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Global energy trilemma

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Abstract

The international community has become increasingly concerned with sustainable development and particularly with preventing climate change. The COVID-19 pandemic and global recession of 2020 will exacerbate the situation not just for 2020–2021, but for many years to come. Sadly, it is a game-changer. The necessity to solve problems of poverty (energy poverty) and inequality, as well as growth and climate change mitigation, now haunts intellectuals, forecasters, and politicians. These three problems constitute the global energy trilemma (GET). There is a wide range of forecasts, scenarios, and political plans emerging after the Paris Agreement in 2015. They demonstrate concerns about the slow progress on the matter; however, they still increase the goals for 2030–2050. The global capital formation is a key tool for changes while also representing the hard-budget investment constraints. This article examines practical features of recent trends in energy, poverty, and climate change mitigation, arguing that allocation and coordinated management of sufficient financial resources are vital for a simultaneous solution of GET. No group of countries can hope to solve each of the Sustainable Development Goals (SDG) separately. The global economy has reached the point where it has an urgent need for cooperation.

Keywords: energy, Sustainable Development Goals, poverty, inequality, energy poverty, capital formation, energy transition.
JEL classification: E2, F21, O44, P28, Q01.

The philosophers have only interpreted the world
in various ways. The point, however, is to change it.

Karl Marx. "Theses on Feuerbach"

1. Introduction

Mankind is currently burdened with a variety of problems in every country, albeit at different stages of development. The common problems and goals were

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combined into Sustainable Development Goals of the UN signed in 2015 (Heun, Brockway, 2019). Resolving some of these issues is basically a precondition of survival. However, it depends on the coordination of efforts, mobilization and complicated institutional settings — global governance in short.

In the energy world, the most central theme is the Transition process. Generally, there is no disagreement on the ultimate objective in this field — sustainable growth with climate change mitigation as stated in the Paris Agreement of 2015. Many states (especially the European Union) have adopted comprehensive strategies and taken their obligations seriously in this respect. The key solutions are seen in technological and political approaches. Nevertheless, the path of development is very different for developed and developing countries with their varying wealth and income levels, as well as energy mixes of resources and accumulation of human capital.

Neither a special agreement (not to mention enforcement) nor even indicators were set for inequality in the Sustainable Development Goals (SDG) 10 context. One may see some tradition when it comes to the study of Growth and Inequality, or Growth and Energy, in the past. Nowadays, however, it increasingly comes to the connection between Inequality and Climate (energy). Our approach is to consider the Growth (SDG 8) and Inequality (SDG 10) as strongly interconnected (including energy poverty) with Climate (SDG 13). We believe these three should be taken together (as a set) in global strategic planning as a global energy trilemma (GET). Without an integrated solution to inequality (poverty and energy poverty), economic growth may not bring us to stability and sustainability.

The most obvious salutary lesson has come from COVID-19 and the accompanying global recession of 2020 with associated health care failures as well as high human, social and economic costs worldwide. The immediate reaction to this problem was developed and published recently by the prominent professor Sergei Bobylev and one of the authors of this article with a call for incorporating these three goals into an interconnected set. Also, we have suggested using certain indicators — "connecting" ones — as a criterion of success not for one, but for a few SDGs (Bobylev and Grigoryev, 2020).

Moreover, there is another issue — time. How long will it take for humanity to become equal, developed, socially stable and democratic? Before 2020 brought the pandemic and recession, the perspectives in this respect were rarely discussed. Even the staunchest proponents of SDG were more concerned about the Climate issue than Energy Poverty, and financial stability rather than the stability of development finance (regardless of the business cycle). With all due respect to international efforts in development and development assistance, no conspicuous success is visible on the horizon. We believe that 2020 has seen a disastrous setback in development in general. The main budget resources of OECD countries are currently supporting unemployed people and vulnerable businesses. Green Recovery appears to be a very promising political idea, but the practical game is not that bright as the recovery is expected in 2022. We assume that for the next two or even three years resources in developed and developing countries will be allocated to more urgent recovery objectives.

The article is organized as follows. The second section is devoted to debates and decisions on energy transition within SDG framework. The third section is focused on the recent history of implementation of plans and decisions, and

the challenge of Global Recession of 2020. And the fourth section concentrates on the investments processes and problems for the future.

2. Debates on energy transition and agreements

Sustainable Development Goals as the global framework for the planet have certain features, which must be taken into account. SDGs are supposed to encompass different interests of countries and elites, in certain cases — conflicting interests. They are supposed to have some coordination (enforcement), not merely the individual moves into a common direction. Furthermore, they require peace and long-term, predictable rules for an international institutional background. Conflicts among elites, involving their clashing visions of the world's future, may take time and resources, which would undoubtedly detract from financing of the SDG process.

As the difficulty of global coordination has become increasingly apparent, the reaction was to construct an adequate language for global affairs. The concept of "trilemma" first appeared in 1963 with the introduction of classical monetary trilemma (Mundell–Fleming model). Since then "trilemma" has become a fashionable term — recall "Trade (or globalization) trilemma" and "Financial trilemma" (Schoenmaker, 2011). It is evidence of a realistic approach to deal with the complexity of the situation "on the ground." Dani Rodrik formulated the definition of trilemma with the crucial importance for our discussion: "An 'impossibility theorem' for the global economy: democracy, national sovereignty and global economic integration are mutually incompatible: we can combine any two of the three, but never have all three simultaneously and in full" (Rodrik, 2007). That is a fundamental limitation not only for the global coordination of efforts for climate change mitigation, but for any other SDG as well. It is one of the reasons for the loss of effectiveness of global governance in recent years.

Recently the phrase "energy trilemma" has emerged as a symbolic term for the complexity of countries' governmental objectives: "Any government seeks to find the optimal answer to three requests from the society to the fuel and energy complex (the "energy trilemma" as defined by the World Energy Council):

- to ensure the *availability of energy* in sufficient quantities and at reasonable prices;
- to ensure the *reliability and safety* of energy supply;
- to ensure its *environmental friendliness* (the requirement to minimize the anthropogenic impact of energy systems on the environment" (Makarov et al., 2019).

World Energy Council understands the transition process as "a connected policy challenge — success involves managing the three core dimensions: Energy Security, Energy Equity and the Environmental Sustainability of Energy Systems throughout the transition process" (WEC, 2019).

In the context of this work, we would call that definition a "national energy trilemma." It is a very important approach, adapted by the recent Russian Energy Strategy (Minenergo RF, 2020). Each and every country has its own set of practical national trilemma problems. And obviously the sum of national energy security problems is not zero for the world community. Countries' interests are different, depending on their energy balances, inherent natural resources, invested physical assets and accumulated human capital. Global security in the long run will be dependent on economic and social stability, for which climate and energy problems

are risks, not autonomous from poverty and inequality. Naturally the difference of countries interests excludes the simple summing up of national trilemmas in order to harmonize world affairs. Our definition of the "global energy trilemma" for this article is designed to cover the problematic combination of the global community's objectives. Mankind needs to make one more step to resolve SDG process in its complexity.

GET is designed for a concrete meaning: supporting simultaneously economic growth (and catching up); energy and climate change mitigation as an intertwining process; and inequality, including energy poverty, or SDGs: 8; 7 & 13 together; and 10. All governments are expected to address their specific national trilemmas, including energy security components. Nevertheless, there is no promise that their solutions would be in conjunction with practical targeting by other countries or groups of countries. An important point here is that issues of social inequality, catching up (level of development) and poverty are rarely addressed in the context of climate change mitigation. Hitherto, the latter has been singled out as a focal point of global coordination (Paris Agreement of 2015) and for intensive debates on energy transition and climate policies. The energy transition and climate change mitigation will not be conducted in the sterile world, but in the environment of the difficult development (on all stages), among poverty and inequality. All types of relative poverty cannot be overcome in this context. The point is that global development should address energy-climate and energy-poverty issues, and the latter is connected to inequality through the life-styles of the middle classes and the necessity to make energy a key component of life among low income strata in coming decades.

It is worth reminding ourselves that the idea of transition is relatively new; the term "energy transition" is quite recent and dates back to the works of Vaclav Smil and marks structural changes in the energy system, both on demand and supply sides. The energy transition is seen as a political decision, primarily driven by social, economic, geopolitical and environmental objectives of a country. However, energy transition also depends on technological development and such economic factors as the prices of a particular fuel.

Historically, one may identify four stages of energy transition by fossil fuel type. The first phase dates back to 1850 and the industrial revolution in the UK when wood and waterpower were replaced by coal. It has also propelled mass production and mass consumption. Barry Solomon and Karthik Krishna highlighted several reasons that caused the transition (Solomon and Krishna, 2011). First, wood supply faced shortages and shipping difficulties, which led to a search for the new sources in abundance in the UK. Second, the development of the British economy at the time gave rise to high wages, motivating business to look for lower-cost energy sources. Finally, technological advances led to the creation of the coal-powered steam engine.

The second one refers to the transition to oil in the late 1910s, influenced by the energy density of oil (Makarov and Makarov, 2010). This phase led to massive infrastructure construction, including pipelines and oil tankers. The most important driver was the invention of the diesel engine. The transition process intensified after World War II and during a long period of prosperity and both GDP and income growth in the developed countries. However, the oil crisis in the 1970s and supply shortages obstructed the replacement process.

The third phase took place in the 1970s and was driven by natural gas (Fouquet and Pearson, 2011). This fossil fuel has proved to be more energy-efficient than coal and oil in certain spheres, such as power generation, heating and industry. Moreover, natural gas is much less harmful from the ecological point of view. For these reasons, gas is often considered as a "bridge" from fossil fuels to renewables (Melsted and Pallua, 2018).

We are now witnessing the fourth phase with an increasing share of the renewables in the energy mix. Technological advances in the commercialization of a wide range of unconventional energy resources and technologies are facilitating the current energy transition: wind power plants, solar panels, and batteries for electricity storage, etc. (Makarov et al., 2019). In addition to the new technologies in renewable energy sources, humanity is searching for opportunities to reduce harm from fossil fuels. Natural gas is a good example: although it is far less noxious than oil and coal, decarbonization is considered vital for further consumption (Stern, 2020).

An analysis of past phases of energy transition draws our attention to essential aspects. First, energy transition proves to be a slow, complex, but still a natural process, which involves political, trade and even spatial dimensions (Bridge et al., 2013). Such a process is not characterized by the total elimination of other fuels; in fact, different types of fuels successfully coexist. Consumption has changed in shares, depending on the sector and the development level of a country. With a gradual maturity of technology and cost reduction, renewables will become available for a broader range of countries.

Second, structural changes are realized through investment into real assets and technological advances. It takes time for new technologies to spread and influence the consumption structure. Companies look for new opportunities to minimize costs and invest in technology and efficient fuels. New companies operate with credits or subsidies, provided by governments to intensify general economic performance. In the UK, the government enforced the third phase by shutting down coal mines and investing in natural gas. Nevertheless, a transition is a gradual process in the sense that production and restructuring of the existing technology for a new fuel cannot happen at once. Moreover, suitable infrastructure must be built.

Nowadays, the transition process is accelerated by ecological standards and norms. The current switch from fossil fuels to renewables is driven primarily by climate change and the necessity to reduce emissions. In comparison to natural gas, coal emits higher levels of carbon dioxide (43,8%), nitrogen oxides (80%) and sulfur dioxide (100%) (Qyyum et al., 2019). For developing countries, those that are dependent on coal, natural gas consumption is considered vital. In China, where air pollution has reached a dangerously high level, the government policy aims at national natural gas industry growth (Zhao et al., 2020). From this viewpoint, all countries will have to strengthen environmental regulations, provide subsidies for R&D in the sphere of energy-saving and emission reduction technologies and optimize their economic structure with regard to clean energy (Cong and Lo, 2017). Besides, governments should help industries (especially manufacturing) by stimulating and motivating entrepreneurs to invest in emissions reduction, including coal-to-gas transition and energy-saving, compensating for possible losses (Xu and Lin, 2019).

The fourth phase of the energy transition is not merely a matter of technological development, business rationality and economic considerations. Although we cannot imagine energy transition to renewables without innovations, it was mostly driven by energy security and environmental policy. In other words, the current transition is a complex mix of natural processes and political initiatives.

As we have already noticed, energy security plays a vital role in energy transition development. When countries and companies are concerned with energy prices and supply, they try to use every possible option to ensure energy safety, including domestic production and innovation in order to find new energy sources. Energy security includes the reduction of imported energy and improvement of energy self-sufficiency (Matsumoto et al., 2018).

The domestic policy comprises another aspect of the political dimension associated with the energy transition (Hatipoglu et al., 2020). The increasing salience of environmental issues has benefited the Greens in Europe, which are expected to grow in support as long as the young continue to back them. Green parties are becoming a real political force by winning seats in parliaments of Germany, the UK and France. According to the European Greens, they see their main aim as fighting the climate change through investing in R&D, the clean economy and renewables.

The outcome of the debates was, to some extent, biased. The core discourse was a combination of focus on emissions reduction by diverting from fossil fuels to renewable sources (from "FF to RES"). That was fine, but the field of implementation was very "uneven." Bold declarations and plans emanated from Germany and the EU in general (Westphal, 2020), but rather weak policies from BRICS countries and the USA at the time of the Obama administration followed by the "no climate policy" of Trump's presidency. The Europe-centric policy was beneficial in terms of experimenting with new instruments and policies for the rest of the world. However, it had some features which were not helping to enlarge this critical experience (Bausch et al., 2017). One was the substantially higher level of wealth and income in the EU compared to non-OECD countries. Public awareness of the importance of climate issues in the EU (especially in Center-North) is connected to high education and income. That had propelled Green policies into the center of the political stage during elections in many countries. The second limiting factor was connected to political conflicts over natural gas supplies from Russia (Gazprom). Financial and political issues were invading the emission discourse, manifesting in an anti-gas stance because that was a Russian gas: North Stream, South Stream and other stream project debates (Boussena and Locatelli, 2013). The Russian position on the objectives of Kyoto Protocol at that time was defined by the severe transitional crisis in the 1990s (which led to a dramatic decline in emissions) and limited financial capabilities to conduct the deep climate connected policies on the enterprise or state levels. From our point of view, it is important in one respect — the prominence of Energy & Climate theme in politics. Repeatedly we see financial policies of the governments changing to promote, stimulate and finance the energy transition, for example, by changing the destination of subsidies from fossil fuels to RES. That is — no doubt — a widespread approach to this particular global problem solution.

The international community had tried to set the global agenda for the future from the Great Moderation of the 1990s. The first attempt was linked to United Nations Framework Convention on Climate Change (signed in 1992) and Kyoto

Protocol (1997). Establishing the UN Millennium Goals of 2000 was a defining moment. The next crucial element in setting the global development agenda was the issue of climate, which started from the landmark Stern review (Stern, 2006). Our point in that context is about the unique role of the climate problem, which figured prominently among development problems right after Growth and Poverty, not in ranking so much but rather in the form of concerted efforts in the intellectual and even political arenas.

The Great Recession of 2008–2009 had switched the focus of the international community towards the more pressing need of restoring growth and financial stability. As soon as the global economy had managed to return to some degree of normality and the restoration of long-term global growth, more fundamental issues arose. The period between 2009 and 2014 was not an upturn comparable to 2003–2008. Nevertheless, it lulled the global community, including intellectual and political elites, and international institutions into a false feeling of security when it came to setting new high objectives for continuous prosperity.

Most international actors saw this period as the right time for "new deals" for global good! This approach included a keen focus on the climate change problem which deserved a separate agreement, as the broader approach to global affairs. The Sustainable Development Goals of the UN were approved the same year as the Paris Agreement. Both documents are interconnected not only by the climate problem *per se* but also by aspirations of the international community over the same period. The strategies of both documents had one important common characteristic — the Global Governance acting not only as one Big Frame of SDG but more as the widespread system of partial agreements, accepted norms, nongovernmental institutions' influence, intellectual ties and practical decisions (Grigoryev and Kurdin, 2013).

Energy transition has recently started to be addressed by many authors and our colleagues in this volume (see Makarov et al., 2019; Hafner and Tagliapietra, 2020; Stern, 2006, 2019; etc.). Recent (before 2020) studies on energy transition tend to be over-optimistic by operating with data on current growth rates in flows (on different fuels), demonstrating fast changes in the energy sector which typify early stages of technological changes. However, they do not fully account for commercial technology readiness: the financing capabilities of firms and governments, and the speed of changing stock composition (mix) in the long run. The discussion around climate change is characterized by escalating expectations, the general satisfaction with China's solar energy efforts, the mantra against coal and fossil fuels (but before creating reliable technological solutions), focusing on the EU's own emissions.

A repercussion is that energy has received far more attention since the Paris Agreement of 2015 whereas other vital problems, poverty (including energy poverty), inequality, and the delayed development of big groups of countries, were relegated to the secondary tier. We believe there is a danger of global poverty returning due to demographic changes, and also the damage to weak economies resulting from the pandemic and the recession. Lagging catching up development is currently evidenced in the examples of Brazil and India. Furthermore, we expect the global community will be forced to address the deep crisis in development by reforming the health care systems across the world and introducing changes in SDG as a system (Bobylev and Grigoryev, 2020). The global energy trilemma may serve as a good approach for looking for simultaneous solutions in this respect.

3. What has been actually happening on the ground?

The global political turnaround from "business as usual" to climate change mitigation has been ongoing on for some time. Let us take as a reference point the publication of the Stern review in 2006. The Great Recession has since taken place, and the period after was rich with long-term reports and projections replete with a great focus on energy. They gave a wide range of results.

McKinsey (2019) revised "Global energy perspectives": a forecast till 2050, while HSBS (Henry and Pomeroy, 2018) introduced "The world in 2030." The prospects differ from each other in particular estimates; however, neither foresee a dramatic reduction of emissions worldwide. Some other important forecasts were introduced by IEA (2020), EIA (2020), Shell (2020). The Paris Agreement of 2015 was based on the certain prognosis of economic growth, energy consumption and energy investment. The most important one, concerning energy investment, was elaborated by IEA (2014).

World energy outlook (IEA, 2014) had three scenarios: Current Policies Scenario (which is closer to actual events), New Policies Scenario and 450 Scenario (Fig. 1). According to them, global total primary demand is to grow annually by 0,6–1,1% and will reach 20 000 million tonnes of oil equivalent (Mtoe) in the worst case. We should also note that according to the Outlook, the share of fossil fuels will be more than 50% even in the 450 Scenario. However, today some countries have raised an ambitious goal to reduce the share to reach carbon neutrality ultimately. We are intentionally using this report (of 2014) in order to show what projections are standing behind the Paris Agreement.

ERI RAS and Analytical Center for the Government of the Russian Federation elaborated another Outlook in 2014 (Makarov et al., 2014). In the base scenario, it also assumed that global energy demand would rise annually (2010–2040) by 1,1%. Energy consumption per capita is projected to decline in developed countries and to grow in developing countries. The structure of energy consumption remains somewhat similar, with the domination of fossil fuels. According to the analysis of the existing prognoses, given by ERI RAS, energy consumption in 2040 generally never exceeds 20000 Mtoe with non-OECD Asian countries

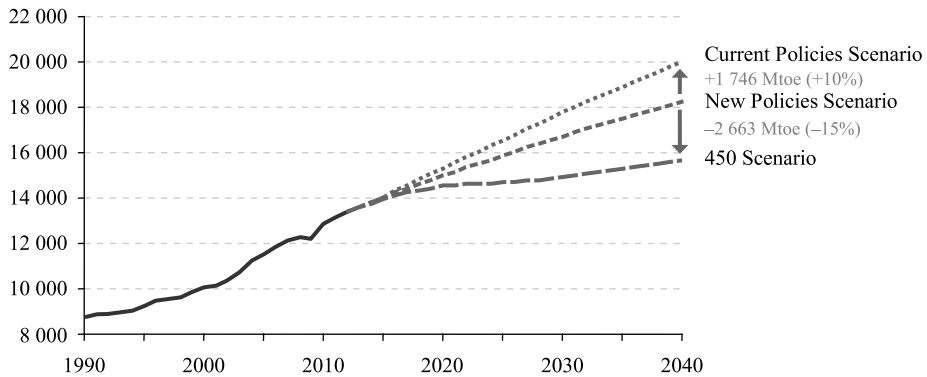

Fig. 1. World total primary energy demand by scenario (million tonnes of oil equivalent).

Source: IEA (2014).

dominating in the structure. The projected structure of the consumption by fuel shows major shares of the fossil fuels, with renewables and nuclear energy remaining rather low — around 20–24%. Moreover, renewables mainly consist of bioenergy, which includes biomass, widely used in developing countries.

The IEA (2014) notices that "The IPCC estimates that to have a 50% chance of meeting the internationally agreed goal of limiting the temperature increase to 2°C over and above pre-industrial levels to avert irreversible and catastrophic climate change, the world cannot emit more than a total of around 1000 Gt of CO_2 from 2014 onwards. We are fast eating into this carbon budget: in the New Policies Scenario, the entire budget is used up by around 2040. Were this to happen, emissions would need to drop to zero immediately thereafter in order to stay within that budget. In other words, achieving the objective requires urgent action now to steer the energy system onto a lower emissions path." Nevertheless, carbon emissions today largely exceed the New Policies Scenario, let alone the 450 Scenario. To summarize the data which influenced the Paris Agreement, we can highlight the following:

- oil and gas prices were at the peak, which led the agencies to assume investment growth and relative compatibility with renewables capital costs;
- energy demand was assumed to grow, driven by non-OECD Asian countries;
- the share of renewable sources in the energy consumption structure was not growing strongly enough to enable emissions reduction in developing countries;
- the reduction of fossil fuels was to be provided by both high prices and investment in the sources of energy.

In 2015 the Sustainable Development Goals (SDG) agreement of the UN was set and signed by 193 countries. This marked the general framework for long term coordination of socio-economic and climate policies worldwide. To reiterate our point about the Climate issue again — it was granted a separate international agreement. The SDG is an important UN agreement, and all countries are supposed to prepare and submit to the UN by 2020 "the voluntary progress report" on the SDG implementation of their national goals. However, the SDG does not have systemic enforcement or specific common targets. In addition, it has not established the direct interconnections between goals, or levels of indicators for countries. The beginning of the SDG process in 2015 was an important step, but it was a brief period after that year before COVID-19 stopped the growth.

Our Trilemma approach requires to make our own reassessment of actual processes on the ground — in the world economy: population and demography, development and energy. Firstly, we need to factor in demography and inequality, which are relatively rare in energy studies. Global population growth proceeds according to well-defined theories (Ivanov, 2020). The latter are reliable, and we can take it and the UN forecasts as relevant background. To begin with, we should refer to the UN calculations (UN, 2019). They show the country-specific path from 6143 million people on the planet in 2000 to 7713 million in 2019 and 9199 million in 2040. In the latter, more than 5,1 billion people will be living in low-middle to low-income countries by current definition compared with 2,75 billion in 2000 and 3,8 billion in 2019. The detailed calculations are now very timely — to estimate Poverty comparing with Millennium Goals results.

The recession of 2020 has already discounted all and every global forecast for GDP in the short and medium terms. We have retained the residual optimism

that long-term growth will be "business as usual" till 2040, and using this vague background we had estimated GDP PPP by countries and regions for 2040 by applying the growth rate of 2010–2019. The results are presented in Table 1; they may be somewhat optimistic for humanity, but we have decided in favor of optimism, leaving space for future detailed forecasts. Meanwhile, the results of our simple test for 2040 look disappointing: the rest of the world with low income per capita represents 47,8% of the global population. Let us repeat: we did not reduce the growth rate for GDP to reflect the current Global Recession. Essentially this picture corresponds to our cluster analysis (Grigoryev and Pavlyushina, 2018a, 2019), which presented the dynamic picture for groups of countries in 1992–2016. This analysis supports the lack of convergence between countries due to economic growth (with the notable exceptions of China and India). Practically for the SDG process, it means that rich countries are slowly but steadily distancing themselves from medium and low-income countries in terms of GDP per capita level (both in actual and PPP measures). By 2040 we may expect more distance between the most developed countries and the rest of "the caravan" — not a success for the SDG 10.

We have made a demonstration example case (not forecasting) to illuminate the scope of possible distancing under elementary assumptions: ignoring for that particular case the recession of 2020 and its consequences. Calculations in Table 1 are prolonging the growth rates of GDP PPP (in new 2017 measures; World Bank, 2020) of 2011–2019 for 21 years: 2020–2040. After that, the estimates of GDP for 2040 were divided by population from UN forecast of 2019 for 2040 (medium case). The GDP PPP per capita in 2040 are very rough estimates, definitely exaggerating the level for China (its growth rate is expected to decline from 7% to 5%), and probably underestimating the level for Brazil and Russia, which have the potential for better results.

Nevertheless, these calculations give a disappointing picture of future inter-country inequality — very far from the original intention of the SDG-2015. The latter does not have indicators for Agenda 2030 for inequality. It is time for the global community to recognize that the future world will be more unequal, and it is quite possible to measure that parameter. COVID-19 pandemic and the recession of 2020 are currently undermining the development in general, switching resources from SDG agenda to "survival and restoring" needs. A number of low and middle-income countries are experiencing serious economic and financial difficulties. The unexpected and disastrous blow to the global economy currently lacks a unified response to contain the recession and its consequences. The wealthiest countries (first cluster in terms of our 2018 article) are growing apart from the world; middle-income countries are meeting difficulties in catching up.

In two decades, low-income countries (15 selected) will continue to have a rather modest income. Besides, millions of the poor may be added in all countries, although somewhat higher income is forecast for 2040. But we need to add a few remarks to better understand Table 1: (a) we did not account for the recession of 2020 and its nearest and longer-term consequences; (b) we consider an assumption of the same GDP growth rates for all countries in the next two decades as in 2010–2019 to be overly optimistic; (c) we did not show here the data for a number of small and/or poor countries, which may not gain a better standard of living due to a deficiency of resources or institutional weaknesses.

Table 1
GDP per capita (constant 2017 international dollars), population growth (million people), and inequality (%), 2000–2019, and projection for 2040.

Country	2000		2010		2019		2040		Income share held by highest 10%
	Population	GDP per capita	Population	GDP per capita	Population	GDP per capita	Population	GDP per capita	
World	6143.5	11.1	6957	13.9	7713.5	16.9	9198.8	28.6	
OECD	1112.3	35.6	1197	39.4	1258.0	44.7	1319.3	70.1	
United States	281.7	50.2	309	54.4	329.1	62.5	366.6	88.9	30.5
Canada	30.6	37.4	34	45.1	37.4	49.0	43.5	65.1	22.3
Sweden	8.9	41.2	9	48.5	10.0	53.2	11.0	76.5	22.3
Germany	81.4	42.9	81	46.9	83.5	53.8	82.0	78.0	24.6
France	59.0	39.9	63	42.4	65.1	46.2	67.6	60.3	25.8
Italy	56.7	43.3	59	42.9	60.6	42.4	57.2	45.4	26.7
Spain	40.8	34.8	47	37.4	46.7	40.9	45.2	53.7	25.4
United Kingdom	58.9	38.1	63	42.2	67.5	46.7	72.5	63.3	26.8
Brazil	174.8	11.6	196	14.9	211.0	14.7	229.1	15.6	42.5
China	1290.6	3.5	1369	8.9	1433.8	16.1	1449.0	69.1	29.3
India	1056.6	2.6	1234	4.2	1366.4	6.8	1592.7	21.9	31.7
Russia	146.4	14.6	143	24.0	145.9	27.0	139.0	40.0	29.9
South Africa	45.0	10.1	51	12.5	58.6	12.5	71.4	14.1	50.5
Selected low-income countries [a)]	942.4	3.1	1168	4.4	1425.8	5.5	2050.1	11.3	
Rest of the world	1375.5	9.1	1598	12.3	1813.9	15.0	2348.2	18.5	

[a)] Afghanistan, Angola, Bangladesh, Democratic Republic of the Congo, Ethiopia, Indonesia, Iraq, Madagascar, Mozambique, Myanmar, Nigeria, Pakistan, Sudan, Uganda, United Republic of Tanzania.

Note: For GDP 2040 PPP (constant 2017 international dollars) — extrapolation: level of 2019 multiplied by assumed compounded annual growth for 2020–2040 equal to the average growth rate for 2010–2019, divided by population (UN World population prospects — medium).

Sources: Population (million people): UN World population prospects; GDP in PPP (constant 2017 U.S. dollars) and Income share held by highest 10%: World Bank, World development indicators database.

Currently, about one billion people globally are living without electricity, three billion — without running water. Several hundred million people in countries with low income and poor living conditions will soon join them. Hence social inequality becomes another component of SDG 10. In the rich, medium-income countries there are still a lot of poor people. With regret, we have discovered that social inequality in most countries of the world seems rigid, and it is a clear picture over the last three decades (Grigoryev and Pavlyushina, 2018b). Furthermore, we have no reason to expect the improvement in this sphere over the next two decades (Grigoryev and Pavlyushina, 2019). The share of income of the 10th decile is a defining factor of social inequality, since it incorporates business income, rents, dividends, and capital gains in all countries. The significant difference between countries and social inequality creates this vast difference between people. However, we are not calling for justice; we are calling for common sense in the global community. These demographic changes with rigid inequality may not overcome absolute poverty, but may lead to such substantial relative poverty, that other objectives would not be sustainable either socially or politically.

Energy consumption growth reflects at least three major factors: growth dynamic; technological progress and inequality. Table 2 gives a clear picture of the different consumption patterns for OECD and other countries in terms of primary energy (the fuel mix gives the next layer of diversity). The result of all effects is primary energy growth, which is higher in the fast-growing developing countries. OECD countries have turned to zero-energy growth consumption, which is by itself a huge success of sustainable development. Russia has also come close to low energy growth due to previous inefficiency — domestic demand is relatively slow, similar (as rather typical for Russia) to Russian post-industrial development. Even ambitious National Projects in the housing sphere would not require notable additional energy consumption.

Table 2
GDP and primary energy consumption, 1991–2018 (annual growth rates, %).

Country	GDP PPP				Primary energy consumption			
	1991–2002	2003–2008	2009–2010	2011–2019	1991–2002	2003–2008	2009–2010	2011–2019
World	2.8	4.4	2.1	3.4	1.5	3.1	1.1	1.6
OECD	2.6	2.5	–0.2	2.0	1.3	0.5	–0.5	0.02
USA	3.1	2.5	0.0	2.2	1.3	0.1	–0.6	0.2
EU	2.1	2.3	–1.2	1.6	0.4	0.3	–0.8	–0.8
Japan	1.1	1.2	–0.7	1.0	1.3	0.0	–1.0	–1.4
Non-OECD	3.2	7.2	5.0	4.8	1.7	6.1	2.5	2.8
Brazil	2.5	4.2	3.6	0.7	3.5	3.7	3.0	1.4
Russia	–2.5	7.1	–1.8	1.6	–2.7	1.4	–0.4	0.7
India	5.4	7.1	8.2	6.5	4.5	6.1	4.1	4.7
China	10.1	11.3	10.0	7.4	4.5	11.4	3.7	3.5
Energy consumption (p.p.) minus GDP (p.p.)								
World					–1.3	–1.3	–1.0	–1.8
OECD					–1.3	–2.0	–0.3	–2.0
Non-OECD					–1.5	–1.1	–2.5	–2.0

Note: For GDP PPP dynamics, values were taken in constant 2017 international dollars.
Sources: Authors' calculations based on World Bank data and BP (2020) .

Key global forecasting agencies: IEA, EIA, and Skolkovo — give more than 70% share of fossil fuel in the global balance for 2040. That means future development should be even more energy-efficient. Global growth after the Great Recession comes with much less energy consumption growth, especially in the OECD countries due to the shift of GDP into the service sector. All the countries at the industrial stage have substantial needs for physical infrastructure, electrical, water, and urban construction. Inequality has two exciting byproducts. Firstly, poor people need to overcome energy poverty. If mankind is serious about eradicating poverty, then that absolutely necessitates the eradication of extreme energy poverty. Secondly, it is in the case of social success that the cohorts of low-income families were marching (before 2020) into the ranks of the middle class, changing their lifestyle, energy consumption, etc. This social upgrading involves more education, interests, travel and more energy consumption of the kind not directly connected to personal use, but important nonetheless.

The global awareness of the Climate problem has come about quite recently by historical terms, while the slowness to solve other global problems such as Poverty, Ecology and Inequality is a reason for concern. Our observations add some salt to the optimistic scenarios of the future in Energy and Climate Change mitigation. Not too much has been done in the past decade or two. Many changes came as a byproduct of a new technological revolution and two immense economic shocks of 2008–2010 and 2020–2022 (or longer). Moreover, through the dramatic contrast to climate debates and activities one can see the shortage of optimistic scenarios and considerable inertia in industrial development. Although the practical results of recent years are very substantial, the distance to the success of the SDG is getting probably longer due to demographic changes, rigid inequality, and the recession of 2020. The SDG needs updating and extending as suggested in our recent work (Bobylev and Grigoryev, 2020). We should also reiterate that the global energy trilemma supposes simultaneous long-term solution for Poverty (Inequality)–Development–Energy.

BOX 1. There is no conventional definition of "energy poverty." For a matter of convenience, we suggest a simple approach to the issue. A low-income family of 4–5 persons in an Asian–African–Latin American country has a regular need of 200 watt for a refrigerator, maybe for a small water pump, home lights and informational equipment (TV, computers). It does not include stable, ample water supply, cooking and heating facilities, no fuel cars or streetlights. This modest definition still gives enormous additional demand on the side of low-income families to secure themselves the minimum for a decent life. Respectively each 100 million families, which do not have access to electricity, would need in sum an additional 20 GW of electrical capacity, built for the people with low income.

4. At the crossroads

Global emissions of GHG is the subject of statistical, economic, and political studies (Crippa et al., 2019). We have added some grain of realism to the problem of an immense scope of energy supplies for the growing population of the planet in the future. In this section, our approach to the SDG is changing to address

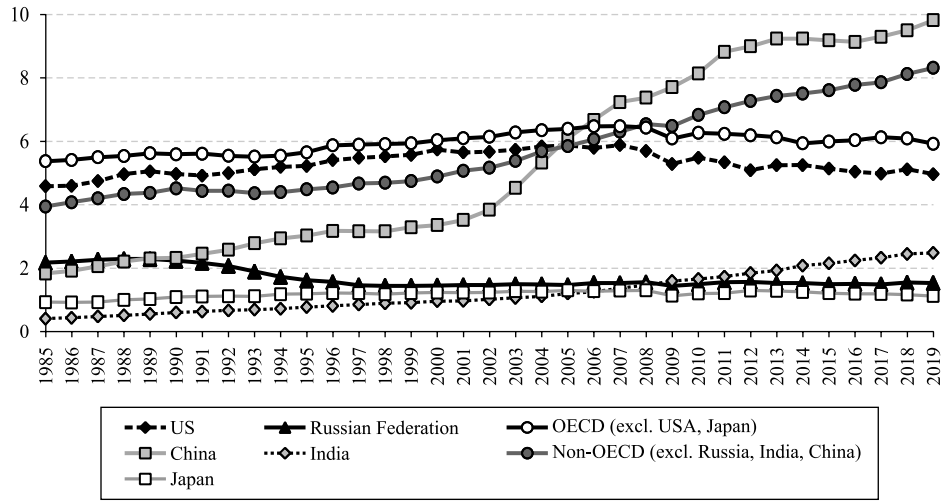

Fig. 2. Global energy-related emissions by countries and group of countries, 1985–2019 (billon tonnes of carbon dioxide).

Source: BP (2020).

the resource side of the problem: we are optimistic, but realistic. We would like to remind to all involved parties that a global approach to solutions requires global coordination and countries' political (and electoral) programs on Poverty–Ecology–Inequality. We need some revision for indicators for SDG 3, 10, and 7 & 13. Also, we should use connecting indicators — i.e. the same indicators for different goals to make sure that the level of success is stable in a few directions.

Meanwhile, we must underline that the expected decline of emissions in 2020 as a result of the COVID-19 pandemic and recession has coincided with new growth of GHG emissions in China, India and other developing countries as a bloc (except Russia) in 2017–2019, as it is shown in Fig. 2. The world is still rather far from the turnaround to the green, carbon-free economy in general, even with the apparent encouraging success in new technologies, widening the role of RES in the EU, China and many other countries. Optimistic scenarios are constructed on sectoral, countries' or technological pictures and advanced cases. The big picture is somewhat different.

4.1. Sources of emission: production vs. consumption

The choice of the path for investment and strategy for solving the problems of the global energy trilemma will be of crucial importance for the next decades. Among critical issues, we see the choice between investing in the reduction of GHG emissions by production approach and consumption approach (Makarov and Sokolova, 2017). Since the UN Framework Convention on Climate Change and the Kyoto protocol, the global community has been trying to reduce emissions by shifting from coal and fossil fuels to RES, by introducing all technological options for reducing emissions from the production of goods and services. Interestingly, the consumption side of the whole chain in the emission was much less in focus. Changing the lifestyle of energy consumers was visible in the expanded use of RES in households (sun panel). The German tax on consumers for

Table 3
Correlation: GDP per capita (PPP, constant 2017 international dollars) and emissions per capita (tonnes), two alternative measures, 106 countries[a)], 1990 and 2017.

GDP per capita, PPP	Production-based emissions per capita	Consumption-based emissions per capita
1990		
All countries (106)	0.84	0.88
Developed countries (29)	0.60	0.61
Developing countries (77)	0.85	0.86
2017		
All countries (106)	0.71	0.89
Developed countries (29)	0.43	0.80
Developing countries (77)	0.73	0.91

[a)] Including retro-data for Russia and the majority of the post-Soviet states.
Notes: Production-based emissions per capita calculated as production-based emissions divided by population. Country groups by the UN classification.
Sources: World Bank World development indicators database; Our World in Data database; IMF database.

inefficient cars also derived from that branch of instruments. Still, the main focus was and is — especially in the EU — on the production side. We consider both approaches as important in the applied studies and climate policies. It depends on the country's development level and economic structure. We have conducted a simple check on the correlations on the sample of 106 countries (above two million people) and received quite expected results (Table 3).

These results confirm earlier findings from the analysis of differences between environmental Kuznets curves for production- and consumption-based CO_2 emissions (Makarov, 2018). Actually, "the devil is in the econometric detail": correlation in two time spots and for groups of countries. The surprise for us was the result for 1990 in Table 3 — a couple of years before UN Framework Convention on Climate Change was signed. We expected the high correlation for GDP and production-based emissions per capita across the board, but not that high for the consumption-based case. Actually, the correlation was rather high for both measures in 1990, especially for developing countries. Twenty-seven years of a very substantial growth and implementation of climate policies have brought interesting changes in the correlations. We should note the reduction of the intensity of connection in the production case for developed countries, that is quite understandable due to decoupling. In addition, we must underline the strengthening of the correlation upon a time in case of consumption-related emissions. This connection demonstrates the importance of recent economic growth for the emission flows, and it shows the role of consumption-related emissions in both developed and developing countries. This correlation may serve as an additional argument to turn the focus on consumption of middle classes around the world (Grigoryev et al., 2020).

The current stress of OECD countries, especially the EU, on the measures to reduce emissions at production level may not be sufficient in the coming decades; or before "the total technological victory" over emissions. The life-style of middle classes in developed countries involves substantial energy consumption. The 2020-year data will demonstrate to what extent the decline of consumption of rich strata (on quarantines) may reduce it. Preserving energy expensive personal

consumption is quite an understandable idea: to keep an enthusiastic drive to the green economy without "over-punishing" the supportive electorate by insisting on immediate changes to their lives. COVID-19 may become a turning point in this respect in terms of modest social habits of consumers.

We may turn to Table 4, which gives a more detailed picture of emissions by major countries. Three major countries of the EU — Germany, France and Italy — have combined emissions from production of 4,5% of the global one, yet by consumption — 5,3%; the difference is covered by import of energy-intensive goods. Swedish imports cover up to 60% of domestic consumption with emissions (Makarov and Sokolova, 2017).

Table 4 gives one more input into the pragmatic and realistic approach to the energy transition, particularly "from coal" to the next generation regime. In the past, the transition would be slow and "natural," based on cost-efficiency, technology, availability and transportation costs. As we see now, the coal has retained some capability for preserving its share in global energy balance. IEA and other forecasts are currently expecting coal to retain its share close to 25% of the balance till 2040. Undoubtedly, there are plans and actions to reduce this share in China and other countries. Coal share is rigid due to relatively low costs, but that is not the sole reason. We would underline another factor of critical importance — the social position of coal miners, coal regions, coal supplies to power stations, coal incomes and taxes, and coal exports (Hafner and Raimondi, 2020). On the project level, we observe more and more progress in the mining and power sector while governments are reluctant (except for M. Thatcher in the UK decades ago) to take dramatic steps to curb coal production. The USA, Australia, Rep. of South Africa, Indonesia, Russia — all of them use and export coal; China, India, Germany and Poland produce and import coal. The problem of coal cannot be resolved only by micro-steps; that would require long-term planning and financing to dramatically restructure the whole life-style, production and income structure of hugely important regions in the above-mentioned countries and many others (Burke and Fishel, 2020). It is worth remembering the political costs of investing in those regions, to some extent protected by certain political parties or by the more important national projects and priorities.

Most countries have accepted certain pledges on the progress on renewables, the reduction of emissions by 2030 through the Paris Agreement of 2015. Table 4 gives a clear picture of those pledges. Our key observation is that strong unconditional pledges have been made by a minority of countries, mostly by EU member states, and their share in global emissions has been declining for a certain time. The problem is that the EU is "responsible" approximately for 12% GHG emissions on consumption with 10% on production (before deducting the Great Britain's share). Huge financial resources have been allocated to that limited platform, while global emissions kept growing until 2019. With all respect and sympathy for the case, the global emissions growth (and level) cannot be stopped that way. Also, taxing the imports from net energy producing countries without a strong policy of reducing domestic consumption would not efficiently work, partially because of the squeeze on financial resources.

The whole concept of net energy consuming countries opting to either buy clean energy or tax imports from them at the border, supposes that net energy exporting countries will have to bear very high social and investment costs associated with

Table 4
Emissions and conditions by countries, 1990 and 2017.

Countries	GDP per capita, PPP const. 2019 thousand dollars	Consumption-based CO_2 emissions, million tonnes				Production-based CO_2 emissions, million tonnes				Emissions (production) per capita, tonnes		Coal share in primary energy balance, %		Unconditional pledge, Paris Agreement
		1990	% of total	2017	% of total	1990	% of total	2017	% of total	1990	2017	1990	2017	
World[a)]	16.9	21,541	100	33,537	100	21,427	100	33,589	100	3.9	4.4	25.2	27.1	–
OECD	44.7	12,900	59.9	14,200	42.3	12,100	56.5	12,600	37.5	10.3	8.9	23.6	16.5	–
United States	62.5	5100.0	23.7	5690.0	17.0	5120.0	23.9	5270.0	15.7	19.2	14.9	24.0	15.3	Withdrew
Canada	49.0	473.7	2.2	591.7	1.8	462.5	2.2	571.1	1.7	15.2	15.5	11.5	5.9	30% of GHG emissions below 2005 level
Sweden	53.2	78.0	0.4	72.0	0.2	57.5	0.3	42.1	0.1	6.1	3.6	5.8	3.9	At least 40% of GHG emissions below 1990 level
Germany	53.8	1160.0	5.4	894.8	2.7	1050.0	4.9	798.0	2.4	11.8	8.2	36.6	22.9	At least 40% of GHG emissions below 1990 level
France	46.2	485.5	2.3	458.8	1.4	400.9	1.9	346.5	1.0	5.9	4.4	9.0	4.0	At least 40% of GHG emissions below 1990 level
Italy	42.4	554.2	2.6	467.9	1.4	439.6	2.1	349.0	1.0	6.9	5.2	10.0	6.1	At least 40% of GHG emissions below 1990 level
Spain	40.9	262.0	1.2	302.3	0.9	231.1	1.1	274.4	0.8	5.2	5.2	21.4	10.0	At least 40% of GHG emissions below 1990 level
United Kingdom	46.7	657.8	3.1	556.5	1.7	600.8	2.8	387.4	1.2	9.6	5.3	30.6	5.4	At least 40% of GHG emissions below 1990 level
Brazil	14.7	234.3	1.1	513.1	1.5	206.9	1.0	463.8	1.4	1.2	2	6.9	5.8	37% of GHG emissions below 2005 level by 2025
China	16.1	2290.0	10.6	8550.0	25.5	2420.0	11.3	9840.0	29.3	1.9	6.7	60.8	63.7	60–65% of CO2 emissions per unit of GDP below 2005 level
India	6.8	616.6	2.9	2260.0	6.7	615.5	2.9	2460.0	7.3	0.6	1.6	30.3	44.3	33–35% of CO2 emission intensity of GDP below 2005 level
Russia	27.0	2430.0	11.3	1370.0	4.1	2530.0	11.8	1650.0	4.9	14.6	10.6	21.6	15.5	25–30% GHG emissions below 1990 by 2030
South Africa	12.5	205.9	1.0	340.9	1.0	313.0	1.5	462.8	1.4	6.5	7.4	74.2	74.3	Policies and measures
Rest of the world	9.2	2864.2	13.3	6303.0	18.8	3241.6	15.1	6112.4	18.2					

[a)] Includes data for 117 countries.
Sources: GDP per capita: calculated as GDP, PPP 2017 (World Bank data) divided by Population (UN Population Prospects Data); Emissions per capita, CO_2 emissions—IEA Data & Statistics; Coal share in energy balances—calculated from IEA Data & Statistics' Consumption-based emissions, Production-based emissions—Our World in Data Database; World, Rest of the World—calculated Our World in Data Database.

restructuring their energy sectors and regions, dependent on extraction industries. Moreover, it is supposed to happen in a very short period. Table 4 also shows that much depends on coal, not only in China, India and South Africa but also in the US and Germany, not to forget Australia, Columbia, Indonesia, Russia, etc.

4.2. Investment's angle

We usually learn about the future direction of market tendencies by monitoring changes in the flows: by the flows of installed devices, rate of changes, by the flow of investments in physical assets, by the flows of financing, corporate equity and debt. Another matter is how to measure the speed of the changes against the stock of existing physical assets or required investments for the scale of the problems in the case.

IEA (2014) "New policies scenario" had assumed spending around $2 trillion per year or $51 trillion until 2040, including $7.4 trillion in renewables. Besides, it was planned to spend about $14.5 trillion on energy efficiency, totaling the sum to $66 trillion. Although we witnessed investment growth in 2014, 2017 was the third year of investment reduction with $1.7 trillion spent (IRENA data). We cannot track the use of energy financing for the whole world for all recent years.

The issue is — how the energy transition goes in terms of investment decisions, choice of technologies and distribution of risks. Capital formation historically has been responsible for being an instrument of structural changes. Impulses were coming from demand, technology shocks, industrial or structural policies. A combination of markets signals, regulatory limitations or state subsidies were turning the wheels of fortune for new and old business, in the opposite directions of course.

We assume that the global community is reacting to urgent problems by investing in solutions by different ways and means: financing the technology; shifting the profitability by adjusting regulations; direct budget financing (subsidies or participation); business decisions of the firms in the "real businesses" on conventional business logic; banking and financial markets by favorable attitude to new projects (co-financing, taking certain risks, etc.). We have seen the picture in the energy transition in developed countries, to some extent in China. The issue is — how the global community is financing its development as a whole, and energy transition in particular. In terms of the general level of global capital financing, as we have shown previously, the picture is not actually bright. After the Great Recession the capital formation rates went the same or somewhat lower than before (see Grigoryev and Makarova, 2019, table 3), but developed countries somewhat reduced their investing intensity. It may reflect the shift to investing in the human capital or personal consumption, or both. All countries still have problems with poverty and inequality, infrastructure needs and energy transition agenda, but the global community had not increased the flow in investment between 2009 and 2020. That confirms our suspicion about the inability of the global community to unite around the urgent (in 1–2 generations terms) problems within the global energy trilemma: Poverty (Inequality — SDG 10) – Development (SDG 8) – Energy Transition (SDG 7 & 13).

A more detailed approach to the investment process brings more questions. In the last decades, energy transition was affected by a business cycle, fluctuating oil

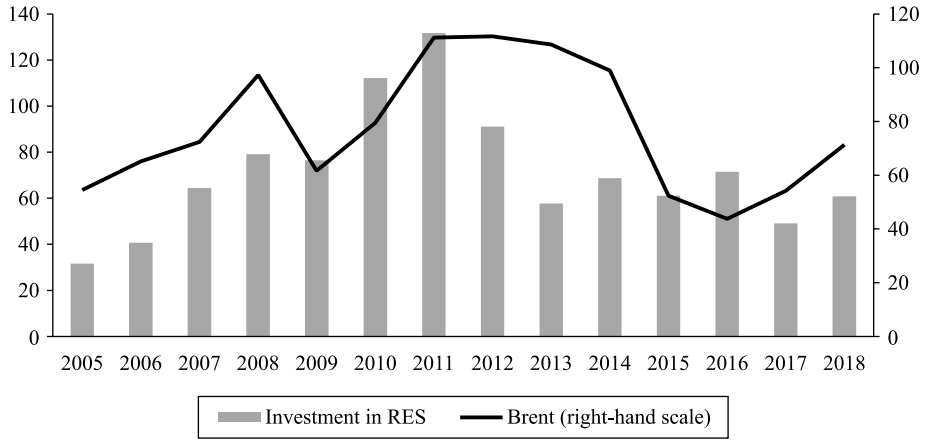

Fig. 3. European investment in renewable energy sources (billion U.S. dollars) and crude oil prices (Brent, U.S. dollars per barrel), 2005–2018.

Sources: FS–UNEP Centre and BNEF (2019); BP (2020); OECD Data (https://data.oecd.org/gdp/investment-gfcf.htm).

prices, and the changes in governmental policies on energy and energy security. And the cumulative effects on the investment side were different from the views of optimists. Fig. 3 gives another realistic insight into investments in alternative energy sources. The high expenditures in 2010–2011 are easy to explain: high oil prices and slow recovery gave excellent timing and reason for an investment decision to replace the old capacity for modern and efficient ones. Respectively the oil prices crash in 2014–2016 had changed the system of profit-based efficiency and led to a decline in investments in alternative energy sources. That gives us a certain clue as to energy investment complex behavior for the next cycle of 2020 onwards.

Furthermore, we need here to invoke the "irreversibility of fixed assets" notion (Bernanke, 1983; Pindyck, 1991). Energy infrastructure capacities are long-term serving and very expensive. It takes much time for planning and financing arrangements, market reorganization, and construction (reconstruction or modernization) of productive, transport and consumptions facilities. Another important notion would be how to measure the success on transition, or current changes. That is not just growth rates of efficient investments or RES production. The transition should be measured against the main flow of output and investments, and against changes in the stock of energy infrastructure.[1]

The business cycle has brought the EU economy and investments to growth in 2011–2019. It was not very fast. Without any doubt, investment dynamics in recent years were very much complicated by oil prices swings in 2015 and 2020 (see Fig. 3).

Overall investments were growing modestly, while investments in RES had shown doubling between 2007 and 2011. Since that year we observe the reverse to stable significant level, but no major growth. This example from the recent EU history shows the negative impact of the lower oil prices on business decisions with respect to investments in RES. Likewise, total investment had an annual growth

[1] We do not have sufficient resources for that study, but we are trying to make the difference in this respect.

Table 5
Total global energy investment, 2017–2020 (billion U.S. dollars).

Indicator	2017	2018	2018/ 2017	2019	2019/ 2018	2020	2020/ 2019
Fuel supply	850	854	0.5	854	0.0	595	–30.3
Power sector	782	769	–1.7	757	–1.6	678	–10.4
Energy end use and efficiency	280	281	0.4	280	–0.4	247	–11.8
Total	1912	1904	–0.4	1891	–0.7	1520	–19.6

Source: IRENA (2020).

Table 6
Global investment in clean energy and efficiency and share in total investment, 2015–2020 (%).

Indicator	2015	2016	2017	2018	2019	2020
Renewable transport & heat	37.5	36.4	35.8	33.9	32.7	28.6
Renewable power	307.7	311.8	309.7	308.0	310.6	281.0
Nuclear	28.9	32.6	34.4	32.6	39.1	35.2
Energy efficiency	239.0	264.9	250.9	251.6	249.4	219.4
Battery storage	1.6	2.5	2.9	4.6	4.0	3.6
CCUS	1.6	0.6	0	0.5	0	0
Total	616.3	648.8	633.7	631.2	635.8	567.8
Share of clean energy and efficiency in total	29.7	33.5	33.0	33.0	33.5	37.3

Source: IEA (https://www.iea.org/data-and-statistics/charts/global-investment-in-clean-energy-and-efficiency-and-share-in-total-investment-2015-2020).

rate of 4.26% in 2011–2018, while investment in RES was declining in the same period by 10.45% on average. Instead of trying to reestablish a full-fledged picture from all sources of data and research or industries and countries, we may address the critically reliable reports of IEA and IRENA (2020) (see Tables 5 and 6).

Between 2015 and 2020, the renewable investments gave very high numbers for global investments in renewables. However, we need to reiterate that these investments are probably very far from being sufficient for transition. Much worse — they were stagnant for a few years, and the growing share of clean energy is misleading since its total had declined, especially in 2020 by the estimate. The overall results are straightforward — the world will need to redefine its investment approach to the energy transition.

4.3. COVID-19 and the recession as a moment of truth

The recession of 2020 has already exerted its specific influence over energy consumption (and emissions) — there has been a dramatic reduction of transportation use of energy, especially cars and in aviation as a whole. According to IMF projections, the world output in 2020 will decline by 4,4%, real GDP of advanced economies — by 5,8% and emerging markets and developing economies will decline by 3,3% (IMF, 2020). Quarantines — for the time being — are pegging energy use at 5–10% below the previous levels. Recession reduced many energy-intensive services (recreation, catering etc.) of the rich strata, essentially changing the lifestyles of the rich (Grigoryev et al., 2020).

COVID-19 has dealt a heavy blow to global integration, which had been already weakened by increasing international tensions, trade wars, sanctions, and

a great reduction in the capability to coordinate international policy on the most urgent short-term issues, not to say the long-term ones.

We believe that the global energy trilemma is also valid for the broad energy field of actions, as it is impossible to combine poverty, climate issues and economic growth without the strong cooperation of major powers. The energy trilemma of WEC is an excellent example of this. Sovereign states must pursue a national specific set (defined by elites) of three objectives on energy at any given moment: availability, safety, and environmental aspects attained. Safety is connected to a sovereign power to protect national interests; availability requires global integration, and the global community should adopt all the complexity of both plus environmental necessities. However, the global energy trilemma includes economic growth instead of safety, because we believe it to be a more urgent matter of concern.

The simultaneous solution of the problems will require vast finance, efficient global governance and a certain altruism on a country level. Overall poverty and energy poverty might not be a crucial problem for advanced economies, which concentrate on a climate change problem and the continuous stability of economic growth. However, developing countries rely on cheap and available energy sources, such as coal, being concentrated on fighting poverty and promoting economic development, often against complex demographic trends. In other words, while the global community is still divided on the issue, each country sets its own priorities and goals, solving its own individual trilemmas. Developing countries still lack technologies and funds to contribute to emissions reduction against that background. At the same time, advanced economies' efforts are not fighting the problem drastically enough to solve the global set of issues, given democratic limitations on funding outside the country (and domestic inequality). Consequently, global emissions are growing in absolute volumes, whatever the shares of individual countries are.

COVID-19 and the recession of 2020 have currently brought another dimension of the "Rodrik's trilemma." If his notion is correct for the relatively "quiet" time of upturns in the global business cycles, it must be even more dramatically true at the time of severe crisis, fear and mistrust. The sovereignty of the pandemic sounds absurd, but that is a current picture of how the global community is handling it. Democracy with a good portion of mistrust opens the gates to populism and visible nationalism. Also, international integration (globalization) has given channels for fast spread of infection, and spillover of the contraction of demand. So far "sovereignty" and probably populism have won.

As we can see in Fig. 4, the preliminary reaction of energy investments decisions to the recession and downfall of financial resources was, expectedly, a decline. No doubt the significant reduction (estimated at about 30%) is happening in the oil sector. Generally, the share of RES should increase in the recession, since RES are more used by households, than by industry or transportation. More importantly, investments in efficiency and electricity are declining while the need for them does not. Natural byproducts of the deep recession are uncertainty regarding long-term demand and a squeeze of financial resources of companies and governments. The pandemic and the recession of 2020 have created both these negative effects plus two more: a failure to cooperate for the coordinated use of limited resources and huge needs for financial support of poor, SME, infrastructure, etc.

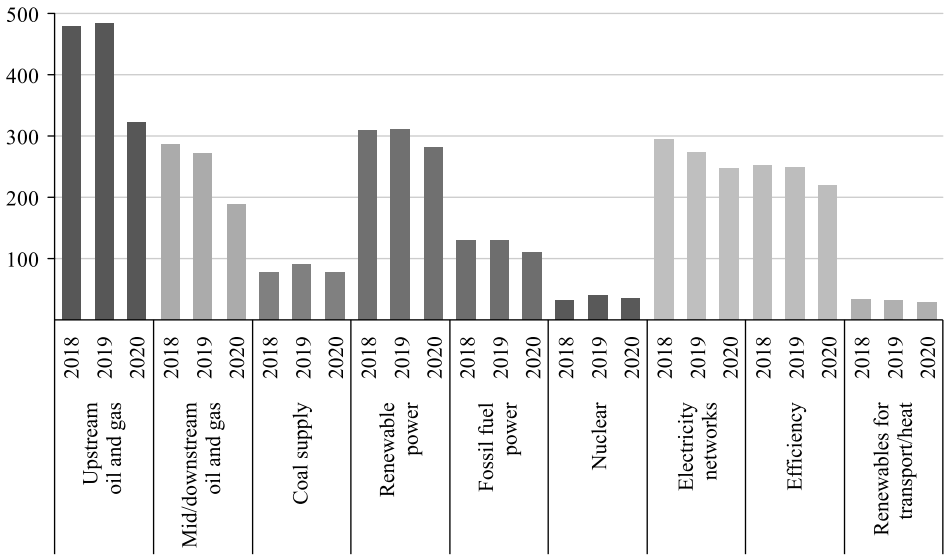

Fig. 4. Energy investment by sector, 2018–2020 (billion U.S. dollars).

Source: IEA (2020).

The important case of the USA will be dependent on the policies of American businesses, people's attitudes and presidential administration policies more than on the UN or other international organizations' recommendations. The case of China requires special attention, but normally observers expect that state control will be capable of implementing declared policies. So far we have seen substantial success in energy policies, resolving the national issues in ecology (by eliminating the bad quality coal, etc.), and changing the energy intensity of GDP growth etc. Against that, and according to IMF calculations, inequality has grown to a new high level (IMF, 2018). The recently announced Road map to 2060, released by Chinese authorities, gives a few essential insights: emissions will peak at 2025–2030; coal will be eliminated by 2050; by 2060 the share of non-carbon sources in energy consumption must reach 84%. It is very encouraging by itself while revealing the tremendous difficulties in the planned process. The estimate for investments till 2060 for this project (size of a quarter of current global emissions) is given as high as $15 trillion (size of GDP of China in 2012). Still, over the 40-year period, this represents approximately a few percentage points of annual GDP on average. Besides, it is not quite clear if these numbers are covering economic and social costs of adaptation of coal mining regions and its population. Nevertheless, this project gives us the approximate investment cost of transition and may be applicable to other Asian countries. It is possible for the well-organized Chinese economic authorities with elements of central planning and financing. But it appears much more difficult for other countries in the region — for some obvious reasons.

We feel ourselves obliged to comment on the Green Deal of the European Union, concerning the current EU share of emissions about 9% (of total emissions). As we understand, the EU is eager to take the bold step of financing anti-recession measures so as to boost green energy investments and production. The whole financing structure of the trillion deal had been defined before the COVID-19

quarantines. But it appeared to be not enough "new money" for the project (Claeys and Tagliapietra, 2020). Now we probably should cautiously note that most of the antirecession money may go into supporting the unemployed, SME, some industries and regions in danger, domestic or international. It will take economic recovery (probably in 2022) before resources can be directed in a major way to the green economy. Nevertheless, economic recovery from the pandemic might as well speed up and intensify the transition process (Makarov et al., 2020).

Finally, most people, elites, intellectuals, governments and media of all countries are eager to support ideas of SDG of the UN. A few intellectuals or politicians will doubtless contest the necessity of climate change mitigation. However, time is going by, and we are probably already not on the mitigation stage, but on the adaptation one. Remarkably, countries and corporations have been pursuing their own interests. So, the sum of support is not equal (actually much less) to the sum of will and actual capability to act. Cooperation is also difficult at the time of global disorder and mistrust. COVID-19 and the recession of 2020 mark the tipping point — if the global community can step over the difference of interests and act in coordination.

Nevertheless, to ensure long-term success, the SDG need even more of good global governance, i.e. coordination with clear rules and institutions. So we need to recognize the substantial potential probability of mankind's failure to prevent climate change, reduce inequality and improve the institutions for development. The attempt by the developed world to focus on climate is understandable but may create the conservation of poverty and inequality. The fast-growing population of the world will need food, shelters, infrastructure and energy, development of human capital and, at least, somewhat alleviated levels of inequality. We do not say that "justice should be brought" to many people for one obvious reason — "justice" is too subjective and elusive in our diverse world. We can — while not without difficulties — measure and discuss some indicators for "equality," but not for "justice" in general (except some current legal issues). Meanwhile justice is coming into the broad picture of debates, and recently by Nobel Prize winner Edmund Phelps (2020).

In more practical terms we would define the precondition for success of the global energy trilemma as follows. Developed countries recognize the unavoidable interconnection between problems of poverty, inequality and energy transition and climate change mitigation. The coming decades will be crucial for global stability. Reestablishing Global Governance is a key problem now — not in 2040. But so far (as we demonstrated in Table 4), the global map of obligations on emissions has an inverted scale: the strong ones are taken by the progressive minority. The rest of the world has weak or very low obligations.

Probably some reduction of an energy intensive consumption in developed countries is unavoidable. The lifestyle of the developed world can be retained with certain costs: the simultaneous solution of problems of climate change, on consumption side, not only on the side of emissions by production. Domestic energy transformation (not substitution by imports) will require substantial investment costs. In major developing countries the GET may be reached within SDG. Forging a decent life in developing countries and catching up start with the eradication of energy poverty. The equation for success of the SDG as a complex of objectives — in our opinion — depends on the global energy

trilemma — with Inequality (poverty) and building infrastructure, institutions and human capital playing as important a role in terms of goals as Climate and Energy Transition. Actually, our message may be rewritten in a very compact way: bring (back) Energy & Climate problem so as to make it more connected to the framework of the SDG to make sure we are all heading to a better and more stable world.

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