to support the Russian economy, may for some time mitigate the oil revenue collapse beyond 2025.

### 3.2.2 Natural gas

The global prospects for natural gas, which was considered a fossil bridge to the non-fossil future, are much brighter for the decades to come (Fig. 3.7). In the BAU and stated policies-like scenarios, global gas demand doesn’t peak until 2050. In the announced pledges scenarios, it peaks before 2030 and then declines quite modestly. In low carbon scenarios, it peaks before 2030 at about the current level or slightly above it, and then declines to 2000-3000 bcm by 2050.

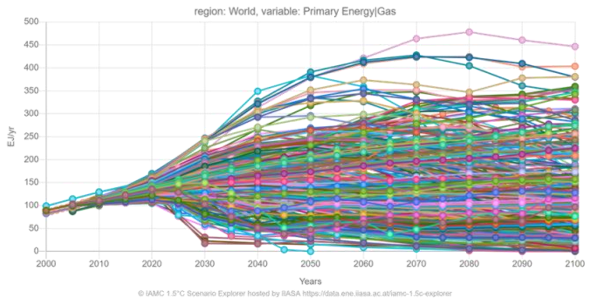
**Figure 3.7. Projections of global gas production to 2050**



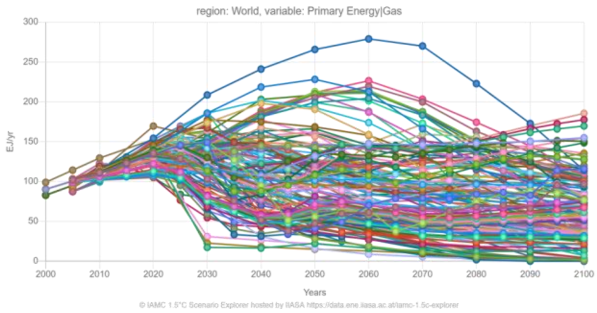

Sources: IEA. 2021. World Energy Outlook. 2021; IEA. 2021. Net Zero by 2050. A Roadmap for the Global Energy Sector; BP. 2021. Energy Outlook 2050; BP. 2022. Energy Outlook: 2022 Edition; DOE. 2021. International Energy Outlook 2021 with projections to 2050. October 2021; OPEC. 2021. World oil outlook. 2045; DNV. 2021. Pathway to net zero emissions. Energy transition outlook 2021.

In IAMs projections, the uncertainty ranges are much greater, but generally, the ‘spaghetti’ of trajectories have a similar shape. In low carbon scenarios to 2050-2060, they are mostly traced below the current production level, while some trajectories depict the absolute end of the “gas era” by 2080-2100 (Fig. 3.8).

**Figure 3.8. IAMC projections of global gas production to 2100**




all scenarios



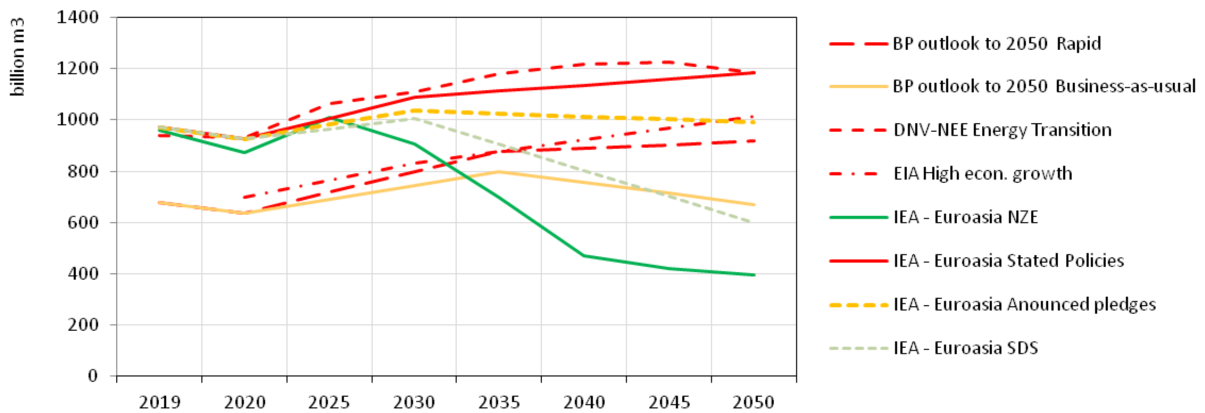

scenarios with less than 2°C warming to 2100

Sources: [IAMC 1.5°C Scenario Explorer hosted by IIASA]

Some 400 trillion cm are needed to maintain gas supply at the current level until 2100, while global proven resources were reported at 184 trillion cm at the end of 2020.[17] It is challenging to provide the growing supply with the required resources. If no additional greenfield investments are provided, gas supply from the currently operating fields will shrink 4-fold to 1000 bcm by 2050.

Until recently, Russia had been contributing 17-18% to the global natural gas supply. Just a little over 70% is consumed locally, the rest is exported (221 bcm in 2019, 203 and 204 bcm respectively in 2020-2021). As the local consumption slowly evolves, future production pathways will largely depend on the expected capacity of foreign markets and on their willingness to absorb Russian gas. The latter was undermined deeply after February 24th. Before this date, BAU projections expected some growth in Russian or Eurasian gas supply (Fig. 3.9). Announced pledges and low carbon scenarios assumed some growth in supply till 2030 and a plateau or a decline at a later stage. Only in the IEA NZE scenario a fast production decline for Eurasia was projected by 2040 with a subsequent stabilization in 2045-2050.

**Figure 3.9. Projections of Russian* gas production to 2050 made before March 2022**




* Projections by DNV and IEA are provided for global subregions, which include Russia.

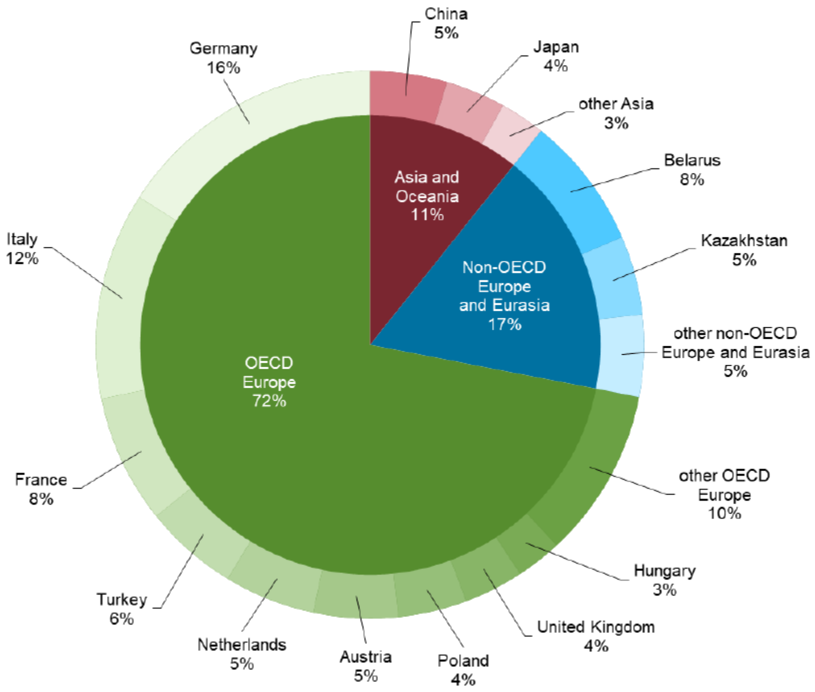
Sources: IEA. 2021. World Energy Outlook 2021; IEA. 2021. Net Zero by 2050. A Roadmap for the Global Energy Sector; BP Energy Outlook 2050: September 2; DOE. 2021. International Energy Outlook 2021with projections to 2050. October 2021; DNV. 2021. Pathway to net zero emissions. Energy transition outlook 2021.

EU (68%) dominates in the geographical structure of Russia's natural gas exports. According to the RF Customs Service statistics, pipeline gas exports to EU was 151 bcm in 2019 and 142 bcm in 2020. In addition, 16 and 31 bcm LNG were imported by EU from Russia in 2019-2020. So the total is close to

[17] BP Statistical Review of World Energy, July 2021.

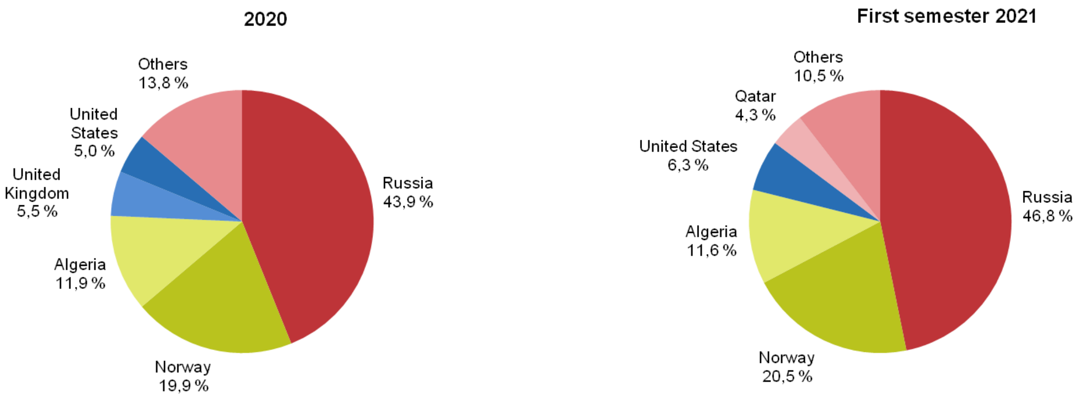
170 bcm, or about 46% of the EU net gas imports, and about a third of total EU gas consumption. EU sources provide close estimates.[18]

**Figure 3.10. Russia's natural gas exports by destination in 2020**




Source: US EIA. Country Analysis Executive Summary: Russia. 2021.

**Figure 3.11. Extra EU imports of natural gas from key trading partners, 2020 and first semester 2021**




Source: Eurostat database (Comext) and Eurostat estimates [European Union Imports of estimate of low valued import transactions from Russia - 2022 Data 2023 Forecast 2000-2020 Historical (tradingeconomics.com)]

It is a challenge for EU to avoid the dependence on Russian gas. If EU is to phase out dependencies on Russian fossil fuels by 2027, it needs to reduce gas consumption and mobilize alternative sources to substitute 170 bcm supplied from Russia. There are even more ambitious plans to replace 100 bcm of Russian gas (two thirds) by the end of 2022.[19] To attain the latter goal gas exports from Norway, the second largest EU supplier, have to double, or supply from Algeria has to triple, or supply from the US

[18] European Union Imports of estimate of low valued import transactions from Russia - 2022 Data 2023 Forecast 2000-2020 Historical (tradingeconomics.com)

[19] EU announces plan to slash Russian gas imports this year | Russia-Ukraine war News | Al Jazeera Joint European action for more affordable, secure energy (europa.eu)

has to more than quadruple over 9 months (Fig. 3.10). If LNG is to be used to replace Russian pipeline gas, then EU and LNG suppliers will probably need to sign long-term contracts for gas deliveries.

In early March 2022, IEA published "*A 10-Point Plan to Reduce the European Union's Reliance on Russian Natural Gas*".[20] Potential gas demand reductions were assessed for many items. *Plan*. 1. *No new gas supply contracts with Russia* action can reduce the imports of Russian gas by 15 bcm in 2022 and by up to 40 in 2030. 2. *Replace Russian supplies with gas from alternative* sources can potentially bring 30 bcm in additional gas supply from non-Russian sources. 3. *Introduce minimum gas storage obligations to enhance market resilience* reduces the vulnerability of gas supply and improves the stability of gas process at the expense of the additional 18 bcm supply in 2022. That fully neutralizes the short-term effects of Item 1 above. 4. *Accelerate the deployment of new wind and solar projects* over and above the already anticipated growth in the short-term may reduce gas demand by 6 bcm. 5. Maximize generation by existing dispatchable low-emissions sources*: bioenergy and nuclear* would allow it to reduce gas use for electricity generation by 13 bcm. *6. Enact short-term measures to shelter vulnerable electricity consumers from high prices* will require introduction of a temporary tax on electricity companies' windfall profits. Gas-fired generation is the marginal source at the wholesale power markets, so higher gas prices lead to windfall profits for all suppliers along the power supply cost curve (up to EUR 200 billion) and part of this amount is going to be reallocated to support vulnerable consumers (around EUR 55 billion). This plan item enlarges gas demand by this group of consumers to enable them to maintain sanitary-required heating levels. 7. *Speed up the replacement of gas boilers with heat pumps* would save additional 2 bcm of gas use within the first year, but will require EUR 15 billion in additional investment. The slowdown of the EU economy may not allow it to mobilize that much within one year. *8. Accelerate energy efficiency improvements in buildings and industry* potentially allows it to reduce gas consumption by 2 bcm within a year. *9. Encourage a temporary thermostat adjustment by consumers:* turning down the thermostats by 1°C would reduce gas demand by 10 bcm a year. *10. Step up efforts to diversify and decarbonize sources of power system flexibility* option was not estimated in terms of demand reduction, but, along with peak power prices, it can push the flexible demand down through real-time electricity price signals.

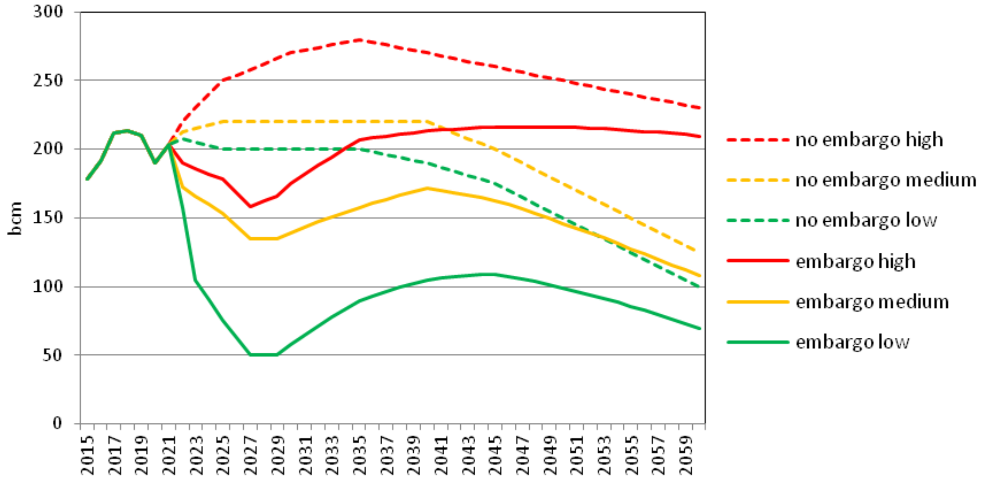
All together, these items could reduce the EU demand by 3-40 bcm in the short-term and by 60-75 bcm by 2030. The goal of completely avoiding the EU's dependence on Russian gas supply by 2027 is highly challenging. It necessitates huge gas savings along with the pathway proposed in the IEA NZE scenario, which yields about 60 bcm in EU gas use savings in 2021-2027, to be supplemented with over 100-110 bcm in additional gas supply from alternative suppliers. The latter equals total current gas supply from alternative sources. If the EU plan is successful, Russia will have problems with finding new markets for 140-150 bcm of pipeline gas supply lost by or before 2027. It may eventually redirect some of the lost export amounts to other global markets, but this strategy takes time, meets with substantial infrastructure demand, and will face technology and financing restrictions.

Prior projections were substantially revised downwards to reflect the potential embargo effects on the Russian gas exports (Fig. 3.12). If EU manages to cut its gas imports from Russia by 100 bcm in 2022 and by 150 bcm by 2027,[21] then Russian total pipeline gas exports may shrink to 50 bcm by 2027. Russia might then rebound it, as some new markets with no sanctions expand, until the scaling effects of the decarbonization policies squeeze gas demand there as well. In 2021, average Russian export gas price (272 US$/1000 cm) was twice the 2020 level. In 2022-2025, it can reach and exceed 360 US$/1000 cm (keeping in mind that under long-term contracts gas prices are lower than in the spot markets). Demand for alternative supply (to substitute the Russian gas) will develop a market pressure to keep the gas prices high. In this case, Russia's gas export revenues in 2022 may exceed the 2021 level, despite a sharp decline in exported volumes. It is not until 2025-2035 that Russia will face a substantial decline in gas export revenues to the level close or below the one registered in 2020 in

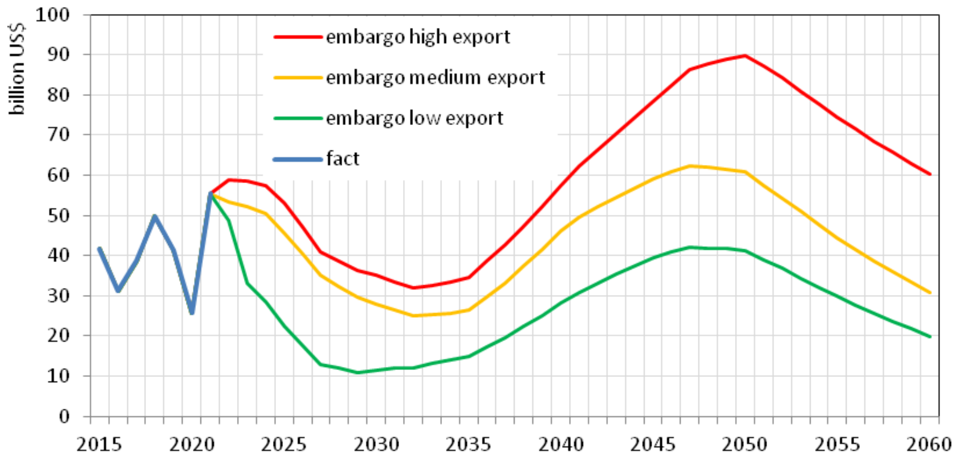
[20] A 10-Point Plan to Reduce the European Union's Reliance on Russian Natural Gas – Analysis - IEA
[21] Practical restrictions to attaining this goal are discussed in: Konoplyanik A. Europe's energy suicide. EXPERT, No. 11, March 14-20, 2022 (in Russian).

nominal terms, but much lower if import prices growth is accounted for. So efforts to reduce the dependence on the Russian gas will bring visible export revenue impacts only beyond 2025.

**Figure 3.12. Russian pipeline gas exports and export revenues accounting for embargo effects**




(a) natural gas export




(b) gas export revenues

Source: CENEf-XXI.

According to the Russian Central Bank and RF Customs Service, in 2020-2021 Russia exported 66-68 bcm as LNG, which brought over US$ 7 billion in revenues in 2021.[22] In 2020, 17 bcm LNG were provided to EU. EU's decision to refuse Russian LNG may change the geography of the LNG trade. In this case, Russian former LNG exports to EU may be redirected to other destinations. Therefore, not many short-term impacts can be expected. In the long-term, lack of domestic technologies and financing will hamper projects aiming to expand LNG supply from Russia.

The conclusions for natural gas are as follows:

- The EU market and some other markets for the Russian gas will be shrinking driven by decarbonization policies, high gas prices and the political unwillingness to purchase the 'toxic' Russian gas;
- Potential expected volumes of Russian gas exports in BAU and announced policies-like scenarios may show a 70-100 bcm drop by 2027. It is very unlikely that gas exports and production in Russia will ever exceed the 2021 level;

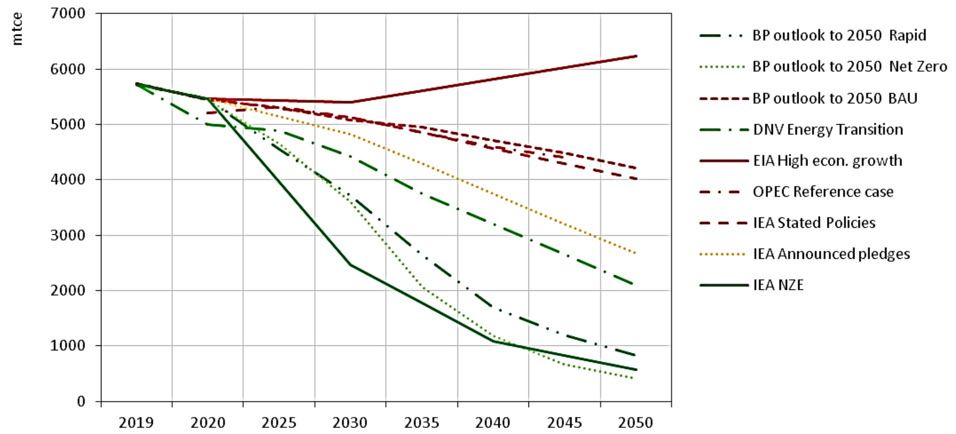
[22] The RF Customs Service (customs.gov.ru)

- Russia has given a substantial push to the low carbon transition process in the OECD countries and worldwide. Global demand for Russian gas on the whole 2060 time span will be much lower than that expected before February 24th;
- Domestic natural gas demand in Russia will be driven by two factors working in the opposite directions. First, the demand will be declining due to the Russian economic recession with a subsequent slow revival; and second, low carbon transformation of the Russian economy will be slowed down by the equipment import restrictions and declining incomes.

### 3.2.3 Coal

Recent developments have revived coal demand even despite higher coal prices, because gas prices have grown much faster making coal-based power generation more competitive even with high carbon prices (these dropped in March 2022 as a reaction to skyrocketing fuel prices). In the early 21st century, coal managed to win back some of the share it had lost in global energy demand. A larger coal use for power generation in China and India after 2000 gave rise to the "second coal wave." Some growth in coal consumption will unlikely last longer than until the mid-2020s. Coal consumption reached an absolute peak of 8 billion tons back in 2011. A return to this peak is possible by 2024[23] partially due to the recent surge in gas prices. Beyond that point, even before 2030, coal consumption will start declining steadily at a pace determined by the decarbonization progress. Only DOE expects some growth in coal use by 2050 (Fig. 3.13). All of the other recent projections show that coal will never come back, and there will be no "third coal wave". Even announced pledges-like scenarios expect a substantial (at least 25%) global coal demand reduction by 2050. Low carbon scenarios expect about 5-fold decline leaving coal use below 1000 mtce at facilities mostly using the CCS technology.

**Figure 3.13. Projections of global coal production to 2050**

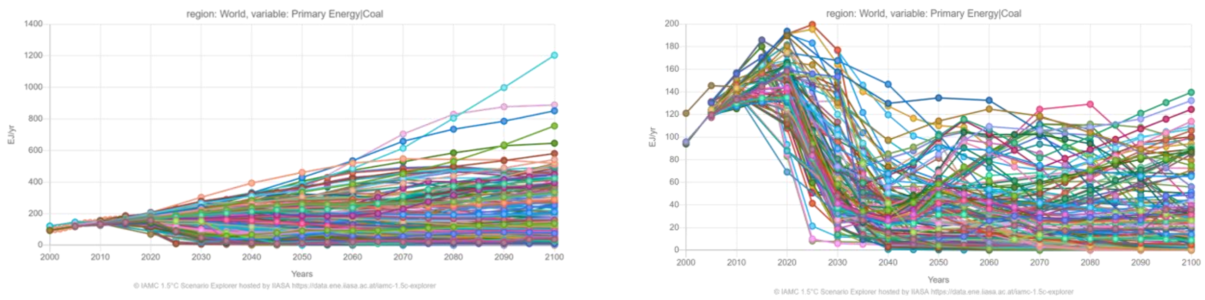



Sources: IEA. 2021. World Energy Outlook. 2021; IEA. 2021. Net Zero by 2050. A Roadmap for the Global Energy Sector; BP Energy Outlook 2050: September 2; DOE. 2021. International Energy Outlook 2021with projections to 2050. October 2021; OPEC. 2021. World oil outlook. 2045; DNV. 2021. Pathway to net zero emissions. Energy transition outlook 2021.

According to the IIASA database, in all scenarios with global warming limited to 2°C coal production declines by a factor of four or more by 2050, and in the scenarios with the warming limited to 1.5°C it declines by almost an order of magnitude (Fig. 3.14). Many countries have already pledged to phase out coal-based power generation. The Powering Past Coal Alliance (PPCA) is a group of more than 137 countries, cities, regions and organizations that have announced the goal of "sending coal into the past" (by 2030 in OECD-countries and no later than 2050 in other countries) by phasing out coal-fired energy production that does not have carbon capture and storage systems in place. Larger-scale deployment of direct reduced iron production technology using hydrogen as a reducing agent will lead to a drop in metallurgical coal demand. Modern systems of taxonomy virtually block funding for new coal projects. The end of coal generation is close, but the exact date is still unclear.

[23] IEA, 2021e. Coal 2021. Analysis and forecast to 2024.

**Figure 3.14. IAMs projections of global coal production to 2100**

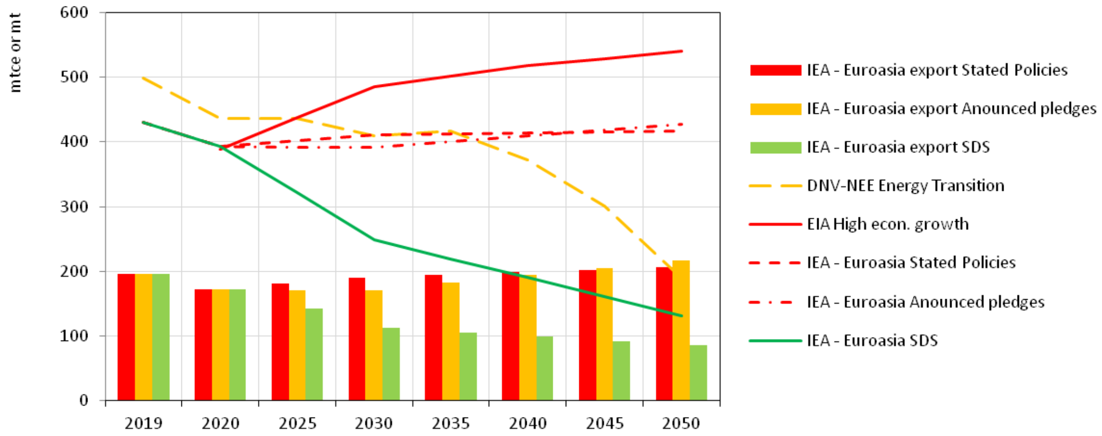



all scenarios scenarios with warming below 2°C to 2100

Sources: [IAMC 1.5°C Scenario Explorer hosted by IIASA]

Russia contributes 5% to the global coal supply. Nearly half of this amount is used domestically, the rest is exported. Domestic coal use has been shrinking since 2000, and the trend will persist for decades to come. In order to bring the growing coal production in line with the DOE's expectations (Fig. 3.15) Russia would need to win new foreign coal markets. In the stated policies and announced pledges scenario, IEA projects Russian coal production nearly stable until 2050 and coal exports growing to about reach the 2019 level. So gaining new and losing current market niches is about balanced. But in the IEA SDS, the global export niche for Russian coal is halved by 2050 along with a reduction in domestic coal use leading to about 3-fold decline in coal production.

**Figure 3.15. Projections of Russian* coal production and exports to 2050**



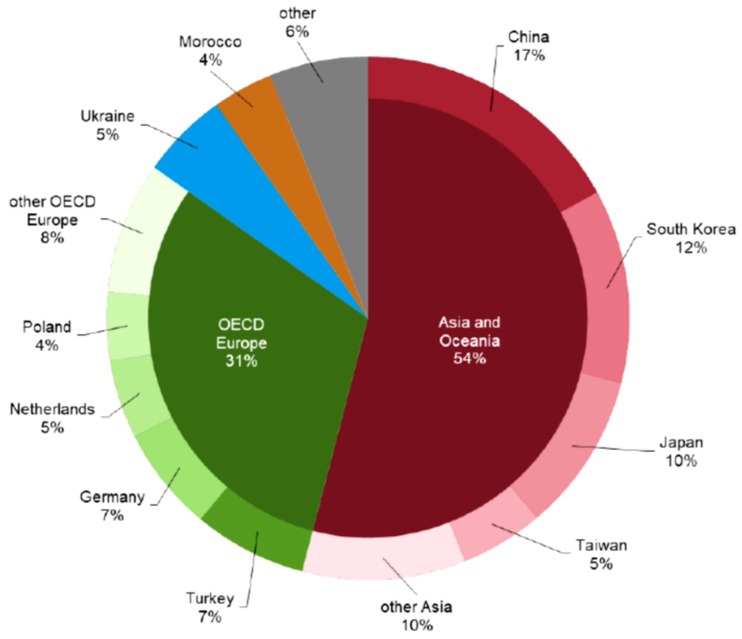

* Projections by DNV and IEA are provided for global subregions, which include Russia. IEA data are provided in mtce.

Sources: IEA. 2021. World Energy Outlook. 2021; IEA. 2021. Net Zero by 2050. A Roadmap for the Global Energy Sector; BP Energy Outlook 2050: September 2; DOE. 2021. International Energy Outlook 2021with projections to 2050. October 2021; DNV. 2021. Pathway to net zero emissions. Energy transition outlook 2021.

According to the RF Customs Service, in 2021 Russia exported 211 Mtons of coal worth $US 17.6 billion (+41.7% to 2020) and imported 22 Mtons (worth $US 0.4 billion). Coke and coal char exports in 2021 were 3.3 Mtons worth $US 1.1 billion (2.2-fold growth from the 2020 level). In all, 2021 Russia's net coal and coke exports were 192 Mtons worth $US 18.3 billion. In 2020, over a third of Russian coal exports went to Europe (more than 20% to the EU) and about 23% to Japan and South Korea (Fig. 3.16). Altogether, nearly 60% of Russia's coal exports were to the OECD countries, which have strong low carbon reduction commitments and therefore not much potential to accommodate more of the Russian coal. In 2019-2021, EU imported 47-60 Mtons of coal and coke from Russia.[24]

**Figure 3.16. Russia's coal exports by destination in 2020**

[24] [European Union Imports of estimate of low valued import transactions from Russia - 2022 Data 2023 Forecast 2000-2020 Historical (tradingeconomics.com)]




Source: US EIA. Country Analysis Executive Summary: Russia. 2021.

Coal is not affected by the announced sanctions so far, but the EU's proposal to phase out the dependencies on Russian fossil fuels by 2027 covers coal as well. In 2021, EU imported over 55 Mt of Russian coal and coke, which was about 30% of Russian net coal exports and over 50% of the EU net coal imports. Back in 2019, the latter were responsible for 44% of total EU coal use. So Russia supplied nearly a quarter of the coal used in the EU. If sanctions are expanded to cover Russian coal exports, a large market niche in the global coal trade may be lost in the medium-term. There is a potential to offset some of the loss by redirecting coal flows eastbound, but logistical bottlenecks (substantially exacerbated by the overcrowded transport infrastructure where coal competes with other goods finding their way to the Asian markets) set limits, and a lot of time and investment will be needed to untap these options. This pushes Russian coal exports closer to the pathways described in the IEA SDS or NZE scenarios (Fig. 3.15) and away from those outlined in the stated policies and announced pledges scenarios. Some decline in coal exports from Russia will be more than outweighed with high coal prices which were ranging between 150 and 420 $US/t in July 2021-March 2022 versus 50-120 $US/t in 2016-2020.[25]

The conclusions for coal are as follows:

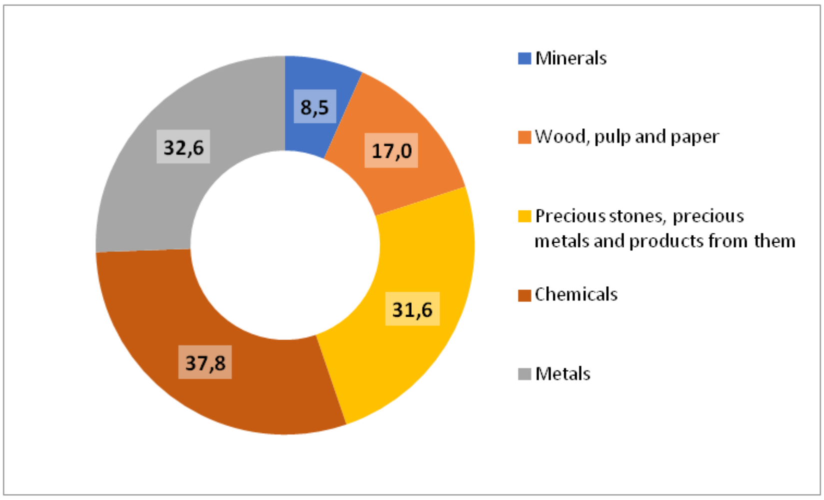
- Moderate progress towards global decarbonization and lack of sanctions on coal may keep Russian coal production and exports close to the current levels with a very low chance to grow;
- A substantial progress in global decarbonization and taking action to cease coal imports from Russia by 2027 will halve Russian coal exports by 2035 and further reduce them beyond that point with a subsequent decline in coal production, as domestic coal use in Russia will be down as well.

### 3.2.4 Basic materials and low carbon goods

Export of basic materials, precious stones, precious metals and relevant products provided 30% of Russian exports of goods, or $US 146 billion in 2021 (Fig. 3.17). With precious stones and metals excluded, the exports come down to $US 114 billion, or 23% of total export. The key items listed in Table 3.1 generated $US 63 billion in 2021, or 13% of total export. A substantial dependence on the exports of basic materials makes it essential to understand, how the global markets and also regional markets that are important for Russia may evolve in the near and distant future.

[25] Coal - 2022 Data - 2008-2021 Historical - 2023 Forecast - Price - Quote - Chart (tradingeconomics.com)

**Figure 3.17. Russia's exports of key basic materials, precious stones and metals in 2021**




Source: RF Customs Service (customs.gov.ru)

**Table 3.1. Key items of Russia's basic materials exports in 2021**

| Products | Volume | USD 1000 | USD/volume |
|---|---|---|---|
| NATURAL CALCIUM PHOSPHATES, NATURAL ALUMINIUM CALCIUM PHOSPHATES, AND NATURAL AND PHOSPHATIC CHALK | 2 039 | 287 300 | 141 |
| IRON ORES AND CONCENTRATES, INCLUDING ROASTED IRON PYRITES | 25 296 | 3 796 000 | 150 |
| *Ores and minerals* | | 4 083 300 | |
| ANHYDROUS AMMONIA | 4 418 | 1 668 300 | 378 |
| METHANOL (METHYL ALCOHOL) | 1 894 | 633 200 | 334 |
| MINERAL OR CHEMICAL FERTILIZERS, CONTAINING NITROGEN | 14 458 | 4 468 600 | 309 |
| MINERAL OR CHEMICAL FERTILIZERS, CONTAINING POTASSIUM | 11 904 | 3 321 100 | 279 |
| MINERAL OR CHEMICAL FERTILIZERS, CONTAINING TWO OR THREE FERTILIZING ELEMENTS | 11 201 | 4 708 600 | 420 |
| SYNTHETIC RUBBER | 1 094 | 1 897 000 | 1 734 |
| Chemical products | | 16 696 800 | |
| WOOD IN THE ROUGH | 13 888 | 1 025 200 | 74 |
| WOOD SAWN OR CHIPPED LENGTHWISE | 17 310 | 6 143 700 | 355 |
| PLYWOOD, VENEERED PANELS AND SIMILAR LAMINATED WOOD | 3 043 | 1 937 900 | 637 |
| PULP OF WOOD | 2 042 | 1 312 300 | 643 |
| NEWSPRINT IN ROLLS OR SHEETS | 922 | 405 400 | 440 |
| Wood, pulp and paper | | 10 824 500 | |
| PIG IRON AND SPIEGELEISEN IN PIGS, BLOCKS OR OTHER PRIMARY FORMS | 3 933 | 1 992 800 | 507 |
| FERRO-ALLOYS | 896 | 1 476 200 | 1 648 |
| SEMI-FINISHED PRODUCTS OF IRON OR NON-ALLOY STEEL | 14 979 | 9 176 400 | 613 |
| FLAT-ROLLED PRODUCTS OF IRON OR NON-ALLOY STEEL | 8 502 | 7 358 000 | 865 |
| REFINED COPPER AND COPPER ALLOYS | 463 | 3 848 200 | 8 311 |
| NICKLE, UNWROUGHT | 45 | 795 800 | 17 529 |
| ALUMINIUM, UNWROUGHT | 3 481 | 7 077 800 | 2 033 |
| Metals | | 31 725 200 | |
| Total basic materials | | 63 329 800 | |
| Total | | 493 344 300 | |

Source: The RF Customs Service (customs.gov.ru)

*Service-accumulated stock-material flow-environment impacts* chain models are increasingly being used to project basic materials demand.[26] Services (such as housing, mobility, healthcare, leisure) and economic activities require infrastructure, buildings, equipment, and durables, which are essentially

[26] Bashmakov I.A. GHG emissions from global iron and steel: past, present, and future // Iron and Steel. Scientific, technical, and economic bulletin. 2021. Vol. 77. No. 8. Pp. 882-901; Bleischwitz, R., V. Nechifor, M. Winning, B. Huang, and Y. Geng, 2018: Extrapolation or saturation – Revisiting growth patterns, development stages and decoupling. *Glob. Environ. Chang.*, 48, 86–96, https://doi.org/10.1016/J.GLOENVCHA.2017.11.008; Cao, Z., L. Shen, A. N. Løvik, D. B. Müller, and G. Liu, 2017: Elaborating the History of Our Cementing Societies: An in-Use Stock Perspective. *Environ. Sci. Technol.*, 51(19), 11468–11475, doi:10.1021/acs.est.7b03077.

accumulated as physical capital. The stock of materials is embodied in this capital. This in-use stock is annually replenished with new objects in which materials are embodied (materials for stock formation), and decreases by the amount of materials embodied in objects whose service life is expired. Some of the materials that have served their first term are recycled and reused, and some are landfilled. The concept of social metabolism and the analysis of material and energy flows (material flow analysis - MFA, material and energy flow analysis - MEFA, Material Inputs, Stocks and Outputs, MISO-model) allows it to see how demand for basic materials evolves as economy develops. The relationship between the dynamics of the accumulated stock of material and its annual consumption is anything but trivial. It depends on the stage of economic development and has certain turning points. In the first stage, both the stock of material and the current materials per capita consumption are growing dynamically, while in the fifth stage, both these indicators are declining. The transition from one stage to another depends on the achieved level of economic development. Therefore, it is erroneous to mechanically extrapolate the past trends.

**Steel.** Empirical data show that when GDP per capita reaches 10-12 thousand dollars, steel consumption per capita saturates at 300-700 kg/capita; however, the accumulated stock of ferrous metals continues to grow. It reaches the saturation level when GDP per capita is in the range of $US 16-20 thousand. The stock per capita reaches the saturation level 30 or 40 years after the peak in per capita consumption. In the developed countries, the accumulated stock of ferrous metals per capita is 10-16 t/person, while in sub-Saharan Africa it is only 0.5 t/person. The global indicator is not expected to reach a saturation level of about 10 t/person before 2100. This means that the world is on a trajectory close to the one travelled by the UK after 1800, but with an almost 100 years shift. Since the early 1980s, the accumulated stock of ferrous metals in the UK has saturated in absolute terms, and the gross additions in the accumulated stock have become equal to its physical retirement. On a per capita basis, it first stabilized and then dropped to a level slightly above 10 t/person. The UK has entered a decoupling stage: the economic growth continues, but no longer requires an increase in the consumption of ferrous metals.[27]

With a mechanical transfer of the UK trajectory, transition to the stage of decoupling and stock saturation for the world may be expected at a level of about 100 Gt of steel with a complete decoupling of economic growth and steel consumption around 2075. With a 2% annual stock replacement rate (by analogy with the UK in 2017), the annual consumption of ferrous metals may stabilize at around 2-2.2 Gt, and production at around 2.3-2.5 Gt. However, the deployment of material-saving technologies and the accelerated replacement of steel with other materials can reshape this trajectory and reduce both the level of saturation (by 2050 at 47–63 Gt) and the time required to achieve it. With the growth of the accumulated stock of ferrous metals, the volume of amortization scrap will increase (up to 950 million tons per year by 2050) and the share of steel produced from scrap may reach 40-45%. By 2075-2100, the volume of scrap will grow up to 2 Gt and the demand for primary metal will markedly shrink.

This logic fits very well with the recent long-term steel demand projections. Until 2050, steel production will be growing just slightly faster than the population. According to the logic of the historically observed cycles, in the next 30 years, a downward phase of steel consumption per unit of GDP should manifest, that is, the increase in the stock of steel and steel consumption should lag behind the GDP growth. According to the IEA's stated policy scenario, steel production will grow up from 1.9 Gt in 2019 to 2.5 Gt in 2050, or by 33%, and final consumption will increase from 1.5 to 2.1 Gt, or by 40%, which is noticeably slower than the global GDP, which is expected to grow 2.5-fold by 2050. It is assumed that GDP elasticity of steel demand will be as low as 0.36, and of steel production 0.33, versus almost 1 in 1900-2020. This is a reflection of both the downward phase in the long cycle of the dynamics of specific steel consumption per GDP, and of the transition to the stage of steel stock saturation in the increasing number of countries, as their level of economic development grows.

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[27] Streeck, J., D. Wiedenhofer, F. Krausmann, H., Helmut (2020): Stock-flow relations in the socio-economic metabolism of the United Kingdom 1800-2017. Resources, Conservation & Recycling. https://doi.org/10.1016/j.resconrec.2020.104960.

In its 2021 publication *Net Zero by 2050. A Roadmap for the Global Energy Sector*, the IEA reduces the 2050 forecasted steel demand for 2050 to 1987 Mt through measures to reduce material intensity.[28] In the developed countries, production will stabilize at the 2030 level until 2050, while in developing countries it will continue to grow, yet very slowly. As a result, in this projection global steel production in 2030-2050 is only 50 Mt up. In *Energy technology perspectives 2020*,[29] IEA shows that by reducing the material intensity steel demand may decline by 0.8 Gt, or by 29%, by 2070. In its 2019 publication *Material efficiency in clean energy transitions*, IEA also shows that by 2050 steel consumption (excluding waste from steel mills) even in the baseline scenario (*Reference Technology Scenario*) is only 2,170 Mt, or by 21%, up from 2019 (1790 Mt) via measures to reduce material intensity. In the other two scenarios (*Clean Technology* and *Material Efficiency*), steel consumption drops to 1,600 and 1,400 Mt, respectively.

Gielen et al. (2020)[30] give the following estimates for 2050: crude steel production 2,400 Mt, finished steel 2,200 Mt, and steel products 2,064 Mt. Wang et al[31] considered 5 scenarios, of which only 3 differ in steel production volumes: inertial scenario S1 with a demand trend close to the IEA STEPS scenario; scenario S3 with improved material efficiency in line with the IEA's "*sustainable development*" scenario; and scenario S5, which estimates the effects of an additional 34% reduction in demand compared to the IEA's *"sustainable development"* scenario. This paper provides cumulative data for steel production. Based on these data, annual data were obtained. In terms of steel production, by 2050 three scenarios reach the levels of 2526 Mt, 2032 Mt and 500 Mt, respectively. The last estimate is the lowest of all.

OECD[32] indicates that by 2060 steel production may increase by 35-60% from the 2017 level to reach 2,344 – 2,878 Mt. In the BCG[33] forecast, steel production grows up to 2.8 Gt by 2050. At the same time, the amount of scrap metal grows to 1.4-1.6 Gt. Thus, the production of secondary metal by or before the middle of the century can be equal to the production of primary metal or even exceed it. According to this forecast, pig iron and coking coal demand may stay at the 2015 level or increase by 650 and 350 Mt, respectively, by 2050. Based on the analysis of various publications, Holapp[34] considers three scenarios, and in the highest steel production reaches almost 3 Gt by 2050. Xilia et al.[35] expect steel production up to 2100. According to this forecast, production will peak at 2.8 Gt by 2070, and then will slowly decline by 2100, as the share of secondary metal increases markedly due to the availability of scrap (around 2 Gt) beyond 2075.

[28] IEA. 2021. Net Zero by 2050. A Roadmap for the Global Energy Sector.

[29] IEA. Energy technology perspectives. 2020.

[30] Gielen D., D. Saygin, E. Taibi, J-P. Birat. Renewables-based decarbonization and relocation of iron and steel making. A case study. March 2020. Journal of Industrial Ecology 24(5). DOI:10.1111/jiec.12997.

[31] Wang P., M. Ryberg, Y. Yang, K. Feng, S. Kara, M. Hauschild and W-Q. Chen. Efficiency stagnation in global steel production urges joint supply- and demand-side mitigation efforts. Nature Communications. (2021). https://doi.org/10.1038/s41467-021-22245-6 www.nature.com/naturecommunications.

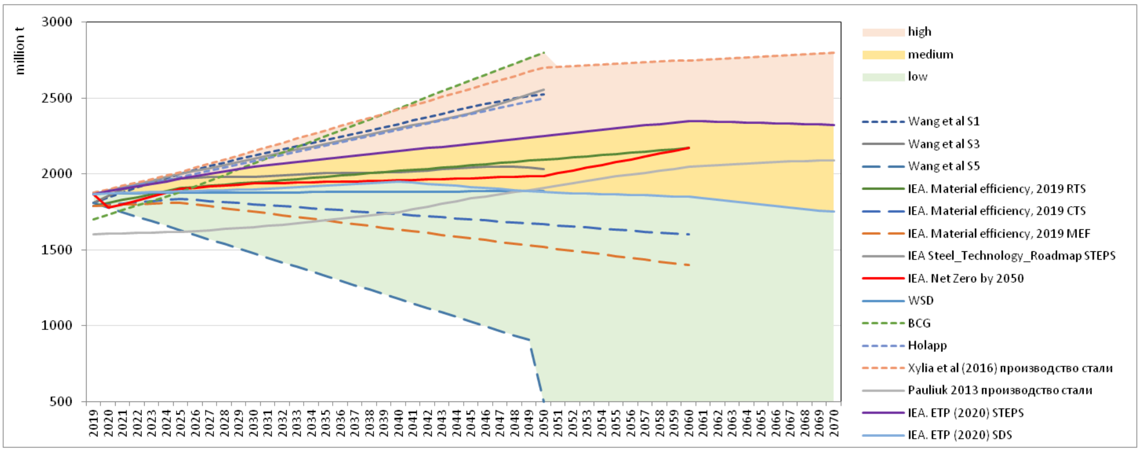
[32] OECD, 2019: Global Material Resources Outlook to 2060. OECD, 210 pp.

[33] Haslehner R., Stelter B., and N. Osio. Steel as a Model for a Sustainable Metal Industry in 2050. Boston Consulting Group. October 07, 2015. Steel as a Model for a Sustainable Metal Industry in 2050 (bcg.com)

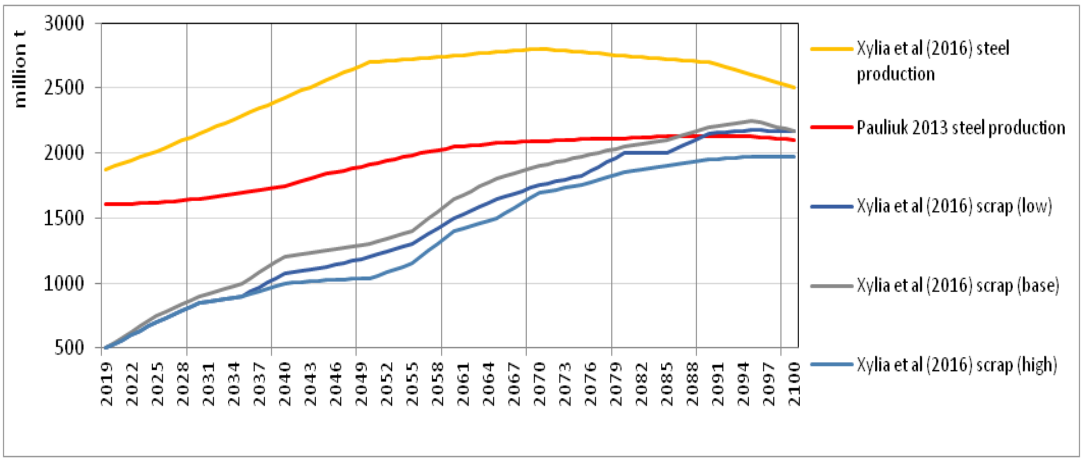
[34] Holapp L. A General Vision for Reduction of Energy Consumption and CO2 Emissions from the Steel Industry Metals 2020, 10, 1117; doi:10.3390/met10091117.

[35] Xylia M., S. Silveira, J. Duerinck and F. Meinke-Hubeny. 2016. Worldwide resource efficient steel production. In SUSTAINABLE PRODUCTION DESIGN AND SUPPLY CHAIN INITIATIVES. INDUSTRIAL EFFICIENCY 2016. Worldwide resource efficient steel production (eceee.org).

## Figure 3.18 Long-term forecasts of global steel production




(a) projections to 2050-2070




(b) projections to 2100

Source: Bashmakov I.A. GHG emissions from global iron and steel: past, present, and future // Iron and Steel. Scientific, technical, and economic bulletin. 2021. Vol. 77. No. 8. Pp. 882-901. DOI: 10.32339/0135-5910-2021-8-882-901.

If we focus on the middle zone of the forecasts, we will see that there will be either a stagnation in demand for steel (4% growth by 2040 and getting back to 2019 level by 2060), or moderate growth by about 25%. If Russian ferrous metals suppliers succeed in maintaining their 2021 global market share, export volumes may evolve in the same way. About 25% of the Russian iron and steel exports go to the EU market. Steel consumption and production in the EU will be slowly growing or stay at the 2019 level until 2050, thus keeping the niche for exporters at about the current level with options for both a slight increase and a slight decrease. If CBAM helps increase the supply of European steel to the EU markets, the effect will be partially offset by the loss of foreign markets due to the fact that after CBAM is introduced, the EU steel will become more costly to produce bringing the exports down.[36]

The EU sanction package banned the imports of some ferrous products from Russia. According to some estimates,[37] it may apply to 40% of Russian steel exports to the EU (5-7 Mt in 2018-2021) with potential losses of $US 3.4 billion (40% of $US 8.6 billion earned in 2021). Total steel exports in 2021 were nearly 28 Mt. Therefore, the Russian exports may be expected to lose some 9%. It is less than 1% of globally traded steel and steel products (382-467 Mt in 2016-2020).[38] When the logistical problems

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[36] CENEf-XXI (2021). CBAM. Implications for the Russian Economy. Moscow. Center for Energy Efficiency. (In Russian).]; Bashmakov I.A. CBAM and Russian export. Voprosy Ekonomiki. 2022;(1):90-109. (In Russ.) https://doi.org/10.32609/0042-8736-2022-1-90-109

[37] Russian steelmakers versus western sanctions – Post mortem - Finam (finam.ru)

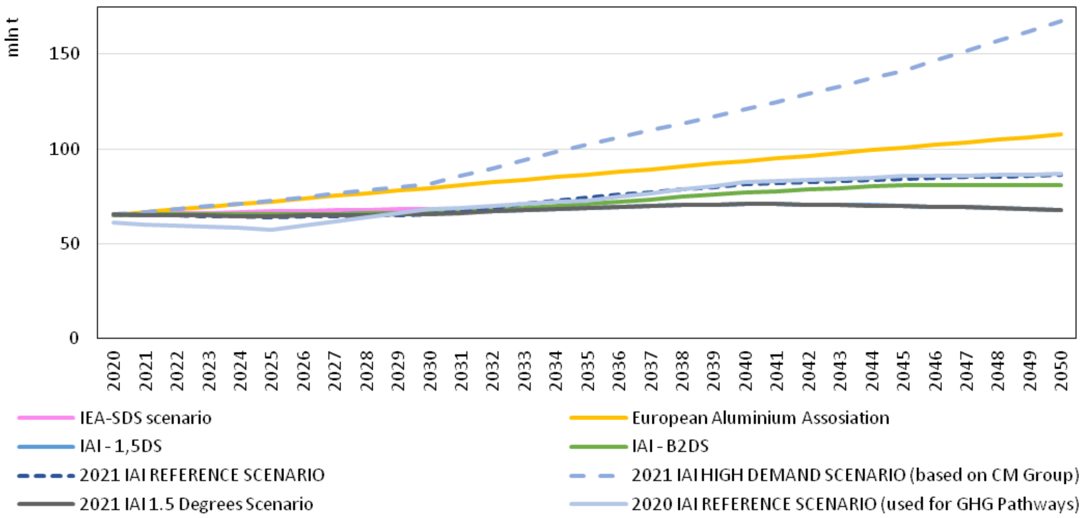
[38] World Steel Association, 2021: *World Steel in Figures 2021*. 32 pp. https://www.worldsteel.org/en/dam/jcr:976723ed-74b3-47b4-92f6-81b6a452b86e/World%2520Steel%2520in%2520Figures%25202021.pdf.

are ultimately resolved, this loss may be partly compensated by redirecting Russian steel to other destinations with some discount. Such discounts are possible, since export prices for plate rolled steel were over 1,400 $US/t in March 2022 (average 2021 price for Russian steel exports was 865 $US/t). With a correction on the effects of partial embargo on Russian steel there is not much room to expand iron and steel exports above the 2021 level. The same goes for the exports of iron ores and concentrates which were 25.2 Mt in 2021 and yielded $US 3.8 billion in export revenues.

**Aluminium**. According to the IAI baseline forecast, the global production of primary aluminum will grow to 86.4 Mt, and of secondary aluminum up to 88 Mt by 2050 (Fig. 3.19). In other words, production of secondary aluminum will account for more than a half of total aluminum production by 2050. In the IAI high consumption scenario, production grows 2.6-fold to 167.4 Mt by 2050. This is the highest forecast. Secondary aluminum production in this scenario grows to 116 Mt. In the *1.5$^o$C* scenario, primary aluminum production grows only to 68 Mt, and secondary aluminum production to 78 Mt. The accumulated aluminum stock embodied in physical capital grows to 2.8 bln t by 2050, and in high scenario up to 3.7 bln t, which lays the basis for secondary aluminum production growth.

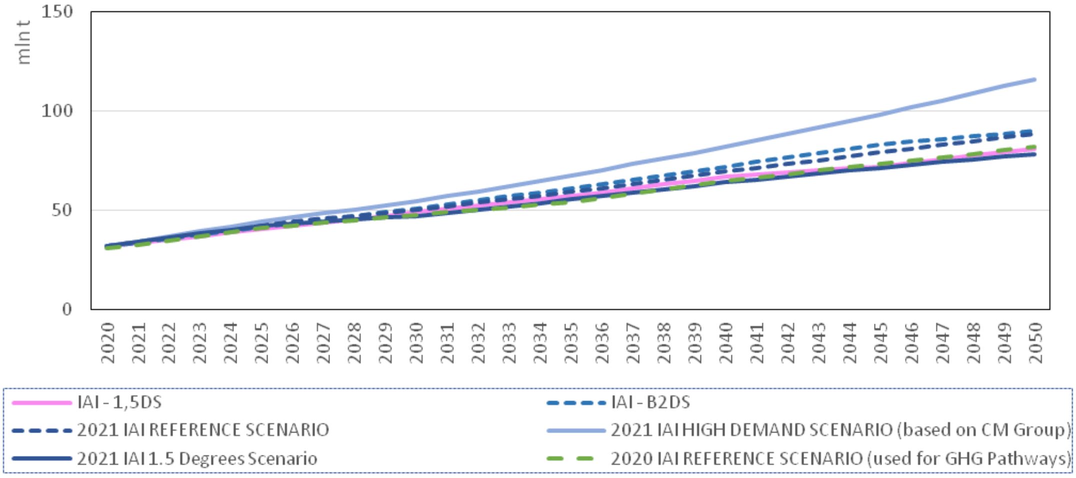
Russia's 2020 aluminum exports were 3.6 Mt ($US 7.6 billion) and 2021 exports were 3.5 Mt ($US 7.1 billion), or about 5% of global supply. In 2019-2020, nearly 1 Mt, or about 25% of produced aluminum, was exported to EU. In 2021, it was reported to reach 1.6 Mt.[39] If these data are correct, EU is responsible for 46% of Russia's overall primary aluminum exports in 2021, being the dominant market one for the Russian aluminum.

**Figure 3.19 Global aluminum production perspectives to 2050**




(a) primary aluminum

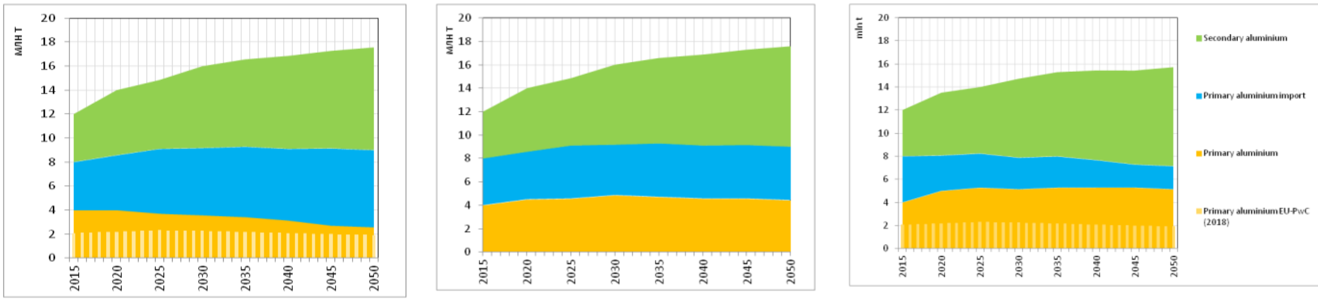
[39] Rolling stop – "Kommersant", No. 43 (7244), 15 March, 2022 (kommersant.ru)




(b) secondary aluminum

Sources: International Aluminium Institute, 2021: *Aluminium Sector Greenhouse Gas Pathways to 2050*, London, UK, 20 pp.; International Aluminum Institute, 2021: International aluminium institute statistics. https://alucycle.international-aluminium.org/public-access/ (Accessed: December 21, 2020).

**Figure 3.20. Projections of aluminum production and imports in EU and EAST to 2050**




Decreasing production case | Base case | Positive case

Source: The Vision 2050. EUROPEAN ALUMINIUM'S CONTRIBUTION TO THE EU'S MID-CENTURY LOW-CARBON ROADMAP. A vision for strategic, low carbon and competitive aluminium. EXECUTIVE SUMMARY. European Aluminium. March 2019.

The European Aluminum Association in its *Vision 2050* considered three possible scenarios for the development of the aluminium market in Europe. In the *Decreasing production case*, 35% of the demand will be met by imports. In the *Positive case scenario*, it is assumed that the indirect costs of rising electricity prices under the ETS will be fully compensated by 2030, and primary aluminium production in Europe may increase by 30%, which will limit the imports.

Australia banned all alumina and bauxite exports to Russia (1.5 Mt, or 19% of UC Rusal's alumina consumption). In addition, production by Nikolaev Alumina Refinery (1.8 Mt of alumina per year, or another 20% of UC Rusal's alumina consumption) halted. In 2021, UC Rusal produced 3.8 Mt of aluminum and 8.3 Mt of alumina. It takes 4 t of alumina to produce 1 t of aluminum. So, the 3.3 alumina shortage brings aluminium production down by 22%, unless the supply shortage is compensated by export from China or other countries when the logistics are in place.

According to the above estimates, until 2050 aluminium consumption will continue to grow, both globally and in the EU. However, additional demand will be partly met by an increase in secondary aluminium production. EU imports in 2060 may stay in the range between 2 and 6 Mt, especially if power prices in the EU stay high for a long time. After the sanctions-based decline in 2022 and subsequent years (depending on how long the sanctions are in place) Russia may re-establish and even expand its aluminium exports by 2050.

**Other metals**. In 2018-2021, Russian exports of copper were down from 0.7 to 0.46 Mt, or from $US 4.1 to 3.9 billion. According to IEA, global copper demand may more than double in 2020-2060.[40] In 2018-2021, Russian exports of nickel was down from 134 to 46 thousand tons, or from $US 1.8 to 0.8 billion. According to OECD, global nickel demand may triple and reach 2 Mt by 2060.[41] The global decarbonisation process expands markets for both Russian copper and nickel exports.

**Wood, wood products, pulp and paper**. This group of Russian exports yielded $US 17 billion in revenues in 2021, including about $US 3 billion from pulp and paper. In 1970-2019, global timber production lagged behind GDP showing annual growth of less than 1% and reached 2,184 million $m^3$. This growth pattern (lagging behind GDP) is expected to persist in all FAO scenarios with projected 10-35% growth in global timber demand in 2019-2050.[42] The leading producers of roundwood are the USA (19%), Russia (10%), China (9%), Canada and Brazil (7% each).[43]

By 2030, global pulp production is expected to slowly decline, while paper production will be declining much faster driven by a deeper penetration of Internet. This may be partially compensated by the growing demand for paperboard for packaging uses, as plastics packaging will be scaling down.[44] According to another projection, global pulp, paper, and paperboard production will increase from 423 to 498 Mt in 2020-2050.[45] As a result, these articles of Russian traditional exports are not expected to significantly expand.

**Chemicals.** In 2021, Russia exported $US 38 billion worth of chemicals. Much of that – 42 Mt and $US 14 billion – are ammonia and fertilizers. 9 Mt of these were exported to EU in 2019. Consumption of nitrogen, phosphate and potassium fertilizers in EU is projected to remain close to the current level in 2050.[46] The general consensus is that global agricultural production will have to increase by about 60-70% from the current levels to meet the growing food demand by 2050.[47] This would drive the global demand for fertilizers up. For phosphate fertilizers, global demand is expected to be 43% up in 2020-2050.[48] For nitrogen fertilizers, the demand in medium scenarios may grow by a third.[49] The market for ammonia used as fuels and feedstock may expand rapidly from 172 to 440 Mt in 2017-2050 in BAU scenarios. In their *1.5°C scenario,* Saygin and Gielen (2021) expect ammonia production from fossil feedstock to drop to 106 Mt by 2050. But the demand for green ammonia may expand to 330 Mt and for ammonia from biomass to 162 Mt by 2050.[50] Russian ammonia exports may expand in the medium term, but then they will only be possible if green or biomass-based ammonia production is launched at scales.

Russia is responsible for 5% of the global methanol production (4.5 Mt, of which half was exported, including 1.9 Mt to EU). This global market (presently 86 Mt) is showing a fast growth, which is expected to continue to 2050 in BAU scenarios (174 Mt) to provide feedstock for fuels, ethylene (methanol-to-olefins), solvents and other products. However, in low carbon scenarios fossil fuels-based methanol production is down to 50 Mt by 2050, while green hydrogen-based methanol production

[40] IEA, 2020: Energy Technology Perspective 2020.
[41] OECD, 2019: *Global Material Resources Outlook to 2060*. OECD, 210 pp.
[42] Forestry-Food and Agriculture Organization of the United Nations. http://www.fao.org/3/X8423E/X8423E14.htm
[43] IRP, 2020: Global Material Flows Database. https://www.resourcepanel.org/global-material-flows-database (Accessed December 20, 2020).
[44] Craig M.T. Johnston (2016), Global paper market forecasts to 2030 under future internet demand scenarios, Journal of Forest Economics: Vol. 25: No. 1, pp 14-28. http://dx.doi.org/10.1016/j.jfe.2016.07.003
[45] Dietz S., W. Irwin, B. Rauis, V. Jahn, J. Noels, V. Komar and R. Goo. Carbon Performance Assessment of Paper Producers: Note on Methodology Transition Pathway Initiative. February 2021 78.pdf (transitionpathwayinitiative.org)
[46] CENEf-XXI. 2021. CBAM: Implications for the Russian economy. Moscow: Center for Energy Efficiency CENEF-XXI.
[47] https://www.canr.msu.edu/news/feeding-the-world-in-2050-and-beyond-part-1
[48] Nedelciu C.E., K.V. Ragnarsdottir, P. Schlyter, I. Stjernquis. 2020. Global phosphorus supply chain dynamics: Assessing regional impact to 2050. Global Food Security 26 (2020). https://doi.org/10.1016/j.gfs.2020.100426
[49] Mogollón J.M. et al 2018 Environ. Res. Lett. 13 044008
[50] Saygin, D., and D. Gielen, 2021: Zero-emission pathway for the global chemical and petrochemical sector. *Energies*, 14(13), 3772, doi:10.3390/en14133772.

skyrockets to 294 Mt.[51] Unless EU expands sanctions on methanol imports from Russia, fossil fuels-based methanol exports may somewhat grow, yet a substantial market expansion is only possible for bio-based and green methanol.

Plastics are another promising market to expand the non-oil&gas Russian exports. Plastics exports from Russia reached 2.4 Mt in 2020. According to the available projections, global plastics production is expected to more than double rising from about 400 Mt in 2019 to 985-1034 Mt in 2050.[52] Even in BAU scenarios, 106 Mt are expected to be produced from recycled plastics and 6 Mt from bio-plastics by 2050. In low-carbon scenarios, plastics production shows a more modest growth – to 450-659 Mt. Projected growth is 28-40% in 2019-2050 with a production peak in 2050 and subsequent 10% decline from that peak by 2060.[53] In *1.5$^o$C scenario*, fuel-based plastics production will be down to 276 Mt by 2050, while hydrogen-based production will reach 154 Mt, and bio-based production – 18 Mt. The accumulated plastics stock has reached 2.5-3.2 Gt,[54] therefore, the recycling potential is substantial. Virgin plastics production by all routes will be 307 Mt, which is below the current level, while recycled plastics production will reach 279 Mt.[55] In other words, the market for traditional unabated fossil-based plastics will be declining, as low carbon transition gains momentum. In the IEA's *Sustainable Development Scenario*, as soon as in 2050 half of fossil fuel-based chemical production facilities will be equipped with CCUS systems.[56] Summing up, there is a potential for traditional chemicals export growth by 2030. Later, as the global economy turns towards low carbon pathways, markets for unabated fossil fuel-based chemicals will be shrinking, while those for low carbon chemicals will be markedly expanding.

**Hydrogen**. The *Concept of hydrogen energy development in the Russian Federation* was approved by the RF Government Decree No. 2162-r of August 5, 2021. Its key parameters are as follows:

- the use of low or no carbon hydrogen to support transition to low carbon economy;
- diverse sources for hydrogen production, including fossil fuels with CCS; steam reforming of natural gas; pyrolysis of hydrocarbon raw materials (hydrogen production technology with simultaneous production of elemental carbon); nuclear power and water electrolysis;
- reducing the costs of hydrogen production to less than 2 USD/kg;
- until 2035, priority for the production of hydrogen from fossil fuels, nuclear, hydro and renewables in regions with low hydrogen production costs;
- attaining hydrogen export volumes of up to 0.2 million tons in 2024, 2-12 million tons in 2035, and 15-50 million tons in 2050.[57]

It is not clear, whether such exports targets are supported by system-wide estimates. To conduct such preliminary analysis, pilot calculations based on the integration of hydrogen into the CENEf-XXI's ENERGYBAL-GEM-2050 model have been made relying on the following assumptions:

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[51] Ibid.

[52] Ibid.

[53] Plastics future: How to reduce the increasing environmental footprint of plastic packaging. Article, January 2021; https://www.climateforesight.eu/global-policy/the-future-of-plastics-is-uncertain/; The Future of Petrochemicals, IEA, Technological report, 2018; Estimation of carbon dioxide reduction by utilization biomass bioplastic in Malaysia using carbon emission pinch analysis (CEPA), Research Paper, 2020; MDPI, Zero-Emissions Pathway for the Global Chemical and Petrochemical Sector, Deger Saygin and Dolf Gielen; https://www.iea.org/t_c/termsandconditions/.

[54] Geyer, R., J. R. Jambeck, and K. L. Law, 2017: Production, use, and fate of all plastics ever made. *Sci. Adv.*, **3**(7), doi:10.1126/sciadv.1700782; Saygin, D., and D. Gielen, 2021: Zero-emission pathway for the global chemical and petrochemical sector. *Energies*, 14(13), 3772, doi:10.3390/en14133772.

[55] Saygin, D., and D. Gielen, 2021: Zero-emission pathway for the global chemical and petrochemical sector. *Energies*, 14(13), 3772, doi:10.3390/en14133772.

[56] IEA, 2020a: *Energy Technology Perspective 2020*. Paris, 397 pp.

[57] In *Operation plan for the implementation of the Low Carbon Development Strategy of the Russian Federation* Russia sets the goal to contribute 20% to the global hydrogen trade by 2030.

- Hydrogen exports will reach 15 Mt by 2050, and domestically, hydrogen will be used only for DRI production and by oil refineries, which in total will result in hydrogen production of 15,9 Mt in 2050;
- Four types of hydrogen will be produced: "green" (hydro and RE); "blue" (steam conversion of methane); "turquoise" (pyrolysis of hydrocarbon raw materials), and "yellow" using nuclear power;
- based on the literature sources, the initial and perspective technology parameters (specific energy consumption), CAPEXs and LCOHs for the above types of hydrogen were specified;
- It is assumed that different types of hydrogen will be competing based on LCOHs;
- It is further assumed that the share of installations for the production of "blue" hydrogen with CCS will grow up to 43% in 2035 and to 100% in 2050, and the efficiency of $CO_2$ capture and storage will be 95%.

Calculations were made for two options of the hydrogen production structure. With a limited availability of carbon-free power, substantial electrification of hydrogen production will lead to a significant increase in GHG emissions. If generation of carbon-free power is limited, more gas (55 bcm by 2050) will be required to fuel additional power production to meet the growing electricity demand, including that from installations that will not be equipped with CCS by 2050. The additional electricity demand in the "green" and "yellow" option will be 380 billion kWh by 2050, and additional heat demand will be 26 million Gcal. Additional electric capacity demand will exceed 75 GW (47% of the 2021 peak load), including 45 GW for renewable energy. Such manoeuvre makes sense only if large resources of cheap carbon-free power generation are available in addition to those already mobilized in the carbon neutrality scenario. If only "green" hydrogen is produced, the power demand will scale up to 608 billion kWh by 2050 and to 937 billion kWh by 2060. The latter value is only 18% below Russia's 2021 total power generation. These effects multiply several times over, when trying to reach the upper levels of hydrogen exports required by the *Concept of hydrogen energy development in the Russian Federation* – 12 Mt in 2035 and 50 Mt in 2050.

With 3-4 $US/kg hydrogen price, the exports of 15 Mt of hydrogen will yield $US 45-60 billion in revenues by 2060, or as much as natural gas in 2021 ($US 55 billion), which is 5% of total export revenues in 2050. According to CENEf-XXI, the amount of $CO_2$ captured in the production of hydrogen from natural gas will reach 104 Mt.[58] With the costs of $40-60/t$CO_2$, annual costs of CCS will be $US 4-6 billion. Therefore, the hydrogen market is a promising option, but only for low or zero carbon hydrogen. Preliminary analysis shows, that scaling up hydrogen exports to 50 Mt may be quite challenging, as it would require a huge additional low carbon power capacity the additional networks development.

**Other low carbon exports**. Low carbon technologies will form new, trillions of dollars-worth markets by mid-century. Annual 2050 market for green buildings will be $US 10-17 trillion, for low GHG cars it will be $US 4-8 trillion, for hydrogen $US 2.5 trillion, for renewables and energy efficiency $US 1 trillion each.[59] This can be compared with $US 6.2 trillion 2019 global market for petroleum products. The technology race for dominance in these emerging markets is already at full swing. For Russia, integration into global technological supply chains is a potential new powerful driver for economic growth. Russia has experience in applying practically all of the low-carbon technologies, but at very modest scales.[60] It is one of the leading nations in the nuclear energy, the use of district heating, and the use of off-road transport in the structure of cargo transportation. However, the additional export potential of these groups of technologies is limited, and other markets need to be explored. Digitalization in all sectors requires a large number of IT experts. After February 24th, thousands of Russian IT experts left the country. Many supply chains were broken. This has undermined Russia's

[58] Bashmakov I.A. Editor. Russia on the carbon neutrality pathway. 2021. CENEf-XXI.

[59] Bashmakov I.A., Bashmakov V.I., Borisov K.B., Dzedzichek M.G., Lunin A.A., Lebedev O.V., Drummond P., Carvalho P. (2020). Monitoring of low carbon technologies deployment in Russia. *Ekologicheskiy Vestnik Rossii*, No. 4, pp. 6–11. (In Russian).

[60] Ibid.

ability to effectively bridge the already large gap with technology leaders and significantly scales down and delays its ability to penetrate these new markets. Machinery exports in 2021 yielded only 6.5% of the total export revenues.Only part of it was high-tech export. This high-tech export was 30-40 times below that of China and 20-25 times below that of the EU.[61]

Summing up, one can conclude that Russia's non-fuel exports can be expected to go down in 2022 and in several subsequent years. After (if) some of the sanctions are lifted, new markets are found for traditional exports, and logistics is developed to supply these new markets, some of the lost exports may be partly or fully re-gained with time. In the longer term, traditional markets for highly carbon intense basic materials will be steadily shrinking.[62] Unless Russia manages to decarbonize its industrial production, these markets may be blocked for it. As to high-tech export expansion, Russia starts from a very low base, and after February 24th it lost a lot of innovators who could drive it up.

[61] Hi-tec products trade saw a substantial growth in the second half of 2020, which was to the benefit of the new Asian exporters (wipo.int).

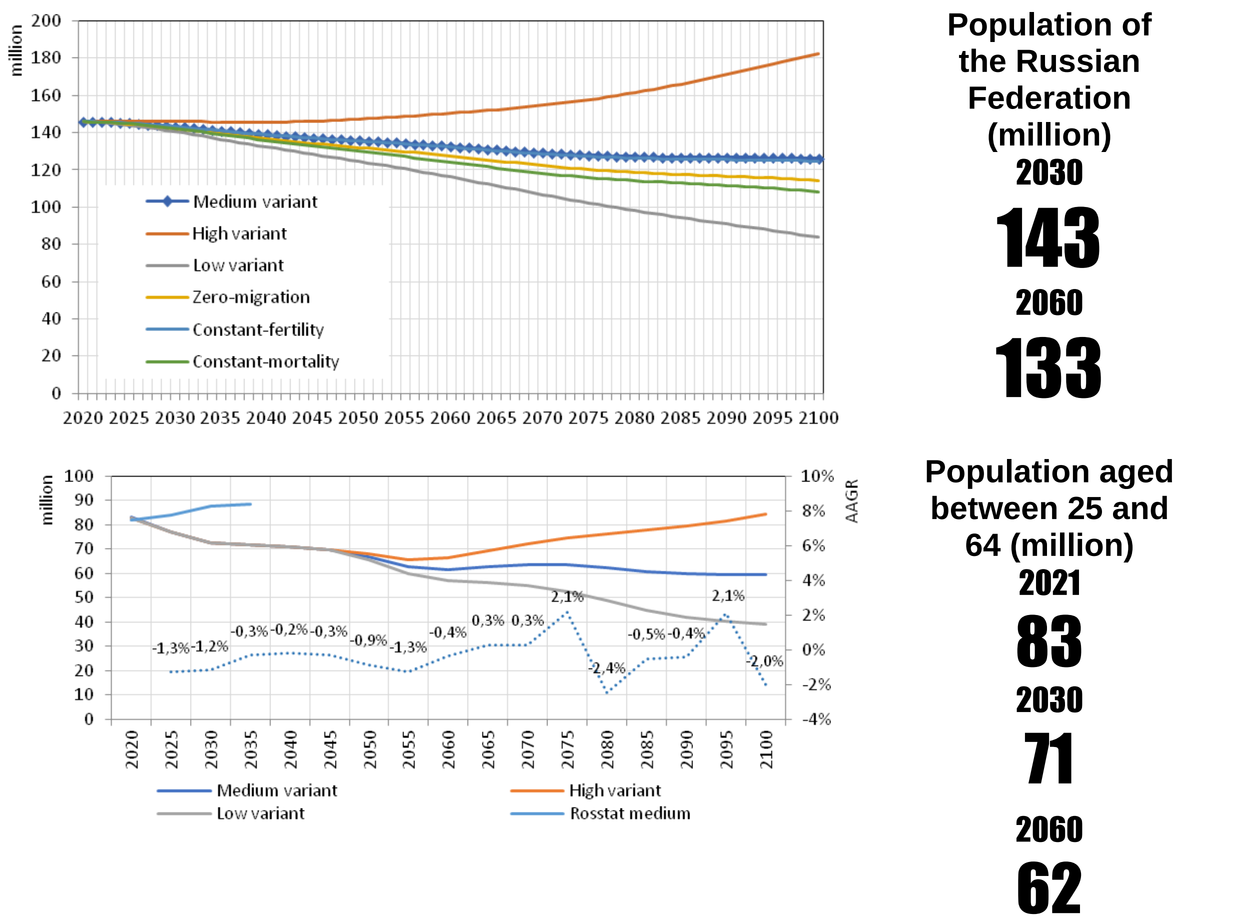
[62] Russia's losses on the 2050 timespan in the EU market from CBAM introduction were estimated to be in excess of 2 Mt for steel products and close to 1 Mt for fertilizers. CBAM. Implications for the Russian economy. https://cenef-xxi.ru/articles/issledovanie-cenef-xxi-%22cbam.-posledstviya-dlya-rossijskoj-ekonomiki%22

# 4 Economic growth

## 4.1 Demographic projections

The population and labour force projections are based on the medium option from the family of demographic projections developed by the UN (Figure 4.1). Those are pre-pandemic projections, which need to be revised downward by nearly a million to account for excessive COVID deaths (2020-March 2022). The medium projection trajectory practically coincides with the constant fertility scenario. The population is estimated at 141 million people in 2036 versus the 2020 medium projection by Rosstat of 143 million people.[63] Population aged between 25 and 65 was determined based on the UN dependence ratio forecast. For this characteristic, the medium option was also chosen. Rosstat reports working age population growth (working age is currently between 15 and the level expected to eventually shift to 65 by 2028) from 82 to 88 million people with subsequent stabilization in 2031-2036. This projection by Rosstat was not used, because participation rate at 60+ is relatively low, and the extension of working age will not add much to full-time employment, as even before the pension reform many people worked after they hit the retirement age.

**Figure 4.1. UN demographic projections for Russia**




Source: United Nations. Population Division. Department of Economic and Social Affairs. World Population Prospects 2019. File POP/1-1: Total population (both sexes combined) by region, subregion and country, annually for 1950-2100 (thousands).

The UN population projections show that:

- Russia's population will be declining slowly until around 2070 and stabilize thereafter;

[63] progn3a.xls (live.com)

- The undulating dynamics of the working-age population will lead to its noticeable reduction until 2030 in all scenarios, with a subsequent stabilization until 2045, followed by another wave of decline. Beyond 2060, the number will vary in the range between 60 and 70 million people.

Such dynamics of demographic indicators makes it much more difficult to sustain the economic growth, especially in 2022-2030 and 2045-2060. When the rates of working age population decline by 1% or more per year, even 2% per year improvement in labour productivity results in just 1% GDP growth. Therefore, demographic situation in the 2030s and 2050s will severely restrict potential growth rates.

## 4.2 Economic projections made before February 24th

Recent scenarios (developed before February 24th 2022) differ markedly regarding the "visions" of the Russian economic growth (Fig. 4.2). Estimates of GDP growth rates are down compared to a similar analysis conducted in 2014.[64] The uncertainty zone is split into three segments: "slow growth" – AAGR up to 1% until 2050; "moderate growth" – AAGR 1-2.5% in 2021-2030 and 1-2% in 2031-2050; "dynamic growth" – AAGR to exceed the upper boundary of the "moderate growth" range. CENEf-XXI estimated AAGR to be below or slightly above 2% in 2030 with some acceleration in the 2030s and a gradual decline in the 2040s. The most pessimistic estimates of AAGR – close to or below 1% – are provided by the IEA, US DOE and BP. These projections account for the negative demographic trend as discussed above.

The most optimistic GDP growth projections have been developed by the Institute of Economic Forecasting of the Russian Academy of Sciences (IEF). In their latest publication they estimate GDP AAGR in 2021-2050 at 1.9% for the 'inertial scenario', at about 3% per year for the 'modest decarbonization ambition' scenarios, at about 2.5% for two more "aggressive" ones, and at 1.8% for the most "aggressive" scenario.[65] So the overall logic is as follows: mitigation associated with some modernization accelerates growth, but higher ambition on the global scale slows it down as energy exports decline. Given the current demographic situation in Russia, slow labour productivity growth and multifactor productivity improvements, the assumption of AAGR acceleration to 3% can hardly be justified. Porfiriev et al.[66] argue, that Russia's fuel and energy sector (FES) has the potential to add up to 1 p.p. to the AAGR until 2035, and the loss of this contribution "will jeopardize the possibility of sustainable growth in the medium and long term". The last 15 years show that FES cannot spur the economic growth, whatever the oil price, and the dynamic global energy transition makes FEC totally unable to accelerate the economic growth in the future. The authors base their forecasts on the hypothesis that "with low economic growth… large-scale GHG reductions are unfeasible." In fact, there is inverse empirical evidence: the lower the economic growth rate, the more dynamic the GHG emission decline.[67]

The sensitivity of Russia's GDP dynamics to fluctuations in the global oil and gas markets is gradually decreasing. Oil and gas revenues growth gives a limited and temporal impulse for the economic growth. This growth pattern for Russia was reflected by the US DOE under the assumption of a significant surge in oil prices (up to 156 $US/bbl) in 2031 in the "high oil price" scenario.

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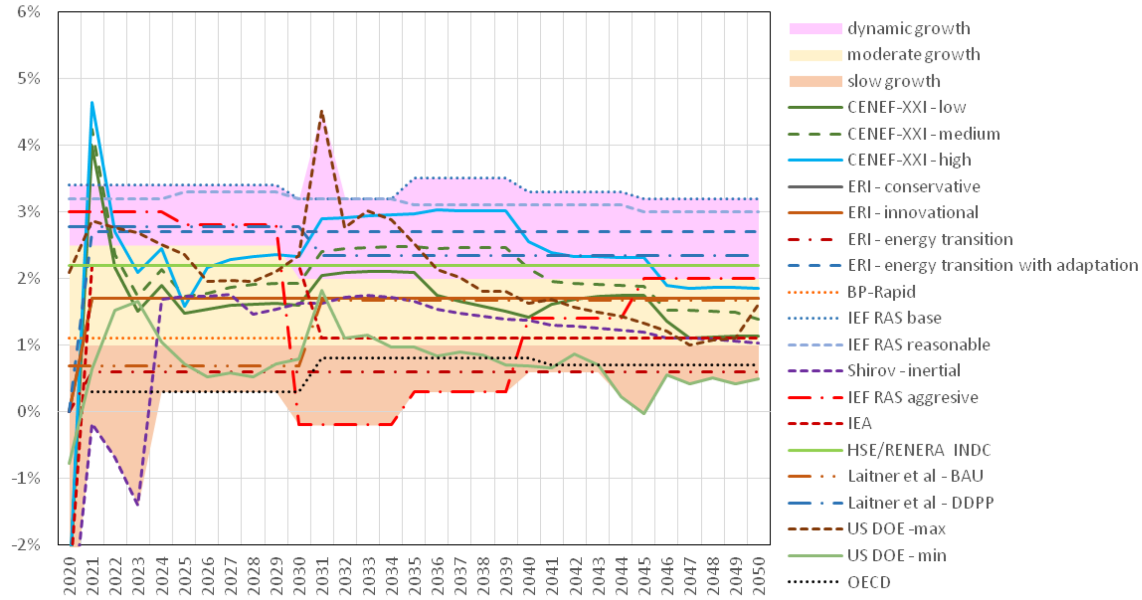
[64] Bashmakov I. Editor. Costs and benefits of low carbon transformation of economy and society in Russia. Perspectives to 2050 and beyond. CENEf. M. 2014.

[65] Porfiriev B.N., Shirov A.A., Kolpakov A.Y., Edinak E.A. Opportunities and risks of the climate policy in Russia. Voprosy Ekonomiki. 2022;(1):72-89. (In Russ.) https://doi.org/10.32609/0042-8736-2022-1-72-89.

[66] Porfiriev B., Shirov A., Kolpakov A. Low carbon development strategy: perspectives for the Russian economy. Mirovaya energetika i mezhdunarodnye otnosheniya. 2020. Vol. 64, No. 9. Pp. 15-25, https://doi.org/10.20542/0131-2227-2020-64-9-15-25.

[67] For more detail see Bashmakov I. Low carbon development and economic growth. Neftegazovaya Vertikal. No. 19-20. 2021.

**Figure 4.2 Russia's GDP projections to 2050**




Sources: Bashmakov et al. (2021). Russia on the carbon neutrality pathway. CENEf-XXI; BP Energy Outlook. 2022 Edition; DOE. 2021; Energy Research Institute of the Russian Academy of Science and the Energy Center of Moscow management school SKOLKOVO. 2019. Global and Russian energy outlook 2019. Moscow; International Energy Outlook 2021with projections to 2050. October 2021; IEA, 2021. World Energy Outlook 2021; Laitner J., Lugovoy O., Potashnikov V. Costs and Benefits of Deep Decarbonization in Russia. Ekonomicheskaya Politika, 2020. No. 2, pp. 86-105. https://doi.org/10.18288/1994-5124-2020-2-86-105; Porfiriev B., Shirov A., Kolpakov A. Low carbon development strategy: perspectives for the Russian economy. Mirovaya energetika i mezhdunarodnye otnosheniya. 2020. Vol. 64, No. 9. Pp. 15-25, https://doi.org/10.20542/0131-2227-2020-64-9-15-25; Safonov G., V. Potashnikov, O. Lugovoy, M. Safonov, A. Dorina, A. Bolotov. 2020. The low carbon development options for Russia. Climatic Change. https://doi.org/10.1007/s10584-020-02780-9 Springer Nature B.V. 2020; Shirov A.A. Ustojchivoe razvitie, klimat i ehkonomicheskij rost: strategicheskie vyzovy i resheniya dlya Rossii. Prezentaciya na seminare "Strategiya dolgosrochnogo razvitiya Rossijskoj Federacii s nizkim urovnem vybrosov". 23 marta 2021 g. [Shirov A.A. Sustainable development, climate, and economic growth: strategic challenges and solutions for Russia] https://cenef-xxi.ru; Shirov A. 2021. Presentation "The risks of the low carbon development policies for the Russian economy. The Institute of Economic Forecasting of the Russian Academy of Science. 2021.

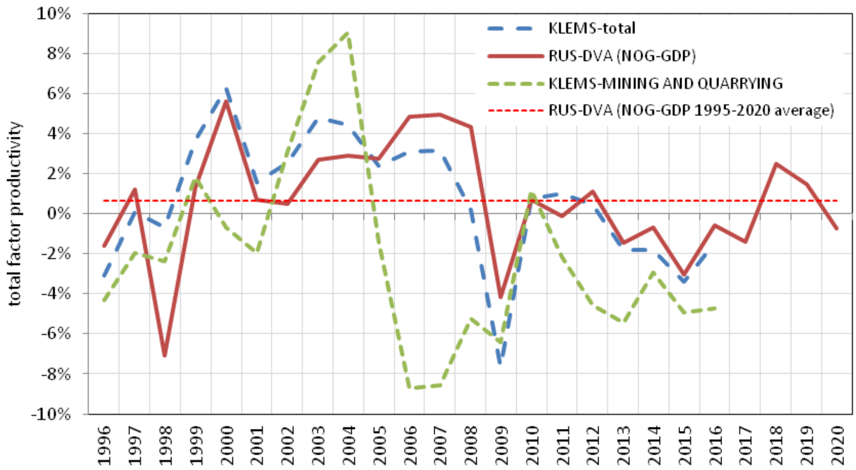
Opportunities for hydrocarbon-led growth are nearly exhausted and undermined by the expected economic losses from declining hydrocarbon exports, which will be increasingly progressing, as the global low carbon transition gains momentum. Relying on the traditional resource-intensive model of the "red economy"[68] can only ensure very low GDP growth rates. Therefore, it is impractical to assume that GDP growth rates will accelerate in the Inertial or BAU-like scenarios. GDP growth can only accelerate through advancing to the fast-growing global markets for low-carbon goods and services that will dominate the global economy in the mid-21st century, and by significantly increasing the productivity of all resources (labour, capital, energy and materials), which is now on average twice lower in Russia, than in the developed countries. Therefore, in low-carbon scenarios, GDP growth rates cannot be lower than in the BAU or Reference scenarios.[69]

[68] Pollution and resources intensive economy.
[69] Ibid.

Russia's KLEMS project[70] provides TFP for the whole economy and by subsectors. In recent publications,[71] the TFP for the expanded mining sector (EMS, which includes mining, processing and refining, transportation and trade of fuels and minerals) was also provided. EMS is responsible for 22.5% of GDP. But in the KLEMS dataset, this aggregate is not shown, so the mining and quarrying sector is shown in Fig. 4.3 as a proxy to illustrate the contribution from TFP to the OG-GDP evolution. Calibrated TFP parameter for NOG-GDP in CENEf's RUS-DVA-2060 model perfectly fits the quite sophisticated assessments of TFP for the whole GDP and its oil&gas part provided in the Russian KLEMS project.

The average TFP for the NOG sector for 1995-2020 was assessed by CENEf-XXI at 0.7%, and for the whole GDP it was assessed by the KLEMS project also at 0.7%. For 2010-2020, it was -0.2% for NOG-GDP and, according to KLEMS, -1.6% in 2007-2016 for the whole economy. Therefore, after 2007 the economic growth was fully extensive, especially in the OG sector (or EMS in KLEMS aggregation). An analysis based on Russia's KLEMS shows, that capital intensity was growing noticeably faster in FES, than in the other sectors: it doubled over the post-2006 decade, pushing capital intensity of the entire economy up and thus slowing down the GDP growth.

**Figure 4.3. Evolution of TFP for the whole economy and subsectors**




Sources: for Russia – CENEf-XXI for NOG-GDP and Russia KLEMS. National Research University Higher School of Economics. December 2019. https://www.hse.ru/russiaklems/dataklems/

TFP in the fuel and energy sector decreased markedly after 2005-2007[72] leading first to a halt, and then to a decline in the economy-wide TFP. Therefore, with a persisting reliance on FES it was impossible to accelerate GDP growth in the recent decade. One additional evidence of the low TFP impact on the economic growth is the result from decade-long market surveys of industrial managers who kept ranking lack of labour high in the list of growth barriers against the background of low-ranking labour

[70] Russia KLEMS. National Research University Higher School of Economics. December 2019. https://www.hse.ru/russiaklems/dataklems/; Voskoboynikov I.B. Recovery experiences of the Russian economy. Implications to the Indian Economy. State Bank Institute of Leadership, Kolkata, 18 September. 2020. 34 p. https://www.hse.ru/mirror/pubs/share/403285320.pdf.; Voskoboynikov I. Accounting for growth in the USSR and Russia, 1950–2012. J Econ Surv. 2021;35:870–894. DOI: 10.1111/joes.12426.

[71] Voskoboynikov I.B. Recovery experiences of the Russian economy. Implications to the Indian Economy. State Bank Institute of Leadership, Kolkata, 18 September. 2020. 34 p. https://www.hse.ru/mirror/pubs/share/403285320.pdf. Voskoboynikov I.B., Baranov E.F., Bobyleva K.V., Kapeliushnikov R.I., Piontkovski D.I., Roskin A.A., Tolokonnikov A.E. Recovery experiences of the Russian economy: The patterns of the post-shock growth after 1998 and 2008 and future prospects. Voprosy Ekonomiki [Issues of Economy]. 2021;(4):5-31. (In Russian) https://doi.org/10.32609/0042-8736-2021-4-5-31.

[72] In 1995-2016, TFP was 37% down in the mining and quarrying sector, and 69% down in the coke and refinery sector. EMS contributed 76% to the TFP decline in 2011-2016.

productivity.[73] Some experts argue that lower productivity of the Russian economy is the 'price of cold', but it was shown that it is the 'cost of bondage' in all dictatorship countries.[74] The growth in the TFP observed in 1999-2007 was a delayed result of the 1990s market reforms. After the architecture of those reforms had been stone by stone dismantled by 2007, TFP went to the negative zone and only a coincidental growth in oil prices, which started in 2000, allowed it to maintain some very moderate, exclusively extensive, and very capital-intense economic growth.

## 4.3 Economic projections made after February 24th

Even some of the previous pessimistic expectations for the economic growth in Russia overnight became quite optimistic on February 24, 2022, as a result of the sanctions. Three effects of the sanctions on the Russian economic growth are discussed below: from the sanctions on exports; on imports; and the implications for the incomes associated with the first two. The calculations rely on Rosstat's 2019 Supply and Use Tables for goods and services for the Russian Federation as a statistical basis, and use Leontiev's inverse matrix $(I - A)^{-1}$ assessed for 2016 (the latest available 98x98 matrix). In addition, data from the RF Customs Service on external trade flows for 2019-2021 were used. The exports data were split by products and destinations. Three Russia's major trade counterparts, which already have imposed sanctions or may do so, were selected (EU-27, USA and Japan). The export sanctions depth parameters show how much export to a certain destination is expected to drop as a result of sanctions.

The effects of export-related sanctions on the Russian economy were explored using input-output tables: $\Delta X^{ex} = (I - A)^{-1} * (\Delta EX)$, where $\Delta EX$ is sanctions-related export decline. The sanctions package is a moving target along time: some sanctions may be added, while others may be laxed or eliminated in certain contexts. Changes in the exports were calculated based on the data from the RF Customs Service, which include a limited list of products. Then, based on the 2019 Supply and Use Tables for goods and services, they were translated into export revenue reductions. Reductions in the export of services were also estimated. In all, 61 economic activities were covered. All that was translated into a 98 dimensions export cuts vector by splitting some of the activities proportionally to their shares in gross outputs subtotals. Finally, export cuts were assessed as $\Delta EX = r * d_{exs} * EX$. The vector $r$ reflects regional coverage of the sanctions. The depth of export cut to the regions is reflected as $d_{exs}$. For the services sectors, export reduction was evaluated as effects of some announced sanctions on the air travel, banking services, etc. The impact on gross value added ($GVA$) was estimated as $\Delta GVA_i^{ex} = \Delta X_i^{ex} * GVA_i/X_i$, or proportionally to $GVA_i/X_i$ ratios, so $\Delta GVA_{ex} = gva * (I - A)^{-1} * (\Delta E)$.

The effects of import sanctions were assessed as: $\Delta X^{im} = d_{ims} * IMP_{int} * (I - A)^{-1} * (GVA - GVA_{ex})$, where $d_{ims}$ is the depth of import sanctions; $IMP_{int}$ is the vector of imported intermediate goods ratios to gross output. Then gross value added losses from the import sanctions are: $\Delta GVA_i^{im} = \Delta X_i^{im} * GVA_i/X_i$.

The loss in $GVA$ resulting from reduced incomes and profits are reflected via depressed final demand (only private consumption and investments were included in the calculations): $\Delta GVA^d = (PC + INV) * (sh^{ex} + sh^{im})$, where $sh^{ex}$ is $\Delta GVA_i^{ex}/GVA$ and $sh^{im}$ is $\Delta GVA_i^{im}/GVA$. The total loss of $GVA$ is: $\Delta GVA^{sanctions} = \Delta GVA_i^{ex} + \Delta GVA_i^{im} +.\Delta GVA^d.$ Then $GVA$ loss was broken down into the loss in the oil and gas sector and the loss in the rest of the economy. Some simplifications were used in the analysis: assumptions about linear effects; assumption that the effects of imported goods shortage is proportional to the total imports needed to satisfy the additional unit of final demand; assumptions that the depth of export- and import-related sanctions is equal across activities and varies only due to the

[73] Tsukhlo S.V. Russian industry in 2021-2022. "Rapid recovery" after the 2020 viral crisis. Science-based workshop on energy and environmental economics in the Moscow School of Economics, 10.02.2022.
[74] Bashmakov I. A. (2007) The Cost of Bondage, Rather Than of the Cold; Problems of Economic Transition, 49:9, 16-20, DOI: 10.2753/PET1061-1991490903.

regional coverage. The possibility for exports of goods and services to other destinations in time is not reflected either. Growing government consumption expenditures may mitigate some of the loss in private consumption and investments.

The results are shown below (Table 4.1) for a variety of combinations of assumptions. The data present a static picture of GDP decline at the point of time the with greatest sanctions coverage and depth. The depth of GDP decline varies between 12 and 20%, and for NOG GDP between 11 and 19%. In reality, the sad road towards these deep bottoms will take some time. In contrast to the consensus forecasts, by the end of 2022 we may be only half way to the bottom, while the remaining part might be travelled over 2023 or later, as the sanctions reach the levels shown in Table 4.1 and are supplemented with higher customs duties for the imports from Russia. If any new markets for the Russian exports or new import suppliers are found, the GDP loss may be partially mitigated. Also, the impacts may be smaller, if the announced import restrictions are not fully implemented.

**Table 4.1. Implications of sanctions for Russian GDP in constant prices**

| Assumptions | Parameter | Export sanctions | Import sanctions | Demand reduction effect | Total |
|---|---|---|---|---|---|
| Export sanctions (EU-27, USA, Japan), 20% coverage for major export items to these countries; 40% for air transport; 20% for other items and services; 30% cut in intermediate imports | GDP | -5.4% | -1.8% | -4.5% | -11.7% |
| | NOG GDP | -3.6% | -2.0% | -5.1% | -10.7% |
| Export sanctions (EU-27, USA, Japan), 50% coverage for major export items to these countries; 40% for air transport; 20% for other items and services; 30% cut in intermediate imports | GDP | -8.3% | -1.8% | -6.2% | -16.2% |
| | NOG GDP | -5.4% | -2.0% | -7.0% | -14.3% |
| Export sanctions (EU-27, USA, Japan), 50% coverage for major export items to these countries; 40% for air transport; 20% for other items and services; 50% cut in intermediate imports | GDP | -8.3% | -4.5% | -7.6% | -20.3% |
| | NOG GDP | -5.4% | -5.0% | -8.5% | -18.9% |
| OECD* | | | | | -10%-15% |
| Consensus projection by Russian experts (Kommersant 11.03.2022; Kommersant 17.03.2022) | GDP | | -2.3-2.8% | | -8% |
| | | 2022 | 2023 | 2024 | 2022-2024 |
| | | -8% | 1.5% | 2% | -5% |
| Consensus projection by foreign experts (Focus economics; Kommersant 18.03.2022) | GDP | -5.7% | -1% | | -6.2 |

* OECD Economic Outlook, Interim Report Economic and Social Impacts and Policy Implications of the War in Ukraine, MARCH 2022.

Source: CENEf-XXI.

The ranges assessed for NOG GDP in Table 4.1 were used to set TFP evolution for this sector in the RUS-DVA model. OG-GDP is more accurately assessed in this model based on the physical fossil fuels export pathways as discussed above.

Based on the assessment presented in Table 4.1, the TFP for NOG GDP was taken to be -10% in 2022 and -4% in 2023, thus reflecting the expected medium estimate of potential output decline at 14%. It is assumed that the effect will slowly weaken over time as the sanctions relax through the progress in the peace process or (and) adaptation of the Russian economy and re-orientation of export and import flows. As a result, TFP for 2024 is assumed at +6%; and for 2025-2027 at +2% per year.

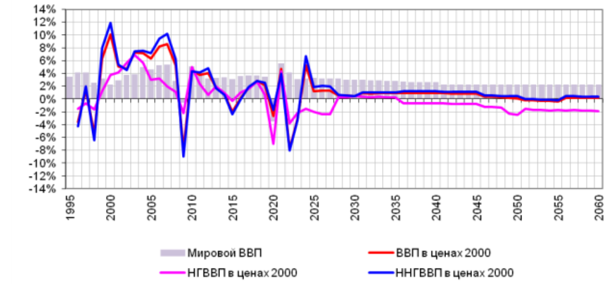
For the subsequent years, an assumption is made that the lower the income from the oil and gas sector and the higher the potential effects of the sanctions and mechanisms such as CBAM, the greater the effort Russia will make to technologically modernize the non-oil&gas sector. The share of the oil and gas sector in the economy will eventually decline. Therefore, it is assumed that the contribution from

TFP will be positive staying at 0.5% per year in option 1, at 1% in option 2, and at 1.5% in option 3 (double of the 1996-2020 average). The two latter values will be difficult to attain as restrictions in terms of access to the foreign capital, cuts in investment goods imports (in the long run), and the accelerated after February 24th brain drain will negatively affect the TFP evolution in the years to come. The availability of the needed sophisticated equipment and qualified labour force will be limited, while the overdependence on Chinese machinery supply will be dangerously growing.

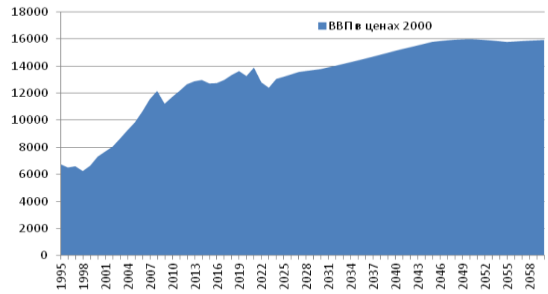
The resulting trajectories are shown in Fig. 4.4-4.5. Three scenarios were considered:

- Scenario 1: low fuel export reductions and low TFP level;
- Scenario 2: medium fuel export reductions and medium TFP level;
- Scenario 3: high fuel export reductions and high TFP level.

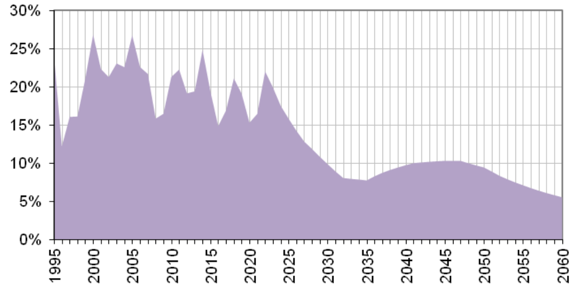
**Figure 4.4. Scenario 1. Parameters of Russian economic development: low fuels export reduction and low TFP growth scenario**



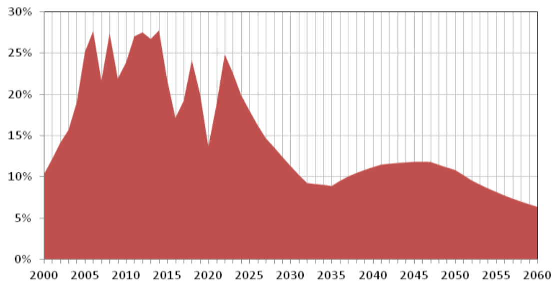

(a) GDP and its components annual growth rates



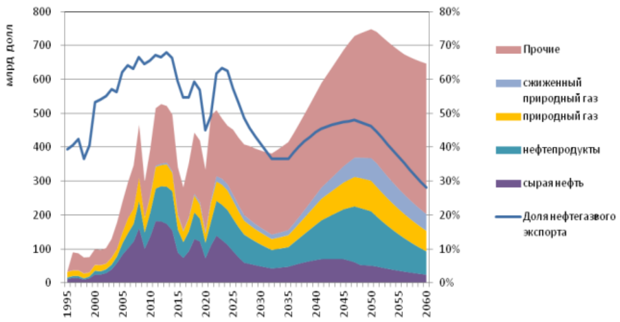

(b) GDP in 2000 prices



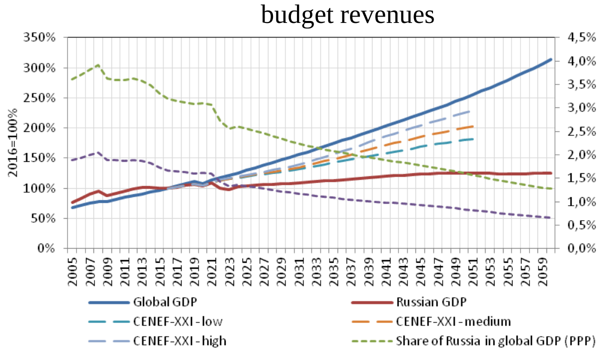
(c) Share of oil and gas GDP



(d) Share of oil and gas revenues in consolidated budget revenues




(e) Structure of goods exports




(f) Russian and global GDP growth (2016=100) and Russian share in global GDP

Source: CENEf-XXI.

Only scenarios 1 and 3 are discussed below, as scenario 2 provides results within the uncertainty range bordered by the former two.

**Scenario 1.** In 2021-2023, Russian GDP will be down by 10.7% (-7,9% in 2022 and -3% in 2023); OG GDP is only 4% down, while NOG GDP is 11% down (Fig. 4.4). The share of oil and gas GDP since

2022 will be much higher, than assessed before February 24th, for the whole timespan to 2060,[75] but particularly in 2022-2024. Thus the economic model based on the reliance on fuels is conserved, followed by a steep decline after 2024, as market niches for the Russian fuels shrink driven by the global decarbonization and energy security policies. Oil exports will never get back to the 2021 level, expected export oil price will decline to 2030-2035.

By 2024 the economic power of the Russian state and of the fuel supply businesses is conserved and still concentrated. The share of government-owned sector in GDP grows at the expense of shrinking private sector, and so the potential to improve overall productivity of the Russian economy is untapped. Export- and import-related sanctions and the conserved dominance of the government in the economy along with the persisting reliance on fuel exports will undermine the potential of the non-oil&gas sector to drive Russian economy. NOG GDP will get back to the 2021 level only by 2027 losing about 20% of the growth potential over those lost years. This will deeply undermine this sector's potential to mitigate the negative contribution from the OG GDP to the economic growth beyond 2035.

The shares of oil and gas in GDP and in the consolidated budget decline rapidly to 10% by 2030-2035 and beyond. The favourable time to support the development of the non-oil&gas sector due to the redistribution of energy export revenues is completely lost. In the longer term this sector faces labour force shortages (as a result of negative demographic trends), low TFP level, lost foreign markets of basic materials and low carbon goods, and is left partially ruined and unprepared to replace the substantially weakened capability of fuel exports to spur GDP growth.

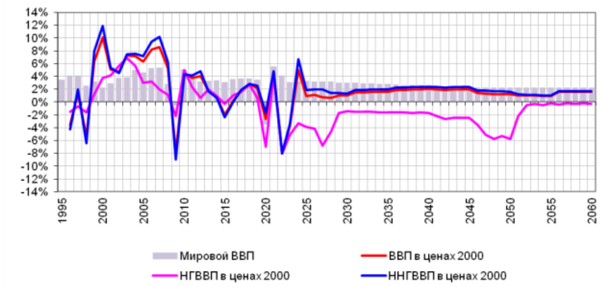
As a result of such developments:

- Russia will lose 10 years of economic growth. The 2021 GDP level will only be back in 2031;
- By 2050, Russia will lose 46% of the previously expected potential GDP growth;[76]
- Russia's GDP in 2060 will only be 21% higher, than in 2021, and it will completely stagnate beyond 2045. The economic revival in the second part of the 2020s will be partially blocked by the labour force shortage. The same situation will be observed after 2045. Low TFP does not fully compensate the annual decline in the labour force, and a slow accumulation of fixed capital in this weakened sector will be the only driver for GDP growth;
- Meanwhile the global GDP will have grown 2.7-fold by 2060, while the share of the Russian GDP will be down from 1.6% in 2021 to 0.7% in 2060, if estimated in exchange rates, and from 3.1% to 1.3%, if estimated in PPP ranking in the middle or closer to the end of the second ten in the list of major economies). Thus the Russian economy will become hardly visible in the global 2060 economic landscape, shadowed by such giants of the time as China, India, and USA. This will deeply undermine Russia's economic security, political role, and the military potential.

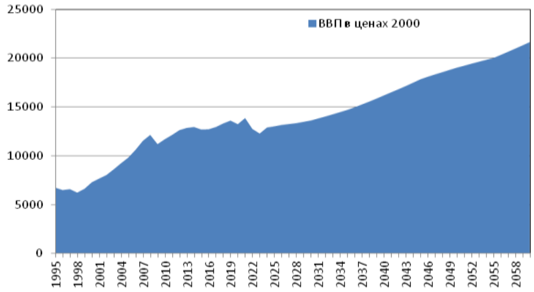
**Scenario 3.** This scenario assumes a much deeper decline in the oil and gas exports by 2027 with a partial revival thereafter (Fig. 3.6 and 3.12) and higher TFP parameters. In 2021-2023, Russian GDP will be 11.4% down (-8% in 2022 and -3.7% in 2023). OG GDP will be 12.8% down, and NOG GDP will be 11.2% below the 2021 level. The OG GDP will be continuously declining (Fig. 4.5) and falling fast to reach 8% by 2030 and drop below 4% by 2060. The current economic model relying on fuel exports will fail to support sustainable growth and will need to be replaced with another model, capable of providing large TFP improvements to save the economy from stagnation by 2060 at the level just 6% above the 2021 GDP.

[75] Bashmakov et al. (2021). Russia on the carbon neutrality pathway. CENEf-XXI.
[76] Bashmakov et al. (2021). Russia on the carbon neutrality pathway. CENEf-XXI.

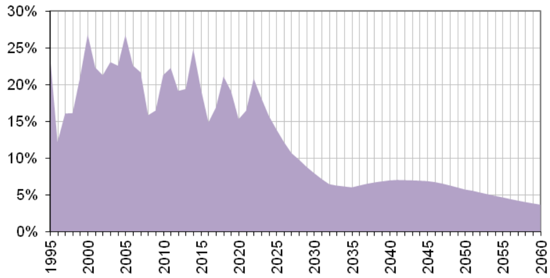
**Figure 4.5. Scenario 3. Parameters of Russian economic development: low fuel exports reduction and low TFP growth scenario**



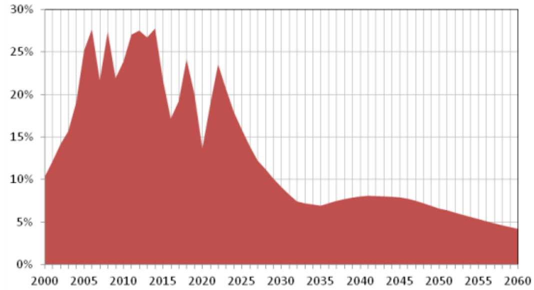

(g) GDP and its components annual growth rates



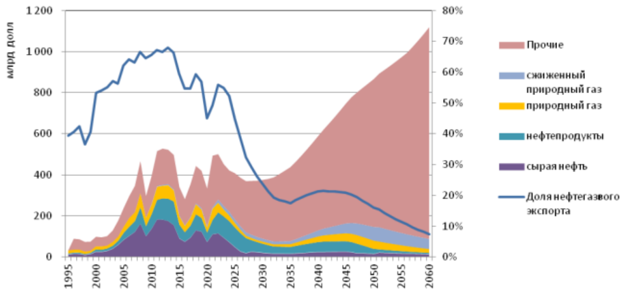

(h) GDP in 2000 prices



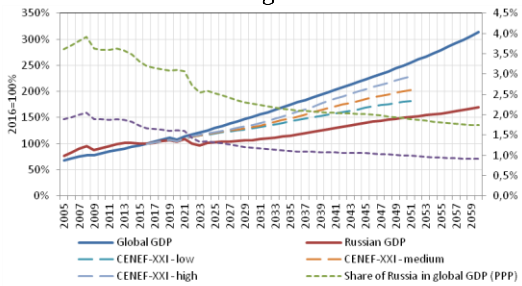
(i) Share of oil and gas GDP



(j) Share of oil gas revenues in consolidated budget revenues




(k) Structure of goods exports




(l) Russian and global GDP growth (2016=100) and Russian share in global GDP

Source: CENEf-XXI.

In this scenario, the economic power of the Russian state and fuel supply businesses declines. The share of the government in GDP first scales up in 2022-2023, yet cannot be sustained much longer. The role of private sector needs to be increased to provide a competitive environment to improve the overall productivity of the Russian economy. As the government dominance declines, export- and import-related sanctions are expected to lax, and Russian businesses will re-enter the global markets of basic materials and enter the new markets of low carbon products. This would enhance the potential for the non-oil&gas sector to expand faster to serve a driver for the whole economy.

As a result of such developments:

- Russia will still lose 10-11 years of economic growth. The 2021 GDP level will only be back in 2031-2032;
- By 2050, Russia will have lost 51% (versus 46% in scenario 1) of the previously expected potential GDP growth;[77]
- In 2060, Russian GDP will be 44% higher, than in 2021 (versus 21% in scenario 1) reaching 1.6% AAGR in 2040-2050 and 1.3% in 2050-2060. This is possible only with an assumption

[77] Bashmakov et al. (2021). Russia on the carbon neutrality pathway. CENEf-XXI.

that the economic and institutional models in Russia will change to enable the TFP improvements. A failure to provide new institutional and socio-political frameworks for the economic growth will limit Russian GDP growth to just 6% in 2060 relative to the 2021 level. This would mean four decades of economic stagnation for Russia;

- In this scenario, the share of Russian GDP in the global GDP will still be shrinking from 1.6% in 2021 to 0.9% in 2060, when estimated in exchange rates, and from 3.1% to 1.7%, if estimated in PPP, but the loss in Russian economic role on the global scale will not be as devastating as in scenario 1.

Back in 2008, the author wrote[78], "The current cultural tradition in Russia is *"a focus on the survival of disunited individuals, focusing on solving tactical problems and having little idea of what the future holds for them."* These values are inertial, but not completely static. They need to be changed, and so do the institutions themselves, otherwise regression, even in the most progressive institutional reform, will be inevitable. It would be naive to expect that a bureaucratic state will begin to modernize itself for the sake of the future... Perhaps Russia is in a trap: in order to reach by 2050 the levels of economic development comparable to the current levels of developed countries, it is important to change the cultural traditions and institutions, yet there is no one to change them. If the need for the change is to be recognized and a capable coalition is to emerge, more evidence is required that Russia's current rigid institutions will be holding back Russia's economic growth. The uncertainty of the institutional situation in Russia is superimposed on many other uncertainties and it does not allow for a clear answer to the question of how much Russia's GDP will have grown by 2050". It was echoed by the statement that basic Russian values are defined by the formula *"high value of security and protection by the state with a weak commitment to the values of novelty, creativity, freedom, independence and risk"*.[79] With such burden, it is difficult to determine the directions of modernization and to develop coalitions for timely modernization in the key directions. After 14 years, these statements are even more valid, because the efforts to develop effective coalitions for modernization have failed.

The problem with modernization is, that titanic efforts were needed simultaneously in many areas: increasing the birth rates; reducing mortality and prolonging the active working life of Russian citizens; competent migration policy with balanced interethnic concord; fundamental modernization of the technological basis of production and a significant increase, on this basis, in labour and capital productivities and energy efficiency; preventing a collapse in oil production, increasing the uptake of renewable energy sources; accelerated development of export-oriented and import-substituting industries. In all of the scenarios assessed more than a decade prior to February 24$^{th}$, the share of OG GDP was steadily declining towards 2050 with a subsequent decline in the influence of the oil and gas elites, growing dependency of the state on other businesses, and gradually dissipating illusions of its omnipotence with a real democracy replacing the decorative one. All these processes were expected to be delayed, as the current elites would do anything to maintain their power and influence. Modernization was inevitably associated with a significant potentially conflicting political component.

Discussions on the Russian modernization paths highlighted that the conservation of current institutions along with the present development model based on raw materials exports fail to ensure high economic growth rates. Many areas of modernization have been recognized and voiced. However, the task of promoting the lexical constructor of modernization concepts to a set of real actions to yield the expected results has failed. Back in 2011, in the article "*Will Russia Have Economic Growth in the Mid-XXI Century?*"[80] it was shown that the loss of the ability of the Russian economy to expand in the 2030's and 2040's, or even a transition to the "shagreen skin" economy (the model of continuously declining GDP) may be a painful punishment for the modernization failure in the 2010's. Research has

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[78] Bashmakov I. Russia-2050. *Voprosy Ekonomiki*. 2008;(8):140-144. (In Russ.). https://doi.org/10.32609/0042-8736-2008-8-140-144

[79] Magun V., Rudnev M. Basic Human Values of Russians and Other Europeans (The Results of 2008 Surveys). *Voprosy Ekonomiki*. 2010;(12):107-130. (In Russ.). https://doi.org/10.32609/0042-8736-2010-12-107-130

[80] Bashmakov I. Will Russia Have Economic Growth in the Mid-XXI Century? *Voprosy Ekonomiki*. 2011;(3):20-39. (In Russ.). https://doi.org/10.32609/0042-8736-2011-3-20-39

also shown that without effective modernization to increase all factors' productivity Russia will have no economic growth in the middle of the 21st century. If GDP growth is to exceed an average of 1% per year in the 40's, it is essential to have either a sustainable dynamic increase in oil prices or a successful modernization. It was shown that without modernization it would be unfeasible to bridge the economic development gap with the leading countries and increase Russia's share in the global GDP, and even to maintain the current one. The price of unsuccessful modernization is the loss of the economic growth in the 2040's, and possibly in the 2030's. A decade after that paper was published, we see this happening. But now we can add the 2020's to the list and rephrase the paper title: "*Will Russia Have Economic Growth after 2021?"* with many factors against the positive answer to this question.