ORIGINAL ARTICLE
DOI: https://doi.org/10.18599/grs.2021.3.7
Russian Original 2021. Vol. 23. Is. 3. Pp. 42–52

From Covid "today" to low-carbon "tomorrow": analysis of foreign forecasts for the development of world energy

A.M. Mastepanov[1,2]
[1]*Oil and Gas Research Institute of the Russian Academy of Sciences, Moscow, Russian Federation*
[2]*Gubkin Russian State University of Oil and Gas (National Research University), Moscow, Russian Federation*
e-mail: amastepanov@mail.ru

Abstract. The article is dedicated to the analysis of forecasts of the world energy development made recently (from September 2020 to May 2021) by the world's leading analytical centers, taking into account "the new reality" – the coronavirus pandemic. The impact of the Covid-19 pandemic on the development of the world economy and energy consumption and the estimates of its consequences on long-term global economic growth made in various forecasts and prognostic studies are considered. It is shown that the priority of most of the prognostic estimates of the world consumption of primary energy resources made by the world's leading analytical centers in recent years is a sharp reduction in CO_2 emissions by energy and stabilization of global anthropogenic greenhouse gas emissions in order to prevent negative climate changes on our planet. A conditional classification of scenarios for the prospective development of global energy is given, depending on the ideology that is embedded in them, an analysis of the fulfilled forecasts is given. It is concluded that Russian research structures need to develop their own similar forecasts.

Keywords: coronavirus pandemic, energy transition, forecasts and scenarios, energy poverty, energy consumption, renewable energy sources, energy efficiency

Recommended citation: Mastepanov A.M. (2021). From Covid "today" to low-carbon "tomorrow": analysis of foreign forecasts for the development of world energy. *Georesursy = Georesources*, 23(3), pp. 42–52. DOI: https://doi.org/10.18599/grs.2021.3.7

Introduction

The period from September 2020 to May 2021 was marked by another portion of forecasts and predictive studies of the development of global energy from leading world (international and national) analytical centers, most of which to one degree or another reflected the "new reality" – the coronavirus pandemic. This pandemic, accompanied by an economic recession and a collapse in energy prices, received an unofficial, but a very succinct and accurate name – the corona-crisis or the pandemic crisis, and accelerated those global changes that have been accumulating in society for years and decades. The pandemic turned out to be a catalyst for global transformations, including the energy transition. Accordingly, many of these projections and predictive scenarios focus on how the COVID-19 pandemic could affect the global energy demand and greenhouse gas emissions, related to it, and how this could impact the efforts to move to the low-carbon economy to come.

Summarizing their views of these processes – the depth, duration and consequences of the coronavirus pandemic as well as the efforts, measures and possible results to achieve the energy transition – BP and DNV GL, Equinor and Rystad Energy, BloombergNEF, McKinsey, Wood Mackenzie, and other leading energy producers and oil industry analysts updated their estimates of the future of the global energy.

The Institute of Energy Economics of Japan (IEEJ), the Secretariats of the Gas Exporting Countries Forum (GECF) and OPEC, the International Energy Agency (IEA) and other analytical and forecasting centers shared their new vision of the energy future as well.

In particular, the IEA, along with the already traditional editions of the World Energy Outlook and Energy Technology Perspectives, published in May 2021 "Net Zero by 2050. A Roadmap for the Global Energy Sector" – a kind of a roadmap for developing of the global energy sector for the period up to 2050 is the world's first comprehensive study of its kind that shows the cost-effective transition to a clean, zero CO_2 energy system, guaranteeing stable and affordable energy resources, ensuring universal energy access and including sustainable economic growth (Net Zero by 2050 ..., 2021).

Naturally, all these studies differ from each other both in the breadth of coverage of the problems and

in the depth of the forecast period, not to mention the differences in the methodology for making forecast estimates and in the database used, as well as other subtleties of forecasting.

But they also have something in common: the predictive scenarios of the studies under consideration have a number of features that differ them from previously published similar works. First, the initial base of these scenarios was, as a rule, the deepest economic recession caused by the coronavirus pandemic since the Great Depression. Secondly, these scenarios were developed during the period of mass awareness and concern of society about the problem of global climate change, and understanding that it is caused by the emission of greenhouse gases of anthropogenic origin[1].

This implies, as it were, "the possibility of humanity's abandonment of hydrocarbon energy sources (coal, oil and gas), which in recent years has increasingly become a topic of serious discussion not only by futurologists, but also by specialists in various fields of knowledge – climatologists, nuclear scientists, power engineers, economists ..." (Mastepanov, 2016). Accordingly, the leading countries and their unions are adopting programs to achieve the so-called carbon-neutral state by the middle of this century.

Most forecasts and forecasting studies of the development of global energy are characterized by a scenario approach that covers a wide range of possible trajectories of future development, since the specialists who develop them are well aware that such assessments and forecasts are associated with an extreme degree of uncertainty in all the constituent parts of this process. Uncertainty, which entails the inability to predict the only rational way to achieve the set goals. This uncertainty concerns both the future demand for energy resources and the possibilities to meet it, and the role of new technologies, and the potential measures that can be taken by society to address the risks associated with climate change, including investment opportunities. Globalization and geopolitics, demographic processes and a sharp increase in social inequality, social revolutions and wars contribute to this uncertainty (Mastepanov, 2019). The situation is aggravated by the looming surplus of energy resources (Mastepanov, 2017). "None of these possible paths is predetermined in advance – all options are possible," the IEA experts note in this regard (World Energy Outlook, 2020).

We should also note that a significant part of the results of such predictive studies of digital material published in the open press contains extremely little digital material – in support of their conclusions and assumptions, the authors of the studies cite mainly Figures. The Figures clearly "confirm" the conclusions drawn, but it is almost impossible to verify them. There is no explanation for this practice. It can only be assumed that the high uncertainty of the possible development of events and the insufficient base of initial materials simply do not allow the authors of such studies to do otherwise.

How do the authors of such forecasts imagine the energy future? Let's consider the results of the main ones.

Impact of the COVID-19 pandemic on the global economy and its assessment in the long term

Coronavirus pandemic COVID-19 2020–2021 sharply slowed down (and even threw back for many years) the development of most of the main components of the global economy – (industry and construction, transport, housing and utilities sectors), stopped the flow of new investments, since the coronavirus pandemic is not only the health and life of the world's population. As we have already noted, the pandemic "had the most direct impact on the state of global energy markets, energy sustainability and security, and even on the attitude towards the problem of global climate change" (Mastepanov, 2020a).

The COVID-19 pandemic has already killed (as of July 20, 2021) more than four million people – 4,096,141 people[2], to be exact. According to UN estimates, it led to a 4.3% contraction in the world economy (global GDP) in 2020. This is two and a half times more than the decline seen in the 2009 global financial crisis[3]. The opinion of the OPEC secretariat experts coincides with these estimates: "The outbreak of the COVID-19 pandemic has led to the sharpest decline in energy and oil demand in the memory of living people. ... led to the worst economic downturn since the Great Depression of the 1930s" (World Oil Outlook 2045, 2020).

Naturally, the socio-economic consequences of the COVID-19 pandemic will be felt for years to come. As UN Chief Economist and Assistant Secretary-General for Economic Development Elliott Harris said, "The depth and severity of the current unprecedented crisis portends a slow and painful recovery"[4]. The World Bank gave even more pessimistic estimates in January 2021:

[1] Is this really so, or the causes of global warming are rooted in the cyclical sequence of climate development on the planet, is not yet fully clear. As we have already noted, "until now, scientists cannot say with 100% certainty as to what causes the modern climate changes. Changes in solar activity and changes in the angle of the Earth's axis of rotation and its orbit, unknown interactions between the Sun and the planets of the solar system, the ocean, volcanic activity, and human activities are named as the causes of global warming. It is likely that the current global warming is the combination of many factors. The Earth is in fact such a complex system that there are many factors that directly or indirectly affect the planet's climate, accelerating or slowing down global warming" (Mastepanov, 2016).

[2] Coronavirus COVID-19. Statistics. April 20, 2021. https://news.mail.ru/coronavirus/stat/msk/

[3] The UN announced a 4.3% contraction in the global economics in 2020. January 25, 2021. TASS. https://tass.ru/ekonomika/10542613

[4] Global economics recovery remains fragile – UN. BRICS TV. January 26, 2021. https://finance.rambler.ru/markets/45680251/?utm_content=finance_media&utm_medium=read_more&utm_source=copylink

"Although the global production volume is recovering after the sharp drop caused by the COVID-19 pandemic, the growth trajectory will be lower for a long time than before the pandemic. The pandemic has exacerbated the risks posed by the decade-long wave of rising debt levels around the world. It is also likely to exacerbate the long-predicted slowdown in potential economic growth over the next decade". Among the risks of a negative development of the situation, experts of the World Bank include the possibility of new waves of the virus spreading, delays in vaccination, a more serious impact of the pandemic on potential growth, as well as the current tensions in the financial sector (Global Economic Prospects ..., 2021).

As noted in the latest edition of the European Commission "Global Energy and Climate Outlook (GECO 2020)", although the forecasts for the development of the situation with COVID-19 and for the duration of the pandemic in the studies of major international institutions do differ, experts agree on two things: COVID-19 will linger on, and the future remains unknown: the duration and severity of the pandemic are among the major uncertainties for future development (Keramidas, 2021). And they add: "The COVID-19 crisis is projected to have lasting consequences ... although it is difficult to predict the duration of the pandemic today" (Keramidas, 2021).

Moreover, the experts of the GECF Secretariat, like many other specialists[5] (Global Economic Prospects ..., 2021; Keramidas, 2021; Baunov, 2020), including the author of this article (Mastepanov, 2020b), proceed from the fact that that economy and the way of life that had existed before the beginning of the COVID-19 pandemic will not exist anymore, and these changes will directly affect the further development of the oil and gas industry. And these differences will be so great that GECF experts labelled the upcoming period "the post COVID-19 era" (GECF Global Gas Outlook 2050, 2021).

The most detailed, at the moment, assessments of the consequences of the pandemic for the long-term global economic development are given in the study "Energy Transition Outlook 2020. A Global and Regional Forecast to 2050", conducted by the (international certification and classification society) DNV GL company[6] and published in September 2020 (Energy Transition Outlook…, 2020), which compares a scenario without COVID-19 with a scenario based on the pandemic. Of course, the model calculations put into these estimates are based on data dating back to the mid-2020 and do not reflect either the second and third waves of the pandemic, nor the associated lockdowns and the measures taken by the governments of many countries to support their economies. Therefore, the DNV estimates given below are most likely underestimated, but even they show the full depth of the global crisis that has gripped the world economy.

The global GDP, having suffered a setback due to the COVID-19 pandemic in 2020, in 2025–2050 will be, according to the DNV experts, 9.4% lower than it would have been if not hampered by the pandemic (Energy Transition Outlook ..., 2020). Meanwhile, the largest decline at the 2050 level is expected for such regions as Europe (-11.8%), North America (-10.7%) and the Middle East and North Africa (-10.2%).

Various ways out of the COVID-19 crisis, with special emphasis on the key ones in this regard for the next ten years (until 2030), are also considered in the latest IEA World Energy Outlook 2020 (WEO-2020), released in autumn 2020 (World Energy Outlook 2020, 2020).

Uncertainty about the duration of the pandemic, its economic and social impact and policy responses opens up a wide range of possible options or scenarios for the future of the energy sector. To assess the economic impact of the pandemic and consider the different outcomes, depending on whether it can be brought under control in 2021, or it turns into a longer crisis and deeper economic recession, this study examined the special Delayed Recovery Scenario – DRS. (World Energy Outlook 2020, 2020).

According to the IEA estimates, the global GDP in 2030, compared to the pre-crisis period, will be lower by almost 14%, and in developing countries – even by 16% (Fig. 1).

Similar assessments of the impact of the COVID-19 pandemic on the dynamics of the global GDP are made in a number of other predictive studies. Thus, experts from the European Commission believe that it will be below the baseline by 6.3% in 2030 (Keramidas, 2021). The GECF Secretariat predicts that in reality the global GDP in 2050 will be 7% lower than projected before COVID-19, as the medical, humanitarian and economic crises caused by the pandemic sharply affect the medium and long-term economic outlook (GECF Global Gas Outlook 2050 Synopsis, 2021).

Accordingly, the global final energy consumption is predicted to be significantly lower in the future only because of the consequences of the pandemic (Table 1, Fig. 1, 2).

The presentation of the GECF Secretariat specialists on the dynamics of the global supply of primary energy resources, taking into account and not taking into account the impact of the coronavirus pandemic, is shown in Fig. 3.

[5] COVID-19. https://www.iea.org/topics/covid-19?utm_campaign=IEA%20newsletters&utm_source=SendGrid&utm_medium=Email

[6] The management of DNV GL, in accordance with the decision taken after the revision of its strategy, decided to shorten the former name of the company to DNV, starting from the 1st of March 2021.

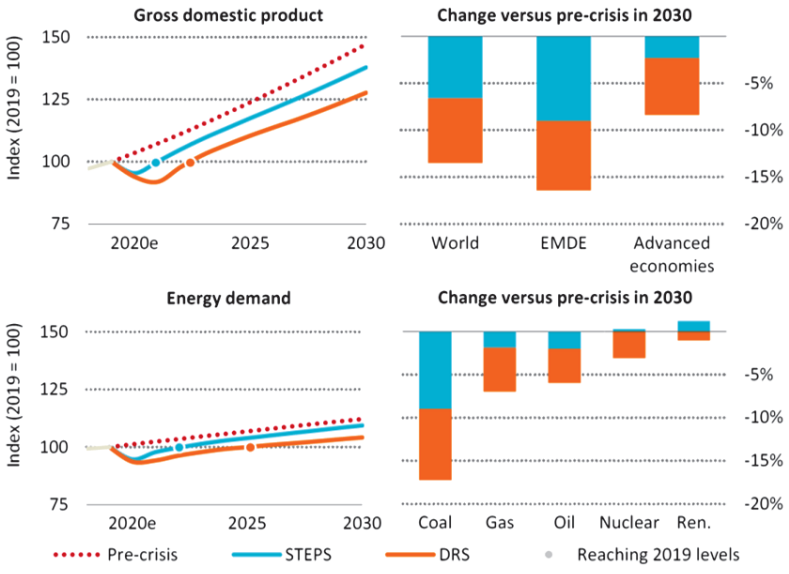

Fig. 1. Dynamics of GDP and demand for primary energy in the world in different scenarios World Energy Outlook (WEO) – 2020. Source: (World Energy Outlook 2020, 2020).

Economy sector	**2020**	**2021**	**2022**	**2025**	**2030**	**2050**
Construction	-2.8	-3.2	-2.6	-4.0	-5.0	-5.8
Industry	-7.2	-8.2	-7.1	-8.7	-7.8	-7.9
Transport	-17.2	-11.6	-8.5	-9.0	-9.8	-9.7
Non-energy needs	-6.0	-9.4	-8.4	-11.3	-10.8	-10.4
Global economy, in total	-8.3	-7.5	-6.0	-7.4	-7.5	-7.6

Tab. 1. DNV: The global cumulative impact of the coronavirus pandemic on the final energy demand sectors, as a percentage of the COVID-19-free situation. Based on materials (Energy Transition Outlook ..., 2020).

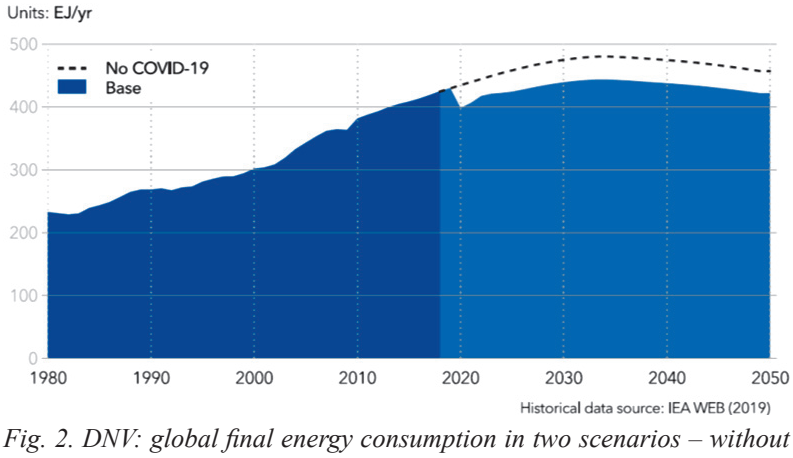

Fig. 2. DNV: global final energy consumption in two scenarios – without and taking into account the global pandemic (Baseline scenario). Source: (Energy Transition Outlook..., 2020).

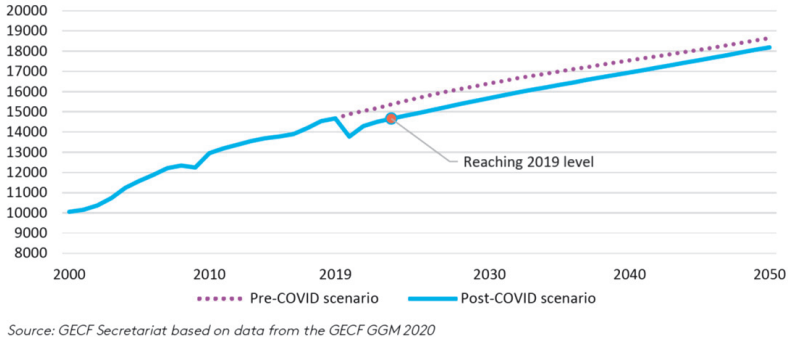

Fig. 3. Global demand for primary energy resources, million TOE. Source: (GECF Global Gas Outlook 2050 Synopsis, 2021)

According to DNV experts, the greatest impact of the coronavirus pandemic will have on the consumption and, accordingly, on the production of such primary energy resources as coal, oil and wind energy (Table 2).

According to IEA estimates, global energy demand in the Public Policy Scenario will return to pre-crisis levels in early 2023, but in the Late Recovery Scenario, due to a prolonged pandemic and a deeper economic downturn, the demand recovery may drag on until 2025 (Fig. 1). Accordingly, energy demand growth for the entire 2019–2030 period is projected at 9% in the Public Policy Scenario and only at 4% in the Late Recovery Scenario, with all the growth taking place in emerging markets and developing countries. At the same time, in the period of up to 2030, the demand for oil and gas, and even less for coal, will not recover (Fig. 1). The expected dynamics of oil demand is also shown in Fig. 4.

A special section on assessing the impact of the COVID-19 pandemic on economic activity and energy demand is given in the latest BP Energy Outlook 2020 edition, released last October (BP Energy Outlook ..., 2020). It emphasizes that the review's estimates of the possible impact of the pandemic are highly uncertain. That said, it is assumed that economic activity will partially recover from the effects of the pandemic over the next few years as restrictions ease, although some of the consequences will linger on. Based on this, it is assumed that the level of world GDP will be about 2.5% lower in 2025 and by some 3.5% in 2050 (Fig. 5). The negative impact of the pandemic on developing economies such as India, Brazil and Africa is especially great, the economic structures of which are most susceptible to the economic consequences of COVID-19.

Accordingly, the energy consumption will also decrease – in the main BP scenarios (the Rapid, Net Zero and Business-as-usual ones – they are to be surveyed below) by about 2.5% in 2025.

And even in 2050, the decline will amount to 3%. The demand for oil will fall especially sharply: by almost 3 million barrels per day in 2025 and by 2 million barrels per day in 2050.

But if new waves of infection follow, the economic losses from COVID-19 could

Energy sources	2020	2021	2022	2025	2030	2050
Biomass	-1.8	-1.7	-1.0	-1.4	-1.1	-2.4
Hydro-energy	-5.6	-1.8	0.3	-1.8	-3.5	-3.2
Sun photovoltaics	-4.6	-3.1	-5.8	-11.2	-12.6	-8.8
Wind energy	-4.6	-1.9	-3.3	-8.5	-14.4	-10.2
Atomic energy	-4.3	-0.5	-0.5	-0.6	-0.5	-2.4
Total non-fuel resources	**-3.3**	**-1.4**	**-1.0**	**-2.4**	**-4.1**	**-6.2**
Coal	-6.1	-8.3	-7.5	-8.2	-6.3	-9.0
Oil	-13.2	-9.9	-7.6	-8.5	-9.3	-9.6
Gas	-6.3	-9.5	-8.7	-10.1	-9.4	-9.3
Total fuel resources	**-8.6**	**-9.2**	**-7.9**	**-9.0**	**-8.5**	**-9.4**

Tab. 2. The global impact of the coronavirus pandemic on the supply of primary energy by its main sources, as a percentage of the situation without COVID-19. Based on materials (Energy Transition Outlook ..., 2020).

be significantly greater. This assumption is taken into account in the Alternative Scenario. Under the latter, COVID-19 could decrease the level of the global GDP in 2025 by 4%, and by almost 10% by 2050. Accordingly, the level of energy demand in the Rapid Scenario – the main scenario of BP Energy Outlook 2020 – will be lower in 2050 by 8%, and the level of oil demand – by about 5 million BOPD (Fig. 5).

The dimension of the impact of the coronavirus pandemic on the dynamics of global demand for basic primary energy resources in the period up of up to 2030 can be estimated from the results of the McKinsey study "Global Energy Perspective 2021" (Fig. 6).

An analysis of CO2 emissions by the global electric power industry also gives a clue to the scale of the impact of the coronavirus pandemic on the dynamics of the global demand for primary energy resources, an estimation of which is presented in the latest forecast by BloombergNEF "New Energy Outlook 2020", published on October 27, 2020 (New Energy Outlook 2020, 2020) (Fig. 7).

The OPEC Secretariat also provides estimates of the impact of the coronavirus pandemic on economic development and energy consumption in the coming years. In its latest, 14th edition of the World Oil Outlook (WOO), released last October, it is noted that the average annual growth rate in the developed countries (Organization for Economic Cooperation and Development – OECD) will amount to only 0.7% in the period from 2019 to 2025 while before COVID-19 their projected growth was estimated at 2.1% (World Oil Outlook 2045 ..., 2020). For non-OECD countries, GDP is expected to grow by an average of 3.4% per annum over the same period, more than 1 percentage point lower than the former forecasts.

Based on the assumption that the COVID-19 pandemic will be largely overcome by next year, oil demand, according to the OPEC Secretariat forecasts, will partially recover, and will reach 94.4 million barrels per day in 2025.

In the same study, two additional scenarios – Higher and Lower GDP growth rates (Higher GDP Case and Lower GDP Case) – are considered in detail, which analyze the dynamics of oil demand in the medium term, depending on the pace of economic recovery after the pandemic crisis. It is noted that outside the medium-term outlook, the growth rates of global GDP in both additional scenarios will broadly correspond to the growth rates in the Reference Case. However, due to the different base reached in 2025, the gap in the level of economic activity in 2045 will amount to almost USD 22 trillion (at purchasing power parity in 2011 prices – at PPP 2011) (World Oil Outlook 2045 ..., 2020).

However, in most of the predictive studies of the prospects for the development of world energy that we have considered, assessments of the consequences of the pandemic for the long-term global economic and energy development are presented in an implicit form. As a rule, in the description of certain scenarios, it is simply noted that these scenarios have been clarified (or made) taking into account the coronavirus crisis.

Estimates of global energy consumption in the middle of the 21st century

The priority of most prognostic assessments of the worldwide consumption of primary energy resources carried out in the recent years by the international leading analytical centers, focuses on a sharp reduction in energy emissions of CO_2 and on stabilizing of the global anthropogenic emissions of greenhouse gases, primarily carbon dioxide, in order to prevent the negative climate changes on our planet. This priority is most often achieved by developing special climate-oriented scenarios, or scenarios aimed at ensuring an energy transition, which are based on reducing or stabilizing the growth of energy consumption coupled with a sharp change in its structure in favor of renewable energy sources (RES). In order to be able to compare the proposed scenarios, so-called baseline scenarios are also being developed.

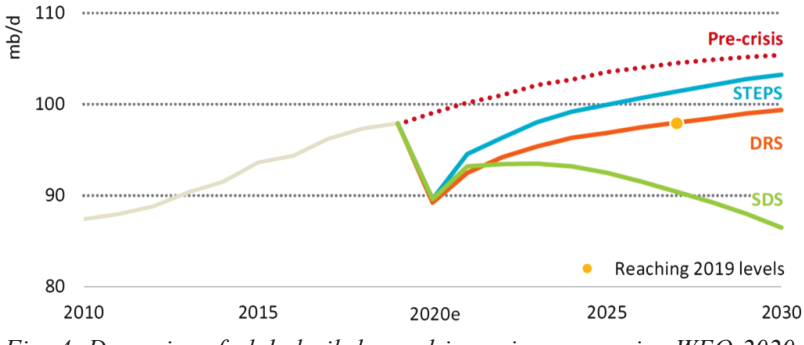

Fig. 4. Dynamics of global oil demand in various scenarios WEO-2020. Source: (World Energy Outlook 2020, 2020).

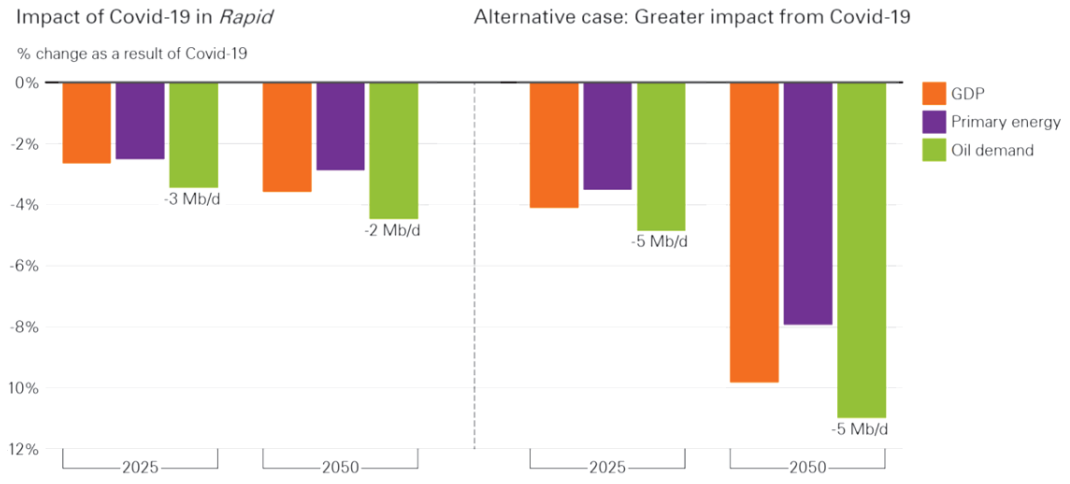

Fig. 5. Assessment of the impact of the Covid-19 pandemic on economic activity and energy demand. Source: (BP Energy Outlook..., 2020).

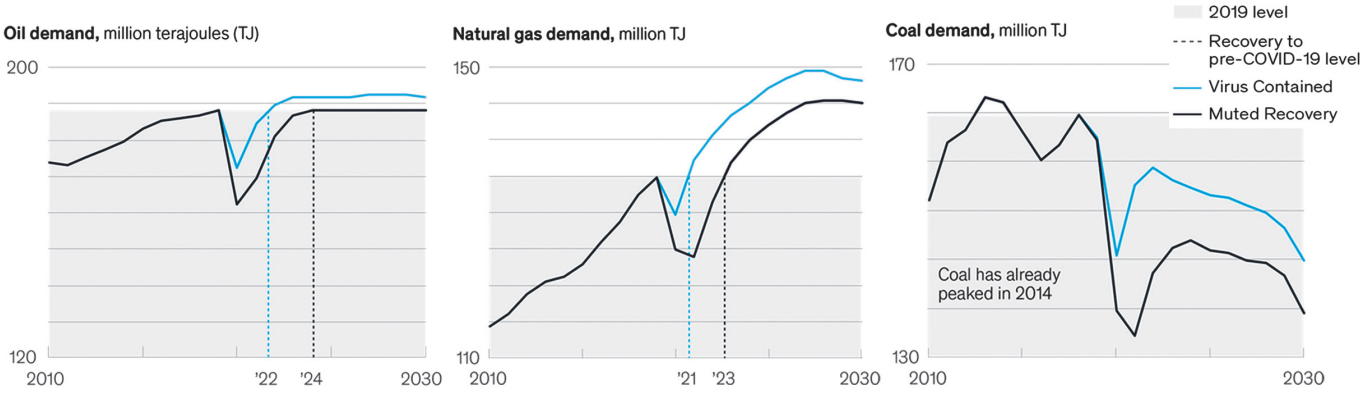

Fig. 6. Global demand for major primary energy resources, million TJ. Source: (McKinsey Energy Insights ..., 2020).

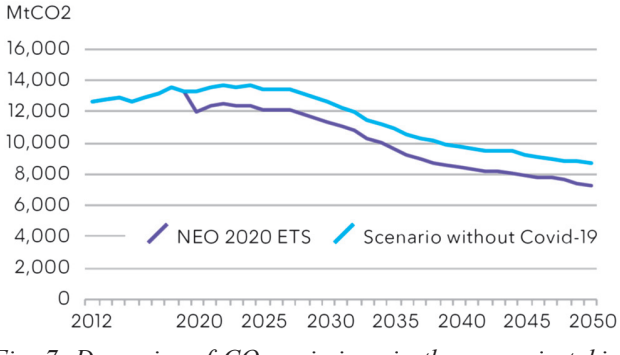

Fig. 7. Dynamics of CO_2 emissions in the scenario taking into account the coronavirus pandemic and in the scenario without it. Source: (New Energy Outlook 2020 ..., 2020).

The scenarios of the future development of global energy that we have considered, depending on the ideology that is embedded in them, can be conditionally divided into several groups.

Group 1 – forecasts and scenarios based on the inertial development of the world economy and energy, the invariability of the existing energy policy and prolonging the existing trends. These include:

- Scenario Current Policies Scenario (CPS) of the IEA’s World Energy Outlook (WEO), which is not considered in the latest WEO-2020;
- Base scenario of the OPEC Secretariat (World Oil Outlook – WOO) – OPEC’s Reference or Reference Case in WOO 2020;
- The base scenario of the GECF Secretariat (Global Gas Outlook) – Reference case scenario (RCS);
- Basic scenario of the Institute of Energy Economics of Japan – IEEJ (Institute of Energy Economics, Japan – IEEJ) – Reference Scenario;
- Equinor’s Rivalry Scenario;
- Planned Energy Scenario (PES) scenario for the World Energy Transitions Outlook of the International Renewable Energy Agency (IRENA) and others.

Group 2 – forecasts and scenarios focused on a significant increase in energy efficiency, the continued development of technologies, taking into account the declared political ambitions, including those related to the Paris Agreement on the climate (the so-called “evolving policy” scenarios). Those read as follows:

- The scenario of new policies (NPS Scenario) of the IEA, which in recent years was considered basic in the WEO forecasts, that is, the most probable. In 2019, it was replaced by the Stated Policies Scenario (STEPS), which provides a detailed view of the direction of the energy sector development in line with today’s political ambitions;

- OPEC Secretariat Accelerated Policy and Technology Case (APT Case) (WOO 2020);
- Scenario of transformation of the world after the coronavirus (Post Corona World Transformation Scenario – Post Corona Scenario – PCS) IEEJ;
- Equinor's Reform script;
- Evolving transition scenario BP Energy Outlook 2019 and Business as Usual (BAU) BP Energy Outlook 2020;
- Basic scenario of IRENA postulates (Global energy transformation: A roadmap to 2050);
- • Economic Transition Scenario BloombergNEF ("New Energy Outlook 2020"), etc.

3rd group – forecasts, scenarios and roadmaps aimed at ensuring the energy transition. These include:

- Sustainable Development Scenario (SDS Scenario) of the IEA;
- Alternative scenarios of the OPEC Secretariat – Scenario A, Scenario B (World Oil Outlook 2020);
- Carbon Mitigation Scenario (CMS) of the GECF Secretariat (GECF Global Gas Outlook 2050 Synopsis);
- Scenario of advanced technologies (Advanced Technologies Scenario) IEEJ;
- Scenarios Renewal and Rebalance by Equinor;
- Rapid Transition Scenario (RT or Rapid) BP – basic in BP Energy Outlook 2020;
- Transforming Energy Scenario of IRENA's postulates;
- Climate Scenario (NEO Climate Scenario – NCS) by BloombergNEF;
- Scenario "New Normal" (New Normal scenario), worked out by the experts of the European Commission (Global Energy and Climate Outlook 2020);

A separate group should include the scenarios that show how the energy sector should develop further or what it should become in order to achieve the goal of limiting the global warming to 1.5 ºC and 2.0 ºC by 2100 compared to the pre-industrial levels. These ambitious climate scenarios primarily (in terms of publication time) include various climate scenarios of the Intergovernmental Panel on Climate Change (IPCC), published in October 2018 (Special Report on Global Warming of 1.5 ºC) and also:

- Circular carbon economy / 4Rs Scenario (CCE) IEEJ;
- Net Zero Scenario (Net Zero) BP Energy Outlook 2020;
- 1.5 ºC Scenario of the latest IRENA forecast (World Energy Transitions Outlook 2021);
- Scenarios "2 ºC" and "1.5 ºC" by the specialists of the European Commission (Global Energy and Climate Outlook 2020);
- Scenario 1.5 ºC Pathway by McKinsey Energy Insights (Global Energy Perspective 2021) and others.

The already mentioned issue of the International Energy Agency "Net Zero by 2050. A Roadmap for the Global Energy Sector" could be considered a kind of peak of such research activities. This study develops and brings to a logical conclusion the ideas laid down earlier in the Net Zero Emission by 2050 (NZE2050) WEO-2020 scenario.

We emphasize once again that such a division of forecasts and scenarios into four groups is very, very arbitrary, since the ideology of many scenarios allows them to be attributed to different groups. Thus, the IEA State Policy Scenario (STEPS) WEO-2020, in terms of its qualitative parameters, should be attributed to the forecasts and scenarios of the second group, which we actually did above. However, due to its place among the other scenarios of WEO-2020, it refers specifically to the baseline scenarios, especially since the Current Policy Scenario (CPS) is not considered in this forecast at all. Therefore, it belongs to the first group (Table 3). But this especially applies to IRENA predictive research scenarios, which are different in each release of their results.

It should also be stressed out that in the overwhelming majority of cases, only one scenario has been worked out in detail in the studies reviewed in the article. As for the rest, especially the alternative scenarios, they represent – with varying degrees of detailization – only some specific components of the global energy, and, as a rule, not for the full forecasting period (for example, the scenarios Net Zero Emissions by 2050 and Delayed Recovery Scenario WEO-2020, which will be discussed below). This makes it impossible not only to compare scenarios in different forecasts, but also to obtain a complete picture of energy development in these scenarios themselves. This fully applies to IRENA scenarios. Taking into account all these and the considerations noted above, the IRENA scenarios, like those of many other forecasting centers, are not considered in Table 3.

Of course, it would be interesting to consider in detail each of the above mentioned scenarios, show its specific features and compare it with other scenarios and forecasts. Analyzing forecasts of investments and energy prices were also of special interest. However, the volume of the article does not facilitate to do it, therefore, we will consider only one – the basic indicator of these scenarios – that of the global energy consumption and its fluctuation in each of the four groups we have specified.

The global demand for primary energy resources in the main considered scenarios of the first group at the level of 2040 lies in the range from 16.6 billion TOE in Equinor's Rivalry scenario (Energy Perspectives

Organization	Scenario	Title of the study	Forecasting period	Primary energy consumption/demand. million TOE					Electricity generation, TWh	Share of RES, %	Emission of CO_2, billion t
				Total	Share of RES, %	Oil	Gas	Coal			
1st group of forecasts											
IEA	Stated Policies Scenario	WEO-2020	2040	17085	22	4832	4321	3314	40 094	47	33.3
OPEC	Reference Case	WOO-2020	2040/ 2045	17473/ 17920	20/ 21	4945/ 4935	4330/ 4523	3611/ 3521	…/ 47000	…/ 37	36.9/ 36.8
GECF	Reference Case scenario	Global Gas Outlook 2050 Synopsis	2040/ 2050	≈17000/ 18190	21/ 24	5455/ 4890	≈5250/ 5920	≈3200/ 2980	≈40 000 /48 050	31/ 35	>33.7/ 33.7
IEEJ	Reference Scenario	IEEJ Outlook 2021	2040/ 2050	17823/ 18556	16/ 17	5328/ 5608	4690/ 5132	4174/ 3884	40519/ 45201	32/ 35	39.5/ 40.0
Equinor	Rivalry	Energy Perspectives 2021	2040/ 2050	16613/ 16643	…/ 20*	5062/ 5050	3939/ 3948	3401/ 2826	38137/ 41252	…	…/ 31.8
2nd group of forecasts											
IEEJ	Post Corona World Transformation Scenario	IEEJ Outlook 2021	2040/ 2050	17494/ 17724	16/ 18	5109/ 4929	4611/ 5019	4042/ 3614	40441/ 45151/	32/ 37	38.0/ 36.2
Equinor	Reform	Energy Perspectives 2021	2040/ 2050	15686/ 15273	…/ 26*	4249/ 3825	3919/ 3842	2785/ 2085	40475/ 45338	…	…/ 24.3
BP	Business as Usual	Energy Outlook 2020	2040/ 2050	16505/ 17317	17/ 22	…/ 4108	…/ 4467	…/ 2938	…	…	32.6/ 30.5
3rd group of forecasts											
IEA	Sustainable Development Scenario	WEO-2020	2040	13020	35	3006	2943	1295	38774	72	14.7
IEEJ	Advanced Technologies Scenario	IEEJ Outlook 2021	2040/ 2050	15925/ 15743	21/ 26	4617/ 4454	3918/ 3802	2939/ 2235	38288/ 41490	41/ 51	29.6/ 25.2
Equinor	Rebalance	Energy Perspectives 2021	2040/ 2050	13409/ 12247	…/ 41*	2795/ 2056	3430/ 2547	1529/ 679	44356/ 50329	…	…/ 8.9
BP	Rapid	Energy Outlook 2020	2040/ 2050	…/ 14929	33/ 44	…/ 2126	…/ 3201	…/ 573	…	…	16.6/ 9.3
4th group of forecasts											
IEA	NZE2050	WEO-2020	2030	≈12000	…	…	…	…	…	60	20.1
IEEJ	Circular carbon economy/ 4R Scenario	IEEJ Outlook 2021	2040/ 2050	16030/ 16061	21 / 25	4350/ 3922	4397/ 4816	2800/ 1980	38297/ 41639/	45/ 58	27.4/ 20.0
BP	Net Zero Scenario	Energy Outlook 2020	2040/ 2050	14905/ 14929	48 /59	…/ 1003	…/ 1959	…/ 287	…	…	9.7/ 1.4

*Tab. 3. The main indicators of some predictive studies of world energy. Conversion in million TOE made on the basis of the following ratios: 1EJ = 23.886 MTOE; 1MBOE/D = 49.598 MTOE. * – only "new" renewable energy sources. Source: calculated and compiled according to (World Energy Outlook ..., 2020; World Oil Outlook 2045 ..., 2021; GECF Global Gas Outlook 2050 ..., 2021; BP Energy Outlook ..., 2020; IEEJ Outlook ..., 2021; Energy Perspectives ..., 2021).*

..., 2021) up to 17.8 billion TOE in the Reference Scenario IEEJ (IEEJ Outlook…, 2021). At the same time, according to in these scenarios, the global demand might continue to grow in the span between 2045 and 2050. The energy balance of these scenarios is based on the traditional energy resources – oil, natural gas and coal, although the time period for reaching the peak demand for them quite differs in various forecasts. Accordingly, the share of renewable energy sources, including traditional biomass, is quite small in them – just about 20–22% – and in the forecasts of the IEEJ, which in all its studies evaluates the potential of RES

	IEA		OPEC	GECF		IEEJ				Equinor		
	WEO-2020		WOO-2020	Global Gas Outlook 2020		IEEJ Outlook 2021				Energy Perspectives 2021		
	Scenarios		Scenario	Scenarios		Scenarios				Scenarios		
	STEPS	SDS	Reference	Reference	CMS	Reference	ATS	PCS	CCE	Rivalry	Reform	Rebalance
Oil	28	23	27	27	25	30	28	28	24	30	25	17
Natural gas	25	23	25	28	30	28	24	28	30	24	25	21
Coal	19	10	20	16	10	21	14	20	12	17	14	6
Atomic energy	5	9	5	5	6	5	8	5	8	…	…	…
RES	22	35	23	24	29	16	26	19	26	10*	15*	28*
Total	100	100	100	100	100	100	100	100	100	100	100	100

Tab. 4. Structure of energy consumption in forecast studies of the IEA, the OPEC Secretariat, the GECF Secretariat, the IEEE and the Equinor company. Only "new" renewable energy sources. Forecast year: IEA – 2040, OPEC – 2045, GECF, IEEE and Equinor – 2050. Calculated and compiled according to (World Energy Outlook ..., 2020; World Oil Outlook 2045 ..., 2021; GECF Global Gas Outlook 2050 ..., 2021; IEEJ Outlook ..., 2021; Energy Perspectives ..., 2021).*

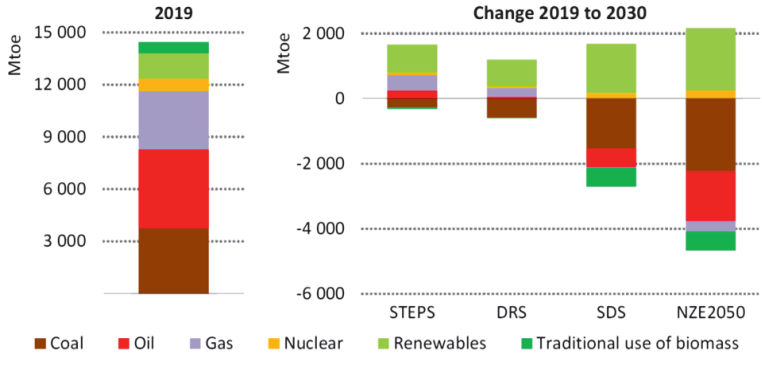

Fig. 8. Changes in the structure of global consumption of primary energy resources in various scenarios WEO-2020 IEA. STEPS – Public Policy Scenario; DRS – Late Recovery Scenario; SDS – Sustainable Development Scenario; NZE2050 – Scenario of zero net emissions by 2050. Source: (World Energy Outlook 2020, 2020).

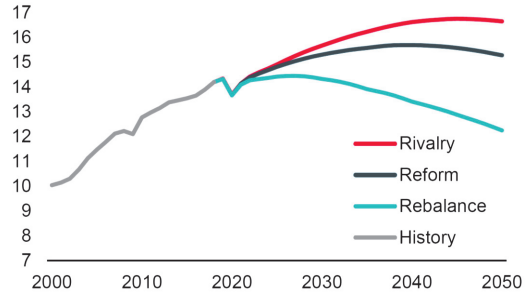

Fig. 9. Dynamics of global energy consumption in different scenarios of the forecast study Energy Perspectives 2021 by Equinor. Source: (Energy Perspectives..., 2021).

very carefully, their share is estimated at an even lower level – just at 16%.

As a typical example of this forecast group can be considered the State Policy Scenario (STEPS) WEO-2020 of the IEA; the structure of the prospective balance of this scenario is presented in Table 4 and Fig. 8.

Quantitatively, the total volume of energy consumption of the second group of scenarios as a whole does not fundamentally differ from the analogous indicators of the scenarios of the first group, since the growth of energy efficiency inherent in them, the continuing development of technologies, taking into account the declared political ambitions, do not fundamentally change the consumption levels. These differences appear only within the forecasts of the corresponding predictive studies, which is clearly seen when comparing Equinor's Rivalry and Reform scenarios (Fig. 9).

And although the structure of energy consumption does not fundamentally change in the scenarios of the second group – compared to the scenarios of the first one, the share of coal in it is as a rule slightly less, and that of natural gas, on the contrary, is larger (Table 4).

The scenarios of the third group, aimed at ensuring the energy transition, are fundamentally different from the aforementioned ones (Tables 3 and 4). The demand for primary energy resources in the main considered scenarios of this group at the level of 2040 lies in the range of 13.0 billion TOE in the Sustainable Development Scenario (SDS) WEO-2021 IEA (World Energy Outlook 2020, 2020) up to 15.9 billion TOE in the Advanced Technology Scenario (ATS) of the IEEJ Outlook ..., 2021). At the same time, the global demand in these scenarios for the period of 2045–2050 will decrease as a result of active energy saving policies and other measures taken. The structure of energy consumption is also fundamentally changing in the energy transition scenarios: the share of traditional energy resources – oil, natural gas and especially coal – is diminishing constantly while the RES are gaining more and more importance (Table 4). These changes are convincingly shown in BP's Energy Outlook studies (Fig. 10), DNV's Single Scenario Energy Transition Outlook (Fig. 11), BloombergNEF's New Energy Outlook (Fig. 12), and such like.

The data shown in Fig. 10–12 demonstrates clearly to what extent the views of the energy future by the experts of various analytical and forecasting centers actually differ. For instance, for 2050 the share of natural gas in the structure of global energy consumption in the forecast of the DNV company is predicted to amount to

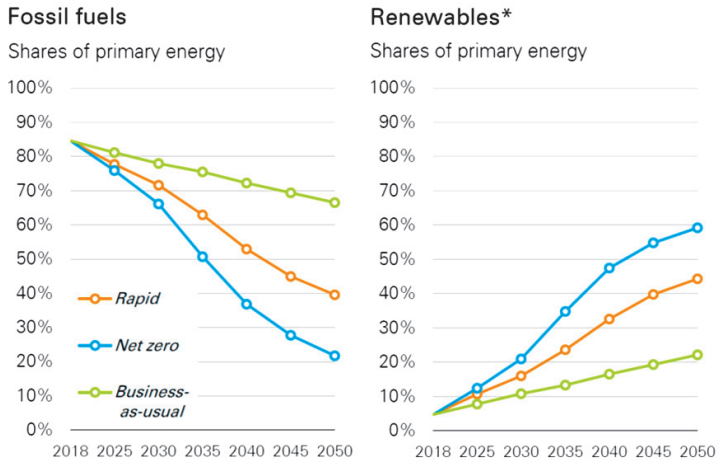

*Fig. 10. The share of fossil fuels and RES in various scenarios of BP Energy Outlook 2020. * – RES excluding large hydroelectric power plants. "Rapid" – Rapid transition script; "Net Zero" – Zero Emissions Scenario; "Business as Usual" – Business as usual scenario. Source: (BP Energy Outlook 2020…, 2020).*

29%, and the assessment in the Climate scenario of the BloombergNEF company is just some 6%. Meanwhile according to this same scenario, the share of the so-called "other" energy resources, including 801 million tons of hydrogen obtained by electrolysis of water, reaches 20%.

Eventually, common to all these scenarios and other comparable studies related to the energy transition is the general presumption that the evolution of energy systems would be based on a significant increase in the use of renewable energy sources and a corresponding reduction in the use of fossil fuels (primarily coal and oil) combined with a simultaneous major progress of the energy efficiency throughout the entire technological chain, i.e. from production to final consumption.

As for the forecasts and scenarios that we have assigned to the fourth group, they tend even more than the energy transition scenarios – to favour either reducing the share of carbon-containing fuels in the global energy balance or using them only in combination with various technologies developed for carbon monoxide extraction and storage. A general idea of such scenarios is provided by the data shown in Tables 3 and 4, as well as Fig. 8 and 10.

The IEA study "Net Zero by 2050. A Roadmap for the Global Energy Sector" as well as the critical stances by some foreign experts deserve separate consideration. However, considering the space limit of this article, we´d rather limit ourselves only to its specific result, i.e. the projection of energy consumption in the world in 2050 (Fig. 13). The projected volume of energy consumption and its structure are expected to ensure the reduction of CO_2 emissions, including emissions from industrial processes, to zero by 2050[7], thus solving the tasks set in the study.

Some other scenarios, based on the circular carbon economy (CCE) model, are also of special interest. As noted by the OPEC Secretariat specialists, the concept of a circular economy is an emerging megatrend that can contribute to mitigating the effects of climate change. The international experts community tends to uses different definitions; however, it widely shares the concept of an economic system based on minimizing the loss of resources and energy through the principles of emission reduction, reuse and recycling (3Rs) (World Oil Outlook 2045 ..., 2020).

Developing the concept of a the circular/closed-circulation carbon economy – CCE based on "3Rs" – the experts of the OPEC Secretariat and IEEJ provided the CCE concept, based on "4Rs" – reduction, reuse, recycling and removal of emissions from the environment through natural effluents (World Oil Outlook 2045 ..., 2020; IEEJ Outlook ..., 2021).

Conclusion

In conclusion, we would like, first of all, to stress out that working-out of long-term predictive studies on the further development of the world energy has become a significant part of scientific activities conducted by various international organizations and leading

[7] Under 2 conditions: 1) 1936 billion tons of CO_2 are captured for further utilization and production of various products, including carbon-neutral fuel, and removed from the atmospheric air due to natural effluents (for example, planting forests); 2) 7602 billion tons of CO_2 are captured and disposed of (Net Zero by 2050 ..., 2021).

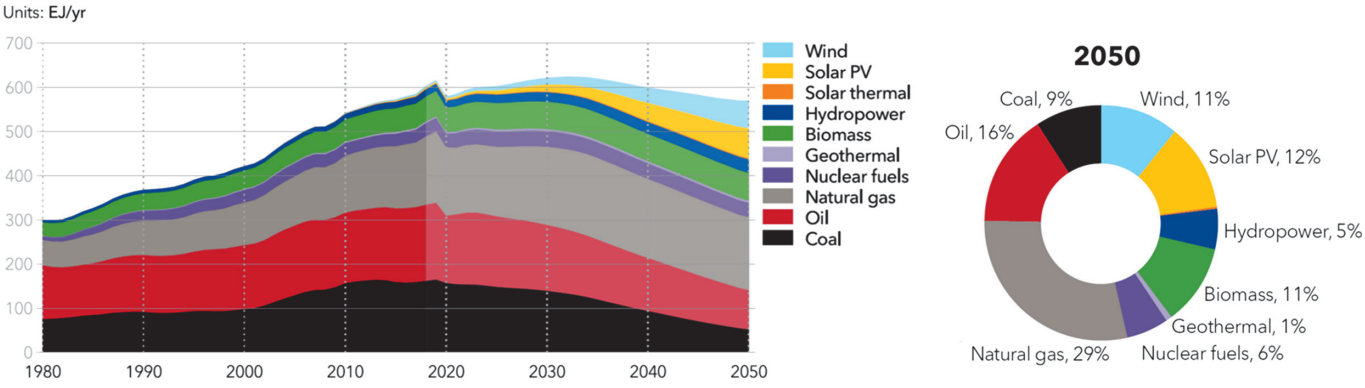

Fig. 11. Dynamics and structure of world consumption of primary energy resources – forecast of DNV company. Source: (Energy Transition Outlook…, 2020).

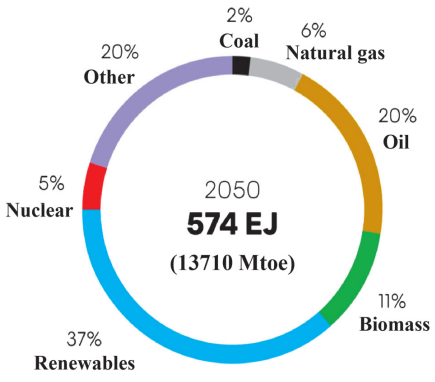

Fig. 12. Structure of consumption of primary energy resources in the world – Climate Scenario (NEO Climate Scenario – NCS) New Energy Outlook by BloombergNEF. Source: (New Energy Outlook 2020…, 2020).

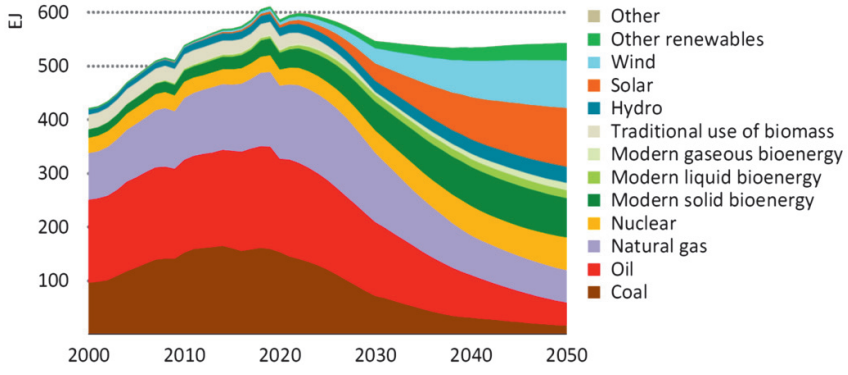

Fig. 13. Total energy supply in the world in the NZE scenario of the IEA study "Net Zero by 2050. A Roadmap for the Global Energy Sector". According to (Net Zero by 2050 …, 2021).

countries (USA, China, the European Union, France, Japan, Republic of Korea, etc.) as well as by the leading multi-energy, oil and gas and energy service companies. Based on the achievements of the 4th industrial revolution in modelling, digitalization, information technology, in development of global networks and data flows, predictive studies make it possible to consider a variety of development scenarios, depending on certain decisions made. As it was noted back in August 2013 by the experts of the Analytical Center for the Government of the Russian Federation, hundreds and even thousands of new energy forecasts appear annually worldwide, reflecting different points of view with regard to the future of the energy sector in the short, medium and long term respectively (Long-term forecasting in the energy sector, 2013). Since then, the number of such forecasts has continued to grow.

Sadly, the Russian contribution to this process is rather modest, especially what the largest Russian oil and gas companies concerns. After all, such forecasts not only make it possible to anticipate the energy future, but also, using them, to pursue the interests of the organizations in question, to push through their views of shaping the energy future. Moreover, we have not even yet organized in a proper way our work on systematic analyzing of foreign forecasts in order not to get confused by their sheer diversity and to monitor the situation in this area constantly.

It seems that this attitude needs to be changed, and changed as soon as possible.

References

BP Energy Outlook 2020 edition. Energy Outlook 2020. 234 p. bp.com

Baunov A. (2020). What will international relations be like after the pandemic? Carnegie Moscow Center. (In Russ.). https://carnegie.ru/commentary/81714?utm_source=rssemail&utm_medium=email&

Energy Perspectives 2021. Long-term macro and market outlook. Equinor ASA, 58 p. https://www.equinor.com/en/sustainability/energy-perspectives.html

Energy Transition Outlook 2020. A Global and Regional Forecast to 2050. DNV GL, 306 p.

GECF Global Gas Outlook 2050 Synopsis (2021). Gas Exporting Countries Forum. https://www.gecf.org/insights/global-gas-outlook?d=2021&p=1

Global Economic Prospects (2021). Washington, DC: World Bank, 234 p. DOI: 10.1596/978-1-4648-1612-3

IEEJ Outlook 2021 (2021). Energy transition in the post corona world. IEEJ, 206 p. https://eneken.ieej.or.jp/data/9417.pdf

Keramidas K., Fosse F., Diaz-Vazquez A., Schade B., Tchung-Ming S., Weitzel M., Vandyck T., Wojtowicz K. (2021). Global Energy and Climate Outlook 2020: A New Normal Beyond Covid-19. Luxembourg: Publications Office of the European Union. https://ec.europa.eu/jrc

Long-term forecasting in energy (2013). *Energy Bulletin*, 5. Analytical Centre for the Government of the Russian Federation. (In Russ.)

Mastepanov A.M. (2016). About global warming, low-carbon energy and the prospects for the oil and gas industry. *Ekologicheskii vestnik Rossii* [Ecological Bulletin of Russia], 5, pp. 20–31. (In Russ.)

Mastepanov A.M. (2017). Climate-driven scenarios in the forecasts of the International Energy Agency. *Ekologicheskii vestnik Rossii* [Ecological Bulletin of Russia], 6, pp. 4–10. (In Russ.)

Mastepanov A.M. (2019). Energy transition: what to prepare for the global oil and gas industry. *Problemy ekonomiki i upravleniya neftegazovym kompleksom*, 11(179), pp. 5–6. (In Russ.)

Mastepanov A.M. (2020a). Big cycles and black swans. *Energeticheskaya politika* [Energy Policy], 6(148), pp. 4–19.(In Russ.)

Mastepanov A.M. (2020b). A world at a breaking point or a new reality: forecasts for the development of the energy sector and its oil and gas industry. *Problemy ekonomiki i upravleniya neftegazovym kompleksom*, 5(185), pp. 9–10. (In Russ.)

McKinsey Energy Insights. Global Energy Perspective 2021 (2020). Energy landscape. McKinsey. https://www.mckinsey.com/industries/oil-and-gas/our-insights/global-energy-perspective-2021

Net Zero by 2050. A Roadmap for the Global Energy Sector (2021). IEA, 223 p. https://www.iea.org/reports/net-zero-by-2050

New Energy Outlook 2020 (2020). Executive Summary. BloombergNEF, 29 p. https://about.bnef.com/new-energy-outlook/#toc-download

World Energy Outlook (2020). OECD/IEA, 464 p. https://www.iea.org/reports/world-energy-outlook-2020

World Oil Outlook 2045 (2020). Organization of the Petroleum Exporting Countries, 311 p. opec.org

About the Author

Alexey M. Mastepanov – Dsc (Economics), Professor, Head of the Analytical Centre for Energy Policy and Security, Chief Researcher, Oil and Gas Research Institute of the Russian Academy of Sciences; Professor, Gubkin Russian State University of Oil and Gas (National Research University)

3, Gubkin st., Moscow, 119333, Russian Federation

Manuscript received 21 July 2021;
Accepted 2 August 2021;
Published 30 August 2021