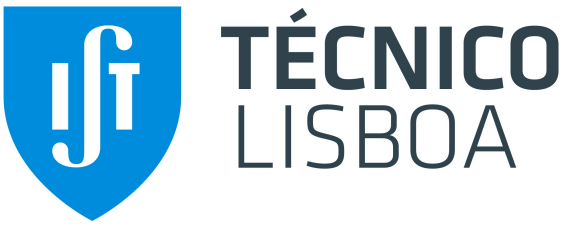

Instituto Superior Técnico

Energy and Sustainability

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Different geostrategies on the path to 100% renewability

Group 45

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i) Executive Summary

The project to be developed at the Energy and Sustainability course aims to develop an essay on a technology or a new strategy, which will contribute to tackle climate change, with the overall goal of achieving climate neutrality in 2050.

In response to the urgent need for sustainable energy solutions, this report meticulously examines the geostrategies implemented by the governments of Denmark, Norway, Iceland, Brazil, and Ukraine. Grounded in the shared commitment to the European Green Deal and the ambitious goal of achieving net-zero emissions by 2050, these nations navigate diverse pathways to address their unique challenges and contribute to global climate objectives. The European Green Deal serves as a guiding framework, propelling collaborative efforts and innovative solutions. As we delve into the energy policies of each country, it becomes apparent that while the overarching goal is shared, the approaches are nuanced, reflecting the distinctive contexts, resources, and priorities of each nation.

The report starts with an exploration of the renewable energies versus fossil fuels dynamics. Denmark stands out with a large portion of its electricity production sourced from wind energy. A detailed comparison of onshore and offshore wind farms unveils Denmark's pioneering role in wind energy development, showcasing both economic and technological advancements.

Norway, leveraging its hydropower resources, emphasizes sustainability in electrification strategies. A historical overview of Iceland's energy transition from fossil fuel dependence to geothermal prominence outlines the country's resilience and adaptability. Brazil's energy evolution, from early hydropower to the Proálcool Program and the Santos Basin discovery, underlines its diversified and evolving energy landscape. The report details Ukraine's current measures and projects aimed at achieving its net-zero target.

Then, the strategies implemented across the years by each country are discussed. A historical overview of Denmark's energy strategies reveals a trajectory marked by significant shifts. Initially focused on oil and natural gas development, Denmark strategically pivoted towards renewable energy, becoming a global leader in wind power. The economic strategies, energy policies, technological innovations, and geopolitical considerations surrounding Denmark's energy evolution are dissected to provide a comprehensive understanding of its contribution to climate neutrality. Norway's unique strategy involves the creation and development of the Government Pension Fund Global, emphasizing responsible investment practices and contributing to the global green finance landscape. Iceland's journey from fossil fuel dependence to geothermal prominence is detailed, encapsulating historical situations and current challenges, including the innovative use of geothermal energy for heating. Brazil's multifaceted energy policies, from hydropower and Petrobras to the Proálcool Program, Santos Basin, and current measures, underscore its diverse and evolving energy landscape. Attention is given to Brazil's efforts in balancing economic development, energy security, and environmental sustainability. The report then turns to Ukraine, examining its energy developments across history, emphasizing the impact of the war with Russia, and the legacy of the Chernobyl incident. Geopolitical considerations are woven into the narrative, illuminating the challenges and resilience of Ukraine in the pursuit of sustainable energy.

A critical analysis of each country's contributions to climate neutrality underscores the significance of their geostrategies. Denmark's wind energy leadership, Norway's responsible investment practices, Iceland's geothermal advancements, Brazil's diversified energy portfolio, and Ukraine's resilience among geopolitical challenges collectively contribute to the global effort for climate neutrality.

However, this report also addresses challenges encountered by each nation, acknowledging that the journey to sustainability is fraught with complexities. Whether it's navigating geopolitical tensions, technological hurdles, or the need for continuous policy adjustments, these challenges shape the trajectory of their energy transitions.

The examined countries showcase diverse approaches to energy transition, reflecting a mix of geographical, technological, and geopolitical considerations. The shift towards renewables aligns with the global imperative to combat climate change and achieve net-zero emissions. While Denmark and Norway lead the way with ambitious renewable energy targets, Iceland, Brazil, and Ukraine navigate distinct challenges, demonstrating the complexity of implementing geostrategies within the realm of energy policy. The global transition to a sustainable energy future demands continued innovation, cooperation, and adaptation to ensure a resilient and low-carbon future.

ii) Index

1 Introduction

1.1 Motivation and goals

Climate change and environmental degradation are an existential threat to Europe and the world. To overcome these challenges, the European Green Deal will transform the EU into a modern, resource-efficient and competitive economy, ensuring,[40]:

- No net emissions of greenhouse gases by 2050;
- Economic growth decoupled from resource use;
- No person and no place left behind;

The above topics are the basis principles of the green deal and our purpose of writing this report is to study some technologies and measurements that help our society to achieve that ambitious target, analyzing some scientific documents of initiatives already implemented and criticise them.

The theme of this report is ”Different geostrategies on the path to 100% renewability”. Depending on the country geographic context, its natural resources and climatic conditions, over the years there have been different ways of converting primary energy to energy services, for example the light that makes this report possible to write. So our goal with this project is to identify interesting measures and strategies that different societies adopted over the years to convert energy into the daily needs services. Some ideas are great to the 100% renewability path, others represent a negative development and our role is criticise them. What make them such good ideas or don't.

Renewable Energies vs Fossil Fuel

Before starting this project it is important to study the current outlook of the world dependency on fossil fuels, renewable energies and nuclear energy.

The following figure 1, illustrated in the article [6], represents exactly that, the share of electricity production sources by country in 2022.

It can be visualize that, in the world, 61% belongs to fossil fuel, 9.2% to nuclear energy and only 30% to renewable energies. Important to note that are various stages on the path to achieve climate neutrality. For example,in one hand we have places like Saudi Arabia that show 100% dependency on fossil fuels and in the other hand, Norway and Iceland are the perfect examples with 99% and 100 % dependency on renewable energies, respectively.

The actual 61% value of the world´s fossil fuel dependency symbolises how ambitious the net zero target in 2050 is.

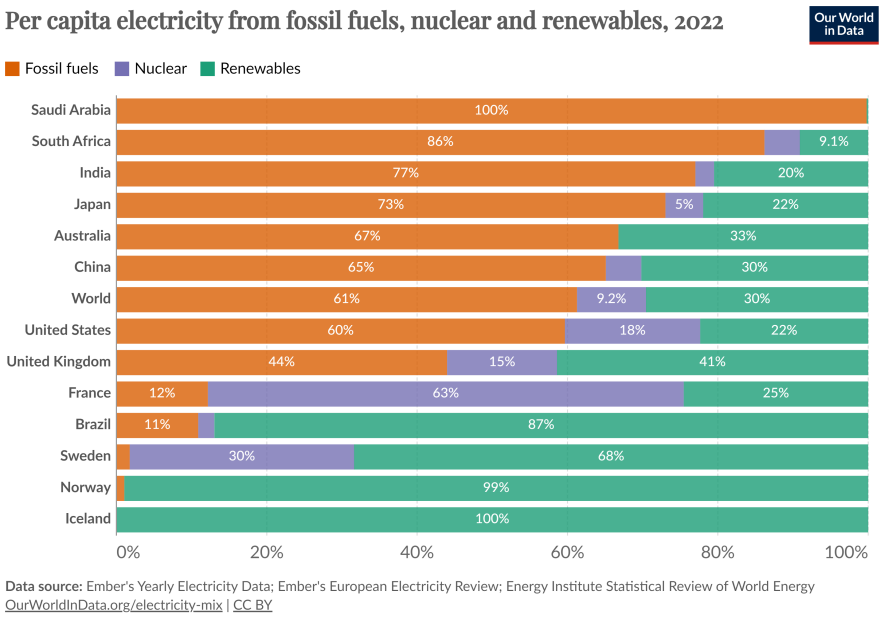

Figure 1: Source of electricity production

Renewable Energy Development

Despite the current outlook of the world's fossil fuel dependency, by looking at the figures below 2, illustrated in the article [7], we can see the positive development of energy sources like hydropower, wind, solar and some others. The latest data indicate that hydropower is by far the renewable energy source that produces more electricity, representing 50% of the total renewable electricity generation. There is an exponential growth in the production of electricity from solar and wind energy and by 2030, according to the International Energy Agency [34], it is expected they overtake hydropower in terms of electricity generation.

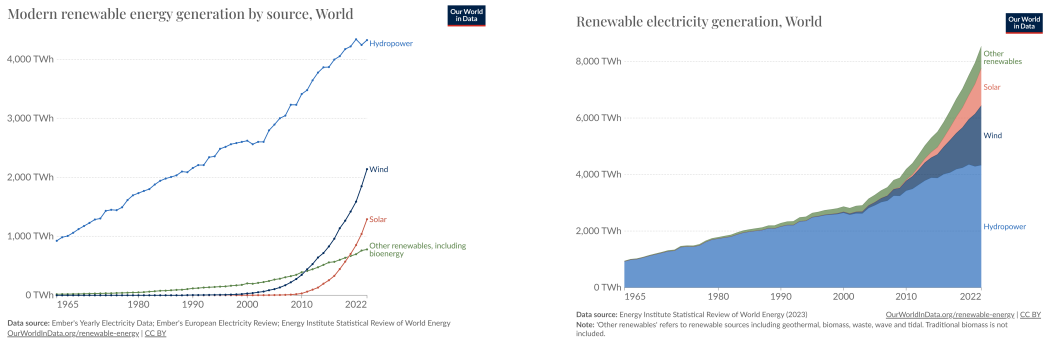

Figure 2: Renewable energies and electricity generation.

1.2 Technology/Strategy analyzed and its contribution to achieving climate neutrality

In the pursuit of global sustainability, the imperative to transition towards a 100% renewable world demands a nuanced understanding of the diverse geostrategies employed by nations worldwide. This section delves into the specific technologies and strategies adopted by selected countries - Denmark, Norway, Brazil, Iceland, and Ukraine — as case studies. Each of these nations presents a unique tapestry of challenges, opportunities, and innovative approaches that contribute significantly to the global discourse on achieving climate neutrality.

Denmark: Harnessing Wind Power Prowess

Denmark stands as a trailblazer in the realm of renewable energy, notably in its utilization of wind power. Analyzing Denmark's wind energy infrastructure reveals a comprehensive industry that has not only positioned the nation as a leader in this sector but has also set a compelling example for others aspiring to decarbonize their energy matrices.

Norway: Oil Wealth Transforming into Sustainable Investments

The Norwegian case unfolds a narrative of transformation, where a nation traditionally reliant on oil revenue has transitioned towards sustainable practices. The establishment of a sovereign wealth fund, fueled by oil revenues, serves as an example of leveraging non-renewable resources to fund renewable initiatives.

Iceland: From Fossil Dependency To Renewable Leadership

Iceland underwent a transformative journey, transitioning from economic hardship and heavy reliance on imported fossil fuels to emerge as a global leader in renewable energy practices. This case study explores key moments and initiatives that propelled Iceland towards sustainability.

Brazil: Navigating Energy Diversity

Brazil's rich history of energy production is explored through a dynamic energy balance analysis. The nation's journey from dependence on conventional sources to a diverse and renewable energy portfolio provides insights into the web of policies and technologies employed. Understanding Brazil's trajectory offers valuable lessons for other countries aiming to balance energy needs while prioritizing environmental concerns.

Ukraine: Navigating Energy Challenges

Ukraine's experience underlines the importance of adaptive strategies in the face of geopolitical and economic challenges. Examining Ukraine's energy policies in the context of adversity provides valuable insights into the resilience required for nations striving to achieve climate neutrality amidst external pressures.

In the subsequent sections, each case study will be dissected, examining the technological advancements, policy frameworks, and geopolitical considerations that have shaped these countries' journeys towards a sustainable,

renewable future. By comprehensively analyzing these geostrategies, this report aims to distil lessons and best practices that can inform global efforts towards achieving carbon neutrality.

1.3 Document organization/ structure

This report is organized to reflect the complexity of the global energy landscape and how different countries are working towards climate neutrality.

The structure is the following: Until you reach chapter 2, as it was readable, it was possible to find three pages of an introduction regarding a broad overview. This introduction compares renewable energies and fossil fuels globally and the challenges and opportunities on the world stage. Even more, a short summary of every country that was chosen was possible to be found. To finalise the introduction the energy report structure is defined in this section.

Reaching chapter 2, an analysis of five different countries is made throughout the following twenty pages. The study relies on initiatives that were made by Denmark, Norway, Iceland, Brazil and lastly Ukraine and their explanation.

In the final chapter it's expected a brief summary regarding some important conclusions on every case country that was studied.

2 Comparative analysis of the proposed technology in the context of alternative solutions

2.1 Denmark-Unveiling the Wind Power Prowess

The Scandinavian nation of Denmark boasts a renowned reputation in the energy industry, especially wind energy and respective technologies. Surrounded by the North Sea, the Jutland peninsula has an abundance of wind resources, some amount of Biomass available, and also some sources of oil and natural gas. This analysis will focus on the transition from fossil fuels to renewable sources, and wind energy's evolution through history, as this has become the country's main strength.

Historic account

Denmark's history of wind energy starts with Poul La Cour, an engineer who built the first wind turbine in Denmark succeeding in producing electricity from wind. A company was then founded, and this was the beginning of the Danish wind power industry.

The project didn't have much traction, since oil and coal energy were more readily available and cheaper to use, in the early 1900s. Each source, however, has its downsides. Fossil fuels had to be imported at the time, and that was subject to international politics. In times of political instability, the country had to turn to national resources, such as wind, to produce electricity, but as soon as trade lanes were open, it turned back to importing mainly oil, but also gas or coal.

The Danish state was not ignorant of this, and in the 1950s it was largely discussed about which source would be most viable. Wind power was being considered, but also nuclear power presented its strengths. Nuclear, however, needed a large initial investment and public opinion was strongly against its use.

The clear choice at the time was oil since it was abundant and inexpensive ([5]). Still vulnerable to worldwide availability though, since it had to be imported. The country became almost completely moved by oil. Power stations rooted out coal, and even the average person started having oil burners and using their car more. The 1960s were marked by economic growth, and the topics of energy stability and renewable energy took the backseat.

The paradigm only changed during the war of Yum Kippur and the oil crises of the 1970s, when Arab Oil-producing nations set an embargo on Western nations supporting Israel. Prices of Oil barrels naturally skyrocketed, from 2.90$ to 11.65$ in 1973, and even to almost 34$ in 1980 (fig. 3). These prices never declined again, forcing economies to look for other energy sources. The crises demonstrated the harsh consequences of relying upon foreign resources to sustain the country.

Year	Average	Low	High	Causes
1970	$2.96	N.A.	N.A.	Regulated prices
1971	$3.17	N.A.	N.A.	
1972	$3.22	N.A.	N.A.	
1973	$4.08	N.A.	N.A.	
1974	$12.52	$9.59	$13.06	OPEC oil embargo ended
1975	$13.95	$12.77	$15.04	Stagflation
1976	$13.48	$13.26	$13.71	Economy recovered
1977	$14.53	$14.11	$14.76	Fed raised and lowered rates
1978	$14.57	$14.40	$14.94	Fed raised and lowered rates
1979	$21.57	$15.50	$28.91	Iran-Iraq War, fed rate 20%
1980	$33.86	$30.75	$35.63	Iran oil embargo

Figure 3: Oil prices in the 1970s ([10])

The Danish authorities' response came in three headlines: diversification, energy conservation and improved efficiency [5]. Several measures were introduced to decrease the consumption of fuel, such as lowering speed limits,

prohibiting motorized circulation on Sundays, and street lighting minimised. The country needed to lower energy consumption, due to the radical rise of the oil prices. Naturally, the economy suffered and unemployment rates went up [4]. The country ended up generating electricity using coal, becoming less dependent on oil. Coal imports were organized by private companies in 1978, from Poland, Australia, Colombia, USA, and South Africa [5].

Not much could done about the transportation sector though, since at the time there weren't many alternatives to oil-based products.

Coincidentally, sources of oil and natural gas were found in 1971 (fig. 4), and production started in 1972 [11], decreasing the country's foreign dependency. As production increased (fig. 5), the Danish government had the prudence not to fall back on the country's resources and continued to push towards a stable and diversified energy supply.

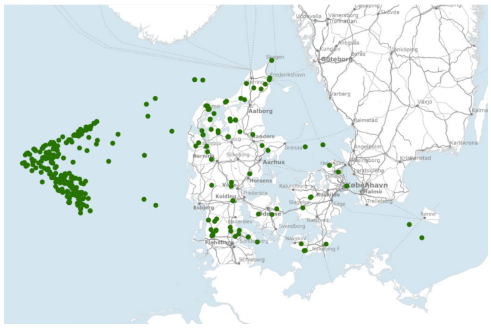

Figure 4: Oil and natural gas wells in Denmark, in 2020 [17]

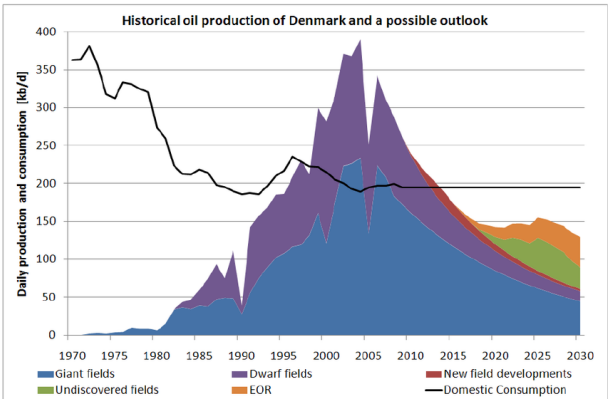

Figure 5: Evolution of oil production [16]

A subtle factor was that Danish companies were capable of exploring the country's newfound resources. This promised economic return, in developing national enterprises, and in ensuring at least part of the wealth doesn't leave the country.

In the same light, for wind energy, there were national companies up to the task of diversifying their energy sources and helping sustain Denmark's energy needs.

Oil and natural gas prospecting was not a new sector, and the market was already saturated with foreign companies. The market of Wind turbines, however, was almost completely unexplored, an opportunity swiftly taken by some companies, such as *Vestas*, discussed further ahead.

This crisis could be looked at as a rude awakening because in 1976 the government started drawing long-term energy policies. It also established the *Danish Energy Agency*, which had the purpose of diversifying the energy sector [8]. Investments in North Sea oil and natural gas development were made. As a result, Denmark was self-sufficient in hydrocarbons by 1979, and net exporter for a few years thereafter. In 1979 the state also started subsidising 30% of the cost of wind turbines, to anyone who wanted to install one [8].

An Energy Policy was created in 1976, planning to reduce the country's dependence on oil and start using coal, natural gas, even nuclear power and some renewable sources. The plan focused on supply security and economic efficiency, but not on the subject of climate change [28].

However, due to the continued public disapproval of nuclear power over the years, it was later removed from the nation's plans in 1985 [28].

Going forward from 1980 the winds of change started blowing. Environmental awareness grew, and people started pushing for renewable sources. By 1987 the Brutland Commission published *Our common Future*, suggesting energy consumption should be halved in 40 years (by 2027), bringing more public attention to environmental problems. Subsequently, 3 years later in 1990, the *Energy 2000 Action Plan for Sustainable Development* was announced. It included progressive reduction of energy consumption and reduction of harmful gases emissions ideas [28].

The Wind turbine industry started picking momentum in 1990 (fig. 7). The first offshore wind farm was built in 1991 off the coast of Lolland, Denmark (Vindeby Havmøllepark: 11 wind turbines; total capacity: almost 5 MW, [4]), and many were requested in the following years.

From 1985 to 2000, Wind-generated electricity climbed from 0,2% to 11,8% [7]. By 2000, Denmark had come a long way from its energy dependence on other countries. The country had become 142% self-sufficient on a net energy basis (fig. 6) and at the end of 2001 had the highest share of electricity generation from CHP (Combined Heat and Power) in the world [3].

In the early 2000s, there were a lot of protests towards planned wind farms from wind opposition groups [4]. It

would appear not everyone agreed with wind power plants spreading across the landscape. This might be the reason for the industry's stagnation which can be seen in figure 7. It is also notable that around 2008, the curve started growing again. However, by 2005 Denmark already held an estimated 40% of the global wind energy market [4].

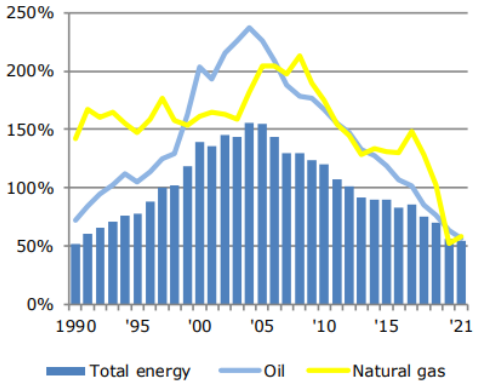

Figure 6: Degree of self-sufficiency [27]

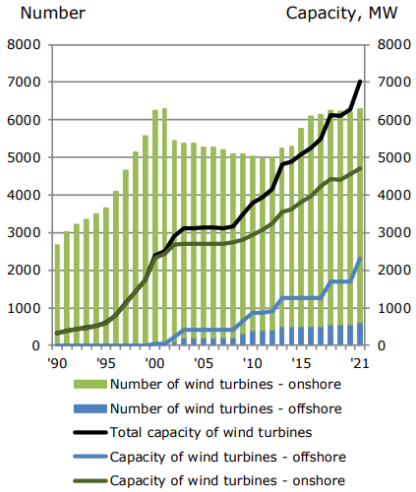

Figure 7: Total Wind turbines and capacity [27]

Offshore wind farms became more popular, and the Danish kept breaking records for their size [4]. The private sector was doing an effective job of innovating and developing new technologies.

Denmark was considered in 2019 to have the second-best energy security, by the World Energy Council [12], with Sweden taking first. In 2010, the share of electricity production by wind had climbed to 20,1%, and in 2020 to 56,8% [7].

Since 2010 the Danish Government has continuously had projects for more wind farms, and that continues to be the case. For instance, as of autumn of 2023, two new projects were started, one in the Baltic Sea and the other in the North Sea [13].

The case of Vestas

Vestas, today one of the largest wind turbine companies in the world, started as a family business started in 1898, in Lem, West Jutland. Initially, it consisted of selling all kinds of products, from kitchen appliances to coolers for turbochargers. It wasn't until 1971 that it entered the wind turbine market and came up to the brink of bankruptcy, but managed to come out on top, and in 1987, wind energy became the company's main focus. In 1991, the corporation's investments in wind turbine technologies paid off, reflected by the international orders from Great Britain, India and New Zealand. From then on, the company continued growing in market share while making serious developments in wind power technology, such as offshore turbines, and many leaps in efficiency and capacity, resulting in the company existing today, a global leader in wind turbine production (fig. 8) [15].

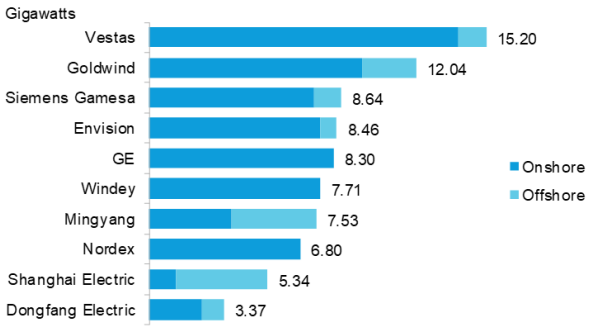

Figure 8: Top 10 global wind turbine makers. Total commissioned capacity was 99,2 GW [14]

Discussion

Denmark's energy transition started when the oil crises in the 1970s showed the vulnerabilities of relying on imported oil for energy supply, especially from countries from the Middle East. It was a slow start, and while the groundwork was being laid for the wind industry (such as technology developments and gathering public opinion support), the country's electricity production relied heavily on coal, likely due to a lack of options.

With the discovery of new oil sources in 1972, the import of oil became less prominent, especially for the transport sector, which was mostly oil-based. Notably, Danish energy policies weren't scrapped when its oil production ramped up (fig. 5). This shows competence from the country's institutions. A less dignified organisation might have settled on the nation's oil and gas reserves, leaving the problem for later generations. A more short-term-oriented government might have stopped the subsidies for installing wind turbines upon the finding of oil, but this did not happen. Denmark had a combination of luck, in finding oil and gas natural resources, and of strategic intelligence, in still striving for energy diversification.

By subsidizing wind turbine installations and promoting private businesses, the government helped build a decentralized power supply. This way, both individuals and private companies could participate in the transition effort to make Denmark a more sustainable country.

This proved to be fertile ground for the growth of wind energy companies such as *Vestas* or *Ørsted*, allowing them to become market leaders. These companies secured contracts to build wind farms all over the world, bringing more wealth to the Danish economy.

Denmark's energy transition made it a world reference, and brought not only energy stability and sustainability, but also made the country richer, by developing an industry and growing the economy.

There's still a long way to go though, as the transport sector is almost entirely reliant on oil [20].

The Danish energy transition was kickstarted by oil crises, and then carried out by a combination of strong, competent government institutions, and innovative private initiatives.

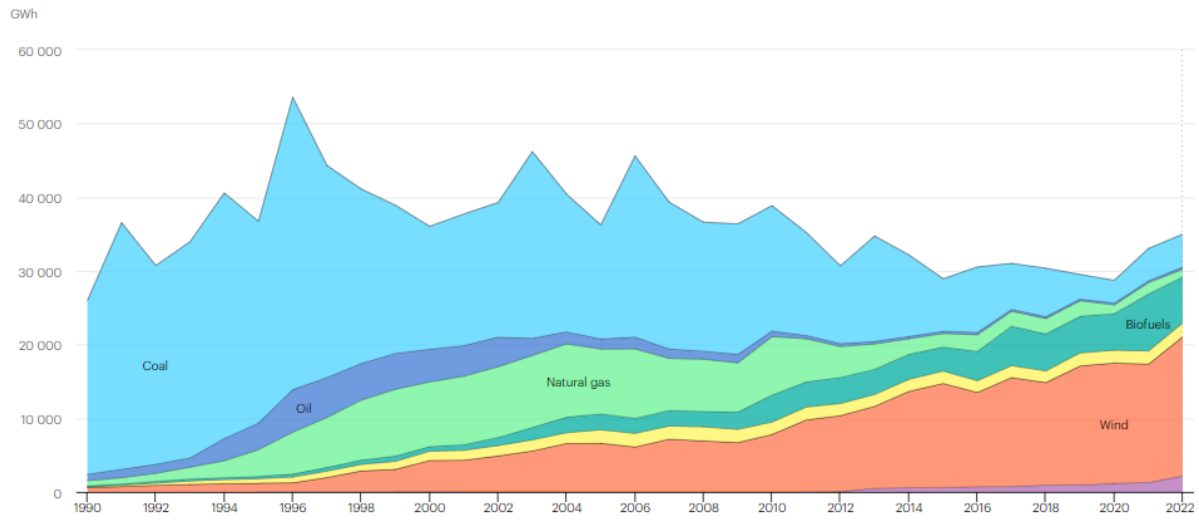

Figure 9: Denmark energy mix 1990-2022 (yellow is Waste, purple is solar) [19]

Offshore vs Onshore

Analysing differences between Offshore and Onshore wind farms, it becomes easier to understand how Denmark relies on wind power. Not only do Offshore wind farms have a higher output, they also have more stability [18]. A big problem of Onshore wind farms is wind consistency. In the sea, that is much less of a problem, allowing for a more stable connection to the energy grid. This makes wind power a much more serious consideration for a power source. Electricity output needs to be stable, so projects that have high energy variance aren't quite adequate. Backups need to be set up to balance out the grid in downtime periods.

Of course, Offshore wind turbines have higher installation costs, in some cases up to double the average Onshore turbine [18], and higher maintenance costs. But each case has its details, and usually to get energy stability with Onshore wind farms, backups would be needed, such as high-altitude water reservoirs, which have their own added costs.

In some circumstances though, Onshore wind farms might have acceptable consistency, for instance due to geographic conditions. Temperature Gradients and areas with wind funnelling might be worth considering, as these conditions increase wind velocity. Specific scenarios need to be thoroughly analyzed to reach the most effective solution.

2.2 Norway-The Government Pension Fund Global

The Norges Bank Investment Management, supervised by the Norwegian central bank, Norges Bank, plays a key role in Norway's economic landscape. Following the discovery of significant oil and gas reserves, the Norwegian Oil Fund was created, which a few years later gave rise to the Government Pension Fund Global (GPFG) to manage the country's new-found wealth. This sovereign wealth fund has experienced substantial growth over the years, as can be seen by the figure 10, becoming a global financial powerhouse with diverse investments, including a notable presence in Portugal.

With a commitment to responsible and ethical investing, the fund aligns with Norway's values and international standards. Its current valuation reflects strategic investment decisions, and its influence extends beyond national borders. The fund's approach to spending prioritizes sustainability, and it maintains a forward-looking vision, integrating environmental, social, and governance considerations into its investment strategies.

Overall, the Norges Bank Investment Management serves as a model for sovereign wealth funds, showcasing Norway's dedication to securing economic well-being through prudent financial management and ethical investments.

Figure 10: Government Pension Fund Global comparison with others sovereign wealth funds

Early Years

After World War II, most of the European countries experienced economic growth, and Norway was no exception. At that time, Norway exported raw material-based commodities like fish pulp and paper. Due to the cheap electricity obtained by the hydroelectric reservoirs, the country also produced big quantities of aluminium, PVC, ammonia and other chemical products. However the economic pillar was shipping and the large, associated industrial sector of shipbuilding. In the mid-1960s, mainly in 1967, Norwegian shipping reached its absolute peak and that was reflected in their GDP growth,[2].

Due to the rising of this sector in Japan and South Korea, Norway´s market space in shipbuilding started to decrease and the annual GDP growth fell from 6.3% to 2.3%, like it can be visualized by the following figure 11 and also in the reference [44].

In 1970, Norway's GDP per capita was slightly higher than the OECD average, as shown in the figure 12. After 1970, Norway's GDP grew more sharply and from then on it distanced itself from the average value associated with OECD members

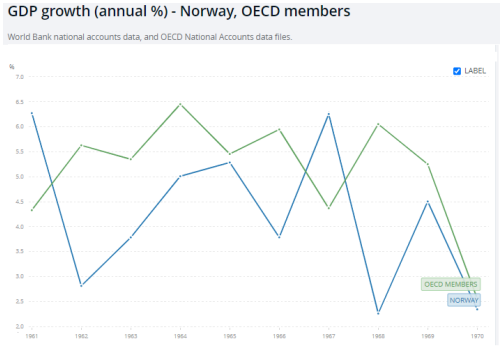

Figure 11: GDP growth of Norway and OECD members.[44].

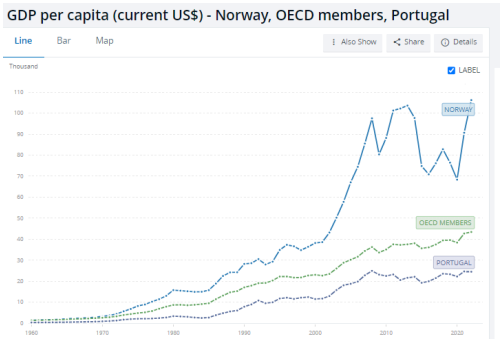

Figure 12: GDP per capita of Norway, OECD members and Portugal[45]

Oil discovery

In 1966 the exploration of oil began and in the next four years 37 wells were drilled but as nothing was found, most of the oil companies gave up. Philips Petroleum had only one well left to drill before it shipped out its last rig, and then, the unexpected happened.

On December 23rd of 1969, Norway finally struck oil. Since then, Norway has been a world leader in offshore oil and gas exploration. In 1969, with the recent discovery of oil in the North Sea by the Norwegians, the Norwegian economy grew exponentially with all that amount of oil sold. At that time, the government knew the revenue from oil and gas should be used cautiously in order to avoid imbalances in the economy.

For the first 20 years, the money was primarily invested in the oil industry and developing the country but it became clear that oil revenues were substantial and, in 1990, the Norwegian Oil Fund was established by law to support the government's long-term management of petroleum revenues. In the course of the first 50 years, Norway extracted half of the oil resources. If it continues at the same pace it is estimated that will last for another 50 years,[32].

Government Pension Fund

In 1996, the first capital was transferred to the fund that is owned by the Norwegian people and managed by Norges Bank, the country's central bank on behalf of the minister of finances.

There have been several changes of governments since 1996, but no matter who has led the minister of finances they all agreed on the main principles and rules of the fund. It is the people's money, earned by everyone, divided equally and for generations to come.

How does the fund grow?

Although revenue from oil and gas production is transferred to the fund, these deposits account for less than half the value of the fund. Most of it has been earned by investing in equities, fixed income, real estate and renewable energy infrastructure. Equities represent approximately 70% of all investments, fixed income and real estate represent 27% and 3%, respectively,[22]. Renewable energy infrastructure represents a small part and could be negligible in a general outlook13.

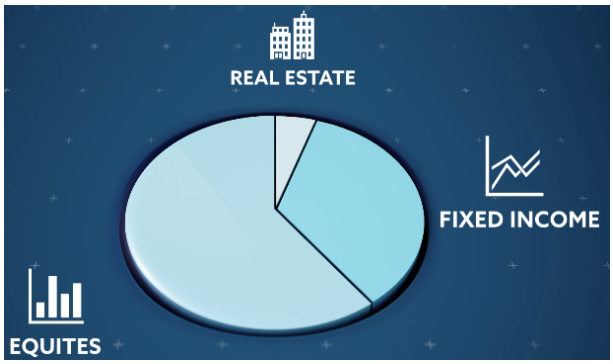

Figure 13: Share of the investments

The fund is now one of the world's largest funds, owning almost 1.5 % of all shares in the world's listed companies. This means that have holdings in around 9,000 companies worldwide, entitling the central bank to a small share of their profits each year, [22]. In addition, the fund owns hundreds of buildings in some of the world's leading cities, which generate rental income for the pension fund. The fund also receives a steady flow of income from lending to countries and companies. By spreading the investments widely, only outside of Norway, the fund reduces the risk of losing money.

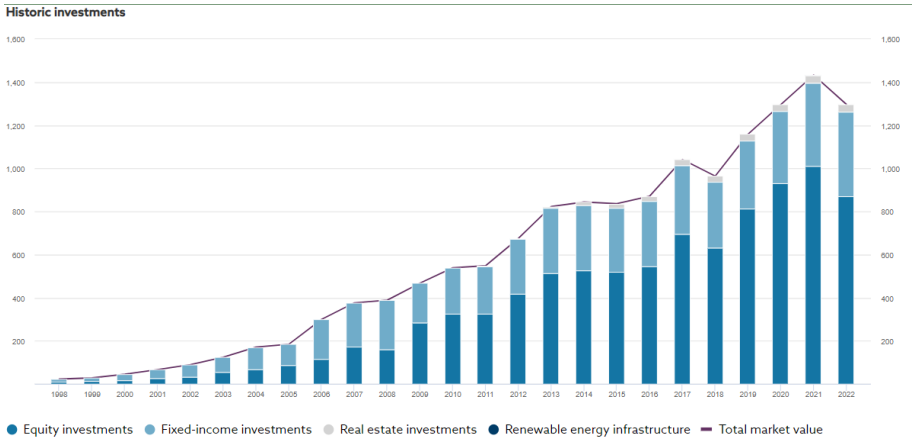

Figure 14: Investments history,[22]

Investments fund purposes

There are two main reasons for having a pension fund and guidelines for spending oil and gas revenues.

One is for the long-term, which allows Norwegians to have great wealth in oil and gas, which is a benefit for many generations. By setting up the fund, the bank is able to make sure that the revenues are a great benefit for many generations for the future of Norway.

The second purpose of the fund is to be used as a stabilisation mechanism for the Norwegian economy to prevent overheating when inflation is dangerous for the heating of the whole economy. It also gives the ability to stimulate the economy when there is danger of high unemployment and low growth and represents a stimulus to the economy to keep it growing.

The fundamental principle for the fund is that the bank manages investments in a long-term perspective. The bank is looking for a good return but, at the same time, for acceptable risks that, in the long-term, will give them a good development of the fund.

The Norwegian pension fund has been a success in the way that had been able to manage huge oil and gas revenues in a responsible way. It has given good returns to the Norwegian society and it has been essential when it comes to short-term business management of the Norwegian economy, but also long-term, by managing the revenues in such a way as to ensure that the oil and gas revenues are useful to them in the future as well.

The bank realized that the fund was going to be very important for Norway and the Norwegian economy and it also realized that it was going to be a great challenge to protect the fund and avoid using too much money too quickly. Many managers underestimated how big the fund was going to be and also underestimated how successful it would be managed. At that time, many experts said that it was a bit naive to believe that the democratic society and democratic system could manage such a large cash flow in a sustainable and responsible way, but experience so far in Norway said that they have been able to do it.

Sustainable investments

The fund's role is to ensure that Norwegian national wealth lasts for as long as possible. Its investments have an extremely long-term perspective, allowing it to deal with large short-term fluctuations in value. Their goal, as fund managers on behalf of the Norwegian people, is to generate the highest possible return with moderate risk so that the fund grows and endures.

Companies' activities have a great impact on surrounding communities and the environment, and society has ever greater expectations for how companies should behave. Over time, this may affect their profitability and the fund's return. As a long-term investor in around 9,000 companies in 70 countries, the central bank has an interest in investors' demands for returns to be aligned with society's broader expectations of companies. The fund managers take environmental and social issues into account and publish clear expectations of the companies in which they invest.

The Norwegian Parliament and the Ministry of Finance established rules for the management of the fund and delegated responsibility for its management to Norges Bank. The Ministry of Finance has set up an independent Council on Ethics to perform ethical evaluations of companies. The Council on Ethics sends its recommendations to Norges Bank's Executive Board, which then makes the final decision on exclusion, observation or active participation. The fund itself may also decide to divest from companies that impose substantial costs on other companies and society as a whole, and so are not considered long-term sustainable and not an option to invest.

Fund Market Value

The following figure 15 shows the geographical distribution of investments around the world. In 2022, 11,549 investments in 69 different countries can be seen in the figure 15. The most recent data is for the 2022 year and in that time, the fund's total market value was valued at 1,261,705,358,661 USD, which corresponds to 1,146 billion EUR, [41]. A very good indication of the dimension of the Norwegian fund that we are dealing with.

An interesting fact that can be deduced from the figure,15 is that there is no record of any investment in Norway and this is, as previously mentioned, to avoid the risk of losing money.

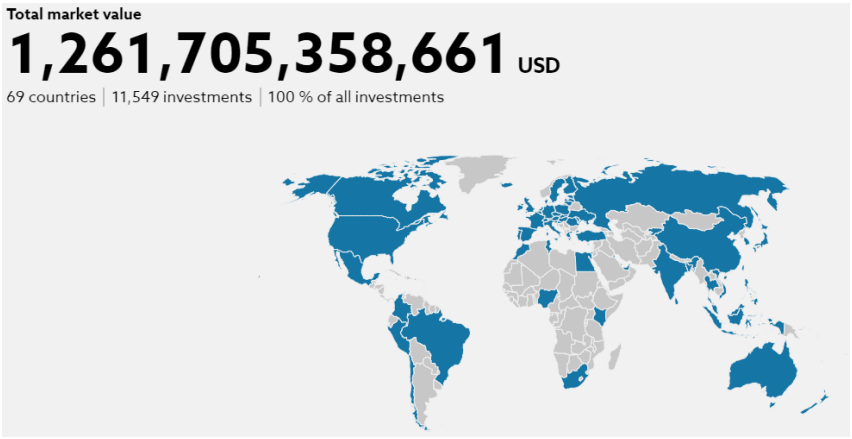

Figure 15: Total market value in 2022,[22]

Norwegian Fund in Portugal

The Norwegian central bank also invests in Portugal and this sub-chapter is about describing which type of investments they made, which sectors they invested in and how much they invested.

In Portugal, the Government Pension Fund Global only invest in equities and fixed incomes. The investments in equities are spread by 15 companies, while fixed-income investments correspond to 5 bonds.

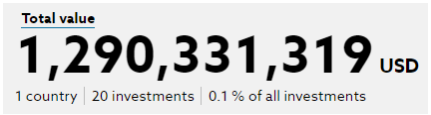

Figure 16: Total value of investments made in Portugal,[22]

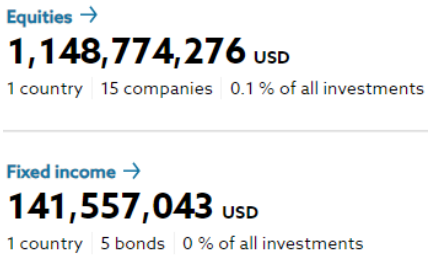

Figure 17: Distribution of investments made in Portugal,[22]

They have equities in Portuguese companies like those that are referenced in the figure below18. As can be seen, these are companies with great experience and reputation in their respective markets. It should be noted that the Norwegian central bank is very keen to invest in companies in the energy sector, such as EDP.

Sonae SGPS SA	22,998,913	Consumer Staples	1.15%	Portugal
Semapa-Sociedade de Investimento e Gestao	8,056,334	Basic Materials	0.75%	Portugal
REN - Redes Energeticas Nacionais SGPS SA	23,537,279	Utilities	1.31%	Portugal
NOS SGPS SA	21,324,435	Telecommunications	1.02%	Portugal
Mota-Engil SGPS SA	326,393	Industrials	0.09%	Portugal
Jeronimo Martins SGPS SA	138,062,684	Consumer Staples	1.02%	Portugal
Ibersol SGPS SA	10,532,641	Consumer Discretionary	3.89%	Portugal
Greenvolt-Energias Renovaveis SA	22,470,375	Utilities	1.94%	Portugal
Galp Energia SGPS SA	85,832,266	Energy	0.78%	Portugal
EDP Renovaveis SA	119,274,387	Utilities	0.57%	Portugal
EDP - Energias de Portugal SA	613,163,696	Utilities	3.11%	Portugal
Corticeira Amorim SGPS SA	16,420,164	Industrials	1.33%	Portugal
CTT-Correios de Portugal SA	16,695,560	Industrials	3.49%	Portugal
Banco Comercial Portugues SA	44,606,443	Financials	1.89%	Portugal
Altri SGPS SA	5,472,706	Basic Materials	0.50%	Portugal

Figure 18: Portuguese companies that Norges Bank invest in equities,[23]

How the fund spends its savings

Each year, the Norwegian government can spend only a small part of the fund, but this still amounts to almost 20 %

The mindset that fund managers have when dealing with spending the savings is: ”The less we spend today, the better the position we will be in to deal with downturns and crises in the future.”

Budget surpluses are transferred to the fund, while deficits are covered with money from the fund. In other words, the authorities can spend more in hard times and less in good times. So that the fund benefits as many people as possible in the future too. Politicians have agreed on a fiscal rule which ensures that they don´t spend more than the expected return on the fund. On average, the government spend only the equivalent of the real return on the fund, which is estimated to be around 3% per year. In this way, oil revenue is phased only gradually into the economy. At the same time, only the return on the fund is spent, and not the fund’s capital.

2.3 Iceland-From Fossil Dependency To Renewable Leadership

During the course of the 20th century, Iceland went from being one of Europe's poorest countries, heavily dependent upon imported coal and oil for its energy, to a country with a high standard of living in which almost all stationary energy is derived from renewable resources. The focus of this section will be Iceland's transition from fossil fuels to renewable sources of energy, with an emphasis on geothermal energy.

Situation Until the 1960s

Until the 1960s, Iceland's energy situation was characterized by a heavy reliance on imported fossil fuels for heating and electricity generation. The country's energy landscape was largely shaped by its geographic location, with limited indigenous fossil fuel resources. As a result, Iceland faced economic and energy security challenges due to its dependence on external sources of energy.

The primary source of energy for space heating was coal, which was imported and used extensively in urban areas. This reliance on coal, combined with other imported fossil fuels like oil, made Iceland vulnerable to fluctuations in global energy markets and exposed the economy to external supply disruptions. The energy sector's dependence on imported fuels also had economic implications, contributing to trade deficits and the outflow of foreign currency.

The transition from traditional sources of energy, such as peat and driftwood, to imported fossil fuels occurred gradually in the early to mid-20th century. The shift was driven by urbanization, industrialization, and the growing demand for energy in a modernizing society. During this period, there was limited awareness of environmental issues associated with fossil fuel combustion, and the focus was primarily on meeting the immediate energy needs of the population and industries.

The economic challenges posed by the reliance on imported fossil fuels became particularly evident during the oil crises of the 1970s. The oil embargoes and price shocks prompted a global reevaluation of energy strategies, and Iceland, like many other nations, began to explore alternative, more sustainable sources of energy.

Paradigm Shift in the Late 1960s and Early 1970s

The late 1960s and early 1970s marked a transformative period in Iceland's energy landscape, catalyzed by the global oil crisis and the country's strategic response to the challenges posed by its dependence on imported fossil fuels. The oil shocks of 1970 and 1973, triggered by geopolitical events in the Middle East, exposed the vulnerabilities of nations heavily reliant on oil. For Iceland, a small island nation with minimal indigenous fossil fuel resources, these crises were pivotal for the paradigm shift in its energy strategy.

In the wake of the oil crises, Iceland faced economic hardships, prompting a reevaluation of its energy policies. The government recognized the urgent need for energy security and sustainability, leading to a fundamental shift in focus from imported fossil fuels to harnessing the nation's abundant renewable energy resources. This marked the beginning of a concerted effort to reduce reliance on oil and coal and transition towards greener, domestically available energy alternatives.

One of the key initiatives during this period was the construction of the Karahnjukar Hydropower Plant, a project that commenced in the late 1960s and was completed in the 21st century. This hydropower plant significantly increased the country's electricity generation capacity and reduced dependence on imported fossil fuels for power generation. The strategic utilization of hydropower, tapping into the country's extensive network of rivers and waterfalls, was emblematic of Iceland's commitment to renewable energy.

Simultaneously, the country further developed its geothermal resources, capitalizing on its unique geological features. The utilization of geothermal energy for district heating and electricity generation expanded, culminating in projects like the Svartsengi Geothermal Power Station and the Reykjanes Geothermal Power Plant.

Investment in Geothermal Energy since the 1970s

After recognizing the need for energy independence and the environmental advantages of utilizing its abundant geothermal resources. The government played a crucial role in promoting the growth of the geothermal sector through a combination of policies, strategies, and targeted investments.

One of the key initiatives during this period was the establishment of the National Energy Fund in 1974. This fund, supported by a tax on hydrocarbon fuels, was designed to finance geothermal exploration and research. The government's financial commitment demonstrated a clear intent to diversify the country's energy mix and reduce its dependence on imported fossil fuels.

In 1975, the Icelandic National Energy Authority (Orkustofnun) was founded, providing a dedicated institution to oversee the nation's energy policies and promote sustainable energy development. Orkustofnun played a pivotal

role in coordinating research and development efforts, providing technical expertise, and formulating policies to advance geothermal energy utilization.

The Strategic Plan for Nature Conservation and Utilization in 1982 further outlined the government's commitment to sustainable development, including the responsible use of geothermal resources. The plan aimed to balance economic growth with environmental preservation, ensuring that geothermal development adhered to stringent environmental standards.

In subsequent decades, Iceland continued to invest in geothermal infrastructure, leading to the development of several major geothermal power plants. The Svartsengi Geothermal Power Station, commissioned in 1976, was one of the early successes, providing electricity and hot water for the town of Grindavík while showcasing the potential of geothermal energy.

The implementation of direct-use applications of geothermal energy, such as district heating, played a crucial role in the widespread adoption of geothermal in Iceland. The capital city, Reykjavik, became a pioneer in utilizing geothermal energy for district heating, reducing reliance on fossil fuels for residential and commercial heating.

In recent years, Iceland's emphasis on geothermal energy has extended beyond its borders. The country has actively shared its expertise and knowledge through international collaborations, assisting other nations in harnessing geothermal resources for sustainable development.

The country has trained professionals from over 80 nations, through initiatives like the Geothermal Training Program (GTP), fostering a network of geothermal experts worldwide. Iceland's collaboration with international entities has been contributing to research and initiatives that advance geothermal technologies.

The Icelandic International Development Agency (ICEIDA) has played a vital role in supporting geothermal projects in collaboration with other countries, providing both technical know-how and financial assistance. In diplomatic forums and bilateral agreements, Iceland advocates for the widespread adoption of geothermal energy, sharing insights on regulatory frameworks and governance.

Economically, Iceland's geothermal prowess has not only reduced its own dependence on imported fossil fuels but has also stimulated economic growth. The development of the geothermal industry has created jobs, attracted investment, and positioned Icelandic companies as leaders in geothermal technology and services. Through international collaborations, Iceland contributes not only to global sustainable development but also to its own economic prosperity, as its expertise is sought after on the international stage.

2005-2010 Renewables Surge

Between 2005 and 2010, Iceland experienced a remarkable surge in renewable energy conversion as shown by the significant increase in both geothermal and hydropower during this period in Figure19, solidifying its status as a global leader in sustainable energy. During this period, the country strategically expanded its capacity in both hydropower and geothermal energy, harnessing its abundant natural resources for economic development and environmental sustainability.

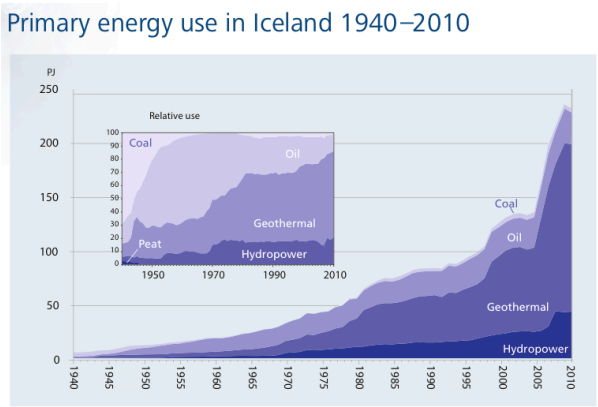

Figure 19: Primary energy in Iceland by source from 1940 to 2010

One of the key contributors to this surge was the completion of the Karahnjukar Hydropower Plant in 2007. This project, one of the largest hydropower developments in Europe, significantly bolstered Iceland's hydropower capacity. The plant's construction involved the creation of dams and power stations in the eastern part of the country, tapping into Iceland's numerous rivers and waterfalls. The Karahnjukar project played a pivotal role in meeting the rising energy demands of the country, particularly in the context of attracting energy-intensive industries like aluminum production.

At the same time, Iceland continued to advance its geothermal energy sector. Existing geothermal plants were expanded, and new projects, such as the Reykjanes Geothermal Power Plant, were initiated. Geothermal energy, a renewable source harnessed from the Earth's heat, remained a cornerstone of Iceland's energy strategy. The country's geothermal potential, characterized by hot springs, geysers, and volcanic activity, was further leveraged to generate more electricity and provide heating for more homes and businesses.

The growth in renewable energy conversion during this period was also supported by a commitment to sustainability at the policy level. The Icelandic government maintained a strong stance in favor of renewable energy, implementing supportive policies and incentives to encourage investment in green energy projects. Additionally, the expansion was driven by economic considerations, as Iceland strategically attracted energy-intensive industries that could benefit from the nation's abundant and cost-effective renewable energy resources.

Current Situation and Main Challenges for the Future

Roughly 85% of primary energy used in Iceland came from domestically produced renewable energy sources, which is the highest share out of any country in the world. In 2016 geothermal energy provided about 65% of primary energy, the share of hydropower was 20%, and the share of fossil fuels (mainly oil products for the transport sector) was 15%. The main use of geothermal energy is for space heating, with the heat being distributed to buildings through extensive district-heating systems. About 85% of all houses in Iceland are heated with geothermal energy. In 2013 Iceland started converting energy from wind, but it remains negligible in comparison with hydropower and geothermal.

Regarding electricity production, almost 100% of electricity in Iceland is obtained from renewable sources, with about 73% coming from hydropower and 27% from geothermal energy.

Iceland is the world's largest green energy converter *per capita* and largest electricity producer *per capita*, with approximately 55,000 kWh of electricity per person per year. In comparison, the EU average is about 6,000 kWh. A big reason for this was the expansion of Iceland's energy-intensive industry, which considerably increased the demand for electricity during the last decades. Currently, it accounts for 77% of electricity usage in Iceland.

While Iceland has made significant strides in utilizing renewable energy and has a relatively low carbon footprint compared to many other countries, achieving carbon neutrality still poses some challenges, the main ones being transitioning off fossil fuels completely in the transportation sector and in energy-intensive industries, such as aluminum production.

Iceland has been progressing in the transport sector with a high adoption of electric vehicles (EVs), thanks to policies that positively stimulated this market, such as:

- Financial incentives that ensure that EVs are priced competitively compared to combustion engine cars;
- A fast rollout of public charging infrastructure in recent years, which has been a priority for the Icelandic government.

This factors in addition to a national grid of renewable, low-carbon and inexpensive electricity, a high urbanization rate and the small size of the country, make EVs in Iceland particularly desirable.

But the country still contends with emissions from heavy-duty vehicles, shipping and aviation. Achieving a complete shift to sustainable transportation involves overcoming barriers such as the development of green technologies for long-haul transport.

Another key challenge in Iceland's journey to carbon neutrality is the carbon footprint associated with aluminum production, an important sector for Iceland's economy. Aluminum smelting, being energy-intensive, historically relied on fossil fuels, contributing to emissions. While Iceland's abundant renewable energy offers a significantly cleaner alternative - the average greenhouse gas emissions from the aluminum production worldwide are six times higher than those of the aluminum produced in Iceland - achieving carbon neutrality in this sector demands comprehensive solutions. This includes transitioning the entire aluminum production chain, from raw material extraction to smelting, towards more sustainable and carbon-neutral practices. Balancing economic interests with environmental goals poses a complex challenge, necessitating innovative technologies and strategic policies to ensure a greener future for the aluminum industry in Iceland.

Even though there are still challenges ahead, Iceland seem to be on a good path towards their ambitious objective to achieve carbon neutrality until 2040. This is thanks to good energy policies and investment that take advantage of the natural resources within the country, prompting Iceland to become more and more energetically independent while exploring renewable energy resources. Following energy independence came economic prosperity.

2.4 Brazil-Navigating Energy Diversity

Brazil, a land of vast natural resources and huge potential, has undergone a remarkable transformation in its energy landscape over the past century. From its early dependence on imported oil to its current status as a major energy producer and consumer, Brazil's energy story is one of innovation, diversification, and leadership.

In the early stages of development, Brazil's energy needs were met primarily through biomass, such as wood and animal dung. This reliance on traditional sources sustained local communities but limited the scalability of energy production.

The late 19th century saw the emergence of hydroelectric power. Hydropower has been a cornerstone of Brazil's energy landscape for over a century, playing a pivotal role in powering the country's growth and development. The nation's abundant water resources and favorable topography have made hydropower a natural and cost-effective source of electricity generation.

Early Hydropower Development

The first hydroelectric plant in Brazil was constructed in 1894 in the city of Mauá, São Paulo. This pioneering project marked the beginning of hydropower's ascent in Brazil's energy mix. However, progress was initially slow, primarily driven by limited investment and infrastructure.

Government Initiatives and the Transmissao Elétrica Brasileira (TEB)

In the 1930s, the Brazilian government identified hydropower's vast potential, prompting initiatives to expedite its growth. This shift was fueled by the necessity to provide electricity to a burgeoning population and facilitate industrialization. By the 1950s, the government initiated the Transmissao Elétrica Brasileira (TEB), a substantial endeavour to establish a countrywide electricity transmission system. This network linked interior hydroelectric plants to coastal cities, seamlessly unifying Brazil's energy infrastructure and establishing hydropower as the dominant force in the nation's power generation.

The Rise of Grand Dams

The 1970s and 1980s witnessed a surge in large-scale hydroelectric projects, with Brazil constructing some of the world's largest dams, including Itaipú and Belo Monte. These mega-projects played a significant role in meeting the country's burgeoning electricity demand and driving economic growth. However, they also raised concerns about their environmental impact, particularly the displacement of indigenous communities and the alteration of ecosystems.

Environmental Challenges and Mitigating Measures

The Tucuruí Dam, constructed in the Amazon rainforest in the 1970s, became a focal point of environmental criticism. Its construction displaced thousands of indigenous people and led to significant deforestation and disruption of the local ecosystem. Additionally, the dam caused the decline of fish populations in the Tapajós River.

In response to these concerns, the Brazilian government has implemented measures to mitigate the environmental impact of hydropower development: environmental impact assessments - mandatory assessments are conducted to evaluate the potential environmental consequences of hydropower projects; restoration of degraded areas - rehabilitation efforts aim to restore ecosystems and mitigate the impact of dam construction; protected areas - the creation of protected areas helps to safeguard biodiversity and reduce the environmental footprint of hydropower projects.

On the other hand, Brazil's oil exploration efforts began in the early 20th century, but initial attempts were met with limited success. The country remained heavily reliant on imported oil, making it vulnerable to the volatile global oil market, particularly during the oil crises of the 1970s.

The Birth of Petrobras: A State-Owned Oil Giant

In 1953, the Brazilian government established Petrobras, a state-owned oil company, to oversee and manage the country's oil exploration and production activities. This marked a turning point in Brazil's approach to the oil industry, signalling a shift towards self-reliance and strategic control over its energy resources.

The mid-20th century brought a seismic shift with the discovery of vast offshore oil reserves. The state-controlled oil company, Petrobras, played a central role in the development of Brazil's oil industry. The exploitation of offshore oil fields, particularly in the Campos Basin, propelled Brazil into the ranks of major oil-producing nations, fostering economic growth and energy self-sufficiency.

In response to the oil shocks of the 1970s and the desire for energy independence, Brazil embarked on a pioneering journey into biofuels.

Sugarcane was brought to Brazil by Portuguese colonists five centuries ago. By 1525, Brazil began exporting sugar to Portugal, becoming a significant contributor to the global sugar trade.

Early indications of ethanol development emerged in the early 20th century. In 1903, the First National Congress on Industrial Applications of Alcohol recommended the establishment of infrastructure to encourage alcohol production and utilization. By 1931, a 5% ethanol blending requirement was already mandated for imported oil, accompanied by guidelines for transportation and commercialization. Two years later, the federal government instituted a supervisory entity, the Institute of Sugar and Alcohol (IAA). The IAA was established with the objectives of regulating the sugar industry, promoting alcohol fuel, offering technical support, and advocating for the interests of small to medium-sized players in the Northeastern sugar industry of Brazil. Despite the absence of a comprehensive national market for ethanol for several decades, the IAA played a pivotal role in the sugar-ethanol sector. It took charge of planning, setting supply targets, determining prices, and establishing allowable export targets.

In the period spanning the 1950s to the 1970s, engineer Urbano Stumpf emerged as a pioneer in exploring ethanol as a fuel for internal combustion engines (ICEs) at the Aerospace Technical Center (CTA). His research, coupled with activities conducted at the Fuel and Mining Experimental Station, laid the groundwork for the development of vehicles capable of running on neat ethanol (including hydrous ethanol, 100% ethanol, or E100) (20). This technological advancement marked a significant milestone, facilitating the initiation of Brazil's modern biofuels transition.

In 1971, the federal government introduced a public sector counterpart to the CTC (Sugarcane Technology Center), known as the National Program for the Improvement of Sugarcane (Planalsucar), operating under the umbrella of the IAA. Planalsucar was tasked with conducting R&D (Research and Development) specifically on the genetic enhancement of sugarcane varieties. The fig.23 represents the ethanol production process. It established experimental stations across the major sugar and ethanol-producing states. Although there might have been some competition in seed breeding between these R&D entities, they differed in their primary areas of focus. The CTC concentrated mainly on production within the state of Sao Paulo, while Planalsucar directed its efforts toward breeding areas throughout the entire country.

Figure 20: Vehicle used for alcohol testing in early 20th-century in Brazil

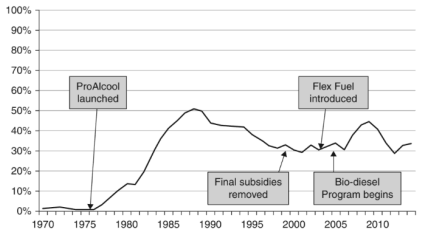

Figure 21: Ethanol as a share of automotive fuels

Brazil's modern shift to biofuels (Figure) represents two distinct transformations: one linked to the Proálcool Program of the 1970s (the National Ethanol Program, discussed in detail below) and a second tied to innovations with flex fuel vehicles that emerged in the 1990s. To understand these developments, one must begin first with the sugar industry (see Figure21).

The Foundation of Brazil's Sugar Supremacy: the Proálcool Program

Proálcool, First Phase (1975 – 1980)

In Brazil, government intervention in sugar and ethanol has been of major importance. Before the first oil shock of 1973, interest already existed in developing a Brazilian market for ethanol. The domestic sugar industry, in particular, considered ways to overcome stagnation following a period of heavy reinvestment. A decline in sugar prices combined with limitations imposed by the International Sugar Agreement left this industry with underutilized capacity. Here, creating a domestic (sugar-based) ethanol market was an obvious choice for a tightly organised industry facing limited export opportunities, especially given the historical foundations of ethanol use and public mandates in Brazil. To revitalize, the Brazilian sugar industry—namely, the Cooperative of Producers of Sugarcane, Sugar, and Alcohol in the State of São Paulo (Copersucar) and the IAA, together with the Ministry of Industry and Commerce put forward a plan promoting increased production of ethanol for use in transport. By introducing a separate market, this stimulus plan was designed to insulate the sugar industry against future flux in sugar prices, while bringing additional gains to the capital goods and automotive sectors. The plan, however, remained largely untouched until the oil shock of 1973. The primary trigger for the crisis in 1973 was an oil embargo imposed by the

Organization of Arab Petroleum Exporting Countries. The embargo was initially intended to penalize nations that had supported Israel in the October 1973 "Yom Kippur" war. However, it was concluded by March 1974. The more consequential development was the subsequent choice by the oil cartel to regulate supplies strategically, aiming to set a "fair" price for crude oil. Concerned about the escalating energy costs, a worsening balance-of-payments situation, and the reliance on foreign fuel sources, Brazil opted to promote the domestic manufacturing of ethanol for blending with gasoline. This initiative, known as the "Proálcool" program, was launched on November 14, 1975. The objective was ambitious: to achieve a production of 925 million gallons by 1980, a significant surge from the 180 million gallons recorded in 1972/1973—representing a five-fold increase. During this period, the Brazilian sugar and ethanol industry grappled with unfavourable global sugar prices and a substantial surplus, leading to the looming threat of bankruptcy. The emergence of a completely new market proved to be a lifeline for the industry.

During its initial stage, the Proálcool program promoted the manufacturing of anhydrous ethanol, intended for blending with gasoline. This measure aimed to tackle trade balance issues and address challenges faced by the sugar industry. As long as the ethanol content in the blend stayed below a technical threshold of 25%, it was compatible with existing engines. The government's role was primarily to mandate the increase in ethanol blending and support the growth of distilleries.

Proálcool, Second Phase (1980 – 1997)

A subsequent phase of the Proálcool initiative was instigated in response to the second oil shock. This particular shock unfolded in 1979, stemming from the Iranian revolution that disrupted oil supplies. The situation escalated the following year with the outbreak of the Iraq-Iran war. Recognizing the imperative to reduce dependence on gasoline, Brazilian authorities determined that a more substantial substitution of gasoline with ethanol was necessary. However, mere blending was not a viable option, as the 25% technical blend limit had already been reached.To address this challenge, the solution involved actively promoting the development and sale of vehicles designed to run on pure alcohol. This approach aimed to eliminate the need for gasoline in a significant portion of the automotive fleet. However, implementing this strategy required the manufacturing of purpose-built engines capable of running on pure alcohol, the establishment of a distinct distribution system, and the assurance of competitive pricing for both these specialized vehicles and hydrous ethanol.

To provide enough demand for all the ethanol that could be produced, the Brazilian government decided to: contract and subsidize the automotive industry to produce alcohol-only engines; give alcohol vehicles a tax advantage; set the price for hydrous ethanol at a level which made it competitive - thus, the price for hydrous ethanol was legally set at 65% of the price for gasohol; to help make ethanol profitable, tax imported oil at 12.5% of its CIF price; subsidize the distribution of the new fuel.

Overall with Proálcool, public sector subsidies and tax breaks helped get the program started: farmers planted more sugar cane, investors built distilleries to convert the crop to ethanol and automakers designed cars to run on 100 percent alcohol. The government financed a distribution network to get the fuel to gas stations and kept alcohol prices low to entice consumers. Petrobras, the government-run monopolistic petroleum company, was in control of the distribution of ethanol and played a key role in managing the fuel market.

The pivotal point lies in the substantial expansion of the Brazilian sugar industry orchestrated by state intervention. The government not only mandated but also structured a market that witnessed a more than twofold increase in its size. This involved specifying production quotas for both sugar and ethanol, offering financial incentives for the construction of distilleries, overseeing the exportation of sugar and ethanol, determining prices for all products, and implementing compulsory blending requirements. Such extensive governmental involvement can be characterized as intervention on an unprecedented scale.

The **effects of the Proálcool program** on the Brazilian sugarcane industry were quite dramatic:

- In 5 years, sugarcane production expanded by 50%;
- Between 1975/76 and 1990/91 sugarcane production surged from 68.5 to 222.4 million tons (+225%), but sugar output grew only by about 25%: practically all of the growth was devoted to ethanol whose supply shot up from 147 million to 3 billion gallons;
- innovations were introduced: field and mill productivities were boosted by payment of the sugarcane based on sugar content, new cane varieties and improved industrial installations;
- In 1985, 96% of all vehicles sold in Brazil were powered by pure-alcohol engines; production of alcohol-powered cars jumped from 3,000 to over 560,000 units per year;
- Domestic gasoline production exceeded consumption.

In 1985, a significant spike in sugar prices prompted factories to prioritize maximizing sugar production, leading to a reduction in ethanol output. Although hydrous ethanol production rebounded by 1987, the growing ethanol fleet, supported by government incentives, still required a steady supply. Additionally, subsidized low ethanol

prices resulted in instances where even owners of gasoline engines opted for pure ethanol instead of gasohol. As a consequence, Brazil found itself in the position of having to import both hydrous ethanol, to meet demand, and anhydrous ethanol, for mandatory blending. Curiously, the country was exporting gasoline surpluses at lower prices than the imported ethanol. This ethanol deficit persisted for at least 8 years.

In summary, post-1985, ethanol demand stabilized as the alcohol vehicle fleet was not renewed, and the domestic industry gradually shifted its focus back to sugar, encouraged by a favourable exchange rate.

Liberalization

The Brazilian sugar and ethanol industry underwent a gradual liberalization process, beginning in 1990 with the dismantling of the Instituto do Açúcar e do Álcool and the deregulation of sugar prices (sugarcane prices remained regulated). While 1997 marked the official removal of government control over sugarcane prices, production quotas, and exports, industry observations indicate persistent government influence. This implies that liberalization was not fully achieved, and the Brazilian government retained tools to influence the ethanol market.

Government incentives failed to sustain the popularity of alcohol-only vehicles. Sales of hydrous ethanol, which peaked in 1991, declined significantly by 2000 due to the removal of tax benefits and the increased competitiveness of gasoline. However, anhydrous ethanol blended with gasoline to create gasohol experienced some growth, driven by government policies and vehicle fleet expansion. Overall ethanol production remained relatively unchanged, while sugarcane diverted for sugar exports increased, potentially hindering ethanol production. Had the government-organized "ethanol miracle" run its course?

-The resurrection of hydrous ethanol: the "flex-fuel" vehicle

Why did flex-fuel cars appear in Brazil? The rise of flex-fuel vehicles in Brazil was driven by a combination of factors, including the growing availability of hydrous ethanol, rising oil prices, and government support for domestic ethanol production. However, consumers' memories of the 1985 ethanol shortage, when sugar production prioritized ethanol production, made a return to pure ethanol engines unappealing. To address this concern, car manufacturers revisited research on technology that could allow engines to operate on a variety of fuel blends, from gasoline only to ethanol only, and anything in between. In 1994, Bosch initiated the development of a "flexible-fuel" mechanism, followed by other equipment manufacturers like Magnetti Marelli and Delphi Automotive Systems. This research was further fueled by government support, which recognized the benefits of promoting a domestic ethanol market. In March 2003, Volkswagen introduced the first commercial flex-fuel car, followed by General Motors (Chevrolet) and others. Four months earlier, the federal government had implemented two key measures: a reduction in sales tax on flex-fuel cars and an increase in taxes on gasohol. By the time flex-fuel car sales became mainstream in 2006, the lower sales tax had provided a $300 million incentive for flex-fuel car buyers, while the additional gasohol tax increase added $29 billion to the cost of gasohol for consumers. It can be argued that the introduction and success of the flex-fuel car was the result of "market" circumstances. However, three of the main market factors which drove this success were the result of government intervention: consumers were influenced by the tax incentive on flex-fuel car purchases, the availability of hydrous ethanol and its low price relative to gasohol. It is clear that consumers flocked to the government-induced lowest-cost automotive solution.

Current Government Support Instruments for Sugar & Ethanol

The Brazilian government continues to provide substantial support to the sugar and ethanol industry through a variety of mechanisms, some of which are specifically tailored to this industry, while others are more broadly applicable. This support is provided through financial support mechanisms, setting the mandatory blend, the power to set gasoline prices, taxation that favors flex-fuel, limiting competition (private diesel vehicles) and the ability to impose export taxes.

Nowadays, Brazil is the largest sugar producer and the second-largest source of ethanol. Supplying nearly 50% of internationally traded sugar, it is also the largest exporter of ethanol (most of which goes to the United States) - Figure22.

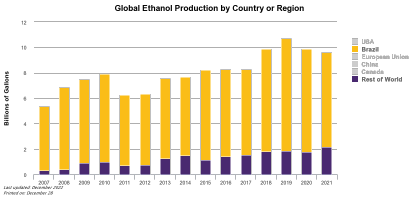

Figure 22: Comparison between Brazil and the rest of the world

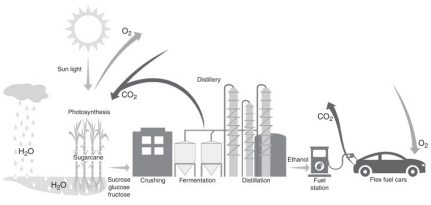

Figure 23: Ethanol production process

The Discovery of Pre-Salt Reserves and Changes in the Regulatory Framework in the Brazilian Oil Industry

In 2006, Brazilian oil giant Petrobras made a groundbreaking discovery – a vast reservoir of oil beneath a thick layer of salt off the coast of Brazil. This discovery, known as the pre-salt layer, held the potential to transform Brazil's energy landscape. However, extracting oil from this challenging environment was no easy feat.

Petrobras initially faced significant obstacles, including the extreme depths of the pre-salt region, the presence of multiple salt layers, and the complex geological formations. To overcome these challenges, the company launched the PROSAL programme, a research and development initiative focused on developing new technologies specific to the pre-salt environment. In 2010, the Brazilian government enacted the Pre-Salt Law, which established Petrobras as the lead operator in the pre-salt region and required foreign companies to partner with Petrobras to participate in exploration and production activities. This move was met with criticism, as some viewed it as a barrier to investment. The 2014 "Operation Car Wash" scandal further tarnished Petrobras' reputation, revealing allegations of corruption and mismanagement. The company's debt soared, and its financial position deteriorated.

In response to these challenges, the Brazilian government sought to amend the Pre-Salt Law, loosening Petrobras' monopoly in the region and allowing foreign companies to operate as lead partners. These reforms were intended to attract more investment and accelerate pre-salt development. As a result of these changes, Brazil witnessed a surge in pre-salt auction rounds, and Petrobras embarked on a $35 billion divestment program. The amended Pre-Salt Law aimed to unlock the full potential of Brazil's pre-salt reserves, ensuring the country's position as a major player in the global energy market.

Brazil's Rise as an Oil Exporter: Energy Independence Achieved

The pre-salt discoveries catapulted Brazil into the ranks of major oil producers, enabling the country to achieve energy independence and become an exporter of oil for the first time in its history. Brazil's oil production has continued to grow in recent years, solidifying its position as a significant player in the global energy market.

Brazil's climate change policies

Brazil's primary energy consumption witnessed a remarkable 38% surge from 2005 to 2021. While hydropower generation and oil continued to dominate the country's energy landscape, 'other renewable energy sources' (RES) experienced an astounding 253% growth, primarily fueled by biomass, which is projected to play an even more prominent role in the future. While oil remained Brazil's top energy source, witnessing a 17% increase in consumption, the country's renewable energy sources (RES) gained significant ground, reaching 46% of primary consumption in 2021. Hydropower, remarkably stable since 2005, accounted for two-thirds of this RES growth. Hydropower's crucial role is expected to continue, while solar and wind power are projected to surge by 2030(Fig24).

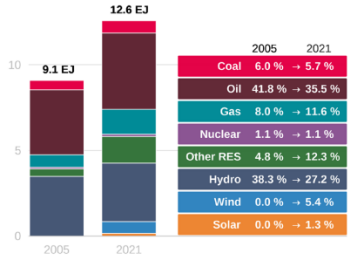

Figure 24: Primary energy consumption by energy source (exajoules, 2005 and 2021)

Brazil's latest NDC (Nationally Determined Contribution), updated in March 2022, reaffirmed its pledge to slash GHG (Greenhouse Gases) emissions by 37% by 2025 and 50% by 2030, compared to 2005 levels. Additionally, Brazil aims to achieve carbon neutrality by 2050, revising its earlier target of 2060. While Brazil has yet to submit its long-term low GHG emission development strategy, as mandated by the Paris Agreement, its 2020-2031 federal development strategy, published in 2020, includes an environmental strand focused on biodiversity preservation, illegal deforestation reduction, native vegetation recovery, and sustainable biomass utilization. This is supported by an announced 2030 climate action plan and a hydrogen national strategy which is being developed.

However, Brazil's climate policy falls short, according to Climate Action Tracker (CAT), indicating that the country's current actions are inadequate and emissions will continue to rise, missing its 2030 NDC target. CAT recommends a more ambitious target and stricter policies. The Climate Change Performance Index highlights the lack of nationwide emissions reduction policies and the inadequacy of existing, underfunded, and poorly monitored strategies.

2.5 Ukraine-Energy Development While Navigating Harsh Adversities

Ukraine´s current status

When reviewing countries that have a fighter mentality it becomes almost mandatory to write Ukraine´s name first. Fighting and surviving a war with one of the worlds most powerful military forces since 2014 while breaking through harsh winters is something remarkably fascinating. Having been invaded in February of 2022 led the Ukrainians to a series of adaptations on their lives, decisions and political measures. Being part of a good offensive strategy, the Russians politics and engineers have been determined to occupy and destroy their enemies sources of energy - for instance, the occupation of Zaporizhzhia nuclear power plant or the demolition of Kakhovka Dam - stating an huge impact on Ukraine's energy production and consequently their energy mix distribution.

Following the U.S. Energy Information Administration ([35]), energy demand exceeds domestic energy supply and therefore imports cover an energy gap of about 35%. Still, nearly 65% of Ukraine's total energy demand is covered by domestic production due to their focus on nuclear. The total installed nuclear power capacity was over 13 GWe, ranking 7th in the world, in 2020.

Ukrainians energy mix is relatively diversified, with no fuel representing more than 30% of the energy mix. In 2018, the share of coal (the country's primary fuel) dropped to 30%, followed closely by natural gas (28%) and nuclear (24%). Ukraine depends on imports for around 83% of its oil consumption, 33% of its natural gas and 50% of its coal. As of 2018 8.5 Mtoe (10.6 bcm) of natural gas, 13.8 Mtoe of coal and 10.4 Mtoe of oil products were imported by this people. Belarus, at the time, was Ukraine's main supplier of refined products. They have abundant mineral resources including oil, natural gas and coal, and great hydro and biomass potential.

Their renewables energy distribution through time is now displayed on the following figure (fig. 25)

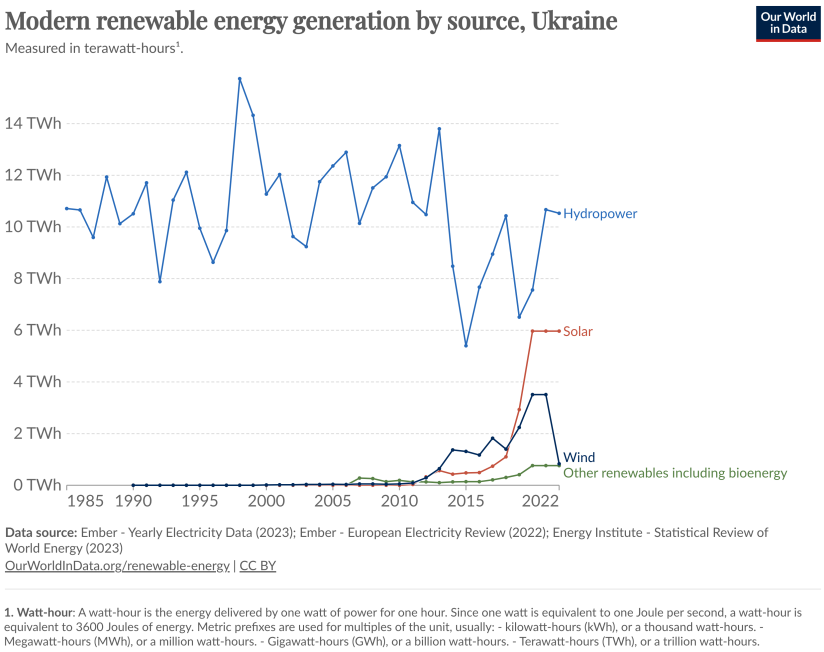

Figure 25: Renewables Distribution through time in Ukraine

By analysing this graph it´s clear that an investment in hydropower was made in Soviet Unions era in Ukraine and it was always the main source of energy inside the renewables share. If we look back in recent Ukrainian history, an investment on other renewables only started in 2017 when the total capacity of renewable energy facilities increased by more than 10%. For the 12 months of 2018, an additional 430 MW of power plant production of electricity from solar energy, wind, biomass, and small hydroelectric power plants were introduced. According to National Commission for State Regulation of Energy and Public Utilities([37]), only on the first quarter of 2019 it was invested the same amount as the whole 2018 for renewables. The investment only stopped when the Russians and their leader declared an invasion on the region of Crimea in 2022. A small downfall of some renewables share in 2022, (for instance solar), was due to war consequences.

With this in mind, a question is now raised: How can a country with a very dark recent past have such good self-sufficiency energy numbers? Well, this question could be answered since they are the second largest country in

Europe and therefore have many natural resources and land area. Also, their successive governments have always implemented measures that stimulate either nuclear energy or more recently renewables.

Communist legacy and three decades of initiatives

Ukraine´s energy story only begins in 1991 when an independence from the Soviet Union regime is declared. Before that, a centralized planning dictated resource allocation with management being made with national decisions instead of local. Nevertheless, an enormous nuclear legacy was left behind with some high caliber investment on the technology. Nowadays there are three nuclear power plants that were built within the old regime: Zaporizhzhia, Rivne and in South Ukraine. In 1986, one very famous accident occured in Chernobyl when reactor number 4 exploded. This was stated as the worlds first nuclear accident (only followed by Fukushima in 2011) which caused a radiation spread over eastern Europe. By rising this power plant, the government thought it would boost pride and could show what a Communist country could do. What they didn´t expect was the risk associated to this type of energy production. There were not only strange mutations on the perimeter of Chernobyl but also an increase on diseases caused by the radiation spread. As it´s observable from the following graph (fig. 26), the number of thyroid cancer cases has increased significantly. During 1992–2000 in Belarus, Russia, and Ukraine, about 4,000 cases were diagnosed in children and adolescents aged 0–18 years, with about 3,000 of these occurring in children aged 0–14 years

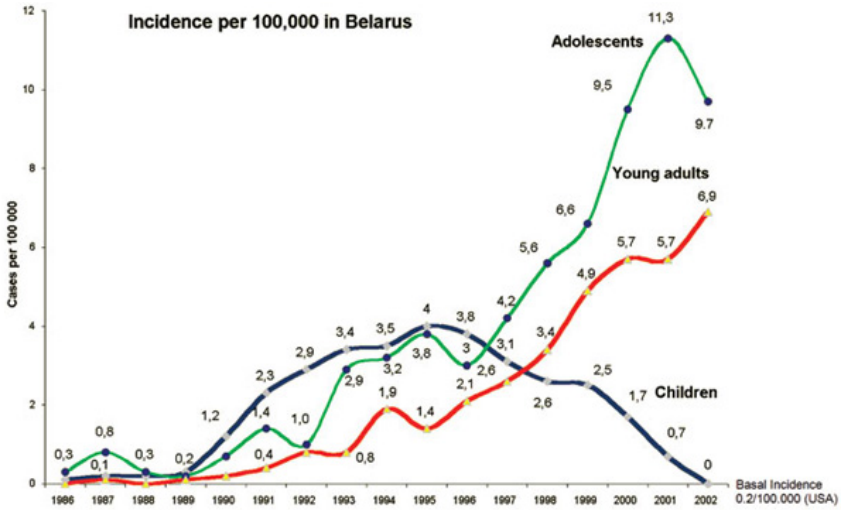

Figure 26: Thyroid Cancer cases In Belurus between the Chernobyl accident (1986) and 2002

After the accident, Chernobyl left a legacy of profound impact on the distribution and perception of nuclear power in Ukraine. It led to heightened awareness of safety issues, the implementation of stricter regulations, and a reassessment of the risks associated with nuclear energy. Reactors similar to those at Chernobyl were gradually phased out, and safety measures were improved at existing plants.

Although the Soviet regime was social and economically devastating, it left in Ukraine not only a huge legacy regarding nuclear energy but also a legacy on hydropower energy generation. The Soviets had made an intense exploration of the Dnieper River, one of the major rivers that flows through Ukraine. This created a fairly high share of hydropower energy in their energy mix. In more recent years, there has been some measures to keep what is already built and incentive new investments on this type of renewable, mainly on exploring smaller rivers and streams.

After their liberation from the Soviet regime, Ukraine proceed their path on energy management and investment. In the late 90's and early 2000´s some key initiatives were made to their land´s energy landscape. There was a market liberalization and privatization with their main example being Naftogaz. Ukraine´s state-owned oil and gas company was divided into several entities responsible for exploration, production, transportation, and distribution. This move aimed to introduce competition, enhance efficiency, and attract private investment. While the process faced challenges and controversies, it marked a crucial step towards a more market-driven energy sector. Another initiative was when some regulations by the National Energy Regulatory Commission (NERC) were made to energy tariffs with the sole purpose of ensuring compliance with market rules and boost competition within the sector.

One of their objectives was to increase the diversification and energy independence from Russia. To achieve it, in 2001 Odessa-Brody oil pipeline was finished and their dependency of russian oil suffered a significant decrease. This pipeline connected to Poland and allowed the Ukrainians to import gas from other sources beside Russia. This

measure started rising some polemics since, only three years later, the government at that time negotiated the change of the pipeline direction with Russia and induced a lost on their independence again. The direction of the flow in the pipeline was later improved and now it´s possible to import oil from western Europe again.

Another proof that they had the right mindset energy wise, is when, in 2005, they established their commitment to align their energy sector with European Union standards. They were presented with a treaty that aimed to create a unified regulatory space and facilitate integration with the EU energy market. After this treaty, they have also started implementing new initiatives towards solar energy and wind. Between 2005 and 2017, just for solar energy, the following main initiatives were established: Introduction of Feed-in Tariffs (2009) - The tariffs provided guaranteed prices for electricity generated from solar sources, incentivizing investments in solar projects which led to the growth of the total solar capacity; Green Tariff System implementation (2010) - it offered fixed prices for electricity generated from renewable sources. This system provided stability for investors and further encouraged the development of solar projects.; Construction of Perovo Solar Park (2011) - Located in Crimea it was built one of the biggest solar parks at the time increasing a lot the share of solar energy on the energy mix; Construction of Nikopol Solar Power Station (2013) - It showcased Ukraine's commitment to large-scale solar projects and added to the country's growing solar capacity;

Although solar energy suffered an huge investment, it wasn´t the only one that started being harvest by the Ukrainians. With their broad landscapes, wind also suffered some initiatives, for instance, also applying feed-in tariffs to wind projects in 2009 and building huge infrastructures like the creation of the Zaporizhia and Syvash wind farms in 2012.

More recently, in 2017 deputy Andrii Zhupanyn of the Ukranian Parliement saw approved his legislation package for a revolutionary boost to reach their energetic goals. It provided for certification of origin for green electricity and biomethane, net billing for prosumers, contracts for difference and better wholesale market integration for utility-scale renewables, as well as conditions for holding auctions for the allocation of quotas to support projects for the construction of new capacities. Thanks to this changes on their laws, Ukraine creates conditions for both public and private investments in renewable energy and overall decentralisation and modernisation of the energy system. New legal provisions also included improving conditions for connecting to grids of the transmission system operator and distribution system operators for decentralised generation and energy storage facilities. This package of legislation was one of the reasons for the renewables energies (beside hydropower) growth that beginned on 2017, as seen in the figure (fig. 25).

Economics upsets through their history

So, if Ukraine has great landscapes, many resources and the right mentality towards renewables, wouldn't it be expected for them to be leaders in this sector? The answer to this question is no. It´s not enough to think right and have good ideas, being economically stable and have good investment attraction mechanisms is the main key to develop this sector. As already explained, Ukraine only got their independence from the Soviet regime in 1991 and dealing with a communist legacy wasn´t the easiest of tasks. Furthermore, Ukraine´s culture was mined with corruption and lack of transparency which led to a difficult adaptation in the early 2000´s. In 2008, the global financial crisis had a significant impact on the Ukrainians books since their economic model wasn´t consolidated and robust. After that, in 2014, with the beginning of the Crimea conflict, this country suffered some political instability which provoked recession. Besides humanitarian consequences of war, inflation, currency depreciation, instability and fear were the main consequences of this conflict.

Ukraine today and tomorrow

Nowadays Ukraine has stopped their large scale investments and initiatives since the war that started in 2014, with Russia, over Crimea, has escalated to an invasion by the Russians. It led to destruction and loss of possession of some of their power plants and wind and solar farms. Not only that, but the control of some dams in the Dnieper river were also lost. Despite all this, the Ukrainian people chose once more to show their resilience since they have set a new objective in march of 2023: to have 50% of its power from renewable energy sources and 50% from nuclear energy by 2035. This alone states an exceptional mentality. Their will to have a more robust and resilient energy mix will help them in the long run once they find more peaceful and stable times. The investments didn´t stop with the war and wind and solar farms, like the one in Mykolaiv region ([21]), are still being constructed. The aim is to provide energy for the populations that are near those farms.

In conclusion, it´s predictable that as long as they are fighting a war in their own territory it will be very difficult for the Ukrainians to invest and promote on renewables or nuclear energy production. Higher values and priorities rise when they have their lives at imminent risk. However when more peaceful time arrive, if transparency and honesty were to be promoted, than Ukraine might become on of the world´s energy references or leaders.

3 Conclusions

The world fights to become renewable and get rid of the urge of fossil fuels exploration. The human species depends on their will to adapt and mitigate the impact of the global warming effect. Sustainability is becoming an objective for countries and the European Green Deal reflects this mindset.

Throughout this report it was presented some key initiatives and strategies that were used by some countries. As it was possible to observe, good management, stability, investment and will to change are the key factors for achieving sustainability since there are small countries with almost no internal resources that lead the sustainability rankings and other "giants" that are still a bit behind. Nevertheless, the fact that these nations are working together and supporting each other shows that there's a chance for everyone to come up with solutions for urgent environmental issues.

As described previously in this report, Denmark has been making good progress towards the net zero target. Through Government policies and private enterprises, the Danish are a hallmark of wind power striving for sustainable development. Subsidizing wind turbine installations and giving room for national companies to grow returned good results in the long run. The only questionable decision was the exclusion of nuclear power. This came about by the pressure of public opinion, which can often have a double-edged nature. While it likely helped with the development of wind energy, it also shut down any plans of investing in nuclear power.

However, it seems like sustainability runs through Nordic blood since Norway and Iceland have also been exemplar when it takes to being responsible and sustainable. Norway's approach to managing its new wealth through the Government Pension Fund Global (GPFG) has been a remarkable success story. The fund's achievements have exceeded expectations and it has become a global financial player. What sets it apart is Norway's deep-rooted commitment to sustainable practices. The Norwegian example serves as an inspiration for countries that want to achieve net-zero emissions targets and integrate sustainability into their financial strategies, showing a path to a greener and more economically robust future. Iceland's evolution from fossil dependency to renewable energy leadership is a testament to its resilience and commitment to sustainability. Through strategic initiatives, policy shifts, and a focus on harnessing geothermal resources, the nation has become a global example of successful energy transition. Despite challenges persisting in achieving carbon neutrality in specific sectors, Iceland achieved notable progress and stands as an inspiring case study in forging a more sustainable and resilient energy future.

In the looks of South America, Brazil's energy journey has been a remarkable tale of adaptation and innovation, from its early reliance on hydropower to the Proálcool program's sugarcane-based ethanol revolution. The discovery of offshore oil reserves further enhanced Brazil's energy independence, while the country's commitment to renewable energy sources like hydropower and biomass shows its dedication to a sustainable future. In line with this commitment, Brazil has set ambitious net-zero targets, aiming to achieve carbon neutrality by 2050. This goal underscores the country's leadership in the global energy transition, with a focus on diversifying its energy matrix, enhancing energy efficiency, and transitioning to a low-carbon economy.

The odd case of Ukraine has aroused interest since their conditions to develop are limited today. The social and economic paradigm is not looking good for the short term and they are now requested once more to show their will to survive and strive. Their nuclear investments are a key factor of their energetic mix history and being one the pioneers on this technology was something to highlight. It´s expected that, once they find peace, become more transparent and relight their investments on renewable energies, they will eventually become 100% sustainable.

Concluding, everyone needs to work together for a sustainable world. Success comes from good leadership, stability, smart investments, and a shared commitment to change. Some countries are doing well with renewable energy, while others facing challenges need to invest in a greener future. Global collaboration is key to addressing climate change impacts, paving the way for a more resilient and environmentally conscious world.

4 Identification of individual contributions

João Abreu, number 96713, was responsible for the section on Denmark (pages[6,9])

Francisco Pereira, number 98628, was responsible for the Introduction (pages [3,5]) and the section on Norway: The Government Pension Fund Global (pages [10,14]).

João Sousa, number 100205, was responsible for the section on Iceland: From Fossil Dependency To Renewable Leadership (pages [15,17]) as well as the respective introduction paragraph (page [4]) and conclusion paragraph (page[26]) regarding Iceland.

Pedro Manuel, number 96303, was responsible for the executive summary (page [1]) and the Brazil section (pages [18,19,20,21,22])

Joaquim Monteiro, number 96254, was responsible for the section on Ukraine: Energy Development While Navigating Harsh Adversities (pages [23,24,25]) and 4 paragraphs on the conclusion section (pages [26]-paragraph 1,2, and last two paragraphs).

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