Impacts of the Russia-Ukraine conflict on the world energy supply

Impactos do conflito Rússia-Ucrânia sobre o fornecimento mundial de energia

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ABSTRACT
The world is facing an urgent need to reduce anthropological environmental impacts. Renewable energies are an alternative that uses natural resources in a more conscious way, representing a big bet by many countries for pollutants reduction. The impacts of the Russian-Ukraine conflicts hit the energy sector mainly due to the rise in oil, natural gas and coal prices caused by the blockade of these resources from the Russian Federation. Such an event may have accelerated the shift in the energy matrix of some countries to the sustainable side. As noted, the world is very dependent on fossil fuels, so the global scenario was impacted. As analyzed in the article, all continents had to adjust themselves to the situation, and the most invested energy types so far are solar power due to the cheapness of photovoltaic panels, wind power due to its minimal impact on the environment and nuclear power, that many European countries have returned to invest.

Keywords: renewable energy, Russia-Ukraine conflict, energy supply.

RESUMO
O mundo está enfrentando uma necessidade urgente de reduzir os impactos ambientais antropológicos. As energias renováveis são uma alternativa que utiliza os recursos naturais de forma mais consciente, representando uma grande aposta de muitos países para a redução de poluentes. Os impactos dos conflitos Rússia-Ucrânia atingem o setor energético principalmente devido ao aumento dos preços do petróleo, do gás natural e do carvão causado pelo bloqueio desses recursos por parte da Federação Russa. Tal evento pode ter acelerado a mudança na matriz energética de alguns países para o lado sustentável. Como foi observado, o mundo é muito dependente dos combustíveis fósseis, portanto o cenário global foi impactado. Como analisado no artigo, todos os continentes
tiveram que se ajustar à situação, e os tipos de energia mais investidos até agora são a energia solar devido à barateza dos painéis fotovoltaicos, a energia eólica devido ao seu impacto mínimo sobre o meio ambiente e a energia nuclear, que muitos países europeus voltaram a investir.

**Palavras-chave:** energia renovável, conflito Rússia-Ucrânia, fornecimento de energia.

### 1 INTRODUCTION

Renewable energy sources have been the target of investment and research on a global scale since the middle of the last century. Reducing greenhouse gas emissions is a common goal to mitigate the carbon footprint. Energy sources with less impact on the environment may be provided by clean or renewable sources, such as solar, wind, hydroelectric and nuclear energy.

Energy dependence on fossil sources such as oil, natural gas and coal is a factor that is gradually changing, mainly due to ecological and financial awareness. The conflicts between Russia and Ukraine affected in a short period of time several sectors, especially in the energy field due to the large import of fossil fuels from Russia by several countries. The higher prices of commodities in the energy sector can be seen as a catalyst for energy improvement towards renewable sources, moving countries away from fossil fuels.

This paper aims to summarize the most used renewable energy sources around the world and investigate the impacts of the conflicts between Russia and Ukraine regarding the post-pandemic energy sector. This document is separated into two segments: initially, an overview of renewable and non-renewable energies in the world and by continents is outlined before 2020, and then an assessment of the effects of the war on energy prospects is made.

### 2 ENERGY VS POPULATION

The way in which energy is produced and the amount needed to generate it to meet the planet's population consumption are factors that change constantly. Power generation can be as simple as turning a crank doing mechanical work to chemical means of burning fossil raw materials. A study carried out at USP (University of São Paulo) in 2007 points out that the evolution of the humanity brings with it the need for an increasing amount of energy. Compared to primitive man who consumed an average of 200 kcal/day, the technological man of the 21st century consumes 23,000 kcal/day. Logically, the space-
time that separates primitive man from the technological one compacts industrial and technological revolutions that facilitated access to energy. Steam engine, invention of the light bulb, discovery of oil, among other factors that made our society evolve towards an exorbitant consumption of daily energy (GOLDEMBERG et al., 2007; AVILA at al., 2017, DONG et al., 2022, FARIAS et al, 2021).

3 RENEWABLE AND CLEAN ENERGY SOURCES

The types of energy can be classified into two large groups, those from renewable sources and those from non-renewable sources. Renewable energies are those that nature itself is able to replace almost immediately, such as solar, wind, hydroelectric energy, etc. It doesn’t mean that nature could not replace the non-renewables ones, but their replacement period is extremely long as in the case of fossil fuels (AVILA et al, 2017; BASHIR et al., 2019, DONG et al, 2022).

Note that renewable energies are not synonymous with clean energies. An energy can be renewable and not clean. Clean energies are those that do not pollute the environment, either through liquid or gaseous effluents. A clear example is hydroelectric energy, which has an immense impact on the environment for the construction of the dam of the hydroplant and the diversion of rivers that affect the flora and fauna of the region. Of course, water is a renewable resource, but its energy generation is not considered clean. There is also the possibility that the energy is clean, but not renewable, which is the case of nuclear energy, which despite of not polluting the environment, it wears out the uranium atom. Clean and renewable energies such as wind and solar are much more attractive today than those that are renewable and not completely clean (AVILA et al, 2017; BASHIR et al, 2019; DONG et al, 2022; FARIAS, 2021).

4 WIND POWER

Wind power comes from the kinetic energy contained in moving air masses (winds). Its use occurs through the conversion of kinetic energy of rotation, based on wind turbines to generate electricity. As a source of electricity generation, the first attempts appeared at the end of the 19th century, but it was only a century later, with the international oil crisis (1970s), that there was sufficient interest and investment to make the development and application of diverse equipment in commercial scale (CASTRO, 2009, DONG et al, 2022; FARIAS et al, 2021).
Table 01 presents the main 3 countries of installed wind power in 2020. The 15 countries with the greatest potential are well distributed across the planet, with representatives from four of the five continents. It is noted that China, the United States, Brazil, Canada and Australia are on the list, as they are countries with a vast territory that can be explored for various sources of renewable energy. China takes the world lead with an installed power of more than 40% compared to second place (IRENA, 2021).

<table>
<thead>
<tr>
<th>Positions</th>
<th>Countries</th>
<th>Power (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>China</td>
<td>281.993</td>
</tr>
<tr>
<td>2</td>
<td>USA</td>
<td>117.744</td>
</tr>
<tr>
<td>3</td>
<td>Germany</td>
<td>62.184</td>
</tr>
</tbody>
</table>

Source: IRENA, 2021.

5 SOLAR POWER

Solar power comes from the light and heat of the sun, being an alternative and sustainable source that can be used both for electricity generation (through photovoltaic and heliothermic solar energy systems) and for water heating (with solar energy heaters) (ALVES et al, 2020; FAPESP, 2007).

Table 2 presents the world ranking of countries with the highest accumulated capacity of photovoltaic solar energy until 2021. Once again, China is the leader in solar energy production, followed by the United States, Japan, Germany and India. China has an accumulated capacity of 306.4 GW, a value more than triple compared to the second position and equivalent to the accumulated capacity of countries in the second to sixth position (IRENA, 2021, DONG et al, 2022).

<table>
<thead>
<tr>
<th>Positions</th>
<th>Countries</th>
<th>Accumulated Power (GW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>China</td>
<td>306.4</td>
</tr>
<tr>
<td>2</td>
<td>USA</td>
<td>93.7</td>
</tr>
<tr>
<td>3</td>
<td>Japan</td>
<td>74.1</td>
</tr>
<tr>
<td>4</td>
<td>Germany</td>
<td>58.4</td>
</tr>
<tr>
<td>5</td>
<td>India</td>
<td>49.4</td>
</tr>
</tbody>
</table>

Source: IRENA, 2021

Solar power is one of the renewable energies that has gained more space in the world market due to its cheapness because of constant technological evolution in last decades, and high-scale production. Figure 1 shows the cheapening of the photovoltaic cells since the beginning of its commercialization in 1977. Costs vary from $76.00, in
1977, to $0.30 per m², in 2015 (DANTAS et al. 2018; DONG et al., 2022; FARIAS et al., 2021; SIQUEIRA et al., 2019).

5.1 HYDROELECTRIC POWER

Hydroelectric power is an energy source generated by transforming the hydropower into electrical energy. To take an advantage of this power, large hydraulic infrastructures are built capable of extracting the maximum potential of this renewable, emission-free resource that originates in the area itself (EPE, 2021). China takes the lead with a total of 1,202.4 TWh, followed by Brazil with just over about 30% of its global hydropower production capacity, as can be observed in Table 3.

Table 3 - The world ranking of countries with the highest hydropower production capacity.

<table>
<thead>
<tr>
<th>Positions</th>
<th>Countries</th>
<th>Power (TWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>China</td>
<td>1,202.4</td>
</tr>
<tr>
<td>2</td>
<td>Brazil</td>
<td>387.7</td>
</tr>
<tr>
<td>3</td>
<td>Canada</td>
<td>387.3</td>
</tr>
<tr>
<td>4</td>
<td>USA</td>
<td>288.7</td>
</tr>
<tr>
<td>5</td>
<td>Russia</td>
<td>190.2</td>
</tr>
</tbody>
</table>

Source: EPE, 2021

6 NUCLEAR POWER

Nuclear power comes from the fission of the nucleus of the enriched uranium atom. This energy is the force that holds together the particles of the nucleus of an atom,
which when breaking into two parts causes the release of a large amount of energy (FERNANDES et al., 2021, FARIAS et al., 2021).

By the year 2020, there were 443 nuclear reactors in operation in a total of 35 countries that produce about 10% of the world's electricity. According to the United Nations' International Atomic Energy Agency (IAEA), in 2021 there are 54 units under construction in 20 countries, including China, India, Russia, South Korea, United Arab Emirates, Finland and France. China is the country that builds the most reactors in the world, with 50 operational units and another thirteen reactors under construction. In second place, with seven reactors under construction, South Korea, with four, the United Arab Emirates (UAE) and Russia with three reactors under construction. The United Arab Emirates recently started the operation of one of its reactors, making it the first Arab country to operate a nuclear energy plant. (FERNANDES at al., 2021; FORO 2020).

When analyzing solar, wind, hydroelectric and nuclear power, there is a tendency for these technologies to overlap with dependence on oil. The countries that occupy the highest positions are, usually, the ones that dictate the world trends in this specific issues.

There is a notable leadership of China in energy. In terms of renewable and clean energy, it is the country that produces the most in the world ranking. In relation to hydroelectric energy (renewable but not clean) this country also stands out with a production 300% higher than Brazil, which is in second position. In the field of nuclear energy, China still does not lead the potential of energy production, but with the large investment in this clean technology, it may soon occupy this position as well.

7 PRE RUSSIA-UKRAINE WAR WORLD SCENARIO

In a pre-war and pre-Covid19 scenario, the world energy matrix in 2019 consisted of 33% of oil, 27% of coal and 24% of gas. In other words, 84% of the general panorama is of non-renewable and extremely harmful and polluting energies. The renewable energy that stood out the most was hydropower, occupying 6% of the global energy matrix, followed by nuclear (6%), wind (2%), and biofuels, solar and others with 1% each, as shown in Figure 2.
In its 2020 international report, Statkraft already highlighted a major trend in the transition of the global energy market to large-scale renewable sources. According to the study, solar power would be the focus, representing the largest share of energy source as of 2035, surpassing hydro, wind, coal and natural gas.

Extrapolating to 2050, the report predicts a tripling of the world's energy production capacity. An increase of 12% per year is a forecast for solar photovoltaics, 8% for wind energy and only 1.5% per year for hydropower. As mentioned earlier, although renewable energies are the current focus, naturally those that, in addition to being renewable, are also considered clean, that is, wind and solar, will be highlighted. The study also provides an overview for coal and oil derivatives, which will be overtaken by the three renewable energies mentioned above. A total of 80% of the world energy matrix in 2050 will be made up of renewable energies.

8 CONTEXTUALIZATION AND IMPACTS OF THE RUSSIA – UKRAINE WAR

The conflict between Russia and Ukraine is an event that has improved since the end of the Cold War when these two territories made up a so-called Soviet Union Separatist Movement. Actually, socio-economic conflicts between the two countries remain since the turn of the century. As a result of those conflicts, including the interest of Ukraine to become a member of NATO, in early 2022 the Russian president decided to invade the Ukraine (ROMANO, 2022; GALVANI et al, 2022; MAIA and LUCENA, 2022; NONNENBERG et al., 2022; COSTA et al., 2022; HOANG et al., 2021).
Assets of Russian banks were frozen in countries around the world, and one of the hardest consequences was the exclusion of Russian banks from the Swift global payment system, isolating Russia from the international business environment (ROMANO, 2022; GALVANI et al., 2022; MAIA and LUCENA, 2022; NONNENBERG et al., 2022; COSTA et al, 2022; RAGA et al., 2022).

The Russian invasion set off a chain reaction globally. Global benchmark oil prices soared above $110 a barrel, hitting an eight-year record. The risk of stagflation -- rising inflation and low economic growth -- also raises eyebrows among monetary policymakers around the world, although Europe's situation is the most delicate. Barclays analysts cut their eurozone growth forecast for 2022 by 1.7. Private consumption, investment and exports are expected to grow at a slower pace across the continent. In the United States, the consumer price index (CPI) rose 7.9% in February, the biggest annual increase in 40 years (ROMANO, 2022; GALVANI et al., 2022; MAIA and LUCENA, 2022; NONNENBERG et al., 2022; COSTA et al., 2022; RAGA et al., 2022).

The price of a barrel of oil also varies according to the conflict in Eastern Europe. According to the Figure 3, when the Russian invasion of the Ukrainian territory took place on February 24 (2022), the barrel of oil reached US$99.08. With the unfolding of the conflict, this value reached US$ 127.98 on March 8th. With the readjustment of fuels by Petrobras and a new outbreak of COVID in China, the value dropped to 98.02 U$$ until March 16, 2022. However, the war that seemed to be heading towards an agreement did not evolve much, which led the price to rise to 107.93 U$$ by the end of March of the same year (ROMANO, 2022; GALVANI et al., 2022; MAIA and LUCENA, 2022; NONNENBERG et al., 2022; COSTA et al., 2022).
According to Presse (2022), the invasion of Ukraine by the Russian president is causing a broad reformulation of the energy policy in Europe and in the world. Europe’s leaders have been outlining a spectrum of crisis strategies not just to focus on other natural gas suppliers – as the United States, which imports far less gas and oil from Russia than Europe – but also to shift from gas to electricity wherever possible and reduce gas consumption in key sectors. The European Union says it plans to triple its renewable energy capacity by 2030. Some critics even advocate that Germany suspend its plan to shut down its three remaining nuclear reactors by the end of this year - a prospect unthinkable before the Ukraine invasion. The European Union has announced a new energy plan that, according to a leaked draft, “will increase renewable energy in Europe, mobilizing additional investment, removing obstacles to the roll-out of renewable energy and empowering consumers to play an active role in the energy market.” (PRESSE, 2022; HOCKENOS, 2022).

The strategy, which aims to reduce the EU’s dependence on Russian gas by two-thirds this year (2022) and completely end dependence on Russian gas supplies “well before 2030”, includes accelerated deployment of solar power and renewable hydrogen, the rapid implementation of achieving energy efficiency measures and the production of 35 billion cubic meters of biogas per year by 2030. European citizens will also be called: they are being asked to reduce thermostats by 1 °C, which could reduce around 7% of annual gas consumption (PRESSE, 2022; HOCKENOS, 2022).
The significant increase in oil and gas prices may have longer-term offsetting effects. On the one hand, it can shift investments back to extractive industries and fossil fuel-based power generation, running the risk of reversing the decarbonization trend documented in the last 5-10 years (UN, 2022).

On the other hand, it can also accelerate the transition to alternative energy sources, especially in countries that want to strengthen their energy resilience to more local sources. It is not yet known which trend will prevail. Much depends on political leadership and maintaining the momentum to deliver on the commitments of the Paris Agreement and the 2030 Agenda (UN, 2022).

Sascha Müller-Kraenner, a German energy expert and author of the book Energy Security, said in an interview: “This is a whole new game now. Europe cannot be in exactly the same position as it is now at the start of next winter.” Still, experts warn that there are prodigious challenges in rapidly accelerating the transition to green energy and finding timely alternatives to Russian natural gas, which Europe depends on for 40% of its gas needs, mainly for heating and certain industrial processes. Russia also supplies around 35% of Europe's crude oil and over 40% of its coal (HOCKENOS, 2022; EPE, 2022).

Germany, which has long relied on Russian gas as a pillar of its own energy security, is now leading the way in a determined effort to establish energy independence from Russia. A few days after Russia broke through Ukraine's borders, Germany took its first concrete steps to end its chronic addiction to Russian gas and declared an immediate increase in its climate targets. With a further €200 billion to accelerate the new agenda, its target is now a 100% of renewable energy supply by 2035 instead of 2050. Subsidies for rooftop solar installations are set to increase, benefiting millions of homeowners, and German regulators will auction more wind energy concessions. In June 2022, the German energy ministry stated that it will increase the use of coal for power generation (HOCKENOS, 2022; EPE, 2022; UOL, 2022).

In addition to investing in coal and renewable energies, the president of Germany knows that the country does not have the capacity to make such an abrupt transition. Germany counts on certain African countries such as Senegal, Nigeria and Algeria (countries with vast reserves of natural gas) to supply its dependence on natural gas until the German national energy matrix can sustain itself in a renewable way (HOCKENOS, 2022; UOL, 2022; ONUKWUE, 2022; MISHRA, 2022).
France, which has long relied on nuclear reactors for 70% of its energy needs, has promised a big push for more renewables. During his recent re-election campaign, French President Emmanuel Macron said that France would be “the first major nation to abandon gas, oil and coal”. Austria, even more dependent on Russian energy than Germany, is pouring money into subsidies for renewable energy. Even Poland, one of Europe's biggest coal consumers, is investing heavily in offshore wind power (HOCKENOS, 2022; EPE, 2022).

High commodity prices are expected to significantly accelerate inflation in Latin America and the Caribbean, which is already facing an average annual rate of 8% in five of the largest economies: Brazil, Mexico, Chile, Colombia and Peru. Central banks may have to further defend credibility in the fight against inflation (KAMMER, 2022; EPE, 2022).

Higher oil prices hurt Central American and Caribbean importers, while exporters of oil, copper, iron ore, corn, wheat and metals can charge more for their products and mitigate the impact on growth (KAMMER, 2022; EPE, 2022).

Financial conditions remain relatively favorable, but the intensification of the conflict could cause global financial difficulties which, with a tighter domestic monetary policy, will weigh on growth. The United States has few ties to Ukraine and Russia, diluting the direct effects, but inflation was already at a four-decade high before the war boosted commodity prices. This means that prices may continue to rise as the Federal Reserve starts raising interest rates (KAMMER, 2022; EPE, 2022).

Latin America will be negatively impacted by increasing competition for US liquefied natural gas (LNG) stemming from Europe's effort to diversify Russian gas supplies. It’s noted that the region would need to increase domestic gas production for natural gas to be an affordable transition fuel in the context of increasing competition for LNG. Representing most of the electricity generated in the region, hydroelectricity has been the backbone and base load of the Latin American grid, but recurrent droughts due to climate change may be compromising this role (CÁRDENAS, 2022).

Although non-hydro renewable energy has become the cheapest source of electricity at the moment, it remains an intermittent source of energy. This reality has led Latin American countries to rely on natural gas plants for grid reliability. Latin America is a producer and consumer of natural gas. Some Latin American countries have been increasing their LNG import capacity because the domestic supply of natural gas has not
kept up with the increase in demand. But, as indicated, LNG imports are becoming very expensive (CÁRDENAS, 2022; OLABI, 2022; OPEYEMI, 2021).

The shift in European energy policy from Russian piped natural gas to US LNG is making Latin America's seasonal dependence on US LNG imports, which help the region cope with droughts, increasingly difficult. Cárdenas said the situation illustrates how “Latin America is rich in oil but poor in gas”. Overall, this scenario highlights the case of green hydrogen as a substitute for natural gas, as Latin America is well positioned to be a producer and exporter of green hydrogen (ZHU, 2022; EPE, 2022; OLABI, 2022).

Africa does not import Russian oil, but like the rest of the world, it faces sharp price increases. In the United States, this has mostly meant more expensive gasoline, but in many African countries, the price of oil also has huge impacts on electricity generation (AUTH, 2022, OLLEIK, 2022).

In West Africa, diesel generators account for over 40% of the total electricity consumed. Senegal currently depends on oil for half of its electricity generation. As fuel prices soar across the continent, companies in countries like Nigeria – which has seen the cost of diesel increase by more than 200% - are struggling to stay afloat (ZHU, 2022; EPE, 2022; AUTH, 2022, OLLEIK, 2022, OLABI, 2022).

The rising cost of natural gas also makes generating electricity at scale much more expensive in markets such as Ghana, Côte d'Ivoire and Nigeria. Higher fossil fuel prices should be a boon for renewables, but adverse market conditions and rising interest rates will also affect them – particularly in lower-income, higher-risk markets (AUTH, 2022).

For China, the immediate effects are likely to be smaller because the fiscal stimulus will support this year's 5.5% growth target and Russia buys a relatively small amount of its exports. Still, commodity prices and weakening demand in major export markets add to the challenges. The consequences of the war are similar for Japan and Korea, where new oil subsidies could alleviate the impacts. Higher energy prices will push up India's inflation, which is already at the top of the central bank's target. Expensive food and energy imports will drive up consumer prices, although subsidies and price caps for fuel, food and fertilizers can alleviate the immediate impact – but at fiscal costs (KAMMER, 2022, OPEYEMI, 2021).

The aftermath of Russia's war in Ukraine has already shaken not only these nations, but the region and the world as well, and points to the importance of a global safety net and regional arrangements to protect economies. While some effects may not come into focus for many years, there are already clear signs that the war and the resulting
rise in the costs of essential commodities will make it more difficult for policymakers in some countries to strike the delicate balance between containing inflation and supporting the economy recovering from the pandemic (KAMMER, 2022, OPEYEMI, 2021).

10 CONCLUSION

It is noted that in a pre-war period, renewable energies were already advancing on a global level and gaining space to replace dependence in relation to fossil fuels. Focused on renewable and clear energy, several countries intended to expand their energy matrix in order to reduce environmental impacts. However, from 2020 onwards, the global scenario was shaken by a pandemic and the start of a war in Eastern Europe.

With the invasion of Ukrainian territory by of the Russian president, the world economy has felt an immense impact on several sectors. In the focus of this work, the energy sector suffered worldwide from the dependence on oil and natural gas. European countries spoke out in relation to increasing investments in renewable energies such as wind and solar.

The hydropower ends up no longer being the 'focus of the future' due to its immense socio-environmental impact. Latin American countries that are extremely dependent on natural gas are looking for alternatives such as green hydrogen to replace the derivative of Petroleum. The conflict between Russia and Ukraine is likely to have triggered an emancipation of oil in which several countries turned to the renewable sources.

There is a possibility that Africa will begin to meet European demands in terms of natural gas, as many Africans countries have large reserves of this fossil fuel. This factor allows for a smoother transition to renewable energy. Possibly the economy of the African continent will come to prominence in the coming years if many countries resort to African natural gas.
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