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Global Energy Consumption: An Analysis of Variables That Shape Per Capita Usage, or How Pump Price, Urbanization, and Fossil Fuels Imports Impact Fossil Fuels Consumption Per Capita Across OECD Countries

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ABSTRACT

GLOBAL ENERGY CONSUMPTION: AN ANALYSIS OF VARIABLES THAT SHAPE PER CAPITA USAGE, OR HOW PUMP PRICE, URBANIZATION, AND FOSSIL FUELS IMPORTS IMPACT FOSSIL FUELS CONSUMPTION PER CAPITA ACROSS OECD COUNTRIES

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Among reasons explaining the importance of studying fossil fuel consumption are: crude oil is a subject of the international commodities market, thus, any fluctuation related to its' availability or price would impact the rest of the World; natural resources like oil, gas, and coal are limited; the extensive use of fossil fuels harms our surroundings, creating many environmental concerns; every human (on average) has been using more energy since 1971 and the trend is expected to continue. The upward trend is not consistent among individual countries. Therefore, the core question of my research is, `Why do some countries consume less Fossil Fuels per Capita (FFCC) than others?` I use a multivariate framework to answer the central question, including three independent (Pump Price for Gasoline, Urbanization, and Fossil Fuel Imports) and two control variables (Latitude and GDP per capita).

My research is built upon three Hypotheses:

1. In a comparison of countries, higher pump prices are associated with a decrease in FFCC compared to those with lower pump prices;

2. In a comparison of countries, a greater urban percentage of the population is associated with a decrease in FFCC compared to those with a less urbanized population;

3. In a comparison of countries, higher fuel imports are associated with a decrease in FFCC compared to those with lower fuel imports.

As a basis of the quantitative method, I use a sample of twenty-eight OECD counties to design and test a model for 2009-2018 (The Model). The output of the multiple regression analysis shows that the Model explains 40% of the variance in the Dependent Variable.

I use a qualitative method to review three case studies (Finland, Canada, and Colombia). Finland's local conditions make the country almost an ideal candidate to fit the Model. Canada's local situation concerning FFCC explains why the country does not fit the Model well, despite significant efforts of urbanized communities to pursue energy efficiency. The Colombian government's continuous interventions prevent the country from fitting the Model and make Colombia an apparent outlier.

Going forward, it is important to develop a worldwide database containing information on taxation and promote energy-related reporting among countries to ensure quantitative data availability.

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CHAPTER 1

WHAT IS IT ALL ABOUT?

1.1. INTRODUCTION

The war in Ukraine illustrated that not only the existing global security system established after World War II is fragile but also many other spheres. "The invasion has had an incredible impact on international energy markets, leading to volatile and significantly higher oil production and natural gas prices in Europe.".[1] Because oil is a market commodity, the American gasoline market also got impacted.[2] Oil market prices jumped from $92.10 on 02/23/22 to $113.90 on 03/25/22[3] per barrel. Even though the second part of 2022 and the first part of 2023 illustrated more stability (as of February 2[nd,] the price was $73.39[4]), the War in Ukraine demonstrated how vulnerable the World could get regarding energy, particularly fossil fuels. Despite the intention of many OECD countries to go green soon, the dependence on fossil fuels is still high.

According to the U.S. Energy Information Administration, in 2019, 80% of domestic energy production was from fossil fuels, and 80% of domestic energy consumption originated from fossil fuels[5]. As for the structure of gross available energy in 2020 in the European Union (the EU), oil and petroleum products held the most significant share (34.5 %), followed by natural gas (23.7 %), whereas solid fossil fuels represented 10.2 %. In other words, 68.4 % of all energy in the EU was produced from coal, crude oil, and natural gas[6].

Given all mentioned above, studying global energy consumption and finding ways to become more efficient is needed more than ever.

My research is about how some variables shape global fossil fuel consumption. The core question of my research is, ` Why do some countries consume less fossil fuels per capita than

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[1] Lehto, E. Finland's Neste boosted by strong refining margins. 2022. Reuters. https://www.reuters.com/business/energy/finlands-neste-boosted-by-strong-refining-margins-2022-07-28/

[2] Blanko, S. U.S. Gas Prices Are Skyrocketing—How Much Worse Will It Get? 2022. Car and Driver. https://www.caranddriver.com/news/a39338671/us-gas-prices-skyrocketing-future/

[3] Oil Futures and Historical Prices. https://markets.businessinsider.com/commodities/oil-price?type=wti

[4] Oil Futures and Historical Prices. https://markets.businessinsider.com/commodities/oil-price?type=wti

[5] U.S. Energy Information Administration. Fossil fuels account for the largest share of U.S. energy production and consumption. https://www.eia.gov/todayinenergy/detail.php?id=45096#:~:text=In%202019%2C%2080%25%20of%20domestic,consumption%20originated%20from%20fossil%20fuels

[6] Eurostat Statistics Explained. Energy statistics - an overview. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Energy_statistics_-_an_overview#Gross_available_energy

others?` I use a multivariate framework to answer the central question, including three independent and two control variables: Pump price for gasoline, Urbanization, Fossil Fuel Imports, Latitude, and GDP per capita consequently. To conduct the research, I use a mixed-method approach. This research design has become popular lately because of combining qualitative and quantitative data. The mixed-method approach allows one to understand a given topic better.

The output of the multiple regression analysis shows that the Model explains 40% of the variance in the Dependent Variable and leaves the rest unexplained. P-values for all variables are less than 0.05. It means that test results are statistically significant, and Null Hypothesis can be rejected for the entire population.

Coefficients outcomes indicate that for every additional percent of fuel imports in merchandise, one can expect FFCC to increase by 0.06 million tonnes of oil equivalent per capita; for every additional dollar increase of pump price for gasoline per liter, one can expect FFCC to decrease by -1.33 million tonnes of oil equivalent per capita; for every additional $1000 increase in GDP, one can expect FFCC to increase by 0.03 million tonnes of oil equivalent per capita; for every additional percent increase of Urban population in the total population, one can expect FFCC to increase by 0.03 million tonnes of oil equivalent per capita. For every additional unit increase in Latitude, one can expect FFCC to increase by 0.01 million tonnes of oil equivalent per capita.

The Pump Price coefficient result supports H1. Because the Pump Price coefficient is closer to 1 than other coefficients, H1 has a greater validity or, in other words - reliability. With various energy sustainability approaches in modern cities, especially in countries of higher economic development, I expected the Model to support Hypotheses #2 (H2). To my surprise, the regression results do not support H2. Hypothesis #3 (H3) is not supported by the regression results either. I expected a higher fuel import percentage of merchandise would be associated with decreased FFCC. Instead, the above outcome is the opposite.

The qualitative analysis of the three case studies clearly illustrated that studying local specifics explains why some countries fit the Model better than others. Finland, for instance, imports all of its fossil fuels for domestic consumption, which, in a way, makes consumers value it more. To some extent, this explains the country's intention to become carbon-neutral in almost one decade. Finland's doors are wide open for investments in renewable energy. Finland's petrol prices are the 5th highest in the European Union, encouraging final consumers to seek alternatives to conventional sources for commuting and energy. Also, refining is conducted by just one company, which eliminates competition rules on the domestic market and, thus, leads to higher pump prices and lower purchasing ability of a final consumer. Such local conditions make Finland's approach to consuming fossil fuels per capita almost an ideal candidate to fit the Model.

Canada's local situation concerning fossil fuel consumption per capita differs from Finland's. Firstly, because the country is a net exporter, imported fossil fuels, mainly crude oil, are less valued by a final consumer. Furthermore, the Canadian market among miners, refiners, and distributors is high. This creates a situation when abundance among competitors does not allow suppliers to neglect cost reduction efforts, which then positively impacts a final gasoline consumer at a pump by enabling them to consume more due to a lower price. All mentioned above explains why Canada does not fit the Model well, despite significant efforts of urbanized communities to pursue energy efficiency.

Colombian government interventions regarding pump prices prevent the country from fitting the Model. The country has been subsidizing gasoline consumption nationwide for decades. This created a situation when market rules could not balance the final prices based on demand and supply. After being `spoiled` by low gasoline prices, the Colombian population does not welcome new initiatives promoting a gradual shift from the highly regulated environment to the one regulated by supply and demand. This makes Colombia an apparent outlier in my Model.

This chapter is divided into four sections. The first one introduces the reader to the global energy consumption trend; the second section explains the relevance of researching it. The third one focuses on my research structure and findings. The final one provides an overview of the dissertation's structure.

1.2. ENERGY CONSUMPTION TREND

Energy is a critical component of existence on Earth. It enables living and non-living things to move, expand and grow. Better than any other life form, humans have mastered transforming energy for self-benefitting. As a result, energy has become an inseparable part of almost any aspect of our daily lives: economic, social, military, science, etc.

On the national level, countries rely on energy as well. Governments worldwide are aware of the urgent need to use the World's energy resources better. For example, improved energy efficiency is a key policy goal of all thirty International Energy Agency (IEA) member countries[7].

While expanding its presence in space and time, humankind kept increasing its energy use. According to British Petroleum, the total World's Primary Energy Consumption (*commercially traded fuels, including modern renewables used to generate electricity*[8]) in 2017 equaled 13,511.2 million tonnes of oil equivalent, 1,922.8 mln tonnes (17%) higher than in 2007[9]. Primary energy consumption growth averaged 2.2% in 2017, up from 1.2% last year and the fastest since 2013. This compares with the 10-year average of 1.7% per year[10]. These numbers illustrate that humankind keeps relying on energy and continues increasing its consumption.

A steadily growing population is among the apparent reasons for the Primary Energy Consumption increase worldwide. The database of the World Bank informs that in 1960 world's population accounted for 3,032,160,395, and by 2017 the number more than doubled and reached 7,530,360,149 people[11]. Between 1965 and 2017 World's Population and Primary Energy Consumption kept steadily increasing[12].

Another recent World Bank dataset exemplified that the World's Energy Use (kg of oil equivalent per capita) increased from 1,336 in 1971 to 1,921 in 2014, meaning that every human

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[7] Final energy use in IEA countries: The role of energy efficiency, Energy Policy. Volume 38, Issue 11, November 2010, Pages 6463-647. https://www.sciencedirect.com/science/article/pii/S0301421509003280

[8] BP stat review of world energy 2018, p. 8. Available at: https://www.bp.com/content/dam/bp/en/corporate/pdf/energy-economics/statistical-review/bp-stats-review-2018-full-report.pdf

[9] BP stat review of world energy 2018, p. 8. Available at: https://www.bp.com/content/dam/bp/en/corporate/pdf/energy-economics/statistical-review/bp-stats-review-2018-full-report.pdf

[10] BP stat review of world energy 2018. Page 2. Available at: https://www.bp.com/content/dam/bp/en/corporate/pdf/energy-economics/statistical-review/bp-stats-review-2018-full-report.pdf

[11] The World Bank Data. https://data.worldbank.org/

[12] https://data.worldbank.org/ and https://www.bp.com/content/dam/bp/en/corporate/pdf/energy-economics/statistical-review/bp-stats-review-2018-full-report.pdf

(on average) has been using more energy since 1971[13]. An increasing consumption per capita means that a reliance on energy by one individual has been elevated.

Since the world population does not explain the per capita change, it is essential to understand the distinction between energy use in general and per capita consumption. Energy use per capita expresses the amount of energy in a given country or area. This increase is not uniform worldwide. Instead, energy use per person is rising more rapidly in some countries (Iran, Hong Kong) than in others (Latvia, Philippines), while in several cases (USA, Canada), per capita use has been declining[14].

Because of the upward trend in energy use, any energy availability disruption could impact our daily routine on any level: individual, national, and even international. For example, "the war in Ukraine has had an incredible impact on international energy markets, leading to volatile and significantly higher oil production and natural gas prices in Europe."[15] Gas prices started skyrocketing following sanctions on Russian oil after it invaded Ukraine in February of 2022.[16]

While energy consumption keeps increasing in absolute terms, relative energy consumption by energy sources remains similar to the one a few decades ago. In 2017, 90% of the energy consumed worldwide (12,106 mln tonnes of oil equivalent) came from non-replenishable sources: oil, natural gas, coal, and nuclear. And only approximately 10% were associated with hydroelectricity and other renewables[17]. The most recent data posted by the World Bank presents a similar picture: the World's consumption of fossil fuels between 1971 and 2015 has not changed significantly. The Oil Crisis of 1970 impacted the drop in fossil fuels consumption by 10%, from 94.6%in 1970 to 84.5%[18] in 1971. Today, oil remains one of the key

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[13] The World Bank Data. https://data.worldbank.org/

[14] The World Bank Data. https://data.worldbank.org/

[15] Lehto, E. Finland's Neste boosted by strong refining margins. 2022. Reuters. https://www.reuters.com/business/energy/finlands-neste-boosted-by-strong-refining-margins-2022-07-28/

[16] Cronin, B. How a massive refinery shortage is contributing to high gas prices. 2022. https://www.npr.org/2022/06/26/1107265390/refinery-shortage-high-gas-prices-russia#:~:text=Gas%20prices%20started%20skyrocketing%20following,first%20time%20ever%20this%20month

[17] BP stat review of world energy 2018, Available at: https://www.bp.com/content/dam/bp/en/corporate/pdf/energy-economics/statistical-review/bp-stats-review-2018-full-report.pdf

[18] The World Bank Data. https://data.worldbank.org/

energy sources. It constituted 35.96% in 2005 and 32.94% in 2015 of the total energy use, the highest percentage of all the energy sources consumed. Although fossil fuels energy consumption as a percentage of total decreased, World's Fossil Fuels consumption increased between 1965 and 2021[19] (see the chart below).

Thus, the role of fossil fuels in generating energy remains crucial. That is why fossil fuels (oil, natural gas, and coal) are closely examined when discussing energy.

One of the ways to soften any energy disruptions is to use energy efficiently. On a national level, energy intensity is often used to evaluate a country's economy. Energy intensity indicates how much energy is used to produce one unit of economic output. A lower ratio indicates that less energy produces one output unit. According to the World Bank[20], the ratio between energy supply and gross domestic product measured at purchasing power parity, Energy Intensity level of primary energy (MJ/$2011 PPP GDP) has decreased from 7.5 in 1990 to 5.1 in 2015. To double-check the trend, one could look at the ratio between GDP per unit of energy use (PPP $ per kg of oil equivalent). It increased from 3.4 in 1990 to 8.3 in 2014.

The World's downward trend of energy used to produce one unit of output is a positive thing. At the same time, it creates a dissonance with alarmingly increasing energy use per capita. Thus, evaluating any nation's energy efficiency and economic output from one individual's standpoint is essential.

Today, energy is essential to the well-being of any national economy. Due to the competitive nature of global markets, the limited availability of natural resources, and the consequences of the extensive use of fossil fuels, it is essential to ensure energy is used as efficiently as possible. Governments in many countries are increasingly aware of the urgent need to use the World's energy resources better. Improved energy efficiency is a key policy goal of all International Energy Agency (IEA) member countries[21].

As one would expect, energy is being used differently across counties. When looking at the national level, evaluating the situation from different angles is essential. Primary energy

[19] Fossil Fuels. https://ourworldindata.org/fossil-fuels#global-fossil-fuel-consumption

[20] The World Bank Data. https://data.worldbank.org/

[21] Final energy use in IEA countries: The role of energy efficiency, Energy Policy. Volume 38, Issue 11, November 2010, Pages 6463-6474
https://www.sciencedirect.com/science/article/pii/S0301421509003280

consumed in 2017[22] ranged from 7.7 in Sri Lanka to 2,234.85 in the US (million tonnes of oil equivalent.) Looking at energy consumption at the country level is often a strong reflection of population size rather than actual fossil fuel consumption per person[23]. Therefore, adjusting consumption for population is essential. The difference in use also applies to primary energy consumed per capita and varies from 0.20 in Bangladesh to 20.52 in Qatar (million tonnes of oil equivalent.)[24] World's Fossil Fuels Consumption per capita has also increased since 1965 from 12,116 Twh to 17,197 Twh in 2021[25].

As one can see, there are differences in energy consumed per capita across countries. Solving why some countries use less energy per capita could provide a valuable remedy to nations with high per capita use.

1.3. WHY IS IT IMPORTANT

Several reasons can be identified for studying fossil fuel consumption.

First, ***natural resources are limited***. Even though it is understood a priori that *non-renewable natural resources are finite*, the data on the availability of fossil fuels looks optimistic. At least from the point of the current generation's view. For instance, BP's annual report on Global proved reserves of oil reports that as of the end of 2017, the World had nearly 1.696.6 billion barrels, sufficient to meet 50.2 years of global production at 2017 levels[26]. According to the same report, Global proved gas reserves in 2017 rose slightly by 0.4 trillion cubic meters (tcm) or 0.2% to 193.5 tcm. This is sufficient to meet 52.6 years of global production at 2017 levels[27].

Those, who study the energy sector, are familiar with the term ` Energy Security.` The International Energy Agency (IEA) defines energy security as the uninterrupted availability of

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[22] BP stat review of world energy 2018. Available at: https://www.bp.com/content/dam/bp/en/corporate/pdf/energy-economics/statistical-review/bp-stats-review-2018-full-report.pdf

[23] Fossil Fuels. https://ourworldindata.org/fossil-fuels#global-fossil-fuel-consumption

[24] Used data from my spreadsheet on Energy Efficiency. Combined data BP2018 and WB2018

[25] Fossil Fuels. https://ourworldindata.org/fossil-fuels#global-fossil-fuel-consumption

[26] BP stat review of world energy 2018. P. 13. Available at: https://www.bp.com/content/dam/bp/en/corporate/pdf/energy-economics/statistical-review/bp-stats-review-2018-full-report.pdf

[27] BP stat review of world energy 2018. P. 27. Available at: https://www.bp.com/content/dam/bp/en/corporate/pdf/energy-economics/statistical-review/bp-stats-review-2018-full-report.pdf

energy sources at an affordable price[28]. Based on this definition, there might be a time when the global production of fossil fuels will reach its maximum rate, followed by a gradual or abrupt decline in production.

For example, such a term as `peak oil` has been looming on the horizon for decades. In 1956, geologist M. King Hubbert at Shell Oil Company (and later at the U.S. Geological Survey) predicted that oil production in the lower 48 U.S. states would peak around 1970. Though his comments generated much controversy, he was later vindicated when institutions such as the National Academy of Sciences and the Energy Information Agency (EIA) confirmed that his now-famous bell curve predicting the 1970 peak was correct, despite industry and government analysts making much rosier predictions [29].

Another Cambridge Energy Research Associates (CERA) research suggested that oil production won't simply reach a peak followed by a steep decline. Instead, "global production will eventually follow an 'undulating plateau for one or more decades before declining slowly." According to the report, regardless of when or how oil production begins to decline, its effects will be global and accompanied by dramatic social, political, economic, and environmental upheaval[30].

While researchers might agree or disagree on declining, one fact remains undebatable – fossil fuels are finite. Undoubtedly, fossil fuels might be extended due to discovering new deposits or improving technologies to extract oil unconventionally from shale rock fragments or tar sands. The parallel economic and affordable renewable energy development process brings the peak oil point closer. Still, it is not moving ahead fast enough to supply us with all the energy needed. As I mentioned earlier, the level of energy consumption by sources remains similar to the one a few decades ago. The World should be preparing for times without fossil fuels faster. Therefore, studying factors improving energy use per capita is essential because it would help diminish the shock of transitioning from fossil fuels to alternative energy sources.

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[28] IEA. Energy security. Reliable, affordable access to all fuels and energy sources. https://www.iea.org/topics/energysecurity/

[29] Lallanilla, M. Peak Oil: Theory or Myth? 2015. https://www.livescience.com/38869-peak-oil.html

[30] Lallanilla, M. Peak Oil: Theory or Myth? 2015. https://www.livescience.com/38869-peak-oil.html

Another limitation is the *geographic location* of non-replenishable energy sources. According to the current estimates, 81.5% of the World's proven crude oil reserves are located in OPEC Member Countries, with the bulk of OPEC oil reserves in the Middle East, amounting to 65.5% of the OPEC total[31]. At the end of 2017, the Middle Eastern region had 47.6% of the total proved oil reserves, while Venezuela - 17.9%[32]. At the end of 2017, 40% of the natural gas reserves were located in the Middle Eastern region and another 30.6% in CIS countries, with the majority in Russian Federation and Turkmenistan.

What does it mean to be the critical resource-based region possessing one of the most traded commodities in the World? On the one hand, this means astronomical revenues from exporting fossil fuels. Assuming that the price of crude oil per barrel is $57[33] and knowing that the current level of Saudi Arabia's crude oil exports is 7,463,400/ day[34], the Kingdom alone receives approximately $373,170,000 of oil revenues daily!

On the other hand, revenues from selling fossil fuels combined with different circumstances, like regional culture or corrupt government, tend to restructure economic, social, and ecological environments. In the Middle East, for instance, governments' practices to redistribute revenues among their citizens impacted the demographic picture of the region. Between 2006 and 2013, the region's population grew by 10% compared to 7% in the US and 4% in the EU and China. The population in the Middle East is expected to double in the next 30 years[35], reaching approximately 800 million people. Such growth increases urban densities, consumerism, and energy use.

Primary Energy Consumption in the ME has increased from 389.6 billion metric tons of oil in 1998 to 895.1 billion metric tons of oil in 2016, which is more than two times[36]. Carbon's report informs us that energy use at home for an average person in a resource-rich country is

[31] Crude Oil Reserves. OPEC. http://www.opec.org/opec_web/en/data_graphs/330.htm
[32] BP stat review of world energy 2018. P. 12. Available at: https://www.bp.com/content/dam/bp/en/corporate/pdf/energy-economics/statistical-review/bp-stats-review-2018-full-report.pdf
[33] Current Crude Oil Prices. https://oilprice.com/
[34] Saudi Arabia facts and figures. OPEC. http://www.opec.org/opec_web/en/about_us/169.htm
[35] The three types of city shaping the Middle East. Worldd Economic Forum. 2015. https://www.weforum.org/agenda/2015/05/the-3-types-of-city-shaping-the-middle-east/
[36] Primary energy consumption in the Middle East from 1998 to 2021. https://www.statista.com/statistics/265594/primary-energy-consumption-in-the-middle-east/

more than three times higher than in a resource-poor one. Similarly, energy use in commercial and public buildings for an average person in a resource-rich country is almost ten times that of an average person in a resource-poor country[37]. For example, a UAE resident consumes 8,271 kilograms of oil equivalent energy (kgoe) per annum, much lower than Qatar's neighbors, with a per capita energy consumption of 12,799 kgoe 12,204 kgoe by the people of Kuwait. In comparison, the per capita energy consumption in the United Kingdom and the United States is 3,254 kgoe and 7,164 kgoe, respectively, while Indians consume 566 kgoe per annum on average.

Despite the tight connections of the UAE and Saudis with the West, the level of trust of the international community in the Middle Eastern fossil fuels sellers will never be the same due to the events of the 1970s Oil Embargo. When asked: `What are the first three words which immediately pop up in your head associated with the ME?` 6 people out of 17 mentioned `conflict or violence.` (see Appendix 1). This mini-survey, as well as the overall Western perception of the region, has a solid basis. This perception might be based on the fact that none of the Middle Eastern countries is a democracy except Israel.

Often, petro-states do not serve as the best examples of order and peace—for instance, a petrostate Venezuela, with its second-largest proven oil reserves. The country has been a subject of the news front lines for many years, primarily due to its' high corruption levels, social instability, economic deprivation, and political turbulence. Venezuela is #134 on the Democracy Index 2018[38]. Russia and Turkmenistan are known for non-diversified economies and authoritarian regimes (144 and 162, consequently.)[39]

In 1983, crude oil futures joined the New York Mercantile Exchange (NYMEX) to be traded like other commodities[40]. Since then, crude oil has been a subject of the international commodities market regulated by the rule of supply and demand. Thus, any fluctuation related to its' availability or price would impact the rest of the World. For example, the slightest conflict

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[37] Elgendy, K. A Visual Guide to Energy Use in Buildings in the Middle East. http://www.carboun.com/sustainable-design/a-visual-guide-to-energy-use-in-buildings-in-the-middle-east/#more-3536
[38] Global insights and market intelligence. http://www.eiu.com/home.aspx
[39] Global insights and market intelligence. http://www.eiu.com/home.aspx
[40] Oil and Gas Pricing. Library of Congress. https://guides.loc.gov/oil-and-gas-industry/pricing#:~:text=In%201983%2C%20crude%20oil%20futures,was%20traded%20like%20other%20commodities

on the Strait of Hormuz would affect the USA, even though the country does not heavily rely upon ME oil, as most of its crude oil comes from Canada (over 50% of imports in 2020[41]).

Unlike in the case of oil, matters related to natural gas tend to have regional consequences. Europe's vulnerability and evident dependence on Russia is a good example. It is not a secret that the country is an important actor, especially when it comes to 'petro-carrots' (using oil and gas to reward allies) and 'petro-sticks' (using resources to punish states which defy the Kremlin). States like Georgia, Ukraine, and the Baltic States have been punished with supply interruptions and higher prices after their governments turned toward the West. Conversely, those who remained friendly to the Kremlin—such as Armenia, Belorussia, Ukraine before 2005, and the tiny statelets of Abkhazia, North Ossetia, and Trans-Dniestria—have been granted ample oil and gas at subsidized prices[42].

Thus, despite the prospect of having access to fossil fuels for at least the next several decades, it is about time to think about global energy use due to the above-mentioned limitations.

The second reason for studying fossil fuel consumption is *environmental concerns, including global warming*, because the extensive use of fossil fuels harms our surroundings.

Conventional energy sources (natural gas, oil, coal, nuclear, and large-scale hydro), especially fossil fuels, are pollutants in nature. Most top managers today recognize the significant financial and strategic benefits of managing operations in a way that minimizes long-term environmental impact[43].

As I mentioned earlier, energy consumption by sources has not changed much in relative terms over the last several decades. At the same time, absolute fossil fuel consumption has increased since 1965. Below is the data provided by the BP 2018 report.

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[41] How much petroleum does the United States import and export? U.S. Energy Information Administration. https://www.eia.gov/tools/faqs/faq.php?id=727&t=6

[42] Newnham, R. Oil, carrots, and sticks: Russia's energy resources as a foreign policy tool, Journal of Eurasian Studies, Volume 2, Issue 2,
2011, Pages 134-143, ISSN 1879-3665, https://doi.org/10.1016/j.euras.2011.03.004.
https://www.sciencedirect.com/science/article/pii/S187936651100011X

[43] Wagner, H. Tax Incentives Make Sustainability More Rewarding.
http://www.areadevelopment.com/taxesIncentives/4-28-2009/sustainability-incentives.shtml

Table 1. Consumption of Fossil Fuels

Fossil Fuel Type	Consumption[45]	
	1965	2017
Oil	30,683 thousand barrels daily	98,186 thousand barrels daily
Natural Gas	630.6 Billion Cubic Metres	3670.4 Billion Cubic Metres
Coal	1388.8 Million tonnes of oil equivalent	3731.5 Million tonnes of oil equivalent

The 2019 version of the interactive Sankey diagram, reflecting the US energy history visualization, shows that the two largest blocks of color represent natural gas and petroleum. Solar and wind energy are represented by lines only a few pixels wide[46].

While there are numerous environmental impacts due to extraction (conventional and non-conventional) and transportation, the most harmful effect of fossil fuels appears during their burning by emitting carbon dioxide and other harmful air pollutants. These emissions lead to various public health and environmental costs at the local, regional, national, and global levels[47]. World's Carbon Dioxide Emissions have increased three times within the last five decades, from 11,190 million tonnes in 1965 to 33,444 in 2017[48]. Based on today's structure of energy sources, decreasing energy consumption per capita and improving energy efficiency would mean using fewer fossil fuels, thus, polluting less.

Besides harming the environment, how else is carbon dioxide dangerous? Most researchers agree that CO2 emissions are the key reason for climate change, global warming, and sea-level rise. Coastal cities are the first ones to feel the effects of environmental changes. Sea level rise and flooding can impact essential energy, transport, and health services. When Hurricane Sandy struck New York in 2012, coastal floods affected an estimated 90,000 buildings,

[45] BP stat review of world energy 2018. P. 12. Available at: https://www.bp.com/content/dam/bp/en/corporate/pdf/energy-economics/statistical-review/bp-stats-review-2018-full-report.pdf
[46] U.S. Energy History Visualization. https://us-sankey.rcc.uchicago.edu/
[47] The Hidden Costs of Fossil Fuels. 2016. https://www.ucsusa.org/clean-energy/coal-and-other-fossil-fuels/hidden-cost-of-fossils
[48] BP stat review of world energy 2018. Available at: https://www.bp.com/content/dam/bp/en/corporate/pdf/energy-economics/statistical-review/bp-stats-review-2018-full-report.pdf

and two million people lost power, which caused extensive damage and disrupted commercial activity to a cost of over $19 billion. By 2050, over 570 low-lying coastal cities will face a projected sea-level rise of at least 0,5 meters. This puts over 800 million people at risk from rising seas and storm surges[49].

In his recently published book Fossil-Fueled Climate Crisis, Raymond Murphy provides interesting statistics about CO2 emissions from heavy passenger planes. The Carbone dioxide emissions for the 17300km roundtrip from Wuhan to Rome are attributable to 2.8 tonnes or 5600 pounds for each economy-class passenger. Multiply those emissions by the billions of passengers flying each year. The result is a massive quantity of Carbone dioxide emissions, which have remained in the atmosphere for a century causing a greenhouse effect and global warming. And aviation is one of many causes of fossil-fouled climate change, albeit an important one without a foreseeable technological solution. Scientific warnings of dangerous climate change have been more numerous than warnings of pandemics. Still, they are also being discounted, emissions continue to exceed carbon withdrawal by forests far, and the problem worsens[50].

The third reason for improving fossil fuel consumption per capita is ***economic benefits***, such as improved energy efficiency, to offset any country's vulnerability.

Today, even a slight energy supply interruption causes discomfort and may lead to unpredictable societal reactions. For example, the most recent cyber-attack on the Colonial Pipeline organized by The Russian criminal group \`DarkSide\` caused a great deal of panic among the population due to the pipeline system being shut down to contain the threat. Shutting down a busy pipeline, which transports more than 100 million gallons of gasoline and other fuel daily from Houston to the New York Harbor, caused an almost immediate reaction from gas stations and drivers of Virginia. Most gas stations closed or remained partially open due to the short gas supply, while hopeless drivers kept driving around, hoping to fill up their gas tanks. While the FBI, Department of Energy, and Department of Homeland Security got quickly engaged in resolving the issue, it took several weeks to turn the situation around from uncertainty back to normal.

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[49] C40. https://www.c40.org/other/the-future-we-don-t-want-staying-afloat-the-urban-response-to-sea-level-rise
[50] Murphy, R. The Fossil-Fuelled Climate Crisis. https://ebookcentral.proquest.com/lib/odu/reader.action?docID=6360869

Using less energy while getting the expected outcome would benefit national economies and help them become less vulnerable. Energy supply and economic growth are closely related[52]. Thus, decreasing a country's vulnerability is vital to improving energy efficiency. In the U.S., for example, energy efficiency has been essential to the nation's energy strategy since the first oil crisis in 1973[53]. To sustain some certainty in tomorrow's day, any aspect of improving energy efficiency should be studied and observed.

1.3.1. HYDROELECTRIC POWER

According to the latest BP 2018 report, hydroelectricity consumption has increased since 1965 from 208.1 mln tonnes of oil equivalent to 918.6 in 2017. In relative terms, it constituted only 6.7% of the total energy consumed in 2017. Hydropower plants provide much-needed flexibility to the power grid in terms of demand and supply of power. While it is trendy to think that hydropower is the cleanest energy source, it also has a damaging compound, primarily during construction. Another limitation relates to the current capability to produce energy, which will never fully satisfy the World's needs.

1.3.2. NUCLEAR POWER

If the Nuclear Energy Agency (NEA) has accurately estimated the planet's economically accessible uranium resources, reactors could run more than 200 years at current consumption rates. Thus, nuclear is considered a necessary supplementary energy source to shift from fossil fuels to renewables entirely.

Nuclear energy consumption in 1965 was 5.8 million tonnes oil equivalent and in 2017 - 596.4.

Limitations of nuclear are limited access to fuel worldwide, radioactive byproducts, hazardous effects from potential leaks, and other accidents.

Although the American domestic uranium mining industry is on the edge of a shutdown, plenty of uranium is mined worldwide, mostly in countries very friendly to the United States. These include Australia, Canada, Kazakhstan — which has the World’s largest uranium deposits — and Namibia.

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[52] Thinking Ahead for the Mediterranean. https://www.medpro-foresight.eu/system/files/MEDPRO%20TR%20No%2027%20WP4b%20Bergasse_2.pdf

[53] Energy Intensity Indicators. https://www.energy.gov/eere/analysis/energy-intensity-indicators

The American experts name several other limitations, namely the lack of a domestic market for new reactors and keeping those plants now operating going. Nuclear sites are at an economic disadvantage in the face of meager natural gas prices and equally low costs for electricity from wind and solar. The market is rigged in favor of the spot price today. It takes no account of probable costs in the out-years of the environmental benefits of specific technologies, particularly nuclear.

1.3.3. NON-CONVENTIONAL ENERGY SOURCES

Less traditional ways of extracting energy are also called non-conventional. Wind, solar, small hydro, tides, geothermal heat, and biomass are among them. All these sources are renewable. Their negative impact on the environment is insignificant compared to the traditional sources of generating energy. I review only wind and hydro since tidal and geothermal are in limited use now.

While newer resources are being developed, wind, solar, and bio are considered the most common non-conventional energy sources. Despite the significant benefit of being renewable, non-conventional sources are associated with a high cost of harnessing energy, availability uncertainty, and transportation difficulty.

Data on the use of renewables is relatively new. Within the last several decades, consumption of non-conventional sources has increased in absolute terms. For example, solar energy had risen from 0.1 mln tonnes of oil equivalent in 1989 to 100.2 in 2017. The increase applies to the wind: 0.1 mln tonnes of oil equivalent in 1988 and 254.00 in 2017.

As mentioned earlier, the use of renewable energy, including non-conventional ones, has not increased in relative terms. Energy consumption rises faster than renewable energy generation can catch up.

One of the major reasons is the high cost of generating energy using non-conventional sources. A report claims that renewable energy will soon be consistently cheaper than fossil fuels[54]. Nevertheless, transitioning from fossil fuels to renewables will be hard. Thus, we need to think about efficiency regardless of the energy sources the World currently uses. However,

[54] Dudley, D. Renewable Energy Will Be Consistently Cheaper Than Fossil Fuels By 2020, Report Claims. 2018. https://www.forbes.com/sites/dominicdudley/2018/01/13/renewable-energy-cost-effective-fossil-fuels-2020/#615b1d7f4ff2

because fossil fuels are still a primary source of Worrld'ss energy, one must put more effort into researching triggest that impact their use per capita.

1.4. RESEARCH STRUCTURE AND MAJOR FINDINGS

My research is about how some variables shape global fossil fuel consumption. The core question of my research is, ` Why do some countries consume less fossil fuels per capita than others?` The available data on World's Fossil Fuel Consumption per capita has shown an upward trend since 1965. World's Fossil Fuel Consumption per capita has steadily increased from 12,116 Twh in 1965 to 17,197 Twh in 2021. And the upward trend is expected to continue. At the same time, the World's trend is not consistent among individual countries. It means that countries with the increasing trend might learn some practices from countries experiencing the opposite trend.

The currently available literature determines the relevance of my research. I utilize literature containing any energy use analysis explained by the independent and control variables mentioned above for search parameters. For those variables where the literature is scarce (for example, fossil fuels), I have included most of the related and available research I could find. When the available literature was abundant, I included only those pieces that would help me shape my research.

Researchers use various methods to explain energy use. The most common approach utilizes the quantitative method to explore the dependent variable across multiple countries. For example, Saucedo et al. estimated static and dynamic panel data models to identify the relationship between CO2 emissions per capita, GDP per capita, energy consumption, and environmental taxes for OECD countries in 1994-2014[55]. Studies with a broad scope of analysis of multiple countries and long periods often use a mixed analysis method. For example, Thonipara et al. took on an exploratory and mixed methods approach to shed some light on some of the energy efficiency policies that had previously been neglected, such as district heating and carbon taxation[56].

[55] Estimating Environmental Kuznets Curve. https://www-proquest-com.proxy.lib.odu.edu/docview/2068860158?accountid=12967&pq-origsite=primo

[56] Thonipara, A., Petrik Runst, Christian Ochsner, Kilian Bizer, Energy efficiency of residential buildings in the European Union – An exploratory analysis of cross-country consumption patterns, Energy Policy, Volume 129, 2019, Pages 1156-1167, ISSN 0301-4215,

Some authors focus on particular aspects of energy use. For example, Thonipara et al. explored energy efficiency in residential buildings and construction[57], Harding et al. studied energy use taxes in 21 European Union countries and across all OECD countries[58], Sachs et al. have observed seasonal and spatial changes in global heating and cooling energy demand[59], gasoline consumption for road transport[60] , etc.

Motives of other researchers studying what shapes energy use evolve around two main areas: environmental and economic. Among environmental ones are: mitigating the effects of human activities, such as lowering greenhouse gas emissions (Pata, 2018[61], Cottrell et al., 2016[62]) or addressing climate change in general, which has become a key theme for many policy initiatives (Thonipara et al., 2019[63], Wang et al., 2020[64]). The economic area includes but is not limited to such topics as improving economic growth or, in other words, establishing economic

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https://doi.org/10.1016/j.enpol.2019.03.003. https://www-sciencedirect-com.proxy.lib.odu.edu/science/article/pii/S0301421519301661

[57] Thonipara, A., Petrik Runst, Christian Ochsner, Kilian Bizer, Energy efficiency of residential buildings in the European Union – An exploratory analysis of cross-country consumption patterns, Energy Policy, Volume 129, 2019, Pages 1156-1167, ISSN 0301-4215, https://doi.org/10.1016/j.enpol.2019.03.003. https://www-sciencedirect-com.proxy.lib.odu.edu/science/article/pii/S0301421519301661

[58] Taxing Energy Use: Patterns and Incoherencies in Energy Taxation in Europe and the OECD https://link.springer.com/chapter/10.1007/978-3-319-21302-6_11

[59] Sachs, J., Diego Moya, Sara Giarola, Adam Hawkes, Clustered spatially and temporally resolved global heat and cooling energy demand in the residential sector, Applied Energy, Volume 250, 2019, Pages 48-62, ISSN 0306-2619, https://doi.org/10.1016/j.apenergy.2019.05.011. https://www.sciencedirect.com/science/article/pii/S0306261919308657

[60] Burke, P., Shuhei Nishitateno, Gasoline prices, gasoline consumption, and new-vehicle fuel economy: Evidence for a large sample of countries, Energy Economics, Volume 36, 2013, Pages 363-370, ISSN 0140-9883, https://doi.org/10.1016/j.eneco.2012.09.008. https://www-sciencedirect-com.proxy.lib.odu.edu/science/article/pii/S0140988312002228

[61] Pata, U. Renewable energy consumption, urbanization, financial development, income and CO2 emissions in Turkey: Testing EKC hypothesis with structural breaks, Journal of Cleaner Production, Volume 187, 2018, Pages 770-779, ISSN 0959-6526, https://doi.org/10.1016/j.jclepro.2018.03.236. https://www-sciencedirect-com.proxy.lib.odu.edu/science/article/pii/S0959652618309132?via%3Dihub

[62] Environmental Tax Reform in Developing, Emerging and Transition Economies https://www.die-gdi.de/uploads/media/Study_93.pdf

[63] Assessment of climate change impacts on energy capacity planning in Ontario, Canada using high-resolution regional climate model https://www-sciencedirect-com.proxy.lib.odu.edu/science/article/pii/S0301421519301661

[64] Wang, S., Jinxin Zhu, Gordon Huang, Brian Baetz, Guanhui Cheng, Xueting Zeng, Xiuquan Wang, Assessment of climate change impacts on energy capacity planning in Ontario, Canada using high-resolution regional climate model, Journal of Cleaner Production, Volume 274, 2020, 123026, ISSN 0959-6526, https://doi.org/10.1016/j.jclepro.2020.123026. https://www.sciencedirect.com/science/article/pii/S0959652620330717

benefits from lower energy consumption (Bakirtas & Akpolat, 2018[65], Yang et al., 2016[66]); and diminishing energy security issues (Wang et al., 2020[67]).

A significant portion of the available research sheds light on local issues of a particular country or region and with a limited number of variables. For example, Sadorsky used urbanization and industrialization variables to investigate their impact on energy consumption in a panel of emerging economies[68]. Gillingham and Munk-Nielsen analyzed how fuel price changes impact the driving habits of households across the population[69]. Only a few studies have attempted to explain how multiple independent and control variables shape energy use globally. For instance, Al-mulali explores how urbanization, energy consumption, and CO2 emission in MENA countries[70].

Overall, the available literature does not answer a straightforward question: which variables shape fossil fuels use per capita across countries and which do not. Given the upward global trend of fossil fuels energy use, the answer to this question would become a great benefit to researchers studying energy use, to policymakers working on the improvements of the existing policies, to resource managers of all levels, from a small production line to any government, and even to average homeowners.

I use a multivariate framework to answer the central question, including three independent and two control variables. Pump price for gasoline, Urbanization, and Fossil Fuel

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[65] Bakirtas, T., Ahmet Gokce Akpolat, The relationship between energy consumption, urbanization, and economic growth in new emerging-market countries, Energy, Volume 147, 2018, Pages 110-121, ISSN 0360-5442, https://doi.org/10.1016/j.energy.2018.01.011.https://www-sciencedirect-com.proxy.lib.odu.edu/science/article/abs/pii/S0360544218300112

[66] Yang, J., Wei Zhang, Zongyi Zhang, Impacts of urbanization on renewable energy consumption in China, Journal of Cleaner Production, Volume 114, 2016, Pages 443-451, ISSN 0959-6526, https://doi.org/10.1016/j.jclepro.2015.07.158. https://www-sciencedirect-com.proxy.lib.odu.edu/science/article/pii/S0959652615010896

[67] Wang, S., Jinxin Zhu, Gordon Huang, Brian Baetz, Guanhui Cheng, Xueting Zeng, Xiuquan Wang, Assessment of climate change impacts on energy capacity planning in Ontario, Canada using high-resolution regional climate model, Journal of Cleaner Production, Volume 274, 2020, 123026, ISSN 0959-6526, https://doi.org/10.1016/j.jclepro.2020.123026. https://www-sciencedirect-com.proxy.lib.odu.edu/science/article/pii/S0959652620330717

[68] The Effect of Urbanization and Industrialization on Energy Use in Emerging Economies: Implications for Sustainable Development. https://onlinelibrary.wiley.com/doi/full/10.1111/ajes.12072

[69] A tale of two tails: Commuting and the fuel price response in driving. https://www-sciencedirect-com.proxy.lib.odu.edu/science/article/pii/S0094119018300779?via%3Dihub

[70] Exploring the relationship between urbanization, energy consumption, and CO2 emission in MENA countries https://www-sciencedirect-com.proxy.lib.odu.edu/science/article/abs/pii/S1364032113001433?via%3Dihub

Imports. In the World of interconnectedness, numerous biases can be escaped while conducting research. That is why to prevent certain variables from influencing the outcome of a study, I chose to control for Latitude and GDP per capita.

My research is built upon three Hypotheses:

1. In a comparison of countries, higher pump prices are associated with a decrease in Fossil Fuels Consumption per Capita compared to those with lower pump prices;

2. In a comparison of countries, a greater urban percentage of the population is associated with a decrease in Fossil Fuels Consumption per Capita compared to those with a less urbanized population;

3. In a comparison of countries, higher fuel imports are associated with a decrease in Fossil Fuels Consumption per Capita compared to those with lower fuel imports.

To conduct the research, I use a mixed-method approach. This research design has become popular lately because of combining qualitative and quantitative data. The mixed-method approach allows one to understand a given topic better. It also adds value by increasing the validity of the findings and assisting with knowledge creation[71].

The quantitative method tests the relationships between FFCC and the Independent variables. As a basis, I use a sample of 28 OECD counties to design and test a model for 2009-2018 (The Model). Thus, the sample has two hundred and eighty observations. Data used in this Model will come from two online databases available for free use: World Bank and British Petroleum.

The output of the multiple regression analysis shows that the Model explains 40% of the variance in the Dependent Variable and leaves the rest unexplained. P-values for all variables are less than 0.05. It means that test results are statistically significant, and Null Hypothesis can be rejected for the entire population.

Coefficients outcomes indicate that for every additional percent of fuel imports in merchandise, one can expect FFCC to increase by 0.06 million tonnes of oil equivalent per capita; for every additional dollar increase of pump price for gasoline per liter, one can expect FFCC to

[71] Hurmerinta-Peltomaki, L., Nummela N. (2006). Mixed methods in international business research: A value-added perspective. Management International Review, 46, 439-459.

decrease by -1.33 million tonnes of oil equivalent per capita; for every additional $1000 increase in GDP, one can expect FFCC to increase by 0.03 million tonnes of oil equivalent per capita; for every additional percent increase of Urban population in the total population, one can expect FFCC to increase by 0.03 million tonnes of oil equivalent per capita. For every additional unit increase in Latitude, one can expect FFCC to increase by 0.01 million tonnes of oil equivalent per capita.

The Pump Price coefficient result supports H1. Because the Pump Price coefficient is closer to 1 than other coefficients, H1 has a greater validity or, in other words - reliability. With various energy sustainability approaches in modern cities, especially in countries of higher economic development, I expected the Model to support Hypotheses #2 (H2). To my surprise, the regression results do not support H2. Hypothesis #3 (H3) is not supported by the regression results either. I expected a higher fuel import percentage of merchandise would be associated with decreased FFCC. Instead, the above outcome is the opposite.

To gain a more in-depth understanding of FFCC across countries through studying local specifics, I use a qualitative method to review three case studies (Finland, Canada, and Colombia). This would help explain why the Model fits well in some instances and not in other cases.

The qualitative analysis of the three case studies clearly illustrated that studying local specifics could explain why some countries fit the Model better than others. Finland, for instance, imports all of its fossil fuels for domestic consumption, which, in a way, makes consumers value it more. To some extent, this explains the country's intention to become carbon-neutral in almost one decade. Finland's doors are wide open for investments in renewable energy.

Finland's petrol prices are the 5th highest in the European Union, encouraging final consumers to seek alternatives to conventional sources for commuting and energy. Also, refining is conducted by just one company, which eliminates competition rules on the domestic market and, thus, leads to higher pump prices and lower purchasing ability of a final consumer. Such local conditions make Finland's approach to consuming fossil fuels per capita almost an ideal candidate to fit the Model.

Canada's local situation concerning fossil fuel consumption per capita differs from Finland's. Firstly, because the country is a net exporter, imported fossil fuels, mainly crude oil, are less valued by a final consumer. Furthermore, the Canadian market among miners, refiners, and distributors is high. This creates a situation when abundance among competitors does not allow suppliers to neglect cost reduction efforts, which then positively impacts a final gasoline consumer at a pump by enabling them to consume more due to a lower price. All mentioned above explains why Canada does not fit the Model well, despite significant efforts of urbanized communities to pursue energy efficiency.

Colombian government interventions regarding pump prices prevent the country from fitting the Model. The country has been subsidizing gasoline consumption nationwide for decades. This created a situation when market rules could not balance the final prices based on demand and supply. After being `spoiled` by low gasoline prices, the Colombian population does not welcome new initiatives promoting a gradual shift from the highly regulated environment to the one regulated by supply and demand. This makes Colombia an apparent outlier in my Model.

1.5. OVERVIEW OF THE DISSERTATION'S STRUCTURE

The dissertation is composed of the following Chapters:

Chapter 1. What is it all about?

Chapter 2. Literature Review.

Chapter 3. Methodology.

Chapter 4. Research Findings.

Chapter 5. Case Studies.

Chapter 6. Conclusion.

The first chapter introduces the reader to the global energy consumption trend, explains the relevance of researching fossil fuel consumption per capita, and presents the research structure and major findings. The second one assesses what the current research says about global energy consumption across countries and shows that this is a relevant topic to discuss. The third chapter presents the research question and hypotheses, narrates the methodological approach, introduces readers to the specifics of the data collection, talks about the methods of analysis, and describes all the variables used in my research. Chapter Four presents the results of the quantitative research. Chapter Five explores the local conditions of Finland, Canada, and

Colombia to see why some cases fit well within the Model, and others do not. Chapter Six explains the results and summarizes key findings.

CHAPTER 2

LITERATURE REVIEW

2.1. INTRODUCTION

Today, the pace of economic growth and industrialization activities is highly contingent on energy consumption[72]. The trend of energy use is well illustrated by the Inside Energy project, which matched up energy use data from the EIA with population data from the U.S. Census Bureau to get a picture of how our per person energy use has changed over time back to 1790[73][74]. With a few sharp peaks and drops around the oil crisis of 1971-1973 and a significant decline during the 2008 recession, the trend of energy use per capita has been increasing from about 90 Mln BTU per person in 1970 to a little over 300 Mln BTU per person in 2015[75].

This increasing trend also relates to fossil fuel use per capita. For example, in 1965, the World consumed 12,104 kWh of fossil fuels per capita. The number increased to 16,492 kWh in 2020, even lower than 17,649 kWh in 2019 [76].

When looking at fossil fuels consumption per capita across countries, one can notice that trends differ individually. Some countries have significantly decreased their per capita use in recent years, some started using a little less, and some show an upward trend. For example, after the peak in the 80s in Germany, fossil fuel consumption per capita steadily decreased from around 50,000 kWh to 30,398 kWh in 2020. The U.S. started consuming less per capita in the recent decade, but the slope does not look as rapid as in Germany. The U.S. fossil fuels consumption was 69,082 in 1965, and after a few peaks in the 70-s went down to 60,167 in 2020.

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[72] Shahzad, U. Environmental taxes, energy consumption, and environmental quality: Theoretical survey with policy implications. Environ Sci Pollut Res 27, 24848–24862 (2020). https://doi-org.proxy.lib.odu.edu/10.1007/s11356-020-08349-4

[73] U.S. Energy History Vosualization. https://us-sankey.rcc.uchicago.edu/

[74] Robert Suits, Nathan Matteson,Elisabeth Moyer. Energy Transitions in U.S. History, 1800–2019 Center of Robust Decision-making on Climate and Energy Policy. (2020). https://static1.squarespace.com/static/54dcfad0e4b0eaff5e0068bf/t/5fbeba6ffa04221c71019ccc/1606335091993/Suits_Matteson_Moyer_2020_Energy_Transitions.pdf

[75] Jordan Wirfs-Brock. Energy Explained: Where Does It Come From And How Much Do We Use? (2017). http://insideenergy.org/2017/01/12/energy-explained/

[76] Hannah Ritchie, Pablo Rosado and Max Roser. Fossil Fuels. https://ourworldindata.org/fossil-fuels

Studying global energy use, particularly fossil fuel consumption, might shed some light on reducing per capita consumption in countries still experiencing increasing per capita consumption.

This chapter aims to understand where the existing research on energy use, particularly fossil fuels, stands. Studying prior scholarship would help me to identify research gaps, learn about unresolved issues, and determine the need for further research.

Assessing the existing literature will also help me to frame my research and better answer why some countries use less Fossil Fuels than others. I divide this chapter into two sections. One is devoted to pump price and its determinants, urbanization, and fossil fuel imports), and the other to control variables (Latitude and GDP per capita).

I utilize literature containing any energy use analysis explained by the independent and control variables mentioned above for search parameters.

Researchers use various methods to explain energy use. The most common approach utilizes the quantitative method to explore the dependent variable across multiple countries. For example, Saucedo et al. estimated static and dynamic panel data models to identify the relationship between CO2 emissions per capita, GDP per capita, energy consumption, and environmental taxes for OECD countries in 1994-2014[77]. Studies with a broad scope of analysis of multiple countries and long periods often use a mixed analysis method. For example, Thonipara et al. took on an exploratory and mixed methods approach to shed some light on some of the energy efficiency policies that had previously been neglected, such as district heating and carbon taxation[78].

Some authors focus on particular aspects of energy use. For example, Thonipara et al. explored energy efficiency in residential buildings and construction[79], Harding et al. studied

[77] Saucedo E., Díaz J., Parra, M. ESTIMATING ENVIRONMENTAL KUZNETS CURVE: THE IMPACT OF ENVIRONMENTAL TAXES AND ENERGY CONSUMPTION IN CO2 EMISSIONS OF OECD COUNTRIES. Dubrovnik Vol. 3, Iss. 1, Dubrovnik: University of Dubrovnik. (Nov 2017): 901-912.https://www-proquest-com.proxy.lib.odu.edu/docview/2068860158?accountid=12967&pq-origsite=primo

[78] Thonipara, A., Petrik Runst, Christian Ochsner, Kilian Bizer, Energy efficiency of residential buildings in the European Union – An exploratory analysis of cross-country consumption patterns, Energy Policy, Volume 129, 2019, Pages 1156-1167, ISSN 0301-4215, https://doi.org/10.1016/j.enpol.2019.03.003 or https://www-sciencedirect-com.proxy.lib.odu.edu/science/article/pii/S0301421519301661

[79] Energy efficiency of residential buildings in the European Union – An exploratory analysis of cross-country consumption patterns. https://www-sciencedirect-com.proxy.lib.odu.edu/science/article/pii/S0301421519301661

energy use taxes in 21 European Union countries and across all OECD countries[80], Sachs et al. have observed seasonal and spatial changes in global heating and cooling energy demand[81], gasoline consumption for road transport[82] , etc.

Motives of other researchers studying what shapes energy use evolve around two main areas: environmental and economic. Among environmental ones are: mitigating the effects of human activities, such as lowering greenhouse gas emissions (Pata, 2018[83], Cottrell et al., 2016[84]) or addressing climate change in general, which has become a key theme for many policy initiatives (Thonipara et al., 2019[85], Wang et al., 2020[86]). The economic area includes but is not limited to such topics as: improving economic growth or, in other words, establishing economic

[80] Harding, Michelle & Martini, Chiara & Thomas, Alastair. (2016). Taxing Energy Use: Patterns and Incoherencies in Energy Taxation in Europe and the OECD. 31. 233-264. 10.1007/978-3-319-21302-6_11. https://link.springer.com/chapter/10.1007/978-3-319-21302-6_11

[81] Sachs, J., Diego Moya, Sara Giarola, Adam Hawkes, Clustered spatially and temporally resolved global heat and cooling energy demand in the residential sector, Applied Energy, Volume 250, 2019, Pages 48-62, ISSN 0306-2619, https://doi.org/10.1016/j.apenergy.2019.05.011 (https://wwwsciencedirect.com/science/article/pii/S0306261919308657)

[82] Burkem, P., Shuhei Nishitateno. Gasoline prices, gasoline consumption, and new-vehicle fuel economy: Evidence for a large sample of countries. Australian Nationall University. (2011). https://www-sciencedirect-com.proxy.lib.odu.edu/science/article/pii/S0140988312002228

[83] Pata, U., Renewable energy consumption, urbanization, financial development, income and CO2 emissions in Turkey: Testing EKC hypothorkut esis with structural breaks, Journal of Cleaner Production, Volume 187, 2018, Pages 770-779, ISSN 0959-6526, https://doi.org/10.1016/j.jclepro.2018.03.236. (https://www.sciencedirect.com/science/article/pii/S0959652618309132)

[84] Cottrell, J., Kai Schlegelmilch, Matthias Runke, Alexander Mahler. Environmental Tax Reform in Developing, Emerging and Transition Economies. German Development Institute. https://www.die-gdi.de/uploads/media/Study_93.pdf

[85] Thonipara, A., Petrik Runst, Christian Ochsner, Kilian Bizer, Energy efficiency of residential buildings in the European Union – An exploratory analysis of cross-country consumption patterns, Energy Policy, Volume 129, 2019, Pages 1156-1167, ISSN 0301-4215, https://doi.org/10.1016/j.enpol.2019.03.003. (https://www-sciencedirect-com.proxy.lib.odu.edu/science/article/pii/S0301421519301661)

[86] Wang, S., Jinxin Zhu, Gordon Huang, Brian Baetz, Guanhui Cheng, Xueting Zeng, Xiuquan Wang, Assessment of climate change impacts on energy capacity planning in Ontario, Canada using high-resolution regional climate model, Journal of Cleaner Production, Volume 274, 2020 123026, ISSN 0959-6526, https://doi.org/10.1016/j.jclepro.2020.123026 (https://www.sciencedirect.com/science/article/pii/S0959652620330717)

benefits from lower energy consumption (Bakirtas & Akpolat, 2018[87], Yang et al., 2016[88]); and diminishing energy security issues (Wang et al., 2020[89]).

A significant portion of the available research sheds light on local issues of a particular country or region and with a limited number of variables. For example, Sadorsky used urbanization and industrialization variables to investigate their impact on energy consumption in a panel of emerging economies[90]. Gillingham and Munk-Nielsen analyzed how fuel price changes influence the driving habits of households across the population[91]. Only a few studies have attempted to explain how multiple independent and control variables shape energy use globally. For instance, Al-mulali explores how urbanization, energy consumption, and CO2 emission in MENA countries[92].

Overall, the available literature does not answer a straightforward question: which variables shape fossil fuels use per capita across countries and which do not? Given the upward global trend of energy use, the answer to this question would become a great benefit to researchers studying energy use, to policymakers working on the improvements of the existing

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[87] Bakirtas, T., Ahmet Gokce Akpolat, The relationship between energy consumption, urbanization, and economic growth in new emerging-market countries, Energy, Volume 147, 2018, Pages 110-121, ISSN 0360-5442, https://doi.org/10.1016/j.energy.2018.01.011. (https://www-sciencedirect-com.proxy.lib.odu.edu/science/article/abs/pii/S0360544218300112)

[88] Yang, J., Wei Zhang, Zongyi Zhang, Impacts of urbanization on renewable energy consumption in China, Journal of Cleaner Production, Volume 114, 2016, Pages 443-451, ISSN 0959-6526, https://doi.org/10.1016/j.jclepro.2015.07.158. https://www-sciencedirect-com.proxy.lib.odu.edu/science/article/pii/S0959652615010896

[89] Assessment of climate change impacts on energy capacity planning in Ontario, Canada using high-resolution regional climate model, Journal of Cleaner Production, Volume 274 2020, 123026, ISSN 0959-6526, https://doi.org/10.1016/j.jclepro.2020.123026. (https://www-sciencedirect-com.proxy.lib.odu.edu/science/article/pii/S0959652620330717)

[90] Sadorsky, P. The Effect of Urbanization and Industrialization on Energy Use in Emerging Economies: Implications for Sustainable Development. The American Journal of Economics and Sociology. 2014. https://onlinelibrary.wiley.com/doi/full/10.1111/ajes.12072

[91] Gillingham, K., Anders Munk-Nielsen, A tale of two tails: Commuting and the fuel price response in driving, Journal of Urban Economics, Volume 109, 2019, Pages 27-40, ISSN 0094-1190, https://doi.org/10.1016/j.jue.2018.09.007. (https://www-sciencedirect-com.proxy.lib.odu.edu/science/article/pii/S0094119018300779?via%3Dihub)

[92] Al-Mulali, U., Hassan Gholipour Fereidouni, Janice Y.M. Lee, Che Normee Binti Che Sab, Exploring the relationship between urbanization, energy consumption, and CO2 emission in MENA countries, Renewable and Sustainable Energy Reviews, Volume 23, 2013, Pages 107-112, ISSN 1364-0321, https://doi.org/10.1016/j.rser.2013.02.041. (https://www-sciencedirect-com.proxy.lib.odu.edu/science/article/abs/pii/S1364032113001433?via%3Dihub)

policies, to resource managers of all levels, from a small production line to any government, and even to average homeowners.

In the conclusion section, I summarize the literature review results and briefly present my approach to explaining how the independent and control variables shape energy use worldwide.

2.2. DETERMINANTS OF GASOLINE PUMP PRICE ACROSS COUNTRIES

The pump price is a retail price per one unit of motor gasoline paid by a consumer at a gas station. I am looking at the pump price variable because transport is the fastest-growing sector for greenhouse gas emissions[93], a sign of transportation's upward trend in fuel consumption.

My search parameters of the literature are any analysis of energy efficiency, energy use, energy intensity, and primary energy consumption related to pump or fuel prices for gasoline. While extensive and mature literature exists on studying and estimating the demand for transportation fuels in different settings, most of these studies have focused on the response of fuel demand to changes in the fuel price or consumers' income[94].

There are several components of the retail (pump) price of gasoline paid by consumers. Among them are crude oil costs, refining costs, and profits; distribution and marketing costs, plus a reasonable profit margin; and local, state, and federal taxes[95]. The price of oil has a major effect on the U.S. economy and the economies of other countries. Results of an empirical model of the relationship between crude oil price and gas consumption, natural gas price, and coal price in the U.S. showed that crude oil price is related to gas consumption, natural gas price, and coal price[96]. Historically, changes in gasoline and diesel prices mirror those of crude oil prices, which are determined in the global crude oil market by the worldwide demand for and supply of crude oil.

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[93] [93] Gillingham, K., Anders Munk-Nielsen, A tale of two tails: Commuting and the fuel price response in driving, Journal of Urban Economics, Volume 109, 2019, Pages 27-40, ISSN 0094-1190, https://doi.org/10.1016/j.jue.2018.09.007. https://www.sciencedirect.com/science/article/pii/S0094119018300779?via%3Dihub

[94] Afkhami, M., Hamed Ghoddusi, Nima Rafizadeh, Google Search Explains Your Gasoline Consumption!, Energy Economics, Volume 99, 2021, 105305, ISSN 0140-9883 https://doi.org/10.1016/j.eneco.2021.105305. https://www.sciencedirect.com/science/article/pii/S0140988321002103

[95] Gas Prices Explained. American Petroleum Institute. https://gaspricesexplained.com/#/?section=whatconsumers-are-paying-for-at-the-pump

[96] Hassan, M. An Empirical Model Of The Relationship Between Crude Oil Price and Gas Consumption, Natural Gas Price, And Coal Price in the U.S. 2014. Wiley College. https://www.iabpad.com/a-empirical-model-of-the-relationship-between-crude-oil-price-and-gas-consumption-natural-gas-price-and-coal-price-in-the-united-states/

Per-barrel costs for crude oil – the number one factor in producing gasoline and diesel – reflect the global oil supply/demand balance and inventories, among other factors. Thus, oil prices are the #1 factor in motor fuel production[97]. U.S. refiners are passing the price of imported crude oil price to the retail price of gasoline within the same month, as are exogenous shocks to the cost of refining. However, the retail supply curve for gasoline is treated as perfectly elastic in the short run. The presumption is that gasoline distributors have enough gasoline stored in underground tanks to supply the required quantities of gasoline at the current retail price[98].

Road transport, in particular, is the most significant use of transport energy[99]. Motor gasoline remains the largest transportation fuel, but its share of total transportation energy consumption declined from 39% in 2012 to 33% in 2040[100]. Therefore, a high level of gasoline consumption might provide enough evidence for researching the relationship between pump price and consumption.

Due to global lockdown measures, road transport in regions with lockdowns has dropped between 50% and 75%, with global average road transport activity almost falling to 50% of the 2019 level by the end of March 2020.[101] However, more gasoline is expected to be consumed this summer than last, but not more than in 2019[102]. Thus, the World is quickly approaching the level of gasoline consumption in the pre-Covid era.

Consumer demand for a common good is mainly shaped by the price of the good, the consumers' disposable income, the price of complementary goods, and the relative attractiveness of substitutes.[103] The pump price is not an exception since the majority of literature on studying and estimating the demand for transportation fuels focuses on the

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[97] Gas Prices Explained. American Petroleum Institute. https://gaspricesexplained.com/#/?section=whatconsumers-are-paying-for-at-the-pump

[98] Kilian, L. (2010). Explaining Fluctuations in Gasoline Prices: A Joint Model of the Global Crude Oil Market and the U.S. Retail Gasoline Market. The Energy Journal, 31(2), 87–112. http://www.jstor.org/stable/41323283 (https://www-jstor-org.proxy.lib.odu.edu/stable/41323283?seq=10#metadata_info_tab_contents)

[99] Harding, M., Martini, C., & Thomas, A. (2014). Taxing Energy Use in the OECD. Economics of Energy & Environmental Policy, 3(1), 19–36. http://www.jstor.org/stable/26189262

[100] Transportation sector energy consumption. EIA. https://www.eia.gov/outlooks/ieo/pdf/transportation.pdf

[101] Global Energy Review 2020. EIA. https://www.iea.org/reports/global-energy-review-2020/oil

[102] More gasoline expected to be consumed this summer than last, but not more than in 2019. U.S. Energy Information Administration. https://www.eia.gov/todayinenergy/detail.php?id=47476

[103] Afkhami, M., Hamed Ghoddusi, Nima Rafizadeh, Google Search Explains Your Gasoline Consumption!, Energy Economics, Volume 99, 2021, 105305, ISSN 0140-9883 https://doi.org/10.1016/j.eneco.2021.105305. https://www.sciencedirect.com/science/article/pii/S0140988321002103

response of fuel demand to changes in two factors, i.e., the fuel price or consumers' income[104]. Most available research indicates a positive relationship between pump price and gasoline consumption.

As of January 2019, crude oil costs accounted for 53 percent of what people were paying at the pump, per the U.S. Energy Information Administration. Excise taxes averaged another 17 percent. That leaves 30 percent for the refiners, distributors, and retailers[105].

Several articles discuss the connection between energy consumption and the pump price. Goodwin and Hanly, for example, have established that if the real price of fuel rises by 10% and stays at that level, the volume of traffic will fall by roundly 1% within about a year, building up to a reduction of about 3% in the longer run (about five years or so) while the volume of fuel consumed will fall by about 2.5% within a year, building up to a reduction of over 6% in the longer run. The fuel consumed falls by more than the traffic volume is probably because price increases trigger a more efficient use of fuel (by a combination of technical improvements to vehicles, more fuel-conserving driving styles, and driving in easier traffic conditions). A further probable differential effect is between high- and low-consumption vehicles since, with high prices, gas guzzlers are more likely to be the vehicles left at home or scrapped[106].

One of the questions Gillingham and Munk-Nielsen have tried to answer was how households across the population change their driving in response to fuel price changes. The research has found that fuel price changes significantly impact certain changes in drivers' behaviors. Particularly, those categories with adequate access to public transport would readily switch from driving to using public transport if fuel prices go up[107].

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[104] Google Search Explains Your Gasoline Consumption!, Energy Economics, Volume 99, 2021, 105305, ISSN 0140-9883 https://doi.org/10.1016/j.eneco.2021.105305.
https://www.sciencedirect.com/science/article/pii/S0140988321002103

[105] Gas Prices Explained. Amerrican Petroleum Institute.
https://gaspricesexplained.com/#/?section=whatconsumers-are-paying-for-at-the-pump

[106] Goodwin, P.J.D. and M. Hanly (2004). "Elasticities of Road Traffic and Fuel Consumption with Respect to Price and Income: A Review." *Transport Reviews: A Transnational Transdisciplinary Journal,* 24(3): 275–92. Retrieved from: http://web.a.ebscohost.com.proxy.lib.odu.edu/ehost/detail/detail?vid=0&sid=63f7978e-04c1-4db4-8f8c-815fac8f63b9%40sdc-v-sessmgr02&bdata=JnNjb3BlPXNpdGU%3d#AN=13532137&db=bth

[107] A tale of two tails: Commuting and the fuel price response in driving
https://www-sciencedirect-com.proxy.lib.odu.edu/science/article/pii/S0094119018300779?via%3Dihub

Analyzing hybrid vehicle demand determinants has shown that higher gasoline prices have increased hybrid vehicle sales[108]. This trend indirectly illustrates that final consumers tend to react to gasoline price changes in a way that would decrease their consumption of gasoline.

According to another study, compared with the developed countries (e.g., the United States), China's gasoline demand elasticity is not high; however, a certain tax adjustment leading to increased gasoline prices can still guide consumers towards saving energy by decreasing gasoline consumption[109].

Analyses of policies to reduce gasoline consumption have focused on two effects, a compositional effect on the fuel economy of the automotive fleet and a utilization effect on how much people drive. However, the literature has missed a third effect: a matching effect, in which policies change how high-utilization households are matched to fuel-efficient vehicles in equilibrium. One of the studies shows that higher gas prices should lead to stronger assortative matching. Empirical estimates using U.S. micro-level data are consistent with this hypothesis. The researchers found that a $0.50 increase in the gas tax would reduce U.S. gas consumption by 0.8% through the matching effect alone, bringing annual environmental benefits of about $1.7 billion[110].

Countries differ considerably in terms of the price drivers pay for gasoline. One of the studies uses data from 132 countries between 1995–2008 to investigate the implications of these differences for gasoline consumption for road transport. It was established that higher gasoline prices induce consumers to substitute for more fuel-efficient vehicles, with an estimated elasticity of + 0.2. Despite the small size of our elasticity estimates, there is considerable scope

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[108] Beresteanu, A., & Li, S. (2011). GASOLINE PRICES, GOVERNMENT SUPPORT, AND THE DEMAND FOR HYBRID VEHICLES IN THE UNITED STATES. International Economic Review, 52(1), 161–182. http://www.jstor.org/stable/23016626)https://www-jstor-org.proxy.lib.odu.edu/stable/23016626?seq=15#metadata_info_tab_contents)

[109] Zhao, L., Ling-Yun He, Lei Cheng, Guan-Rong Zeng, Zhimin Huang, The effect of gasoline consumption tax on consumption and carbon emissions during a period of low oil prices, Journal of Cleaner Production, Volume 171, 2018, Pages 1429-1436, ISSN 0959-6526, https://doi.org/10.1016/j.jclepro.2017.10.117. (https://www-sciencedirect-com.proxy.lib.odu.edu/science/article/pii/S0959652617324162?via%3Dihub)

[110] Banzhaf, H. Spencer, M. Taha Kasim, Fuel consumption and gasoline prices: The role of assortative matching between households and automobiles, Journal of Environmental Economics and Management, Volume 95, 2019, Pages 1-25, ISSN 0095-0696, https://doi.org/10.1016/j.jeem.2018.11.010. (https://www.sciencedirect.com/science/article/pii/S0095069618301761)

for low-price countries to achieve gasoline savings and vehicle fuel economy improvements by reducing gasoline subsidies and/or increasing gasoline taxes[111].

Another innovative study used Google Search Volume data as a proxy to measure the tendency of consumers to use public transportation services. The sign of the estimated parameters suggests that higher attention paid to public transportation may coincide with lower gasoline demand[112].

Marrouchab and Mourad have evaluated the impact of gasoline prices on the demand for cars of different fuel efficiency for the new and used car markets. The results indicate that an unexpected increase in gasoline prices directly and instantaneously affects the demand for new midsize cars. The demand for new midsize cars increases by 1.35% one month after the positive gasoline price shock and becomes insignificant again. As for the new lowest fuel efficiency cars, a positive shock in gasoline prices has a significant positive effect of 1.12% two months following the shock[113].

Havranek and Kokes, in their meta-analysis, have synthesized empirical estimates of the income elasticity of gasoline demand in previous studies. The studies cover many countries and report a mean elasticity of 0.28 for the short run and 0.66 for the long run. They show, however, that these mean estimates are biased upwards because of publication bias—the tendency to suppress negative and insignificant estimates of the elasticity. Even after employing mixed-effects multilevel meta-regression to filter out publication bias from the literature, the results suggest that the income elasticity of gasoline demand still exists at 0.1 for the short run and 0.23 for the long run[114].

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[111] Burke, P., Shuhei Nishitateno, Gasoline prices, gasoline consumption, and new-vehicle fuel economy: Evidence for a large sample of countries, Energy Economics, Volume 36, 2013, Pages 363-370, ISSN 0140-9883, https://doi.org/10.1016/j.eneco.2012.09.008.
(https://www.sciencedirect.com/science/article/pii/S0140988312002228)

[112] Google search explains your gasoline consumption!
https://www.sciencedirect.com/science/article/pii/S0140988321002103

[113] Marrouch, W., Jana Mourad, Effect of gasoline prices on car fuel efficiency: Evidence from Lebanon, Energy Policy, Volume 135, 2019, 111001, ISSN 0301-4215, https://doi.org/10.1016/j.enpol.2019.111001. https://www-sciencedirect-com.proxy.lib.odu.edu/science/article/pii/S0301421519305889

[114] Havranek, Tomas and Kokes, Ondrej, (2015), Income elasticity of gasoline demand: A meta-analysis, Energy Economics, 47, issue C, p. 77-86,
https://econpapers.repec.org/article/eeeeneeco/v_3a47_3ay_3a2015_3ai_3ac_3ap_3a77-86.htm

Walsh, Enz, and Canina conducted another interesting relationship related to gasoline consumption and the pump price. Their hypotheses were devised to test the relationship between gasoline prices and lodging demand for specific hotel locations and price segments. Using fixed-effects models, the results reveal that lodging demand decreases as gasoline prices rise in all segments except upper-upscale and all locations except urban areas.[115] This result suggests that increased pump prices positively impact driving habits.

Waduda, Noland, and Graham's research results show that price responses vary with demographic variables such as income, multiple vehicle holding, multiple wage earners, or rural or urban residential locations. Households' responses to a price change decrease with higher income. Multiple vehicles and multiple-earner homes also show higher sensitivity to a price change. Households located in urban areas reduce consumption more than those in rural areas in response to an increase in price[116].

Another interesting study was conducted by Ghoddusi, where he researched the price elasticity of gasoline smuggling. This finding supports the hypothesis that increased domestic gasoline prices will significantly reduce the demand for gasoline smuggling in Iran due to decreased demand[117].

I found the only study illustrating that gasoline demand is price inelastic and suggesting that it may be difficult for the government to limit future growth in gasoline consumption using only increases in the administered price of gasoline[118]. This study, however, was conducted in

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[115] Walsh, K., Cathy A. Enz, Linda Canina, The impact of gasoline price fluctuations on lodging demand for US brand hotels, International Journal of Hospitality Management, Volume 23, Issue 5, 2004, Pages 505-521, ISSN 0278-4319, https://doi.org/10.1016/j.ijhm.2004.02.004. https://www-sciencedirect-com.proxy.lib.odu.edu/science/article/abs/pii/S0278431904000222

[116] Wadud, Z., Robert B. Noland, Daniel J. Graham, A semiparametric model of household gasoline demand, Energy Economics, Volume 32, Issue 1, 2010, Pages 93-101, ISSN 0140-9883, https://doi.org/10.1016/j.eneco.2009.06.009. https://www-sciencedirect-com.proxy.lib.odu.edu/science/article/pii/S0140988309001054

[117] Ghoddusi, Hamed and Rafizadeh, Nima and Rahmati, Mohammad Hossein, Price Elasticity of Gasoline Smuggling: A Semi-Structural Estimation Approach (April 17, 2017). Energy Economics, Vol. 71, 2018, Available at SSRN: https://ssrn.com/abstract=2954034 or http://dx.doi.org/10.2139/ssrn.2954034 https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2954034

[118] Atalla, Tarek N., Anwar A. Gasim, Lester C. Hunt,Gasoline demand, pricing policy, and social welfare in Saudi Arabia: A quantitative analysis, Energy Policy, Volume 114, 2018, Pages 123-133, ISSN 0301-4215, https://doi.org/10.1016/j.enpol.2017.11.047. (https://www.sciencedirect.com/science/article/pii/S0301421517307942)

Saudi Arabia. And the country is a natural outlier in the relationship between consumption and fuel price due to the local specifics, like governmental subsidies.

The rebound effect is essential when analyzing the relationship between pump price and consumption. However, based on the available and presented research, the rebound effect does not significantly impact the relationship between pump price and consumption.

Fuel efficiency policies aim to decrease gasoline consumption; however, the effect can be mitigated by changes in consumer behavior, such as traveling more distances — a rebound effect. Thus, the fuel efficiency policy's effectiveness depends on the magnitude of the rebound effect. In their paper, Moshir and Aliyev estimate the rebound effect for personal transportation in Canada using data from the household spending survey for the period 1997–2009. Their estimation results show a relatively high average rebound effect of 82–88% but with significant heterogeneity across income groups, provinces, and gasoline prices. Specifically, the rebound effect ranges from 63% to 96% across income groups, provinces, and gasoline prices.[119]

The review of 17 studies suggests that the long-run direct rebound effect for personal automotive transport lies between 10% and 30%. Overall, it must be concluded that direct rebound effects in this sector have not prevented the benefits of technical improvements in vehicle fuel efficiency. Between 70% to 100% of the potential benefits of such improvements appear to have been realized in reduced motor-fuel consumption[120].

To summarize, gasoline is shaped by the price of the good or pump price, like any other common good. Most available research indicates a positive relationship between pump price and gasoline consumption. Since transport is the fastest-growing sector for greenhouse gas emissions, which is a sign of the upward trend in fuel consumption, I keep the variable of Pump price for gasoline (US$ per liter) constant in my research.

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[119] Moshiri, S., Kamil Aliyev, Rebound effect of efficiency improvement in passenger cars on gasoline consumption in Canada, Ecological Economics, Volume 131, 2017, Pages 330-341, ISSN 0921-8009, https://doi.org/10.1016/j.ecolecon.2016.09.018. https://www-sciencedirect-com.proxy.lib.odu.edu/science/article/pii/S0921800915303438

[120] Sorrell, S. The Rebound Effect: An Assessment of the Evidence for Economy-wide Energy Savings from Improved Energy Efficiency. 2007. https://d2e1qxpsswcpgz.cloudfront.net/uploads/2020/03/the-rebound-effect-an-assessment-of-the-evidence-for-economy-wide-energy-savings-from-improved-energy-efficiency.pdf

Today, taxation is considered one of the energy policy instruments actively utilized to impact energy use and CO_2 emissions. There is enough empirical evidence illustrating that taxes affect energy consumption. For example, the continuous increase of the electricity tax revenue after 1993 and the increase of the carbon tax revenue after 2000 mirror the declining energy consumption trend[121].

To demonstrate the connection between the variables, I searched for literature containing any analysis of energy efficiency, energy use, and primary energy consumption related to taxation.

Unfortunately, there is no worldwide database on energy taxes. Therefore, most quantitative or mixed studies analyze European or OECD countries.

The investigation of the effect of energy taxes in the European Union (E.U.) across different levels of residential final energy consumption (RFEC) in the period 2005–2016 has revealed that in less energy-consuming E.U. countries, an increase in energy taxes and energy prices influences stronger RFEC[122]. Another good example is a recent study of the Environmental Kuznets Curve, illustrating that environmental taxes have a negative impact on CO_2 emissions[123].

Since energy taxation leads to the increased prices of taxable energy products, one could expect it to reduce energy consumption, including gasoline. Higher energy prices encourage citizens and businesses to consume less energy. Energy savings can result from energy conservation, e.g., heating less in the winter or shifting to less energy-intensive economic activities. Energy savings may also result from energy-efficiency improvements, which reduce the energy needed for a given output (products, services, comfort, etc.). Citizens faced with higher energy prices may, for instance, choose to insulate their homes better than they would if tax

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[121] Energy efficiency of residential buildings in the European Union – An exploratory analysis of cross-country consumption patterns, Energy Policy, Volume 129, 2019, Pages 1156-1167, ISSN 0301-4215, https://doi.org/10.1016/j.enpol.2019.03.003. https://www-sciencedirect-com.proxy.lib.odu.edu/science/article/pii/S0301421519301661

[122] Borozan, D., Unveiling the heterogeneous effect of energy taxes and income on residential energy consumption, Energy Policy, Volume 129, 2019, Pages 13-22, ISSN 0301-4215, https://doi.org/10.1016/j.enpol.2019.01.069. https://www-sciencedirect-com.proxy.lib.odu.edu/science/article/pii/S0301421519300825?via%3Dihub

[123] Saucedo, E., Díaz J., Parra, M. ESTIMATING ENVIRONMENTAL KUZNETS CURVE: THE IMPACT OF ENVIRONMENTAL TAXES AND ENERGY CONSUMPTION IN CO2 EMISSIONS OF OECD COUNTRIES. Dubrovnik Vol. 3, Iss. 1, Dubrovnik: University of Dubrovnik. (Nov 2017): 901-912. https://search-proquest-com.proxy.lib.odu.edu/docview/2068860158?accountid=12967&pq-origsite=primo

rates were lower. Similarly, businesses facing or anticipating higher energy prices can be expected to invest in research, development, and deployment of more energy-efficient technologies, leading to energy savings, e.g., for aluminum smelters[124].

Some literature confirms that the demand for energy products decreases as prices rise. Over the last few years, energy deregulation and sharp movements in the price of primary energy goods, together with policies related to climate change and energy security concerns, have fostered renewed interest in this area[125]. A meta-analysis of the price elasticity of energy demand shows that agents react to price changes in energy products; this reaction is more significant in the long term than in the short term. It is pretty similar among different energy products. In this sense, price fluctuations affect gasoline consumption the most in the short and long term, making consumption of these particular energy goods more vulnerable to price changes[126].

Gasoline is primarily used in the transportation sector. In the U.S., for example, 28% of total energy consumption in 2019 was for transporting people and goods from one place to another[127]. At the same time, the transportation sector contributes 29 percent of 2019 greenhouse gas emissions, which makes it the most significant generator of greenhouse gas emissions[128]. This means that certain countries could use better practices in taxing gasoline use.

The history of energy taxation goes back to 1990 when Finland and Poland introduced a carbon tax, followed by Sweden in 1991[129]. In past decades, environmental- and carbon-related taxes have gained importance as an instrumental factor in economic policies for emerging and developing countries such as China, India, Indonesia, Thailand, Singapore, and Vietnam[130].

[124] OECD (2019)
[125] Labandeira, X., José M. Labeaga, Xiral López-Otero, A meta-analysis on the price elasticity of energy demand, Energy Policy, Volume 102, 2017, Pages 549-568, ISSN 0301-4215, https://doi.org/10.1016/j.enpol.2017.01.002. https://www-sciencedirect com.proxy.lib.odu.edu/science/article/pii/S0301421517300022?via%3Dihub
[126] A meta-analysis on the price elasticity of energy demand. https://www-sciencedirect-com.proxy.lib.odu.edu/science/article/pii/S0301421517300022?via%3Dihub
[127] Energy use for transportation. U.SS. Energy Information Administration. https://www.eia.gov/energyexplained/use-of-energy/transportation.php
[128] Sources of Greenhouse Gas Emissions. U.S. Environmental OProtection Agency. https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions
[129] Carbon Tax. The World Bank Data. https://data.worldbank.org/
[130] Environmental Tax Reform in Developing, Emerging and Transition Economies. German Development Institute. https://www.die-gdi.de/uploads/media/Study_93.pdf

Israel has implemented The Green Tax scheme on Cars to encourage consumers to choose less polluting cars targeting reductions in all polluting vehicle emissions, not only carbon dioxide (CO_2)[131]. As a part of the Vietnam Green Growth Strategy, the country introduced the Environmental Protection Tax (EPT), one of the goals of which was to reduce energy consumption per unit of GDP by 2.5-3% annually[132]. In 2014, Mexico launched the carbon tax, the first tax on selling or importing fossil fuels and covering 40% of greenhouse gas emissions[133].

Since different governments utilize different tools, effective tax rates are applied to different forms of energy use. For example, taxation of transport, heating, process purposes, fuels (excise fuel taxes), and electricity production and consumption. Another way to approach energy taxation is to apply rates to carbon emissions from energy use (carbon taxation). Transport taxes are considerably higher than in other sectors, where fuels that cause considerable harm to the environment and human health are often taxed at very low – or zero – rates[134]. Effective carbon price signals are stronger in road transport, primarily because of relatively high fuel excise taxes, but the non-climate related external costs are also relatively high in road transport (e.g., local air pollution impacts). Brazil and Indonesia are the only countries that do not tax road emissions at EUR 30 per tonne of CO_2 or more[135].

Taxes are considered fundamental driving forces of climate change policies[136]. At the same time, energy savings are likely to play a crucial role in attaining climate objectives[137] since providing incentives for energy savings through taxes generally improves environmental

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[131] Israel's Green Tax on Cars. Lessons in Environmental Policy Reform. OECD iLibrary. https://www-oecd-ilibrary-org.proxy.lib.odu.edu/environment/israel-s-green-tax-on-cars_5jlv5rmnq9wg-en

[132] Environmental Tax Reform in Developing, Emerging and Transition Economies. German Development Institute. https://www.die-gdi.de/uploads/media/Study_93.pdf

[133] Environmental Tax Reform in Developing, Emerging and Transition Economies. German Development Institute. https://www.die-gdi.de/uploads/media/Study_93.pdf

[134] Taxing Energy Use 2015: OECD and Selected Partner Economies, OECD Publishing, Paris, OECD (2015), https://doi-org.proxy.lib.odu.edu/10.1787/9789264232334-en

[135] OECD (2019)

[136] Environmental taxes, energy consumption, and environmental quality: Theoretical survey with policy implications.
https: https://www.eia.gov/energyexplained/use-of-energy/transportation.php
https://www.eia.gov/energyexplained/use-of-energy/transportation.php //search-proquest-com.proxy.lib.odu.edu/docview/2399239420?accountid=12967&pq-origsite=primo

[137] IPCC, 2014. Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel for Climate Change. Edited by Edenhofer, O., et al., Cambridge University Press, Cambridge

outcomes if the foregone energy use would have created environmental damage[138]. Therefore, energy taxes typically target energy use or CO2 emissions, or both.

Taxing energy use can shift energy demand towards cleaner energy sources. By taxing combustible sources – which emit CO2 when combusted – at higher rates than non-combustible sources, energy tax systems can provide abatement incentives in support of decarbonization objectives and co-benefits such as reduced local air pollution[139]. In most countries, taxes on energy use are set at the national level. However, there are exceptions to this rule, for instance, in Canada and the United States, where taxes on energy use are also set at the subnational level[140].

Some researchers strongly believe that carbon taxation is an effective energy-efficient means. In this regard, the scope of the carbon tax plays a crucial role. Such a statement is based on the evidence that a tax of 30 € and a tax of 120 € per ton of CO2 cause markedly different reductions in energy consumption[141].

Most governments seek to improve energy efficiency to pursue their energy policy goals. The potential ‘energy savings from improved energy efficiency are commonly estimated using basic physical principles and engineering models. However, the energy savings realized in practice generally fall short of these engineering estimates. One explanation is that improvements in energy efficiency encourage greater use of the services. Behavioral responses such as these have come to be known as the energy efficiency “rebound effect.” It is important to emphasize that energy and carbon taxes avoid direct rebound effects since they affect investment decisions and increase the marginal cost of energy-related products and services[142].

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[138] Taxing Energy Use 2019: Using Taxes for Climate Action, OECD Publishing, Paris, https://doi-org.proxy.lib.odu.edu/10.1787/058ca239-en

[139] Taxing Energy Use 2019: Using Taxes for Climate Action, OECD Publishing, Paris, https://doi-org.proxy.lib.odu.edu/10.1787/058ca239-en

[140] Taxing Energy Use 2019: Using Taxes for Climate Action, OECD Publishing, Paris, https://doi-org.proxy.lib.odu.edu/10.1787/058ca239-en

[141] Energy efficiency of residential buildings in the European Union – An exploratory analysis of cross-country consumption patterns, Energy Policy, Volume 129, 2019, Pages 1156-1167, ISSN 0301-4215, https://doi.org/10.1016/j.enpol.2019.03.003. (https://www.sciencedirect.com/science/article/pii/S0301421519301661)

[142] A meta-analysis on the price elasticity of energy demand. http://dx.doi.org/10.1016/j.enpol.2017.01.002.

Even though the relationship between taxation and energy use is widely researched, the analysis of effective tax rates, in energy and carbon terms, on the full spectrum of energy use in 21 European Union countries and across all OECD countries suggests that countries are not fully harnessing the full power of taxes on energy use for environmental purposes and that realignment of energy taxes could help to ensure that countries pursue their environmental, social and economic goals as effectively as possible[143]. Furthermore, there are significant differences in the overall level of energy taxation across the OECD area when all taxes on energy are taken into account, whether tax rates on energy are considered effective tax rates per unit of energy or per unit of carbon emissions[144].

The literature on the effectiveness of energy policy instruments, such as energy taxes, differs by scope and methods. Some studies concentrate on building regulations in a particular country, while others look at various carbon taxes across OECD countries by considering different time periods, variables, and methods. The current literature on the theoretical and empirical evidence focusing on the interlinkages between environmental taxes and energy consumption is rather meager[145]. Most of the available quantitative research is based on the OECD countries due to the accessibility of the data on taxation.

One of the studies across OECD countries analyzed taxes levied directly on a unit of energy product when consumed (excise taxes or carbon taxes levied based on volume, mass, or energy content)[146]. It is important to emphasize that no worldwide energy tax database exists. Thus, the author has gathered tax information through contact with national officials and publicly available national sources. The highest overall tax rates on carbon tend to be in European countries[147]. Countries with higher average effective tax rates on CO2 tend to have lower carbon emissions

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[143] Taxing Energy Use: Patterns and Incoherencies in Energy Taxation in Europe and the OECD. https://link.springer.com/chapter/10.1007/978-3-319-21302-6_11

[144] Taxing Energy Use 2019: Using Taxes for Climate Action, OECD Publishing, Paris, https://doi-org.proxy.lib.odu.edu/10.1787/058ca239-en

[145] Shahzad, U. Environmental taxes, energy consumption, and environmental quality: Theoretical survey with policy implications National Library of Medicine. Environmental science and pollution research international Vol. 27, Iss. 20, (July 2020): 24848-24862. DOI:10.1007/s11356-020-08349-4 https://search-proquest-com.proxy.lib.odu.edu/docview/2399239420?accountid=12967&pq-origsite=primo

[146] Taxing Energy Use 2019: Using Taxes for Climate Action, OECD Publishing, Paris, https://doi-org.proxy.lib.odu.edu/10.1787/058ca239-en

[147] Taxing Energy Use 2019: Using Taxes for Climate Action, OECD Publishing, Paris, https://doi-org.proxy.lib.odu.edu/10.1787/058ca239-en

per unit of GDP (i.e., less carbon-intensive economies). This correlation suggests that there may be a linkage between the rate of taxation applied to carbon and the extent of carbon usage within an economy[148]. The study also established that oil products (predominantly gasoline and diesel) tend to be taxed significantly more heavily and more frequently than other energy products, such as natural gas and coal, among transport, heating, and process fuels. Despite its significant adverse environmental impacts, there is often a very low (or zero) tax rate on coal, particularly considering its greater contribution to greenhouse gas emissions and other air pollutants per unit of energy[149].

Another research illustrates a long-run effect of a broad-based carbon tax on energy consumption. The results show that a one-euro increase in energy taxes reduces carbon emissions from fossil fuel consumption by 0.73 percent in the long run[150].

Thus, taxation is a significant policy lever available to the government to influence energy use patterns. It affects the price, and therefore the use, of energy. Therefore, understanding the structure and level of energy taxes is central to policy discussions regarding energy use[151].

2.3. URBANIZATION

Today, 60 percent of the World's population (approximately 4.78 billion people) reside in urban areas[152]. Although cities occupy only two percent of the World's landmass, they consume over two-thirds of its energy and account for more than 70% of global CO2 emissions[153].

While investigating the existing literature, I have searched for any analysis of energy efficiency, energy use, and primary energy consumption related to urbanization.

Although empirical studies measuring the relationship between energy consumption and urbanization are limited, enough literature illustrates the relationship between the two variables.

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[148] Taxing Energy Use 2019: Using Taxes for Climate Action, OECD Publishing, Paris, https://doi-org.proxy.lib.odu.edu/10.1787/058ca239-en

[149] Taxing Energy Use 2019: Using Taxes for Climate Action, OECD Publishing, Paris, https://doi-org.proxy.lib.odu.edu/10.1787/058ca239-en

[150] Sen, S. and H. Vollebergh (2018), "The effectiveness of taxing the carbon content of energy consumption", Journal of Environmental Economics and Management, Vol. 92, pp. 74-99, http://dx.doi.org/10.1016/j.jeem.2018.08.017.

[151] Taxing Energy Use in the OECD. http://www.jstor.org/stable/26189262

[152] https://databank.worldbank.org/

[153] https://www.c40.org/why_cities

Some researchers have established a positive relationship between urbanization and energy consumption, while some have demonstrated a negative one.

Besides direct physical impact, cities drive the global economy, and urban decisions impact well beyond city boundaries. In this case, the impact is the greenhouse gas (GHG) emissions from urban consumption of building materials, food, clothing & textiles, private transport, electronics & household appliances, and private aviation travel[154].

Cities and urban consumers significantly impact emissions beyond their borders since 85% of the emissions associated with goods and services consumed in C40 cities are generated outside the city; 60% are in their own country, and 25% are from abroad[155].

EIA names urbanization as one of the key factors leading to the rising demand for energy[156]. For example, primary energy demand in Mexico has increased by 25% since 2000 because of the expansion of the economy and urbanization[157].

In a macroeconomic context, while urbanization turns out specialization in the economy, industrialization and acceleration in economic development depend upon this; urbanization enhances residential and industrial energy consumption. It is a fact that a high urbanization ratio is positively related to a high-income level. While urbanization provides a shift in production structure from the agricultural sector to tertiary and industrial sectors, it also reveals a technology-oriented production structure. Therefore, it brings about an acceleration process of an increase in energy consumption. In this context, economic development and growth phenomena generate both urbanization and a structure in which energy consumption increases due to the structure of consumption and production that urbanization leads[158].

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[154] The Future Of Urban Consumption in a 1.5°C World. https://c40-production-images.s3.amazonaws.com/other_uploads/images/2270_C40_CBE_MainReport_250719.original.pdf?1564075036
[155] https://c40-production-images.s3.amazonaws.com/other_uploads/images/2270_C40_CBE_MainReport_250719.original.pdf?1564075036
[156] https://www.eia.gov/todayinenergy/detail.php?id=41433
[157] https://www.eia.gov/todayinenergy/detail.php?id=41433
[158] The relationship between energy consumption, urbanization, and economic growth in new emerging-market countries. https://doi.org/10.1016/j.energy.2018.01.011. (https://www.sciencedirect.com/science/article/pii/S0360544218300112)

Jones identifies mechanisms whereby urbanization affects energy consumption. Industrialization and urbanization accompany each other during economic development, but urbanization exerts a number of independent influences on energy use. It permits economies of scale in production but requires more transportation. Food must be transported to urbanized populations, and relatively smaller agricultural populations must modernize, entailing considerable agricultural energy use increases. In cities, a number of production activities that were domestically provided in rural areas, using human or animal energy, shift to sources outside the household, using modern energy sources. The largest single source of change in energy use is personal transportation. Aggregate statistical evidence indicates that a 10% increase in city population would increase current energy consumption per capita by 4.5% or 4.8%/$ GDP, holding constant per capita income and industrialization[159].

The investigation of the impact of urbanization on renewable energy consumption growth (RECG) in China showed that the energy mix, economic, and population effects positively affected RECG. The increase in renewable energy consumption is attributed to urbanization, energy mix, energy intensity, economic, and population effects. The contribution of urbanization differed in RECG stages, and urbanization contributed more to the total energy consumption growth than to RECG[160].

An exploratory assessment of the possible global greenhouse consequences of economic development in general and urbanization in particular has established a positive relationship between urbanization and energy consumption[161].

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159 Jones, D. How urbanization affects energy-use in developing countries, Energy Policy, Volume 19, Issue 7, 1991, Pages 621-630, ISSN 0301-4215, https://doi.org/10.1016/0301-4215(91)90094-5. (https://www.sciencedirect.com/science/article/pii/0301421591900945)

160 Yang, J., Wei Zhang, Zongyi Zhang, Impacts of urbanization on renewable energy consumption in China, Journal of Cleaner Production, Volume 114, 2016, Pages 443-451, ISSN 0959-6526, https://doi.org/10.1016/j.jclepro.2015.07.158. https://www-sciencedirect-com.proxy.lib.odu.edu/science/article/pii/S0959652615010896

161 Parikh, J., Vibhooti Shukla, Urbanization, energy use and greenhouse effects in economic development: Results from a cross-national study of developing countries, Global Environmental Change, Volume 5, Issue 2, 1995, Pages 87-103, ISSN 0959-3780, https://doi.org/10.1016/0959-3780(95)00015-G. (https://www.sciencedirect.com/science/article/pii/095937809500015G)

The investigation of the impact of urbanization on energy consumption during the period of 1970Q1–2011Q4 in Malaysia illustrated the existence of cointegration and exposed that urbanization is a significant contributor to energy consumption[162].

When analyzing the impact of urbanization on energy consumption in one of the most developed regions in China called Jiangsu, it was established that urbanization accelerated the produce energy consumption over the study period of 1995 and 2011. The produce energy consumption jumped from 50.7 Mtce in 1995 to 166.6 Mtce in 2011. Furthermore, due to rapid urbanization, the gap between residential energy consumption for urban and rural regions has gradually become wide since 2002[163].

The investigation of the long-term and causal relationship between energy intensity, real GDP per capita, urbanization, and industrialization in Saudi Arabia over the period 1971–2012 illustrated that urbanization positively affects energy intensity in both the short and long term. Causality tests indicate that urbanization causes economic output that causes energy intensity in the long term[164].

Another study has illustrated that urbanization adds to energy consumption in the case of Pakistan for the period of 1972Q1-2011Q4 by employing the STIRPAT (Stochastic Impact by Regression on Population, Affluence, and Technology) model. The authors have also found that urbanization, economic growth, technology, and transportation positively relate to energy consumption.[165]

After assessing the relationship among energy consumption, financial development, economic growth, industrialization, and urbanization in Tunisia from 1971 to 2008, the authors

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[162] Shahbaz, M., Nanthakumar Loganathan, Rashid Sbia, Talat Afza, The effect of urbanization, affluence and trade openness on energy consumption: A time series analysis in Malaysia, Renewable and Sustainable Energy Reviews, Volume 47, 2015, Pages 683-693, ISSN 1364-0321, https://doi.org/10.1016/j.rser.2015.03.044. https://www-sciencedirectcom.proxy.lib.odu.edu/science/article/pii/S1364032115001975?via%3Dihub

[163] Zhang, M., Li, P. Analyzing the impact of urbanization on energy consumption in Jiangsu Province. Nat Hazards 76, 177–190 (2015). https://doi.org/10.1007/s11069-014-1479-7 https://link.springer.com/article/10.1007/s11069-014-1479-7

[164164] The Impact of Urbanization on Energy Intensity in Saudi Arabia file:///C:/Users/md9wf/Downloads/sustainability-08-00375.pdf

[165] Shahbaz, M., Chaudhary, Amatul. (2017). Does urbanization cause increasing energy demand in Pakistan? Empirical evidence from STIRPAT model. Energy. 122. 10.1016/j.energy.2017.01.080. https://www.researchgate.net/publication/312541899_Does_urbanization_cause_increasing_energy_demand_in_Pakistan_Empirical_evidence_from_STIRPAT_model

have confirmed a long-run relationship among energy consumption, economic growth, financial development, industrialization, and urbanization in Tunisia[166].

It may seem that urban areas, for example, cities, are less efficient and consume way more energy per capita than rural areas. This assumption is easy to make when looking at higher population densities, never-ending traffic jams, well-lit streets, or constantly circulating public transportation. But things are not as simple as they seem at first. For example, the temperature in the summertime is always higher [in cities], so they use more air conditioning. But in the wintertime, urban areas are also warmer, so they use less heat than rural areas. This heat-island effect is created when concrete and asphalt replace soil and plants on a large scale[167].

Despite hosting regular traffic jams, cities win the head-to-head efficiency matchup in transportation thanks to their mass transit systems and denser layouts promoting walking and bicycling. Over 97% of rural households own at least one car vs. 92% of urban households; 91% of trips are made by car in rural areas vs. 86% in urban areas[168]. Urban U.S. households own an average of 1.8 vehicles each, compared with 2.2 for each rural household. Urban families also drive about 7,000 fewer miles annually than their rural counterparts[169]. More considerable distances and a lack of public transportation leave no choice for residents of rural areas but to drive themselves to get around.

A similar concept applies to energy used by households. Cities have the lowest annual energy use per household. For example, an average annual household site's energy consumption in an urban U.S. area is 75.8 mln Btu per household, compared with 82.4 mln Btu per household in a rural area[170]. Why the difference? Aside from environmental factors, it's a combination of

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[166] Shahbaz, M., Hooi Hooi Lean. Does financial development increase energy consumption? The role of industrialization and urbanization in Tunisia Energy Policy, 2012, vol. 40, issue C, 473-479 https://econpapers.repec.org/article/eeeenepol/v_3a40_3ay_3a2012_3ai_3ac_3ap_3a473-479.htm

[167] McLendon, R. The University of Georgia. Urban or Rural: Which Is More Energy-Efficient. 2018. https://www.treehugger.com/urban-or-rural-which-is-more-energy-efficient-4863586#:~:text=Despite%20hosting%20regular%20traffic%20jams,%2C%20which%20isn't%20cheap

[168] John Pucher, John L. Renne. Urban-Rural Differences In Mobility and Mode Choice. Bloustein School of Planning and Public Policy. Rutgers University https://vtc.rutgers.edu/wp-content/uploads/2014/04/Articles.Urban-Rural_differences.pdf

[169] Urban or Rural: Which Is More Energy-Efficient. 2018. https://www.treehugger.com/urban-or-rural-which-is-more-energy-efficient-4863586#:~:text=Despite%20hosting%20regular%20traffic%20jams,%2C%20which%20isn't%20cheap

[170] EIA stats https://www.eia.gov/consumption/residential/data/2015/c&e/pdf/ce2.1.pdf https://search.usa.gov/search?utf8=%E2%9C%93&affiliate=eia.doe.gov&query=urban+or+rural&search=

infrastructure and behavior. The compact construction of urban condo towers and apartment buildings helps insulate their indoor climates. At the same time, large homes, typically in less dense areas, need more energy for heating and cooling and have a more challenging time keeping air from leaking outside[171].

Sadorsky investigated the impact of urbanization and industrialization on energy consumption in a panel of emerging economies. He indicated that income increases energy consumption, while urbanization decreases energy consumption and increases industrialization[172].

A strong negative relationship was established between electricity consumption and urban density by Lariviere and Lafrance[173].

Some researchers established that the relationship between energy consumption and urbanization is not obsolete but is also impacted by other factors. For example, an exploration of the relationship between urbanization, energy consumption, and CO2 emission in the MENA countries during the period of 1980–2009 showed that urbanization, energy consumption, and CO2 emission were cointegrated. The results also showed a long-run bi-directional positive relationship between urbanization, energy consumption, and CO2 emission. However, the significance of the long-run relationship between urbanization, energy consumption, and CO2 emission varied across the countries based on their level of income and development. From the results of this study, the urban planners and policymakers in the MENA countries need to slow the rapid increase in urbanization. The level of energy consumption and CO2 emission in the MENA countries increased more than double. Thus slowing down the urbanization level can help reduce pollution and energy consumption. In addition, the increased energy efficiency,

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[171] McLendon, R. University of Georgia. Urban or Rural: Which Is More Energy-Efficient. 2018. https://www.treehugger.com/urban-or-rural-which-is-more-energy-efficient-4863586#:~:text=Despite%20hosting%20regular%20traffic%20jams,%2C%20which%20isn't%20cheap

[172] Sadorsky, P. The Effect of Urbanization and Industrialization on Energy Use in Emerging Economies: Implications for Sustainable Development. https://onlinelibrary.wiley.com/doi/abs/10.1111/ajes.12072

[173] Larivière, I., Gaëtan Lafrance, Modelling the electricity consumption of cities: effect of urban density, Energy Economics,
Volume 21, Issue 1, 1999, Pages 53-66, ISSN 0140-9883, https://doi.org/10.1016/S0140-9883(98)00007-3. https://www.sciencedirect.com/science/article/pii/S0140988398000073

implementation of energy savings projects, energy conservation, and energy infrastructure outsourcing reduce the pollution produced by urban areas[174].

Another study has established that urbanization and industrialization have significant impacts on energy consumption and CO2 emissions, but their relationship varies at different stages of economic development. The main results are obtained by dynamic panel threshold regression models, which divide a balanced panel dataset of 73 countries from 1971 to 2010 into four groups according to their annual income levels. According to the results, a 1% increase in industrialization or urbanization would lead to a 0.009% or 0.150% increase in total energy consumption. This finding means that industrialization and urbanization are positively related to energy consumption and that urbanization exerts a greater effect than industrialization. It also reveals that population growth is the main factor responsible for increased energy consumption, and previous energy consumption positively affects current energy consumption, denoting strong inertia or path dependence. The more specific key results are: (1) in the low-income group, urbanization decreases energy consumption but increases CO2 emissions; (2) in the middle-/low-income and high-income groups, industrialization decreases energy consumption but increases CO2 emissions, while urbanization significantly increases both energy consumption and CO2 emissions; (3) for the middle-/high-income group, urbanization does not significantly affect energy consumption, but does hinder the growth of emissions; while industrialization was found to have an insignificant impact on energy consumption and CO2 emissions; (4) from the population perspective, it produces positive effects on energy consumption and also increases emissions except for the high-income group. [175]

Another paper aimed to study the impact of population density and energy-consuming density to space together on energy consumption in Beijing's urban districts. It is concluded that non-economic and non-technological factors significantly reduced energy consumption. Even

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[174] Exploring the relationship between urbanization, energy consumption, and CO2 emission in MENA countries. https://doi.org/10.1016/j.rser.2013.02.041. https://www-sciencedirect-com.proxy.lib.odu.edu/science/article/abs/pii/S1364032113001433?via%3Dihub

[175] Li, Ke, Boqiang Lin, Impacts of urbanization and industrialization on energy consumption/CO2 emissions: Does the level of development matter?, Renewable and Sustainable Energy Reviews, Volume 52, 2015, Pages 1107-1122 ISSN 1364-0321,
https://doi.org/10.1016/j.rser.2015.07.185.https://www-sciencedirect-com.proxy.lib.odu.edu/science/article/pii/S1364032115008321

population density did not reduce energy consumption. When it was combined with energy-consuming density to space together, the contribution was efficient. It indicates that compacted urban space with a low-carbon city is the most efficient way to reduce energy consumption in urban areas[176].

Numerous energy consumption studies develop models, including other variables along with urbanization. For instance, Shahbaz et al. illustrated that urbanization adds to energy consumption in Pakistan's case for 1972Q1-2011Q4 by employing the STIRPAT (Stochastic Impact by Regression on Population Affluence) Technology) model. The authors have also found that urbanization, economic growth, technology, and transportation positively relate to energy consumption.[177] An assessment of the relationship among energy consumption, financial development, economic growth, industrialization, and urbanization in Tunisia from 1971 to 2008 has confirmed a long-run relationship among energy consumption, economic growth, financial development, industrialization, and urbanization[178].

2.4. FOSSIL FUELS

The concept of fossil fuels, specifically their imports, being connected on the state level with primary energy consumption per capita comes from the natural resource curse. The British economist Richard Auty coined the term “resource curse” in a 1993 book investigating why resource-rich countries underperformed other developing economies[179].

One of the first studies, which applied the resource curse concept, showed that economies with abundant natural resources had grown less rapidly than natural-resource-scarce economies. The paper illustrates that economies with a high ratio of natural resource exports to GDP in 1971 (the base year) tended to have low growth rates from 1971 to 89. This negative relationship holds true even after controlling for variables essential for economic growth, such

[176] Yongling,Y. Energy Consumption and Space Density in Urban Area, Energy Procedia, Volume 5, 2011, Pages 895-899 ISSN 1876-6102,
https://doi.org/10.1016/j.egypro.2011.03.158. https://www-sciencedirect-com.proxy.lib.odu.edu/science/article/pii/S1876610211010940

[177] Does urbanization cause increasing energy demand in Pakistan? Empirical evidence from STIRPAT model
https://www.researchgate.net/publication/312541899_Does_urbanization_cause_increasing_energy_demand_in_Pakistan_Empirical_evidence_from_STIRPAT_model

[178] Does financial development increase energy consumption? The role of industrialization and urbanization in Tunisia https://econpapers.repec.org/article/eeeenepol/v_3a40_3ay_3a2012_3ai_3ac_3ap_3a473-479.htm

[179] The Resource Curse. Melissa Mittelman. 2017. https://www.bloomberg.com/quicktake/resource-curse

as initial per capita income, trade policy, government efficiency, investment rates, and other variables[180].

The resource curse term is widely used to describe a paradoxical situation when a county underperforms economically, despite being home to valuable natural resources. The resource curse may also be called the resource trap or the paradox of plenty[181]. The resource curse hypothesis is widely debated in the literature, exploring many responsible reasons[182].

While researching the existing literature about the connection between fossil fuels and energy consumption, I have looked at any analysis of energy efficiency, energy use, energy intensity, and primary energy consumption as they relate to fossil fuels imports, fossil fuels exports, fossil fuels rents, and the resource curse. Although the literature discussing the connection is scarce, enough evidence sheds light on the discussed topic.

The World Bank data provides support to the resource curse concept in the energy sector. For example, major oil-exporting countries like the U.S., Saudi Arabia, Russia, Canada, and the United Arab Emirates have some of the highest primary energy consumption per capita of 294.8, 323.4, 209.6, 390.2, and 492.34 Gigajoules accordingly. With its abandoned removable energy resources, Norway has 370.6 Gigajoules per capita. In comparison, the World's average PEC per capita is 76 Gigajoules per capita[183].

Adekoya's study opens up a new insight into the link between energy (oil) consumption and economic growth by considering the influence of natural resource endowments. Findings from the baseline model reveal that the economic growth of the resource-rich countries negatively responds to oil consumption in the long run, although the short-run impact is positive.

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[180] Sachs, J., Andrew M. Warner, 1995. "Natural Resource Abundance and Economic Growth," NBER Working Papers 5398, National Bureau of Economic Research, Inc. https://ideas.repec.org/p/nbr/nberwo/5398.html
[181] Resource Curse. https://www.investopedia.com/terms/r/resource-curse.asp
[182] Hussain, M., ZhiWei Ye, Muhammad Usman, Ghulam Mustafa Mir, Ahmad Usman, Syed Kumail Abbas Rizvi, Re-investigation of the resource curse hypothesis: The role of political institutions and energy prices in BRIC countries, Resources Policy, Volume 69, 2020, 101833, ISSN 0301-4207, https://doi.org/10.1016/j.resourpol.2020.101833. https://www.sciencedirect.com/science/article/abs/pii/S0301420720308655
[183] British Petroleum. Statistical Review of World Energy. Retrieved from: https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html

On the other hand, oil consumption fails to significantly affect economic growth in the short run and long-run in resource-poor countries[184].

Yang's et al. research addressed an emerging and relevant issue of an asymmetric effect of natural resource utilization and rents earned on economic growth, which may result in the incorrect interpretation of either resource curse or resource blessings if not properly captured and identified. For this study, time-series data from 1988 to 2019 was analyzed using the nonlinear autoregressive distributed lag (NARDL) model. The main findings of this research are surprisingly interesting and confirm the existence of a resource curse for Russia triggered by the positive shocks of natural gas rents. However, the shocks in oil rents, broadly recognized as the main causes of resource course, tend to be a blessing because both positive and negative affect GDP growth. These findings have significant policy consequences for the Russian economy, including limiting natural gas supply in the face of high global demand and rising prices[185].

Palegrini et al. research has established that the development of oil operations in Basilicata, Italy, has generated no detectable improvement in employment, a range of social indicators, or educational attainment[186]. However, the study has not looked at changes in energy consumption.

Ullah et al. examined the nonlinear relationship between renewable energy consumption, natural resource rent, and ecological footprint in the World's top 15 renewable energy consumption economies to achieve sustainable development. Panel time-series data from 1996 to 2018 is focused on concluding the study. The results suggest a positive relationship between natural resource rent and ecological footprint in low and high regimes in these 15 economies. Thus, the recommendation to the nations was to shift their energy consumption policies towards

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[184] Adekoya, O. Revisiting oil consumption-economic growth nexus: Resource-curse and scarcity tales, Resources Policy, Volume 70, 2021, 101911, ISSN 0301-4207, https://doi.org/10.1016/j.resourpol.2020.101911. https://www.sciencedirect.com/science/article/abs/pii/S0301420720309429

[185185] Yang, J., Syed Kumail Abbas Rizvi, Zhixiong Tan, Muhammad Umar, Mansoor Ahmed Koondhar, The competing role of natural gas and oil as fossil fuel and the non-linear dynamics of resource curse in Russia, Resources Policy, Volume 72, 2021, 102100, ISSN 0301-4207, https://doi.org/10.1016/j.resourpol.2021.102100. https://www.sciencedirect.com/science/article/abs/pii/S0301420721001148

[186] Pellegrini, L., Luca Tasciotti, Andrea Spartaco, A regional resource curse? A synthetic-control approach to oil extraction in Basilicata, Italy, Ecological Economics, Volume 185, 2021, 107041, ISSN 0921-8009, https://doi.org/10.1016/j.ecolecon.2021.107041. https://www.sciencedirect.com/science/article/pii/S0921800921000999

renewable energy sources by investing in renewable energy technology and research for more sustainable development[187].

Another study examined the role of energy demand, natural resources, and financial development indicators on carbon (CO_2) emissions, emissions from fossil fuel (FFUEL) combustion, and greenhouse gas (GHG) emissions in the context of Saudi Arabia for the period of 1975–2018. The 'resource curse hypothesis' is confirmed in relation to ores and metal (ORM) exports and FFUEL combustion[188].

Some countries use knowledge about the resource curse to conduct regional reforms. For example, a group of Chinese researchers appraised the impacts on the regional "resource curse" in China's "Energy Golden Triangle area" by resource policy adjustment. The results have shown that the reform (coal resource tax in particular) has curbed the regional "resource curse" in the "Energy Golden Triangle area" and that the reform can effectively suppress energy consumption and reduce emissions of major pollutants in the applied area[189].

2.5. CONTROL VARIABLES

2.5.1. LATITUDE

Latitude is the measurement of distance north or south of the Equator. It is measured with 180 imaginary lines that form circles around the Earth east-west, parallel to the Equator. These lines are known as parallels. A circle of Latitude is an imaginary ring linking all points sharing a parallel. The Equator is the line of 0 degrees latitude. Each parallel measures one degree north

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[187] Ullah, A., Mansoora Ahmed, Syed Ali Raza, Sajid Ali, A threshold approach to sustainable development: Nonlinear relationship between renewable energy consumption, natural resource rent, and ecological footprint, Journal of Environmental Management, Volume 295, 2021, 113073, ISSN 0301-4797, https://doi.org/10.1016/j.jenvman.2021.113073. https://www.sciencedirect.com/science/article/pii/S030147972101135X

[188] Anser, M., Zahid Yousaf, Khalid Zaman, Abdelmohsen A. Nassani, Saad M. Alotaibi, Hanifah Jambari, Aqeel Khan, Ahmad Kabbani, Determination of resource curse hypothesis in mediation of financial development and clean energy sources: Go-for-green resource policies, Resources Policy, Volume 66, 2020, 101640, ISSN 0301-4207, https://doi.org/10.1016/j.resourpol.2020.101640. https://www.sciencedirect.com/science/article/abs/pii/S0301420719309973

[189] Xiaoliang Xu, Xuefen Xu, Can resource policy adjustments effectively curb regional "resource curse" ? new evidences from the "energy golden triangle area" of China, Resources Policy, Volume 73, 2021, 102146, ISSN 0301-4207, https://doi.org/10.1016/j.resourpol.2021.102146.https://www.sciencedirect.com/science/article/abs/pii/S0301420721001604

or south of the Equator, with 90 degrees north of the Equator and 90 degrees south of the Equator[190].

Latitude is one of the primary factors that affect temperature. As one moves further away from the Equator, the temperature falls because regions receive less sunlight[191]. An average surface temperature impacts how much energy we use. According to the U.S. Environmental Protection Agency, geographic location and climate are among several key factors affecting the amount of energy an individual household uses[192].

Furthermore, an average surface temperature also impacts certain behaviors related to energy consumption. For example, most cars in the northern states of the U.S. are equipped with either an electric heater coupled to a cooling system or a diesel heater, which also heats an engine coolant a couple of hours before a car is driven. It allows a driver to start a vehicle quickly during cold winter days. Another instance would be American households in a warmer climate using more electricity for air conditioning and less natural gas, oil, and wood for heating[193].

The analysis of 50 cities in the UTC+0800 time zone of China's centralized winter heating zone has illustrated a positive correlation between the effects of geographical Latitude and the per-capita electricity and heating consumption[194].

Available studies of the relationship between energy consumption and temperature-related factors are not systematic. But there are several ways to illustrate the connection

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[190] Latitude. National Geographic. https://www.nationalgeographic.org/encyclopedia/latitude/#:~:text=1%2F3-,Latitude%20is%20the%20measurement%20of%20distance%20north%20or%20south%20of,west%2C%20parallel%20to%20the%20Equator.&text=Each%20parallel%20measures%20one%20degree,degrees%20south%20of%20the%20Equator

[191] What Is The Effect Of Latitude On Temperature? https://www.worldatlas.com/articles/what-is-the-effect-of-latitude-on-temperature.html#:~:text=Latitudes%20are%20angles%20that%20range,degrees%20South%20at%20the%20poles.&text=Temperature%20is%20inversely%20related%20to,and%20cooler%20towards%20the%20poles

[192] Use of energy explained. U.S. Energy Informattion Administration. https://www.eia.gov/energyexplained/use-of-energy/homes.php

[193] Climate Impacts on Energy. U.S. Environmental Protectionn Agency. https://19january2017snapshot.epa.gov/climate-impacts/climate-impacts-energy_.html#:~:text=Top%20of%20Page-,Temperature%2C%20Energy%20Demand%2C%20and%20Energy%20Supply,oil%2C%20and%20wood%20for%20heating

[194] Chenshuo Ma, Yifei Zhang, Wei Zhao, Influence of latitude on raw material consumption by biomass combined heat and power plants: Energy conservation study of 50 cities and counties in the cold region of China, Journal of Cleaner Production, Volume 278, 2021, 123796, ISSN 0959-6526, https://doi.org/10.1016/j.jclepro.2020.123796. https://www.sciencedirect.com/science/article/pii/S0959652620338415

between temperature and energy use. Most of the studies are based on predicting electricity consumption from temperature.

Energy use and climate conditions are often studied through the lens of climate change, which is also related to an average surface temperature. It is expected that temperature increases will likely increase our energy demand and change our ability to produce electricity and deliver it reliably[195]. If the U.S. nation's climate warms by 1.8°F, the need for energy used for cooling is expected to increase by about 5-20%, while the demand for energy used for heating is expected to decrease by about 3-15%[196]. Heating demand would decrease the most in the northern United States, and cooling demand would increase the most in the southern United States. Since demand for electricity for cooling is expected to grow due to temperature increases and extreme heat events, the energy delivery balance will likely shift from natural gas and fuel oil used for heating to electricity used for air conditioning[197]. Changes in energy demand will likely affect greenhouse gas emissions, but the net effect depends on which energy sources, including alternative energy, are used for electricity and heating[198].

Another study investigates the long-term energy security responses to climate change in Ontario (Canada). Results indicate that winter warms more rapidly than summer in the studied area. This leads to heating degree days decreasing two times faster than cooling degree days increasing. Changes in degree days increase summer electricity demand and a reduction in winter

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[195] Climate Impacts on Energy. U.S. Environmental Protectionn Agency. https://19january2017snapshot.epa.gov/climate-impacts/climate-impacts-energy_.html#:~:text=Increases%20in%20temperature%20will%20likely,oil%2C%20and%20wood%20for%20heating

[196] Effects of Climate Change on Energy Production and Use in the United States. A Report by the U.S. Climate Change Science Program and the subcommittee on Global change Research. Wilbanks, T.J., V. Bhatt, D.E. Bilello, S.R. Bull, J.Ekmann, W.C. Horak, Y.J. Huang, M.D. Levine, M.J. Sale, D.K. Schmalzer, and M.J. Scott. Department of Energy, Office of Biological & Environmental Research, Washington, DC, USA. CCSP (2008). https://downloads.globalchange.gov/sap/sap4-5/sap4-5-final-all.pdf

[197] Dell, J., S. Tierney, G. Franco, R. G. Newell, R. Richels, J. Weyant, and T. J. Wilbanks, 2014: *Ch. 4: Energy Supply and Use. Climate Change Impacts in the United States: The Third National Climate Assessment*, J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds., U.S. Global Change Research Program, 113-129. doi:10.7930/J0BG2KWD. USGCRP (2014). https://nca2014.globalchange.gov/report/sectors/energy

[198] Climate Impacts on Energy. U.S. Environmental Protectionn Agency. https://19january2017snapshot.epa.gov/climate-impacts/climate-impacts-energy_.html#:~:text=Top%20of%20Page-,Temperature%2C%20Energy%20Demand%2C%20and%20Energy%20Supply,oil%2C%20and%20wood%20for%20heating

gas consumption. The team also finds that decreased resource availability could reduce hydropower and wind energy efficiencies on different scales. The efficiency of nuclear power is sensitive to the temperature rise but relatively less reduced compared to other energy sources. Solar energy production can benefit from climate change from a decrease in rainy and cloudy days. With the increased electricity demand and decreased availability of water and wind resources, more green energy capacities are expected to build to ensure long-term energy security for Ontario[199].

Hirano and the group of researchers conducted the study to clarify the impact of regional climatic conditions on energy consumption in Japan's commercial sector. The results showed a regionality to the ratio of increments during summer and winter regarding heating and cooling for the types of buildings addressed in the research. The team was able to roughly determine the level of fluctuations in energy consumption as an impact of temperature[200].

Zarco-Soto, Zarco-Periñán & Sánchez-Durán presented a methodology that allows for calculating the thermal and electric energy consumption together with CO_2 emissions of cities by inhabitant and household based on climate. With this aim, the climate was analyzed, and cities were classified based on it. According to the study, the extremer the city's climate is, the higher the thermal energy consumption is. This consumption decreases in softer climates[201]. Thus, the influence of climate on consumption habits is once again noticed: the total energy consumption is higher or lower depending on weather conditions (rough or smooth weather), and most of the energy consumed is thermal or electric depending on which the severest season is (winter or

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[199] Shuo Wang, Jinxin Zhu, Gordon Huang, Brian Baetz, Guanhui Cheng, Xueting Zeng, Xiuquan Wang, Assessment of climate change impacts on energy capacity planning in Ontario, Canada using high-resolution regional climate model, Journal of Cleaner Production, Volume 274, 2020, 123026, ISSN 0959-6526, https://doi.org/10.1016/j.jclepro.2020.123026.
https://www.sciencedirect.com/science/article/pii/S0959652620330717

[200] Yujiro Hirano, Kei Gomi, Shogo Nakamura, Yukiko Yoshida, Daisuke Narumi, Tsuyoshi Fujita, Analysis of the impact of regional temperature pattern on the energy consumption in the commercial sector in Japan, Energy and Buildings, Volume 149, 2017, Pages 160-170, ISSN 0378-7788, https://doi.org/10.1016/j.enbuild.2017.05.054.
https://www.sciencedirect.com/science/article/pii/S0378778817300385

[201] Zarco-Soto, I.M., Zarco-Periñán, P.J. & Sánchez-Durán, R. Influence of climate on energy consumption and CO2 emissions: the case of Spain. Environ Sci Pollut Res 27, 15645–15662 (2020).
https://link.springer.com/article/10.1007/s11356-020-08079-7#Sec1

summer, respectively). This is because thermal energy is used for heating, while electricity is used mainly for air conditioning[202].

Another way to connect energy use and temperature is through analyzing seasonal peak electricity demand since most air conditioning systems use electricity as a source of power. The study assessing the electricity demand pattern in the relatively temperate climate of the Netherlands (Latitude 52°30'N) has shown significant increases in the temperature dependence of electricity demand in May, June, September, October, and during the summer holidays, meaning that a higher temperature leads to increased electricity demand[203]. Another study has shown that global warming by two °C reduces heating electricity demand in most European countries[204]. Silva, Soares, and Pinho study the relationship between average temperatures and electricity consumption in Portugal. Control variables include electricity prices and economic activity. The results indicate a U-shaped relationship between temperature and electricity consumption. While changes in average temperature do not affect electricity consumption to a large extent, extreme temperatures have more substantial impacts[205].

Santamourisa, Cartalisb, Synnefab, and Kolokotsac have analyzed eleven studies dealing with the impact of ambient temperature on peak electricity demand. The result has shown that for each degree of temperature increase, the peak electricity load increases between 0.45% and 4.6%. This corresponds to an additional electricity penalty of about 21 (±10.4) W per degree of temperature increase per person. In parallel, an analysis of fifteen studies examining the impact

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[202] Zarco-Soto, I.M., Zarco-Periñán, P.J. & Sánchez-Durán, R. Influence of climate on energy consumption and CO2 emissions: the case of Spain. Environ Sci Pollut Res 27, 15645–15662 (2020). https://link.springer.com/article/10.1007/s11356-020-08079-7#Sec1

[203] M. Hekkenberg, R.M.J. Benders, H.C. Moll, A.J.M. Schoot Uiterkamp, Indications for a changing electricity demand pattern: The temperature dependence of electricity demand in the Netherlands, Energy Policy, Volume 37, Issue 4, 2009, Pages 1542-1551, ISSN 0301-4215, https://doi.org/10.1016/j.enpol.2008.12.030. https://www.sciencedirect.com/science/article/pii/S0301421508007696

[204] Andrea Damm, Judith Köberl, Franz Prettenthaler, Nikola Rogler, Christoph Töglhofer, Impacts of +2°C global warming on electricity demand in Europe, Climate Services, Volume 7, 2017, Pages 12-30, ISSN 2405-8807, https://doi.org/10.1016/j.cliser.2016.07.001. https://www.sciencedirect.com/science/article/pii/S2405880716300012

[205] Susana Silva, Isabel Soares, Carlos Pinho, Climate change impacts on electricity demand: The case of a Southern European country, Utilities Policy, Volume 67, 2020, 101115, ISSN 0957-1787, https://doi.org/10.1016/j.jup.2020.101115. https://www.sciencedirect.com/science/article/abs/pii/S0957178720301090

of ambient temperature on the total electricity consumption showed that the actual increase of the electricity demand per degree of temperature increase varies between 0.5% and 8.5%[206].

Looking at the global map of per capita energy consumption, one can notice an apparent general pattern: low-latitude countries have lower per capita consumption than mid to high-latitude countries. (Exceptions exist. For example, Saudi Arabia has anomalously high per capita energy consumption compared to surrounding countries because it is a wealthy, oil-rich country with a low population)[207]

Some studies use the relationship between temperature and energy consumption patterns for energy planning. For example, Sachs et al. (2019) used global high-resolution heat and cooling energy density maps to capture the seasonal and spatial changes in global heating and cooling energy demand.[208]

Another study devoted to electricity demand forecasting in Greece was conducted by Morasgedis et al. and illustrated that demand depends not only on economic variables and national circumstances but also on climatic conditions. Following the analysis of the time series of electricity demand in the past decade, two statistical models have been developed, one providing daily and the other monthly demand predictions, to estimate medium-term demand up to 12 months ahead, utilizing primitive (relative humidity) and derived (heating and cooling degree-days) meteorological parameters. Autoregressive structures were incorporated in both models to reduce serial correlation, which appears to bias the estimated effects of meteorological parameters on electricity demand. Both modeling approaches show a high predictive value with adjusted R2 above 96%[209].

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[206] M. Santamouris, C. Cartalis, A. Synnefa, D. Kolokotsa, On the impact of urban heat island and global warming on the power demand and electricity consumption of buildings—A review, Energy and Buildings, Volume 98, 2015, Pages 119-124, ISSN 0378-7788, https://doi.org/10.1016/j.enbuild.2014.09.052. https://www.sciencedirect.com/science/article/abs/pii/S0378778814007907

[207] Global Energy Demand and Consumption https://www.e-education.psu.edu/geog438w/node/376

[208] Julia Sachs, Diego Moya, Sara Giarola, Adam Hawkes, Clustered spatially and temporally resolved global heat and cooling energy demand in the residential sector, Applied Energy, Volume 250, 2019, Pages 48-62, ISSN 0306-2619, https://doi.org/10.1016/j.apenergy.2019.05.011. https://www.sciencedirect.com/science/article/pii/S0306261919308657

[209] S. Mirasgedis, Y. Sarafidis, E. Georgopoulou, D.P. Lalas, M. Moschovits, F. Karagiannis, D. Papakonstantinou, Models for mid-term electricity demand forecasting incorporating weather influences, Energy, Volume 31, Issues 2–3, 2006, Pages 208-227, ISSN 0360-5442, https://doi.org/10.1016/j.energy.2005.02.016. https://www.sciencedirect.com/science/article/abs/pii/S0360544205000393

Bessec and Fouquau have covered a wider geographic area in their research. Their paper investigates the relationship between electricity demand and temperature in the European Union. The authors address this issue using a panel threshold regression model on 15 European countries over the last two decades. The results confirm the non-linearity of the link between electricity consumption and temperature. By distinguishing between North and South countries, Bessec and Fouquau also find that this nonlinear pattern is more pronounced in warm countries. Finally, rolling regressions show that the sensitivity of electricity consumption to temperature in summer has increased in the recent period[210].

Some authors concentrate on a specific energy source when studying temperature's impact on consumption. Szoplik's study presents the results of forecasting the gas demand obtained with artificial neural networks. Design and training of the multilayer perceptron model (MLP) were carried out using data describing the actual natural gas consumption in Szczecin (Poland). In the model, calendar (month, day of month, day of week, hour) and weather (temperature) factors, which have a pronounced effect on individual consumers and small industry gas consumption, were considered. The results show that one of the MLP models (22-36-1) can be successfully used to predict gas consumption on any day of the year and any hour of the day[211].

2.5.2. GDP PER CAPITA (US$ CURRENT)

GDP per capita is an important indicator of economic performance and helpful for cross-country comparisons of average living standards and economic wellbeing[212]. Changes in the output of goods and services per person (GDP per capita) are often used to measure whether the average citizen in a country is better or worse off[213].

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[210] Marie Bessec, Julien Fouquau, The non-linear link between electricity consumption and temperature in Europe: A threshold panel approach, Energy Economics, Volume 30, Issue 5, 2008, Pages 2705-2721, ISSN 0140-9883, https://doi.org/10.1016/j.eneco.2008.02.003. https://www.sciencedirect.com/science/article/pii/S0140988308000418

[211] Jolanta Szoplik, Forecasting of natural gas consumption with artificial neural networks, Energy, Volume 85, 2015 Pages 208-220, ISSN 0360-5442, https://doi.org/10.1016/j.energy.2015.03.084. https://www.sciencedirect.com/science/article/abs/pii/S036054421500393X

[212] GDP per capita. https://www.focus-economics.com/economic-indicator/gdp-per-capita

[213] TIM CALLEN. GROSS DOMESTIC PRODUCT: AN ECONOMY'S ALL. https://www.imf.org/external/pubs/ft/fandd/basics/gdp.htm

I used any energy efficiency, energy use, energy intensity, and primary energy consumption related to GDP per capita or economic growth for my search parameters. The literature analyzing the connection is provided in abundance. Most studies agree that the relationship exists. But there is no absolute conclusion about the nature of the relationship. In some cases, the results vary significantly. Some studies claim that energy consumption causes economic growth or vice versa. At the same time, some researchers state that energy consumption and development are interrelated or have no link between them.

In many cases, national wealth is linked to the size of houses, although the trend varies worldwide[214]. According to EIA, and for apparent reasons, larger homes and larger households tend to use more energy overall than smaller homes and smaller households. For example, because of higher space-heating demand, households in the Northeast and Midwest regions of the United States consume more energy on average than households in the South and West regions. [215]

Agovino's paper discusses an original article by Gales et al. (2007) concerning the relationship between total energy intensity and GDP per capita of four European countries (Sweden, the Netherlands, Italy, and Spain) over the last two centuries. The estimates show a U-shaped relationship between total energy intensity and GDP per capita. In addition, after decomposing total energy intensity, two different relationships emerge a hyperbolic pattern (traditional energy carriers) and a U-shaped inverse pattern (modern energy carriers). Agovino concludes that the decreasing branch of the U-shaped relationship between total energy intensity and GDP per capita is driven by traditional energy sources when the latter dominate modern energy sources (low GDP per capita). In contrast, the ascending branch of the U-shaped relationship is driven by contemporary energy sources when prevailing over traditional sources (high levels of GDP per capita)[216].

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[214] Joe Pinsker. Why Are American Homes So Big?. 2019. https://www.theatlantic.com/family/archive/2019/09/american-houses-big/597811/

[215] Use of energy explained. https://www.eia.gov/energyexplained/use-of-energy/homes.php

[216] Massimiliano Agovino, Silvana Bartoletto, Antonio Garofalo, Modelling the relationship between energy intensity and GDP for European countries: An historical perspective (1800–2000), Energy Economics, Volume 82, 2019, Pages 114-134, ISSN 0140-9883,
https://doi.org/10.1016/j.eneco.2018.02.017.
https://www.sciencedirect.com/science/article/pii/S0140988318300756

Garba and Bellingham used data from 46 sub-Saharan African countries. They provided empirical evidence of the impacts of the continued utilization of traditional fuels on economic development (employing Gross Domestic Product (GDP) per Capita as a variable). The research has established a negative causal relationship between conventional fuel use (solid) and GDP per capita[217].

Because GDP per capita and energy consumption are known to affect CO2 positively, [218] some studies concentrate on CO2 emissions, which is a good indicator of energy use. For example, Aslam et al. explore the nexus of industrialization, economic growth, and carbon dioxides (CO2) emission for the Chinese economy, along with trade openness and population density. The computed estimates reveal that a GDP per capita increase deteriorates CO2 emissions in the long-run[219].

Bildirici and Bakirtas investigated the causality relationship between economic growth and coal, natural gas, and oil consumption in BRICTS (Brazil, Russia, India, China, Turkey, and South Africa). Countries for the 1980–2011 period. In this study, GDP was used as a measure of economic growth. The Granger causality and the forecast error variance decomposition approaches indicate evidence of a causal relationship between variables. According to empirical results, there is evidence of a unidirectional Granger causality from the real gross domestic product (GDP) to carbon dioxide (CO2) emissions in analyzed countries, unidirectional causality from coal consumption to carbon dioxide (CO2) emissions, unidirectional causality from oil consumption to carbon dioxide (CO2) emissions in China, India, Turkey, and South Africa and bi-directional causality in Brazil and Russia. Meanwhile, there is bidirectional causality from GDP to coal consumption, from coal to oil consumption for Brazil, Russia, China, Turkey, and South Africa.

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[217] Ifeoluwa Garba, Richard Bellingham, Energy poverty: Estimating the impact of solid cooking fuels on GDP per capita in developing countries - Case of sub-Saharan Africa, Energy, Volume 221, 2021, 119770, ISSN 0360-5442, https://doi.org/10.1016/j.energy.2021.119770.
https://www.sciencedirect.com/science/article/pii/S0360544221000190

[218] Arifur Rahman, S. M. Woahid Murad, Fayyaz Ahmad, Xiaowen Wang. Evaluating the EKC Hypothesis for the BCIM-EC Member Countries under the Belt and Road Initiative. Sustainability 2020, 12(4), 1478; https://www.mdpi.com/2071-1050/12/4/1478

[219] Bilal Aslam, Jinsong Hu, Sadaf Shahab, Awais Ahmad, Mudassar Saleem, Syed Shoaib Ahmad Shah, Muhammad Sufyan Javed, Muhammad Kashif Aslam, Shahid Hussain, Masood Hassan, The nexus of industrialization, GDP per capita and CO2 emission in China, Environmental Technology & Innovation, Volume 23, 2021, 101674 ISSN 2352-1864, https://doi.org/10.1016/j.eti.2021.101674.
https://www.sciencedirect.com/science/article/abs/pii/S2352186421003229

India's causality results reveal a bidirectional causality from GDP to coal consumption, oil consumption, and carbon dioxide (CO2) emissions. The results of forecast error variance supported the results of the causality test[220].

Alkhathlan and Javid's study attempts to analyze the effect of total oil consumption and oil consumption in the transport sector of Saudi Arabia with respect to income over the period from 1971 to 2013. To measure income, the real income variable (billions) was used. The results reveal that the elasticity of carbon emissions with respect to income and the square of income is positive and significant, implying a monotonically increasing relationship between carbon emissions and income in Saudi Arabia. The results further reveal that the elasticity of carbon emissions with respect to total oil consumption and transport oil consumption is positive and significant. The empirical findings of this study demonstrate that growth in real income forces CO2 emissions to grow[221].

Danish et al. (2018) analyze the nexus between energy consumption and financial development in the Next-11 countries. Analyzing data on economic growth per capita, globalization, and urbanization from 1990 to 2014 concludes that financial development stimulates energy consumption.

The pace of globalization continues to increase, expanding economic activities around the globe and influencing energy consumption in both developing and developed countries. However, views have become different on whether globalization increases or decreases energy consumption. Danish and Ulucak present research investigating the nexus among financial development, globalization, and energy consumption from 1980 to 2017 in Pakistan. Empirical results confirm that both globalization and financial development increase energy consumption in Pakistan. Further, per capita GDP promotes energy consumption[222].

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[220] Melike E. Bildirici, Tahsin Bakirtas, The relationship among oil, natural gas and coal consumption and economic growth in BRICTS (Brazil, Russian, India, China, Turkey and South Africa) countries, Energy, Volume 65, 2014, Pages 134-144, ISSN 0360-5442, https://doi.org/10.1016/j.energy.2013.12.006. https://www.sciencedirect.com/science/article/abs/pii/S0360544213010633

[221] Khalid Alkhathlan, Muhammad Javid, Carbon emissions and oil consumption in Saudi Arabia, Renewable and Sustainable Energy Reviews, Volume 48, 2015, Pages 105-111, ISSN 1364-0321, https://doi.org/10.1016/j.rser.2015.03.072. https://www-sciencedirect.com.proxy.lib.odu.edu/science/article/pii/S1364032115002257?via%3Dihub

[222] Danish, Recep Ulucak. A revisit to the relationship between financial development and energy consumption: Is globalization paramount?,

Chiu and Lee explore the impacts of country risks on the relationship between energy consumption and financial development for 79 countries. The full sample results show that financial development could help reduce energy consumption under stable country risk environments. The results also show that banking sector development has more significant impacts on energy consumption than stock market development[223].

Bah and Azam explore the causal relationship among electricity consumption, economic growth (GDP per capita), financial development, and CO2 emissions in South Africa from 1971 to 2012. The Autoregressive Distributed Lag (ARDL) bounds test is used to test for the presence of cointegration. In contrast, the Toda and Yamamoto augmented Granger causality test is used for the direction of causality. The results of the ARDL-bounds test validate the existence of cointegration among the included variables. Further, the Toda and Yamamoto Granger causality test affirms no causality between electricity consumption and economic growth[224].

Bakirtas and Akpolat investigated the causal relationship between energy consumption, urbanization, and economic growth using the qualified panel stationarity and Granger causality tests for the period 1971–2014 in New Emerging-Market Countries (Colombia, India, Indonesia, Kenya, Malaysia, and Mexico). The results show that economic growth and urbanization are crucial factors determining energy consumption[225].

Kraft and Kraft were some of the first researchers to determine the relationship between energy consumption and economic growth. For variables, they used gross energy inputs and GNP.

Energy, Volume 227, 2021, 120337, ISSN 0360-5442, https://doi.org/10.1016/j.energy.2021.120337. https://www-sciencedirect-com.proxy.lib.odu.edu/science/article/abs/pii/S0360544221005867

[223] Yi-Bin Chiu, Chien-Chiang Lee, Effects of financial development on energy consumption: The role of country risks, Energy Economics, Volume 90, 2020, 104833, ISSN 0140-9883, https://doi.org/10.1016/j.eneco.2020.104833. https://www-sciencedirect-com.proxy.lib.odu.edu/science/article/pii/S0140988320301730

[224] Muhammad Maladoh Bah, Muhammad Azam, Investigating the relationship between electricity consumption and economic growth: Evidence from South Africa, Renewable and Sustainable Energy Reviews, Volume 80, 2017, Pages 531-537, ISSN 1364-0321, https://doi.org/10.1016/j.rser.2017.05.251. https://www.sciencedirect.com/science/article/pii/S1364032117308973

[225] Tahsin Bakirtas, Ahmet Gokce Akpolat, The relationship between energy consumption, urbanization, and economic growth in new emerging-market countries, Energy, Volume 147, 2018, Pages 110-121, ISSN 0360-5442, https://doi.org/10.1016/j.energy.2018.01.011. https://www.sciencedirect.com/science/article/pii/S0360544218300112

The main empirical finding is that causality is unidirectional, only from GNP to energy for the postwar period[226].

Muhammed Ashiq et al. examined the asymmetric impacts of electricity consumption on economic growth in Bangladesh by using the Nonlinear Autoregressive Distributed Lag (NARDL) model over the annual data of 1971–2014. After confirming the long-run asymmetric cointegration between the series, the long-run result indicates that economic growth responds to electricity consumption asymmetrically in Bangladesh. The long-run result also indicates the dominant effect of negative shocks in electricity consumption over its positive shocks while affecting the economic growth in Bangladesh[227].

Nasreen et al. analyze data from 18 Asian countries, spanning from 1980 to 2017, to determine panel long-run causality between income growth, transport energy consumption, and environmental quality. After these methodological advances, a bi-directional long-run Granger causality is found between transport energy consumption, environment, and GDP growth. It is revealed that a 1% increase in transport energy consumption and GDP growth deteriorates environmental quality by about 0.57% and 0.46%, respectively, in Asian countries. Furthermore, the magnitude of elasticities varies from country to country. The empirical findings add new dimensions to energy-efficient technologies in the transport sector that positively affect economic growth without compromising environmental quality[228].

2.6 CONCLUSION

The most important aspects of the existing literature are related to the methods other researchers used, motives to pursue a particular study, different scopes of studies, and various dimensions of energy use explored.

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[226] Kraft J., Kraft, A. Relationship between energy and GNP Relationship between energy and GNP. J. Energy Dev.; (United States). https://www.osti.gov/biblio/6713220-relationship-between-energy-gnp

[227] Muhammed Ashiq Villanthenkodath, Mantu Kumar Mahalik, Does economic growth respond to electricity consumption asymmetrically in Bangladesh? The implication for environmental sustainability, Energy, Volume 233, 2021, 121142, ISSN 0360-5442, https://doi.org/10.1016/j.energy.2021.121142. https://www.sciencedirect.com/science/article/pii/S0360544221013906

[228] Samia Nasreen, Mounir Ben Mbarek, Muhammad Atiq-ur-Rehman, Long-run causal relationship between economic growth, transport energy consumption and environmental quality in Asian countries: Evidence from heterogeneous panel methods, Energy, Volume 192, 2020, 116628, ISSN 0360-5442, https://doi.org/10.1016/j.energy.2019.116628. https://www.sciencedirect.com/science/article/pii/S0360544219323230

Researchers use various methods to explain energy use. The most common approach utilizes the quantitative method to explore the dependent variable across multiple countries. For example, Saucedo et al. estimated static and dynamic panel data models to identify the relationship between CO2 emissions per capita, GDP per capita, energy consumption, and environmental taxes for OECD countries in 1994-2014[229]. Studies with a broad scope of analysis of multiple countries and long periods often use a mixed analysis method. For example, Thonipara et al. took on an exploratory and mixed methods approach to shed some light on some of the energy efficiency policies that had previously been neglected, such as district heating and carbon taxation[230].

Some authors focus on particular aspects of energy use. For example, Thonipara et al. explored energy efficiency in residential buildings and construction[231], Harding et al. studied energy use taxes in 21 European Union countries and across all OECD countries[232], Sachs et al. have observed seasonal and spatial changes in global heating and cooling energy demand[233], gasoline consumption for road transport[234] , etc.

Motives of other researchers studying what shapes energy use evolve around two main areas: environmental and economic. Among environmental ones are: mitigating the effects of

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[229] ESTIMATING ENVIRONMENTAL KUZNETS CURVE: THE IMPACT OF ENVIRONMENTAL TAXES AND ENERGY CONSUMPTION IN CO2 EMISSIONS OF OECD COUNTRIES https://www-proquest-com.proxy.lib.odu.edu/docview/2068860158?accountid=12967&pq-origsite=primo

[230] Anita Thonipara, Petrik Runst, Christian Ochsner, Kilian Bizer, Energy efficiency of residential buildings in the European Union – An exploratory analysis of cross-country consumption patterns, Energy Policy, Volume 129, 2019, Pages 1156-1167, ISSN 0301-4215, https://doi.org/10.1016/j.enpol.2019.03.003. https://www-sciencedirect-com.proxy.lib.odu.edu/science/article/pii/S0301421519301661

[231] Energy efficiency of residential buildings in the European Union – An exploratory analysis of cross-country consumption patterns https://www-sciencedirect-com.proxy.lib.odu.edu/science/article/pii/S0301421519301661

[232] Michelle Harding, Chiara Martini, Alastair Thomas. Taxing Energy Use: Patterns and Incoherencies in Energy Taxation in Europe and the OECD. (2015). https://link.springer.com/chapter/10.1007/978-3-319-21302-6_11

[233] Julia Sachs, Diego Moya, Sara Giarola, Adam Hawkes. Clustered spatially and temporally resolved global heat and cooling energy demand in the residential sector, Applied Energy, Volume 250, 2019, Pages 48-62, ISSN 0306-2619, https://doi.org/10.1016/j.apenergy.2019.05.011. https://www.sciencedirect.com/science/article/pii/S0306261919308657

[234] Paul J. Burke, Shuhei Nishitateno, Gasoline prices, gasoline consumption, and new-vehicle fuel economy: Evidence for a large sample of countries, Energy Economics, Volume 36, 2013, Pages 363-370, ISSN 0140-9883, https://doi.org/10.1016/j.eneco.2012.09.008. https://www-sciencedirect-com.proxy.lib.odu.edu/science/article/pii/S0140988312002228

human activities, such as lowering greenhouse gas emissions (Pata, 2018[235], Cottrell et al., 2016[236]) or addressing climate change in general, which has become a key theme for many policy initiatives (Thonipara et al., 2019[237], Wang et al., 2020[238]). The economic area includes but is not limited to such topics as improving economic growth or, in other words, establishing economic benefits from lower energy consumption (Bakirtas & Akpolat, 2018[239], Yang et al., 2016[240]); and diminishing energy security issues (Wang et al., 2020[241]).

A significant portion of the available research sheds light on local issues of a particular country or region and with a limited number of variables. For example, Sadorsky used urbanization and industrialization variables to investigate their impact on energy consumption in a panel of emerging economies[242]. Gillingham and Munk-Nielsen analyzed how fuel price changes impact the driving habits of households across the population[243]. Only a few studies have attempted to explain how multiple independent and control variables shape energy use globally. For instance, Al-mulali explores how urbanization, energy consumption, and CO2 emission in MENA countries[244].

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[235] Ugur Korkut Pata, Renewable energy consumption, urbanization, financial development, income and CO2 emissions in Turkey: Testing EKC hypothesis with structural breaks, Journal of Cleaner Production, Volume 187, 2018, Pages 770-779, ISSN 0959-6526, https://doi.org/10.1016/j.jclepro.2018.03.236. https://www-sciencedirect-com.proxy.lib.odu.edu/science/article/pii/S0959652618309132?via%3Dihub

[236] Environmental Tax Reform in Developing, Emerging and Transition Economies https://www.die-gdi.de/uploads/media/Study_93.pdf

[237] Energy efficiency of residential buildings in the European Union – An exploratory analysis of cross-country consumption patterns https://www-sciencedirect-com.proxy.lib.odu.edu/science/article/pii/S0301421519301661

[238] Assessment of climate change impacts on energy capacity planning in Ontario, Canada using high-resolution regional climate model https://www.sciencedirect.com/science/article/pii/S0959652620330717

[239] The relationship between energy consumption, urbanization, and economic growth in new emerging-market countries https://www-sciencedirect-com.proxy.lib.odu.edu/science/article/abs/pii/S0360544218300112

[240] Impacts of urbanization on renewable energy consumption in China https://www-sciencedirect-com.proxy.lib.odu.edu/science/article/pii/S0959652615010896

[241] Assessment of climate change impacts on energy capacity planning in Ontario, Canada using high-resolution regional climate model https://www-sciencedirect-com.proxy.lib.odu.edu/science/article/pii/S0959652620330717

[242] The Effect of Urbanization and Industrialization on Energy Use in Emerging Economies: Implications for Sustainable Development
https://onlinelibrary.wiley.com/doi/full/10.1111/ajes.12072

[243] A tale of two tails: Commuting and the fuel price response in driving https://www-sciencedirect-com.proxy.lib.odu.edu/science/article/pii/S0094119018300779?via%3Dihub

[244] Exploring the relationship between urbanization, energy consumption, and CO2 emission in MENA countries https://www-sciencedirect-com.proxy.lib.odu.edu/science/article/abs/pii/S1364032113001433?via%3Dihub

The current state of the literature reviewed is such that it does not answer a straightforward question: which variables shape energy, and fossil fuel, use per capita across countries and which do not. Given the upward global trend of fossil fuel consumption, the answer to this question would become a great benefit to researchers studying energy use, to policymakers working on the improvements of the existing policies, to resource managers of all levels from a small production line to any government, and even to average homeowners around.

The most significant flaw in the existing knowledge is that most studies are limited to the maximum of three variables in their framework, resulting in an omitted variable bias. Thus, it is essential for future mixed studies to concentrate on broader scopes and to include as many potentially impacting independent variables as possible. This would help to explore fossil fuel use per capita globally better.

CHAPTER 3

METHODOLOGY

3.1. INTRODUCTION

This Chapter discusses the methodology I use to research how some variables shape global energy consumption. The core question of my research is, `Why do some countries consume less fossil fuels per capita than others?` I use a multivariate framework to answer this question, including three independent and two control variables. Since energy use across countries is underresearched, I aim to conduct a basic exploratory type of research, particularly after the second chapter revealed a lack of knowledge on global energy consumption across counties.

The three independent variables are Pump price for gasoline, Urbanization, and Fossil Fuel Imports. In other words, the key question could also be re-phrased into `How do pump price, urbanization, and fuel imports impact Fossil Fuels Consumption per capita across countries?`

To conduct the research, I use a mixed-method approach. This research design has become popular lately because of combining qualitative and quantitative data. The increased interest is evident in thesis and dissertation methodologies and conferences. According to Courtney McKim, a steady increase in the number of theses and dissertations containing the word "mixed methods" has been seen over the past 30 years (from 3 in 1980-1984 to 2538 in 2010-2013)[245].

The mixed-method approach allows one to understand a given topic better. It also adds value by increasing the validity of the findings and assisting with knowledge creation[246]. Interestingly, mixed methods articles receive more citations than studies not utilizing mixed methods[247]. Another value of mixed methods is the integration component. The integration gives readers more confidence in the results and the conclusions they draw from the study[248].

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[245] https://journals.sagepub.com/doi/full/10.1177/1558689815607096#:~:text=Another%20value%20of%20mixed%20methods,et%20al.%2C%202010)

[246] Hurmerinta-Peltomaki L., Nummela N. (2006). Mixed methods in international business research: A value-added perspective. Management International Review, 46, 439-459.

[247] Molina-Azorin J. F. (2011). The use and added value of mixed methods in management research. Journal of Mixed Methods Research, 5(1), 7-24.

[248] O'Cathain A., Murphy E., Nicholl J. (2010). Three techniques for integrating data in mixed methods studies. British Medical Journal, 314, 1147-1150.

The quantitative method will test the relationships between FFCC and the Independent variables. As a basis, I use a sample of 28 OECD counties to design and test a model for 2009-2018 (The Model). Data used in this Model will come from two online databases available for free use: World Bank and British Petroleum.

To gain a more in-depth understanding of FFCC across countries through studying local specifics, I use a qualitative method to review three case studies (Finland, Canada, and Colombia). This would help explain why the Model fits well in some instances and not in other cases.

The Chapter is divided into five sections. The first one is devoted to the research question and hypotheses. The second one narrates the methodological approach. The third part introduces readers to the specifics of the data collection. Section four talks about the methods of analysis. And the final one is devoted to all the variables used in my research.

3.2. RESEARCH QUESTION AND HYPOTHESES

The central question of the dissertation is: **Why do some countries consume less fossil fuels per capita than others?**

To begin investigating the Central Question, I suggest several explanations for why some countries consume less fossil fuels per capita than others. This work is built upon the three Hypotheses, which assume that independent variables shape energy use. All three Independent variables are expected to impact the Dependent Variable (DV) positively.

The three Hypotheses are:

H1. In a comparison of countries, higher pump prices are associated with a decrease in Fossil Fuels Consumption per Capita (FFCC) compared to those with lower pump prices;

H2. In a comparison of countries, a greater urban percentage of the population is associated with a decrease in Fossil Fuels Consumption per Capita compared to those with a less urbanized population;

H3. In a comparison of countries, higher fuel imports are associated with a decrease in Fossil Fuels Consumption per Capita compared to those with lower fuel imports.

To research all three hypotheses, I use quantitative and qualitative methods.

3.3. METHODOLOGICAL APPROACH

I use the multivariate framework to answer the central question in my research. By doing so, I do not reinvent the wheel since the multivariate model is a popular statistical tool that allows using multiple variables to explain possible outcomes of an independent variable.

To ensure the scope is narrow enough and countries in a tested sample have similar economic development levels, my Model will include only countries that are members of the Organisation for Economic Cooperation and Development (OECD). OECD is an international organization that works to build better policies for better lives. As of today, it accounts for thirty-eight members: Austria, Australia, Belgium, Canada, Chile, Colombia, Czech Republic, Finland, France, Germany, Greece, Hungary, Israel, Italy, Japan, Republic of Korea, Mexico, Netherlands, New Zeland, Norway, Poland, Portugal, Spain, Sweden, Switzerland, Turkey, United Kingdom, United States, Costa Rica, Lithuania, Latvia, Estonia, Slovenia, Slovak Republic, Danmark, Iceland, Ireland, Luxemburg. Based on the Framework for considering prospective members, new members are being accepted based on specific criteria, where good economic and public governance practice is necessary. Among key characteristics are: a rules-based open market economy, tax transparency and international cooperation, a stable and transparent financial system, and access to information. [249] Because of specific economic requirements for becoming a member, one can expect OECD members to be at similar economic development levels.

Several trusted online databases are available to use for researchers for free. Thus, I don't need to collect primary data for quantitative research. I use secondary data from two reliable organizations, World Bank and British Petroleum.

I also need some quantitative data to gain a more in-depth understanding of fossil fuels consumption per capita across countries and explain why the quantitative Model fits well in some instances and not in others.

I use an exploratory mixed methods approach, a standard way of researching energy use across countries by other researchers.

[249] Meeting of the OECD Council at Ministerial Level. Paris. 2017. https://www.oecd.org/mcm/documents/C-MIN-2017-13-EN.pdf

3.4. DATA COLLECTION

3.4.1. QUANTITATIVE DATA COLLECTION

I used several sources to obtain the necessary data for creating the Model.

Fossil Fuels Consumption per capita came from the British Petroleum (BP) website[250]. I have downloaded the Excel spreadsheet called bp-stats-review-2019-all-data. There are several tabs containing information for every country in the world: Oil Consumption, Gas Consumption, and Coal Consumption. I converted the consumption of all three fossil fuel types to million tonnes of oil equivalent, added the transformed data for every country, and divided fossil fuel consumption by the population. The data on population came from the World Bank Data website[251].

BP is one of the few major global oil and gas multinational giants. The BP dataset was chosen because it only provides up-to-date energy production and use information. It is also available to the general public and provides the detail needed for my analysis's quantitative part.

The data on most independent and control variables, except Latitude, comes from the World Bank Open Data website[252]. The website provides free and open access to global development data.

Below is the table showing how the terms of the variables in my research correspond with those I downloaded from the World Bank Open Data website.

Table 2. Variables

Variable in my research	**Variable to search for on the WB Open Data website**	**Year**
Urbanization	Urban population (% of the total population)	2009-2018
Fossil Fuels	Fuel Imports (% of merchandise)	2009-2018
GDP per capita	GDP per capita (current US$)	2009-2018
Pump price	Pump price for gasoline (US$ per liter)	2009-2016[253]

[250] https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html
[251] https://data.worldbank.org/
[252] The World Bank Data. https://data.worldbank.org/
[253] Note. The data for 2017 and 2018 is missing on the WB Open Data website

I have used the online dataset with GPS coordinates for every country and every USA state to source the Latitude variable[254].

After obtaining all the available data, I eliminated several OECD countries from the sample due to the missing information in the World Bank database on specific variables for Costa Rica, Lithuania, Latvia, Estonia, Slovenia, Slovak Republic, Denmark, Iceland, Ireland, and Luxemburg. Thus, my Model will include only countries with the available data for all the variables. As a result of this necessary elimination, my sample ended up having 28 OECD countries out of the existing 38 countries, which represents approximately 74% of the population. The Model's size is two hundred eighty observations (twenty-eight countries during the period of ten years from 2009 to 2018). The list of twenty-eight OECD countries used in the research is presented below.

1	Austria
2	Australia
3	Belgium
4	Canada
5	Chile
6	Colombia
7	Czech Republic
8	Finland
9	France
10	Germany
11	Greece
12	Hungary
13	Israel
14	Italy
15	Japan
16	Korea, Rep.
17	Mexico

[254] Latitude and Longitude for Every Country and State. https://www.kaggle.com/paultimothymooney/latitude-and-longitude-for-every-country-and-state

18	Netherlands
19	New Zealand
20	Norway
21	Poland
22	Portugal
23	Spain
24	Sweden
25	Switzerland
26	Turkey
27	United Kingdom
28	United States

Generally, the smaller the population, the larger the sampling ratio needed. For populations under 1,000, a minimum ratio of 30 percent is advisable to ensure the sample's representativeness[255]. According to the sample size calculator, a population of 380 must have at least 191 items in a sample[256]. Thus, 74% or 280 observations ensure the representativeness of the entire population.

Despite eliminations, the model will still represent a broad spectrum of variety in geographic location, fossil fuel consumption, GDP per capita, urbanization, and pump price.

3.4.2. QUALITATIVE DATA COLLECTION

To gain a more in-depth understanding of fossil fuels consumption per capita across countries, I use a qualitative method to review three case studies (Finland, Canada, and Colombia). This would help explain why the Model fits well in some instances and not in other cases.

I selected the three case studies based on the preliminary multiple regression analysis results: one of them illustrated the closest to the predicted value result (Finland (residual of -0,05)), and the other two cases have the most distant predicted values from the actual ones (Canada and Colombia with their residuals 2.54 and -1.95 consequently).

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[255] Sample Size. St. Olaf College. https://wp.stolaf.edu/iea/sample-size/#:~:text=Sampling%20ratio%20(sample%20size%20to,ensure%20representativeness%20of%20the%20sample

[256] Sample Size. https://researchbasics.education.uconn.edu/sample-size/

3.5. METHODS OF ANALYSIS

I employ an exploratory and mixed methods approach to shed some light on how pump price, urbanization, and fuel imports shape fossil fuel consumption per capita across OECD counties. My analysis will be divided into two parts, namely, a quantitative and an exploratory qualitative part.

3.5.1. QUANTITATIVE METHOD

My goal in conducting the quantitative method is to examine the relationship between the dependent variable of Fossil Fuels Consumption per capita and the independent variables of Pump Price, Urbanization, and Fossil Fuel. In the World of interconnectedness, there are numerous biases to be escaped while conducting research. That is why to prevent certain variables from influencing the outcome of a study, I chose to control for Latitude and GDP per capita. I expect the quantitative method results to explain how Independent variables shape FFCC across counties.

My analysis of the Model is limited to testing the pre-existing statistical data. After gathering the data, I eliminated the countries with the missing variables. I have transformed the GDP/ cap (US$ current) variable into the GDP/ cap (US$ current) in thousands by dividing each by 1000. The rest of the variables remained untransformed. Then, I ran a multiple regression analysis using Excel's Analyze Data tool.

3.5.2. EXPLORATORY QUALITATIVE METHOD

Because I can not control for country-specific conditions in a multivariate study, I also have to use an exploratory qualitative method. This will allow me to gain a more in-depth understanding of Fossil Fuels Consumption per capita across countries and the factors shaping it. It would also help explain why the Model fits well in some instances and not in other cases.

The subsequent qualitative analysis will be based on the results of my quantitative research. I investigate how selected countries fit the general pattern of the Model, and if they don't fit, I try to explain why not. Factors outside those used in the Model may explain why a specific case doesn't fit the Model. I review existing energy efficiency policies and tax rates with respect to fossil fuel use, oil imports, and urbanization trends. The gathered material will be evaluated with regard to the central question. Since it is an exploratory analysis, I aim to draw conclusions based on the existing qualitative evidence, which might be validated in further research.

The three countries chosen as case studies are Finland, Canada, and Colombia. I selected the three case studies based on the preliminary multiple regression analysis results: one of them illustrated the closest to the predicted value result (Finland (residual of -0,05)), and the other two cases have the most distant predicted values from the actual ones (Canada and Colombia with their residuals 2.54 and -1.95 consequently).

3.6. VARIABLES

This section will introduce the readers to the dependent, independent, and control variables. For convenience, the below table contains a summary of all variables and their basic descriptive statistics.

Table 3. Variables and their basic descriptive statistics

Variable	**Description note**
Fossil Fuels Consumption per Capita (Gigajoule per capita)	Fossil Fuels Consumption comprises oil, natural gas, and coal. Oil consumption includes inland demand plus international aviation and marine bunkers and refinery fuel and loss. Consumption of biogasoline (such as ethanol), biodiesel, and derivatives of coal and natural gas are also included. Natural gas excludes natural gas converted to liquid fuels but includes derivatives of coal as well as natural gas consumed in Gas-to-Liquids transformation. Coal includes Commercial solid fuels only, i.e. bituminous coal and anthracite (hard coal), lignite and brown (sub-bituminous) coal, and other commercial solid fuels.
Urban population (% of the total population)	Urban population refers to people living in urban areas as defined by national statistical offices. The data are collected and smoothed by United Nations Population Division.
Fuel Imports (% of merchandise)	Fuels comprise the commodities in SITC section 3 (mineral fuels, lubricants, and related materials)
Pump price for gasoline (US$ per liter)	Fuel prices refer to the pump prices of the most widely sold grade of gasoline. Prices have been converted from the local currency to U.S. dollars.
Latitude	N/A

Table 3. Continued

Variable	Description note
GDP per capita (current US$)	GDP at purchaser's prices is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without deductions for depreciation of fabricated assets or depletion and degradation of natural resources. Data are in current U.S. dollars. Dollar figures for GDP are converted from domestic currencies using single-year official exchange rates. An alternative conversion factor is used for a few countries where the official exchange rate does not reflect the rate effectively applied to actual foreign exchange transactions.

3.6.1. REVIEW OF THE DEPENDENT VARIABLE: FOSSIL FUELS CONSUMPTION PER CAPITA

I use the Dependent Variable of Fossil Fuels Consumption per capita to research the central question in my Model. This variable was chosen because it would allow me to objectively analyze primary energy use across OECD countries and answer the central question.

The FFCC data in my research comprises commercially traded oil, natural gas, and coal.[257] The variable measures the total fossil fuels demand of a country. It covers consumption of the energy sector itself, losses during transformation (for example, from oil or gas into electricity) and distribution of energy, and the final consumption by end-users. It excludes energy carriers used for non-energy purposes (such as petroleum not used not for combustion but for producing plastics)[258].

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[257] BP Stats Review 2019. Excel Spreadsheet with all the data. https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html

[258] World Primary Energy Production. https://www.theshiftdataportal.org/energy/primary-energy?chart-type=line&chart-types=line&chart-types=ranking&disable-en=false&energy-families=Oil&energy-families=Coal&energy-families=Gas&energy-families=Nuclear&energy-families=Hydroelectricity&energy-families=Biomass%20and%20Waste&energy-families=Wind&energy-families=Solar%2C%20Tide%2C%20Wave%2C%20Fuel%20Cell&energy-families=Fuel%20Ethanol&energy-families=Geothermal&energy-families=Biodiesel&energy-unit=toe&gdp-unit=GDP%20(constant%202010%20US%24)&group-names=World&is-range=true&dimension=perCapita&end=2015&start=1900&multi=true&type=Production

According to the available BP data, World's FFCC has been showing an upward trend since 1965. It had increased from 12,116Twh in 1965 to 17,197Twh in 2021[259]. In 2021, values of FFCC across countries varied from 2,694 Twh per capita in Bangladesh to 197,993 Twh per capita in Qatar. The trend of the last decade showed a positive trend as well. The world's FFCC has increased from 17,625 Twh in 2011 to 198,933 in 2021 Twh per capita[260].

3.6.2. INDEPENDENT VARIABLES

I use three independent variables to research what shapes global energy consumption across countries: pump price, urbanization, and fossil fuels. After studying the available research, I concluded that enough empirical evidence illustrates that these variables shape energy consumption. However, the existing literature does not offer a solid analysis of how these three variables would simultaneously impact energy use across countries. That is why I chose to combine those three variables in my research.

3.6.2.1. PUMP PRICE FOR GASOLINE (US$ PER LITER)

According to the U.S. Energy Information Agency, in 2019, total gasoline consumption (including aviation gasoline and motor gasoline, including fuel ethanol) accounted for about 58% of total transportation sector energy consumption, 45% of total petroleum consumption, and 17% of total U.S. energy consumption. Light-duty vehicles (cars, sport utility vehicles, and small trucks) account for about 92% of gasoline consumption in the United States[261]. Since gasoline consumption is a significant part of Primary Energy Consumption, it is essential to control for.

In my research, the pump price will be presented in US dollars per liter. The most recent data was collected in 2016. Thus, the 2018 model will use the 2016 Pump price for gasoline (US$ per liter) information. According to the source note, fuel prices refer to the pump prices of the

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[259] BP Stats Review 2019. Excel Spreadsheet with all the data. https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html

[260] BP Stats Review 2019. Excel Spreadsheet with all the data. https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html

[261] U.S. Energy Information Administration. Gasoline explained. https://www.eia.gov/energyexplained/gasoline/use-of-gasoline.php#:~:text=In%202019%2C%20total%20gasoline%20consumption,of%20total%20U.S.%20energy%20consumption

most widely sold grade of gasoline. Prices have been converted from the local currency to U.S. dollars[262]. The source organization is the German Agency for International Cooperation (GIZ).

Historically, about two in three consumers shopped based on price, whether gas was as low as $1.62 per gallon at the start of 2009 or as high as $3.28 per gallon at the beginning of 2013. Today, pump price remains the most important characteristic in purchase decisions (59%)[263]. Thus, gasoline pump price fluctuations might impact the level of consumption. For example, the Model shows that in 2018 Portugal, with a pump price of $2.01, consumed 1.88 million tonnes of oil equivalent, while Japan, with a pump price of $1.46, consumed 3.16 million tonnes of oil equivalent.

In recent years, automotive diesel and gasoline prices have tracked movements in crude oil prices. Not surprisingly, global pump prices are, on average, significantly higher than the underlying crude spot prices as they reflect transformation, transport, and marketing costs, besides taxes levied on fuel sales[264].

3.6.2.2. URBANIZATION

The second independent variable I use to evaluate FFCC is the Urban population (% of the total population). According to the source note[265], Urban Population refers to people living in urban areas defined by national statistical offices. The data are collected and smoothed by United Nations Population Division.

Although empirical studies measuring the relationship between energy consumption and urbanization are limited, enough literature illustrates the relationship between the two variables (Jones[266], Yang, et al.[267], Parikh, Shukla[268] , etc.).

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[262] The World Bank Data. https://data.worldbank.org/indicator/EP.PMP.SGAS.CD

[263] Consumer Behavior at the Pump. NACS. 2019. https://www.convenience.org/topics/fuels/documents/how-consumers-react-to-gas-prices.pdf

[264] EIA. Energy Prices 2020. https://www.iea.org/reports/energy-prices-2020

[265] The World Bank Data. https://data.worldbank.org

[266] Donald W. Jones, How urbanization affects energy-use in developing countries, Energy Policy, Volume 19, Issue 7, 1991, Pages 621-630, ISSN 0301-4215, https://doi.org/10.1016/0301-4215(91)90094-5.https://www-sciencedirect-com.proxy.lib.odu.edu/science/article/pii/0301421591900945?via%3Dihub

[267] Jun Yang, Wei Zhang, Zongyi Zhang, Impacts of urbanization on renewable energy consumption in China, Journal of Cleaner Production, Volume 114, 2016, Pages 443-451, ISSN 0959-6526, https://doi.org/10.1016/j.jclepro.2015.07.158. https://www-sciencedirect-com.proxy.lib.odu.edu/science/article/pii/S0959652615010896

[268] Jyoti Parikh, Vibhooti Shukla, Urbanization, energy use and greenhouse effects in economic development: Results from a cross-national study of developing countries, Global Environmental Change, Volume 5, Issue 2,

In 2018, the World's average rate of Urban population was 55.71% of the total population. The rate gradually increased from 33.6% in 1960 to 55.71% in 2019. Countries listed with the 100% rate are Bermuda, Cayman Islands, Gibraltar, Hong Kong SAR, China, Kuwait, Macao SAR, China, Monaco, Nauru, Singapore, and Sint Maarten (Dutch part). Countries listed with the lowest rates of 13%, 13.1%, and 14.64% are Burundi, Papua New Guinea, and Liechtenstein[269].

I expect a higher percentage of the urban population in the country's total improves Primary Energy Consumption per capita. In 2018, for example, Israel's Urban population was 92.42% of the total population, with an FFCC of 2.83 million tonnes of oil equivalent, while Colombia's numbers were 80.78% and 0.68 million tonnes of oil equivalent.

3.6.2.3. FUEL IMPORTS

The third independent variable I use to evaluate global energy consumption across countries is related to fossil fuels. Unlike taxation and urbanization, the statistical data across countries related to fossil fuels is limited. It is either not up to date or non-existent. I use Fuel imports (% of merchandise imports), which fits well within the existing Model and is up to date. Source organizations for the information on Fuel Imports are: World Bank staff estimates through the WITS platform from the Comtrade database maintained by the United Nations Statistics Division. According to the source note, fuels comprise the commodities in Section 3 of the Standard International Trade Certification (SITC). Among commodities included in the third section are coal, petroleum, natural gas, and electric current[270].

The world's 2018 average rate of Fuel imports was 12.28% of merchandise imports. During the same year, countries listed with the lowest rates were Kuwait (0.57%), Antigua and Barbuda (0.6%), and Suriname (0.65%). The highest rates are associated with Mauritania (32.75%), India (33.19%), and Yemen (33.54%).

I expect that higher rates of fuel imports of merchandise imports improve Primary Energy Consumption per capita. The logic behind such expectation is simple – importing fuel makes countries appreciate energy more and use it thriftily than countries with lower fuel import rates.

1995, Pages 87-103, ISSN 0959-3780, https://doi.org/10.1016/0959-3780(95)00015-G. https://www-sciencedirect-com.proxy.lib.odu.edu/science/article/abs/pii/095937809500015G

[269] The World Bank Data. https://data.worldbank.org/

[270] Standard International Trade Classification (SITC) Revision 3. https://unctadstat.unctad.org/en/Classifications/DimSitcRev3Products_Official_Hierarchy.pdf

The WB database provides good examples of such instances. In 2018, for example, Australia's Fuel Imports were 13.6% of merchandise imports with an FFCC of 5.33 million tonnes of oil equivalent, while Sweden's numbers were 11.82% and 1.72 million tonnes of oil equivalent.

3.6.3. CONTROL VARIABLES

In the World of interconnectedness, there are numerous biases to be escaped while conducting research. That is why, to prevent certain variables from influencing the outcome of a study, I chose to control for Services in GDP, Latitude, GDP per capita, and Pump Price.

3.6.3.1. LATITUDE

The Latitude variable is essential to control because FFCC may be impacted based on the geographic location of a particular country. Besides subjective reasons for some countries having a higher FFCC, which this research is trying to establish, objective reasons impact energy consumption. Latitude is one of those objective reasons.

It is rational to expect that energy consumption increases with more heating degree days and with increasing Latitude. A country with numerous snow days in a year is expected to have higher FFCC than a country where generations of inhabitants have never experienced a single snow day. It would be surprising to see Sri Lanka (Latitude of 7.9), where the weather is hot and humid throughout the year, using more FFCC than Finland (Latitude of 62), with its long and cold wonders across the country.

I have used the dataset with GPS coordinates as a source of the Latitude variable[271].

3.6.3.2. GDP PER CAPITA

GDP per capita is an important indicator of economic performance and helpful for cross-country comparisons of average living standards and economic wellbeing[272]. Changes in GDP per capita would serve as a good measure of whether a country's average citizen is better or worse off.

The existing literature provides enough evidence of the relationship between energy use and GDP per capita. However, there is no absolute conclusion about the nature of the

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[271] Latitude and Longitude for Every Country and State. GPS coordinates for every world country and every USA state. https://www.kaggle.com/paultimothymooney/latitude-and-longitude-for-every-country-and-state

[272] GDP per capita. Focus Economics. https://www.focus-economics.com/economic-indicator/gdp-per-capita

relationship, and the research results vary. Some studies claim that energy consumption causes economic growth or vice versa (Garba and Bellingham[273], Aslam et al.[274], Bildirici and Bakirta[275]).

In my research, GDP per capita will be presented in current US dollars. According to the source note, GDP per capita is gross domestic product divided by the midyear population. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without deductions for depreciation of fabricated assets or depletion and degradation of natural resources. Data are in current U.S. dollars[276]. Source organizations are World Bank national accounts data and OECD National Accounts data files.

The variable is a fair indicator of how much energy one individual can afford to consume. The Model illustrates that countries with lower GDP per capita consume less and vice versa. For example, with a $9,670 GDP per capita, Mexico had 1.36 million tonnes of oil equivalent of FFCC. In contrast, with a $47,640 GDP per capita, Germany had 3.08 million tonnes of oil equivalent of FFCC.

3.7. CONCLUSION

The chapter comprises five sections and discusses the methodology I use to research global energy use across countries. The first part is devoted to the research question and hypotheses. The second one narrates the methodological approach. The third part introduces readers to the specifics of the data collection. Chapter Four talks about the methods of analysis. And the final one is devoted to all the variables used in my research.

To answer the central question of `Why do some countries consume less Fossil Fuels per capita than others?`, I use a multivariate framework of three independent and two control variables. Since energy use in general and fossil fuels use in particular across countries is

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[273] Ifeoluwa Garba, Richard Bellingham, Energy poverty: Estimating the impact of solid cooking fuels on GDP per capita in developing countries - Case of sub-Saharan Africa Energy, Volume 221, 2021, 119770, ISSN 0360-5442, https://doi.org/10.1016/j.energy.2021.119770. https://www.sciencedirect.com/science/article/pii/S0360544221000190

[274] Ifeoluwa Garba, Richard Bellingham, Energy poverty: Estimating the impact of solid cooking fuels on GDP per capita in developing countries - Case of sub-Saharan Africa Energy, Volume 221, 2021, 119770, ISSN 0360-5442, https://doi.org/10.1016/j.energy.2021.119770. https://www.sciencedirect.com/science/article/abs/pii/S2352186421003229

[275] Melike E. Bildirici, Tahsin Bakirtas, The relationship among oil, natural gas and coal consumption and economic growth in BRICTS (Brazil, Russian, India, China, Turkey and South Africa) countries, Energy, Volume 65, 2014, Pages 134-144, ISSN 0360-5442, https://doi.org/10.1016/j.energy.2013.12.006. https://www.sciencedirect.com/science/article/abs/pii/S0360544213010633

[276] The World Bank Data. https://data.worldbank.org/indicator/NY.GDP.PCAP.CD

underresearched, I aim to conduct a basic exploratory mixed research composed of the qualitative and quantitative parts.

The quantitative analysis combines the variables into the 2009-2018 Model. I chose Fossil Fuel Consumption per capita across 28 OECD countries during 2009-2018 as the Dependent Variable. While researching the critical question, I focus on Independent variables organized into three groups (pump price, urbanization, and fossil fuels). To prevent certain variables from influencing the outcome of a study, I chose to control for Latitude and GDP per capita.

In addition to analyzing the quantitative data across countries, I review three unique case studies. Each country has a specific set of circumstances related to fossil fuel use. Studying local specifics, policies, tax rates, urbanization trends, and other economic factors would help explain why the Model fits well in some cases and not in others.

CHAPTER 4

RESEARCH FINDINGS

4.1. INTRODUCTION

The core question of my research is, `Why do some countries consume less fossil fuels per capita than others?` Since energy use in general and fossil fuels consumption across countries are under-researched, I aim to conduct a basic exploratory type of research, particularly after the second chapter revealed a lack of knowledge on global energy consumption across counties.

My research uses a multivariate framework to answer the central question, including one dependent, three independent, and two control variables. The dependent variable of Fossil Fuels Consumption per capita in a million tonnes of oil equivalent is composed of oil, natural gas, and coal. The three independent variables are Pump price for gasoline, where taxation plays an important role, Urbanization (percent of the total population), and Fuel Imports. The two control variables are GDP per capita and Latitude.

Today, much of the variation in energy use worldwide is a function of development. Therefore, my research only utilizes the statistics for Organization for Economic Co-operation and Development (OECD) countries. Because it will help uncover the determinants of energy usage, limiting analysis of the OECD would let me hold a level of development relatively constant. Furthermore, many countries do not have the state capacity to tax the populace effectively; hence, looking at OECD countries separately will help get a better picture.

Based on all mentioned above, the key question could also be re-phrased into `How Pump Price, Urbanization, and Fuel Imports impact Fossil Fuels Consumption per Capita across OECD countries? `

My research design is built to test three Hypotheses:

1. In a comparison of countries, higher pump prices are associated with a decrease in Fossil Fuels Consumption per Capita compared to those with lower pump prices;

2. In a comparison of countries, a greater urban percentage of the population is associated with a decrease in Fossil Fuels Consumption per Capita compared to those with a less urbanized population;

3. In a comparison of countries, higher fuel imports are associated with a decrease in Fossil Fuels Consumption per Capita compared to those with lower fuel imports.

To conduct the research, I use a mixed-method approach composed of the qualitative and the quantitative parts. The quantitative method will test cause-and-effect relationships between Fossil Fuels Consumption per Capita and the Independent variables. As a basis for the quantitative part, I use a sample of twenty-eight OECD counties to create a 2009-2018 model (Model). The size of the model population is composed of two hundred eighty observations (twenty-eight OECD countries during the period of ten years from 2009 to 2018). Data used in this Model will come from two online databases available for free use: World Bank and British Petroleum.

The chapter shares the results of the quantitative data analysis of global energy use across twenty-eight OECD countries during the period 2009-2018 and interprets the results.

4.2. OUTPUT OF THE MULTIPLE REGRESSION ANALYSIS

After using the Model to run the multiple regression analysis in Excel's Analyze Data tool, I got the below summary output.

Table 4. Regression Statistics and AVONA Results

Regression Statistics	
Multiple R	0.63
R Square	0.40
Adjusted R S	0.39
Standard Error	1.12
Observations	280

AVONA	*df*	*SS*	*MS*	*F*	*Significance F*
Regression	5.00	224.95	44.99	35.99	0.00
Residual	274.00	342.56	1.25		
Total	279	567.51			

Table 5. Output of the Multiple Regression

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.29	0.67	0.44	0.66	-1.02	1.61	-1.02	1.61
Fuel imports, %	0.06	0.01	5.94	0.00	0.04	0.09	0.04	0.09
Pump price	-1.33	0.18	-7.43	0.00	-1.68	-0.98	-1.68	-0.98
GDP per cap/ 1000	0.03	0.00	8.45	0.00	0.02	0.04	0.02	0.04
Urbanization	0.03	0.01	3.64	0.00	0.01	0.05	0.01	0.05
Latitude	0.01	0.00	3.42	0.00	0.00	0.02	0.00	0.02

4.3. RESULTS AND THEIR MEANING

4.3.1. MULTIPLE R AND R SQUARED

The sample has two hundred and eighty observations. The correlation coefficient (Multiple R) tells us that the linear relationship is relatively strong at 63% (1 means a perfect positive relationship, and a value of zero indicates no relationship at all). R squared of 0.396 means that approximately forty percent (40%) of the variation of y-values around the mean is explained by the x-values. In other words, the Model explains 40% of the variance in the Dependent Variable and leaves the rest unexplained.

One of the multiple regression analysis's most valuable results is the Probability value (P-value). It shows whether test results are statistically significant or not. Generally, test results are statistically significant if a p-value equals or is less than 0.05. In my research, p-values for all variables are less than 0.05. It means that test results are statistically significant, and Null Hypothesis can be rejected for the entire population. Or, in other words, there is no effect, and it is very unlikely to observe greater deviation from the output results we already observe on the sample.

4.3.2. COEFFICIENTS

Coefficients are some of the most important regression results to evaluate. The above-presented outcomes indicate that for every additional percent of fuel imports in merchandise, one can expect FFCC to increase by 0.06 million tonnes of oil equivalent per capita; for every additional dollar increase of pump price for gasoline per liter, one can expect FFCC to decrease by -1.33 million tonnes of oil equivalent per capita; for every additional $1000 increase in GDP, one can expect FFCC to increase by 0.03 million tonnes of oil equivalent per capita; for every additional percent increase of Urban population in the total population, one can expect FFCC to increase by 0.03 million tonnes of oil equivalent per capita. For every additional unit increase in Latitude, one can expect FFCC to increase by 0.01 million tonnes of oil equivalent per capita.

The Pump Price coefficient result supports Hypotheses #1 (H1), where higher pump prices are associated with decreased FFCC. This regression outcome correlates with my expectations that higher pump prices would reduce the demand of an average gasoline consumer at the pump because of the decreased purchasing ability. In many cases, higher gasoline prices indicate increased crude oil prices, which might lead to lower gasoline supply on the market as refineries cannot adjust quickly to rapid crude oil price fluctuations.

Because the Pump Price coefficient is closer to 1 than other coefficients, H1 has a greater validity or, in other words - reliability.

Many articles in Chapter 2 supported H1. Goodwin and Hanly, for example, have established that if the real price of fuel rises by 10% and stays at that level, the traffic volume will fall by around 1% within about a year, building up to a reduction of about 3% in the longer run[277]. Gillingham and Munk-Nielsen have tried to study how households across the population change their driving in response to fuel price changes. The research has found that fuel price changes significantly impact certain changes in drivers' behaviors. Particularly, those categories with adequate access to public transport would readily switch from driving to using public transport if fuel prices go up[278]. Another innovative study used Google Search Volume data as a proxy to

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[277] Goodwin, P.J.D. and M. Hanly (2004). "Elasticities of Road Traffic and Fuel Consumption with Respect to Price and Income: A Review." *Transport Reviews: A Transnational Transdisciplinary Journal,* 24(3): 275–92. Retrieved from: http://web.a.ebscohost.com.proxy.lib.odu.edu/ehost/detail/detail?vid=0&sid=63f7978e-04c1-4db4-8f8c-815fac8f63b9%40sdc-v-sessmgr02&bdata=JnNjb3BlPXNpdGU%3d#AN=13532137&db=bth

[278] A tale of two tails: Commuting and the fuel price response in driving

measure the tendency of consumers to use public transportation services. The sign of the estimated parameters suggests that higher attention paid to public transportation may coincide with lower gasoline demand[279].

With various energy sustainability approaches in modern cities, especially in countries of higher economic development, I expected the Model to support Hypotheses #2 (H2). To my surprise, the regression results do not support H2, where a greater urban percentage of the population was expected to be associated with a decrease in FFCC. The outcome illustrates the opposite effect. This result, however, is not unexpected as the literature review did not fully support H2. Some articles correspond with the regression results. EIA names urbanization as one of the key factors leading to the rising demand for energy[280]. Primary energy demand in Mexico has increased by 25% since 2000 because of the economy's expansion and urbanization[281]. Aggregate statistical evidence indicates that a 10% increase in city population would increase current energy consumption per capita by 4.5% or 4.8%/$ GDP, holding constant per capita income and industrialization[282]. The increase in renewable energy consumption is attributed to urbanization, energy mix, energy intensity, and economic and population effects. Urbanization contributed more to the total energy consumption growth than to renewable energy consumption growth[283].

While many cities in OECD countries are committed to becoming energy efficient, Chapter 5 will demonstrate that implementing energy-efficient projects is not always easy and might take some time before bringing positive results. Also, energy efficiency and sustainability initiatives might not necessarily mean decreased fossil fuel consumption.

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https://www-sciencedirect-com.proxy.lib.odu.edu/science/article/pii/S0094119018300779?via%3Dihub

[279] Google search explains your gasoline consumption! https://www.sciencedirect.com/science/article/pii/S0140988321002103

[280] https://www.eia.gov/todayinenergy/detail.php?id=41433

[281] https://www.eia.gov/todayinenergy/detail.php?id=41433

[282] Donald W. Jones, How urbanization affects energy-use in developing countries, Energy Policy, Volume 19, Issue 7, 1991, Pages 621-630, ISSN 0301-4215, https://doi.org/10.1016/0301-4215(91)90094-5. (https://www.sciencedirect.com/science/article/pii/0301421591900945)

[283] Jun Yang, Wei Zhang, Zongyi Zhang, Impacts of urbanization on renewable energy consumption in China, Journal of Cleaner Production, Volume 114, 2016, Pages 443-451, ISSN 0959-6526, https://doi.org/10.1016/j.jclepro.2015.07.158. https://www-sciencedirect-com.proxy.lib.odu.edu/science/article/pii/S0959652615010896

Hypothesis #3 (H3) is not supported by the regression results either. I expected a higher fuel import percentage of merchandise would be associated with decreased FFCC. Instead, the above outcome is the opposite. As I illustrate in Chapter 5, countries like Canada export and import fossil fuels. The literature review primarily concentrated on the concept of the resource curse. H3 is a reflection of the idea that if a country's imports have a higher % of fossil fuel imports in merchandise, such commodities as oil, natural gas, and coal would be more valued and, thus, the use per capita would be lower compared to countries with lower % of fossil fuel imports in merchandise. Perhaps, one of the ways to improve the outcome when expanding the research in the future would be to consider only those countries that import fossil fuels but are not net exporters.

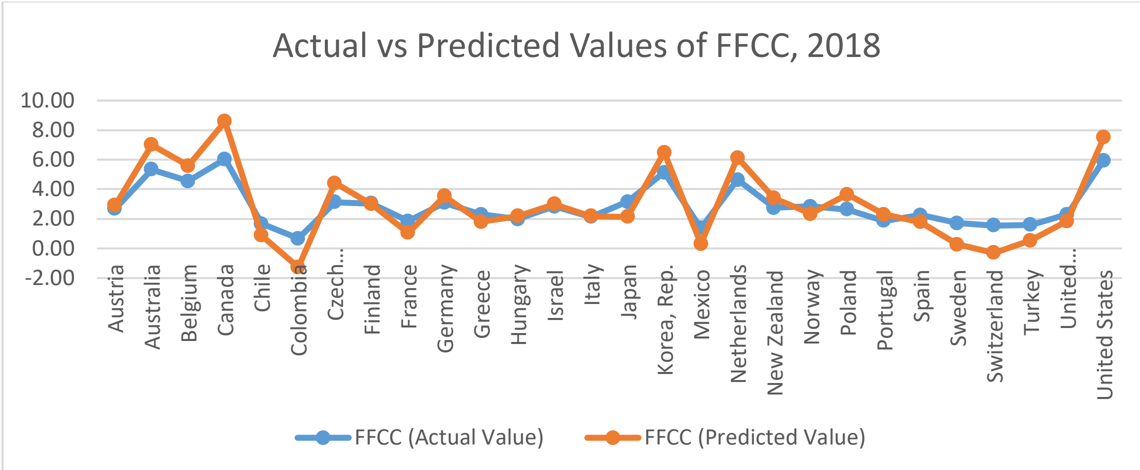
4.3.3 RESIDUALS

Another important measure is a residual size, which illustrates how far away a point is vertically from the regression line. In other words, it is the error between a predicted value and the observed actual value[284].

The below chart illustrates that predicted values of Fossil Fuels Consumption per capita are close to the actual values of the dependent variable. I obtained the FFCC predicted values by adding the actual FFCC values to the residual values from the multiple regression. For example, Austria's actual FFCC value for 2018 is 2.68 and the residual size is 0.22. In this case, the predicted value would be 2.68 + 0.22 = 2.91. For better visual comprehension, I used only the data for 2018 in the below chart.

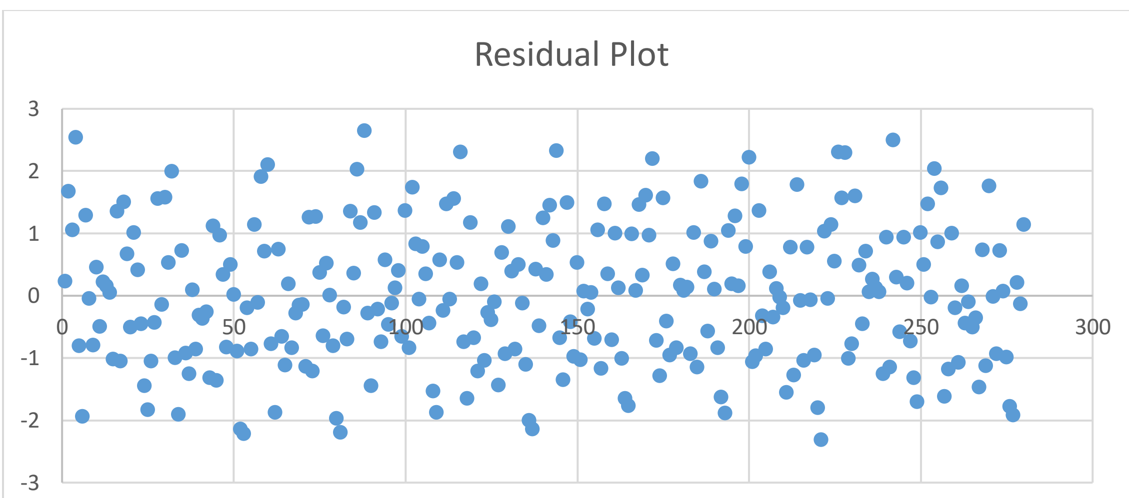
[284] Usman Gohar. How to use Residual Plots for regression model validation? 2020. https://towardsdatascience.com/how-to-use-residual-plots-for-regression-model-validation-c3c70e8ab378

Figure 1. Actual vs Predicted Values of FFCC, 2018



The residual plot graph below illustrates the residual output results for the Model. This is a helpful tool to see if the Model is appropriate in modeling the used data. Residual plot shows how data points deviate from the model[285]. As one can see, the residuals are randomly scattered around 0 and there are no extreme outliers beyond 3 or -3.

Figure 2. Residual Plot for the Model



[285] How to Interpret a Residual Plot. https://study.com/skill/learn/how-to-interpret-a-residual-plot-explanation.html#:~:text=Residual%20Plot%3A%20A%20residual%20plot,in%20modeling%20the%20given%20data

Since residuals illustrate how close the predicted values of FFCC are to the actual values of the dependent variable, looking at the residual output can be revealing. For example, Fossil Fuels Consumption per capita is best predicted for Portugal in 2016 and 2017 (residuals of -0.003 and 0.01, consequently). The least predicted cases in the Model are Canada in 2015 (residual of 2.64) and Switzerland in 2011 (residual of –2.32).

4.3.4. IDENTIFYING CASES FOR QUALITATIVE RESEARCH

In addition to analyzing the quantitative data across countries, I also review several unique case studies in Chapter Five. Each country has a specific set of circumstances related to energy use. Studying local specifics, policies, tax rates, urbanization trends, and other economic factors would help explain why the Model fits well in some cases and why it does not fit in other cases.

After carefully analyzing the residual outputs, I chose three countries for the qualitative analysis: Finland, Canada, and Colombia. Compared to other countries, Fossil Fuels Consumption per capita is less predictable for Canada and Colombia (residuals of 2.54 and -1.95 in 2018, consequently) and is one of the best predicted for Finland (residual of -0,05).

4.4. CONCLUSION

This chapter shared the results of the quantitative data analysis of global energy use across twenty-eight OECD countries during the period 2009-2018 and interpreted the results.

According to the multiple regression outputs, approximately forty percent (40%) of the values fit the Model. P-values for all variables are less than 0.05, which means that test results are statistically significant. The coefficients show that Fuel Imports, GDP per capita, Urbanization, and Latitude impact the increase in Fossil Fuels Consumption per capita. At the same time, Pump Price leads to a decrease in the dependent variable. Based on the sizes of the residuals, some values are better predicted than others.

In addition to analyzing the quantitative data across countries, I review several unique case studies in Chapter Five. Each country has a specific set of circumstances related to energy use. Studying local specifics, policies, tax rates, urbanization trends, and other economic factors would help explain why the Model fits well in some cases and why it does not fit in other cases. I evaluated the residuals' sizes to identify cases for the qualitative part of my research. Based on such analysis, case studies are Finland, Canada, and Colombia. FFCC Canada and Colombia (residuals 2.54 and -1.95) and is best predicted for Finland (residual of -0,05).

CHAPTER 5
CASE STUDIES

5.1. INTRODUCTION

The current chapter reviews several unique case studies. Each country has a specific set of circumstances related to energy use. Studying local specifics, policies, tax rates, urbanization trends, and other economic factors would help explain why the 2009-2018 Model fits well in some cases and not in others. To see which cases fit the general pattern described by the model, I evaluated the residuals' sizes generated after running the regression. The closer the predicted value of the Fossil Fuels Consumption per capita (FFCC) from the actual, the better a particular case fits the Model. Based on such analysis of the residuals, I chose three case studies: one of them illustrated the closest to the predicted value result (Finland (residual of -0,05)), and the other two cases have the most distant predicted values from the actual ones (Canada and Colombia with their residuals 2.54 and -1.95 consequently).

Even though there were other cases with similar residuals, I chose those particular ones for several reasons:

1. Finland, Canada, and Colombia are geographically located in different parts of the world: Northern Europe, North America, and South America. Even though both Finland and Canada are northern countries and experience cold, snowy winters, they differ in size and population density. Thus, it would be helpful to research how two countries with relatively similar climates approach fossil fuel consumption per capita and to compare those cases with a country like Colombia, where freezing days during winter are rare.

2. Although all three countries are OECD members, their economic backgrounds differ. For example, in 2018, GDP per capita was $46,310 (Canada), $6,720 (Colombia), and $50,020 (Finland)[286]. Based on this data, one would expect fossil fuel consumption per capita levels to be somewhat similar in Canada and Finland and substantially lower in Colombia since GDP per capita is generally used to determine the prosperity level of a nation. However, the difference in consumption per capita is substantial. Between 2009-2018, average fossil fuel consumption per capita in Finland accounts for 2.96 million tonnes of oil equivalent, in Canada –

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[286] The World Bank. Retrieved from: https://databank.worldbank.org/

6.13, and in Colombia – 0.61. Further exploration of local circumstances would allow for explaining such dramatic differences.

3. The three countries have different natural resource deposits regarding fossil fuels and gasoline consumption patterns at the pump. Finland, for instance, imports all of its fossil fuels, with petrol prices being the 5th highest in the European Union, which might encourage consumers to seek alternatives to conventional sources for commuting and energy. Canada presents the opposite case of being a net exporter of fossil fuels, mainly crude oil. Canadian final consumer of gasoline at the pump pays significantly less than the Finnish one. The Colombian case is intriguing at first glance. With a population of 52 mln, the country only uses twice as much energy as Finland. This might mean it is less industrial than Finland and Canada and has fewer people accessing electricity and vehicles. Low energy consumption volumes could also be driven by the specifics of climate and extended daylight. Despite low consumption volumes, a fossil fuel consumption per capita trend shows a smooth, steady growth in Colombia from 2009 to 2018, unlike in the previous two cases. Interestingly, even the 2012 crude oil supply fluctuations did not impact the increasing consumption trend in Colombia. This fact is worth exploring further.

The current chapter is divided into three subsections, each devoted to a separate case study: 5.1. Finland, 5.2. Canada, and 5.3. Colombia. All three cases will be evaluated based on the research of the local conditions within each country. The conclusion will provide a comparison of the three case studies as well as a summary of the research results in this chapter.

5.2. FINLAND

5.2.1. SPECIFICS OF ENERGY AND DOMESTIC CONSUMPTION

Finland is chosen as a case study because it is one of the best examples in my quantitative research that helps answer why some countries consume less FFCC than others. According to the 2009-2018 Model, Finland's 2018 residual is -0,05, one of the best-predicted values among observations in the model. Thus, researching the local specifics of this country is essential.

The Republic of Finland is slightly smaller in area than Montana, with a population of 5.2 million. Norway borders Finland to the north, Russia to the east, Sweden and the Gulf of Bothnia to the West, and the Gulf of Finland to the south. There are six provincial administrative divisions (called 'läänit'), subdivided into 20 regional councils (called 'maakuntalitto'). Finland is a member of the European Union[287] and OECD.

Finland is diverse when it comes to energy sources. Based on the BP Report[288], Finland used 28.09 mln tonnes of oil equivalent in 2018, where the share of fossil fuels was 56.38%, nuclear energy 18.29%, hydroelectric 11.89%, and renewables 13.43%.

Table 6. Energy Sources in Finland

Million tonnes of oil equivalent	**Oil**	**Natural Gas**	**Coal**	**Nuclear energy**	**Hydro electric**	**Renewables**	**Total**
Finland 2017	10.26	1.58	4.00	5.14	3.34	3.77	**28.09**
2017, %	36.53	5.61	14.24	18.29	11.89	13.43	**100**
Finland 2018	10.75	1.76	4.27	5.21	3.00	4.27	**29.27**
2018, %	36.72	6.00	14.59	17.81	10.27	14.60	**100**

According to a more recent source, the share of renewables in total energy consumption constituted about 40% in 2020, a significant increase compared to 2018. Carbon dioxide emissions from the energy use of fuels decreased by 10% percent. Total electricity consumption fell to its lowest in 20 years[289]. More likely, such low CO2 numbers are related to Covid, but this claim would require some additional research. The aim set in Finland's National Energy and Climate Strategy for 2030 is to increase the use of renewable energy so that during the 2020s, its share in energy end-consumption rises to more than 50 percent.[290]

In 2019, the market was relatively stable, and oil represented approximately 23% of Finland's total annual energy consumption. Therefore, oil constitutes one of Finland's most

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[287] Fossil Energy International. An Energy Overview of the Republic of Finland. Retrieved from: http://www.geni.org/globalenergy/library/national_energy_grid/finland/EnergyOverviewofFinland.shtml
[288] British Petroleum. Statistical Review of World Energy. Retrieved from: https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html
[289] Ministry of Economic Affairs and Employment of Finland. Renewable Energy in Finland. Retrieved from: https://tem.fi/en/renewable-energy#:~:text=In%20Finland%20renewable%20energy%20sources,more%20than%2050%20per%20cent
[290] Ministry of Economic Affairs and Employment of Finland. Renewable Energy in Finland. Retrieved from: https://tem.fi/en/renewable-energy#:~:text=In%20Finland%20renewable%20energy%20sources,more%20than%2050%20per%20cent

significant total energy consumption shares[291]. In 2020, the use of fossil fuels and peat decreased by 10 percent compared to 2019. Their share of total energy consumption decreased to 37 percent. The drop was most significant for peat, the consumption of which fell by one quarter. The consumption of coal also reduced significantly by 22 percent. The ban on the use of hard coal for energy production, which will enter into force in 2029, is already affecting the decrease in coal consumption. Because of the coronavirus, the consumption of transport fuels, which is usually relatively stable, decreased, which was visible as a six percent drop in the consumption of fossil oil[292].

In terms of the end-use demand by sector, in 2020, transport was the largest consuming sector for oil products. However, its share is relatively modest (45%); industry accounted for 31% (mainly non-energy uses), buildings (residential and services) for 13%, and district heating for 10%. Power plants accounted for 37% of gas consumption in 2020, followed by industry (33%). The district heating sector also consumes a large part of the gas (around 10%). The power sector is the leading consumer of coal and peat, with 57% of total consumption in 2020 (40% of peat), followed by industry (21%)[293].

It is important to mention that transitioning to green energy sources without nuclear supplementation would not be an easy task. Finland has four operational nuclear reactors, and in 2017, the nuclear reactors provided 33.2 percent of the total (65 TWh) electricity generated in the country. In addition to the existing ones, one new reactor is being built (TVO's OL3), and another is in the planning stages (Fennovoima's Hanhikivi1). There are no inactive reactors[294]. When looking at the overall energy consumption by source, nuclear energy consumption was 19.1% in 2020 and 18.2% in 2021[295].

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[291] Thomson Reuters Practical Law. Oil amd gas regulation in Finland. Retrieved from: https://uk.practicallaw.thomsonreuters.com/1-630-0426?transitionType=Default&contextData=(sc.Default)&firstPage=true

[292] Statistics Finland. Retrieved from: https://www.stat.fi/til/ehk/2020/04/ehk_2020_04_2021-04-16_tie_001_en.html

[293] Enerdata. Finland Energy Information. Retrieved from: https://www.enerdata.net/estore/energy-market/finland/

[294] International Trade Administration. Finland – Energy. Retrieved from: https://www.export.gov/apex/article2?id=Finland-Energy

[295] International Trade Administration. Finland – Country Commercial Guide. Retrieved from: https://www.trade.gov/country-commercial-guides/finland-energy

Finland is one of the world leaders in using renewable energy sources. The most important form of renewable energy in Finland is bioenergy: fuels from forest industry side streams and other wood-based fuels, hydropower, wind power, and geothermal power. Bioenergy is also generated from biodegradable waste, side streams of agriculture and industrial production, and municipal waste. Solar electricity has a growing role, especially where on-site energy generation substitutes for energy bought from the grid. Solar heating is used as a supplement to the main heating system[296].

Finland aims to become carbon-neutral by 2035 but is one of the last countries in the world to still use peat as a significant energy source. Burning peat for electricity emits more C02 than coal, while its harvesting causes other environmental damage. However, the halt in wood imports from Russia and the sharp rise in energy prices since the Russian attack on Ukraine have changed the outlook for peat. This high-emission energy source may return to Finland's energy portfolio after a dramatic decline in recent years[297].

Finland has no domestic oil production; it depends entirely on crude oil imports. The same applies to natural gas and coal[298]. This might explain the country's intention to become carbon-neutral in almost one decade. The country is open to investments. For instance, the Chinese-owned Sunshine Kaidi (Finland) New Energy Company Oy plans to build a new biomass plant in Kemi. The plant will produce 225,000 metric tonnes of biofuel annually, of which 75% will be renewable diesel and 25% renewable gasoline. The total investment for the plant is estimated to be around EUR900 million[299].

A few large companies with ownership ties to the state dominate Finland's fossil energy market. The private sector's role is relatively smaller than that of other OECD countries. For example, the government has a 50.1% stake in Vapo Oy, one of the world's largest peat

[296] International Trade Administration. Finland – Energy. Retrieved from: https://www.export.gov/apex/article2?id=Finland-Energy
[297] YLE News. Peat production drops faster than expected in Finland – but may be on the way back. Retrieved from: https://yle.fi/a/3-12409412
[298] OECD. Fossil Fuels Support Country Note. Retrieved from: file:///C:/Users/md9wf/Downloads/EN_FIN_Country_Brief_Jun2020.pdf
[299] Wilson Center. Sunshine Kaidi New Energy Group, Kaidi Finland, second-generation biofuel refinery. Retrieved from: https://www.wilsoncenter.org/project/sunshine-kaidi-new-energy-group-kaidi-finland-second-generation-biofuel-refinery

producers. As demand for energy peat in Finland is expected to halve in the next 10-15 years, Vapo decided in December 2019 to discontinue energy peat production in about 90 of its sites. Energy peat now represents less than a quarter of the Vapo Group's total turnover[300].

Similarly, the state maintains a 44.7% controlling interest in Neste, which dominates the Finnish petroleum market. Over the past decade, Neste has developed from being a regional oil refining company to now engaging in renewable and circular solutions. Neste uses approximately ten different sustainably-produced raw materials at their renewable refineries, mainly waste and residue-based. These currently account for 80% of annual renewable raw material inputs, the target being 100% in 2025[301].

The Finnish gas market was opened to competition on January 1, 2020. Third parties have equal and nondiscriminatory opportunities for network access in the natural gas transmission and distribution networks, including interconnectors from Russia and Estonia. The transmission system operator Gasgrid Finland is responsible for selling transmission capacity in the system, and shippers and traders are responsible for selling natural gas. The state owns Gasgrid Finland. The 1 200 km transmission network is interconnected with the gas networks in Russia and Estonia. Finland's retail electricity market is fully liberalized, and customers can choose their suppliers. Grid companies must connect customers, i.e. access for small independent electricity producers is guaranteed. Monitoring occurs through the Energy Authority (Energiavirasto), which oversees Finland's electricity and natural gas markets[302].

Finland has become the most energy-intensive economy in the EU. But with winter approaching, the country is bracing for rolling blackouts, planned in response to Russian energy cuts. Although Russian energy only made up a small fraction of Finland's total supply, its loss threatens to have a considerable impact, and Finns are being forced to choose between bad

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[300] OECD. Fossil Fuels Support Country Note. Retrieved from: file:///C:/Users/md9wf/Downloads/EN_FIN_Country_Brief_Jun2020.pdf
[301] Neste. Growing Our Portfolio with waste and residues and raw materials. Retrieved from: https://www.neste.com/products/all-products/raw-materials
[302] OECD. Fossil Fuels Support Country Note. Retrieved from: file:///C:/Users/md9wf/Downloads/EN_FIN_Country_Brief_Jun2020.pdf

options[303]. The threat of blackouts due to not importing Russian oil and gas might mean only one thing – the country is still heavily reliant on fossil fuels.

As a Member of the IEA, Finland is obliged, under article 2 of the International Energy Programme (IEP), to maintain oil reserves equal to 90 days of net imports of the previous year[304]. Finland meets its stockholding obligation to the IEA by holding government stocks and placing a minimum stockholding obligation on the industry. Under the relevant acts, the National Emergency Supply Agency (NESA) manages the public oil emergency reserves. Oil importers must hold at least two months of stock based on an average of their imports from the previous year[305]. For instance, Finland had 29 million barrels (mb) of oil stocks for oil emergencies at the end of April 2012, equating to 148 days of 2011 net imports. Some 40% of the total reserves were held in middle distillates, while the share of crude oil was around 23%. Finland's oil stocks in terms of days of net imports have consistently been well above 120 days since July 2008, and government stock levels have been above 50 days of net imports since September 2006[306].

5.2.2. THE CLIMATE

Finland is situated in northern Europe by the Baltic Sea. Some 5.5 million inhabitants[307] enjoy urban life while having easy access to nature. Due to its' specific geographic location, Finland is a land of stark contrasts. In the summer, the sun doesn't set at all in the northernmost parts of the country. In the winter, the opposite happens, and the sun disappears for months. This time, called "Kaamos," isn't completely dark. The white snow, bright moon and stars, and – if you're lucky – the colorful Northern Lights create a surprisingly light and magical nightscape.

The climate of Finland is of the continental type, cold and with a long winter in the north and the interior, and relatively milder along the western and southern coasts. However, even in

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303 Bloommberg. ByKati Pohjanpalo and Leo Laikola. Darkest Days of Winter Have Finland Bracing for Blackouts. Retrieved from: https://www.bloomberg.com/news/articles/2022-10-29/darkest-days-of-winter-have-finland-bracing-for-blackouts?leadSource=uverify%20wall

304 IEA. Finland's legislation on oil security. Retrieved from: https://www.iea.org/articles/finland-s-legislation-on-oil-security

305 EIA. Oil and Gas Security 2012. Finland. Retrieved from: https://iea.blob.core.windows.net/assets/97a133e9-4565-4388-9c17-7dfacb6bcf2c/CountryChapterFinland.pdf

306 EIA. Oil and Gas Security 2012. Finland. Retrieved from: https://iea.blob.core.windows.net/assets/97a133e9-4565-4388-9c17-7dfacb6bcf2c/CountryChapterFinland.pdf

307 Visit Finland. The Happiest Country in the World. Retrieved from: https://www.visitfinland.com/en/

the south, there are a few months with sub-freezing temperatures and usually snow-covered ground.

The average temperature in January and February is around -13 °C (8.5 °F) in the North, in Lapland, around -8.5 °C (16.5 °F) in Kuopio, in the central inland areas, around -4.5 °C (24 °F) in Helsinki, on the South coast, while it is only around -1.5 °C (29.5 °F) in the mildest areas of the Southwest. During winter, weather conditions can vary a lot: when Finland is affected by cold air masses from neighboring Russia, the temperature drops below -20 °C (-4 °F); on the contrary, when mild winds from the Atlantic Ocean reach it, the temperature remains around the freezing point. On colder periods, the temperature can fall to as low as -50 °C (-58 °F) in the far North (Lapland). In January 1987, the temperature reached -36 °C (-33 °F) even in Helsinki's "Southern" city. The thaw usually occurs in late March in the South and during April in the Center-North. In autumn, snow typically begins to fall in October in Lapland and in November in the South[308].

Summer in Finland is mild or pleasantly warm, although it can sometimes get cold at night. The rains are quite frequent. Average temperatures range from 14/15 °C (57/59 °F) in the North to 18 °C (64.5 °F) in the south and Helsinki. However, there can sometimes be short, hot periods. The highest records are around 31/32 °C (88/90 °F) in Lapland and 33/34 °C (91/93 °F) in the Center-South[309].

In the dead of winter, Finland can be a miserable place. Temperatures often dip below -20C; in the year's darkest months, Helsinki gets less than six hours of light daily[310].

5.2.3. GDP PER CAPITA

Finland’s GDP per capita between 2009 and 2018 increased from $47,294 to $50,020 (almost 6%). Both numbers are significantly higher than the average of $37,191 in the sample used for my OECD model. My model's highest GDP per capita happened in Norway in 2013 at $102,914; the lowest was in Colombia in 2009 at $5,193.

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[308] Climate and Travel. Climate – Finland. Retrieved from: https://www.climatestotravel.com/climate/finland
[309] Climate and Travel. Climate – Finland. Retrieved from: https://www.climatestotravel.com/climate/finland
[310] Bloommberg. ByKati Pohjanpalo and Leo Laikola. Darkest Days of Winter Have Finland Bracing for Blackouts. Retrieved from: https://www.bloomberg.com/news/articles/2022-10-29/darkest-days-of-winter-have-finland-bracing-for-blackouts?leadSource=uverify%20wall

Thus, between the privilege of enjoying its beautiful nature and a relatively high GDP per capita, it is not surprising that this Nordic country has been recognized as the happiest place in the world for several years running[311].

Meanwhile, a recent survey of foreign-born workers in Finland revealed that the country had fallen to the near-bottom of the list in a ranking of best and worst countries to work, owing mainly to the high cost of living and relatively low purchasing power compared to other countries. In a recent Eurostat survey, Finland was Europe's eighth most expensive country for overall consumer prices[312]. Therefore, ensuring that Finland's purchasing power parity has no extraordinary specifics is essential. PPP considers the relative cost of living rather than using only exchange rates, providing a more accurate picture of the real differences in income. In 2017, Finland was in 25th place out of 190 countries, following Canada (second case study). Colombia (third case study) was #90 on the list. In 2017, Finland's PPP GDP per capita was $46,344 compared to the World's PPP GDP per capita of $17,000. The highest value was in Qatar ($128,647), and the lowest was in the Central African Republic ($727).[313]

Based on another ranking, GDP per capita, Purchasing Power Parity, 2021 - Country rankings: The average for 2021 based on 182 countries was 21283.47 U.S. dollars. The highest value was in Luxembourg: 115683.49 U.S. dollars, and the lowest was in Burundi: 705.03 U.S. dollars. Finland was in 22nd place with $48,753.36[314].

Based on the presented above data, one can tell that Finland's PPP GDP per capita is mildly overrated compared to the US dollar, which might impact domestic pump prices to some extent.

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311 Visit Finland. https://www.visitfinland.com/en/articles/10-best-things-to-do-in-finland/

312 Helsinki Times. Finland revealed to have 2nd highest petrol prices in Europe. Retrieved from: https://www.helsinkitimes.fi/finland/news-in-brief/19642-finland-revealed-to-have-2nd-highest-petrol-prices-in-europe.html

313 Worldommeter. GDP per Capita. Retrieved from: https://www.worldometers.info/gdp/gdp-per-capita/

314 Global Economy. GDP per capita, PPP - Country rankings. Retrieved from: https://www.theglobaleconomy.com/rankings/gdp_per_capita_ppp/#:~:text=GDP%20per%20capita%2C%20Purchasing%20Power,available%20from%201990%20to%202021

5.2.4. DESCRIPTIVE EXERCISE

5.2.4.1. FOSSIL FUELS AND CONSUMPTION PER CAPITA

5.2.4.1.1. FOSSIL FUELS CONSUMPTION PER CAPITA

Finland's FFCC between 2009 and 2018 decreased from 3.55 million tonnes of oil equivalent to 3.04 million tonnes (17%). Finland's average FFCC 2009-2019 is 3.24 million tonnes of oil equivalent, slightly higher than the average of 2.96 million tonnes for the 2009-2018 sample. Interestingly, the highest consumption in the sample is associated with Canada in 2014, with 6.31 million tonnes of oil equivalent. The lowest in Colombia in 2009 was 0.5 million tonnes of oil equivalent, which are my remaining two case studies.

According to my model, Finland's case predicts fossil fuel consumption per capita more than any other case. The predicted value of Finland's FFCC in 2018 is 3.1 million tonnes of oil equivalent, about 0.05 million tonnes more than the actual number provided by the World Bank data of 3.04.

Over the last several decades, Finland's Gasoline Prices went through ups and downs, averaging 1.73 USD/Liter from 1995 until 2022 and reaching an all-time high of 2.53 USD/Liter in May of 2022 and a record low of 1.06 USD/Liter in December of 2000.[315]

According to a recent survey by the European Commission, Finland's petrol prices are the 5th highest in the European Union. For example, in May 2019, 95-octane petrol was the most expensive in the Netherlands, costing 1.72 euros per liter. Denmark ranked the second-highest price for gasoline, at 1.68 euros, with Greece at 1,65 euros per liter. Just ahead of Finland was Italy, at 1.63 euros per liter. Drivers in Finland paid 1.59 euros[316].

5.2.4.1.2. FACTORS IMPACTING PUMP PRICES

Generally, among the primary factors impacting gasoline prices are **global crude oil costs (61%), refining costs (14%), distribution and marketing costs (11%), and federal & state taxes (14%)**, which are generally reflected in the wholesale costs that gasoline retailers pay to distributors.[317] Thus, what we pay at the pump is mainly impacted by crude oil prices, so we see

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[315] Trading Ecinimics. Gasoline Prices in Finland. Retrieved from: https://tradingeconomics.com/finland/gasoline-prices#:~:text=Gasoline%20Prices%20in%20Finland%20averaged,Liter%20in%20December%20of%202000

[316] YLE news. Finland's petrol prices 5th highest in EU. Retrieved from: https://yle.fi/a/3-10784567

[317] American Petroleum Institute. Gas Prices Explained. Retrieved from: https://www.api.org/oil-and-natural-gas/energy-primers/gas-prices-

the effects when they fluctuate (as they often do)[318]. Because oil is a market commodity, its' prices change depending on the supply available in the market and the demand for that supply.

5.2.4.1.3. CRUDE OIL PRICES

According to the BP stats used in the Model, Crude oil prices during 2011-2013 were higher ($121.24, $119.22, and $114.33, accordingly) compared to the beginning of the period ($110.72), which impacted overall increased pump price with its peak in 2012 of $2.08[319].

Various factors may cause changes in the fluctuation of global petroleum product prices. One of them is changes to global currency values because crude oil prices are based on the US dollar[320]. For example, a falling dollar diminishes its purchasing power internationally, eventually translating to the consumer level. Also, a weak dollar increases the cost of importing oil, causing oil prices to rise. This means a dollar buys less gas, and that pinches many consumers[321]. Currency fluctuations are a natural outcome of floating exchange rates, the norm for most major economies. Numerous factors influence exchange rates, including a country's economic performance, the outlook for inflation, interest rate differentials, capital flows, etc[322].

According to EIA, crude oil prices went through significant ups and downs in 2012. Crude oil prices rose during the first quarter of 2012 as concerns about possible international supply disruptions pushed petroleum prices. Prices then fell during the second quarter before turning sharply upward again at the start of the third quarter[323]. For example, Brent and U.S. West Texas Intermediate (WTI) crude oil started 2012 above $100 per barrel. They peaked in early March at

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explained#:~:text=The%20primary%20factors%20impacting%20gasoline,gasoline%20retailers%20pay%20to%20distributors

[318] Pay at the Pump: Understanding How Gas Prices are Determined. Retrieved from: https://www.leithcars.com/blogs/1421/lifestyle/pay-pump-understanding-gas-prices-determined/#:~:text=The%20price%20of%20gasoline%20is,)%2C%20we%20see%20the%20effects

[319] British Petroleum. Statistical Review of World Energy. Retrieved from: https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html

[320] YLE news. Finland's petrol prices 5th highest in EU. Retrieved from: https://yle.fi/news/3-10784567

[321] How U.S. Firms Benefit When the Dollar Falls.. Retrieved from: https://www.investopedia.com/articles/economics/09/how-us-benefits-when-dollar-falls.asp#:~:text=A%20falling%20dollar%20diminishes%20its,and%20that%20pinches%20many%20consumers

[322] Currency Fluctuations: How they Affect the Economy. Retrieved from: https://www.investopedia.com/articles/forex/080613/effects-currency-fluctuations-economy.asp#:~:text=Currency%20fluctuations%20are%20a%20natural,capital%20flows%20and%20so%20on

[323] U.S. Energy Information Administration. Crude oil prices peaked early in 2012 . Retrieved from: https://www.eia.gov/todayinenergy/detail.php?id=7630#:~:text=Crude%20oil%20prices%20rose%20during,disruptions%20pushed%20up%20petroleum%20prices

just over $125 per barrel for Brent and almost $110 per barrel for WTI as positive economic news that could lead to more robust oil demand and worries about supply disruptions linked to Iran's nuclear program contributed to higher prices. Crude oil prices fell during the second quarter due to concerns about lower oil demand with a global economic slowdown. By the end of June, oil prices were down almost 30% from their peak to just under $78 per barrel for WTI and $91 per barrel for Brent[324].

Among some of the significant factors that influenced crude oil prices during the first half of 2012 were:

1. Changes in global economic growth expectations. Robust job growth data in the U.S., lower interest rates for several European countries, and increased manufacturing data in China all contributed to increased expectations for economic growth and higher crude oil prices during the first quarter of this year. A reversal of these factors in the second quarter helped push crude oil prices to their 2012 lows;

2. Oil supply disruptions. Production disruptions such as those in Syria, Sudan, and Yemen took about 1 million barrels of oil per day off the world market, raising oil prices;

3. Iran sanctions. Ongoing U.S. and European sanctions on imports of Iranian oil intended to pressure Iran to give up its nuclear program (1) played a part in reducing Iran's oil exports and (2) raised fears that Iran would retaliate by disrupting oil shipments through the Strait of Hormuz. Both caused oil prices to rise;

4. It was rising oil production. U.S. oil production topped 6 million barrels per day in early 2012, the highest level since 1998, and contributed to building U.S. crude oil inventories that put downward pressure on oil prices[325].

Such rise and fall of crude oil prices were reflected at the pump as gasoline prices. In the U.S., gasoline prices increased for the first 14 weeks of 2012 (except for one week) to a peak of

[324] U.S. Energy Information Administration. Crude oil prices peaked early in 2012 . Retrieved from: https://www.eia.gov/todayinenergy/detail.php?id=7630#:~:text=Crude%20oil%20prices%20rose%20during,disruptions%20pushed%20up%20petroleum%20prices

[325] U.S. Energy Information Administration. Crude oil prices peaked early in 2012 . Retrieved from: https://www.eia.gov/todayinenergy/detail.php?id=7630#:~:text=Crude%20oil%20prices%20rose%20during,disruptions%20pushed%20up%20petroleum%20prices

$3.94 per gallon in early April. Then they fell for 13 weeks to $3.36 per gallon at the beginning of July, the lowest pump price in 2012 since $3.30 per gallon during the first week of January[326].

Diesel fuel prices followed a similar path, increasing for 15 weeks (except for three weeks) to a peak of $4.15 per gallon, followed by 12 straight weeks of falling prices to a low of $3.65 per gallon. The higher price for diesel versus gasoline reflected more robust domestic diesel demand than gasoline consumption and recorded U.S. diesel exports to help satisfy rising international demand for diesel[327]. Thus, one of the secondary factors, at least in the U.S. market, that intensified the decrease in gasoline use was an increased demand for diesel due to the increased gasoline prices.

5.2.4.1.4. REFINING

Despite the global impact of crude oil prices, there is also a domestic impact. It would be helpful to research every component of the gas price in Finland, which might introduce us to what else impacts higher pump prices in Finland.

The next item on the list impacting the gasoline process is refining costs. Refiners help a country meet its fuel needs by turning crude oil into usable products like gasoline, diesel, and jet fuel[328]. Furthermore, an oil refiner usually keeps strategic petroleum reserve (SPR) crude oil to cover a short time country's needs in oil due to exigent circumstances. Therefore, having a reliable domestic refiner is key to experiencing less short-term fluctuations in gasoline prices within a particular country.

While refining is a complex process, the goal is straightforward: to take crude oil, which is virtually unusable in its natural state, and transform it into petroleum products used for various purposes such as heating homes, fueling vehicles, and making petrochemical plastics. Several processes are involved in refining depending on the wanted end product. Hydrotreating removes unwanted elements, such as sulfur and nitrogen, from hydrocarbons; cracking breaks molecules

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[326] U.S. Energy Information Administration. Crude oil prices peaked early in 2012 . Retrieved from: https://www.eia.gov/todayinenergy/detail.php?id=7630

[327] U.S. Energy Information Administration. Crude oil prices peaked early in 2012 . Retrieved from: https://www.eia.gov/todayinenergy/detail.php?id=7630#:~:text=Crude%20oil%20prices%20rose%20during,disruptions%20pushed%20up%20petroleum%20prices

[328] NPR. How a massive refinery shortage is contributing to high gas prices. (2022). Brittany Cronin. Tertieved from: https://www.npr.org/2022/06/26/1107265390/refinery-shortage-high-gas-prices-russia

into smaller fragments to produce gasoline and lighter hydrocarbons. The gasses produced by cracking are used to create other products like synthetic rubber and plastics. When making gasoline, refiners need high octane numbers to prevent engine knocking. Refineries are usually located near population centers to facilitate the marketing and distribution of final products[329].

Until recently, there were two refineries in Finland Porvoo Refinery and Naantali Refinery. Both were owned by Neste Oil Corporation – large Finnish refining and marketing company concentrating on low-emission, high-quality traffic fuels. The company produces a comprehensive range of major petroleum products and is the world's leading supplier of renewable diesel.

The Naantali refinery was closed in 2021 and converted to a post and distribution terminal[330]. This decision is based on the lower demand for fossil-based oil products, and the share of renewable energy solutions will continue to grow in the coming years. The COVID-19 pandemic has substantially accelerated the decline in demand for oil products, which is not expected to recover to previous levels[331].

According to Neste's website, Neste's Naantali terminal and port will continue distributing transportation fuels in Southwest Finland. Naantali terminal operations will consist of the port, the distribution terminal in charge of tanker truck distribution, the large tank area, and various support functions such as the wastewater treatment plant. Finished products will be delivered to customers through the distribution terminal as before. According to the company's web-site, the discontinued refining operations will have no significant impact on the distribution terminal's operations or volumes, and distribution areas will remain unchanged. Furthermore, this change will not impact the security of the fuel supply in Finland[332].

Thus, as of today, there is only one refinery in Finland. The Porvoo operations are in the Kilpilahti industrial area, the biggest chemical industry consortium in the Nordics. The Porvoo

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[329] Library of Congress. Downstream: Refining and Marketing. Retrieved from: https://guides.loc.gov/oil-and-gas-industry/downstream

[331]Neste. Neste's refining operations in Naantali have ended. Retrieved from: https://www.neste.com/about-neste/who-we-are/production/porvoo-and-naantali/naantali-refining-operations-have-ended#da9f759d

[332] Neste. Neste's refining operations in Naantali have ended. Retrieved from: https://www.neste.com/about-neste/who-we-are/production/porvoo-and-naantali/naantali-refining-operations-have-ended#da9f759d

refinery manufactures both fossil and renewable products. The Porvoo refinery comprises four production lines and more than 40 production units, including two NEXBTL units producing Neste MY renewable diesel. Production is highly automated and modern – the refinery is among Europe's most efficient and versatile refineries. The crude oil refining capacity is approximately 10.5 million tons/a, or 206,000 barrels daily. In addition to crude oil, other feedstocks are transported to Porvoo, producing a total production capacity of approximately 12.5 million tons/a. The most important products of the Porvoo refinery are traffic fuels (diesel, gasoline), marine fuels, and base oil[333].

Based on the available data, Finland's petroleum consumption fluctuated substantially in recent months; it tended to decrease from December 2021 - November 2022, ending at 178 thousand barrels per day in November 2022[334]. This means that the country's only refinery provides enough supply to satisfy Finland's domestic needs in petroleum.

At the same time, having just one refiner on the market might lead to a situation when no competitors make a single supplier neglecting cost reduction efforts, which would then impact a final consumer of gasoline at a pump. For example, operating profit at Neste's oil division jumped to 571 million euros in 2022 from 8 million in 2021 when profitability was weighed down by pandemic restrictions and maintenance at Neste's Porvoo refinery[335].

5.2.4.1.5. TRANSPORTATION

Having its refinery helps Finland meet its fuel needs and decrease transportation costs to deliver ready-to-use gasoline at a pump to a final user. There are no oil pipelines in Finland. All oil is transported in trucks or containers on trains or ships[336]. On the one hand, this might increase transportation costs. On the other hand, because Finland is a relatively not big country (about 3.3 times bigger than Virginia), transportation costs should not be extremely high.

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[333] Neeste. Pronovo. Retrieved from: https://www.neste.com/about-neste/who-we-are/production/porvoo#da9f759d
[334] World Data Atlas. Finland. Retrieved from: https://knoema.com/atlas/Finland/topics/Energy/Oil/Petroleum-consumption
[335] Reiters. Essi Lehto. Finland's Neste boosted by strong refining margins. https://www.reuters.com/business/energy/finlands-neste-boosted-by-strong-refining-margins-2022-07-28/
[336] Thomson Reuters Practical Law. Oil and gas regulation in Finland. Retrieved from: https://uk.practicallaw.thomsonreuters.com/1-630-0426?transitionType=Default&contextData=(sc.Default)#:~:text=There%20are%20no%20oil%20pipelines,containers%20on%20trains%20or%20ships

Meanwhile, the population of Virginia is ~8.0 million people (2.4 million fewer people live in Finland)[337], which means that population density in some regions of Finland might be lower than in Virginia. Consumption in such areas might be limited to longer travel distances or lower income levels. For example, one woman in Lapland, the frozen northernmost region in Finland, went viral after posting a video of her reindeer-powered sled. Janita Kenttälä said on Tik Tok that she was traveling to the supermarket the old-school way because it's more eco-friendly and gas prices are so high. Kenttälä captioned the video with more than 600,000 likes and 4,700 comments[338]. While my research does not consider how many carrots per mile one needs to feed a reindeer to get from point A to point B, the statistics of responses might signify how relevant the issue of high pump prices in Finland is.

5.2.4.1.6. MARKETING

In the petroleum world, marketing is the wholesale and retail distribution of refined petroleum products to businesses, industry, government, and public consumers. Generally, crude oil and petroleum products flow to the markets that provide the highest value to the supplier, which usually means the nearest market first because of lower transportation costs and higher net revenue for the supplier. In practice, however, the trade flow may not follow this pattern due to other factors, such as refining configurations, product demand mix, and product quality specifications. Gasoline service stations handle the bulk of public consumer sales, and oil companies sell their petroleum products directly to factories, power plants, and transportation-related industries[339].

Because gasoline is a commodity that is more or less the same, competition for customers requires creative marketing tactics; retail gasoline stations offer free services like maps, car washing, and dinnerware. Oil company brands offered credit cards starting in the 1950s to ensure customer loyalty. Radio, billboard, and television ads promoted catchy slogans, additives, and

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337 Country Siize Comparison. Finland to Virginia. Retrieved from: https://www.mylifeelsewhere.com/country-size-comparison/finland/virginia-usa#:~:text=Finland%20is%20about%203.3%20times,fewer%20people%20live%20in%20Finland)

338 Nothing Runs Like a Deer. (2022). Lonnie Lee Hood. Retrievd from: https://futurism.com/the-byte/gas-prices-travel-reindeer

339 Library of Congress. Downstream: Refining and Marketing. Retrieved from: https://guides.loc.gov/oil-and-gas-industry/downstream

adjectives like "premium" and "high performance" to attract drivers. Mobil used advertisements, or sponsored op-eds, in the New York Times to publish pro-oil industry commentary. Social media allows companies to promote various energy initiatives and mitigate negative news[340].

In Finland, fuel cards play a significant role. In a way, fuel providers use them to attract businesses to use their services. They are also called fleet cards or business gas cards. Fuel cards help control costs in ways other payment methods can't, ensuring money is only spent on fuel for company vehicles[341].

Two key channels found for the fuel cards market in Finland involve the Fleet Card and CRT card. Fuel sold from fleet cards registered continuous growth between 2015 and 2019. In 2020, fleet card volumes decreased due to the impact of COVID-19 on total fuel card volumes[342].

The Finnish fuel card market is consolidated, with the top three operators accounting for over 67% of total fuel card volume sales in 2020. The leading three card operators in Finland are Neste, Teboil, and ABC. Neste remained the fuel card market leader in 2020, increasing its market share by 0.03 percentage points from 2019. ABC focuses on the growing fleet market, with its fuel card volume coming from this market segment. Neste remained the most significant fleet card and CRT card operator for fuel card categories, selling more than 34% of fleet volumes and contributing more than 33% of CRT volumes sold in 2020. Finland's top five fuel card operators retained their position in 2020, as smaller domestic fleets relied on prominent card operators to benefit from an international card acceptance network and a more comprehensive range of services[343].

There are marketing approaches to delivering fuel to the final consumer – via automated retail sale points, specialized stores, or service stations. Based on the available data, fuel sales points have decreased, which is another sign of reducing gasoline consumption. For instance, the number of enterprises in the automated retail sale of automotive fuel in Finland fluctuated. As

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[340] Library of Congress. Downstream: Refining and Marketing. Retrieved from: https://guides.loc.gov/oil-and-gas-industry/downstream
[341] Global Data. Fuel Cards in Finland 2021. Retrieved from: https://www.globaldata.com/store/report/finland-fuel-cards-market-analysis/
[342] Global Data. Fuel Cards in Finland 2021. Retrieved from: https://www.globaldata.com/store/report/finland-fuel-cards-market-analysis/
[343] Global Data. Fuel Cards in Finland 2021. Retrieved from: https://www.globaldata.com/store/report/finland-fuel-cards-market-analysis/

of 2020, the amount was 32, which was a decrease of 12 enterprises compared to 2015[344]. In recent years, the number of enterprises in the retail sale of automotive fuel in specialized stores in Finland also decreased. While more than 740 automobile fuel retailers operated in the country in 2013, the amount has been reduced to 608 as of 2020[345]. While more than 700 service stations operated in the country in 2013, the amount was 576 as of 2020. A service station originally incudes a full-service filling station, an automobile repair shop, and a rest area[346].

Another way of attracting consumers is by providing easy-to-use payment systems. One interesting factor of such services is that they quickly adjust to the local market's needs. Thus, adequately illustrating demand. One example of a successful fuel-use marketing strategy is SEO or Suomalainen Energiaosuuskunta. It is a Finnish oil company controlled by traders. The SEO network already covers more than 200 gas stations in Finland. Stations can be found from Hanko to Nuorgam. Values such as domesticity, locality, and utilization of renewable energy are essential factors in the operations of the service station network. Additionally, all of the stations are led by independent entrepreneurs. The latest mobile payment technology of credit card companies enables, among other things, risk-based seamless payments[347].

5.2.4.1.7. DOMESTIC POLICY ON GASOLINE USE AND TAXATION

Finland’s domestic policies and taxation of fossil fuels, particularly gasoline, evolved around the Government Programme. The country aims to be carbon neutral by 2035 and the world’s first fossil-free welfare society. Carbon neutrality means that emissions and the sinks that sequester carbon are balanced, i.e., emissions caused by human activity are calculated to be as high as greenhouse gas removals. The emission reduction targets in the Climate Change Act are based

[344] Statista. Number of enterprises in the retail sale of automotive fuel in specialized stores in Finland from 2013 to 2020. Retrieved from: https://www.statista.com/statistics/1053405/number-of-automotive-fuel-retailers-in-finland/

[345] Statista. Number of enterprises in the retail sale of automotive fuel in specialized stores in Finland from 2013 to 2020. Retrieved from: https://www.statista.com/statistics/1053405/number-of-automotive-fuel-retailers-in-finland/

[346] Statistaa. Number of enterprises in the service station activities sector in Finland from 2013 to 2020. Retrieved from: https://www.statista.com/statistics/1053407/number-of-service-stations-in-finland/

[347] SEO serves the whole Finland. Retrieved from: https://www.seitatech.fi/en/seo-serves-the-whole-finland/

on the recommendations of the Finnish Climate Change Panel. The emission reduction targets are -60% by 2030, -80% by 2040, and at least -90%, but aiming at -95% by 2050, compared to the levels in 1990[348].

Interestingly, the Annual Climate Report 2022, published in late October, revealed that while there were no significant changes in Finland's total emissions in 2021, the land use and forestry sector has become a net source of emissions for the first time. Large harvesting volumes and slower forest growth are assumed to be the main reasons for this. The loss of carbon sinks increases Finland's net emissions and may increase the need for emission reductions in other sectors[349].

Even though some cities and communities in Finland joined the worldwide initiatives to ban fossil fuel advertisements[350][351], there is no practical application of this movement in the country. For example, in the city council of Helsinki, a motion was presented to ban all fossil fuel advertisements[352]. Or, as a part of the initiative to ban fossil fuels advertisements in the EU, the organizers reported that 10,508 out of 279,280 statements came from Fins[353]. As of today, the Finnish oil market is not explicitly regulated. However, the government does heavily tax the use of oil[354].

One of the recent studies analyzed Finnish energy policy based on current legislation related to renewable energy production and budget policy related to renewable-energy subsidies. This study shows that the polluter-pays principle is implemented quite well in Finland due to the emissions trading scheme and taxation. Still, this principle is not entirely implemented

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348 State Treasury Republic of Finland. Climate Neutral Finland 2035. Retrieved from: https://www.treasuryfinland.fi/investor-relations/sustainability-and-finnish-government-bonds/climate-neutral-finland-2035/#:~:text=According%20to%20the%20Government%20Programme,high%20as%20greenhouse%20gas%20removals

349 State Treasury Republic of Finland. Climate Neutral Finland 2035. Retrieved from: https://www.treasuryfinland.fi/investor-relations/sustainability-and-finnish-government-bonds/climate-neutral-finland-2035/#:~:text=According%20to%20the%20Government%20Programme,high%20as%20greenhouse%20gas%20removals

350 Fossil Fuel Advertising Ban: The Cities Taking the Lead. Retrieved from: *https://energytracker.asia/fossil-fuel-advertising-ban/*

351 Worldwide initiatives to ban fossil fuel advertisements. Retrieved from: *https://verbiedfossielereclame.nl/only-words/*

352 Worldwide initiatives to ban fossil fuel advertisements. Retrieved from: https://verbiedfossielereclame.nl/only-words/

353 Ban Fossil Fuel Ads. Retrieved from: https://banfossilfuelads.org/

354 Thomson Reuters Practical Law. Oil and gas regulation in Finland. Retrieved from: *https://uk.practicallaw.thomsonreuters.com/1-630-0426?transitionType=Default&contextData=(sc.Default)&firstPage=true*

in electricity production as electricity tax is not based on the carbon intensity of the fuel used but on who uses the electricity. National subsidy policies focus on a short-term increase in renewable energy production as most subsidies are production subsidies granted through a bidding process, making these subsidy policies partly technology-neutral. These policies do not consider long-term needs for energy policy as much as they could[355].

Globally, the country ranks 5th when it comes to the adoption of electric vehicles, outpaced only by other northern European states. Yet, that is the same context within which Finland is used to setting its ambitions[356].

The number of electric vehicles in traffic use in Finland has grown significantly over the past decade. In 2021, roughly 77 thousand hybrid cars and nearly 22.9 thousand electric cars were registered nationwide. From 2015 onwards, plug-in hybrid vehicles saw a considerable increase, while the number of all-electric passenger cars grew somewhat slower[357].

Since 2018, Finland has offered a EUR 2,000 subsidy for purchases of new electric vehicles or committing to a three-year lease. The current subsidy program is scheduled to end in November 2021, with electric cars composing less than 1% of vehicles on the road.

The government's budget proposal for 2022 includes scrapping the entire car tax[358], currently at 2.7 percent on electric vehicles. As a matter of principle, this is an essential step for a country that has used car ownership as an integral part of its tax base since the 1950s. However, such relative relief may not have the impact that an absolute sum in the form of a higher subsidy would.

Even though Finland has endeavored to be out in front among European Union countries when it comes to climate change commitments by moving forward with plans to promote the circular economy and smart cities, Finns remain resistant to giving up gas-powered automobiles,

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[355] How could Finland promote renewable-energy technology innovation and implementation? Eelis Paukku. Clean Energy, Volume 5, Issue 3, September 2021, Pages 447–463. Retrieved from: https://academic.oup.com/ce/article/5/3/447/6347951

[356] FINLAND'S ELECTRIC VEHICLE SUBSIDY IS AN OPPORTUNITY FOR DRIVERS AND MANUFACTURERS. (2021) Retrieved from: https://geostreams.org/finland-electric-vehicles/

[357] Statista. Number of electric and hybrid passenger cars in Finland from 2010 to 2021. Retrieved from: https://www.statista.com/statistics/1177464/number-of-electric-and-hybrid-passenger-cars-in-finland/

[358] Sähköautojen autovero poistuu ja hankintatuelle luvassa jatkoa. (2021) AUTOT JA LIIKENNE. Retrieved from: https://www.apu.fi/artikkelit/sahkoautojen-autovero-poistuu-ja-hankintatuelle-luvassa-jatkoa see google translate

particularly in rural areas where charging stations remain few and far between. The transition to electricity also raises difficult questions of income and geographic equity.

Regarding taxes, the country's retail and wholesale electricity prices are unregulated. Electricity can be traded through bilateral contracts and via the power exchanges Nord Pool and EPEX SPOT. Finland has a comprehensive set of taxation rules on electricity, coal, natural gas, peat, biofuels such as tall oil, and liquid fuels. Rates are based on a fuel's energy content, lifetime carbon dioxide emissions, and type of use (e.g., reduced rates for industry and agriculture). A strategic stockpile fee and an oil pollution levy also apply[359].

In 2011, Finland completely reformed its energy taxation structure on transport and heating fuels. As a result, taxes on different energy sources are now determined based on both their energy content and the level of lifetime carbon dioxide emissions. Following the 2011 reforms, many energy-related tax expenditures have been halted or terminated[360].

In Finland, the vast majority of support measures are tax expenditure items geared towards lowering the cost of energy consumption in the industry, transport, and agriculture sectors. The two most significant measures are the reduced energy tax rate on diesel used for transport (benchmarked against the rate for transport fuels, with passenger car drivers compensating for the reduced rate through an additional circulation tax) and the reduced energy tax rate for light fuel used in mobile machinery (with transport fuel rates as its benchmark). Recently, the government set a target to halt the use of oil heating in all local and central government properties by 2024[361].

To facilitate and foster cross-border trade and to prevent significant competitive distortions, the European Union requires EU countries to levy a minimum excise duty of €0.36 per liter (US $1.55 per gallon) on gas. Today's map shows that only Bulgaria and Hungary stick to the minimum rate, while all other EU countries opt to levy higher excise duties on gas. All EU countries also levy a value-added tax (VAT) on gas and diesel. The excise amounts shown in the

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[359] OECD. Fossil Fuels Support Country Note. Retrieved from: file:///C:/Users/md9wf/Downloads/EN_FIN_Country_Brief_Jun2020.pdf
[360] OECD. Fossil Fuels Support Country Note. Retrieved from: file:///C:/Users/md9wf/Downloads/EN_FIN_Country_Brief_Jun2020.pdf
[361] OECD. Fossil Fuels Support Country Note. Retrieved from: file:///C:/Users/md9wf/Downloads/EN_FIN_Country_Brief_Jun2020.pdf

map above relate only to excise taxes and do not include the VAT charged on the gas and diesel sales value[362].

Finland is ranked #3 with a gasoline tax of $3.3 per gallon. The highest rate is associated with the Netherlands – $3.51; the lowest of the 28 countries researched is Bulgaria – $1.57. The average per selected country is $2.4[363].

Interestingly, in Finland, fuel used in private leisure traffic vessels is subject to excise duty and the strategic stockpile fee. However, fuel used by merchant or authority vessels, by fishing vessels in commercial fishing, and by other such vessels is exempt from excise duty, and the strategic stockpile fee need not be paid, either. In other words, fuel used for the above purposes is exempt from tax. You can request a refund for the fuel excise duty for the whole year in one go or separately for January–June and July–December. Request a refund for the fuels you have used for tax-exempt purposes during the period. You can request a refund after the application period has ended[364].

Emissions reduction targets in road transport are unlikely to be achieved without increasing the cost of driving petrol and diesel-powered passenger cars. Fuel taxes are an effective means to reduce emissions and do not mainly fall upon low-income households. Recycling tax revenue back to households is one method of balancing the tax burden between households and can also lead to fuel taxes being considered more acceptable[365].

A possibly uneven incidence of taxation across income categories can be mitigated, for instance, through partial or full tax refunds to households. This tax refund must be independent of the household's fuel expenses. This way, taxation incentivizes people to reduce their fuel consumption. For example, every adult resident in British Colombia, Canada, is given a state tax

[362] Tax Foundation. Gas Taxes in Europe (2021). Retrieved from: https://taxfoundation.org/gas-taxes-in-europe/
[363] Tax Foundation. Gas Taxes in Europe (2021). Retrieved from: https://taxfoundation.org/gas-taxes-in-europe/
[364] Vero Skatt. Excise duty refunds for fuels used in vessels. Retrieved from: https://www.vero.fi/en/businesses-and-corporations/taxes-and-charges/excise-taxation/excise-duty-refunds/excise-duty-refunds-for-fuels-used-in-vessels/#:~:text=You%20can%20request%20a%20refund%20for%20the%20excise%20duty%20on,exempt%20purposes%20during%20the%20period
[365] Finland's fuel tax does not particularly fall upon low-income households. (2021). Anna Sahari and Kimmo Palanne. Retrieved from: https://vatt.fi/en/-/finland-s-fuel-tax-does-not-particularly-fall-upon-low-income-households

refund four times yearly. The refund is paid from the state's carbon dioxide tax revenue, and the tax return is higher for households with lower incomes[366].

In Finland, passenger cars account for roughly one-half of road traffic emissions and roughly 10% of all greenhouse gas emissions. Given the target to halve transport emissions by 2030, it is inevitable that passenger vehicles will also face emission reduction measures.

Studies show that motorists' choices can be influenced by taxation (Palanne, Sahari 1). If a car's purchase, ownership, and use are taxed according to the car's emissions, people will buy vehicles that pollute less and drive less. A fuel tax reduces emissions more cost-effectively than any other tax. For example, an increase in the car tax will result in lower emission reductions than a comparable increase in the fuel tax.

However, a concern related to fuel taxes is that they are borne disproportionately by low-income households. An increase in fuel taxes would mostly fall on those households who spend the largest share of their income on fuel. Statistics do not support the conclusion that fuel taxation in Finland mainly falls on the lowest income categories. On average, low-income households do not incur more fuel costs in relation to their income compared to average-income households. [367] However, Finland has no tax refunds on used gasoline for households yet.

A possibly uneven incidence of taxation across income categories can be mitigated, for instance, through partial or full tax refunds to households. This tax refund must be independent of the household's fuel expenses. This way, taxation incentivizes people to reduce their fuel consumption. For example, every adult resident in British Colombia, Canada, is given a state tax refund four times yearly. The refund is paid from the state's carbon dioxide tax revenue, and the tax return is higher for households with lower incomes[368].

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[366] Finland's fuel tax does not particularly fall upon low-income households. (2021). Anna Sahari and Kimmo Palanne. Retrieved from: https://vatt.fi/en/-/finland-s-fuel-tax-does-not-particularly-fall-upon-low-income-households

[367] Finland's fuel tax does not particularly fall upon low-income households. (2021). Anna Sahari and Kimmo Palanne. Retrieved from: https://vatt.fi/en/-/finland-s-fuel-tax-does-not-particularly-fall-upon-low-income-households

[368] Finland's fuel tax does not particularly fall upon low-income households. (2021). Anna Sahari and Kimmo Palanne. Retrieved from: https://vatt.fi/en/-/finland-s-fuel-tax-does-not-particularly-fall-upon-low-income-households

The full range of local environmental costs from vehicle use warrants Finland's gasoline and diesel fuel taxes. Finland also promotes low-emission passenger vehicles through registration fees and annual taxes related to CO2/km[369].

Finland has pledged to cut net greenhouse gas emissions to zero by 2035 and has sectoral targets for deploying electric vehicles, phasing out coal generation, and oil-based space heating. Fiscal policies at the national and sectoral levels could be critical in achieving these objectives. Carbon dioxide emissions are already priced significantly in Finland, but prices vary substantially across fuels and sectors[370].

A well-designed package of fiscal measures to promote the transition to carbon neutrality in Finland while addressing adverse impacts on households and competitiveness could help build momentum inside the EU and globally for similar policies. Carbon and fuel taxes are other critical instruments for reducing emissions, particularly in Finland's effort-sharing sector. According to OECD estimates, the effective carbon tax for gasoline is currently €77 per tonne. Additional fuel taxes are equivalent to carbon charges of €234 on gasoline per tonne for use — substantial taxation of road fuels is, however, warranted by non-carbon externalities. Finland's carbon tax, nonetheless, is at the top end of many carbon pricing schemes — only Sweden has significantly higher prices (for non-EU ETS emissions)[371].

5.2.4.2. URBANIZATION AND FOSSIL FUELS CONSUMPTION PER CAPITA

Based on the data presented in tables 1-3, quantity does not always provide an answer. Thus, it is essential to see how seriously highly urbanized areas (cities) in chosen countries are moving toward energy sustainability.

Sustainable development comes under the spotlight, especially in an urban context. The reason lies in the extent of human settlement[372]. Cities are where most actions take place. Today, more than 50% of the world's population lives in urban areas, with the percentage expected to

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[369] IMF Working Paper. Fiscal Policies for Achieving Finland's Emissions Neutrality Target. Ian Parry and Philippe Wingender. Retrieved from: file:///C:/Users/md9wf/Downloads/wpiea2021171-print-pdf.pdf

[370] IMF Working Paper. Fiscal Policies for Achieving Finland's Emissions Neutrality Target. Ian Parry and Philippe Wingender. Retrieved from: file:///C:/Users/md9wf/Downloads/wpiea2021171-print-pdf.pdf

[371] IMF Working Paper. Fiscal Policies for Achieving Finland's Emissions Neutrality Target. Ian Parry and Philippe Wingender. Retrieved from: file:///C:/Users/md9wf/Downloads/wpiea2021171-print-pdf.pdf

[372] Sustainable Development of Istanbul Built Environment. Burak Ünal. 2014. Retrieved from: http://www.diva-portal.org/smash/get/diva2:731291/FULLTEXT01.pdf

grow to 66% by 2050[373]. Cities consume nearly 2/3 of the world's energy, accounting for more than 70% of global greenhouse gas emissions[374].

In the western context, notions of sustainable development often refer to the need to adjust existing economic models to maintain better balances between economic growth and social needs while protecting local ecologies and reducing the negative impact of growth on the global environment[375].

Sustainable development is not about adjustments to maintain balances in developing fuel-exporting countries. Instead, it is about building the foundations of a new economic model in which sustainability and the environment are integral[376]. A significant part of such a model is the city's constructed reality, which defines and shapes the daily routine of its inhabitants. Our transportation and buildings, for example, determine how much energy we use to commute or to maintain our thermal comfort.

Developing low-carbon, compact, and connected cities are critical for managing urbanization. Unfortunately, rapid developments have often been disregarding strategic and global approaches.

While studying the matter, I am going to look if the capital and the other two most populated cities in the chosen three countries meet the below criteria:

1. A city is a member of C40[377] or a part of other collaborations concentrating on resilient and sustainable development in the energy sector.
2. A city promotes a low-carbon or carbon-neutral environment.

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[373] United Nations. World's population increasingly urban with more than half living in urban areas. (2014). Retrieved from: http://www.un.org/en/development/desa/news/population/world-urbanization-prospects-2014.html

[374] The World Bank Data. http://www.worldbank.org/en/topic/urbandevelopment/overview

[375] Sustainable Development and the Built Environment in the Middle East: Challenges and Opportunities. Karim Elgendy. Retrieved from: http://www.carboun.com/sustainable-design/sustainable-development-and-the-built-environment-in-the-middle-east-challenges-and-opportunities/

[376] Sustainable Development and the Built Environment in the Middle East: Challenges and Opportunities. Karim Elgendy. Retrieved from: http://www.carboun.com/sustainable-design/sustainable-development-and-the-built-environment-in-the-middle-east-challenges-and-opportunities/

[377] C40 – one of leading organizations in the world that unites mayors and cities in their approach to build sustainable, resilient and equitable future. https://www.c40.org/cities/

Table 7. Energy Sustainability Approaches in three most populated cities

City		Population	C40 or other collaborations	Low-carbon programs
1	Helsinki (Finland)	631,695	C40 – no, others - yes	Yes
2	Vantaa (Finland)	216,973	C40 – no, others - yes	Yes
3	Kuopio (Finland)	117,331	C40 – no, others - yes	Yes

The overview of the available urban energy sustainability programs shows four out of nine cities are members of C40. Two Colombian cities, where FFCC is the lowest out of three case studies, and two Canadian cities, where FFCC is the highest, are listed as C40 participants[378].

Strangely, none of the Finnish cities participate in the C40 initiative. However, many Finnish people worried about climate change are also doing something about it. Towns and cities across Finland are succeeding with various strategies for zero emissions. Even small actions can have a significant cumulative effect[379]. Finland is positioning itself as one of the leading European countries in developing smart cities, leveraging its experience in developing living spaces that represent 21st-century styles. The main idea is that several Finnish cities, including Helsinki, Espoo, Vantaa, Turku, Tampere, and Oulu, have been developed on sustainable and smart city principles. Furthermore, the nation is keen to share its experiences and knowledge[380].

Helsinki, for example, is continuously at the top of comparisons and evaluations of European and global smart cities. Smart city development is determined by the strong role of the city, where the staff actively works directly with the citizens and other stakeholders[381]. Helsinki opened an exciting project called Smart Kalasatama: Smart Kalasatama is a Helsinki city innovation platform where various Smart City solutions can be tested and developed in an urban

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[378] C40. https://www.c40.org/cities/
[379] IT ALL ADDS UP: HOW FINNISH TOWNS ARE TAKING ACTION AGAINST CLIMATE CHANGE. Retrieved from: https://finland.fi/business-innovation/it-all-adds-up-how-finnish-towns-are-taking-action-against-climate-change/
[380] https://www.aseanbriefing.com/news/smart-cities-cooperation-indonesia-and-finland/#:~:text=Several%20Finnish%20cities%2C%20including%20Helsinki,sustainable%20and%20smart%20city%20principles
[381] mySMARTLife activities in Helsinki. Retrieved from: https://www.mysmartlife.eu/cities/helsinki/

environment. By the 2030s, Kalasatama district will offer a home for approximately 20,000 residents and jobs for 8,000 people[382].

Also, Helsinki is one of the most functional cities in the world. This is a sum of many factors: availability of open data, early adoption of digital developments, commitment, and cooperation between the whole ecosystem, from citizens to companies and government. This tightly-knit yet globally connected society offers the perfect setting for developing and piloting scalable solutions for smart cities. Our dedicated team here at Helsinki Business Hub is focused on helping foreign companies find possibilities within the intelligent city sphere in Helsinki. From top R&D possibilities, product development opportunities, unique piloting platforms, global expansion, university & research collaboration, funding, talent, and partners – we'll help you tap into the Helsinki region smart city ecosystem[383].

The concept of smart cities generally includes smart residents, smart businesses, smart electricity use, and a decrease in fossil fuel use. Smart cities are always in a look for green energy. The time has come to replace fossil fuels with carbon-neutral energy from renewable sources such as wind, solar, and hydroelectric power[384].

Helsinki brought its carbon neutrality target forward to 2030. The new City Strategy also specifies that the City will have a zero-carbon target for 2040. Our practical decisions during this council period of office will be crucial for achieving the objectives set[385].

Another Finnish city Vantaa is less ambitious than Helsinki regarding energy sustainability. However, while the city has no zero-carbon target goal, it has a well-developed plan goal is zero-emission electricity and heat production, increasing energy and resource efficiency, and wise

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[382] Helsinki Business Hub. Retrieved from: https://helsinkibusinesshub.fi/smart-city/#:~:text=Smart%20Kalasatama%3A%20Smart%20Kalasatama%20is,and%20jobs%20for%208%2C000%20people

[383] Helsinki Business Hub. Retrieved from: https://helsinkibusinesshub.fi/smart-city/#:~:text=Smart%20Kalasatama%3A%20Smart%20Kalasatama%20is,and%20jobs%20for%208%2C000%20people

[384] Smart Cities and the Need for Green Energy. (2022). Maurizio Di Paolo Emilio. Retrieved from: https://www.powerelectronicsnews.com/smart-cities-and-the-need-for-green-energy/

[385] Carbon Neutral Cities Alliance. Helsinki. Retrieved from: https://carbonneutralcities.org/cities/helsinki/#:~:text=Helsinki%20brought%20its%20carbon%20neutrality,for%20achieving%20the%20objectives%20set

energy consumption[386]. The challenge is quickly improving the existing building stock's energy efficiency. The city aims to phase out oil heating in its properties by 2030. Oil-heated units will systematically switch to geothermal energy. Geothermal heat is also to be implemented in all new buildings, the most carbon-neutral and cost-effective form of heating. Photovoltaic electrical systems will also be implemented for all suitable new projects[387].

Vantaa is also involved in a Green Deal agreement for zero-emission construction sites, which aims to phase out fossil fuels at the city's construction sites by 2025. In addition, by the end of 2030, at least 50 percent of construction machinery and site transportation will be powered by electricity, biogas, or hydrogen[388].

Vantaa Energy's role in achieving the carbon neutrality target is significant, as district heating production currently generates about a third of all of Vantaa's greenhouse gas emissions. Vantaa Energy has decided to give up fossil fuels in 2026. The transition of Vantaa Energy to fossil-free production is to be implemented with the help of renewable energy sources, energy from waste energy use, and energy storage solutions. The plan is to stop using peat in 2021. In addition to mixed waste, the waste treatment capacity of the Vantaa Energy Waste Power Plant will be expanded in 2022 to commercial and industrial waste and in 2024 to waste requiring a higher treatment temperature. Plans also include the construction of a medium-deep geothermal heating plant. A significant part of the whole is the seasonal storage of thermal energy, which enables the use of heat stored during low heating demand during the frost season[389].

Another Finnish city Kuopio has signed an agreement with Väre Ltd to purchase green electricity. From now on, renewable energy sources will produce all the electricity the city of Kuopio uses. This is a significant decision from the point of view of environmental responsibility because Kuopio´s total electricity consumption is 55,000 megawatt-hours in a year. The decision to use only green electricity is part of Kuopio´s climate policy program 2020-2030. This program

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[386] Implementation of the UN Sustainable Development Goals in Vantaa 2021. Retrieved from: https://gold.uclg.org/sites/default/files/vantaa_2021.pdf
[387] Implementation of the UN Sustainable Development Goals in Vantaa 2021. Retrieved from: https://gold.uclg.org/sites/default/files/vantaa_2021.pdf
[388] Implementation of the UN Sustainable Development Goals in Vantaa 2021. Retrieved from: https://gold.uclg.org/sites/default/files/vantaa_2021.pdf
[389] Implementation of the UN Sustainable Development Goals in Vantaa 2021. Retrieved from: https://gold.uclg.org/sites/default/files/vantaa_2021.pdf

aims to create a carbon-neutral Kuopio by the year 2030. Using green electricity city of Kuopio will reduce carbon dioxide emissions by 13,7 million kilograms. The City of Kuopio has taken a significant step towards its carbon-neutrality goal by using only electricity produced by renewable energy sources. The agreement made with Väre Ltd is substantial nationally, for Kuopio's total electricity consumption is 55,000 megawatt-hours in a year. Using green electricity city of Kuopio will reduce 13,7 million kilograms of CO2 emissions[390].

5.3. CANADA

5.3.1. SPECIFICS OF ENERGY SOURCES AND DOMESTIC CONSUMPTION

Canada is chosen as a case study because it is one of the least predictable examples in my quantitative research. Canada's consumption was much higher than the overall model predicts. My qualitative analysis helps to identify the unique determinants of Canada's oil consumption.

Canada is the second largest country in the world in area (after Russia), occupying roughly the northern two-fifths of the continent of North America. Despite Canada's great size, it is one of the world's most sparsely populated countries. Canada shares a 5,525-mile- (8,890-km-) long border with the United States (including Alaska)—the longest border in the world not patrolled by military forces. A founding member (1961) of the OECD, Canada is also a member of the Group of Seven (G7)[391]. As of 2020, countries' population was 38.6[392], about seven times greater than Finland's.

Canada is diverse when it comes to energy sources. Based on the BP report, in 2018, Canada used 324.7 mln tonnes of oil equivalent, where the share of fossil fuels was 65.01%, nuclear energy 6.57%, hydroelectric 25.44%, and renewables 2.98%. While the use of fossil fuels is high, the same as in Finland, the share of nuclear energy use in total use is much lower; the same applies to renewables. A significant difference is evident in hydroelectric use – it is significantly higher in Canada than in Finland percentage-wise.

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[390] The city of Kuopio. Retrieved from: https://www.kuopio.fi/
[391] Britannica. Canada. Retrieved from: https://www.britannica.com/place/Canada/Indigenous-peoples
[392] Wordometer. Canada population. Retrieved from: https://www.worldometers.info/world-population/canada-population/

Table 8. Energy Sources in Canada

Million tonnes of oil equivalent	Oil	Natural Gas	Coal	Nuclear energy	Hydro electric	Renewables	Total
Canada 2017	108.80	94.32	18.61	22.72	89.72	9.52	**343.70**
2017, %	31.65	27.44	5.42	6.61	26.10	2.77	**100**
Canada 2018	109.97	99.52	14.42	22.64	87.63	10.25	**344.42**
2018, %	31.93	28.89	4.19	6.57	25.44	2.98	**100**

Same as Finland, Canada is an EIA member. One of the critical criteria for becoming a part of the EIA is that a country must be a member of the OECD. Therefore, these two countries might have a similar approach regarding SPRs, reducing national oil consumption, and emergency responses related to oil supply[393].

Canada has made a series of international and domestic commitments, putting the country on a path toward an ambitious transformation of its energy system while remaining a stable and reliable energy supplier to the world. Canada set a target to cut greenhouse gas emissions by 40-45% from 2005 levels by 2030 and legislated a commitment to reach net zero emissions by 2050[394].

In terms of end-use demand by sector, in 2019, for instance, The most significant industry for energy demand was industrial at 52% of total demand, followed by transportation at 23%, residential at 13%, and commercial at 12%[395].

As mentioned above, nuclear energy sources are essential for going green. Nuclear is Canada's second-highest source of electricity generation after hydropower, contributing 8.9% of the total energy supply (TES) in 2020. Canada has four nuclear power plants with 19 operational reactors, located in Ontario and New Brunswick, with a full installed capacity of 14 gigawatts (GW), including the most significant operating nuclear plant in the world in terms of capacity

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393 IEA. Membership. Retrieved from: https://www.iea.org/about/membership
394 IEA. Canada 2022. Energy Policy Review. Retrieved from: https://iea.blob.core.windows.net/assets/7ec2467c-78b4-4c0c-a966-a42b8861ec5a/Canada2022.pdf
395 Canada Energy Regulator. Provincial and Territorial Energy Profiles – Canada. Retrieved from: https://www.cer-rec.gc.ca/en/data-analysis/energy-markets/provincial-territorial-energy-profiles/provincial-territorial-energy-profiles-canada.html

(Bruce Power in Ontario, with an annual net output of about 48 terawatt hours [TWh]). Nuclear generated 98 TWh of electricity in 2020, accounting for 15% of Canada's total electricity generation. Electricity production from nuclear energy grew slightly from 2000 to peak in 2014, with moderate fluctuations, and was relatively stable at around 101 TWh/year between 2015 and 2019. In 2020, due to an overall decrease in electricity demand, electricity generation from nuclear decreased to 98 TWh. Today, Canada is also at the forefront of developing advanced nuclear reactors, with several demonstration projects under consideration[396].

Unlike Finland, Canada has domestic oil production. The country produced 4.66 million barrels per day (MMb/d) of crude oil in 2020, a decline of 5% from 2019. This ranked Canada as the fourth largest oil producer in the world. Since 2010, Canada's crude oil production has increased by 57%. Canada holds some of the largest oil reserves in the world (almost 10%) and is surpassed only by Venezuela and Saudi Arabia as of 2020. In 2020, 75% of total Canadian production, or 3.50 MMb/d was exported to the United States (U.S.). Of the remaining 25%, 21% was refined within Canada, and the remainder was exported directly to other countries[397].

Canada's oil and gas industry is divided into three main segments: upstream, midstream, and downstream. Upstream companies engage in crude oil and natural gas exploration and production (E&P). This entails searching for oil below the ground and drilling wells to access those reserves. Midstream companies are engaged in the storage and transportation of oil and gas, while downstream companies refine and sell finished petroleum products[398].

Despite having its oil reserves, Canada imports oil from foreign suppliers. For example, more than half of the oil used in Quebec and Ontario is currently imported from foreign sources[399].

Unlike in Finland, Canada's fossil energy market is not dominated by just a few companies. Instead, there are numerous participants present in all three segments, among the ten biggest

[396] IEA. Canada 2022. Energy Policy Review. Retrieved from: https://iea.blob.core.windows.net/assets/7ec2467c-78b4-4c0c-a966-a42b8861ec5a/Canada2022.pdf

[397] Canada Energy Regulator. Provincial and Territorial Energy Profiles – Canada. Retrieved from: https://www.cer-rec.gc.ca/en/data-analysis/energy-markets/provincial-territorial-energy-profiles/provincial-territorial-energy-profiles-canada.html

[398] 10 Biggest Canadian Oil & Gas Companies. Retrieved from: https://www.investopedia.com/investing/canadian-oil-companies/#:~:text=The%20top%2010%20oil%20and,YCharts

[399] Context Energy Examined. Markets. Retrieved from: https://www.capp.ca/energy/markets/

Canadian oil and gas companies as measured by trailing 12-month (TTM) revenue that is publicly traded in the U.S. or Canada as of December 21, 2022: Cenovus Energy, Suncor Energy Inc., Imperial Oil, Enbridge Inc., Canadian Natural Resources, Parkland Corporation, TC Energy Corp, Pembina Pipeline Corporation, Gibson Energy, and ARC Resources Ltd[400].

Unlike Finland, Canada does not have an IEA stockholding obligation, neither holds any public emergency oil stocks nor imposes stockholding obligations on the industry. With a robust oil industry and supply infrastructure, Canada's emergency policy relies primarily on a well-functioning market to ensure supply security while at the same time reflecting the jurisdictional authority of provinces and territories over energy resources[401].

Canada has been producing natural gas for over a century now. In 2020, Canada was the world's sixth largest natural gas producer, averaging 15.5 billion cubic feet per day (Bcf/d), a 1.6% decline from 2019[402].

Besides traditional crude oil mining, there is a unique way to mine crude oil in Canada – by extracting it from oil sands. Canada's oil sands are the world's largest deposit of crude oil. The oil sands (or tar sands as sometimes inaccurately referred to) are a mixture of sand, water, clay, and oil called bitumen. Modern innovation and technology allow oil recovery from the oil sands, providing energy security for the future. About 20% of Canada's oil sand deposits are within 70 meters (200 feet) of the surface and can be recovered with surface mining. Still, most oil sands reservoirs are more profound and require drilling and production methods called "in situ," which creates much less surface land disturbance and mining[403].

Environmentalists say oil from tar sands is one of the planet's most destructive, carbon-intensive, and toxic fuels. Producing it releases three times as much greenhouse gas pollution as conventional crude oil. Tar sands oil comes from a solid mass that must be extracted via energy-

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[400] 10 Biggest Canadian Oil & Gas Companies. Retrieved from: https://www.investopedia.com/investing/canadian-oil-companies/#:~:text=The%20top%2010%20oil%20and,YCharts

[401] IEA. Canada Oil Security Policy. (2022). Retrieved from: https://www.iea.org/articles/canada-oil-security-policy-2

[402] Canada Energy Regulator. Provincial and Territorial Energy Profiles – Canada. Retrieved from: https://www.cer-rec.gc.ca/en/data-analysis/energy-markets/provincial-territorial-energy-profiles/provincial-territorial-energy-profiles-canada.html

[403] Context Energy Examined. What are the Oil Sands? Retrieved from: https://www.capp.ca/oil/what-are-the-oil-sands/

intensive steam injection or destructive strip mining, which destroys ecosystems, puts wildlife at risk, and defiles large land areas. Finally, when transported by pipeline or rail, communities, wildlife, and water supplies are in danger of toxic spills that are nearly impossible to clean up[404].

The sands pump out more than 3 million barrels of oil daily, accounting for most Canadian crude oil production[405]. The oil sands comprise over 98 percent of Canada's 173 billion barrels of proven oil reserves[406]. Despite environmental concerns, oil sand production in Canada amounted to nearly 180 million cubic meters in 2021, reaching a peak in production[407].

Canada is one of the largest consumers of energy globally when measured as a ratio to economic activity. Figure 6 illustrates Canada's energy intensity is second among OECD nations at 7.70 MJ per $2011 GDP. The global average for energy intensity is 5.36 MJ per $2011 GDP, while the OECD average is 4.66 MJ per $2011 GDP[408].

Just as Canadian refineries process both domestic and imported oil, gasoline terminals import gasoline in addition to domestic supply. Although Canada is a net exporter of gasoline, some imports are required to meet local demand due to differences in regional production[409].

The war in Ukraine and sanctions against Russia did not impact the Canadian energy supply. At the same time, Canada plans to increase oil and gas exports by up to 300,000 barrels per day (bpd) to help replace Russian supplies for its allied nations[410].

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[404] NO TAR SANDS. Retrieved from: https://www.biologicaldiversity.org/campaigns/no_tar_sands/index.html#:~:text=Tar%20sands%20oil%20%E2%80%94%20even%20the,as%20conventional%20crude%20oil%20does

[405] Reuters. Canadian oil barrels head out of the U.S. Gulf in record numbers. (2022). https://www.reuters.com/business/energy/canadian-oil-barrels-head-out-us-gulf-record-numbers-2022-02-11/

[406] Government of Canada. Oil Sands. Retrieved from: https://natural-resources.canada.ca/sites/www.nrcan.gc.ca/files/energy/pdf/eneene/pubpub/pdf/OS-brochure-eng.pdf

[407] Statista. Total oil sands production in Canada from 1967 to 2021. Retrieved from: https://www.statista.com/statistics/484927/canadian-oil-sands-total-production/

[408] Canada Energy Regulator. Canada's Energy Transition: Historical and Future Changes to Energy Systems – Update – An Energy Market Assessment. Retrieved from: https://www.cer-rec.gc.ca/en/data-analysis/energy-markets/canadas-energy-transition/canadas-energy-transition-historical-future-changes-energy-systems-update-energy-market-assessment-energy-emissions.html#:~:text=Energy%20Use%20in%20Canada,7.70%20MJ%20per%20%242011%20GDP

[409] Canada Energy Regulator. Where does Canada's gasoline come from? Retrieved from: https://www.cer-rec.gc.ca/en/data-analysis/energy-commodities/crude-oil-petroleum-products/report/archive/2019-gasoline/index.html#:~:text=Just%20as%20Canadian%20refineries%20process,to%20differences%20in%20regional%20production

[410] Offshore Techhnology. Canada to boost oil and gas exports amid Russia-Ukraine conflict. (2022). Retrieved from: https://www.offshore-technology.com/news/canada-exports-russia-ukraine/

5.3.2. THE CLIMATE

Because of its great latitudinal extent, Canada has a wide variety of climates. Ocean currents play an essential role, with the warm waters of the Gulf Stream in the Atlantic and the Alaska Current in the Pacific affecting the environment. Westerly winds, blowing from the sea to the land, are the prevailing air currents in the Pacific and bring coastal British Colombia heavy precipitation and moderate winter and summer temperatures. Inland, the Great Lakes moderate the weather in southern Ontario and Quebec. In the east, the cold Labrador Current meets the Gulf Stream along the coast of Newfoundland and Labrador, cooling the air and causing frequent fog[411].

The northern two-thirds of the country has a climate similar to Scandinavia north, with frigid winters and short, cool summers. The central southern area of the interior plains has a typical continental climate—freezing winters, hot summers, and relatively sparse precipitation. Southern Ontario and Quebec have an environment with hot, humid summers and cold, snowy winters, similar to some portions of the American Midwest. Except for the west coast, all of Canada has a winter season with average temperatures below freezing and continuous snow cover[412].

Those parts of the country farthest from open water are the coldest in the winter, so the winters are frigid in the interior plains and the North. The lowest temperature ever recorded was −81 °F (−63 °C) at Snag, Yukon 1947. During the summer, however, the parts of Canada farthest from open water are the warmest. The highest temperature recorded was 113 °F (45 °C) at Midale and Yellow Grass in Saskatchewan in 1937. Thus, west-coast Vancouver has an average January temperature of 37 °F (3 °C) and an average July temperature of 64 °F (18 °C), while in Regina, Saskatchewan, on the interior plains, average temperatures vary from −1 to 67 °F (−18 to 19 °C). The daily temperature range is also narrower on the coasts than in interior locations[413].

Like Finland, Canadian temperatures vary thorough out the year. Both countries have cold, snowy winters and mild summers.

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[411] Britannica. Drainage. Retrieved from: https://www.britannica.com/place/Canada/Drainage
[412] Britannica. Drainage. Retrieved from: https://www.britannica.com/place/Canada/Drainage
[413] Britannica. Drainage. Retrieved from: https://www.britannica.com/place/Canada/Drainage

5.3.3. GDP PER CAPITA

Canada's GDP per capita between 2009 and 2018 increased from $40,773 (vs. $47,294 in Finland) to $46,313 (vs. $50,020 in Finland) (almost 12%) — both numbers higher compared with the average of $37,191 in the sample used for my OECD model. My model's highest GDP per capita belongs to Norway in 2013 at $102,914; the lowest was in Colombia in 2009 at $5,193.

Even though Canadians are not on the top of the list of the happiest country in the world, sixty-seven percent of them report being very happy, generally speaking, and 68 percent are very satisfied with their lives, according to a new nationwide Gandalf Group survey conducted for The Globe and Mail[414]. Perhaps not surprisingly, the survey found that income is strongly associated with happiness; the higher the payment, the happier people are. Nearly 80 percent of respondents in households earning more than $150,000 annually report being very happy, compared with 57 percent of those making less than $50,000[415].

As discussed above, taking GDP at Purchasing Power Parity (PPP) per capita is also important, since PPP considers the relative cost of living rather than using only exchange rates, providing a more accurate picture of the real differences in income. In 2017, Canada was in 24th place out of 190 countries (followed by Finland). In 2017, Canada's PPP GDP per capita was $46,510 compared to the World's PPP GDP per capita of $17,000. The highest value was in Qatar ($128,647), and the lowest was in the Central African Republic ($727).[416]

Based on another ranking, GDP per capita, Purchasing Power Parity, 2021 - Country rankings: The average for 2021 based on 182 countries was $21,283.47 U.S. dollars. The highest value was in Luxembourg: $115,683.49 U.S. dollars, and the lowest was in Burundi: 705.03 U.S. dollars. Canada was in 23rd place with $47,892.95 (right after Finland)[417].

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[414] The Globe and Mail. Most Canadians happy, Globe survey finds. Retrieved from: https://www.theglobeandmail.com/life/article-most-canadians-happy-globe-survey-finds/

[415] The Globe and Mail. Most Canadians happy, Globe survey finds. Retrieved from: https://www.theglobeandmail.com/life/article-most-canadians-happy-globe-survey-finds/

[416] Worldometer. GDP per Capita. Retrieved from: https://www.worldometers.info/gdp/gdp-per-capita/

[417] Global Econnomy. GDP per capita, PPP - Country rankings. Retrieved from: https://www.theglobaleconomy.com/rankings/gdp_per_capita_ppp/#:~:text=GDP%20per%20capita%2C%20Purchasing%20Power,available%20from%201990%20to%202021

5.3.4. DESCRIPTIVE EXERCISE

5.3.4.1. FOSSIL FUELS AND CONSUMPTION PER CAPITA

5.3.4.1.1. FOSSIL FUELS CONSUMPTION PER CAPITA IN CANADA

Canada's FFCC pita between 2009 and 2018 increased from 5.88 million tonnes of oil equivalent up to 6.04 million tonnes of oil equivalent (2.77% increase), the opposite trend from the one observed in Finland. The average FFCC 2009-2018 in Canada is 6.13 million tonnes of oil equivalent, significantly higher than the average of 2.96 million tonnes of oil equivalent for the entire 2009-2018 sample and the average for Finland of 3.24 million tonnes of oil equivalent. Furthermore, the highest consumption in the sample is associated with Canada in 2014, with 6.31 million tonnes of oil equivalent. The lowest was in Colombia in 2009, with 0.5 million tonnes of oil equivalent, the remaining case study.

According to my model, Canada's case predicts less fossil fuel consumption per capita than any other case. The predicted value of Canada's FFCC in 2018 is 3.51 million tonnes of oil equivalent, about 2.54 million tonnes less than the number provided by the World Bank data.

Canada's energy system is dominated by oil, gas, and coal and is, therefore, susceptible to the geopolitics of global producers and unpredictable market forces. The cost of renewable energy has declined to the point where, in many markets, it is less expensive than gas or coal-fired electricity.[418]

Similarly to the situation in Finland over the last several decades, Canada's Gasoline Prices went through dramatic ups and downs from the late 1990-s till 2022. Gasoline Prices in Canada averaged 0.98 USD/Liter from 1992 until 2023, reaching an all-time high of 1.59 USD/Liter in June of 2022 and a record low of 0.41 USD/Liter in December 1998.[419]

According to the WB data in my model, the pump price in Canada went from $0.76 in 2009 to $1.32 in 2018, with an average of $1.11 (significantly lower than in Finland). Thus, while we observe an increase in gas prices over the decade, we also keep a change in FF consumption per capita within the same decade. Canada's fossil fuel consumption per capita between 2009

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[418] International Institute for Sustainable Development. Why Canada's Energy Security Hinges on Renewables. Retrieved from: https://www.iisd.org/articles/deep-dive/canadian-energy-security-renewables#:~:text=Canada's%20energy%20system%20is%20dominated,gas%20or%20coal%2Dfired%20electricity

[419] Trading Economics. Gasoline Prices in Canada. Retrieved from: https://tradingeconomics.com/canada/gasoline-prices

and 2018 increased from 5.88 to 6.04, and the average for the period was 6.13. However, if we look at the sharp change in 2012 due to the earlier discussed disruption of crude oil supply on the global market, the FF Consumption per capita in Canada decreased from 6.30 in 2011 to 6.11 in 2012, while the pump price rose by almost 10 cents (from 1.21 in 2011 to 1.32 in 2012).

5.3.4.1.2. FACTORS IMPACTING PUMP PRICES

As with Finland's case study, I research the same components of a pump price in Canada to better understand local circumstances: **global crude oil price, refining costs, distribution and marketing costs, and taxes**.

5.3.4.1.3. CRUDE OIL PRICES

Since crude oil is a market commodity, the impact on the international area would impact Canada's pump prices trend similarly to how they impacted Finland. Notably, the changes in crude oil prices in 2012 also impacted the pumping process on the domestic Canadian level during that year.

5.3.4.1.4. REFINING

Unlike Finland, with only one refinery and no oil mining, Canada is the complete opposite, with its 17 refineries in operation, including 14 refineries producing gasoline. Generally, refineries in the country are located on major waterways, near major cities, or in crude oil production. For example, all Alberta refineries are located in the heart of the Western Canadian Sedimentary Basin (WCSB), where they source their crude oil. Similarly, all Ontario refineries are located in the south of the province on significant waterways or near major cities where demand for refined products is highest. Refineries in Quebec and the Atlantic Provinces are located on major waterways that allow them to source their oil by marine vessels from overseas[420].

Canada promotes competition by involving multiple players in crude oil refining. The competition encourages cost reduction efforts, impacting the final gasoline consumer at a pump. This might be one of the factors impacting significantly lower pump prices in Canada compared to those in Finland.

[420] Canaada Energy regulator. Where does Canada's gasoline come from? Retrieved from: https://www.cer-rec.gc.ca/en/data-analysis/energy-commodities/crude-oil-petroleum-products/report/archive/2019-gasoline/index.html#:~:text=Canada%20has%2017%20refineries%20in,they%20source%20their%20crude%20oil

There are 14 gasoline-producing refineries in Canada (17 refineries total): 6 in western Canada, 4 in Ontario, 2 in Quebec, and 2 in the Atlantic Provinces. Although production varies by the refinery, gasoline comprises the largest portion of refinery output at 36%, on average. Refineries also produce a number of other refined petroleum products (RPPs), including diesel and jet fuel[421].

Another difference with Finland is that despite having 14 petroleum refineries, which produce more refined petroleum products (RPPs) than Canadians consume, the country still imports these products because some parts of Canada do not produce enough RPPs to supply local needs. These areas are often not well-connected by transportation infrastructure to parts of Canada that have excess RPPs to spare. Alberta imports nearly half of Canada's total imported RPPs. Quebec is the next most significant importer of refined products, making up almost 20% of Canadian imports, followed by Ontario at 10%. These two provinces are home to most Canadians; therefore, they have some of the highest demands for refined products[422].

The U.S. supplies most of Canada's imported RPPs, with 76% (340 000 b/d) coming from the U.S. in 2021, while the Netherlands provided 8% (35 000 b/d). The remainder came from several countries worldwide, including the Russian Federation, which supplied about 2% (10 000 b/d) of Canada's total RPP imports[423]. In 2022, Canada stopped importing crude oil from Russia; Federal data shows that Canada still imports significant aviation turbine fuel[424].

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[421] Canaada Energy regulator. Where does Canada's gasoline come from? Retrieved from: https://www.cer-rec.gc.ca/en/data-analysis/energy-commodities/crude-oil-petroleum-products/report/archive/2019-gasoline/index.html#:~:text=This%20is%20due%20to%20higher,process%20WCSB%20heavy%20crude%20oil

[422] Canaada Energy regulator. Where does Canada's gasoline come from? Retrieved from: https://www.cer-rec.gc.ca/en/data-analysis/energy-markets/market-snapshots/2022/market-snapshot-crude-oil-imports-declined-in-2021-while-refined-petroleum-product-imports-rose-modestly.html#:~:text=Crude%20oil%20is%20used%20as,Canada%20still%20import%20crude%20oil

[423] Canaada Energy regulator. Where does Canada's gasoline come from? Retrieved from: https://www.cer-rec.gc.ca/en/data-analysis/energy-markets/market-snapshots/2022/market-snapshot-crude-oil-imports-declined-in-2021-while-refined-petroleum-product-imports-rose-modestly.html#:~:text=Crude%20oil%20is%20used%20as,Canada%20still%20import%20crude%20oil

[424] Gloobal News. Canada's imports from Russia dipped nearly 80% since Ukraine invasion. Dylan Robertson and Mia Rabson. (2023). Retrieved from: https://globalnews.ca/news/9505720/canada-russia-trade-decline-ukraine-war/#:~:text=Federal%20data%20show%20Canada%20is,and%202022%20saw%20an%20increase

5.3.4.1.5. TRANSPORTATION

Because of the country's size, Canada must have various ways of transporting gasoline to its final consumer. Unlike in Finland, Canada's gasoline markets are highly localized, and production in each region tends to stay local. This also might impact pump prices to be significantly lower than in Finland.

A web of pipelines, railways, shipping routes, and highways distributes gasoline from refineries to terminals between Vancouver Island and Thunder Bay. Similar webs of infrastructure distribute gasoline from refineries in Ontario to terminals between Sarnia and Ottawa, from refineries in Quebec to airports between Ottawa and the Atlantic coast, and from refineries in New Brunswick and Newfoundland to terminals around the Atlantic Provinces. Terminals serve as receipt and distribution points for domestic and imported gasoline and decide wholesale pricing for local markets. Due to the relatively small volumes demanded by individual and dispersed facilities, gas transportation from terminals is done almost exclusively by truck[425]. Trucks are also used in Finland to deliver gasoline to the final consumer. However, trucks in Finland might have to cover longer distances due to just one source of the refined product.

After gasoline is purchased at local gas stations and bulk storage plants, it powers personal and freight transport vehicles and other industrial machinery. In 2018, domestic sales of motor gasoline totaled 46 billion liters and represented 42% of total domestic RPP sales[426].

5.3.4.1.6. MARKETING

As of December 31, 2021 — 11,934 retail gasoline stations were operating in Canada, or 3.1 outlets for every 10,000 people. This is an increase of 26 sites over last year's result, marking a decade in which the number of sites in Canada has varied little from the 12,000 mark, declining

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[425] Canaada Energy regulator. Where does Canada's gasoline come from? Retrieved from: https://www.cer-rec.gc.ca/en/data-analysis/energy-commodities/crude-oil-petroleum-products/report/archive/2019-gasoline/index.html#:~:text=This%20is%20due%20to%20higher,process%20WCSB%20heavy%20crude%20oil

[426] Canaada Energy regulator. Where does Canada's gasoline come from? Retrieved from: https://www.cer-rec.gc.ca/en/data-analysis/energy-commodities/crude-oil-petroleum-products/report/archive/2019-gasoline/index.html#:~:text=This%20is%20due%20to%20higher,process%20WCSB%20heavy%20crude%20oil

just 2.4% over the last decade. This follows the previous two decades in which Canadian retail gas stations declined by nearly 40%[427].

A diversity of brands continuously presents the Canadian petroleum market. In 2021, there were 96 of them on the market. However, the refined products sold by these brands originate primarily from just 13 refineries in Canada. The brands these refining organizations represent account for just over 60% of all sites in Canada, virtually unchanged in the last decade[428].

Increasingly, the posted brand at a gas station is less indicative of the marketer relationship or ownership at that site. In 2021, 37% of the fuel marketers in Canada were operating a portion of their network under a brand owned by another company, representing 38% of stations in Canada, up from just over 18% a decade ago. These marketers typically operate under a branded supply agreement with the brand owner (often a refiner such as Shell or Esso), benefitting from the established brand's brand recognition, marketing support, and loyalty programs[429].

In total, we identified 67 distinct companies marketing gasoline in Canada. Of these 67 companies, 59 market at least a portion of their fuels under their brands, representing 50% of Canadian stations, down from 68% of sites a decade ago[430].

Nearly half of the sites in Canada (5,500) are price-controlled by individual operators (retailers or dealers). In contrast, 6,400 locations are directly price-controlled by refiner and non-refiner marketers, selling fuel through their controlled networks of stations. The brands owned

[427] Kalibrate. Canadian 2021 National Retail Petroleum Site Census — Executive summary. Retrieved from: https://kalibrate.com/insights/blog/data-intelligence/canadian-2021-national-retail-petroleum-site-census-executive-summary/

[428] Kalibrate. Canadian 2021 National Retail Petroleum Site Census — Executive summary. Retrieved from: https://kalibrate.com/insights/blog/data-intelligence/canadian-2021-national-retail-petroleum-site-census-executive-summary/

[429] Kalibrate. Canadian 2021 National Retail Petroleum Site Census — Executive summary. Retrieved from: https://kalibrate.com/insights/blog/data-intelligence/canadian-2021-national-retail-petroleum-site-census-executive-summary/

[430] Kalibrate. Canadian 2021 National Retail Petroleum Site Census — Executive summary. Retrieved from: https://kalibrate.com/insights/blog/data-intelligence/canadian-2021-national-retail-petroleum-site-census-executive-summary/

by the three "major" oil companies (by their cross-Canada presence) of Petro-Canada, Esso, and Shell appear at 42% of stations across Canada; only 11% come under their direct price control[431].

Providing goods or services other than gasoline is vital to the competitiveness and availability of retail gasoline outlets. The gross margin on gasoline itself is rarely sufficient to provide for the operating costs and reasonable return on the operation of these facilities. Such features and offerings as a type of pump service (full, self, or split), convenience store size, car washes, fast food, automotive service, and diesel are essential to have at gasoline stations in Canada[432].

Similarly to the situation in Finland, in 2020, there was a significant decline in petroleum demand due to travel restrictions instituted to curb the spread of the COVID-19 virus. This caused an astounding drop of 16.8% (3.3 million annual liters) in consumption. Although conditions eased somewhat in 2021, the average site throughput at Canadian gas stations has not returned to pre-pandemic levels, reaching just 3.5 million annual liters in 2021, 11.7% below 2019[433].

Similarly to Finland, Canadian retailers offer fuel cards, which guarantee savings at the pump (between two-three pence a liter, depending on the rate) and promote fuel use accountability.

5.3.4.1.7. DOMESTIC POLICY ON GASOLINE USE AND TAXATION

Canada has joined over 120 countries in committing to net-zero emissions by 2050, including all other G7 nations (United Kingdom, United States, Germany, Italy, France, and Japan); a number of provinces and cities have already made net-zero-by-2050 commitments, including Guelph, Vancouver, Hamilton, Toronto, Halifax, Newfoundland, and Labrador, and most recently Quebec. Prince Edward Island has also pledged to reach net-zero greenhouse gas emissions by 2040. Nova Scotia and British Colombia have put into place, or plan to put into place,

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[431] Kalibrate. Canadian 2021 National Retail Petroleum Site Census — Executive summary. Retrieved from: https://kalibrate.com/insights/blog/data-intelligence/canadian-2021-national-retail-petroleum-site-census-executive-summary/

[432] Kalibrate. Canadian 2021 National Retail Petroleum Site Census — Executive summary. Retrieved from: https://kalibrate.com/insights/blog/data-intelligence/canadian-2021-national-retail-petroleum-site-census-executive-summary/

[433] Kalibrate. Canadian 2021 National Retail Petroleum Site Census — Executive summary. Retrieved from: https://kalibrate.com/insights/blog/data-intelligence/canadian-2021-national-retail-petroleum-site-census-executive-summary/

provincial net-zero-by-2050 legislation. The Canadian Net-Zero Emissions Accountability Act, which became law on June 29, 2021, enshrines in legislation Canada's commitment to achieving net-zero emissions by 2050. The Act ensures transparency and accountability as the government works to deliver on its targets. The Act requires public participation and independent advice to guide the Government of Canada's efforts. [434]

Three principal Canadian cities (Montréal, Toronto, and Vancouver) are members of C40, where C40 mayors and the cities lead by taking ambitious, collaborative, and urgent climate action that aligns with science-backed targets. They work together across borders to protect people and communities everywhere and build a more sustainable, resilient, and equitable future[435]. The fact that local Canadian communities take action is a sign of proactive communities.

Similarly to Finns, a prominent Canadian community representing 700,000 health professionals signed an open letter calling on Ottawa to ban advertising for fossil fuels, gas utilities, and gasoline vehicles. Their claims are based on a recent Health Canada report that found that fossil fuel air pollution kills between 15,000 to 34,000 Canadians annually – while children who live in homes with gas stoves face a 24% to 42% greater risk of developing asthma[436]. For comparison, a similar initiative in Finland got 10,508 signatures[437].

Since 2015, Canada has made a series of enterprising international and domestic commitments to put the country on a path towards transforming its energy system, including a target to cut greenhouse gas emissions by 40-45% by 2030 from 2005 levels and to reach net zero emissions by 2050. Canada's energy transformation presents challenges and opportunities given its profile as a major producer, consumer, and exporter of energy and its highly decentralized government system. The sizeable weight of fossil fuel production in employment and economic output means strong attention should be placed on ensuring a people-centered approach to Canada's clean energy transition. Canada has a number of

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[434] Government of Canada. Net-Zero Emissions by 2050. Retrieved from: https://www.canada.ca/en/services/environment/weather/climatechange/climate-plan/net-zero-emissions-2050.html

[435] C40. https://www.c40.org/cities/

[436] Korporate Knigh. Will more countries ban fossil fuel ads? RICK SPENCE. (2022). Retrieved from: https://www.corporateknights.com/leadership/will-more-countries-ban-fossil-fuel-ads/

[437] Ban Fossil Fuel Ads Survey. Retrieved from: https://banfossilfuelads.org/

policy measures in place, including an ambitious carbon pricing scheme, clean fuel regulations, a commitment to phase out unabated coal use by 2030, nuclear plant extensions, upstream methane regulations, energy efficiency programs, and measures to decarbonize the transport sector[438].

Energy production and use in Canada accounts for over 80% of the country's GHG emissions, with fuel combustion in energy industries (including oil and gas extraction, electricity and heat generation, and refining) representing 26%, transportation 26%, buildings 13%, manufacturing industries 9%, and fugitive emissions 7% of overall emissions. Canada's electricity system is 83% non-emitting and among the cleanest in the world, with heavy dominance of hydropower and an essential role for nuclear. Considerable variation in electricity generation profiles across jurisdictions means that increased interconnectivity across regions will ensure balanced progress across provinces and territories to meet national targets[439].

Canada has a number of policy measures in place to support its national and international targets. Canada introduced an ambitious carbon pricing scheme in 2019, providing appropriate price signals to shift consumption to cleaner fuels. To complement the carbon price, Canada's policies include the 2016 Pan-Canadian Framework on Clean Growth and Climate Change (PCF) and 2020 Strengthened Climate Plan, the Greenhouse Gas Pollution Pricing Act, the Clean Fuel Regulations, a commitment to phase out unabated coal use by 2030, nuclear plant extensions, upstream methane regulations, stringent vehicle emissions standards, and energy efficiency measures[440].

There are different fuel/ transportation taxes in Canada: fixed and sales. The Federal Government levies fixed taxes as an excise tax at a flat rate of 10 cents per liter on gasoline (in effect at that rate since 1995) and 4 cents per liter on diesel (in development at that rate since 1987). Additionally, provincial governments collect gasoline and diesel taxes, varying considerably by province. Lastly, three municipalities in Canada (Vancouver, Victoria, and Montreal) also apply taxes on gasoline[441].

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[438] IEA. Canada 2022 Energy Policy Review. (2022). Retrieved from: https://www.iea.org/reports/canada-2022
[439] IEA. Canada 2022 Executive Summmary. Retrieved from: https://www.iea.org/reports/canada-2022/executive-summary
[440] IEA. Canada 2022 Executive Summmary. Retrieved from: https://www.iea.org/reports/canada-2022/executive-summary
[441] Government of Canada. Fuel Consumption Levies in Canada. Retrieved from: https://natural-resources.canada.ca/our-natural-resources/domestic-and-international-markets/transportation-fuel-prices/fuel-consumption-taxes-canada/18885

Sales tax is based on a percentage of the retail price, a method known as ad valorem. The federal goods and services tax (GST)/ harmonized sales tax (HST) is charged on crude oil, refining, and marketing costs and margins, the federal excise tax, applicable federal and provincial carbon levies, and provincial road taxes. Federal GST Sales tax on gasoline equals 5%, in addition to the exciting tax of 10 cents per liter[442].

Provincial sales taxes do not apply to fuels such as gasoline or diesel, except where they have the harmonized sales tax (HST), and in Quebec (QST)—provincial gasoline taxes vary between 9.9% and 15%. Provincial Fuel Taxes are also diverse: 0 cents/liter in Alberta, 6.2 in Yukon, and 27 in British Colombia – Vancouver Area. Federal and local carbon levies vary between 1.1 cents/liter in Nova Scotia and 11.05 in Manitoba and British Colombia[443].

In terms of incentives to use fully electric vehicles, Canada still has a long way to go before approaching the first target in 2026. Despite various incentives, for instance, $5,000 through investing $1.7 billion to extend the Incentives for Zero-Emission Vehicles Program until March 2025, percent of electric vehicles on Canadian roads is still low.

The number of road motor vehicles registered in Canada increased to 26.2 million in 2021, up 1.9% over 2020. 24.1 million light-duty vehicles accounted for 9 out of every ten motor vehicles registered in 2021, with passenger cars remaining the most common type. While 94.9% of all registered light-duty vehicles remained motor gasoline in 2021, 303,073 hybrid electric cars, 152,685 battery electric vehicles, and 95,896 plug-in electric vehicles were registered[444]. In the first six months of 2022, fully-electric and plug-in hybrid vehicle sales made up just 7.2 percent of new car registrations. For all of 2021, the share was 5.2 percent[445].

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442 Government of Canada. Fuel Consumption Levies in Canada. Retrieved from: https://natural-resources.canada.ca/our-natural-resources/domestic-and-international-markets/transportation-fuel-prices/fuel-consumption-taxes-canada/18885

443 Government of Canada. Fuel Consumption Levies in Canada. Retrieved from: https://natural-resources.canada.ca/our-natural-resources/domestic-and-international-markets/transportation-fuel-prices/fuel-consumption-taxes-canada/18885

444 Statistics Canada. Automotive statistics. Retrieved from https://www.statcan.gc.ca/en/topics-start/automotive

445 CBC News. Canada moves to make one-fifth of all vehicle sales electric starting in 2026. Retrieved from: https://www.cbc.ca/news/politics/canada-ev-mandates-2026-1.6693967#:~:text=Canada%20still%20has%20a%20long,share%20was%205.2%20per%20cent

According to some reports, availability is the most challenging aspect of getting people to abandon gas-powered vehicles. Long waiting lists are discouraging consumers ready to make the switch[446]. This might explain why Canada's FF consumption remains at high levels.

5.3.4.2. URBANIZATION AND FOSSIL FUELS CONSUMPTION PER CAPITA

Table 9. Energy Sustainability Approaches in three most populated cities

City		Population	C40 or other collaborations	Low-carbon programs
1	Ottawa (Canada)	994,837	C40 – no, others - yes	Yes
2	Toronto (Canada)	2.93 mln	C40 yes	Yes
3	Montreal (Canada)	1.78 mln	C40 yes	Yes

Ottawa, Canada's capital, is not a part of C40. However, it is a part of other collaborations promoting sustainable energy use and a low-carbon environment. The city has a bold Climate Change Master Plan, which includes setting new short-, mid-, and long-term targets to reduce community GHG emissions by 100% by 2050 and corporate GHG emissions by 100% by 2040. Energy Evolution is one of eight priority actions under this plan. Energy Evolution sets the framework for what it will take for Ottawa to achieve these GHG emission reduction targets. It is a community energy transition strategy designed to manage energy consumption, promote the use of renewable energy and advance local economic development opportunities in Ottawa. Developed in collaboration with more than 40 staff representing six departments, almost 200 public and private stakeholders representing more than 90 organizations, and the Climate Change Council Sponsors Group, Energy Evolution is a community-wide initiative with a vision to transform Ottawa into a thriving city powered by clean, renewable energy[447]. According to the

[446] CBC News. Canada moves to make one-fifth of all vehicle sales electric starting in 2026. Retrieved from: https://www.cbc.ca/news/politics/canada-ev-mandates-2026-1.6693967#:~:text=Canada%20still%20has%20a%20long,share%20was%205.2%20per%20cent
[447] OTTAWA'S COMMUNITY ENERGY TRANSITION STRATEGY – FINAL REPORT. Retrieved from: https://documents.ottawa.ca/sites/documents/files/energy_evolution_strategy_en.pdf

plan, by 2050, all fossil fuels will have to be phased out, heating and transportation systems will have to be nearly fully electrified, or transition to zero-emission, waste heat utilization, and renewable natural gas production will have to be added, sufficient renewable electricity (primarily wind and solar) generation and electricity storage will be required to meet demand and offset emissions on the provincial grid[448].

Toronto is way ahead of the green game. The City continues to develop and implement innovative policies and programs, inspire the community to address climate change and make Toronto one of the most environmentally sustainable cities in the world. Toronto City Council has adopted an ambitious strategy to reduce community-wide greenhouse gas (GHG) emissions in Toronto to net zero by 2040 – 10 years earlier than initially proposed. The City's 2040 target is one of the most ambitious in North America. Meeting the City's future GHG reduction targets will require rapid action to scale up existing programs, additional authorities for the City to implement effectively, and significant levels of investment and coordination with other levels of government. The strategy identifies actions and targets to be achieved by 2030 in key sectors, including buildings, transportation, and waste. (Below, more target information is available in the 2030 Goals by Sector tab.) Toronto's community-wide emissions must be cut in half in the next ten years to meet the 2030 target of a 65 percent emissions reduction[449]. For example, over the past 20 years, more than 100 renewable energy systems have been installed on City buildings and properties. Using solar photovoltaic (PV), solar thermal, geothermal, and biomass, these and future systems will support the City's environmental, energy security, and economic goals[450].

Despite significant population growth, community-wide emissions have decreased by 38 percent since 1990, and Toronto's gross domestic product (GDP) has continued to rise. Like other major cities globally, the City issues its emissions inventory on a two-year lag cycle to ensure the

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[448] OTTAWA'S COMMUNITY ENERGY TRANSITION STRATEGY – FINAL REPORT. Retrieved from: https://documents.ottawa.ca/sites/documents/files/energy_evolution_strategy_en.pdf https://ottawa.ca/en/living-ottawa/environment-conservation-and-climate/climate-change-and-energy/energy-evolution#section-fa5b88e5-10e8-4ed9-8031-67c6c73d7df3

[449] City of Toronto. TransformTO Net Zero Strategy. Retrieved from: https://www.toronto.ca/services-payments/water-environment/environmentally-friendly-city-initiatives/transformto/

[450] City of Toronto. Renewable Energy. Retrieved from: https://www.toronto.ca/services-payments/water-environment/environmentally-friendly-city-initiatives/greening-city-operations/renewable-energy/

best available data[451]. Toronto's 2020 GHG Inventory, released in 2022, tracks and identifies direct and indirect GHG emissions from three dominant sectors- buildings, transportation, and waste – indicates that Toronto's GHG emissions were 43 percent lower in 2020 than in 1990. Toronto's future sector-based GHG reduction targets are 45 percent by 2025, 65 percent by 2030, and net zero by 2040[452].

Montreal pays a lot of effort to decrease greenhouse gas emissions around construction sites and buildings. Montreal is developing, along with its C40 partners and various foundations. This strategy will enable it to lower the carbon emissions of its properties and make them more energy-efficient by gradually moving away from heating oil and towards renewable energies. The city aims to reach carbon neutrality for all municipal buildings by 2030, all new buildings on its territory by 2030, and all existing buildings by 2050[453].

Beginning in 2024, construction permits in Montreal for small buildings (below 2,000 square meters) will only be granted to buildings whose operations will produce no greenhouse gas emissions," Le Devoir reports. The requirement will be extended to larger buildings in 2025[454]. The plan will treat renewable natural gas as a carbon-neutral fuel. The city will not regulate the choice of heating systems but instead focus on carbon dioxide released into the atmosphere. The city will use performance standards for existing buildings that will become more stringent over time, ending with a carbon-neutral target by 2040. Building owners must also reveal whether their properties run on fossil fuels.[455]

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[451] City of Toronto. TransformTO Net Zero Strategy. Retrieved from: https://www.toronto.ca/services-payments/water-environment/environmentally-friendly-city-initiatives/transformto/

[452] City of Toronto. 2020 Sector-Based Greenhouse Gas Emissions Inventory. Retrieved from: https://www.toronto.ca/wp-content/uploads/2023/01/8eab-2020-Sector-based-Greenhouse-Gas-Emissions-Inventory-v1.pdf

[453] The City of Montréal announces a first step towards carbon neutrality for its real estate assets. (2019). Retrieved from: https://electricenergyonline.com/article/energy/category/general/16/766509/the-city-of-montreal-announces-a-first-step-towards-carbon-neutrality-for-its-real-estate-assets.html

[454] Montreal Sets Zero-Emission Terget for All New Buildings by 2025. Retrieved from: https://www.theenergymix.com/2022/05/06/montreal-sets-zero-emission-target-for-all-new-buildings-by-2025/

[455] Montreal aims to lower greenhouse gas emissions by 2025. (2022). Retrieved from: https://www.constructioncanada.net/montreal-aims-to-lower-greenhouse-gas-emissions-by-2025/

5.4. COLOMBIA

5.4.1. SPECIFICS OF ENERGY SOURCES AND DOMESTIC CONSUMPTION

Colombia is chosen as a case study because, same as Canada, it is one of the least predictable examples in my quantitative research. According to the 2009-2018 Model, Colombia's 2018 residual is -1.95, which makes the prediction better than Canada's but not as close as Finland's. Thus, it would be valuable to research the local specifics of this country.

The Republic of Colombia is a country in northwestern South America. The waters of the Caribbean Sea bathe its 1,000 miles of coast to the north, and the Pacific Ocean washes its 800 miles (1,300 km) of coast to the west. The country borders Panama, which divides the two bodies of water on the northwest, Venezuela and Brazil on the east, and Peru and Ecuador on the south. It is more than twice the size of France. It includes the San Andrés y Providencia archipelago, located off the Nicaraguan coast in the Caribbean, some 400 miles (650 km) northwest of the Colombian mainland. As of 2020, countries' population was 52.3[456], which is over ten mln people greater than in Canada and almost ten times greater than in Finland. Similar to Finland and Canada, Colombia is a member of the OECD.

Regarding energy sources, Colombia is an interesting case to look at. One of the apparent specifics is that the country does not generate and thus does not use nuclear energy. Another feature distinguishing Colombia from the other two cases is that the country with a population of 52mln uses only twice as much energy as Finland. This might mean that either country is less industrial and have fewer people with access to electricity and vehicles, or due to the specifics of climate and extended daylight, the use of energy, or perhaps, other local specifics might impact such low volumes of energy consumption. Based on the BP report, in 2018, Colombia used 46.95 mln tonnes of oil equivalent, where the share of fossil fuels was 71.66% (which is way higher than in Canada or Finland), hydro electric 27.3% (almost three times higher than in Finland and 2% higher than in Canada), and renewables 1.03% (nearly ten times lower than in Finland and three times lower than in Canada).

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456 Worldometer. Colombia Population. Retrieved from: https://www.worldometers.info/world-population/colombia-population/

Table 10. Energy Sources in Colombia

Million tonnes of oil equivalent	Oil	Natural Gas	Coal	Nuclear energy	Hydro electric	Renewables	Total
Colombia 2017	16.45	10.46	5.18	0.00	12.98	0.45	**45.51**
2017, %	36.15	22.97	11.38	0.00	28.51	0.99	**100**
Colombia 2018	16.57	11.20	5.87	0.00	12.82	0.49	**46.95**
2018, %	35.29	23.86	12.51	0.00	27.30	1.03	**100**

According to most recent data, the energy matrix in Colombia is currently dominated by hydropower, accounting for 69.6% of power generation, followed by natural gas at 12.3% and coal at 9.3%. Gasoline and diesel account for 7.8%, while non-conventional renewable resources contribute only 1.0% to energy generation[457].

Unlike Finland and Canada, Colombia is not an EIA member. However, it is one of the four countries seeking accession to full membership (Chile, Colombia, Israel, and Latvia)[458]. Colombia meets one of the critical criteria for becoming a part of EIA: a country must be a member of the OECD. As of today, Colombia has no SPR sites. Based on the available data, Colombia is a net oil exporter[459]; therefore, the country, like Canada, will likely not be obliged to create an SPR site after gaining EIA membership.

In December 2020, Colombia released its revised Nationally Determined Contributions (NDC) to the United Nations Framework Convention on Climate Change, pledging to reduce greenhouse gas emissions by 51 percent in 2030 (compared to the baseline scenario) and working towards achieving carbon neutrality by 2050. Subsequently, Colombia has taken several steps to transform its intentions into action[460].

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[457] Colombia's prospects for renewables. Carlos Caicedo. (2021). Retrieved from: https://www.spglobal.com/marketintelligence/en/mi/research-analysis/colombias-prospects-for-renewables.html
[458] IEA. Membership. Retrieved from: https://www.iea.org/about/membership
[459] IEA. Membership. Retrieved from: https://www.iea.org/about/membership
[460] The World Bank. Colombia: Leading the Path to Sustainability in Latin America. Retrieved from: https://www.worldbank.org/en/news/feature/2022/08/31/colombia-leading-the-path-to-sustainability-in-latin-america

Interestingly, the government fostered the development of a local green bond market as a public funding tool to meet the country's environmental, climate, and sustainability targets. It was the first green emerging market sovereign bond issued through auction in local currency, following the German twin bond structure. The transactions yielded positive results regarding demand, cost, and diversification of the investor base. The transactions achieved a balanced split between foreign (60 percent) and local (40 percent) investors. Environmental Finance awarded the inaugural issuance of the Sovereign Green Bond of the Year in 2022[461].

Colombia has significant reserves of mineral resources. In addition to large deposits of coal, oil, and natural gas, there are shale and extra heavy oil reserves. In terms of tonnes of oil equivalent, proved reserves of coal were 89.9%, of the total fossil fuel resources in 2021, oil resources 7.9%, and gas 2.2%. Colombia has the second largest coal reserves in South America behind Brazil, amounting to 5 trillion short tons in 2020. According to other sources, oil reserves in Colombia in 2022 were estimated at 1.8 billion barrels, 2.036, and 2.0 billion barrels in 2021[462].

Colombia has an extensive crude oil distribution infrastructure, primarily located in the northwest and center of the country, close to most of the crude oil and gas production[463].

There is significant scope for renewables growth in Colombia, which has led the government of President Iván Duque to establish a comprehensive regulatory framework to incentivize the sector's development. Solar energy, wind, and biomass are believed to offer the most potential. Colombia's energy transition plan aimed to increase renewable energy to 12% by end-2022 [464].

Today, Colombia predominately uses hydropower as its primary source of power generation. However, droughts can significantly affect the generation mix. Droughts have led to significant demand increases for fossil fuels in periods of low rain. In 2020, thermal generation

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[461] The World Bank. Colombia: Leading the Path to Sustainability in Latin America. Retrieved from: https://www.worldbank.org/en/news/feature/2022/08/31/colombia-leading-the-path-to-sustainability-in-latin-america

[462] Advanced Energy Technologies. Energy Industry in Colombia. Retrieved from: https://aenert.com/countries/america/energy-industry-in-colombia/#:~:text=Primary%20energy%20consumption%20in%202021,(3.6%25)%20%5B7%5D

[463] Colombia Oil and Gas Midstream Market. Retrieved from: https://www.mordorintelligence.com/industry-reports/colombia-oil-and-gas-midstream-market

[464] Colombia's prospects for renewables. Carlos Caicedo. (2021). Retrieved from: https://www.spglobal.com/marketintelligence/en/mi/research-analysis/colombias-prospects-for-renewables.html

increased to account for the lower levels of hydroelectricity resulting from low water inputs during the year[465].

Colombia's non-hydropower renewables sector is not as extensive as its hydropower sector. Still, Colombia's Mining and Energy Planning Unit (UPME) expects non-hydropower renewables to grow through 2030 because of significant solar and wind power opportunities. Colombia does not have enough transmission infrastructure to develop non-hydropower renewables in rural areas with the highest renewable power potential[466].

As mentioned above, nuclear energy sources are considered essential, at least in the Western hemisphere, when it comes to going green. However, nuclear power is not a prevalent energy source in Latin America. Currently, only seven nuclear power reactors are in operation, producing just 2.2% of total energy consumption in Latin America: three in Argentina, two in Brazil, and two in Mexico[467]. Colombia has a single nuclear reactor that was activated in 1965 and deactivated in 1997[468]. Thus, observing how Colombia will achieve its carbon neutrality by 2050 would be interesting.

In 2021, Colombia was South America's largest coal producer and second-largest petroleum and other liquids producer after Brazil. The country is also a significant oil exporter; in 2021, it was the fifth-largest crude oil exporter to the United States. Colombia's total petroleum and other liquids production fell from 808,000 barrels per day (b/d) in 2020 to an average of 760,000 b/d in 2021, continuing a production decline trend from recent years. Production declines in both years resulted from shut-ins driven by COVID-19-related lockdowns, delayed exploration, and social protests and attacks by guerilla groups on critical midstream oil infrastructure[469].

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[465] U.S. Energy Information Administrattion. Colombia Executive Summary. (2022). Retrieved from: https://www.eia.gov/international/analysis/country/COL

[466] U.S. Energy Information Administrattion. Colombia Executive Summary. (2022). Retrieved from: https://www.eia.gov/international/analysis/country/COL

[467] Has nuclear power been abandoned in Latin America?. Lillian Sol Cueva. Retrieved from: https://energytransition.org/2016/09/has-nuclear-power-been-abandoned-latin-america/#:~:text=Nuclear%20power%20is%20not%20a,Brazil%20and%20two%20in%20Mexico

[468] Latin America also has Nuclear Reactors. Laura Viviana Guevara. Retrieved from: https://latinamericanpost.com/29115-latin-america-also-has-nuclear-reactors#:~:text=Colombia,gold%20and%20coal%20in%20Colombia%22

[469] U.S. Energy Information Administrattion. Colombia Executive Summary. (2022). Retrieved from: https://www.eia.gov/international/analysis/country/COL

Supply disruptions due to local guerillas are a unique circumstance not present in Finland or Canada. Such a factor decreases the reliability of oil exports. Despite a 2016 peace agreement between the Revolutionary Armed Forces of Colombia (FARC) guerillas and the government, Colombia's oil industry continues to be the target of pipeline attacks. The National Liberation Army (ELN) and the Colombian government had been in peace negotiations, but those were suspended after attacks by ELN in early 2018. Attacks by the ELN targeting oil pipelines and other infrastructure in Colombia are frequent—over 30 such incidents were recorded in 2021. In 2020, Ecopetrol recorded 51 oil infrastructure attacks, and EIA estimates that 8,000 b/d were disrupted during that year and 14,000 b/d in 2021. Attacks on crucial midstream infrastructure, especially Caño Limón–Coveñas pipeline, have disrupted the supply of crude oil for export[470].

In addition to attacks, production was shut in 2020 because of social protests and lockdowns during the COVID-19 pandemic. Protests in April 2020 began in opposition to a tax proposal, and these protests blocked access to oil fields in the Arauca, Meta, and Putumayo provinces until June 2020. Several companies announced cuts in production or suspension of exploration activities amid the protests. EIA estimates that an average of 31,000 b/d was offline between April and June 2020. Including these shut-ins, Colombia's petroleum and other liquids production in 2020 fell approximately 100,000 b/d year-over-year and 48,000 b/d in 2021[471]. Social unrests with such a high impact on the local economy are absent in Finland or Canada.

While Finland is not known for causing severe environmental issues by refining fossil fuels, Canada is known for its oil sand and their ruination of habitats and species. Colombia is known for oil spills, flaring, and other environmentally damaging incidents. Colombia is among the continent's worst perpetrators in South America. For example, between 2015 and 2022, more than 2,133 environmentally harmful incidents involving Colombia's oil industry occurred. However, that number has been difficult to verify because of a lack of government transparency. Oil spills in Colombia are not only the fault of energy companies operating in the country and are caused by poor maintenance, operational failures, or human error. In many cases, they are the

[470] U.S. Energy Information Administrattion. Colombia Executive Summary. (2022). Retrieved from: https://www.eia.gov/international/analysis/country/COL
[471] U.S. Energy Information Administrattion. Colombia Executive Summary. (2022). Retrieved from: https://www.eia.gov/international/analysis/country/COL

consequence of sabotage and petroleum theft. As mentioned earlier, guerillas regard Colombia's petroleum industry as a legitimate target in their armed struggle against the state[472].

5.4.2. THE CLIMATE

Colombia, officially the Republic of Colombia, Spanish República de Colombia, is in northwestern South America. The waters of the Caribbean Sea bathe its 1,000 miles (1,600 km) of coast to the north, and the Pacific Ocean washes its 800 miles (1,300 km) of coast to the west. The country borders Panama, which divides the two bodies of water on the northwest, Venezuela and Brazil on the east, and Peru and Ecuador on the south. It is more than twice the size of France. It includes the San Andrés y Providencia archipelago, located off the Nicaraguan coast in the Caribbean, some 400 miles (650 km) northwest of the Colombian mainland. The population is primarily concentrated in the mountainous interior, where Bogotá, the national capital, is situated on a high plateau in the northern Andes Mountains[473].

Colombia presents a remarkable study of contrasts in its geography and society. The lofty snow-tipped peaks of the country's interior cordilleras tower high above equatorial forests and savannas where surviving indigenous groups still follow the traditions of their ancestors. In the cooler mountains, at intermediate elevations, modern cities are juxtaposed with traditional rural landscapes where mestizo farmers cultivate their small plots of coffee, corn (maize), and other crops. The more accessible Atlantic lowlands, dominated by large livestock haciendas and a tri-ethnic population, have a distinctively different character[474].

Because of the country's proximity to the Equator, its climate is generally tropical and isothermal. Temperatures vary a little throughout the year. The only genuinely variable climatic element is the amount of annual precipitation. Climatic differences are related to elevation and the displacement of the intertropical convergence zone between the two central air masses from which the northeast and southeast trade winds originate[475].

[472] Colombia's Oil Industry Is An Environmental Disaster. (2023). Matthew Smith. Retrieved from: https://oilprice.com/Energy/Energy-General/Colombias-Oil-Industry-Is-An-Environmental-Disaster.html
[473] Britannica. Colombia. Retrieved from: https://www.britannica.com/place/Colombia/Climate
[474] Britannica. Colombia. Retrieved from: https://www.britannica.com/place/Colombia/Climate
[475]Britannica. Colombia. Retrieved from: https://www.britannica.com/place/Colombia/Climate

As one can see, unlike Finland and Canada, where temperatures vary thorough out the year, Colombia goes throughout a year cycle without any real change of seasons with insignificant temperature variations.

5.4.3. GDP PER CAPITA

Colombia's GDP per capita between 2009 and 2018 increased from $ 5,193 (vs. $47,294 in Finland and $40,773 in Canada) to $6,718 (vs. $50,020 in Finland and $46,313 in Canada) (almost 30%). Both numbers are still significantly lower than the average of $37,191 in the sample used for my OECD model and the numbers for Finland and Canada. Furthermore, my model's lowest GDP per capita was Colombia in 2009 at $5,193.

Regarding life satisfaction, Colombia went from being the happiest country in the world to being among the least satisfied nations. This was announced in the most recent report of the World Happiness Report, which assesses the joy, well-being, and quality of life of the inhabitants of each territory. The information, financed by the United Nations (UN), is considered the most important in terms of happiness in the world because it rates not only the satisfaction of the inhabitants but also the per capita income, the Gross Domestic Product (GDP), social support, life expectancy, freedom to making decisions, perception of corruption, among others. Considering these factors, the World Happiness Report placed Colombia in 66th place in the ranking. Interestingly, Finland topped the list with a score of 7.82 out of 10[476].

As discussed above, taking GDP at Purchasing Power Parity (PPP) per capita is also important, since PPP considers the relative cost of living rather than using only exchange rates, providing a more accurate picture of the real differences in income. In 2017, Colombia was in the 90th place out of 190 countries with a PPP GDP per capita of $14,503 compared to the World's PPP GDP per capita of $17,000.[477] This number is also significantly lower compared to Canada ($46,510) and Finland ($46,344), which are in 24th and 25th places.

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476 Even happiness was lost in Colombia: survey places it among the least happy countries in the world. Retrieved from: https://www.infobae.com/en/2022/03/18/even-happiness-was-lost-in-colombia-survey-places-it-among-the-least-happy-countries-in-the-world/#:~:text=Colombia%20went%20from%20being%20the,the%20inhabitants%20of%20each%20territory

477 Wordometer. GDP per Capita. Retrieved from: https://www.worldometers.info/gdp/gdp-per-capita/

5.4.4. DESCRIPTIVE EXERCISE

5.4.4.1. FOSSIL FUELS AND CONSUMPTION PER CAPITA

Overall, Colombia's FFCC between 2009 and 2018 increased from 0.50 million tonnes of oil equivalent to 0.68 million tonnes of oil equivalent (36% increase). This is a similar trend in Canada. However, levels of consumption in Colombia are ten times lower. And it is the opposite trend from Finland, where even the decreased consumption is still five times higher than in Colombia. Furthermore, the lowest level of consumption was in Colombia in 2009, with 0.5 million tonnes of oil equivalent.

Unlike in the previous two cases, a smooth, steady growth in FF consumption per capita is observed in Colombia from 2009 to 2018. Even the 2012 crude oil supply fluctuations did not seem to impact consumption. Low volumes of consumption might explain this. In 2020, Colombia imported $251M in Crude Petroleum, becoming the world's 65th largest importer of Crude Petroleum. The same year, Crude Petroleum was Colombia's 25th most imported product. Colombia imports Crude Petroleum primarily from: the United States ($250M), Panama ($1.72M), Spain ($11.9k), Austria ($1.63k), and Peru ($760)[478].

Interestingly, unlike in Finland and Canada, Colombia's Gasoline Prices did not go through dramatic ups and downs during the observed period. Furthermore, the pump price for gasoline decreased throughout the researched period from $1.04 in 2009 to $0.59 in 2018, with the average for the period of $1.05 (which is lower than in Finland and Canada). Currently, Gasoline prices in Colombia equal $0.558/liter[479], which is even lower than in 2018 and is significantly lower than the current process for the previous two cases ($1.252 in Canada and $2.056 in Finland).

At first, it looked like the FFCC went up regardless of pump price changes. However, one can notice that pump prices were relatively high from 2010 to 2012. This might indicate a small number of vehicle owners in the country. In that case, a low gasoline consumption decrease

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478 OEC. Refined Petroleum in Colombia. Retrieved from: https://oec.world/en/profile/bilateral-product/crude-petroleum/reporter/col#:~:text=Imports%20In%202020%2C%20Colombia%20imported,Crude%20Petroleum%20in%20the%20world

479 Colombia Gasoline prices. Retrieved from: https://www.globalpetrolprices.com/Colombia/gasoline_prices/

would not increase overall FFCC. However, after evaluating the EIA data below, petroleum and other liquids consumption increased between 2010 and 2012[480].

However, after careful evaluation of the domestic situation, it turned out that in Colombia, government intervention has significantly marked the evolution of the gasoline price throughout history; with the measures taken by the government, there have been several objectives such as facing inflation, improving the income of the producer to guarantee its development and duration in the market, stimulate competitiveness, among others[481].

According to the nation's finance chief, the most recent comment on the current situation suggests that Colombia needs to carefully reduce fuel subsidies to lower the fiscal deficit without exacerbating its inflation problem. Jose Antonio Ocampo estimates that subsidies on gasoline and diesel given through state-owned oil company Ecopetrol will cost public coffers about 2.5% of gross domestic product this year and 2.1% in 2023[482].

While government interventions will be reviewed more carefully later in this chapter, one can say that based on all of the above, the relationship between pump price and consumption in Colombia departs from the general cross-national trend.

5.4.4.1.1. FACTORS IMPACTING PUMP PRICES

5.4.4.1.1.1. CRUDE OIL PRICES

Even though crude oil is a commodity, the Colombian market might not react to external fluctuations because of government interventions. Notably, one can see that the changes in crude oil prices in 2012 did not impact FF consumption per capita. Furthermore, the pump price in 2012 decreased by $0.13 (9%) compared to the previous year.

5.4.4.1.1.2. REFINING

The oil and gas sector is critical for Colombia's national revenue. Although private foreign investment is allowed, all the country's refineries are 100 percent owned and operated by the

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[480] U.S. Energy Information Administrattion. Colombia Executive Summary. (2022). Retrieved from: https://www.eia.gov/international/analysis/country/COL

[481] ANALYSIS OF THE GASOLINE PRICE IN COLOMBIA. Dyna rev.fac.nac.minas vol.77 no.163 Medellín July/Sept. 2010. Retrieved from: http://www.scielo.org.co/scielo.php?script=sci_arttext&pid=S0012-73532010000300029

[482] Bloomberg. Colombia to Raise Fuel Prices With Eye on Inflation, Ocampo Says. Retrieved from: https://www.bloomberg.com/news/articles/2022-09-09/colombia-to-raise-fuel-prices-with-eye-on-inflation-ocampo-says#xj4y7vzkg

Colombia National Oil Company, Ecopetrol. The company also operates approximately 64 percent of the country's total oil and gas production. The remaining share is primarily made up of smaller independent producers, of which Canada-based Frontera Energy (formerly Pacific E&P), UK-based GeoPark Holdings, and U.S.-based Occidental Petroleum have the most share[483].

The domestic situation differs from the ones in Finland (where only one privately-owned refinery accommodates all local needs) and Canada (with numerous parties from upstream to downstream productions).

As of January 2021, Colombia had 378,600 b/d of crude oil refining capacity. Colombia's central oil blend is the Castilla Blend, a heavy and sour (high sulfur-1.97%) crude oil. In addition to output from the Castilla field, the blend includes crude oil from other heavy oil fields, such as the Rubiales and Quifa fields. Ecopetrol's refineries were initially built to process light, sweet crude oil from Cusiana and Cupaigua. Colombia's increasingly heavy crude oil production has challenged the refining and midstream sectors.

Colombia has two large refineries, the Barrancabermeja refinery and Cartagena (Reficar) refinery, both operated by Ecopetrol. In addition, Ecopetrol's subsidiaries and independent refiners operate smaller units. In 2016, the Reficar refinery was modernized to allow the facility to run heavy and sour crude oil feedstock, which is more dominant domestically. In 2021, Ecopetrol announced plans to upgrade and expand Reficar further, investing $180 million. According to Ecopetrol, capacity is expected to grow from 165,000 b/d to 200,000 b/d[484].

Refined product demand declined by 20% to 282,000 b/d in 2020. The COVID-19 pandemic national quarantine measures that restricted travel also decreased refined fuel consumption. Gasoline and fuel oil demand typically account for over 70% of all refined petroleum products consumption in Colombia. Consumption of refined products rebounded to 328,000 b/d in 2021 as travel restrictions and quarantine measures were lifted[485].

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[483] International Trade Administration. Oil and Gas Exploration and Production Equipment. Colombia Commercial Guide. Retrieved from: https://www.trade.gov/country-commercial-guides/colombia-oil-and-gas-exploration-and-production-equipment

[484] U.S. Energy Information Administrattion. Colombia Executive Summary. (2022). Retrieved from: https://www.eia.gov/international/analysis/country/COL

[485] U.S. Energy Information Administrattion. Colombia Executive Summary. (2022). Retrieved from: https://www.eia.gov/international/analysis/country/COL

The country has to import some petroleum because local refineries cannot meet local needs in full. However, it remains a net exporter. In 2020, Colombia imported $1.95B in refined petroleum, becoming the world's 51st largest importer of Refined Petroleum. In the same year, refined petroleum was Colombia's 2nd most imported product. Colombia imports refined petroleum primarily from the United States ($1.77B), the United Kingdom ($74.4M), Brazil ($15M), South Korea ($12.1M), and Peru ($9.29M)[486].

5.4.4.1.1.3. TRANSPORTATION AND MARKETING

Colombia has 6,134 kilometers of oil pipelines and 3,140 kilometers of refined-products pipelines. The country has five major oil pipelines, four connecting with the Caribbean export terminal at Puerto Coveñas.

Around 50 supply facilities currently manage 17 wholesale distributors, where TERPEL has the largest market share, holding 40.8% of the total sales volume. In addition, the country has a retail distributor network comprising approximately 5,570 gas stations. Fuels are transported by tanker trucks to gas stations or major institutional consumers (industries, airports, transportation companies, etc.)[487] Among the main fuel companies are Terpel, Biomax, Petromil, Primax, ExxonMobil DE COLOMBIA, ENERGIZER AVIACION, and others. [488] In 2021, Distracom S.A. was the leading automotive fuel retail company in Colombia, with a revenue of over 2.2 trillion Colombian pesos. The company, headquartered in Medellín, specializes in liquid fuels, natural gas, and lubricants. Masser S.A.S ranked second, reaching 1.3 trillion pesos worth of revenue[489].

Under Article 3 of Decree 1073 of 2015, the National Government has reassigned some functions from the Ministry of Mines and Energy to the Energy and Gas Regulatory Commission, including regulating liquid fuel transportation operations.[490]

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[486] OEC. Refined Petroleum in Colombia. Retrieved from: https://oec.world/en/profile/bilateral-product/refined-petroleum/reporter/col
[487] Colombia Fuel. Retrieved from: https://dlca.logcluster.org/display/public/DLCA/3.1+Colombia+Fuel
[488] Colombia Fuel. Retrieved from: https://dlca.logcluster.org/display/public/DLCA/3.1+Colombia+Fuel
[489] Leading automotive fuel retailers in Colombia in 2021, by revenue. Retrieved from: https://www.statista.com/statistics/1074812/colombia-automotive-fuel-retailers/
[490] Colombia Fuel. Retrieved from: https://dlca.logcluster.org/display/public/DLCA/3.1+Colombia+Fuel

In all cases, the lighting change resulted in energy savings and a significant improvement in lighting. Clean energies guarantee the sector's sustainability, from the environmental to the economic sphere[491].

Colombia’s pipeline capacity is expected to remain stagnant during the forecast period due to no new investment proposal being made in the pipeline sector. Also, continuous attacks on pipelines by the rebels make them a risky investment[492].

Shell is again in the fuel market through Biomax SA, a wholesale distributor of petroleum derivatives with the brand's license to distribute its fuel in Colombia. During the next few days, the operation of the first three Shell-branded service stations will begin, which will be located in Bogotá. The entry of this representative player in the sector, whose long-term goal is to have 250 additional stations nationwide, represents a unique opportunity for local consumers around one of the most advanced fuel portfolios in the world[493].

5.4.4.1.2. DOMESTIC POLICY ON GASOLINE USE AND TAXATION

A "Controlled Freedom” system is in place for the fuel market in Colombia. The above implies that the Government, through the Ministry of Mines and Energy, sets the current fuel price by means of a decree/resolution. Distributors and gas stations set their prices without exceeding the price set by the Government. The average gas or diesel oil price per gallon is calculated by adding the producer's income, biodiesel, national tax, territorial tax, distribution margin, and transportation costs. Each one of these items, represented in different percentages, adds up to the total fuel price. Also, per available information, there are no national priorities for fuel availability, and fuel is not subsidized for low-income/vulnerable people[494].

For quite some time, Ecopetrol was obliged to finance the fuel subsidies. In 2003, the status of Ecopetrol changed from being a state company to a mixed company with public and

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[491] GAS STATIONS IN COLOMBIA. Retrieved from: https://www.goodworkint.com/en/proyecto/gas-stations-colombia/

[492] Colombia Oil & Gas Midstream Market Size. Retrieved from: https://www.mordorintelligence.com/industry-reports/colombia-oil-and-gas-midstream-market

[493] Shell returns to the Colombian fuel market. (2022). Retrieved from: https://www.bnamericas.com/en/news/shell-returns-to-the-colombian-fuel-market

[494] Colombia to reform fuel pricing, encourage imports. (2020).https://www.argusmedia.com/en/news/2161305-colombia-to-reform-fuel-pricing-encourage-imports

private investors. Financing the fuel subsidy was no longer desirable since the company needed financial autonomy to expand its operations (i.e., exploration and refineries) and increase its competitiveness. This new situation and the high subsidy costs led the government to announce its gradual elimination. The gasoline subsidy would be eliminated over one year and the diesel subsidy over three years, causing a 20% price increase (holding everything else constant). However, the plan was delayed due to political pressures. The problem was that in addition to the fuel price increase caused by the subsidy elimination, increasing oil prices and the appreciation of the Colombian peso also pushed the price upwards. Ultimately, Ecopetrol funded the subsidy until 2007, when it began looking for private capital to fund its exploration and exploitation activities, leading its board to demand more transparent accounting. Since then, Ecopetrol has paid total dividends to the government, which has funded the subsidy through its Fuel Price Stabilisation Fund (FEPC).

In 2008, the spike in international oil prices forced the government to disburse as much as EUR 2 063 million (1% of GDP) to finance the fuel subsidy. In 2010, FEPC resources were exhausted, not only as a consequence of high international prices but also because the MME did not take proper mitigating actions. Gasoline and diesel prices were frozen for seven months in 2009 and six months in 2010, entailing fiscal costs of EUR 20.7 million per month. Yet the FEPC cannot function if consumer prices do not fluctuate to compensate for international price variations[495].

To avoid a re-occurrence of these situations, new formulas to calculate producer income regarding gasoline and diesel were implemented in November 2011 and November 2012. In January 2013, a fiscal reform changed the tax structure for gasoline and diesel. Value-added tax (VAT) and global tax were merged as a single excise tax (fuel tax) of EUR 0.44 per gallon. This measure reduced consumer prices by 2.3% for gasoline and 0.45% for diesel, reducing the space for discretionary price setting by the MME. Before the fiscal reform, the Ministry determined the

[495] OECD ILibrary. The Political Economy of Fuel Subsidies in Colombia. Retrieved from: https://www.oecd-ilibrary.org/docserver/5k3twr8v5428-en.pdf?expires=1677511288&id=id&accname=ocid194310&checksum=38DA4B2C2063FA69D6FE6312634F1293

tax base for VAT on diesel and gasoline every month, using it to control prices. Instead of a 16% tax according to the value, the tax was effectively 9% for gasoline and 8% for diesel[496].

Thus, fuel prices in Colombia have always been regulated by the Ministry for Mining and Energy (MME), which determines monthly prices for diesel and gasoline[497].

As of 1 July 2018, the central taxes on energy use in Colombia were the following:

• The National Gasoline Tax (Impuesto Nacional a la Gasolina) applies to gasoline, diesel, and all other liquid motor fuels used in vehicles and stationary combustion engines. The tax is adjusted annually for inflation.

• The Surcharge on Gasoline and Diesel (Aceite Combustible Para Motores – Sobretasa a la Gasolina y al ACPM) applies to the same fuels subject to the National Gasoline Tax.

• The National Carbon Tax (Impuesto Nacional al Carbono) is set to a nominal rate of COP 15764 (~EUR 5) per tonne of CO2, adjusted annually to inflation plus one percentage point. The tax applies to liquid and gaseous fossil fuels used as propellants, stationary combustion engines, or heating fuels. It does not apply to coal, other solid fossil fuels, or natural gas unless used by refineries or in the petrochemical industry. Emitters can meet their carbon tax liability by using offset credits generated from domestic projects.

Colombia has no emissions trading system for CO2 emissions from energy use.[498]

Tax rates can differ across energy products and users. Energy and carbon taxes apply to different energy categories across the economy. They are based on the six economic sectors: road, off-road, Industry, agriculture and fisheries, residential and commercial, and electricity[499].

Recently, reforms were suggested to shift wholesale motor fuel pricing from export to import parity to reflect the growing domestic market imbalance, particularly in gasoline. In line

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[496] OECD ILibrary. The Political Economy of Fuel Subsidies in Colombia. Retrieved from: https://www.oecd-ilibrary.org/docserver/5k3twr8v5428-en.pdf?expires=1677511288&id=id&accname=ocid194310&checksum=38DA4B2C2063FA69D6FE6312634F1293

[497] OECD ILibrary. The Political Economy of Fuel Subsidies in Colombia. Retrieved from: https://www.oecd-ilibrary.org/docserver/5k3twr8v5428-en.pdf?expires=1677442863&id=id&accname=ocid194310&checksum=B1E8BC90F687D34A9F9250F101566E07

[498] OECD Library. Taxing Energy Use 2019: Country Note – Colombia. Retrieved from: https://www.oecd.org/tax/tax-policy/taxing-energy-use-colombia.pdf

[499] OECD Library. Taxing Energy Use 2019: Country Note – Colombia. Retrieved from: https://www.oecd.org/tax/tax-policy/taxing-energy-use-colombia.pdf

with other Latin American countries, gasoline and diesel prices would move within a band designed to mitigate market volatility through an existing government-run fuel subsidy fund[500].

Colombia oil companies will pay as much as 85% of their revenue in levies from the current 65%, following the recently approved tax reform, which includes: Royalties are non-deductible; surcharge on the oil sector is calculated, so companies pay an additional 15%, Companies will also pay a dividends tax. Not yet clear how the government will substitute oil income as it transitions away from fossil fuels.[501]

For obvious reasons, fuel subsidies are inefficient and environmentally harmful. However, their use is widespread. Colombia has provided explicit and implicit subsidies to gasoline and diesel since 1983, costing the government up to 1.6% of GDP[502]. Public opinion holds a very dim view of increases in fuel prices. Colombians do not understand why the country, despite its oil producer and exporter status, has the highest gasoline prices in Latin America, behind Uruguay, Brazil, and Chile. Their obvious points of comparison are Venezuela and Ecuador, two countries with meager fuel prices and high government subsidies. The public rejects price increases, and there is debate about whether fuel subsidies exist. Since the subsidies are no longer explicit[503]

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[500] Colombia to reform fuel pricing, encourage imports. (2020). Retrieved from: https://www.argusmedia.com/en/news/2161305-colombia-to-reform-fuel-pricing-encourage-imports

[501] Colombia Oil Companies to Pay 85% in Taxes After Reform: Group. Andrea Jaramillo. Retrieved from: https://news.bloombergtax.com/daily-tax-report-international/colombia-oil-companies-to-pay-85-in-taxes-after-reform-group

[502] OECD ILibrary. The Political Economy of Fuel Subsidies in Colombia. Retrieved from: https://www.oecd-ilibrary.org/docserver/5k3twr8v5428-en.pdf?expires=1677442863&id=id&accname=ocid194310&checksum=B1E8BC90F687D34A9F9250F101566E07

[503] OECD ILibrary. The Political Economy of Fuel Subsidies in Colombia. Retrieved from: https://www.oecd-ilibrary.org/docserver/5k3twr8v5428-en.pdf?expires=1677442863&id=id&accname=ocid194310&checksum=B1E8BC90F687D34A9F9250F101566E07

5.4.4.2. URBANIZATION AND FOSSIL FUELS CONSUMPTION PER CAPITA

Table 11. Energy Sustainability Approaches in three most populated cities

	City	Population	C40 or other collaborations	Low-carbon programs
1	Bogotá (Colombia)	8 mln	C40 yes	Yes, but the process is slow. Low support of the population due to high levels of poverty.
2	Medellín (Colombia)	2.6 mln	C40 yes	The process is slow due to economic challenges and a lack of regional cooperation.
3	Soledad (Colombia)	666,247	C40 no, others – no evidence found	No evidence was found.

Bogota, the capital of Colombia, recently adopted Climate Action Plan to reduce greenhouse gas emissions by 15% in 2024 and 50% in 2030 and to reach carbon neutrality by 2050[504]. Meanwhile, the city tries to be realistic about its goals regarding lowering CO2 in the air. Every day more than 67,000 delivery trucks and vans clog the streets of Bogotá, contributing to the city's traffic congestion and emitting 850,000 tonnes of CO2 and over 700 tonnes of PM2.5 per year. More than 70% of the vehicles belong to small fleet owners, many operate under informal conditions, and 40% are empty trips at any time. Bogota is looking for proposals to increase these operations' efficiency to reduce congestion and emissions[505].

In Bogota, transport accounts for nearly half of all greenhouse gas emissions. To slash those, officials are expanding bike lanes and pedestrian paths, using more electric buses, and extending the reach of electric cable cars - some partly driven by renewable solar power - that serve poor areas in the city’s south. Greening transport remains one of Bogota’s most significant

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[504] Climate Smart Cities Challange. Bogota. Retrieved from: https://climatesmart.citieschallenge.org/bogota/#:~:text=What%20do%20we%20hope%20to,reach%20carbon%20neutrality%20by%202050

[505] Climate Smart Cities Challange. Bogota. Retrieved from: https://climatesmart.citieschallenge.org/bogota/#:~:text=What%20do%20we%20hope%20to,reach%20carbon%20neutrality%20by%202050

challenges to net-zero emissions. Fossil fuel-powered cars, buses, and cargo trucks - some belching black clouds of smoke - emit a substantial share of the 14,000 tonnes of carbon dioxide entering Bogota's atmosphere daily. With no nationwide railway system, goods and food are mainly transported by trucks traversing Colombia's high Andean mountains. But efforts to get truck drivers and private bus companies to switch to lower-carbon energy always spark a "heated debate."[506]

Numerous attempts by previous mayors to rid Bogota of old polluting buses have met with strikes and street protests by bus and driver groups - and ultimately, city hall has backed down. Now, officials are providing incentives to eliminate old polluting buses, with the city sometimes buying them. Bogota now has about 350 electric buses circulating, used by about 180,000 people daily. It plans to roll out 1,485 buses by 2022, making it the largest city fleet outside China. The city's electric bus fleet reduces emissions equivalent to taking 42,000 cars off the road each year[507]. In recent weeks, however, Bogota and cities across Colombia have struggled with violent street protests over concerns about rising inequality and poverty sparked by a proposed tax change by Colombia's president. That reform, now canceled, includes tax breaks and incentives for businesses looking to turn to clean energy[508].

The City of Medellín has an exciting story. About 30 years ago, Medellin was considered one of the most dangerous cities in the world. Drug cartels reigned, homicides and explosions were commonplace, and only the foolish strolled the streets at night. Through smart investments in poor communities, transportation infrastructure, schools, technology, and public parks, the city has transformed into a model of urban planning and innovation, garnering international recognition for its entrepreneurialism and modernity. Given the current economic conditions, Medellin's ambitions for a low-carbon future are high. The government's ambitious plans are to

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[506] Reuters. Bogota crowdsources a green transport future to cut emissions. Anastasia Moloney. Retrieved from: https://www.reuters.com/article/us-colombia-climate-change-transportatio/bogota-crowdsources-a-green-transport-future-to-cut-emissions-idUSKCN2D7203

[507] Reuters. Bogota crowdsources a green transport future to cut emissions. Anastasia Moloney. Retrieved from: https://www.reuters.com/article/us-colombia-climate-change-transportatio/bogota-crowdsources-a-green-transport-future-to-cut-emissions-idUSKCN2D7203

[508] Reuters. Bogota crowdsources a green transport future to cut emissions. Anastasia Moloney. Retrieved from: https://www.reuters.com/article/us-colombia-climate-change-transportatio/bogota-crowdsources-a-green-transport-future-to-cut-emissions-idUSKCN2D7203

cut carbon emissions by 20 percent, electrify all public transport by 2030, expand bike lanes by 50 percent, and double the number of public transport lines. Medellin's bike lanes are one of its initiatives to help the city become Latin America's first 'eco-city.' Medellin already has an advantage with Colombia's only metro system, bike lanes, a fleet of electric buses, and its "green corridors" network of urban greenery that line congested streets[509].

While Medellin has to face a lack of cooperation among neighboring municipalities in the region, international support, like C40 collaboration, might help the city to overcome difficulties on its way to creating a low-carbon environment[510].

While there is not much information on Soledad's energy efficiency programs, one of the studies that analyzed ten Colombian cities says that Soledad included climate adaptation in its political agenda and elaborated detailed measures[511]. However, no evidence was found that this statement is true or that the city implements effective programs related to energy efficiency.

5.5. CONCLUSION

The above analysis of the three case studies clearly illustrated that studying local specifics could explain why some countries fit the Model better than others. Finland, for instance, imports all of its fossil fuels for domestic consumption, which, in a way, makes consumers value it more. To some extent, this explains the country's intention to become carbon-neutral in almost one decade. Finland's doors are wide open for investments in renewable energy.

Finland's petrol prices are the 5th highest in the European Union, encouraging final consumers to seek alternatives to conventional sources for commuting and energy. Also, refining is conducted by just one company, which eliminates competition rules on the domestic market and, thus, leads to higher pump prices and lower purchasing ability of a final consumer.

All mentioned above makes Finland's approach of consuming fossil fuels per capita almost an ideal candidate to fit the Model.

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[509] Aljazeera. Medellin strives to become Latin America's first 'eco-city'. (2021). Genevieve Glatsky. Retrieved from: https://www.aljazeera.com/news/2021/8/31/medellin-strives-to-become-latin-americas-first-eco

[510] Aljazeera. Medellin strives to become Latin America's first 'eco-city'. (2021). Genevieve Glatsky. Retrieved from: https://www.aljazeera.com/news/2021/8/31/medellin-strives-to-become-latin-americas-first-eco

[511] PressBooks. Florian Koch, Helmholtz Centre for Environmental Research UFZ, Germany. Retrieved from: https://pressbooks.pub/isscbookofblogs/chapter/climate-adaptation-vs-urban-politics-some-evidence-from-colombian-cities/

Canada's local situation concerning fossil fuel consumption per capita differs from Finland's. Firstly, because the country is a net exporter, imported fossil fuels, mainly crude oil, are less valued by a final consumer. Furthermore, the Canadian market among miners, refiners, and distributors is high. This creates a situation when abundance among competitors does not allow suppliers to neglect cost reduction efforts, which then positively impacts a final gasoline consumer at a pump by enabling them to consume more due to a lower price. All mentioned above explains why Canada does not fit the Model well, despite significant efforts of urbanized communities to pursue energy efficiency.

Colombian government interventions regarding pump prices prevent the country from fitting the Model. The country has been subsidizing gasoline consumption nationwide for decades. This created a situation when market rules could not balance the final prices based on demand and supply. After being `spoiled` by low gasoline prices, the Colombian population does not welcome new initiatives promoting a gradual shift from the highly regulated environment to the one regulated by supply and demand. This makes Colombia almost an outlier in my Model.

CHAPTER 6

SUMMARY

The War in Ukraine demonstrated how vulnerable the World is regarding energy use, particularly fossil fuels. One would ask why an invasion across the ocean impacts gasoline pump prices in the United States and Worldwide. In 1983, crude oil futures joined the New York Mercantile Exchange (NYMEX) to be traded like other commodities[512]. Since then, crude oil has been a subject of the international commodities market regulated by the rule of supply and demand. Thus, any fluctuation related to its' availability or price would impact the rest of the World. For example, the slightest conflict on the Strait of Hormuz would affect the USA, even though the country does not heavily rely upon ME oil, as most of its crude oil comes from Canada (over 50% of imports in 2020[513]).

Unlike in the case of oil, matters related to natural gas tend to have regional consequences. Europe's vulnerability and evident dependence on Russia is a good example. It is not a secret that the country is an important actor, especially when it comes to 'petro-carrots' (using oil and gas to reward allies) and 'petro-sticks' (using resources to punish states which defy the Kremlin). States like Georgia, Ukraine, and the Baltic States have been `punished` with supply interruptions and higher prices after their governments turned toward the West. Conversely, those who remained friendly to the Kremlin—such as Armenia, Belorussia, Ukraine before 2005, and the tiny statelets of Abkhazia, North Ossetia, and Trans-Dniestria—have been granted ample oil and gas at subsidized prices[514].

In addition to the above circumstances, several other reasons explain the importance of studying fossil fuel consumption in particular. First, natural resources like oil, gas, and coal are limited. Thus, one should be careful about using them. Second, the extensive use of fossil fuels

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[512] Oil and Gas Pricing. Library of Congress. https://guides.loc.gov/oil-and-gas-industry/pricing#:~:text=In%201983%2C%20crude%20oil%20futures,was%20traded%20like%20other%20commodities

[513] How much petroleum does the United States import and export? U.S. Energy Information Administration. https://www.eia.gov/tools/faqs/faq.php?id=727&t=6

[514] Randall Newnham, Oil, carrots, and sticks: Russia's energy resources as a foreign policy tool, Journal of Eurasian Studies, Volume 2, Issue 2,
2011, Pages 134-143, ISSN 1879-3665, https://doi.org/10.1016/j.euras.2011.03.004.
https://www.sciencedirect.com/science/article/pii/S187936651100011X

harms our surroundings, creating many environmental concerns, including global warming, air pollution, and high carbon dioxide (CO2) production. There is a growing consensus based on compelling evidence that the World faces a climate crisis, and rapid action to reduce greenhouse gas emissions is necessary. It is now clear that reducing consumption will be essential as part of the global effort to mitigate climate change[515]. Third, improving energy efficiency brings numerous economic benefits.

Additionally, the World's Energy Use (kg of oil equivalent per capita) increased from 1,336 in 1971 to 1,921 in 2014, meaning that every human (on average) has been using more energy since 1971[516]. An increasing consumption per capita means that a reliance on energy by one individual has been elevated. The available data on World's Fossil Fuel Consumption per capita has shown an upward trend since 1965. World's Fossil Fuel Consumption per capita has steadily increased from 12,116 Twh in 1965 to 17,197 Twh in 2021. And the upward trend is expected to continue. At the same time, the World's trend is not consistent among individual countries. It means that countries with the increasing trend might learn some practices from countries experiencing the opposite trend.

While newer resources are being developed, wind, solar, and bio are considered the most common non-conventional energy sources. Despite the significant benefit of being renewable, non-conventional sources are associated with a high cost of harnessing energy, availability uncertainty, and transportation difficulty. The use of renewable energy, including non-conventional ones, has not increased in relative terms. Energy consumption rises faster than renewable energy generation can catch up.

Thus, despite the prospect of having access to fossil fuels for at least the next several decades, it is about time to think about fossil fuels use due to the limitations mentioned above.

My research is about how some variables shape global fossil fuel consumption. The core question of my research is, `Why do some countries consume less fossil fuels per capita than others?` The currently available literature determines the relevance of my research.

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[515] https://c40-production-images.s3.amazonaws.com/other_uploads/images/2270_C40_CBE_MainReport_250719.original.pdf?1564075036

[516] The World Bank Data. https://data.worldbank.org/

I use a multivariate framework to answer the central question, including three independent and two control variables. Pump price for gasoline, Urbanization, and Fossil Fuel Imports. In the World of interconnectedness, numerous biases can be escaped while conducting research. That is why to prevent certain variables from influencing the outcome of a study, I chose to control for Latitude and GDP per capita.

My research is built upon three Hypotheses:

1. In a comparison of countries, higher pump prices are associated with a decrease in Fossil Fuels Consumption per Capita compared to those with lower pump prices;

2. In a comparison of countries, a greater urban percentage of the population is associated with a decrease in Fossil Fuels Consumption per Capita compared to those with a less urbanized population;

3. In a comparison of countries, higher fuel imports are associated with a decrease in Fossil Fuels Consumption per Capita compared to those with lower fuel imports.

To conduct the research, I use a mixed-method approach. This research design has become popular lately because of combining qualitative and quantitative data. The mixed-method approach allows one to understand a given topic better. It also adds value by increasing the validity of the findings and assisting with knowledge creation[517].

The quantitative method tests the relationships between FFCC and the Independent variables. As a basis, I use a sample of 28 OECD counties to design and test a model for 2009-2018 (The Model). Thus, the sample has two hundred and eighty observations. Data used in this Model will come from two online databases available for free use: World Bank and British Petroleum.

The output of the multiple regression analysis shows that the Model explains 40% of the variance in the Dependent Variable and leaves the rest unexplained. P-values for all variables are less than 0.05. It means that test results are statistically significant, and Null Hypothesis can be rejected for the entire population.

[517] Hurmerinta-Peltomaki L., Nummela N. (2006). Mixed methods in international business research: A value-added perspective. Management International Review, 46, 439-459.

Coefficients outcomes indicate that for every additional percent of fuel imports in merchandise, one can expect FFCC to increase by 0.06 million tonnes of oil equivalent per capita; for every additional dollar increase of pump price for gasoline per liter, one can expect FFCC to decrease by -1.33 million tonnes of oil equivalent per capita; for every additional $1000 increase in GDP, one can expect FFCC to increase by 0.03 million tonnes of oil equivalent per capita; for every additional percent increase of Urban population in the total population, one can expect FFCC to increase by 0.03 million tonnes of oil equivalent per capita. For every additional unit increase in Latitude, one can expect FFCC to increase by 0.01 million tonnes of oil equivalent per capita.

The Pump Price coefficient result supports H1. Because the Pump Price coefficient is closer to 1 than other coefficients, H1 has a greater validity or, in other words - reliability. With various energy sustainability approaches in modern cities, especially in countries of higher economic development, I expected the Model to support Hypotheses #2 (H2). To my surprise, the regression results do not support H2. Hypothesis #3 (H3) is not supported by the regression results either. I expected higher fuel imports would be associated with decreased FFCC. Instead, the above outcome is the opposite.

To gain a more in-depth understanding of FFCC across countries through studying local specifics, I use a qualitative method to review three case studies (Finland, Canada, and Colombia). This would help explain why the Model fits well in some instances and not in other cases.

The qualitative analysis of the three case studies clearly illustrated that studying local specifics could explain why some countries fit the Model better than others. Finland, for instance, imports all of its fossil fuels for domestic consumption, which, in a way, makes consumers value it more. To some extent, this explains the country's intention to become carbon-neutral in almost one decade. Finland's doors are wide open for investments in renewable energy.

Finland's petrol prices are the 5th highest in the European Union, encouraging final consumers to seek alternatives to conventional sources for commuting and energy. Also, refining is conducted by just one company, which eliminates competition rules on the domestic market and, thus, leads to higher pump prices and lower purchasing ability of a final consumer. Such local conditions make Finland's approach to consuming fossil fuels per capita almost an ideal candidate to fit the Model.

Canada's local situation concerning fossil fuel consumption per capita differs from Finland's. Firstly, because the country is a net exporter, imported fossil fuels, mainly crude oil, are less valued by a final consumer. Furthermore, the Canadian market among miners, refiners, and distributors is high. This creates a situation when abundance among competitors does not allow suppliers to neglect cost reduction efforts, which then positively impacts a final gasoline consumer at a pump by enabling them to consume more due to a lower price. All mentioned above explains why Canada does not fit the Model well, despite significant efforts of urbanized communities to pursue energy efficiency.

Colombian government interventions regarding pump prices prevent the country from fitting the Model. The country has been subsidizing gasoline consumption nationwide for decades. This created a situation when market rules could not balance the final prices based on demand and supply. After being `spoiled` by low gasoline prices, the Colombian population does not welcome new initiatives promoting a gradual shift from the highly regulated environment to the one regulated by supply and demand. This makes Colombia an apparent outlier in my Model.

My research has several boundaries and limitations:

- The researched population represents OECD countries only;
- Quantitative data for some countries is not available, which impacts the population size of the Model;
- The study includes only three groups of variables, which means that some factors are not considered. On a positive note, two additional variables are controlled for;
- Unintended consequences and butterfly effects are impossible to take into account. Thus, when applying this study to a particular country, one should also consider local specifics;
- My work does not consider potential oil shocks. However, based on the experience of the 1970 Oil Embargo and the ongoing war in Ukraine, oil shocks are expected to impact increased global crude oil prices;

- The Model tests the pre-existing statistical data from different sources, which increases the odds of pulling insufficient data;
- My research does not consider an energy efficiency gap, which potentially exists due to individuals' lack of efficiency measures despite the current technological advancements;
- Despite my expectation, there is much greater diversity among OECD countries in terms of the variables used in my study;
- Urbanization rate does not take into account the density of the population.

Given the mentioned limitations, one should consider taking into account the below *recommendations* when researching fossil fuels consumption per capita in the future:

1. As the qualitative part of my research illustrated, considering local specifics is crucial. For example, Canada might not be a good candidate to be included in a sample when exploring H3 because it is still a net fossil fuels exporter despite importing a significant amount. Or in the case of Colombia, which did not fit the Model well, mainly due to governmental interventions regarding pump prices by subsidizing gasoline consumption nationwide for decades.
2. Help to develop a worldwide database containing information on energy-relayed taxation. This would allow to modify my model and expand the researched population beyond OECD countries.
3. Promote reporting related to energy among countries to ensure quantitative data availability. An improved data collection process would allow modifying a population and expanding researched samples.
4. Utilize a mixed-method approach. This research design combines qualitative and quantitative data analysis. The mixed-method approach allows one to understand a given topic better.

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VITA

Mila was born and raised in Kyiv, Ukraine, a city of over five million, but with family ties to the rural agricultural area. Like most Ukrainians, her family is close, possesses a strong work ethic, and values a broad-based education.

Mila planned to become an interpreter with the ability to acquire proficiency in four languages. However, after becoming more practical about the future, she chose financial management. Eventually, financial institutions are not only numbers but also creative thinking.

Mila began her professional career in the international finance area after one year of student life in Germany and graduation from a Ukrainian university. Her extensive career allowed her to use foreign languages and learn about international business practices.

After Mila's destiny brought her to the United States, she continued providing financial management services.

The Ukrainian events of 2014 (The Revolution of Dignity) and love to the Homeland encouraged Mila to create The Americans in Ukraine Foundation, which is devoted to strengthening relations between The United States and Ukraine through implementing educational and charitable projects.

Combining years of experience, Ukrainian heritage, and new life in the United States naturally brought Mila to pursue a Doctoral degree in the International Relations field.