The Economic Impact of the Russian Invasion of Ukraine on the Energy Market in The European Union

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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Introduction

The Russian invasion of Ukraine in late February 2022, has heightened the already damaging European energy crisis. The European Union decided to sever relations with Russia and wean off of their reliance on Russian energy supply in support of Ukraine (Tavernise, 2022). In retaliation, Russia began to dramatically decrease and eventually cut off oil and natural gas exports to Europe (Gelles, 2023). The decline in Russian energy supply poses a major threat to European energy supply since the EU depended on Russia for 40% of its gas consumption (Rojanasakul, 2022). The EU had become very reliant on Russia natural gas in the latter half of the 20th century after their previous domestic source, the North Sea gas fields supply depleted. Being the cheapest foreign importer, and having the largest gas reserves, it made sense for the EU to rely so heavily on Russian natural gas and allowed for the desired phasing out of coal and nuclear energy (CatClifford, 2022).

The energy shortage after the Russian invasion, sent energy prices soaring all around Europe. Within the first six months since the invasion, electricity costs increased by 70% and gas bill prices doubled (Gelles, 2023). Panic in the EU as the gas and oil supply continued to dwindle caused countries to try and buy up as much supply as they could for storage, at the expense of countries bidding against one another. Bidding against one another not only increased the energy prices even higher (O'Leary, 2022), but also exposed the disparity in energy security between counties. Wealthier countries could continue to purchase the high prices from alternative sources and sell at affordable prices while maintaining these somewhat reliable sources of energy, while poorer countries, were left with few energy options (Tavernise, 2022).

Realizing a greater effort was required to resolve the current state of the energy crisis, the EU put forward a plan to reduce overall energy demand, increase energy storage for the winter months and find new energy sources in order to make up for the loss. While the increased energy

prices gave scientists hope that the surplus in money could be invested back into developing cleaner and more renewable energy to meet energy needs, this is a long-term solution that will take time and is not able to meet the current energy needs (Birol, 2022). One of the main short-term solutions the EU turned to is Liquified Natural Gas (LNG) (Reed, 2023). LNG is natural gas that has been converted to liquid, making it easy to be stored and transported to further distances than gas. However, the economic capabilities and energy storage capacity in each country varies greatly and thus required coordinated measures across the EU to address energy insecurity.

The research topic of my Capstone technical project is on the topic of the Ukraine Food Crisis and how the Russian invasion has exacerbated the issue. This food crisis is a very broad topic that both influences and affects a wide variety of industries and stakeholders all around the world. Thus, my group have split up the topic into five research topics in order to best understand the reach of influence of our project topic. I have been tasked with researching how the ongoing energy crisis in Europe is related to the food crisis, which I have chosen to use as the jumping off point for my thesis. I will be exploring which European countries were impacted the most severe by the loss of the Russian energy supply and how disparities in European Union countries wealth and resources played a role.

Case Context

The reduction in Europe's use and access to energy sources is caused by a combination of EU sanctioning Russian sourced gas and Russia weaponizing the EU's access to the energy. (Gelles, 2023). In late August of 2022, Russia began weaponizing Europe's access to both nuclear energy sources and oil and natural gas. With the help of western weapons, Ukraine stabilized enough to begin driving Russia out of southern Ukraine. However, in direct line of the path out of Ukraine is the Zaporishshia Nuclear Power Plant, the largest nuclear power plant in

Europe (Barbaro, 2022). Ukraine was not able to fend Russia off of the power plant and soon Russia had taken control over the power plant. This Russian occupation led to multiple blackouts across Europe. The Nord Stream 1, is the single biggest pipeline for gas from Russia to Europe which Russia also halted gas flow through the pipe on August 31st for multiple days, only to return to 20% flow capacity when turned back on (Lawson, 2022). Both Russia and the EU's actions have led to a decrease of the EU's imports of Russian natural gas from 40% to 7% (Tavernise, 2022). This almost complete depletion of energy supplies from Russia to Europe along with the looming threat of winter has increased anxieties about where future energy sources will come from.

Europe's initial reaction to the energy crisis was to focus on reducing demand. Governments asked their citizens to turn off their lights, take shorter showers, and turn down heaters. The Eiffel Tower even turned off its lights in order to save electricity (Tavernise, 2022). However, the beginning of this crisis occurred during the warmer summer months, with longer daylight hours and no need for heat, so reducing the amount of power used is much easier than during the winter months when the days are shorter and temperatures are colder. Concerned the gas supply from Russia would eventually amount of none, countries began to buy up the limited available natural gas and filling up storage facilities in order to make it through the winter (Tavernise, 2022). The EU set a goal to fill 80% of natural gas storage by November 1st, 2022. In the initial frenzy to buy as much natural gas as possible, having to bid against many countries both in and outside of Europe, the gas prices just increased the even more. Not only did this lead to tensions between European countries which gave Russia more power, this also exposed the inequality in wealth between countries (Tavernise, 2022). While richer countries such as Germany were successful in filling up these storage facilities or building new ones if needed

even as prices continue to increase, other poorer countries such as Estonia were not able to compete.

Realizing that the splintering of European countries only allowed Russia to continue to raise prices even more, the EU determined that solidarity among one another is the most important while addressing the high energy prices and supply uncertainty (European Council. 2022). The EU created a plan for new regulations in May 2022 in order to support the people and companies that had been most affected by the energy crisis, hopefully provide a solution to the raising energy prices. The emergency regulations consist of aiming to reduce all electricity use by 10%, capping revenues on electricity and fuel producers that have had significant financial gains due to increase in energy prices, and redistributing the surplus of profits from those producers to those hit the hardest by high bills and to companies that have invested in new, clean energy (European Council). The EU also looked to diversify to energy suppliers outside of Russia, an important effort in order to increase energy security. The EU turned to using Liquid Natural Gas (LNG). LNG is 600 times more compact than natural gas is in liquid form, which allows it to be easily transported by ship (Rojanasakul, 2022). Countries in the EU began building new terminals in order to store the LNG coming mostly from The United States and Qatar, for the winter (Reed, 2023). While there was inter-country coordinated efforts conducted, the varied resources available in between countries still led to varied economic situations.

STS Section

Infrastructure is the foundation or background of other kinds of systems, and so by definition is invisible (Star, 1999). This does not always necessarily mean it is actually unable to be seen, but also implies that it is not paid attention to or noticed. This leads to its operation being taken for granted, and not enough attention brought to possible future concerns. However,

infrastructure is part of our human organization and can be just as complicated and problematic as any other organization (Star, 1999). The reliance the EU had on Russian natural gas depended greatly on the network of pipelines, terminals, and ports all around Europe. Once Russia became an unreliable source of natural gas after the invasion of Ukraine, many of the properties and issues of the current natural gas infrastructure became more apparent than before.

Described in Susan Leigh Star's (1999), The Ethnography of Infrastructure, infrastructure has many properties, one being that infrastructure becomes visible upon breakdown. The strains to the energy trade system by the Russian and Ukraine war has shed light on the infrastructure behind the global energy distribution. Prior to the disruption of supply, it was not as evident the issue with Europe relying so heavily on the natural gas supplied through pipelines from Russian. While some countries, such as Estonia had raised concerns in recent years that it was dangerous to almost solely rely on Russia for Natural Gas, other countries outside of former Soviet Republics or Communist Bloc countries who were not as aware of Russia's "power plays", were not as weary of relying so much on Russia for cheap energy (Cohen, 2022). The halt of flow through the Russian supplied pipelines, revealed the importance diversifying energy sources has in ensuring energy security. Russia's sudden halt or limitation of flow through the pipelines that deliver natural gas all around Europe made visible where the current pipelines lay and what countries have access. Some countries, such as Hungary, due to geographical location apart from alternate pipelines, do not have any short-term alternatives without the reliance of Russian gas (Eddy, 2022). This halt in supply also exposed the access to natural gas storage facilities, which became important as the EU adopted the goal of filling up storage facilities to save energy before the colder months. While the majority of the countries in the EU have gas storage capacity, eight countries including Estonia, have no storage capacity at all (European Council, 2023). The

disparity in access to alternate energy sources and energy storage facilities between EU countries, which became more apparent due to all the sudden breakdowns of current energy practices, facilitated the EU to determine intercountry, organized efforts were key to ensuring all countries were able to survive the energy crisis.

The EU's decision to explore the use of Liquified Natural Gas (LNG), was in effort to be able to supply countries with energy using non-Russian natural gas and pipelines. This was possible due to the compacted nature of the liquified gas enabling it to be shipped further distances boat or over road (European Commission, 2023). However, in order for the focus of the source of energy to be on the use of LNG to reduce the crisis with minimal additional obstacles, the LNG must be able to comply with the existing infrastructure. Another property of infrastructure defined by Star (1999), is the property of embodying the standard. This property describes infrastructure as becoming transparent by plugging into other infrastructures in a standard fashion. While long term goals may include completely changing the convention of energy sources in a greener and more renewable direction to combat climate change, the energy crisis requires much faster solutions that can comply with the current standard of energy infrastructure, which includes natural gas pipelines. LNG imports requires specially designed ships or road tankers to transport the liquid, and then ports at the final destination that can re-gasify the gas to distribute through pipelines (European Commission, 2023). The new infrastructure needed to ensure the LNG systems are compatible with current energy infrastructure requires extensive funding, causing limitations in some regions in Europe that may not have as much money to invest in energy infrastructure, leading again to disparities in access to alternate energy sources. Recognizing the countries that are suffering the most and being able

to determine how and from where they will be able get assistance is just as important as the actual energy source solution.

Methods

The research question I have set out to answer is, which countries did the decrease in supply of Russian natural gas effect the worst economically and why?

In order to determine how various European Union countries were affected by the energy crisis, I first researched news sources to keep up to date on the developments in the crisis and determine the main factors creating strain in the energy supply chain. I gathered this information from the New York Times, The European Council, and Reuters articles. From this research I was able to identify key factors that played a role in the degree of how the country was affected by the crisis including, the wealth of countries, the energy storage capacity, and the countries energy reliance and relationship with Russia before the Russian invasion of Ukraine. With this understanding, I collected data from the International Energy Association (IEA, 2022) and obtained the percent of total imports EU countries relied on Russia for natural gas. To quantify the wealth of the countries, I gathered Gross Domestic Production (GDP) data from The World Bank (The World Bank, 2021). From the European Council (European Council, 2023), I collected natural gas storage capacity and natural gas price data in order to analyze energy infrastructure capabilities and the economic impact on countries, respectively. To make the analysis more concise, I chose 13 countries from the European Union to compare based on their varying GDP values. Once I had collected necessary data, I began to make initial observations by creating scatter plots, adding a trendline to notice the relationship between various factors. I first plotted the natural gas storage capacity of the countries against GDP to see the relationship between wealth and energy infrastructure. I then plotted the storage capacity of the countries

against the percent natural gas prices increased after the invasion (Compared 2021 and 2022 prices), to understand if there was a relationship between energy infrastructure and the degree of economic impact in that country.

I then chose four countries to do further and more in-depth research to understand what conditions these countries had prior to the invasion and what they did in response to the energy crisis. I chose to build out case studies using Germany, France, Hungary, and Estonia due to their diverse characteristics, economic situations, and differences in oil imports from Russia between 2020 and 2022. Using Star's framework, I will investigate the extent of the impact that the Russian invasion has had on various countries energy supplies, how the energy infrastructure played a role, which countries hurt the most economically, and why.

Results

After the loss of Russian energy, the countries that had invested more into energy infrastructure were less likely to be financially impacted by the decrease in Russian energy supply. The development of energy infrastructure in a country is closely linked to its economic wealth, meaning wealthier countries often have more resources to invest in developing domestic energy storage and production than much poorer countries. The country's past relationship with Russia also played a role in the impact of the energy crisis by influencing their willingness to step away from Russian energy at the expense of their country's economy. Energy infrastructure also allows countries to have diverse energy sources, which is a crucial aspect to increasing energy security.

The infrastructure that a country has for energy storage, production, and transportation, is greatly influenced by the country's wealth. Shown in Figure 1, where the GDP is plotted against the amount of energy storage capacity the county has. The trendline displays a positive direct

relationship between GDP and energy storage, meaning as the GDP of the country increases, the energy storage capacity also increases. Germany and France, both in the top three largest GDPs in the EU and the greatest amount of gas storage capacity evident by Figure 1, were able to buy enough oil to achieve this goal in August, way ahead of the EU's goal to fill up all storage capacity to 80% before the winter months (Chestney, N. & Sharafedin, B, 2022). Whereas Estonia and Hungary, two the EU's smallest GDP, have little to no domestic energy storage capacity.

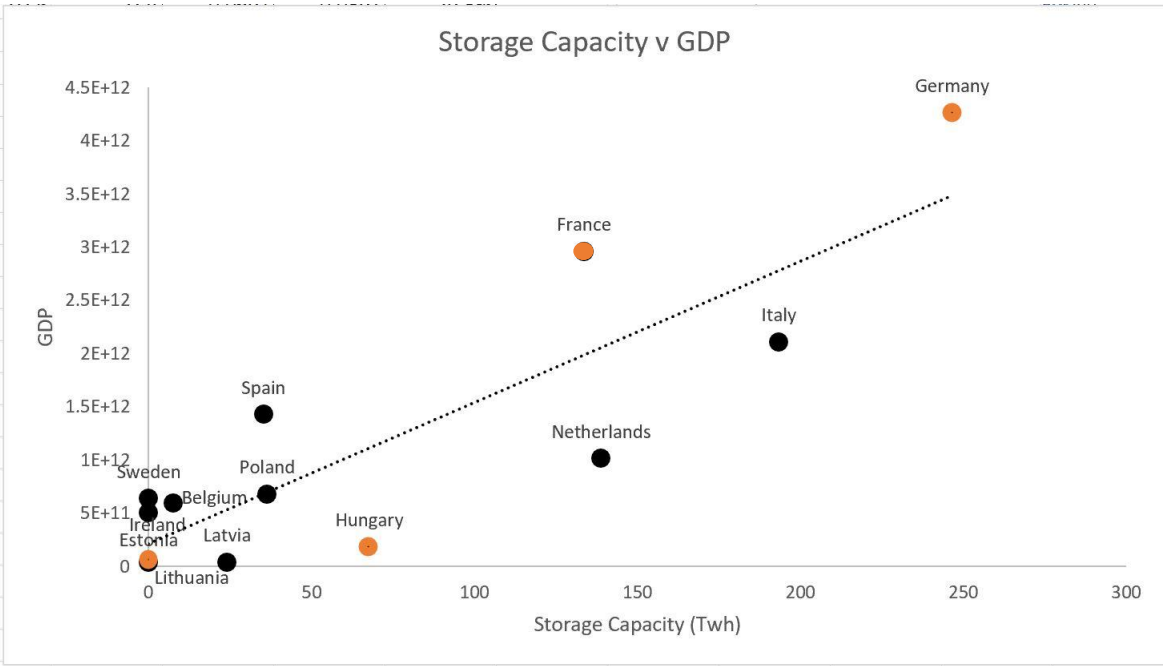

Figure 1: Graph shows scatter plot of the GDP of countries plotted against the energy storage capacity. Sources: The World Bank and The European Council.

The infrastructure that wealthier countries were able to build allows them to have more energy available to them at all times and limits the need to find new energy sources in time of crisis, and thus the wealth allows countries to keep prices similar to what they were before the Russian invasion. Figure 2 shows the natural gas storage facility capacity of each country is

plotted against the percent change that occurred in natural gas prices in each country before and after the Russian invasion of Ukraine. Evident by the trendline, there is an inverse correlation between the storage capacity and the percent increase in natural gas prices. This means that as the energy storage capacity increases in the country, the change in prices decreases. Countries that have little to no storage capacity, had to continuously increase prices since the limited supply available had high price tags due to high demand.

In addition to being an indicator of the amount of investment in infrastructure, the country's wealth is an indicator of the amount the country can subsidize the price of energy. Germany, the EU's largest GDP, announced in September 2022 a $65 billion aid package to ease the high energy costs of citizens for the remainder of the year, and France, the EU's third largest GDP, spent over $26 billion since the invasion to keep energy prices affordable (Alderman, 2022). While, Estonia, one of the smallest economies in the EU, invested only $138 million in energy subsidies from October 2022 to March 2023 (Person, 2022). Although Estonia's investment allowed for some relief in energy prices, displayed in Figure 2, Estonia had to increase natural gas prices over 150%, a much greater increase in price than France or Germany whose gas price raised less than 25% after the invasion. Hungary on the other hand, which will be discussed in greater detail below, was forced to scrap all energy price caps in August 2022 that had been imposed back in April, unable to keep up as energy prices continued to climb (Eddy, 2022).

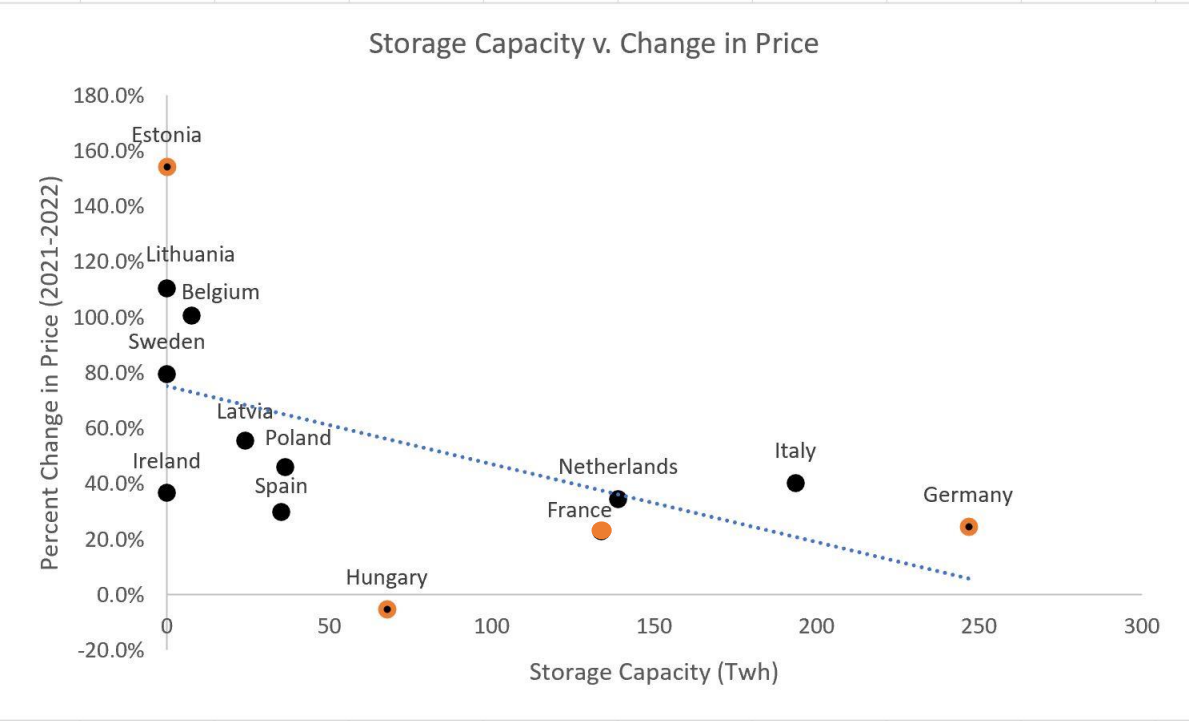

Figure 2: Graph shows scatter plot of natural gas storage capacity plotted against the percent change in natural gas price after the Russian Invasion of Ukraine. Source: The European Council.

Energy infrastructure that impacted the financial situations of EU countries included other infrastructure besides gas storage facilities. The pipeline systems and port or terminal infrastructures also affects the degree to which countries were impacted. Hungary who is highly dependent on Russian energy, experienced a decrease in supply after Russia halted oil delivery to Hungary via the Druzhba pipeline due to an outstanding bill that had not been paid as a result of EU sanctions. Due to these Hungary's location at the south end of the Druzhba pipeline, shown in Figure 3, they had no short-term alternatives to Russian supply while other countries including Germany, at the North end of the pipeline are able to receive additional supply on their northern coasts (Eddy, 2022).

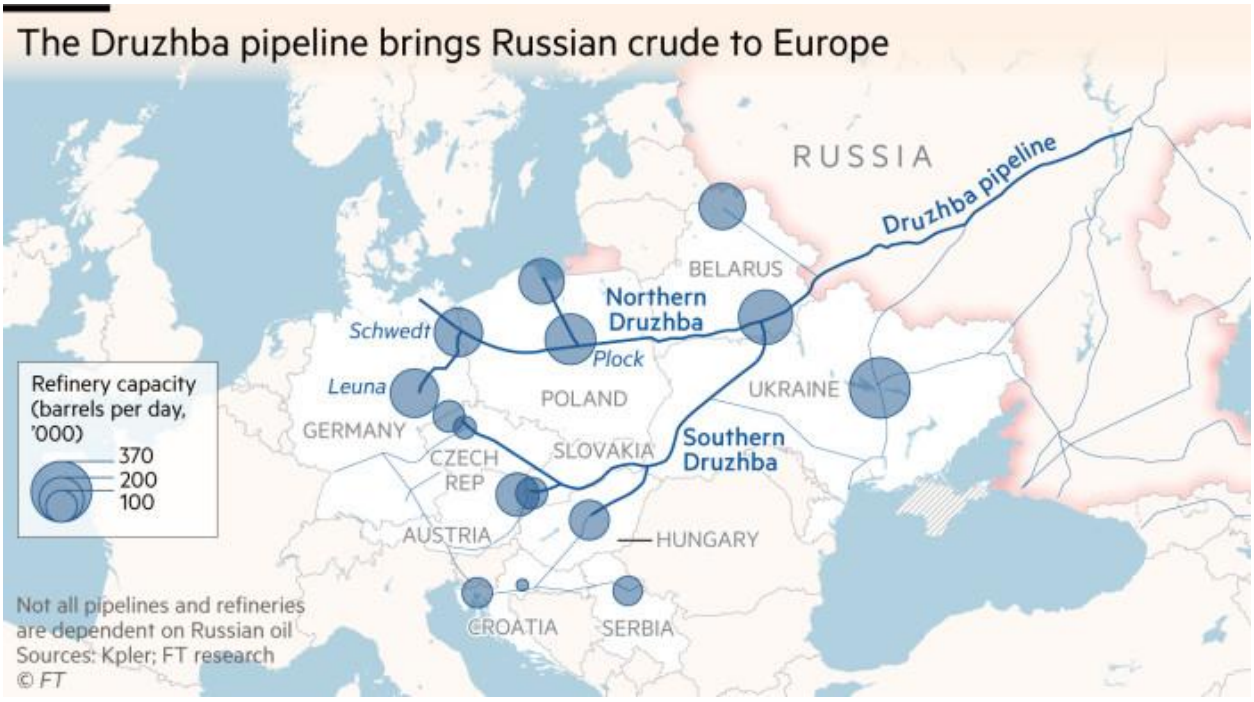

Figure 3: Map shows the locations and capacity of the Druzhba pipeline across Europe. Source: Financial Times

While both Estonia and Hungary are poorer countries that were greatly incredibly reliant on Russian energy, their varied relationships with Russia induced very different outcomes in how they were affected economically. As shown on Figures 1 and 2, Hungary is an outlier, not experiencing significant increases in gas prices despite their smaller GDP and storage capacity as well as lack of investment in price subsidizes. Since the start of the energy crisis in Europe, Hungary has been very vocal about their opposition to the EU placing sanctions on Russian gas, describing price caps on Russian energy as "friendly fire", claiming sanctions are hurting European countries more than they are hurting Russia (Eddy, 2022). The country's opposition to the EU's sanction efforts and Hungary claiming to have no other options outside of Russian energy in addition to a continuous increase in prices after scrapping the energy price caps and the fact that "Budapest is the Kremlin's most vocal defender among EU countries" (Preussen, 2022)

has all led Hungary to sign new deals with Russia to continue to receive their cheap energy supply. While Hungary's closer relationship with Russia has caused them to not suffer as badly economically as other EU countries, Hungary's actions have placed them in a dangerous place of at the mercy of Russia, and waning support from the rest of the EU.

Estonia on the other hand, as a former Soviet republic, has been especially wary of the "power plays" of Russia, and thus for years had been trying to convince other European countries to understand the importance of diversifying their energy outside of Russia (Cohen, 2022). Estonia did still rely on Russia for some of their energy supply receiving approximately 40% of their total energy demand from Russia (Laizans, 2022). After the Russian invasion of Ukraine, due to Estonia's lack of domestic energy storage facilities, additional energy outlets were needed to make up for the loss in supply from Russia. As with many other European countries, Estonia turned to Liquified Natural Gas (LNG) (Cohen, 2022). In April, 2022, Estonia and Finland agreed to share the costs of renting LNG processing vessels and to build a floating terminal in the port city of Paldiski in the northwest corner of Estonia. Estonia's eagerness to become nondependent on Russian oil, motivated them to turn to LNG supply at the expense of significantly increasing prices, as shown by Estonia's location at the upper left corner of Figure 2.

Having various energy sources available, allows countries to rely more on an alternate source if the main source no longer becomes reliable. While Germany is one of the most reliant EU countries on Russian energy, Germany has been able to keep prices lower than many other countries due to their ability to receive energy from other sources. Even with the loss of 80% of the Nord Stream pipeline capacity, many German companies have still been able to use less natural gas. However, this reduction in demand is not due to loss of output or economic

downturn, but due to “flexibility in production or the ability to find import substitutions” (Eddy, 2022). Germany entered into an agreement with France in October, 2022 that France would pump gas towards Germany in exchange for electricity (Alderman, 2022). Germany and France’s capability to enter a deal with one another, despite the energy shortage, is due to their various domestic energy sources. France relies on Russia for only 17% of their gas needs, significantly less than Germany and many other neighboring countries (Person, 2022). While it would seem that France would not be as bad off during the energy crisis because of their lesser reliance, France’s main supply of energy, nuclear energy, had been struggling in recent years due to necessary maintenance plant shut downs, which added strain to the energy shortage. Nuclear energy still accounts for about 70% of the country’s energy needs (U.S. Energy Information Administration, 2023), however, France still had to turn to large conservation efforts, entering an era of energy “sobriety”, to keep up with energy demand (Alderman, 2022). In addition, France is able to import power from Qatar and Algeria, a former French colony, and has begun firing up domestic coal plants in order to meet energy needs (Alderman, 2022). The greater investment that France and Germany have put into energy sources infrastructure, made possible by their large economies, has increased their ability to diversify their energy supply and thus, not suffer as severely economically during the energy crisis as many other countries with less energy options such as Hungary and Estonia.

Discussion

The systems of energy infrastructure and the disparity in investment throughout Europe is something that became apparent after the disruption in supply of Russian, following Star’s property of infrastructure discussed in, ‘The Ethnography of Infrastructure’, that infrastructure becomes visible upon breakdown. The discrepancy in pipeline locations within Europe was not

as apparent until the supply of energy was no longer a guarantee, and it became apparent that some countries such as Hungary were in worse condition to deal with the crisis than other countries such as Germany who had multiple pipelines and terminals available. A similar realization of the energy infrastructure occurred in the United States in 2021 when the entire Texas power grid failed, leaving millions of people without heat during a winter storm. After this failure occurred, the country became more aware of the issues with the power grid and the infrastructure behind the power supplied to their houses. Another property of infrastructure that is defined by Star's (1990) is the embodiment of standards. New implementations of energy infrastructure such as the Paldiski LNG terminal in Estonia, are only helpful to relieving the energy strain if they are able to plugged into the current standard of energy supply. While the push for new energy sources long term is often towards more renewable energy sources, the energy crisis requires more immediate solutions that can be useful to the current standards of infrastructure, including the natural gas infrastructure.

The extent of my research and analysis on the economic consequences of the energy crisis focused on natural gas prices of the 13 countries I chose based on their GDP's. While natural gas is a main energy source that Europe imports from Russia, it is not the only resource used for energy, and including more energy sources in the analysis such as oil or nuclear energy, may have presented in slightly different results. The same could be true if I had selected different countries in the EU to be analyzed. The Russian and Ukraine conflict is also a very recent and constantly changing issue and thus, the results that I have concluded on this paper may be outdated as soon as published.

In the future if I were to conduct another analysis on the aftermath of the Russian invasion of Ukraine, I would want to focus less on what had already happened and why, and

instead more on what actions would be the most effective to relieving the energy strain. The energy crisis opened up a possibility of an accelerated switch to greener energy, and thus the analysis would include whether these renewable energy sources would be effective in making up for energy loss. I would also research the trade capabilities and relationships of countries in order to know what trade patterns would be helpful to getting necessary energy where needed. I would also consider this analysis through the lens of the Techno politics STS framework, to understand what political obstacles exist that would affect the willingness of some countries to help others.

My research for this thesis has made me realize the importance of recognizing inequality and understanding how technology impacts inequality. While new technological advances are often made with the intention of helping people, they sometimes have the unintentional outcome of widening wealth and resource gaps. In the context of this thesis, greater access to storage facilities and pipelines wealthier countries have only expanded the economic gap with poorer countries, facilitating wealthy countries to continue production, leaving poorer countries behind. Within my own engineering practice, I will use this understanding to ensure that it is considered how people of all demographics will be impacted by any future engineering projects I work on.

Conclusion

The Russian invasion of Ukraine sent the world spiraling in many ways. The economic consequences of the resulting energy crisis throughout Europe were some of the worst in world history, and will take many years to recover from. Each European country is very different with various resources, economic states, and politics, all which contributed to how they were impacted by the energy crisis. Analysis into the degree of damage in each country is needed to understand where assistance is most needed. It is essential to understand what factors led to some countries being more severely impacted than others and why, in order to not only know where

assistance is needed the most, but to also figure out how to prevent similar crises occurring in the future. This thesis discovered the vulnerable situation that heavy reliance on a single supplier of energy leaves a country in and net import countries, who do not have the money or resources to produce their own domestic energy supply, are left to suffer the worst in times of supply strain. In the face of possible future global conflicts, it is vital to the global trade system for not only the energy market, but all trade systems including food and other natural resources, to diversify trading partners in order to reduce dependencies on individual countries for such crucial resources such as natural gas. Further research on this topic could dive deeper into other resources outside of energy that have been impacted by the invasion and if similar trends were observed concerning the means and resources of various countries.

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