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EUROPEAN USE OF NATURAL GAS AND THE IMPACT OF THE ENERGY TRANSITION

Undergraduate Thesis

Advisor: Amanda Schutze

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DEPARTMENT OF ECONOMICS

UNDERGRADUATE THESIS

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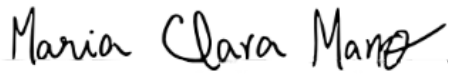
December 2023

"I declare that the present work is my own and that I did not resort to any form of external help to complete it, except when authorized by the advising professor."



"The opinions expressed in this work are solely and exclusively the responsibility of the author."

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Abstract

Natural gas generates around one fifth of Europe's electricity, it is fundamental for heating residential and commercial areas and it is also necessary for multiple industrial processes. The year of 2022 was particularly turbulent for the natural gas market, due to the Russian War against Ukraine making prices skyrocket, with the fear of an European winter without the continent's main gas supplier. With Russia cutting most of its natural gas flows to Europe, questions were raised around the necessity of energy independence, and the need to boost other energy sources, such as renewable energy or even coal for a temporary period of time. Consequently, with the need to lower demand and replace supply, many challenges emerged, which are explained in depth in the following chapters. At the same time, Europe has already made promises and signed agreements with the goal to lower greenhouse gas emissions, a task that becomes more urgent every year, with increases in global temperatures nearing irreversible levels. With this scenario in mind, this project discusses the balance between energy transition and energy independence, in an attempt to understand the future of natural gas in Europe.

Contents

1. Introduction

Natural gas in Europe is used for many necessary activities: in the electric power sector, to generate electricity, in industries, for some transformation processes and in the residential and commercial sector, for heating for example. Due to the importance of heating during the winter, inventories decrease during this period, creating the need to build inventories during the rest of the year. Also, if temperatures are colder than average during the winter, gas consumption increases more than the seasonality would indicate.

Nowadays, fossil fuels are still a fundamental source of electricity in Europe, with the two main fossil fuels used for electricity being gas and coal. These two sources combined generated 34% of Europe's total electricity generation in 2021 (20% gas and 14% coal), according to Visual Capitalist Elements[1], which uses IEA (International Energy Agency) data. Another very significant source of electricity is nuclear power, which accounted for 25% of the total generation in Europe in 2021. Also, renewable energy has grown in importance over the last decade and, in 2021, the main renewable sources (hydro, wind and solar power) were responsible for 32% of the European power generated (13% hydropower, 13% wind and 6% solar. The remaining 9% of Europe's power generation is a combination of minor sources of electricity, like oil, which can increase slightly in importance when the price of natural gas increases and there are efforts to substitute it, biofuel and others.

Although nuclear energy is the largest single source of electricity in Europe, its use has been declining over the last couple of decades. The decrease, from 33% of Europe’s electricity generation in 2001, to 25% in 2021, is due to a shutdown in part of Europe's nuclear energy facilities, specially in Germany and Sweden. The decision that some countries made to shut down the facilities was influenced by the fear of nuclear disasters, like the ones that happened in Chernobyl, in Ukraine, in 1986 and in Fukushima, in Japan, in 2011, creating a stop in the expansion of nuclear energy.

As for renewables, while hydropower electricity generation stayed almost flat for the last few years, wind and solar energy generation are in a rapid increase, with the two of them together surpassing gas power generation for the first time in 2022 in the

[1] CONTE, N. Mapped: Europe 's biggest sources of electricity by country. Available at: <https://elements.visualcapitalist.com/mapped-europes-biggest-sources-of-electricity-by-country/>. Access on: Nov 28th, 2023.

European Union. Increasing the share of renewable energy used in total power generation is one of the goals of the European Green Deal, which focuses on a more sustainable future. With the deal's approval in 2020, the EU set climate neutrality by 2050 as their main goal. To successfully become an economy with net-zero greenhouse gas emissions by 2050, the EU aims to reduce greenhouse gas emissions by at least 55% by 2030.

With the goals to reduce greenhouse gasses, a lot of effort is also being made to reduce coal generated energy. Even though gas is also a fossil fuel, it produces much less carbon dioxide (CO2), just around 56% of the CO2 that coal produces per unit of energy when burned, with gas consumption for electricity generation producing 117 pounds of CO2 per million British thermal units (MMBtu) and coal consumption producing 209 pounds of CO2/MMBtu. Therefore, the share of coal in power generation decreased from 25% in 2011 to 14% in 2021, as part of the attempt to lower greenhouse gasses emissions.

Given this scenario, this paper will research the changes in policies that have been occuring during the last decades and more specifically the most recent changes being adopted by Europe to transition from fossil fuels to greener energies. That will also take into account the dependency that the region has on other countries, the physical limitations of greener energies, that rely mainly on weather conditions, such as sun intensity, rain and wind, and other exogenous factors, like the Russian war against Ukraine.

For many years, Europe has depended largely on Russia's natural gas exports to generate energy, however, the recent Russian war against Ukraine made Europe cut ties with its biggest supplier of fossil gas. The abrupt decrease in Russian gas imports called for a lot of adjustments in order for Europe to survive winter 2022-23 without relying on Russian gas, which drew attention to the discussion around energy independence. Overall, Europe managed to get through 2022's energy crisis without resorting massively to emissions-intensive coal power for electricity generation, contributing to their alignment to the European Green Deal. However, if Europe doesn't expand its capacity to generate other types of energy, resorting to coal is still a possible outcome for the next couple years, which would dismantle some of the progress in the path to cleaner energy.

Therefore, this project's main goal is to analyze the possible outcomes Europe has for the future in terms of energy and their likelihoods. By doing that, it will be

possible to trace the natural gas framework through time and point out the consequences of the energy transition, as well as determine whether or not the goals of the European Green Deal seem achievable.

2. Europe's Reliance on Russia and the War in Ukraine

Russia has the world's largest reserves of natural gas, due to their Siberian fields, and it is also the third biggest oil producer in the world, which explains its importance in the energy market. For Europe, more specifically, Russia was responsible for around 40% of the total gas used by the continent in the years prior to the attack on Ukraine[2]. Given that more than 20% of Europe's energy is generated by gas, the reliance on Russia was evident.

2.1 Powering Europe: Russian-European Pipelines

The exports of natural gas to Europe started before the separation and end of the Soviet Union, with exports to Poland in the 1940s and laid pipelines in the 1960s to deliver natural gas to and through satellite states[3]. Gas deliveries were steady even during the Cold War, however, since the dissolution of the Soviet Union, Russia and Ukraine have had many disagreements over pipelines that pass through Ukrainian territory.

The largest pipeline connecting Russia to Europe is the Nord Stream 1 (NS1), which is usually referred to as a single pipeline, but actually consists of two parallel pipelines that deliver gas from Russia to Germany, passing under the Baltic Sea. Nord Stream 1 became operational in 2011 and has a capacity of 55 billion cubic meters of natural gas per year.[4] To double this capacity, the project of the Nord Stream 2 was created, which would follow an undersea route that's very similar to the NS1, and, since 2015, Gazprom (biggest Russian energy company) and 5 EU companies have spent around 11 billion dollars by on the project, that remains non-operational. Other

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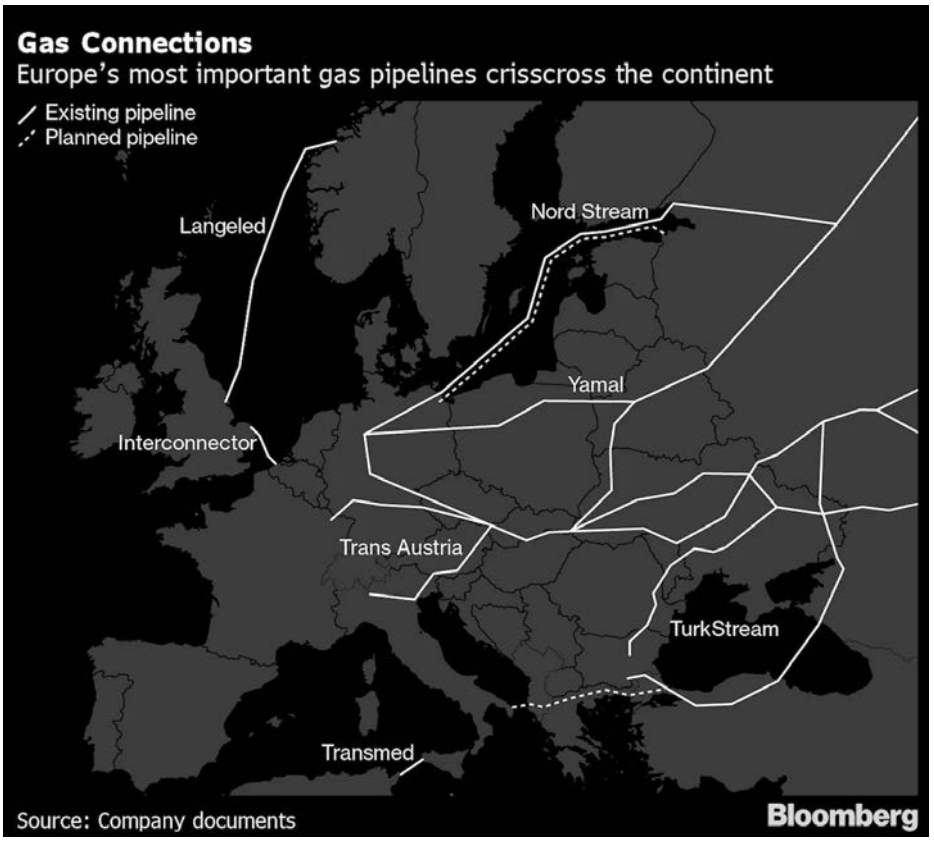
[2] THE. If the supply of Russian gas to Europe were cut off, could LNG plug the gap? Economist (London, England: 1843), 2022. Available at: <https://www.economist.com/the-economist-explains/2022/02/26/if-the-supply-of-russian-gas-to-europe-were-cut-off-could-lng-plug-the-gap>. Access on: Nov 28th, 2023

[3] Bloomberg.com. Available at: <https://www.bloomberg.com/news/articles/2021-11-10/how-europe-has-become-so-dependent-on-putin-for-gas-quicktake>. Access on: Nov 28th, 2023.

[4] GEOPOLITICAL ISSUES. The Nord Stream 2 pipeline. Available at: <https://www.europarl.europa.eu/RegData/etudes/BRIE/2021/690705/EPRS_BRI(2021)690705_EN.pdf>. Access on: Nov 28th, 2023.

pipelines, such as Yamal and TurkStream are also important routes connecting Russian gas to European markets.

Picture 1: Europe's most important gas pipelines



Source: Bloomberg.com. Available at: <https://www.bloomberg.com/news/articles/2021-11-10/how-europe-has-become-so-dependent-on-putin-for-gas-quicktake>. Access on: Nov 28th, 2023.

2.2. Unfolding Crisis: Escalation of the Russo-Ukrainian Conflict

Despite the high European dependency on Russian gas, more recently, the Russo-Ukrainian war and the deterioration of relations between Russia and NATO countries have had enormous impacts on the gas flows to Europe. The conflict between Russia and Ukraine started in February 2014, when Russia invaded and annexed Crimea, which until then was Ukrainian territory. The attack was a response to protests in Ukraine against the former president Viktor Fedorovych Yanukovych, who had accepted a trade deal with Russia instead of signing an association deal with the EU and was eventually overthrown. Russia never wanted to lose influence in former Soviet Union countries, and some nationalist groups believe the Ukrainian territory should be

theirs. Therefore, the Russian government supported the Ukrainian separatists fighting against the Ukrainian military, and since 2014 there has been a lot of tension between the two countries.

On February 24th, 2022, Russia launched a full-scale invasion of Ukraine, immensely escalating the Russo-Ukrainian war. Right before sending missiles and military troops to Ukraine, Wladimir Putin declared he had no plans to occupy the country, and his only goal was the "demilitarization and denazification"[5] of Ukraine, which has proven to be false. The invasion started a few months after Russia demanded that NATO (North Atlantic Treaty Organization) signed a treaty prohibiting Ukraine from ever joining the organization, which was refused by NATO due to their "open door" policy. Therefore, the further Ukraine gets from Russia politically, the more Russia tries to use force to limit Western influence in the region.

NATO countries, including the US and multiple European countries, were quick to condemn the attack, with the European Union approving ten sanction packages[6] up until March 2023. From the long list of measures adopted, there are a lot of financial restrictions, such as freezing the reserves held by the Central Bank of Russia (CBR) in the West and unableling Russian oligarchs to travel to or access their possessions in Western countries. Another form of sanctions are import control, which consists in prohibiting different Western companies from selling their products to Russia and can do a lot of damage to the country in the long term, hurting their manufacturing industries and consumers. Also, there are energy sanctions, mainly imposing restrictions in Russian oil exports, which are responsible for 36% of the Russian federal budget[7]. Among these restrictions on oil exports, the EU and other Western countries pro-Ukraine agreed to stop buying crude oil from Russia, which was implemented on December 5th 2022, and also stop importing petroleum products from Russia, which was implemented on February 5th 2023.

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[5] 'No other option': Excerpts of Putin's speech declaring war. Available at: <https://www.aljazeera.com/news/2022/2/24/putins-speech-declaring-war-on-ukraine-translated-excerpts>. Access on: 21 jun. 2023.

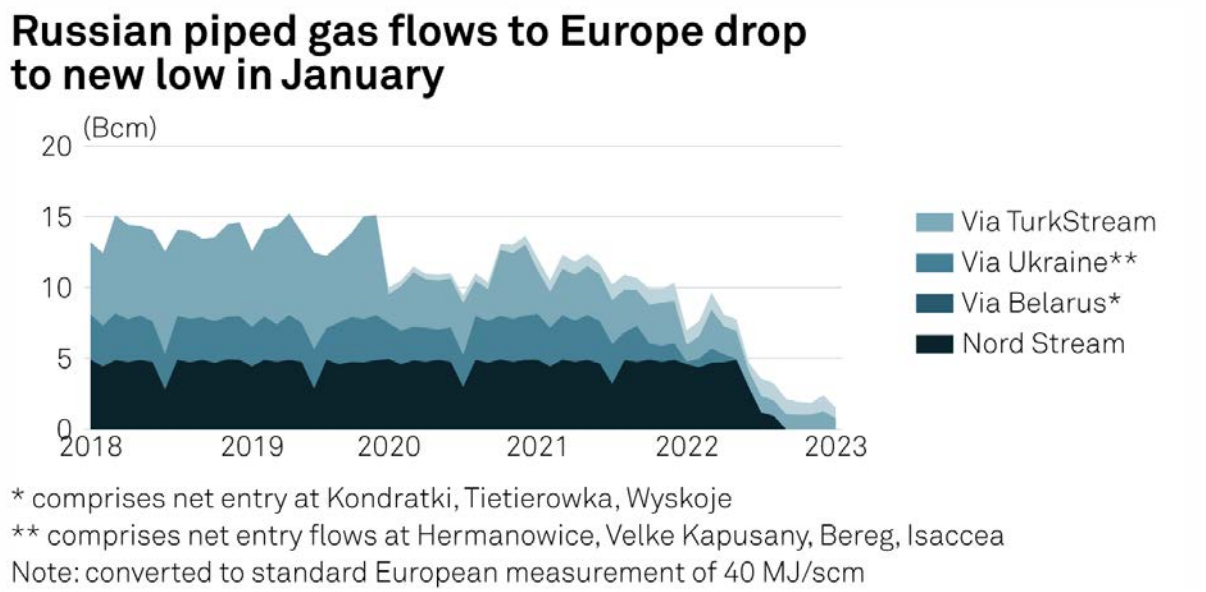
[6] Sanctions adopted following Russia's military aggression against Ukraine. Available at: <https://finance.ec.europa.eu/eu-and-world/sanctions-restrictive-measures/sanctions-adopted-following-russias-military-aggression-against-ukraine_en>. Access on: 21 jun. 2023.

[7] THE. Western sanctions will eventually impair Russia's economy. Economist (London, England: 1843), 2022. Available at: <https://www.economist.com/finance-and-economics/2022/08/24/western-sanctions-will-eventually-impair-russias-economy>. Access on: Nov 28th, 2023.

The energy sanctions didn´t have the planned outcome, due to Russia rearranging oil shipments to Asia, mainly India and China, which kept their oil exports near before the invasion levels. However, Russia saw their natural gas exports, which are responsible for less than 10% of the country's revenue, as a way to punish Europe and retaliate from the sanctions, since it's way harder for Europe to replace gas than it is oil.

In June 2022, Russia started to cut flows from the Nord Stream 1, and in July the pipeline stopped for its annual maintenance, which usually lasts 10 days. However, when the flows restarted, they were significantly lower, around 20m cubic meters per day, when the original flows were 170m cubic meters of gas a day[8]. In August the flows were completely stopped, allegedly due to equipment problems, however many believe that Russia was voluntarily halting flows to Europe as payback for the sanction packages. Finally, on the 26th of September 2022, explosions under the Baltic Sea compromised the Nord Stream pipeline, ending the flows from the pipeline. There are suspicions that the explosions were a sabotage from Russia, to make building inventories harder for Europe, in a period when they were preparing for the winter, however, Putin blamed pro-Ukraine countries for the attack.

Picture 2: Russian gas flows to Europe



Source: ELLIOTT, S. Russian pipeline gas flows to Europe drop to new low in January. Available at: <https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/natural-gas/020223-russia

[8] BBC NEWS. Nord Stream 1: How Russia is cutting gas supplies to Europe. BBC, 2022. Available at: <https://www.bbc.com/news/world-europe-60131520>. Access on: Nov 28th, 2023.

n-pipeline-gas-flows-to-europe-drop-to-new-low-in-january?_its=JTdCJTIydmlkJTIyJTNBJTIyNjgxOGVmMDQtYTQ4OC00YTNmLThlNjktZWUyZTdiNmM1MjM3JTIyJTJDJTIyc3RhdGUlMjIlM0ElMjJybHR%2BMTY4ODE2OTY4MH5sYW5kfjJfMTAwMjJfc2VvXzhmZDYzY2Q1NDk4MTA4M2YyZTVkZDFiMDMxZjk2Mzc5JTIyJTdE>. Access on: Nov 28th, 2023.

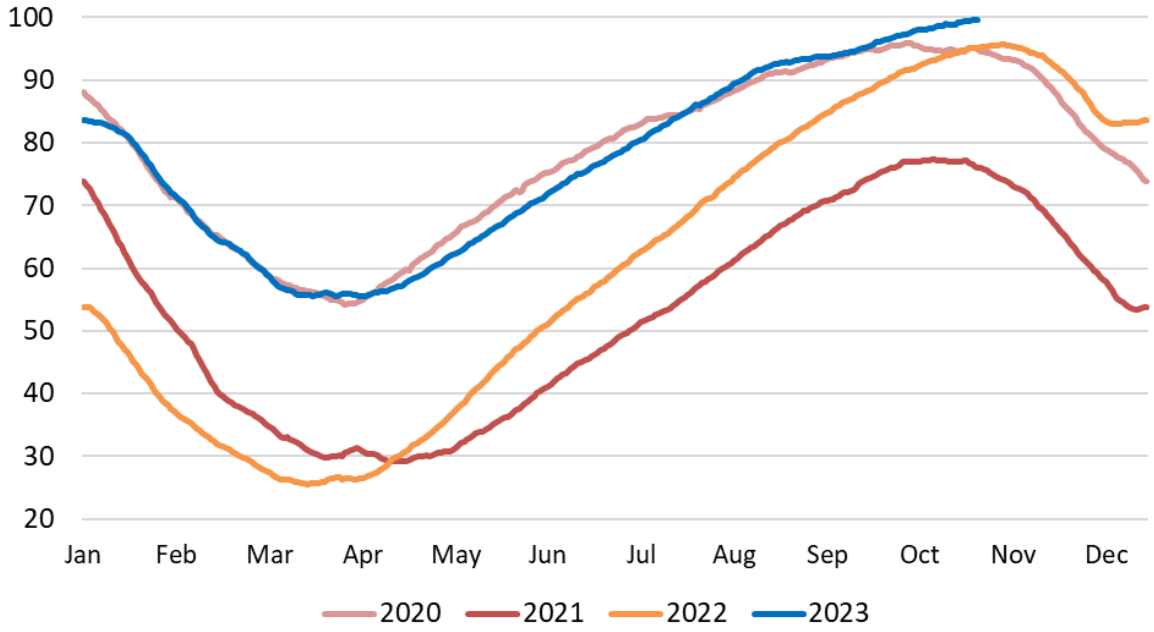
Besides Nord Stream, Russia also ended deliveries via the Yamal-Europe pipeline, and sharply declined deliveries via Ukraine. Meanwhile, the war has had periods of Russian advances and periods of Ukrainian advances, with western countries supporting the Ukrainian army with military aid and Russia needing to mobilize way more troops than they originally planned to. Also, on September 30th 2022, Russia announced the annexation of several regions of Ukraine: Donetsk, Kherson, Luhansk and Zaporizhzhya, escalating the conflict since Ukraine wants to regain sovereignty over all of its original territory.

With no apparent sign that the war will come to an end any time soon, Europe continues to receive very limited gas flows from Russia, and replacements were needed for the continent to survive the winter. Also, tensions continue high, and Russia's possession of nuclear weapons worsens the situation, due to fear of the imminent threat.

3. Aftermath of a Winter Without Russian Gas

With a high dependence on Russian gas, Europe had two main strategies to guarantee enough inventories for the winter: (1) hike imports from other suppliers, such as Norway and the United States, and (2) lower demand by establishing new policies and promoting campaigns to change behavior. As seen in the picture below, the new measures worked, and inventories in 2022 rose from 25,55% of fullness in March to 95,68% of fullness in November, guaranteeing natural gas for the winter. Since the winter was warmer than usual, inventories continued to be above seasonal average throughout 2023, and even peaked in November at 99,63% fullness[9].

Picture 3: EU natural gas inventory fullness



Source: Data overview / historical data - AGSI. Gie.eu. Available at: <https://agsi.gie.eu/data-overview/eu>. Access on Nov 8th, 2023.

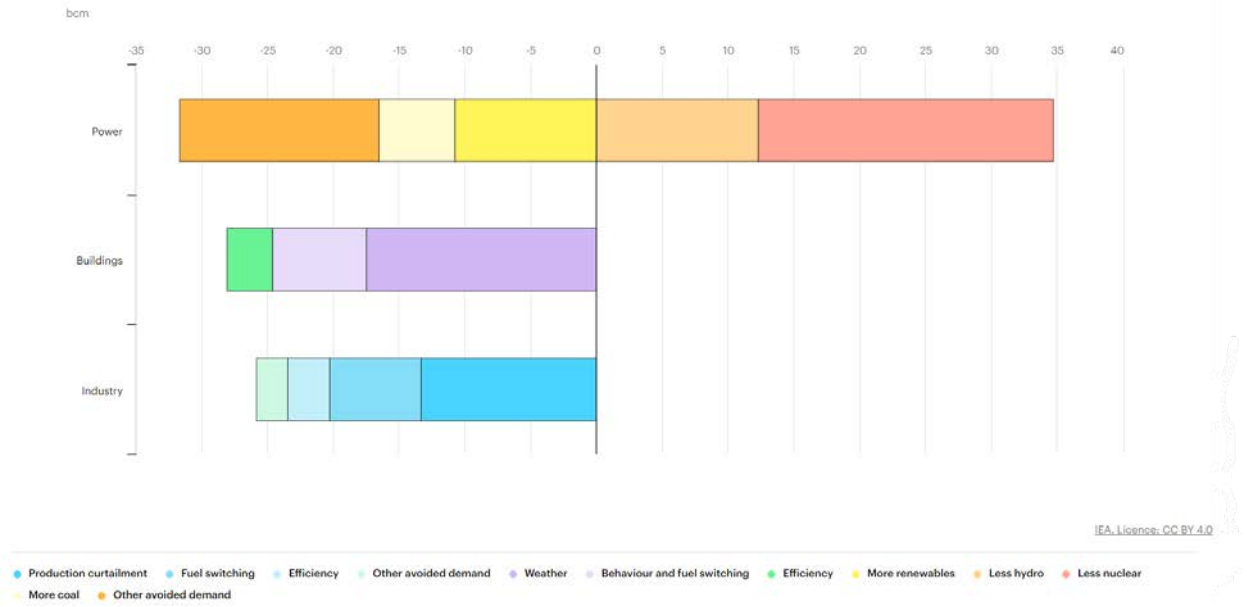
3.1. Lowering Demand

[9] Data overview / historical data - AGSI. Gie.eu. Available at: <https://agsi.gie.eu/data-overview/eu>. Access on: Nov 8th, 2023.

On the demand side, there was a 13% drop in natural gas consumption in the European Union in 2022[10], corresponding to about 51 billion cubic meters below 2021 levels. The steep decrease in demand was caused by many factors, including fears of an energy shortage in the absence of Russian gas, which made prices skyrocket, reducing demand in households and industries, especially in energy-intensive industries, along with warmer temperatures and an increase in the electricity generated by renewable energy. Dividing demand in the three main sectors - power, buildings (residential and commercial) and industry - it is possible to observe the culprits of lower gas demand.

As seen in the graph below, buildings represented the largest absolute decrease in demand, followed by the industrial sector. As for the power sector, decreases in nuclear and hydro power generation made gas consumption go up, while decreases in overall electricity generation and increases in solar and wind power generation helped offset most of the increase in power generated by natural gas.

Picture 4: Estimated drivers of change in billion cubic meters of natural gas demand in the power, buildings and industry sectors in the European Union in 2022 versus 2021

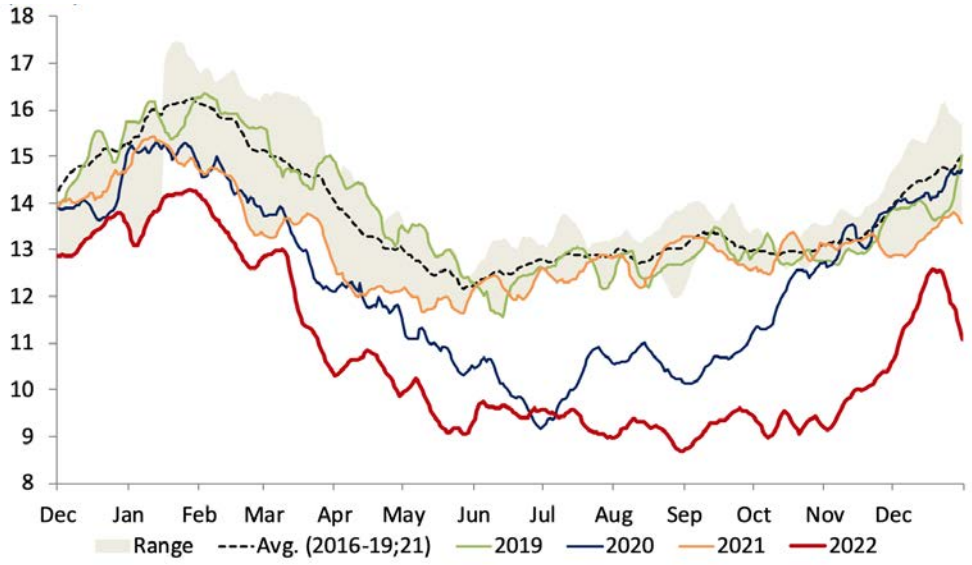


Source: Europe's energy crisis: What factors drove the record fall in natural gas demand in 2022?<https://www.iea.org/commentaries/europe-s-energy-crisis-what-factors-drove-the-record-fall-in-natural-gas-demand-in-2022>. Access on Nov 8th, 2023.

[10] Europe's energy crisis: What factors drove the record fall in natural gas demand in 2022? <https://www.iea.org/commentaries/europe-s-energy-crisis-what-factors-drove-the-record-fall-in-natural-gas-demand-in-2022>. Access on Nov 8th, 2023.

Starting with power generation, which was responsible for a 2 bcm increase in gas demand, it's clear that limiting natural gas demand in the sector was hard in 2022 due to declines in nuclear and hydro power generation. As picture 5 shows, nuclear power generation declined 22 bcm year-over-year (YoY), as a consequence of decisions made over ten years before, that determined that countries such as France and Germany would follow a path away from nuclear power plants, establishing that they would gradually close capacity due to the magnitude of the accidents with this type of energy. Besides nuclear, hydropower production also dropped in 2022, but for different reasons. Due to higher than average temperatures in Europe and extreme droughts[11], water levels in major rivers were exceptionally low, compromising 12 bcm of hydropower generation.

Picture 5: Nuclear Power Generation in European Sample[12] in bcfe (billion cubic feet equivalent)



Source: Entsoe.eu. Available at: <https://www.entsoe.eu/Pages%20/default.aspx>. Access on: Nov 28th, 2023.

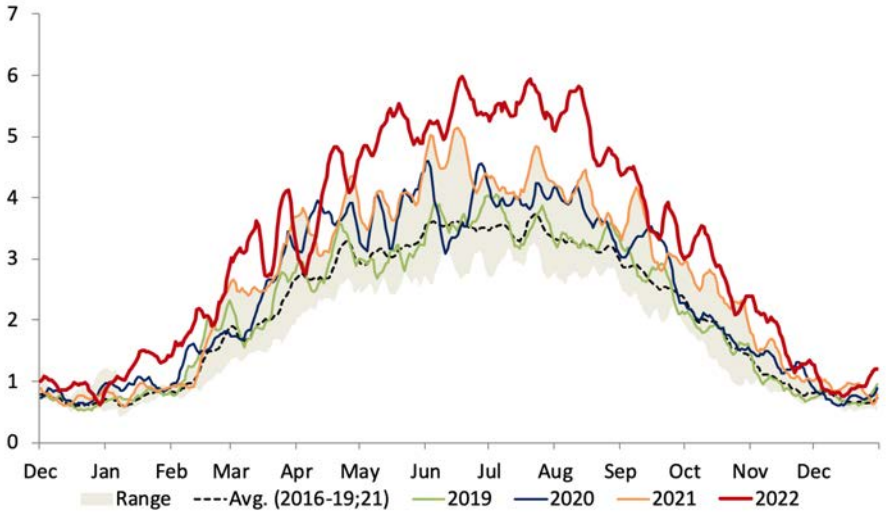
To compensate for this loss, equivalent to 34 bcm, without significantly increasing power generation from natural gas, it was necessary to boost power generation from other fuels, including renewables, such as solar and wind energy, but

[11] GARCIA, L. Global hydropower generation to fall in 2023. Available at: <https://www.eiu.com/n/global-hydropower-generation-to-fall-in-2023/>. Access on Nov 13th, 2023.

[12] Germany, United Kingdom, France, Belgium, Italy, Spain, Portugal, Poland, Hungary, Austria, Slovakia, Slovenia and Romania

also coal. Renewables were responsible for a 11 bcm decrease in the need for natural gas, with solar additional capacity being responsible for most of this boost. In picture 6, the increase in solar energy from 2021 to 2022 is visible, and it will be interesting to observe if the European efforts to minimize their energy dependence in other countries will continue to accelerate investments in renewable energy. However, coal power generation increased by 6 bcm, going in the opposite direction of reducing emissions, but preventing an even higher need for natural gas.

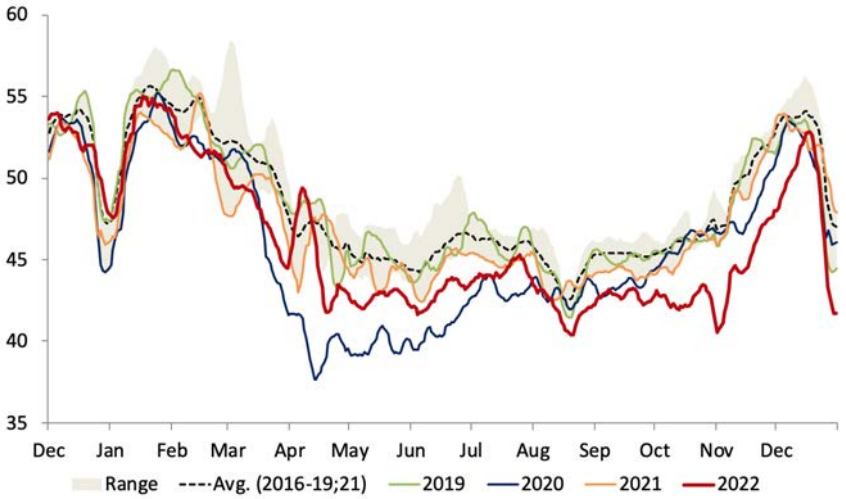
Picture 6: Solar Power Generation in European Sample in bcfe



Source: Entsoe.eu. Available at: <https://www.entsoe.eu/Pages%20/default.aspx>. Access on: Nov 28th, 2023.

Furthermore, the biggest reason why power generated from gas didn't increase even more, was due to the decrease in total power generation. Warmer temperatures played an important role in this decrease and, as seen in the graph below, electricity was around 15 bcm lower in 2022, when compared to 2021, specially during the winter, when electricity use always spikes due to lower temperatures, but seasonally high temperatures kept power demand lower.

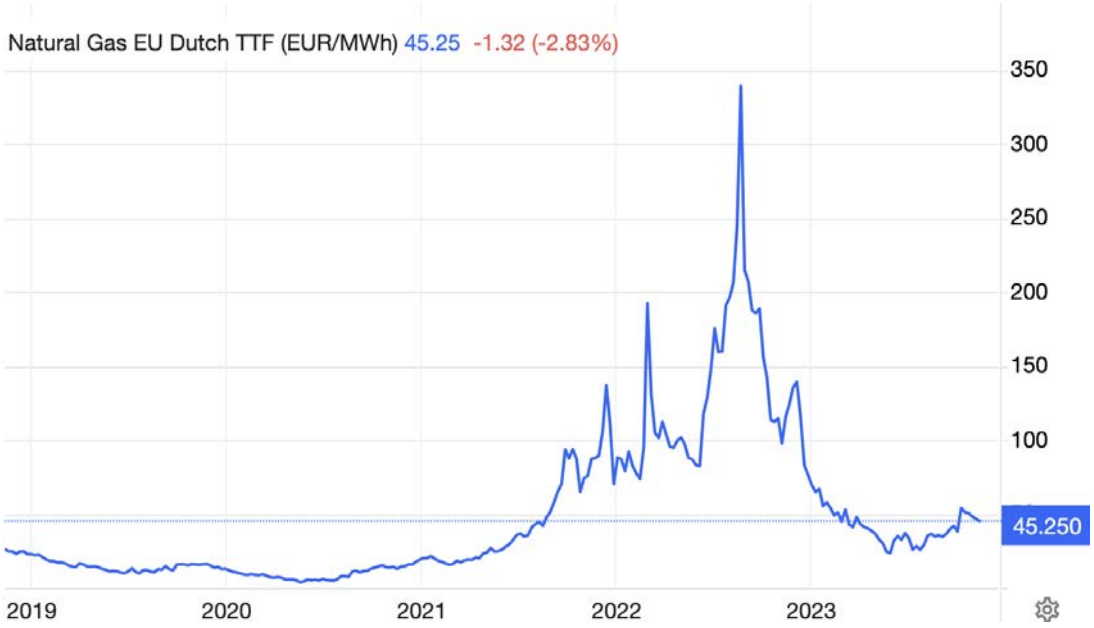
Picture 7: Total Power Generation in European Sample in bcfe



Source: Entsoe.eu. Available at: <https://www.entsoe.eu/Pages%20/default.aspx>. Access on: Nov 28th, 2023.

Going to the buildings sector, where we saw the largest drop in natural gas usage (-28 bcm), weather was also the main contributing factor for lower gas demand, being responsible for 18 bcm less consumption. Another fundamental contributor for lower gas demand were the high gas prices, with the fear of an energy shortage affecting price, as we can see in picture 7. Higher gas prices increased fuel poverty, with the more vulnerable European citizens reducing gas consumption, resulting in colder homes and a shift to cheaper, often more polluting, sources of energy. Besides, during the winter, European governments launched many campaigns focused on lowering gas usage for heating, with thermostats in the European Union being set approximately 0.6ºC lower in 2022, according to the International Energy Agency. Overall, this behavioral and fuel switching changes were responsible for 7 bcm of the drop in natural gas demand, and the remaining 3 bcm in the buildings sector drop was due to a higher energy efficiency.

Picture 8: Natural Gas EU Dutch TTF Price (EUR/MWh)



Source: TRADING ECONOMICS. EU Natural Gas - Price Data. , 20231113.00Z. . Access on: 13 nov. 2023

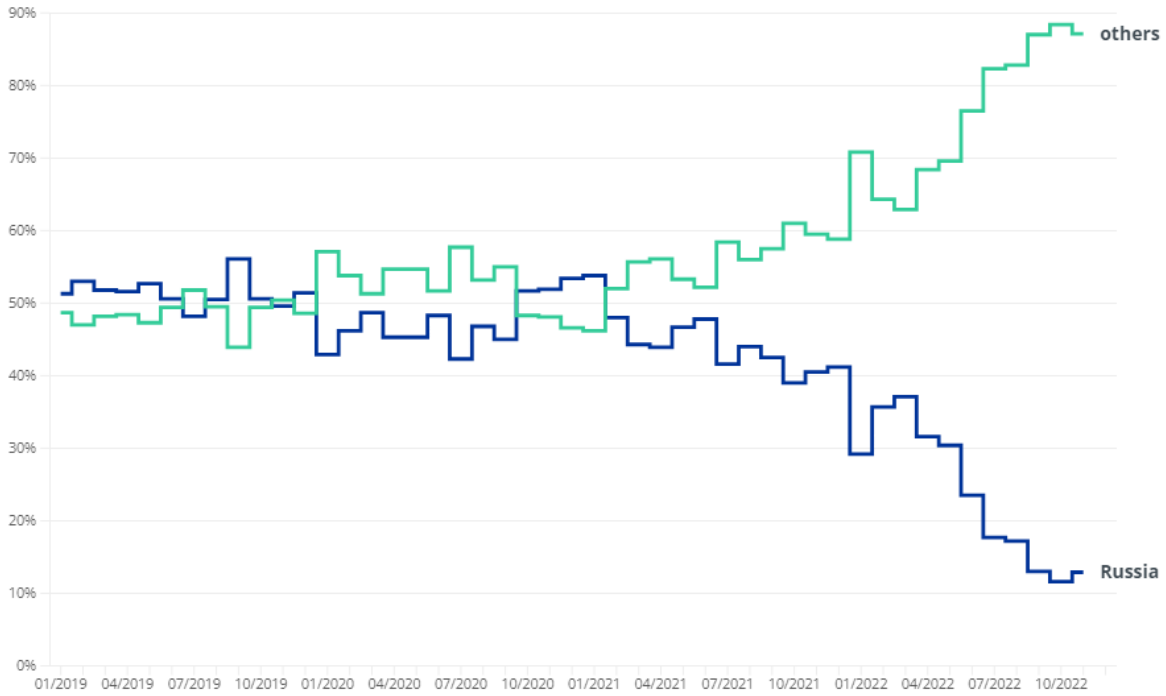
Lastly, the industrial sector was also significantly responsible for lower natural gas demand, with most of the 25 bcm drop in the sector coming mostly from production curtailment and fuel switching. The fall in production, equivalent to 13 bcm of natural gas, was mainly a response to higher gas prices, which affected specially energy-intensive industries. In such industries, like the fertilizer industry, it became cheaper to import the finished product than to produce domestically. Other industries continued to produce but started to import intermediate goods, when such goods were gas-intensive, helping to decrease natural gas usage in Europe. Besides lower production, many industries that could substitute their gas usage for oil usage made the change, with gas-to-oil switching playing an important role (-7 bcm) in lowering gas demand.

3.2. Changing Supply Sources

On the supply side, Europe needed to replace most of their Russian gas imports, which was done mainly by increasing their pipeline imports from Norway and their liquified natural gas (LNG) imports from the US. Therefore, looking at the share of gas imported from Russia and from other countries in picture 8, it is clear that the share of

Russian gas was lowered from 41.2% of all the natural gas supplied to the European Union at the end of 2021 to around 13%, at the end of 2022.

Picture 9: European Union's diversification away from Russian natural gas



Source: Europa.eu. Available at: <https://www.consilium.europa.eu/en/infographics/eu-gas-supply/>. Access on Nov 26th, 2023.

While Norway, which supplied around a quarter[13] of EU's natural gas in 2022, has a pipeline system connecting the country to several other countries in Europe[14] - Great Britain, Germany, France, Belgium and Denmark -, the US supplies Europe by producing liquified natural gas. To produce LNG, natural gas is cooled down until it acquires liquid form, which makes the transportation by ships much easier.

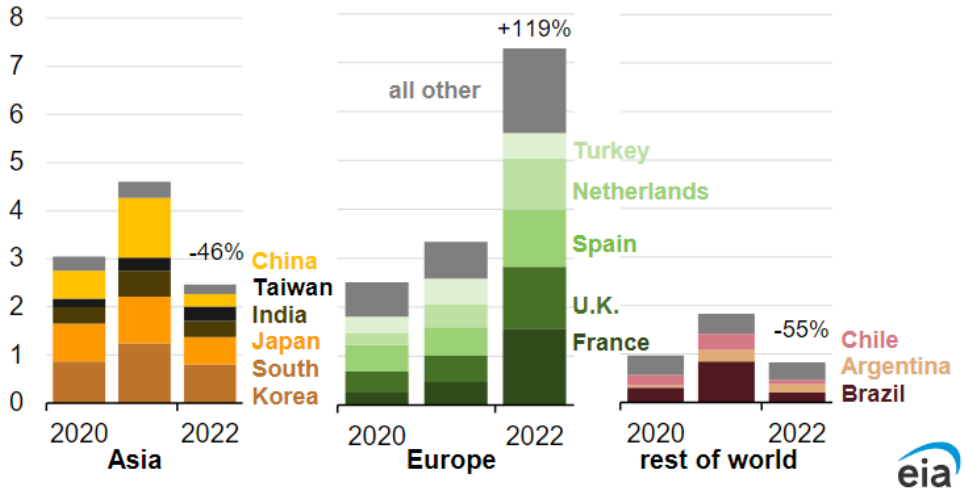
In 2022, the US increased their liquified natural gas capacity, being able to produce and export more than in previous years, helping Europe replace Russian gas. Besides the increase in American production, the US also exported less to Asia,

[13] Europa.eu. Available at: <https://www.consilium.europa.eu/en/infographics/eu-gas-supply/>. Access on: Nov 26th, 2023.

[14] Explainer: How does Norway export its natural gas? Reuters, 2023. Available at: <https://www.reuters.com/business/energy/how-does-norway-export-its-natural-gas-2023-10-12/>. Access on: Nov 26th, 2023.

particularly China, in 2022, since Chinese demand for natural gas was down due to continuous lockdowns and strict policies regarding Covid-19. Therefore, lower exports to China also facilitated the increase in exports to Europe.

Picture 10: Annual US LNG exports by destination (2020-2022) in bcf/d

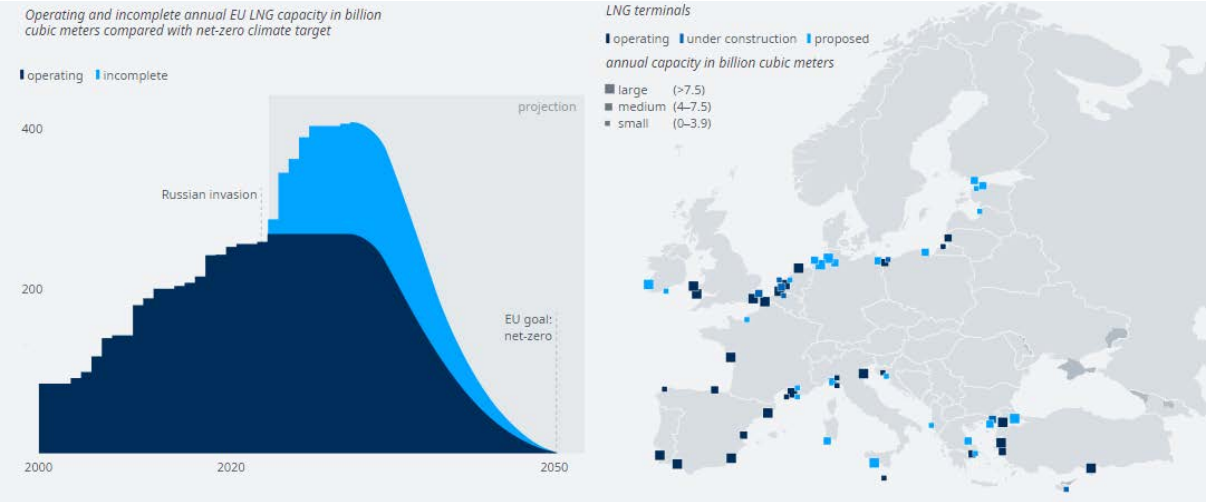


Source: Europe was the main destination for U.S. LNG exports in 2022. Eia.gov. Available at: <https://www.eia.gov/todayinenergy/detail.php?id=55920>. Access on: Nov 26th, 2023.

Also, to accommodate these new LNG imports, European governments are increasing investments in infrastructure to receive LNG, since it has to be regasified after it arrives in European ports. However, lots of investments in LNG terminals has been criticized recently, because it could potentially increase import capacity to higher levels than the forecasted European gas consumption, assuming the net zero emission goals are achieved. More specifically, the Institute for Energy Economics and Financial Analysis (IEEFA) expects LNG import capacity to increase 143 billion m3 between 2021 and 2030[15], reaching 406 billion m3. Meanwhile, natural gas consumption, according to the IEEFA, is expected to fall to around 400 billion m3, if the continent follows its policies to limit greenhouse emissions, indicating a short future for LNG in Europe.

Picture 11: The EU's short LNG future

[15] REED-MARTIN, Theodore. IEEFA: Europe plans continued LNG infrastructure buildout. LNG Industry. Available at: <https://www.lngindustry.com/special-reports/06112023/ieefa-europe-plans-continued-lng-infrastructure-buildout/>. Access on: 26 nov. 2023.



Source: MERK, Julia; PENKE, Michel. To quit Russian gas, EU burns billions on LNG. Deutsche Welle. Available at: <https://www.dw.com/en/to-cut-off-russian-gas-eu-burns-billions-on-lng/a-63863444>. Access on: Nov 26th, 2023.

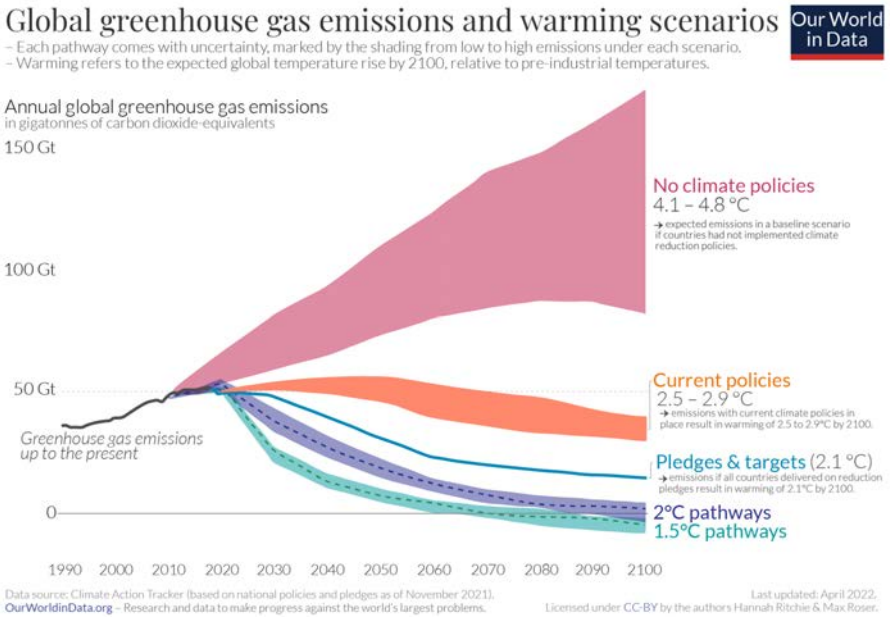
4. Climate Commitments

To forecast energy usage in Europe it is necessary to take into account promises made by the EU to lower greenhouse gas emissions. Greenhouse gasses are gasses that trap heat in the atmosphere[16], such as carbon dioxide (CO2), methane (CH4) and nitrous oxide (N2O). Human activities that increase the concentration of these gasses in the air have been responsible for an increase of approximately 1.1ºC in global surface temperatures relative to pre-industrial temperatures (1850-1900), as stated by the IPCC (Intergovernmental Panel on Climate Change)[17]. The IPCC has warned policymakers of the consequences of the continuance of greenhouse gas emissions, which include extreme temperatures that could eventually make regions inhabitable, an increase in ocean acidification, leading to a loss of marine life, a rise in sea level, an increase in heavy precipitation and flooding and an agricultural and ecological drought. To prevent drastic consequences, scientists determined a maximum increase of 1.5ºC from pre-industrial levels, but even though we are approaching this limit, many countries still haven't established effective policies to help control greenhouse gas emissions, as we can see in the graph below, that compares current policies with the climate goals.

Picture 12: Global greenhouse gas emissions and future warming scenarios

[16] KROEZE, Carolien; DE VRIES, Wim; SEITZINGER, Sybil P. Editorial overview: N-related greenhouse gases: Innovations for a sustainable future. Current opinion in environmental sustainability, v. 9–10, p. 105–107, 2014. Available at: <http://dx.doi.org/10.1016/j.cosust.2014.09.009>.Access on: Nov 26th, 2023.

[17]Ipcc.ch. Available at: <https://www.ipcc.ch/report/ar6/syr/downloads/report/IPCC_AR6_SYR_SPM.pdf>. Access on: Nov 26th, 2023.

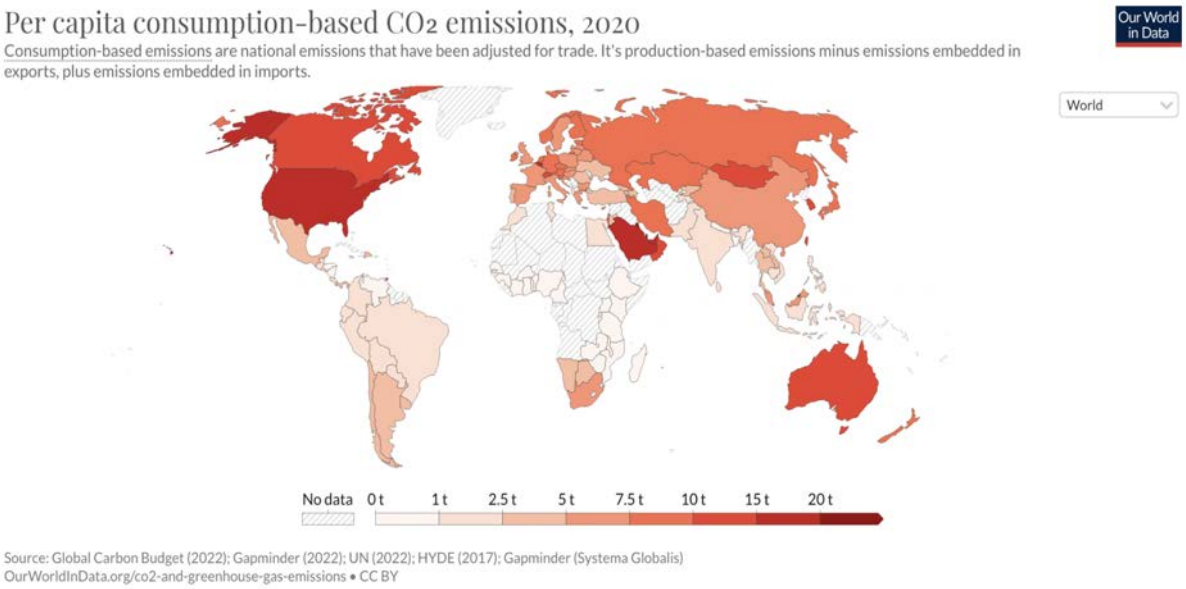


Source: Ourworldindata.org. Available at: <https://ourworldindata.org/future-emissions>. Access on: Nov 28th, 2023.

Carbon dioxide (CO2) is the primary greenhouse gas emitted through human activities since the industrial revolution, with the combustion of fossil fuels, including oil, coal and gas, being the leading cause of global warming. Therefore, policies adopted to prevent temperatures from rising above the 1.5ºC increase established as the ideal limit normally focus on the substitution of fossil fuels in transportation, electricity and industrial processes.

Also, while the increases in temperatures are a global problem, some countries, specially less developed ones, have low greenhouse gas emissions per capita, as we can see in the picture below, but will probably face the worst consequences since they don't have the money to create better infrastructure to help with extreme heat, heavy rains and floods for example. For these countries, it can also be hard to substitute fossil fuels without compromising growth, which extends the discussions on how to make globally accepted deals. However, in spite of the complications, world leaders reached a breakthrough at the UN Climate Change Conference (COP21) in Paris on 12 December 2015, creating the Paris Agreement.

Picture 13: Per capita CO2 emissions



Source: Per capita consumption-based CO_2 emissions. Our World in Data. Available at: <https://ourworldindata.org/grapher/consumption-co2-per-capita?time=2020&country=GBR~DEU~CHN~FRA~IND>. Access on: Nov 28th, 2023.

4.1. Paris Agreement

The Paris Agreement is a legally binding international treaty between 194 parties, including 193 states and the European Union. The agreement's main goals, as stated by the United Nation[18] are:

- to substantially lower global greenhouse gas emissions so that the global temperature increase in this century is limited to 2 degrees Celsius and to pursue efforts to limit the increase even further to 1.5 degrees;
- to review the countries' commitments every five years;
- to provide financing to developing nations to mitigate climate change and enhance abilities to adapt to climate impacts.

By establishing these goals, the Paris Agreement is a commitment from all countries to reduce their emissions together to help minimize the impacts from climate change. The agreement also gives developed nations the responsibility to assist developing countries in their efforts to reach climate goals, and creates a monitoring system to hold countries accountable for their promises regarding the reduction of greenhouse gas emissions.

[18] UNITED NATIONS. The Paris agreement | united nations. Available at: <https://www.un.org/en/climatechange/paris-agreement>. Access on: Nov 28th, 2023.

4.2. European Green Deal

Aside from the Paris Agreement, which is a global agreement, the European Union has other goals regarding climate change. The European Green Deal, for example, was first presented in December 2019, and in it the EU aims to reduce greenhouse gas emissions by at least 55% by 2030, compared to pre-industrial levels, and to achieve climate neutrality (net-zero greenhouse gas emissions) by 2050[19]. A net-zero emission goal means that, by 2050, the European Union plans to be able to offset all emissions related to human activities by removing greenhouse gasses from the atmosphere. As the World Resources Institute explains[20], the process of carbon removal can happen in many ways, including reforestation as well as more technological processes, such as direct air capture, which consists in chemically scrubbing carbon dioxide from the air and sequestering it, and biomass carbon removal and storage (BiCRS), which includes processes that use biomass from plants or algae to remove carbon dioxide from the air and then store it. However, emissions related to human activities need to lower considerably for carbon removal alternatives to be enough to offset all of the EU's greenhouse gas emissions.

By setting the "Fit For 55" package[21], which focuses on the commitment to reduce greenhouse gas emissions by 55% by 2030, the EU has set a very ambitious goal, which will require considerable investments and effort from European countries. The package also sets specific objectives regarding renewable energy, with the Commission approving a target of 40% for the share of renewable-energy sources in total energy consumption by 2030, indicating the need to invest in renewable sources to lower the importance of fossil fuel sources in the energy mix. The existence of such a target, as stated by the European Climate Foundation[22], also indicates that the development of clean-energy technologies rely not only on mandatory cuts in greenhouse gas emissions from fossil fuels but also on government efforts to promote renewable sources.

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[19] LAPIERRE, Anne; MCDOUGALL, Katie. The EU Green Deal explained. 2021. Available at: <https://www.nortonrosefulbright.com/en/knowledge/publications/c50c4cd9/the-eu-green-deal-explained>. Access on: Nov 28th, 2023.

[20] MULLIGAN, James; ELLISON, Gretchen; LEVIN, Kelly; et al. 6 ways to remove carbon pollution from the atmosphere. 2023. Available at: <https://www.wri.org/insights/6-ways-remove-carbon-pollution-sky>. Access on: Nov 28th, 2023.

[21] The European green deal - European climate foundation. Available at: <https://europeanclimate.org/the-european-green-deal/>. Access on: Nov 28th, 2023.

[22] The ‘Fit For 55’ package at a glance - European Climate Foundation. Available at: <https://europeanclimate.org/stories/the-fit-for-55-package-at-a-glance/>. Access on: Nov 28th, 2023.

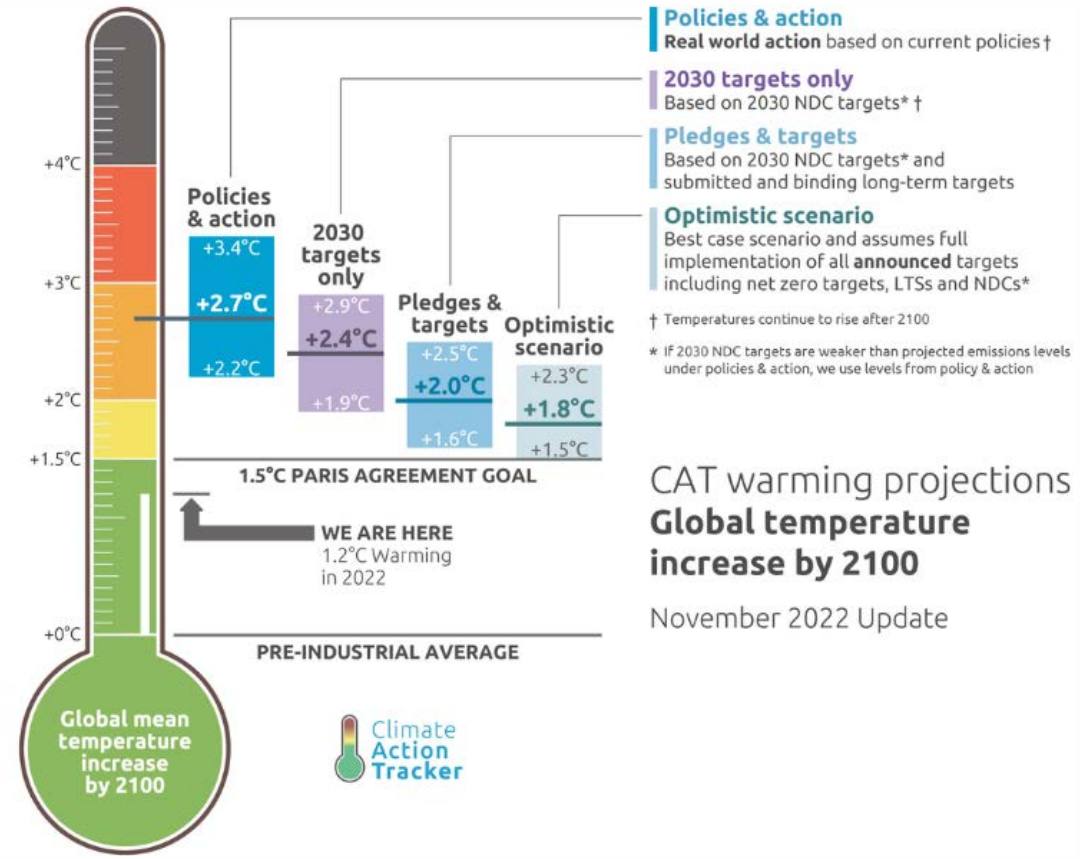
The European Green Deal also specifies many other guidelines. The countries, for example, agreed on efforts to accelerate the development of electric cars and on rules to force automakers to reduce CO2 emissions. They are also encouraging clean-energy options for aviation and shipping, and, in the manufacturing sector, the EU has decided to tax some imported goods, which do not need to comply with costly climate-protection rules due to being produced in non-EU countries. By taxing these imported products, the EU aims to incentivize other countries to set stricter climate rules for manufacturing companies and also to prevent local manufacturing companies that need to comply with EU's climate rules from having a disadvantage in the market.

Given the recent pandemic, the EU has also determined that this moment of recovery could be an unique opportunity to make relevant changes towards a more sustainable and climate-neutral society. Therefore, they have created the Resilient Recovery project, to guarantee that the post-Covid-19 European economy is aligned with the goals stated by the European Green Deal.

4.3. Challenges in Limiting Temperature Increase

Although the commitments already made are fundamental to slow down the increase in emissions, experts still say that the promised policies are not ambitious or quick enough to limit the temperature rise to 1.5°C. In fact, according to the Climate Action Tracker (CAT), created by Climate Analytics and the NewClimate Institute, taking into consideration only the policies already implemented, a 2.7°C increase is likely. And, as shown in the CAT projections in picture below, assuming the countries in the Paris Agreement comply with their 2030 Nationally Determined Contribution (NDC) targets to mitigate global warming, which are the action plans the agreement requires each country to establish and update every 5 years, the increase lowers to 2.4°C. Incorporating long-term targets to the calculation, the increase lowers again to 2.0°C, and in the most optimistic scenario, including even the assumption of net-zero targets being achieved, the increase would most likely be limited to 1.8°C. Taking into consideration that the original goal is a 1.5°C increase limit, and that we are already on the 1.2°C mark, projections are not looking good for the future.

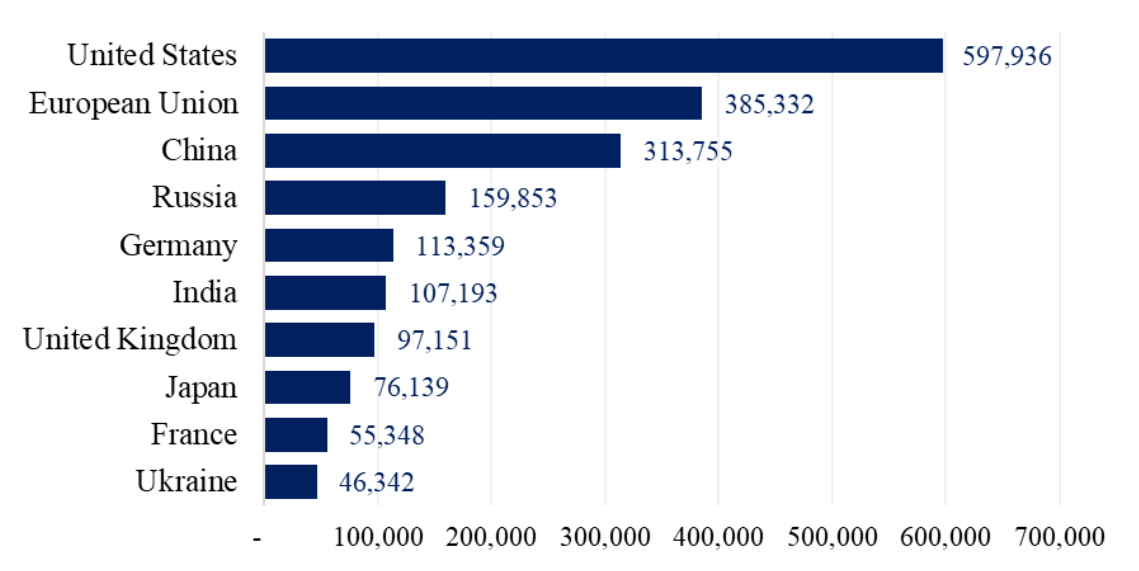
Picture 14: CAT warming projections



Source: The CAT thermometer. Available at: <https://climateactiontracker.org/global/cat-thermometer/>. Access on: Oct 7th, 2023.

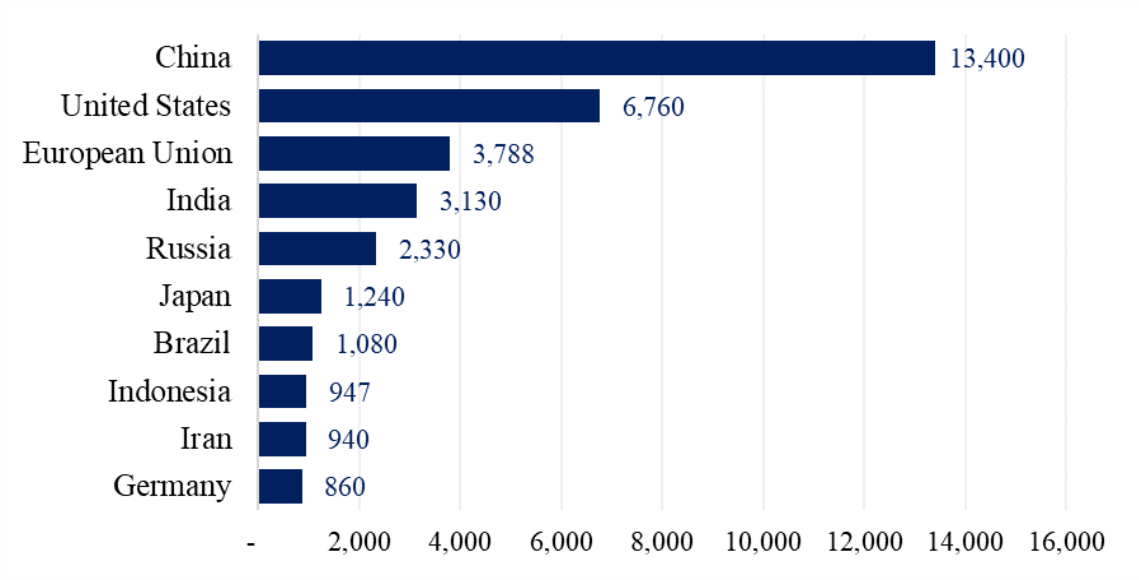
However, even with the need to implement new targets and make sure the ones that are already established are achieved, coming to agreements that are acceptable for a multitude of countries has proven to be very difficult. Less developed countries claim that the use of fossil fuels facilitates their development, and since developed countries have historically polluted more, it's hard to find solutions every country considers fair.

Picture 15: Main Greenhouse Gas Emitters Since 1850 (metric tons of carbon dioxide equivalent, as of 2018)



Source: MAIZLAND, L. Global climate agreements: Successes and failures. Available at: <https://www.cfr.org/backgrounder/paris-global-climate-change-agreements>. Access on: Oct 7th, 2023.

Picture 16: Top Greenhouse Gas Emitters in 2018



Source: MAIZLAND, L. Global climate agreements: Successes and failures. Available at: <https://www.cfr.org/backgrounder/paris-global-climate-change-agreements>. Access on: Oct 7th, 2023.

As the graphs above show, the United States and European countries are the main emitters of greenhouse gas historically, before scientists warned the globe about the dangers of climate change. However, China is by far the main emitter nowadays, partly due to their large population of more than 1.4 billion people, and partly due to

their large usage of fossil fuels, specially coal, and rapid growing economy and industry sector.

Besides the asymmetry in the emissions, the consequences are also asymmetrical. Countries that do not have the resources or infrastructure to endure draughts, heavy storms, floods and high temperatures will suffer the most from climate change, which also needs to be taken into account.

When thinking about setbacks regarding the energy transition and climate commitments, it is important to mention the Russian War on Ukraine. Given the fear Europe faced of a winter without gas, a lot of the discussions surrounding energy shifted from energy transition to energy security. Even though Europe was successful in sustaining high levels of gas inventories, which were more than enough, especially due to a warmer than average winter, the idea of relying too much on other countries for energy began to be considered riskier than before. Although energy security is extremely important, it is important to observe if countries will aim for higher security at the expense of more greenhouse gas emissions or if these two goals will be able to be achieved together.

Also due to the war, emerging markets in Asia had to increase their coal usage, because Europe was buying as much LNG as it could from around the world to store more gas, leaving fewer options for the rest of the countries.[23] Since coal releases more greenhouse gas in its combustion, that is a set back in reducing global emissions.

Therefore, there are many obstacles in limiting emissions, and a lot more needs to be accomplished, but the targets set by the countries on the Paris Agreement and the European nations on the European Green Deal are a start to prevent irreversible consequences from climate change. With a lot of targets being set, investments in non-renewable sources are lowering, but the countries need to guarantee that there is sufficient investment in renewable sources so that the energy supply continues to be sufficient to meet the demand. Investment is particularly important to prevent an energy shortage, which would have devastating economic impacts.

[23] Despite policy and technological progress, the 1.5-degree ambition is becoming increasingly difficult to achieve. Available at: <https://www.equinor.com/news/20230608-energy-perspectives>. Access on: 7 oct. 2023.

5. The Future of Natural Gas in Europe

The International Energy Agency (IEA) divides the future of natural gas in 3 possible outcomes[24]: Stated Policies Scenario (STEPS), Announced Pledges Scenario (APS) and Net Zero Emissions by 2050 Scenario (NZE). For each scenario, the IEA estimates the changes in supply and demand in each region, providing a better understanding of the forecasts.

In the Stated Policies Scenario (STEPS), IEA expects global natural gas demand to rise 0.4% per year on average between 2021 and 2030, with the growth rate declining considerably from the 2.2% average seen between 2010 and 2021. After 2030, IEA would expect growth to stop, with demand reaching 4372 billion cubic meters (bcm) and staying practically flat until 2050, according to this scenario.

Differently, in the Announced Pledges Scenario (APS), global natural gas demand would hit its peak sooner than in STEPS, and start declining a couple years from now, which would mean that by 2030, natural gas demand globally would already be around 3874 bcm, approximately 8% lower than 2021 levels of 4213 bcm. In this scenario, in which there is a decline in global natural gas demand from 2021 to 2030, decreases in the demand of advanced economies, such as Europe, more than offset the increase in natural gas demand from emerging markets and developing economies. In the European Union, for example, natural gas demand would decline 45% from 2021 to 2030, due to renewable energy growth and efficiency gains, facilitating Europe's energy independence from Russian gas. In the APS scenario, global gas demand would also continue to decrease after 2030, reaching 2661 bcm, 37% below 2021 levels, in 2050 according to the IEA.

In the last scenario, which is Net Zero Emissions by 2050 (NZE), natural gas demand drops even more from 2021 to 2030 than in the previous scenario, going from 4213 bcm in 2021 to 3268 bcm in 2030, which is a 22% drop. By 2050, the number lowers to 1159 bcm, with more sustainable forms of energy replacing most of natural gas usage, and with most of the remainder of natural gas being used to produce low-emission hydrogen or used alongside with carbon capture technologies.

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[24] World Energy Outlook 2022. IEA. Available at: <https://www.iea.org/reports/world-energy-outlook-2022>. Access on: 23 nov. 2023.

To summarize the scenarios, the table below shows the projected global natural gas demand in the following years in STEPS, APS and NZE.

Picture 17: Global Natural Gas Demand by Scenario in billion cubic feet equivalent

			STEPS		APS		NZE	
	2010	2021	2030	2050	2030	2050	2030	2050
Natural gas demand	3329	4213	4372	4357	3874	2661	3268	1159
Power	1345	1633	1590	1469	1422	880	1177	119
Industry	701	882	1003	1116	891	644	802	213
Buildings	757	886	890	852	737	372	486	-
Transport	108	147	159	172	126	58	99	12
Low-emissions H2 production inputs	-	1	10	32	41	266	145	566
Other	417	664	720	717	658	441	559	248

Source: Windows.net. Available at: <https://iea.blob.core.windows.net/assets/830fe099-5530-48f2-a7c1-11f35d510983/WorldEnergyOutlook2022.pdf>. Access on: 27 nov. 2023.

Also, when analyzing by region, Europe is expected to be, percentually, the biggest driver of the decline in natural gas consumption in the following decades, due to their ambitious goals regarding emissions. Therefore, even in the APS scenario, which implies more emissions than the NZE scenario, being easier to reach, the IEA expects that by 2050 Europe will demand less than 20% of the natural gas that was demanded in 2021.

Picture 18: Global Gas Demand in the STEPS and APA (bcfe)

			STEPS		APS	
	2010	2021	2030	2050	2030	2050
North America	835	1106	1118	820	933	396
United States	678	871	864	575	716	252
Central and South America	147	161	159	179	141	96
Brazil	29	42	34	37	28	17
Europe	698	625	511	395	394	122
European Union	446	421	340	235	242	45
Africa	105	172	215	292	189	193
North Africa	85	132	155	182	137	120
Middle East	391	567	689	833	638	582
Eurasia	578	662	626	635	587	532
Russia	472	543	498	470	470	424
Asia Pacific	576	920	1043	1173	983	731
China	110	368	443	442	406	238
India	64	66	115	170	110	102
Japan	95	103	64	43	57	17
Southeast Asia	150	162	203	272	194	177
International bunkers	0	0	11	30	8	8
World natural gas	3329	4213	4372	4357	3874	2661

Source: Windows.net. Available at: <https://iea.blob.core.windows.net/assets/830fe099-5530-48f2-a7c1-11f35d510983/WorldEnergyOutlook2022.pdf>. Access on: 27 nov. 2023.

6. Conclusion

While hard to predict with certainty what will be the future of natural gas in Europe, it is likely that it will continue to guide global movements towards more sustainable energy. As discussed in subchapter 4.3, this is due to most of Europe being composed of developed nations, which have historically used fossil fuels to develop, but now have governments and populations concerned about the impacts of climate change. Therefore, European countries have the capital to invest in the energy transition and citizens who will demand that politicians keep their promises regarding greenhouse gas emissions.

And even with the eventual decline in global natural gas demand being a certainty, the world still has to lower the use of more polluting fossil fuels first, such as coal, which will keep natural gas fundamental for global energy for longer. Furthermore, the shift in priority from energy transition to energy security, which was seen by a lot of countries after the pandemic and the Russian war against Ukraine, also negatively impacts progress in the path to limit greenhouse gas emissions. As an example, as seen in subchapter 3.2, Europe plans to increase their LNG import capacity so significantly to avoid Russian dependence that, by 2030, it would be able to receive and regasify more gas than they would demand, if the agreements to limit temperature increase are followed.

Therefore, the NZE scenario by the IEA seems too optimistic, unless we see significant advances in technology that cheapen renewable energy sources, accelerating their growth more than expected. However, as seen in chapter 4, even if all currently announced pledges to achieve net zero emissions by 2050 were implemented, the increase in temperature would probably still surpass the 1.5°C increase, determined as the limit to prevent irreversible consequences of climate change. More specifically, the Climate Action Tracker (CAT), presented in picture 13, estimates a 1.8°C increase in global temperatures from pre-industrial times if all announced pledges are followed.

Having this in mind, the Stated Policies Scenario (STEPS) from the IEA also seems less probable than the Announced Pledges Scenario (APS), because with temperatures rising and the consequences of climate change being more noticeable, it is likely that governments will receive more pressure to comply to their current pledges and even make more promises for the future.

That way, we should see global natural gas demand peaking in the following years, with it already lowering by 2030, and with the decline rate increasing through 2050. In Europe specifically, as seen in subchapter 3.1, increases in wind and solar capacity should continue to boost renewables' power generation, with the share of renewables in total electricity generation increasing the most among all energy sources for the following years. These increases should lower coal demand and eventually gas demand as well, but natural gas will still be an important source of additional energy in case of colder than average winters.

Also, it will be important to see if behavioral changes seen in the winter of December 2022 - March 2023 will continue to be seen in the winters to come. In 2022, the European governments, worried about the first winter after Russia cut most of their gas flows to Europe, launched many campaigns focused on lowering gas usage for heating, which worked, with citizens setting thermostats in the European Union higher. However, with the normalization of natural gas prices in Europe, the population doesn't have the same need to lower consumption, which could indicate that demand patterns would go back to how they were before the war.

Therefore, higher than ever inventories and consequently low gas prices in Europe will take the pressure of lowering natural gas demand off. In that way, natural gas demand, which lowered 51 billion cubic meters (13%) from 2021 to 2022, shouldn't see such large declines in the following years, specially in years with colder than average winters, but the replacement of fossil fuels with renewable energy is an inevitable trend, which will imply a lower consumption of natural gas in the following decades.

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