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The Potential Role of Renewable Energy in Providing Energy Security of Azerbaijan

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Sopot 2022

ABSTRACT

The development of the renewable energy industry is high on the global agenda due to reasons like the reduction of carbon emissions, additional economic benefits, and added value to the strengthening of energy security. Being a long-standing adherent of hydrocarbon-based energy generation motivated by abundant domestic reserves, Azerbaijan has to take a big step forward in order to catch up with the global trend. Recent developments, agreements on different green projects demonstrate the will to improve the industry. Surely, the transition will come with implications on many spheres. This thesis studies the potential role of renewables in providing the energy security of Azerbaijan, keeping in mind its implications on the economy.

The prove the hypotheses that the *Development of the renewable energy industry accompanied with the increasing share of carbon-free electricity in total consumption can significantly increase the energy security of Azerbaijan and positively impact the economy*, thorough analyses of experiences of specially selected countries, estimated added value to the economy, the present stage of energy security and implications of green energy on it have been carried out.

The assessment of the energy security of Azerbaijan and the potential impact of renewables has been carried out based on the following methods: 1) the International Energy Agency's (the IEA) Model of Short-term Energy Security (MOSES) methodology; 2) International Institute for Applied System Analysis' (IIASA) Global Energy Assessment (GEA); and 3) Winzer's methodology. Estimation of added value to the economy was carried out in line with the findings and schemes produced by the International Renewable Energy Agency combined with calculations made with the figures provided locally.

The findings reveal the positive impact of renewables on energy security and added value to the economy. Despite serious shortcomings in terms of the legal framework, expertise, and experience, there is a strong momentum demonstrated with an increasing number of debates and projects on green energy. Recommendations made after analysis of findings are aimed to boost the effectiveness and efficiency of the transition to carbon-zero energy generation.

Contents

INTRODUCTION

The collapse of the Soviet Union left 14 fragile states besides Russia on their own in a transitioning world where power balances shattered and shifted enormously following the breakup of the mighty empire. The first country to start the disintegration process of the Union of Soviet Socialist Republics (USSR) was Lithuania which declared its pre-war independence in March 1990 with the newly-elected Parliament adopting a bill on the restoration of Lithuanian sovereignty (Current Digest of the Soviet Press, 1990). Shortly after Azerbaijan continued the blueprint of other countries and the *Ali Soviet* (Supreme Council) adopted a Declaration of Independence of the Republic of Azerbaijan on October 18, 1991 (Constitutional Act on Declaration of Independence of the Republic of Azerbaijan, 1991). Thus, after 71 years of Soviet rule Azerbaijan restored its sovereignty claiming itself to be the historical successor of the Azerbaijan Democratic Republic which lived shortly during 1918-1920 (Constitutional Act on Declaration of Independence of the Republic of Azerbaijan, 1991).

Though regaining independence was what millions were desiring of, vulnerable political and economic condition and lack of leaders who could lead the country resulted in full chaos with two presidents changing in 2 years only. Political, economic, and social conditions were further hampered by the ongoing conflict with Armenia over Nagorno-Karabakh. Weak central power and anarchic state of being in government led to the occupation of districts of Azerbaijan one-after-another (Croissant, 2010). As a result, millions had to flee their homes heading to different regions and Baku. They were homeless and living in miserable conditions without any income source which was stimulating continuing deterioration of socio-economic life.

Azerbaijan was on the edge of disintegration with ethnic minorities uprising for independence in different regions of the country when the National Leader Heydar Aliyev arrived in Baku to take the office of the head of the state after the preceding statesmen escaped the scene failing to deliver their promises. On October 3, 1993, he became the official elect president and run the country till 2003 (History of Azerbaijan, 2008). It became a turning point in the history of the two-year-old state with the conflict reaching ceasefire agreement in 1994, and the historical “Contract of the Century” signed in at the same year with eleven companies representing seven countries on joint development and production sharing of hydrocarbon resources in Azeri, Chirag and Gunashli fields located in the Azerbaijani sector of the Caspian

Sea (Waal, 2004; Mirbabayev, Coincise History of Azerbaijani Oil, 2008). As of 1994, Azerbaijan's economy started expanding extensively each year thanks to petrodollars which didn't become a curse for the country as in many other experiences. Instead, wise utilization of incoming revenues, a strong hand in unifying the population around a single idea of powerful statehood, and a decent political will put the country on the flourishing path.

Oil and gas resources helped the government to shift the course of the political, economic, and social life of the country which was deteriorating at a fast pace. After the Baku-Tbilisi-Ceyhan pipeline was put to exploitation in 2006, revenues from the sale of natural resources peaked and the Gross Domestic Product (GDP) of Azerbaijan set an astonishing growth rate of 34,5 percent at the same year making it one of the fastest expanding economies in the world (World Bank, 2020).

Nonetheless, oil and gas are depletable resources and full reliance on fossils for long-term is not sustainable. According to the BP report, the reserves-to-production (R/P) ratio of oil in Azerbaijan is slightly more than 24 years, and the same figure for natural gas is close to 117 years, as per 2020 statistics (Statistical Review of World Energy, 2020). The extraction of oil started to decrease as of 2011, and the government opted for gas to sustain the development for the next couple of decades (State Oil Company of the Republic of Azerbaijan, 2018). A second "Contract of the Century" was signed on September 20, 2014, opening the doors of the European market for Azerbaijani gas (Presidential Administration of Azerbaijan, 2018). However, Baku is aware of the limits of its depletable energy resources and is working hard on diversification of its economy and ensuring the energy security of the country. To accomplish the first mission, a number of strategic plans and roadmaps were developed to boost the development of the non-oil industry, including tourism, agriculture and information technologies. To ensure energy security the government looks forward to the development of the renewable energy industry.

This thesis will dive into the renewable energy resources of Azerbaijan trying to discover whether green energy is the real deal for the country to ensure full safety from fossil fuel exhaustion.

Similar to the renewable energy industry (REI), research and academic studies around renewables in Azerbaijan is a novelty. A select number of local specialists have ever conducted a scientific work on the green energy generation. The majority of existing local literature focuses on broad topics like the assessment of wind or solar potential of the country but has significant data restrictions. The main goal of this thesis is to explore the potential contribution level of renewable energy, focusing on solar and wind potential, to increasing the energy security of Azerbaijan. At the same time, financial feasibility and impact on the economy will be assessed to check the worthiness of investments into the REI, at least at the current stage.

Throughout the thesis following research questions will find their answers:

1. What is the present stage of the development of the renewables industry in Azerbaijan?
   1.1. What is the share of renewables in overall energy consumption?
   1.2. What are the perspectives of solar and wind power production?
   1.3. What is the current situation regarding the legal framework of renewables?
2. What is the present stage of the energy security of Azerbaijan?
3. Can renewable energy strengthen the energy security of Azerbaijan?
4. What are the financial and economic implications of the development of the renewable energy industry in Azerbaijan?

The thesis employs qualitative research methodology combined with deductive reasoning and is built around the below hypothesis:

> *The development of the renewable energy industry accompanied by the increasing share of carbon-free electricity in total consumption can significantly strengthen the energy security of Azerbaijan and positively impact the economy.*

Up to date, no study in Azerbaijan has ever been conducted analyzing the potential impact of renewables on the energy security. The financial feasibility and economic impact of green energy are also undiscovered from the academic point of view. In light of a lack of comprehensive scientific study, this thesis aims to fill the gap and contribute to the future development of renewables in Azerbaijan.

Due to data limitations, the study employs qualitative approach with focus on existing energy security assessment frameworks. The International Energy Agency's Model of Short-term Energy Security (MOSES), International Institute for Applied System Analysis' Global Energy Assessment (GEA), and Winzer's methodology of energy security assessment framework will be applied in combination throughout this study to explore the current situation in Azerbaijan in regards to the energy security and potential contribution of renewable energy development.

Approaches of MOSES and GEA to the notion of energy security is identical in broad terms: main energy systems, risk sources and factors, resilience capacities are identified and analyzed in the lieu of pre-defined understanding of energy security. The MOSES model presents four main aspects into energy security analysis.

Table 1.1 Dimensions of energy security as per MOSES methodology (Jewell, 2011)

	Risk	**Resilience**
External	Risks associated with potential disruptions of imports of energy or raw material necessary to generate energy.	Ability to respond to potential disruptions by substituting imports.
Domestic	Risks associated to domestic production and transformation.	Ability to respond to production and transformation related risks.

The GEA's IIASA model adds more dimensions like global or domestic resource scarcity, market volatility, energy infrastructure and related risks factors, etc. (Cherp Aleh, 2010). It should be noted that both MOSES and IIASA methods are applying qualitative approach based on available data. In his 2011 study names *Conceptualization of Energy Security*, Christian Winzer describes assessment framework which consists of four main pillars: operational definition; energy systems, risk and resilience capacity; and interpretation (Winzer, 2011).

Comparative case analyses will be conducted to explore the current situation with a transition to green energy in a select number of countries and possibilities of applying similar practices in Azerbaijan. Business models will be developed to assess the economic and financial feasibility of the development of green energy industry. The thesis will come up with recommendations based on findings. The distribution and contents of chapters are disclosed below.

Chapters 1 and 2 are of descriptive character and aim to give an overall, yet detailed overview of the energy industry in Azerbaijan, its development history, present situation around renewables, and the modeling of energy security. The energy security will be analyzed based on the following methods: 1) the IAE's MOSES methodology; 2) the IIASA's GEA methodology; and 3) Winzer's methodology. Being globally recognized as one of the best methods, the

MOSES scheme allows to overcome the restraints in terms of data availability and fits the rationale of qualitative research method.

Chapter 3 will carry out the case study of the countries with similar geographic conditions, and wind and solar power indicators to Azerbaijan, but with a high degree of success in terms of green energy penetration into consumption. Detailed analysis of the development of renewables in those countries, together with the applied legal framework and supportive policies will be conducted and findings will be tested for applicability in Azerbaijan in Chapter 4.

Chapter 5 will present wind and solar power projects with estimated output capacity, financial implications, feasibility, and opportunities of integration to the energy system. The major restriction of the study is a lack of reliable data, especially for long-term wind and solar indicators like mean wind speed, mean wind density, average sunlight power density, etc. Hence, accurate calculations to find wind and solar potential for a given territory or project is challenging, since the globally accepted methodologies and tools require at least one to two years of daily data on the above-mentioned indicators. Therefore, assessment of solar and wind power generation, together with its financial aspects will be carried out based on overall data available in sources like the World Bank, IRENA, and Ministry of Energy of Azerbaijan. The main purpose of Chapter 5 is to answer the question of whether the development of wind and solar plants are financially feasible, especially for private generators.

Chapter 6 will present final findings on the contribution of renewables to the energy security of Azerbaijan, its implications on the economy, and provide recommendations on how to develop the renewable energy industry.

Chapter 1. The Historic Role of Hydrocarbon Resources in the Development of Economy of Azerbaijan

Chapter 1.1. Background of oil production and its contribution to the economy

Hydrocarbons are minerals composed of hydrogen and carbon molecules and represent natural resources like oil, gas, and coal (University of Calgary, 2018). This study will dive into the oil and gas industries of Azerbaijan as no significant coal sources are found in the country.

The oil history of Azerbaijan can be divided into three main stages:

- **First stage: Pre-industrial era.** Remarks about the oil and its utilization in Azerbaijan can be found in the notes of travelers and other authors even in the fifth century. Researching the existing literature on the history it is not hard to find dozens of various local and foreign sources where authors indicate about hydrocarbon resources of Azerbaijan. Nonetheless, up to the mid-XIX century, exploration and production of oil were delivered with simple non-industrial methods where the whole process mainly laid on manpower and was resulting in low output like ten barrels per day or even less (Baghirov, 1996).
- **Second stage: Industrial era up to the independence of Azerbaijan.** As of mid-XIX century, the first oil well was drilled in Azerbaijan with industrial methods beating its closest rival in Pennsylvania with eleven years (Mirbabayev, Azerbaijan's Oil History, 2002). This development became a milestone in oil history of Azerbaijan boosting its export and contribution to the economic life. As of 1871, the hydrocarbon industry of Azerbaijan started to develop robustly up to 1910-1920 and continued expanding at a rapid pace after short fragile period related to the *Bolshevik* revolution, and establishment and break-down of the Azerbaijan Democratic Republic which existed for 23 months only. The industry further flourished before and after World War II up to late 1980s making a stupendous contribution to the existence of the Soviet Union.
- **Third-stage: "Contract of the century" and onwards.** September 20, 1994, became a milestone in the hydrocarbon industry of Azerbaijan with the "Contract of the Century" signed with eleven companies representing seven countries. As a part of long-term oil strategy, Baku-Tbilisi-Jeyhan main oil pipeline was set to exploitation as of 2006 which boosted revenues from the sales of natural resources seeing its historical peak in 2011. Most of the companies which signed the contract on production sharing of the oil and gas resources in Azeri, Chirag, and Gunashli oilfields are still operating in Azerbaijan contributing to overall production level and to the economy respectively.

Pre-Industrial Era

The very first notes on the oil industry and its connection to political and economic life in Azerbaijan go as back as to the fifth century. Prisk Pontic, a Byzantine author described flames in sea rocks of Caspian, which was no doubt hinting at oil and gas fields in the basin (Aleskerov, 2012). The very first notes on the utilization of fossil fuels started to appear in remarks of Arabian traveler Al Belazuri Ahmad (ninth century), who mentioned in his notes that the life in Absheron peninsula has long been tied with the production of oil. A century later, historian Masudi Abdul Hussein identified two main oil sources in Azerbaijan and another historian Istahri Abu-Ishkak described how people used oil as fuel in Baku (Mirbabayev, Azerbaijan's Oil History, 2002). Similar records of hydrocarbon resource production in Azerbaijan can be found in dozens of other sources belonging to XIII century and later.

The prominent traveler Marco Polo wrote that already in 14th century, Absheron peninsula was home to many oil wells and the product was exported to Eastern countries (Baghirov, 1996; Mirbabayev, Azerbaijan's Oil History, 2002). The American meteorologist Charles Marvin observed back in 1877 that oil had been being imported from Absheron peninsula to foreign countries for already more than two hundred years (Wilson, 2013).

Professor Miryusif Mirbabayev, a scientist who made important research into Azerbaijan's oil history noted that:

> *"By the 19th century, Azerbaijan was by far the frontrunner in the world's oil and gas industry. In 1846 - more than a decade before the Americans made their famous discovery of oil in Pennsylvania - Azerbaijan drilled its first oil well in Bibi-Heybat. By the beginning of the 20th century, Azerbaijan was producing more than half of the world's supply of oil."* (Mirbabayev, 2002)

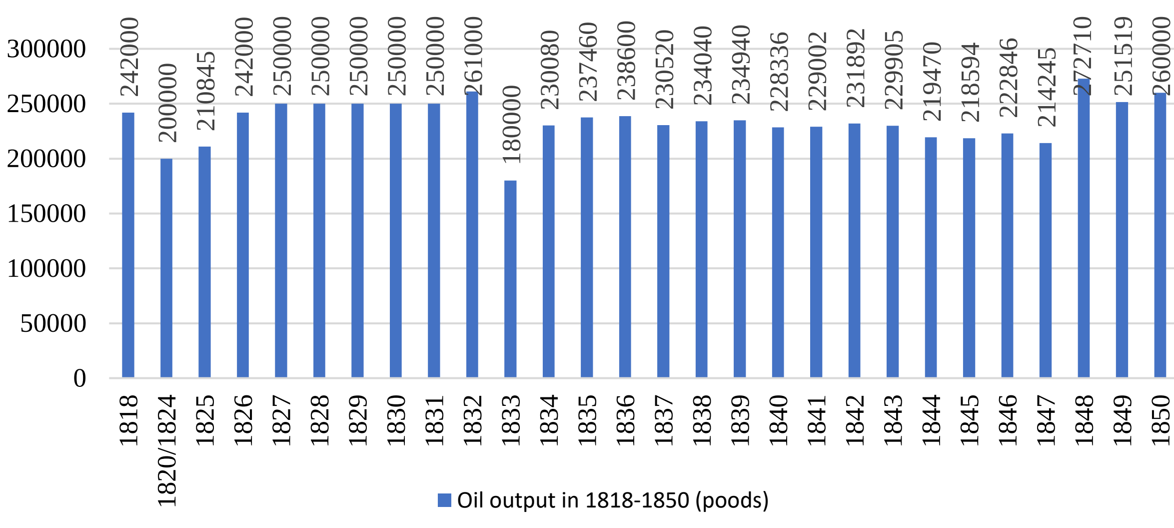
Nonetheless, the very first oil wells were dug rather than drilled with almost no engines or steam power included in the process. Exploration and overall production process were handled by manpower only. Thus, daily oil output at the time was not even close to the later stages of development when engines were introduced into the industry. Existing sources report approximately fifty oil wells with an average depth of three to five meters by 1806. By 15 years, this number yielded more than twice with 120 wells dug in up to 1821. Daily output figures, however, was very low with little more than ten barrels per day (bpd), and accumulated oil was stored in state-owned storehouses (Baghirov, 1996).

Though oil was already widely produced and even exported, its contribution to the economy of the country cannot be said to be significant up to late XIX and early XX century. It was mainly used for greasing camels, night-time lighting and heating with Iran being major importer (80 percent) of the product (Azerbaijan SSR Academy of Sciences, 1949; Zeynalov, 2016). Azerbaijan was under *tsarist* Russian rule at the time which imposed short-term leasing system for the exploitation of oil fields and lacked the capacity to absorb high output potential of Baku. Sources share different information on the introduction of the short-term leasing system with local authors claiming it was enforced back in 1807, while Western literature insists on 1821 and onwards (M. Ibrahimov, 1991; Martellaro, 1985). Though with the short-term leasing system leaseholders enjoyed privileges of extracting oil in state-owned lands and monopoly over the product, there were several factors undermining interest in starting the business:

- They had to pay annual sum irrespective of the output and revenues;
- They never gained actual ownership over the well or the assets used;
- They had to hand over all their investments and assets to the next leaseholder upon the contract end date, etc. (Zeynalov, 2016)

The annual oil output varied between 1818 and 1850 with 183,000 poods[1] being the lowest and 272,000 poods the highest figure reached. Below is the graph representing the output in the mentioned timeframe (M. Ibrahimov, 1991).

Graph 1.1 Oil production volume in 1818-1850 (poods)



[1] *Pood* is a unit of mass measurement equivalent to 16.38 kilograms. Yakovlev, *Development of Wrought Iron Production*, Metallurgist press, 1957.

Source: (M. Ibrahimov, 1991)

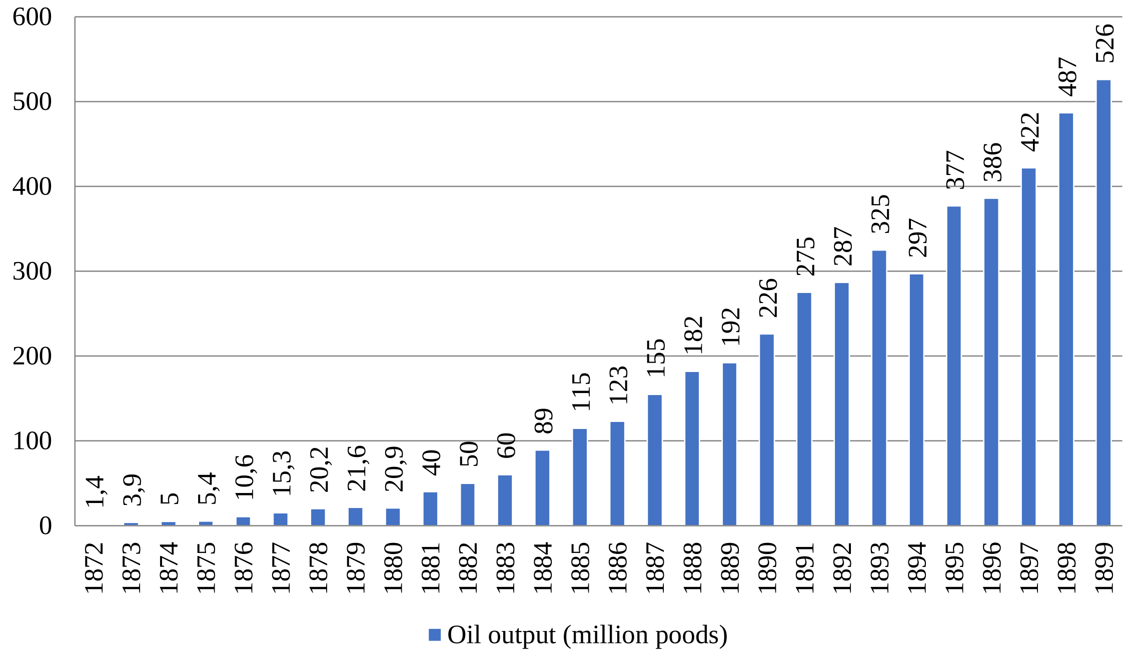
Tsar regime started regulating the price of oil as of 1839 setting 35 *kopeiks* (cents) per liter. Later, the price was increased up to 40 *kopeiks* in 1846, and 45 *kopeiks* in 1847 (M. Ibrahimov, 1991). In 1834, after the end of the leasing period, contract holders rejected prolonging their ownerships of oilfields, due to low interest and other disadvantages listed above. Hence, oilfields remained under the state balance up to 1850 when the scene had evolved enormously with the introduction of technological advancements (M. Ibrahimov, 1991).

The share of fossil fuels in the economy of Azerbaijan was relatively low with leaseholders abstaining from developing the industry sticking to a long-term vision. Thus, despite high enthusiasm, restrictive *tsarist* management of oil production with short-term leasing system, and lack of technological advancement up to the introduction of fully industrial drilling methods in *Bibi-Heybat* and *Balakhani* (in 1848 and 1871 respectively) hindered potential contribution of hydrocarbon resources to the economy. Moreover, after the Russian invasion of Azerbaijan, though on paper all oil wells were confiscated from *khans* and private landlords and transferred to the state balance until 1820 they were actually abandoned (M. Ibrahimov, 1991). Nonetheless, the situation has completely changed with first mechanical and industrial oil wells drilled in Absheron peninsula in the second half of the XIX century.

Industrial Era

The hydrocarbon industry of Azerbaijan saw a revolutionary development with the introduction of technological advancements into the exploration, drilling and extraction process. Local sources claim the first ever industrial oil well was drilled in *Bibi-Heybat* in 1848, while Western authors insist that though technology was applied, the oil well in *Bibi-Heybat* can't be considered as the first industrial well since no concrete steam power or engine was used in the drilling process, and the well was not cased. Thus, it could be the first mechanical one, but not industrial. Considering this mere factor, many claim Edwin Drake's 1859 well in Pennsylvania is the first industrial oil well in the world (Vassiliou, 2009; Mirbabayev, Azerbaijan's Oil History, 2002). Nonetheless, the *Bibi-Heybat* and *Balakhani* (1871) wells transformed the industry into a new path of development drastically increasing the yearly output. As of 1872, Azerbaijan was already extracting more than a million *poods* of oil and reached hallmark of 500 million *poods* in 1899. Graph 1.2 demonstrates production volumes in 1872-1899 (M. Ibrahimov, 1991).

Graph 1.2 Oil production volume in 1872-1899 (million, poods)



Source (M. Ibrahimov, 1991)

If in-between 1821-1872 the government earned only 5 million *manats* from the oil industry during 51 years, in 1872 alone, the revenue from the hydrocarbon resource sales exceeded 3 million *manats* (M. Ibrahimov, 1991).

Technological advancement was not the sole locomotive of such speedy progress in fossil fuel production. 1872 February rulings of the Russian *tsar* forever abandoned the short-term leasing system adopted earlier allowing private landlords to start exploration and extraction of oil in 'special state lands' for long-term business. Besides, Russia's absorption capacity increased enormously as the oil was not used for lighting and heating purposes only but became a major source of energy in different industries. *White oil* was especially successfully exported as Baku was able to force out American oil from the Russian market. In 1880, Absheron's white oil constituted 80 percent of Russia's total oil import. Up to 1889, Baku oil was already exported to countries like England, Austria-Hungary, Holland, India, China, and Japan (M. Ibrahimov, 1991). At early XX century, Azerbaijan was producing 10 million tons of oil in a year which accounted for half of the world's output at a time (Baghirov, 1996).

During apace development period of the industry, Azerbaijani oil *magnates* were playing a key role in the business constituting 29,3 percent of all entrepreneurs (49 out of 167) operating in the Russian oil industry. Millionaires Hadjy Zeynalabdin Taghiyev, Isa bey Hadjinsky, Murtuz Mukhtarov, Shamsi Asadullayev, Seyid Mirbabayev, and others were leading players in the market (Heydar Aliyev Fund, 2018). Nonetheless, aggressive progress was not overlooked by leading at that time foreign companies. In the late 1870s and 1880s eight British, three French, two Swedish, two German, two Belgian and one Danish company were operating in the oil industry of Azerbaijan. Soon arrived Nobel Brothers (1879) and Rothschilds (1883) opening a new page in the hydrocarbon industry history of Baku (Guliyeva, 2007; Mirbabayev, 2018). In early 1900s Emmanuel Nobel and Alphonse Rothschild signed a cartel agreement merging their forces in newly established "Nobmazut" company and started dominating the industry for the next decade.

Starting from 1910 the industry shrank due to vulnerabilities within the Russian empire and fragile economy. In 1918, Azerbaijan Democratic Republic (ADR) – the first ever Muslim majority democratic republic in the Eastern hemisphere was founded (Tahirov, 2018). ADR started privatization of oil companies helping to revive the industry, though for short time. With the establishment of the USSR, oilfields were again nationalized which further dumped the production. Nonetheless, till the 1940s the industry recovered playing a crucial role in the Soviet's victory over Nazi Germany. During the World War II, Azerbaijan was providing 63 percent of overall oil output of Russia (Baghirov, 1996). Production reached its peak in 1941 with 23.5 million tons of oil extracted accounting for 71.4 percent of overall extraction in the Soviet Union (Azvision, 2015). During the War, Azerbaijani oilmen produced staggering 75 million tons of oil, 22 million tons of gasoline, 22 million tons of lubricants, and 6,5 million m^3 of natural gas ensuring non-stop operation of engines used in military operations (Ulduzov, 2013).

Commissioning of the *Neft Dashlary* - the first offshore oilfield in the history of mankind became another milestone in the hydrocarbon industry history of Azerbaijan. Along with extensive offshore oil extraction development, several onshore gas fields were discovered in Absheron peninsula (Kurovdag, Mishovdag, Kursanga, and etc.) during the 1950s and 1960s (Heydar Aliyev Fund, 2018).

The 1960s and 1970s were marked with the continuing development of the industry highlighted with penetration of solid material and technological basis into the exploration and extraction process. Introduction of new technologies allowed exploration of oil and drilling of wells at the depth of 80-350 meters leading to the discovery of “Azeri”, “Chirag”, “Gunashli”, and “Kapaz” fields in the late 70s and early 80s. “Azeri”, “Chirag”, and “Gunashli” (ACG) platforms became a cornerstone of the new oil strategy adopted by the National Leader Heydar Aliyev after Azerbaijan restored independence in 1991. According to available data, oil production volume varied approximately at 10-12 million tons during the 70s reaching its highest output in 1970 with 12,9 million tons. However, these figures decreased starting from 1984 and overall production dropped down by 34 percent during 1984-1990 in comparison to 1969-1982 (Ulduzov, 2013). The aftermath of the industry is connected to the restoration of sovereignty and the adoption of the new long-term oil and gas strategy.

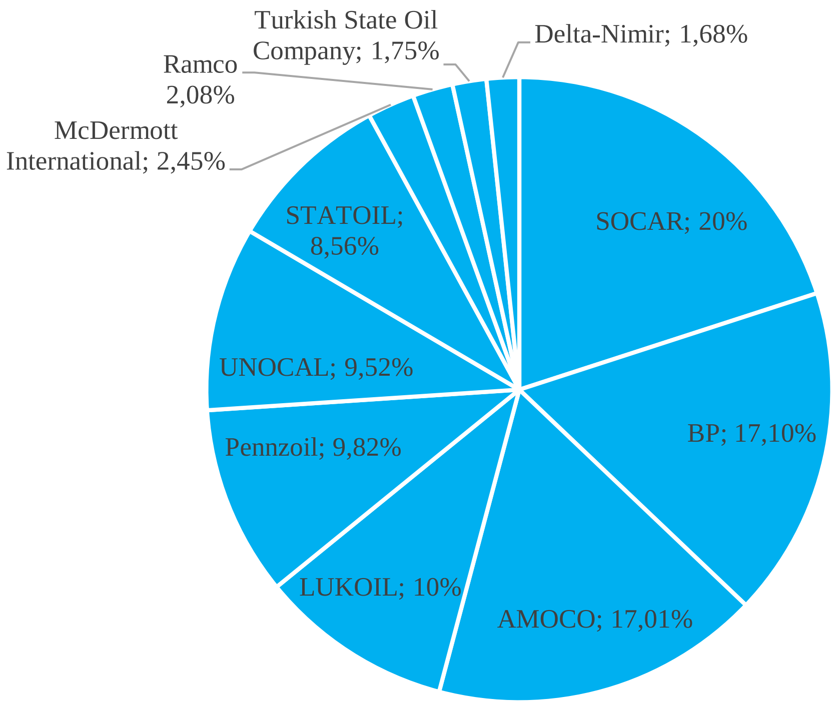
The Third Stage: Oil industry of Azerbaijan After Independence

The 1991 Declaration on the restoration of the sovereignty of Azerbaijan started a new page in the oil industry of the country and its contribution to the economy, though not immediately. Stabilization of the socio-economic and political life, soothing of the tensions within different groups took three years laying grounds for the inception of the new era in the history of Azerbaijan. The implementation of the new oil strategy designed by the government headed by the National Leader Heydar Aliyev kicked off with the signing of 400-page joint development and production sharing agreement over “Azeri”, “Chirag”, and “Gunashli” fields with 11 global scale companies representing seven countries. The contract, labeled as the “Contract of the Century” was signed on September 20, 1994, envisioning long-term cooperation for at least 30 years. To implement the agreement and manage it, international consortium named Azerbaijan International Operating Company (AIOC) was formed on February 1995. AIOC includes ten companies and is led by BP holding 30.25 percent of its shares (Woodward, 1998).

Though the initial potential of the fields was estimated at 511,000,000 tons of crude oil, later investigations revealed the potential of 1,072,000,000 tons (Presidential Administration of Azerbaijan, 2018).

Following companies took part at the initial stage of the agreement:

Graph 1.3 Share of companies in the "Contract of the Century"



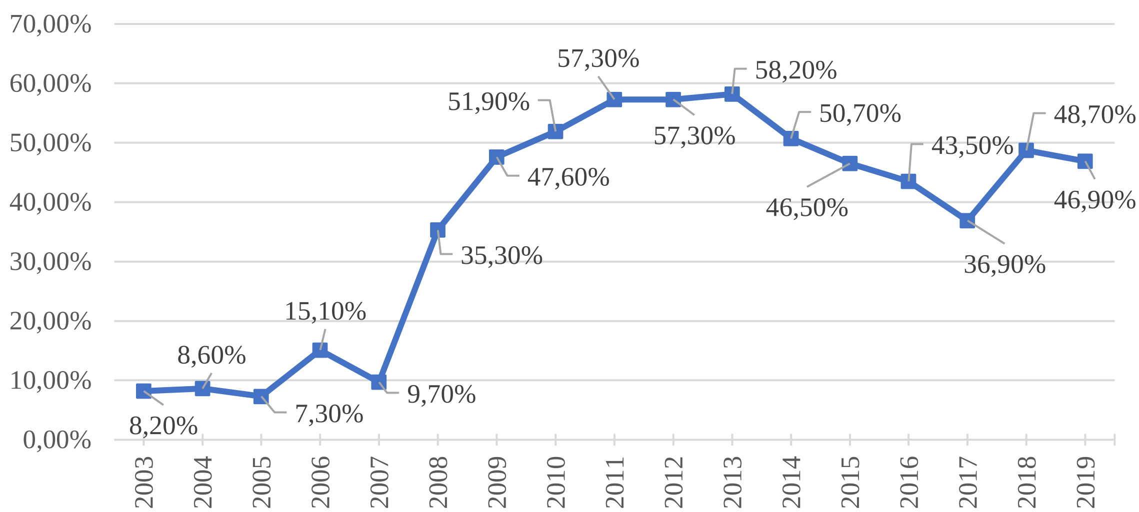
Source: Azerbaijan International Journal (Nasser Sagheb, 1994)

The Contract was later amended with American Exxon and Japanese ITOCHU companies entering the agreement. Besides, Exxon and Turkish TPAO each acquired 5 percent of SOCAR's share and became participants to the production sharing (Nasirov, The Contract of the Century, 2010). Later, this agreement was further enhanced with the signing of another 26 contracts with 41 international companies representing 19 countries (Presidential Administration of Azerbaijan, 2018). On September 2017, the Contract was extended up to 2049 with SOCAR's share in the PSA projected to grow to 25 percent (current, 11.65%) (Oil and Gas Journal, 2017). Thus, the Contract became the backbone of the oil strategy and the major contributor to the country's wealth. To deliver the product to the global market, two pipelines, Baku-Novorossiysk (1997) and Baku-Supsa (1999) were commissioned prior to Baku-Tbilisi-Jeyhan, the main oil pipeline inaugurated in 2005 (Boris Najman, 2008). The first tanker with oil from the Caspian Sea was sent to global markets in 1999 (Presidential Administration of Azerbaijan, 2018).

Fossil fuel became an aorta of the economy of Azerbaijan supplying vital financial power necessary to reconstruct the exhausted infrastructure, boost socio-economic life and increase the livelihood of the population. At the same time, it was crucial to effectively manage petrodollars in order to prevent possible macroeconomic degradation due to a huge inflow of money into the economy. Baku took right measure establishing in 2000 the State Oil Fund of the Republic of Azerbaijan (SOFAZ) responsible to accumulate wealth from the sales of natural resources and safeguard macroeconomic stability.

Though pivotal contribution of the oil industry (and signing of the Contract) into the economy of Azerbaijan since the very inception of the strategy is undeniable, tracking its share in the state budget, GDP or income of the country up to early 2000s is difficult due to its diffusion to statistics under different sections. Up to 2003, no state laws identified revenues from the sales of hydrocarbon resources as the income source of the budget.[2] Starting from 2003, the government included transfers from SOFAZ into the state budget as a source income thus clarifying share of oil and gas revenues in the economy of the country. Below graph demonstrates the percentage of the allocations from SOFAZ in the state budget for 2003-2019.

Graph 1.4 Share of the transfers from SOFAZ in the state budget

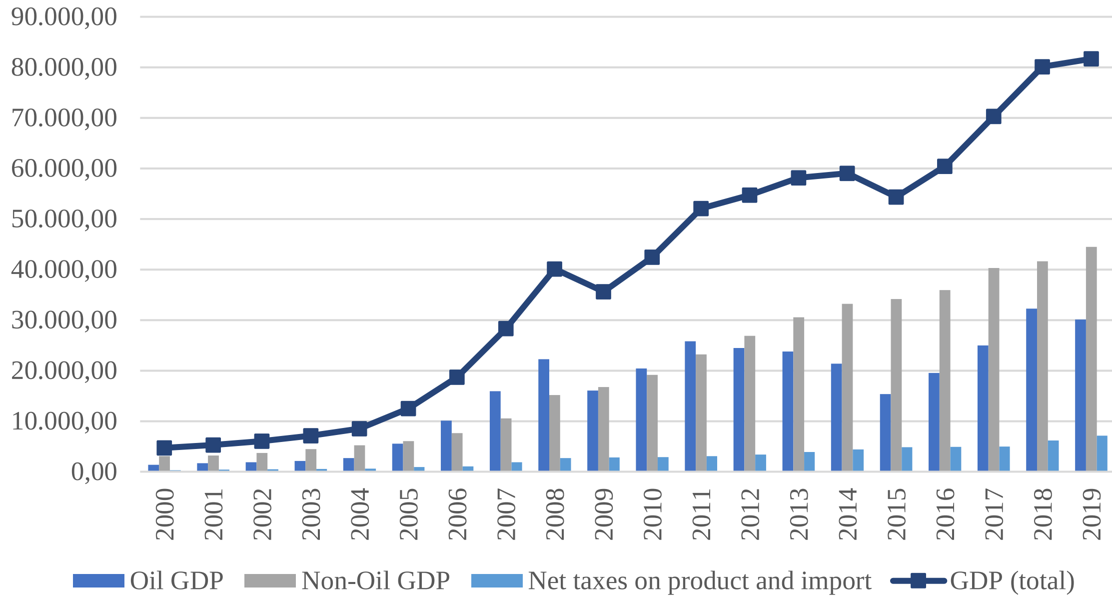


Source: State Oil Fund of the Republic of Azerbaijan (State Oil Fund of the Republic of Azerbaijan, 2019)

Graph transparently shows a heavy reliance on the income generated from the sales of oil and gas resources with a contribution to the state budget climbing above 50 percent threshold from 2010 up to 2015 reaching its maximum (58,2 percent) in 2013.

[2] All laws on the state budget of Azerbaijan since 1994 can be found at the online legislative document database at www.e-qanun.az. Though laws provide breakdown of the income sources of the state budget, revenues from the sales of hydrocarbon resources as income source are never indicated up to 2003.

Graph 1.5 Composition of GDP of Azerbaijan (AZN, million)

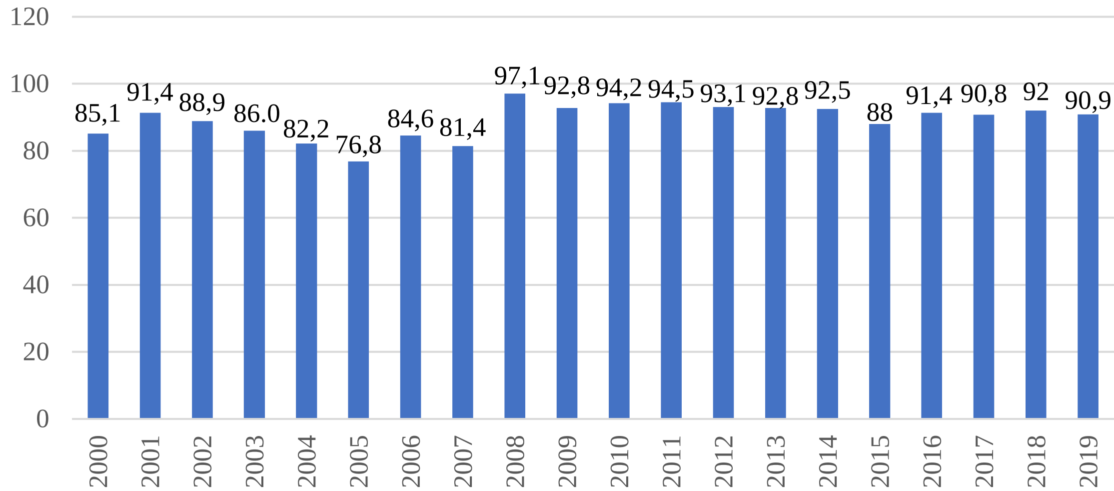


Source: Data obtained from the State Statistics Committee of the Republic of Azerbaijan (available online) (State Statistics Committee of the Republic of Azerbaijan, 2020)

Hydrocarbon industry constituted a significant part of the GDP as well, according to the data available as of 2000.

Impact of the fossil fuel in the economic indicators can also be obviously seen in the foreign trade statistics since 1994. Again, according to the data provided by the State Statistics Committee (SSC) oil and gas products constitute lion's share of the country's export. Despite stupendous efforts allocated to the diversification of economy and adoption of several state programs aimed at decreasing dependency on revenues streamed from the sales of natural resources, the share of hydrocarbon resources in overall export of Azerbaijan has never fallen below astounding 76 percent since 2000.

Graph 1.6 Share of oil and gas products in the foreign trade of Azerbaijan (percentages)

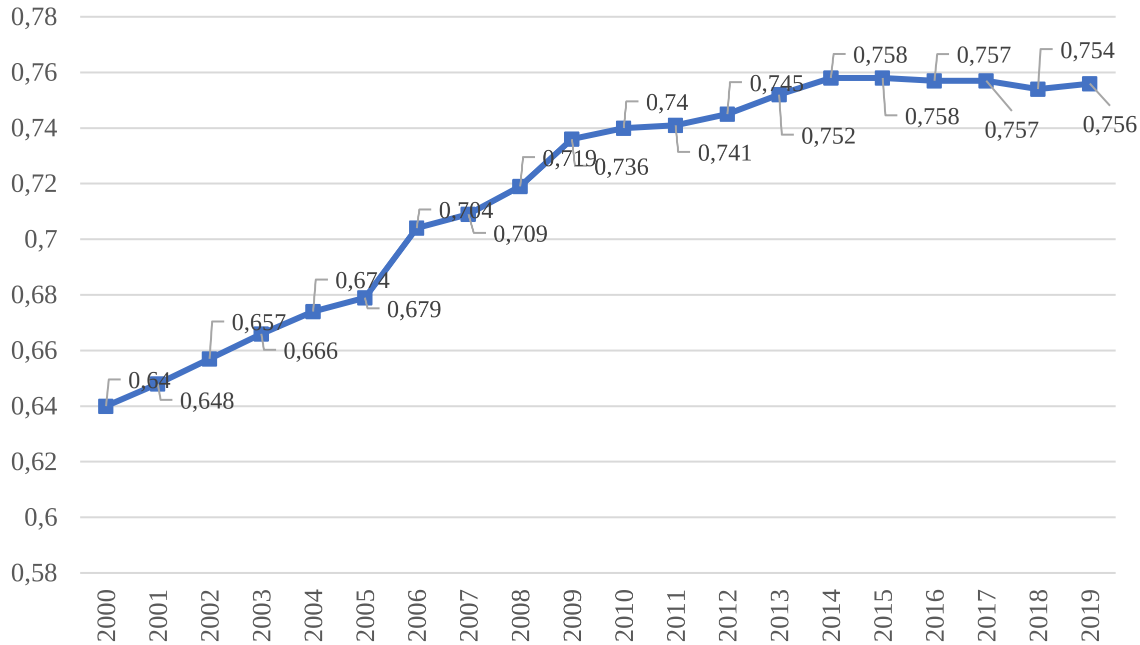


Source: (State Statistics Committee of the Republic of Azerbaijan, 2020)

Impact of hydrocarbon industry in the rapid development of the country is undeniable. Above data indicates immense contribution natural resources has made and continue to make to the economy. Huge cash and capital inflow did not become a curse like in many other cases but instead transformed Azerbaijan into the aggressively progressing country. Macroeconomic indicators yielded upwards tremendously in a short span of time making Azerbaijan leading country in South Caucasus. The total GDP augmented almost five times reaching USD 48.05 billion in 2019 compared to USD 8 billion in the first year of independence, while Gross National Income (GNI) skyrocketed from USD 703 million in 1991 to USD 44,680.2 million in 2017 (World Bank, 2020; State Statistics Committee of the Republic of Azerbaijan, 2020). Considering significant share of hydrocarbon resources in GDP, export and the state budget, direct contribution of natural resources into the economy and wellbeing of the country is apparent.

Intensive growth of economy led to apace social development as well highlighted with increased life expectancy, literacy, employment level, strengthened social care, and decreased poverty rate. The United Nations (UN) Human Development Report demonstrates decent improvement Azerbaijan made during its independence, currently being ranked 80th (United Nations, 2018).

Graph 1.7 Human Development Index (Azerbaijan)



Source: UN Human Development Report

Though oil reserves of Azerbaijan is yet relatively high with ACG not exhausted fully and evidences indicating a high probability of undiscovered fields in central part of Azerbaijan where Mugan monocline is located, decreasing extraction levels, vulnerable and low prices after the collapse of the market pushes the government towards natural gas as an alternative income source (Dadashov, 2007). Baku spared no efforts at nailing the second “Contract of the Century”, signed on September 19, 2013, on the construction of a pipeline which would deliver natural gas from the Caspian Basin to Italy providing Azerbaijan with an alternative income, and Europe with an alternative energy source. Groundbreaking ceremony of the relevant pipeline would take place symbolically on September 20, 2014, at the 20th anniversary of the first “Contract of the Century”.

Chapter 1.2. Shift to Natural Gas as an Alternative Source of Energy

Alas in lower volumes up to the last couple of years, natural gas extraction and its realization have always been part of hydrocarbon industry of Azerbaijan. Though much attention has been allocated to the oil sector as its production and penetration into the global market is easier. Unlike oil, finding trustworthy buyers of gas with long term contracts of minimum 20-25 years is much more burdensome (The Oxford Institute for Energy Studies, 2017). Despite all the challenges the gas industry faces, Azerbaijan managed to successfully implement a historical project aimed at delivering liquified natural gas (LNG) to the European market through Turkey. A very comprehensive and multifaceted project named Southern Gas Corridor (SGC) has been completed in 2020 that includes three different pipelines bridging Caspian Basin gas with Turkey and Europe. SGC is the development phase of the first large scale contract on exploration, development and production sharing of natural gas in Shah Deniz field signed on June 4, 1996, between SOCAR and group of international companies enlisted below. BP estimates Shah Deniz reserves at 1.2 trillion cubic meters, while the Azerbaijani government claims more than 2 trillion cubic meters of natural gas is available on the field. (Roberts, 2016).

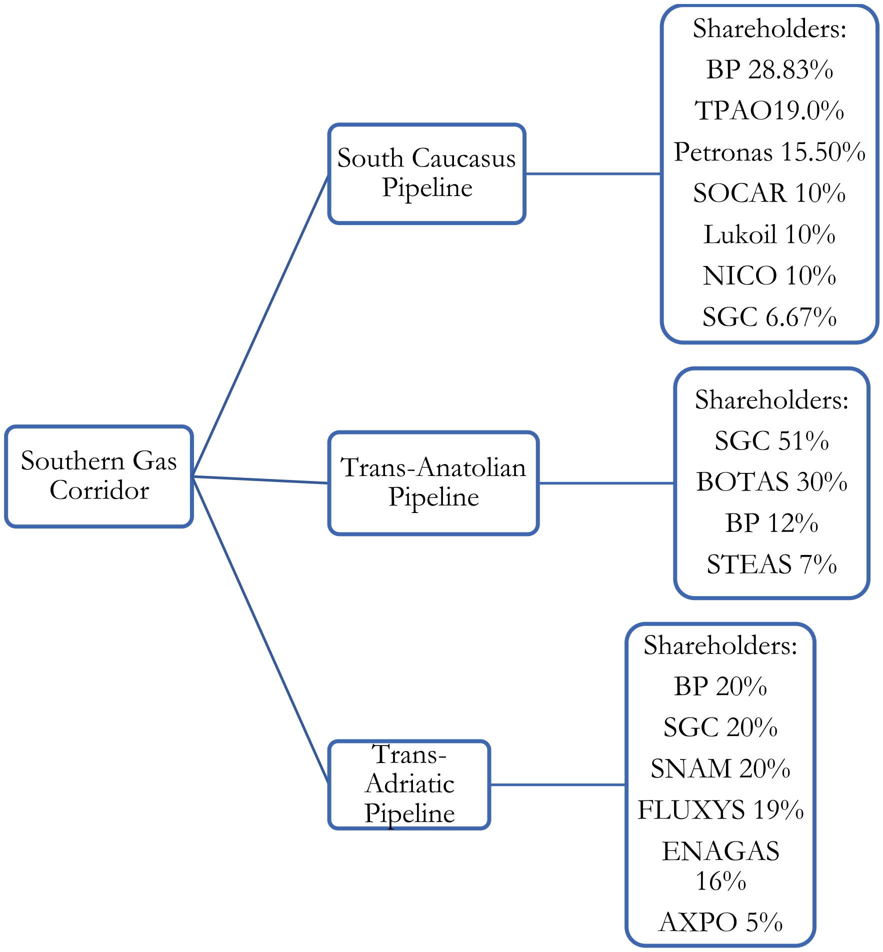
Table 1.2 List of companies which participated in Shah Deniz PSA

Contractor Parties	**Share**
SOCAR Commercial Affiliate (SCA)	10%
BP Exploration Azerbaijan Limited	25.5%
Elf Petroleum Azerbaijan	10%
Lukoil International	10%
Oil Industries Engineering and Construction	10%
Statoil Azerbaijan	25.5%
Turkish Petroleum Overseas Company Limited	9%

Source**:** PSA provided in BP’s official website (BP, 2009)

The first phase of Shah Deniz was initiated after BP announced the discovery of large gas reserves. Following the announcement, Baku-Tbilisi-Erzurum gas pipeline labeled as South Caucasus Pipeline (SCP) was constructed and commissioned in 2006 with the initial transportation capacity of 8 billion cubic meters (bcm) per year, with Turkey committing to buy 6 bcm per annum (Southern Gas Corridor CJSC, 2018). SCP is the first pipeline in the structure of the Southern Gas Corridor with 692 km length and was extended in 2018 up to 1181 km (renamed as SCPX). With two phases completed, the SGC will have an output capacity of 26 bcm of gas and 120 000 bpd of gas condensate, reported BP in 2017 (Dittrick, 2018).

Graph 1.8 Structure of the Southern Gas Corridor



Source: Southern Gas Corridor CJSC

On September 19, 2013, gas sales agreements were signed with 9 European companies thus launching one of the largest and most complex gas projects in the history - Shah Deniz Phase II. In line with the Decree signed by the President Ilham Aliyev on February 25, 2014, Southern Gas Corridor CJSC was established to consolidate and manage the project on the state's behalf (Southern Gas Corridor CJSC, 2018).

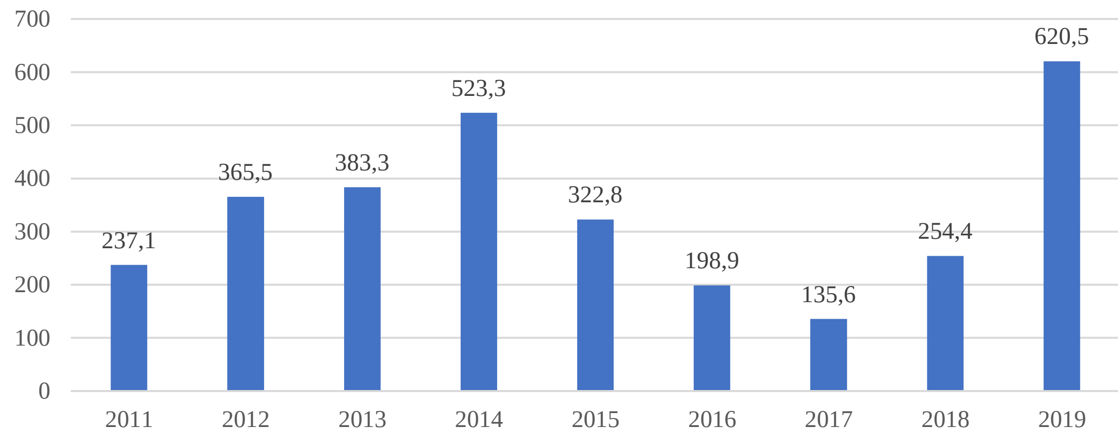
The second pipeline designed to develop the existing infrastructure is the Trans-Anatolian Pipeline (TANAP) whose construction started in 2015 and was commissioned in 2018. Initial transportation capacity of TANAP is 16.2 bcm with the possibility to expand up to 30.7 bcm per year. TANAP is linked with the SCPX and extends up to Turkey-Greece border where it should be connected to Trans-Adriatic Pipeline (TAP) continuing up to Italy. The total length of TANAP is 1345 km. (Southern Gas Corridor CJSC, 2018).

The third pipeline within the SGC project is TAP designed to take the Azerbaijani gas to Italy through Greece, Albania and the Adriatic Sea with a total length of 878 km. The groundbreaking ceremony of the TAP was held in 2016 and was inaugurated in 2020 with an annual transportation capacity of 10 bcm per year (expandable to 20 bcm) (ibid.).

SGC's complexity is defined not only with its cost summitting USD 28 billion but also with the complexity of the political environment around it (Dittrick, 2018; The Oxford Institute for Energy Studies, 2017). Up to 2018 Russia was the major natural gas supplier of Europe with Nord Stream 2 project delivering the fossil fuel to Germany. Thus, Azerbaijan's initiative of creating an alternative source of energy targeting the south of Europe was not warmly welcomed by Russia. Kremlin responded with an offer to launch another project named South Stream which failed due to a violation of EU regulations, conflict over Crimea and following sanctions. European Union has avowedly warned Bulgaria with possible measures over its initial agreement with Moscow. (Overland, 2017; Jim Yardley, 2014). The international conflict resulted in tough sanctions pushing Kremlin to drop out of the project. Nonetheless, Russia did not halt its attempts to come up with a counteroffer which would hamper Baku's initiative and offered another mammoth pipeline project with a very similar route to SGC. Moscow negotiated a TurkStream pipeline and after reaching an agreement started implementation phase of the project in 2017. The pipeline was built in a short span of time and inaugurated in November 2018 with an output capacity of 15.75 bcm per annum. Its total length is 1090 km and ends in Luleburgaz where the gas is sought to be further transported to Europe via other pipelines (Gazprom, 2018). Since the very inception of the Moscow's initiative, a series of debates were raised whether SGC and TurkStream can co-exist or one of them will drop out failing investments and hopes. Though, many express high concerns over this issue considering destination of two pipelines, Azerbaijani and Russian officials believe Europe's appetite for gas is high enough to absorb all output (Azernews, 2018; Nasirov, Turk Stream is not a rival for SGC, 2018).

Shah Deniz field has already been contributing to the economy of Azerbaijan for a while as the resource extracted was sold in global markets. Revenues were accumulated at SOFAZ which started differentiating incomes from ACG and Shah Deniz fields as of 2011. Below graph illustrates profits earned from the sale of natural gas as collected by the Fund. SOFAZ stated that as of December 2019 approximately USD 620.5 million was received from the sale on condensate from Shah Deniz field (Annual Report 2019).

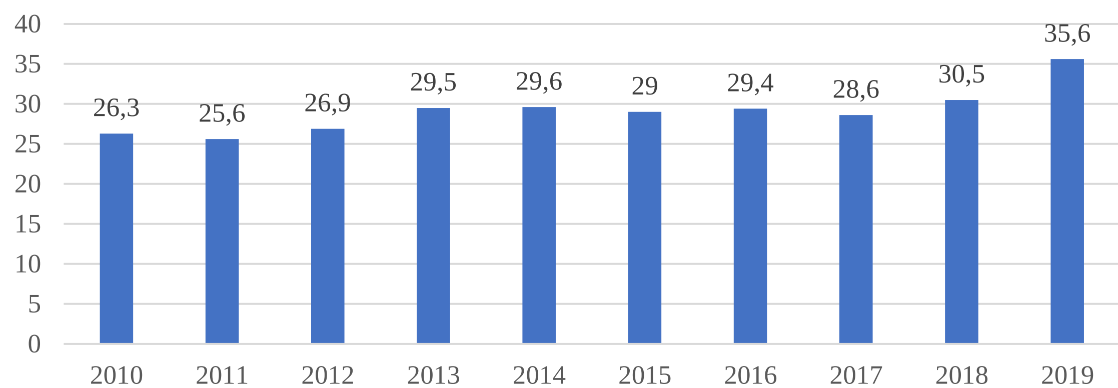
Graph 1.9 Revenues from the Shah Deniz field (USD, million)



Source: Annual reports of SOFAZ (State Oil Fund of the Republic of Azerbaijan, 2018)

Though much attention on the gas industry is devoted to Shah Deniz II project, it should not be overseen that it is also extracted at ACG with respectable output volume. According to SOCAR reports, in 2019, 26 237.0 thousand tons of oil condensate was extracted at ACG, whereas only 3533.5 thousand tons at Shah Deniz. At the same year, SOCAR stated 2 064.6 mln. m^3 of natural gas received from ACG and 6397.1 mln. m^3 from Shah Deniz (Annual Report 2019).

Graph 1.10 Gas extraction volume in Azerbaijan (bcm)

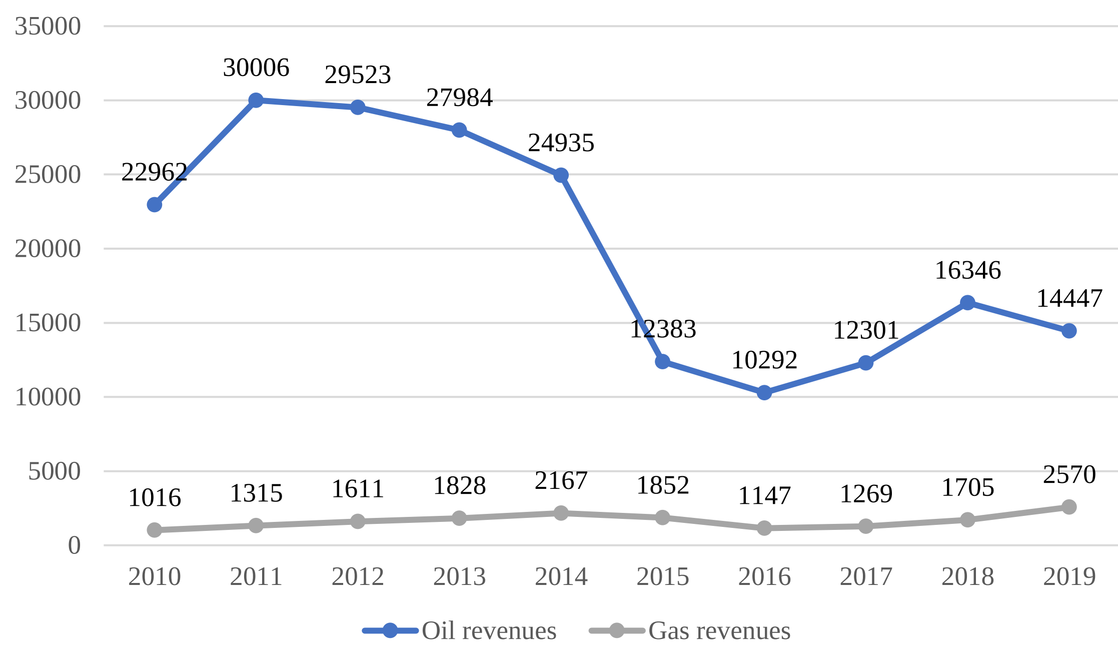


Source: (State Oil Company of the Republic of Azerbaijan, 2020)

The main oil company of the country reported below gas extraction volumes in Azerbaijan for the period of 2010-2019.

The share of gas in the export of Azerbaijan is provided by the State Statistics Committee as of 2006 and backed by SOCAR and AIOC since 2010. Below graph summarizes revenues generated from natural gas exports and its comparison to oil related revenues (data provided by SOCAR and AIOC).

Graph 1.11 Revenues generated from the sale of oil and gas (USD, million)



Source: (State Statistics Committee of the Republic of Azerbaijan, 2020)

Baku's enthusiasm about gas reserves and its potential in terms of alternative revenue source is understandable considering abovementioned. SGC proved to be a worthy initiative led solely by Azerbaijan and finalized with relevant agreements. Its three main pipelines are already operating delivering natural gas extracted from the Caspian basin to international markets, including the Europe. Both ACG and Shah Deniz fields are already pumping gas to pipelines converting the natural resource into economic wealth. Despite attempts to neutralize Caspian Basin as an alternative energy source for Europe, Baku masterly maneuvered to please all the sides and realize its dreams of developing gas industry with a ready market to purchase the product. Data mentioned in above graphs demonstrate high levels of natural gas contribution to the economy and the most important pipeline designed to connect the Caspian with Italy is to start to bring revenue. If right, 2 trillion cubic meters of natural gas reserves combined with favorable political conditions can be handy for Azerbaijan in ensuring significant revenue source for the long term. Along with local authorities, many European authors and institutions believe the SGC is a vital project to strengthen Europe's energy security decreasing dependency on one source (European Investment Bank, 2018). Taking into account all, Azerbaijan's high hopes in gas industry is justified, though it would not be right to label it as a total shift since oil remains a major income generating natural resource and apparently will remain so at least till the ACG is completely exhausted.

Figure 1.1 Map of the Southern Gas Corridor pipeline (Trans Adriatic Pipeline, 2020)

Chapter 1.3. Present Stage of the Energy Security of Azerbaijan and Its Level of Dependence on Hydrocarbons

Energy security is a comprehensive term which saw significant transformation over time and yet lacks unified definition accepted globally. In its classical version offered by the International Energy Agency (IEA), it is "uninterrupted availability of energy sources at an affordable price" (International Energy Agency, 2018). This definition is based on a conventional understanding of the term which emerged in the early XX century and was mainly connected with the supply of oil for armies (Yergin, The Prize: The Epic Quest for Oil, Money & Power, 1991). Similar to the IEA, Colglazier and Yergin also explained the energy security in the 80s as a stable supply of oil at an affordable price under the risk of manipulations and embargoes (Yergin, 1988; William Colglazier, 1983). Nonetheless, understanding of energy security has evolved enormously since the 80s and currently encompasses a much wider circle of issues

(Yergin, 2006). New studies in this field include physical security of the energy facilities, the ability of the economy to ensure stable supply, development of biofuels and renewable energy sources into the understanding of energy security phenomenon along with its conventional partitions (Alhajji, 2008; Winzer, 2011).

Azerbaijan's energy security is included into the National Security Concept of the Republic of Azerbaijan adopted in 2007. The document presents comprehensive national security concept where energy security is envisioned in three major components:

1. Cooperation with international organizations.
2. Cooperation with regional partners.
3. Physical security of the energy infrastructure and related facilities.

The paragraph 4.3.8. of this Concept titled Energy Security Policy includes the below main points (National Security Concept of the Republic of Azerbaijan, 2007):

- Discovery, development and extraction of hydrocarbon resources from the Azerbaijani part of the Caspian Basin.
- Management of the increasing risks associated with the main oil and gas pipelines delivering Azerbaijan's natural resources to the European market.
- Physical protection of the energy infrastructure (oil and gas platforms, related infrastructure, pipelines, etc.) from natural disasters and other potential provocations.
- Development of the renewable energy industry with a focus on solar, wind, hydro and biomass power, in anticipation of a global recession in energy market.

Possessing large oil and gas reserves, the major factor of the energy security of Azerbaijan is fossil reserves and security of associated elements. Although domestic resources play a crucial role in ensuring the energy security, high dependence on them undermines it on the other hand.

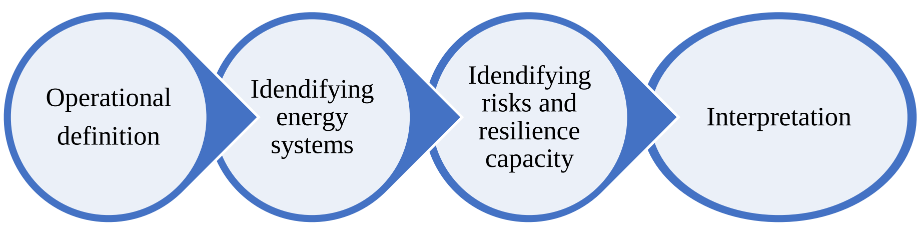
To analyze the present stage of Azerbaijan's energy security, it is crucial to first come up with an assessment framework and delineate indicators. The literature on energy security calculation methods offers several options prepared by different institutions and authors. The mostly cited methods are IEA's Model of Short-term Energy Security (MOSES), and the Global Energy Assessment (GEA) model developed by the International Institute for Applied System

Analysis (IIASA) which focuses on long-term vision (Jewell, 2011; Cherp, 2012). MOSES analysis is carried out based on energy security profiles of IEA's 28 member states (out of 30) and tries to illustrate the landscape of their energy security, whereas GEA main purpose is to "identify common energy security concerns (in over 130 countries) affecting significant parts of the world's population" (Cherp Aleh, 2010).

Nonetheless, as several authors noted in their studies, no universally applicable method of the energy security assessment exists as it may vary depending on availability of necessary data and the economic and political environment the country exists in (Cherp, 2010; Winzer, 2011; and et. al). Lack of precise data about average supply interruption duration and frequency hinders the application of calculation methods for coming up with average interruption index and related GDP loss. Therefore, the energy security of Azerbaijan is mostly about the qualitative analysis of the situation rather than quantitative calculations and is based on an assessment framework offered and analyzed in this study.

To analyze Azerbaijan's current energy security combined and adapted version of MOSES, GEA and Winzer's methods will be used in this dissertation.

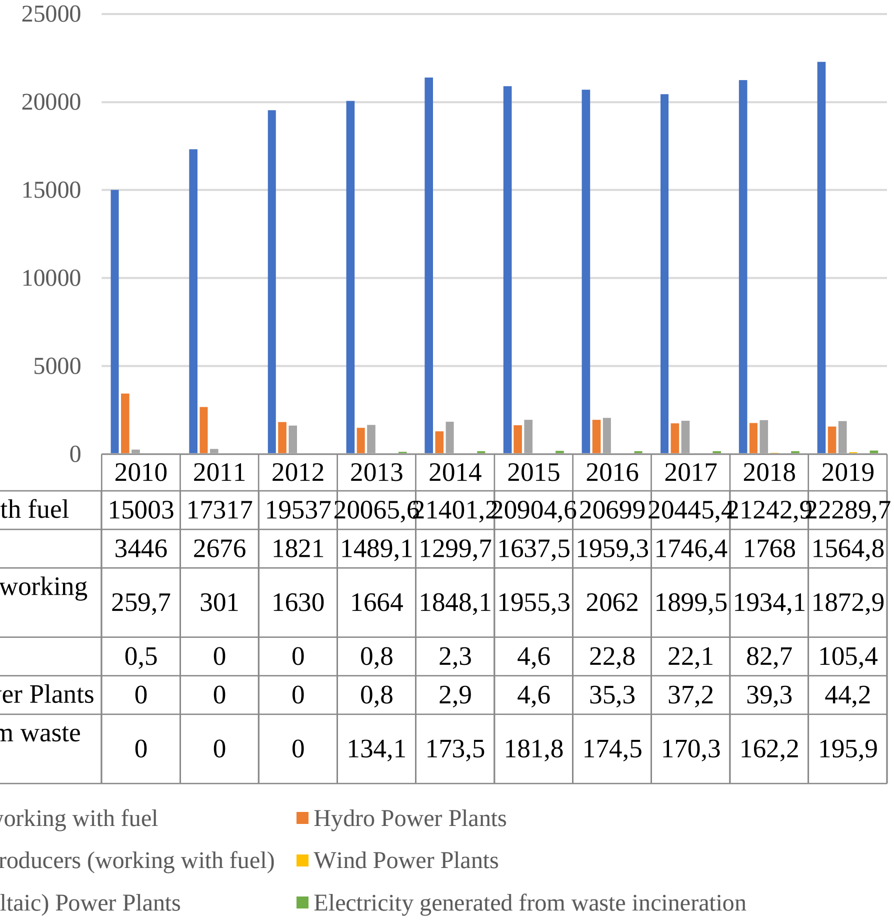
Graph 1.12 Energy security assessment framework



Operational definition. Considering existing definitions and characteristics of Azerbaijan, for the purpose of this study the energy security is defined as a "*non-stop supply of energy at an affordable price able to withstand possible risks and threats posed by natural, geopolitical and economic circumstances.*" *Non-stop supply of energy* implies the existence of enough resources and systems to generate power, and the ability to provide end-users (industries, households, etc.) with uninterrupted energy.

Being fossil-rich country, Azerbaijan is privileged to maintain almost 100 percent autonomy in power generation as it mainly produced from oil and gas supplied internally.

Graph 1.13 Power generation and types of resources used in Azerbaijan (million kW/hour)



	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
TPP and PPs working with fuel	15003	17317	19537	20065,6	21401,2	20904,6	20699	20445,4	21242,9	22289,7
Hydro Power Plants	3446	2676	1821	1489,1	1299,7	1637,5	1959,3	1746,4	1768	1564,8
Autonomous producers (working with fuel)	259,7	301	1630	1664	1848,1	1955,3	2062	1899,5	1934,1	1872,9
Wind Power Plants	0,5	0	0	0,8	2,3	4,6	22,8	22,1	82,7	105,4
Solar (photovoltaic) Power Plants	0	0	0	0,8	2,9	4,6	35,3	37,2	39,3	44,2
Electricity generated from waste incineration	0	0	0	134,1	173,5	181,8	174,5	170,3	162,2	195,9

***TPP –** Thermal Power Plant
**** PP –** Power Plant
Source: (Energetics, Electricity Production, 2020)

In 2019, Azerbaijan produced 26 072.9 million kilowatt (kW)[3] of power out of which 22 289.7 million kW was generated in plants operating with oil and natural gas. Hydrocarbons have been primary resource for generating power in Azerbaijan since 1991 as per the data provided by the SSC (State Statistics Committee of the Republic of Azerbaijan, 2020). Usage of renewable energy resources started in 2009, but results are still insignificant to talk about a major development in this field.

[3] 1 kW equals to 0,001 MW.

However, lower usage of renewables and biofuels is not a risk or threat indicator in Azerbaijan's case as the country is fossil-rich and enjoys capacity of fully supplying internal demand and even exports energy to neighboring countries (Azertag, 2018). Thus, *non-stop supply* in terms of production resources is ensured.

Affordability of the power supply in terms of production is ensured as the raw materials for generation of power is internally supplied and backed with a strong economy. From the end-user (households, industrial units, etc.) perspective, energy is also affordable as its price equals to AZN 0.07 per kWh (approximately EUR 0.036 in current exchange rate) for households and AZN 0.09 per kWh (approximately EUR 0.046) for non-household units (industry, businesses).[4] This is a much cheaper comparison to the European Union countries where the average energy price amounts to EUR 0.2134 per kWh for households (Tarriff Council of Azerbaijan, 2018; Eurostat, 2020). Table 1.3 further breaks down the analysis to assess the affordability in terms of monthly average salaries in European countries and its comparison to Azerbaijan.

Table 1.3 Monthly average salaries and electricity price in European countries and Azerbaijan (2020)

	Monthly average salary (EUR)[5]	Electricity price (EUR/kWh)	Affordable monthly electricity purchase (kWh)
Luxembourg	5 143	0,199	25 909
Netherlands	2 855	0,136	20 977
Finland	3 380	0,177	19 064
Sweden	3 194	0,172	18 591
Denmark	5 179	0,282	18 372
Austria	3 811	0,217	17 587
France	3 097	0,196	15 817
Ireland	3 867	0,262	14 782
Germany	4 035	0,301	13 423
Belgium	3 401	0,270	12 587
Cyprus	1 992	0,170	11 731
Hungary	1 154	0,101	11 437
Estonia	1 472	0,129	11 402
Italy	2 442	0,215	11 342
Slovenia	1 855	0,169	10 950

[4] Two major utilities Azerenerji (generator) and Azerishiq (distributor) are both being subsidized by the government.

[5] The officially announced monthly average salary in Azerbaijan amounts to AZN 693. The figure is converted to EUR based on exchange rates provided by the Central Bank of Azerbaijan for May 6, 2021.

Malta	1 379	0,130	10 624
Lithuania	1 381	0,132	10 454
Spain	2 279	0,230	9 917
Serbia	707	0,074	9 593
Azerbaijan	**340**	**0,036**	9 444
Croatia	1 214	0,131	9 288
Ukraine	342	0,040	8 636
Turkey	700	0,082	8 516
Latvia	1 152	0,143	8 045
Poland	1 191	0,151	7 887
Romania	1 075	0,145	7 419
Czechia	1 280	0,180	7 131
Bulgaria	690	0,098	7 026
Portugal	1 418	0,213	6 648
Greece	1 060	0,164	6 459
Slovakia	1 086	0,172	6 299
Georgia	336	0,057	5 915
Moldova	384	0,099	3 867

***Sources*:** (Reinis Fischer, 2020; Interfax, 2020; Eurostat, 2020)

As it can be seen from the above table, in comparison to the European countries the affordability of electricity for household level user in Azerbaijan is very close or even higher in some cases. Only select number of highly developed countries demonstrate better results in this indicator. It should also be noted that there is drastic difference between the real earnings and official average nominal wages in Azerbaijan. This is related to different models of rewarding applied in various industries are not reflected as salaries per se, but adds to income of population. (e.g., bonuses for achievements; one-time payments in relation to public holidays; additional income generated to incoming revenues to a common pool; etc.). According to 2021 report of the Average Salary Survey, typical annual income in Azerbaijan amounts AZN 11,915 which translates into AZN 992 or EUR 486 per month (Average Salary Survey, 2021). This wage allows the purchase of 13,520 kWh/month electricity outperforming the same indicator of many countries mentioned in Table 1.3.

Identifying energy systems. Understanding of *energy systems* in this study differs from the one offered by IEA and explicitly depicts existing power generating infrastructures and their security. Power generating infrastructures of Azerbaijan and their capacity are provided in below table.

Table 1.4 Power generating plants in Azerbaijan (projected, winter (*w*) and summer (*s*) time generation capacities) [6]

Thermal Power Plants (TPP)	Hydro Power Plants (HPP)	Small Hydro Power Plants (SHPP)
Azerbaijan TPP – 2 400 MW *w:2000 MW s:1800 MW*	Mingachevir HPP - 402 MW *w:340 MW s:240 MW*	Gulabird SHPP – 7.5 MW *w:5 MW s:0.5 MW*
Janub PP - 780 MW *w:755 MW s:620 MW*	Shamkir HPP - 380 MW *w:320 MW s:280 MW*	Oghuz SHPP 1,2&3 – 3.6 MW *w:0.4 MW s:0.3 MW*
Sumgait PP - 525 MW *w:485 MW s:430 MW*	Yenikend HPP - 150 MW *w:140 MW s:90 MW*	Goychay SHPP - 3.1 MW *w:1 MW s:0.5 MW*
Shimal 1 and 2 PPs - 800 MW *w:770 MW s:660 MW*	Fuzuli HPP - 25 MW *w:14 MW s:5 MW*	Ismayıllı-1 SHPP - 1.6 MW *w:0.5 MW s:0.2 MW*
Sangachal PP - 300 MW *w:287 MW s:220 MW*	Takhtakorpu HPP - 25 MW *w:18 MW s:10 MW*	Ismayıllı-2 SHPP - 1.6 MW *w:0.5 MW s:0.2 MW*
Baku TEC - 107 MW *w:62 MW s:40 MW*	Shamkirchay HPP - 25 MW *w:14 MW s:10 MW*	Balaken-1 SHPP - 1.5 MW *w:0.5 MW s:0.2 MW*
Baku PP - 105 MW *w:97 MW s:80 MW*	Varvara HPP - 16.5 MW *w:14 MW s:12 MW*	Gusar SHPP - 1 MW *w:0.2 MW s:0.1 MW*
Shahdagh PP - 105 MW *w:102 MW s:85 MW*	Araz HPP - 44 MW *w: N/A s: N/A*	Vaykhır SHPP - 5 MW *w: N/A s: N/A*
Astara PP - 87 MW *w:82 MW s:55 MW*	Bilev HPP - 22 MW *w: N/A s: N/A*	
Shaki PP - 87 MW *w:80 MW s:55 MW*	Arpachay 1& 2 - 21.9 MW *w: N/A s: N/A*	
Khachmaz PP - 87 MW *w:87 MW s:65 MW*	Ordubad HPP – 36 MW *w: N/A s: N/A*	
Lerik PP – 16.5 MW *w:15 MW s:12 MW*		
Nakhchivan PP - 87 MW *w: N/A s: N/A*		
Nakhchivan TPP – 64 MW *w: N/A s: N/A*		

Source: (Azerenerji, 2021)

Azerbaijan TPP is the main aggregator responsible for the energy supply of the country with Janub Power Plant (PP), Shimal 1 and 2 PPs, Sumgait PP and Mingachevir HPP supporting the overall production. Azerenerji Open Joint Stock Company is responsible for maintaining internal security and sustainability of the infrastructure. Two blackouts occurred on July 3-4, 2018 when major cities of the country were deprived of power supply after an incident in thermal power plant located in Mingachevir revealed a major issue for the energy security of the country. The

[6] Table presents maximum capacities of the facilities.

whole supply was mainly relied on one power plant and was not effectively backed up by any other infrastructure as the second power plant designed as back up broke down as well. Blackouts were eliminated in a couple of hours and demonstrated good resilience capacity in emergency situations.

Identifying risks and resilience capacity. Risks are associated with the supply of resources, emergency situations (natural disasters, accidents, etc.), possible attacks, including terrorism, to the infrastructure and affordability of the energy. Below table summarizes risks and resilience capacity analysis of energy security for Azerbaijan.

Table 1.5 Risk and resilience capacity analysis

Source of the risk	Risks and Threats	Incidents and risk factors	Resilience Capacity
Internal	**Resource supply**	No resource supply related incidents recorded in Azerbaijan.	Azerbaijan is capable of fully supplying resources for power production and meeting internal demand. Dependency on external supply is non-existent.
	Emergency Situations	No public data is available on the electricity supply continuity and disruptions in Azerbaijan. The only major incident for the last 20 year happened in July 2018 when a fire in one of the generation units in Mingachevir thermal plant caused a country-wide blackout. The incident happened in the early hours of July 3 and the power supply was partially restored in the morning of the same day. The full restoration of supply was achieved on July 4.	Though blackouts revealed weak backup system, overall high resilience capacity was demonstrated as the reasons of the incidents were eliminated quickly. However, heavy reliance on one thermal power plant remains a security issue. Thus, complex actions needed to ensure supply diversity through different infrastructures and backup systems.
	Affordability	The affordability dimension is strong in Azerbaijan with cheap electricity prices and competitive results against the monthly income in comparison to the EU countries.	Though affordability of resources for power generation is not a significant risk indicator, the price of the energy sold to end users might become an issue in long-term.
	Utilization of renewable	No renewable energy related incident or any potential risk	The current share of renewable energy sources and biofuels in power

	energy sources	factor was recorded in Azerbaijan. This is mostly due to the very low green energy generation.	generation is insignificant. Fossil fuels remain the main resource converted into energy. Nonetheless, progress in terms of utilization of green energy is obvious and grows steadily.
External	**Physical attacks**	Two missiles landed in the area of the Mingachevir Thermal Power Plant during September – November 2020, in the course of 44-day escalation of the Nagorno-Karabakh conflict. One of the missiles landed close to a infrastructure unit but did not explode. The second attack was neutralized by the Air Defense Systems. No terror or any other criminal attack to the energy facilites was recorded in Azerbaijan.	Physical attacks remain a major risk source as the overall generation is heavily dependant on the plant located in Mingachevir. Several missiles targeted to the main facility during the upsurge of hostilities within the Nagorno-Karabakh conflict (from September 27 till November 10) demonstrated the real risk, although the attacks were denied at time by the Air Defense Units. The physical risk remain a problem for potential terror attacks that could theoretically be organized within the country.

Interpretation. Rich in fossil fuels, Azerbaijan has always been confident in terms of its energy security. However, the definition of energy security has evolved significantly as mentioned and includes many aspects. Therefore, existence of vast amount of hydrocarbons alone does not guarantee energy security.

Energy security of Azerbaijan is highly reliable in terms of resources used for energy production as the country enjoys large reserves of hydrocarbons. Thus, the risk associated with high dependence on traditional resources is eliminated. Oil and gas remain the major products converted into power with the utilization of renewable sources and bio-fuels developing gradually. Resilience capacity in cases of emergency proved to be high though lack of enough infrastructure to maintain uninterrupted supply in such cases remains to be a risk factor. Abovementioned blackouts stimulated adoption of measures at reducing the dependency through strengthened backup systems and diversification of generation.

Affordability of energy at a reasonable price for end-users is currently not a risk source as Azerbaijan provides one of the cheapest deals in the region and Europe. Measures to maintain stable energy prices are vital to take considering experts’ claims on the high probability of price upsurge needed to increase revenues of the economy.

To conclude, Azerbaijan's energy security is apparently strong due to rich natural resources, zero dependency on external suppliers, affordable production and sale price. "Azerenerji" OJSC and "Azerishiq" OJSC possesses enough infrastructure objects to fully meet internal demand, create backup systems for possible emergency situations, and export energy to neighboring countries. Table 1.5 is indicative of high resilience capacity, zero external dependency, undisrupted raw material supply, only one major distribution incident resulting in blackout for major part of country during last 20 years. Historical agreements over ACG and SGC ensures a long-term supply of hydrocarbons for power generation activities. Recently, authorities started allocating much attention to the development of green energy sector with first wind and solar (photovoltaic) power plants installed in several districts (State Agency for Alternative and Renewable Energy Sources, 2016).

Despite the massive contribution of hydrocarbon industry to the economy and energy security of the country, Baku has always understood that depletable energy is not something to build the country on infinitely. Thus, as mentioned above, State Agency for Alternative and Renewable Energy Sources (SAARE)[7] implements several projects designed to establish a network of wind and solar power plants in Azerbaijan. Results of activities are already present in Khizi, Surakhani, Nakhchivan and other districts of Azerbaijan. Government's interest in green energy is apparently high which lays a good foundation for the solid development of the sector.

[7] On September 22, 2020 the SAARE was re-organized as Alternative and Renewable Energy Agency operating under the auspices of the Ministry of Energy of the Republic of Azerbaijan. Thus, terms SAARE and AREA mentioned throughout the thesis imply the same organization.

Chapter 2. Current production and future potential of renewable energy in Azerbaijan

Chapter 2.1. The historic and current level of production of renewable energy in Azerbaijan

Azerbaijan's renewable energy attempts go as back as to the early 1880s though it can't be said through more than one hundred years, the share of renewables is significant in the overall production of energy in the country.

Before proceeding with discussions on the topic, it is important to differentiate renewable energy and alternative energy as the two are close to each other yet might have different fuels as a production component. Though existing literature presents various understandings and definitions, most of them carry one common point. This paper will focus on the following definitions offered by Zachary Alden Smith and Katrina Taylor in their handbook for renewable and alternative energy sources.

- Renewable energy is produced from sources that are inexhaustible like wind or sunlight;
- On the other hand, alternative energy harness finite but not currently exploited sources (Zachary Alden Smith, 2008). An example can be nuclear energy in a country possessing uranium resources, but not utilizing it for power generation. The most important ingredient – uranium is a finite source, yet nuclear energy production is an alternative to classic hydrocarbons.

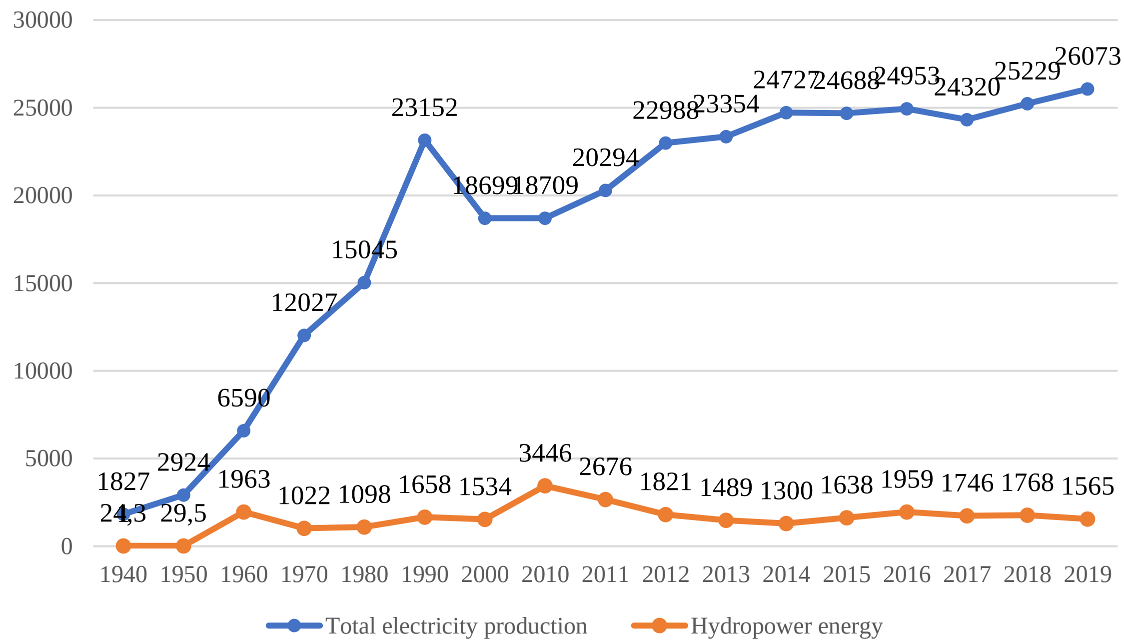
Another important difference is that renewables are environmentally safe and hve no ecological footprint. Hence, though nuclear energy production is an alternative, it is not considered environmentally friendly. Nonetheless, renewable energy can be alternative as well in its essence, as many argue. If country A does not use sunlight for energy production despite having a sunbath for most of the year, then solar energy production can be considered alternative and renewable at the same time. It uses the same nondepletable source but is an alternative to fossils. Another debated raw material for power generation is water. Opinions on its classification differ across existing studies on the topic. Though the amount of the water does not decrease during the energy production, and water plants do not emit greenhouse gases or other pollutants, it still has a significant ecological footprint in terms of impact on fisheries and water flaws (Sen, 2018; Daigneau, 2013). Nonetheless, this thesis will classify hydropower as a renewable energy source considering its wide recognition as such, including by the Environmental Protection Agency (Environmental Protection Agency, 2019). Considering current traits and reserves, this study will mainly focus on renewable energy sources – wind, sunlight, water, biomass, and waste - as Azerbaijan is privileged to have a vast amount of enlisted resources thanks to its geographical location and nature.

Historic background of renewable energy production in Azerbaijan

The historic roots of renewable sources in power generation in Azerbaijan go back to 1883 when the first hydropower plant (HP) was constructed in Galakend village of Gedebey district. That plant was designed to supply electricity to the residents, and also to the industrial infrastructures of the community (Azerbaijan State Agency for the Alternative and Renewable Energy Sources, 2018). The next stage of the development of hydropower plants started in the 1950s when Varvara HP and Mingachevir HP were constructed. Mingachevir Hydropower Plant remains one of the biggest renewable energy producing fields in Azerbaijan up to date. In 1971 Araz HP was set to exploitation in the Nakhchivan Autonomous Republic. The utilization of water as a renewable energy source continued with Terter HP and Shemkir HP constructed in the 1970s and 80s, respectively. The total capacity of mentioned plants is more than 800 megawatt (MW) although not all of them were or are being exploited in full capacity (Azerbaijan State Agency for the Alternative and Renewable Energy Sources, 2018). Detailed analysis of existing hydropower and other renewable energy plants will be conducted in the next paragraph.

Water was the only source of renewable energy production up to 2009 when the first kW of electricity was produced by windmills in Azerbaijan. Below is the graph demonstrating overall electricity and share of hydropower plants.

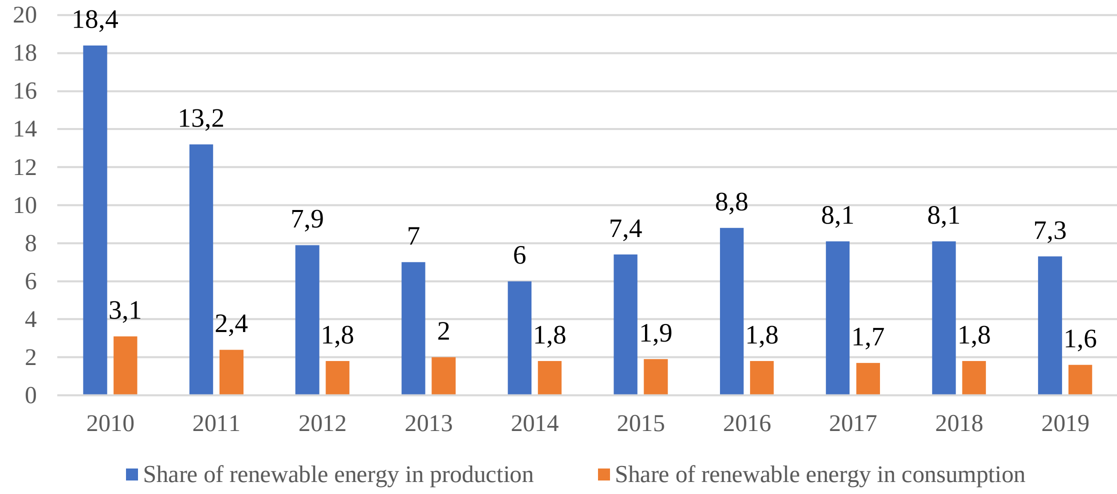
Graph 2.1 Total electricity production and share of hydropower energy, million kW hour (1940-2009)



Source: Power generation, State Statistics Committee (State Statistics Committee, 2020)

At its peak point renewable energy, or to say precisely energy generated in hydropower plants constituted slightly more than 13 percent of overall production. The results surely have room to improve in comparison with green-oriented countries. According to the data provided by the Global Energy Statistical Yearbook in most countries of Europe the same figure is well above 20 percent with Norway and Sweden topping the list (Enerdata, 2018). High levels of renewables in energy production drag up a share of renewables in gross final energy consumption as well. According to the Eurostat data, the overall percentage of renewables in this indicator for the European Union has reached 17.0 percent and was targeted to climb up to 20 percent in 2020. Sweden and Finland remained the most successful countries in this term reaching 53.8 and 38.7 percent respectively (Eurostat, 2018). For Azerbaijan, this indicator is below 5 percent and more importantly was steadily decreasing since 2010 until 2014 when slight positive momentum took off, according to the data provided by the State Statistics Committee.

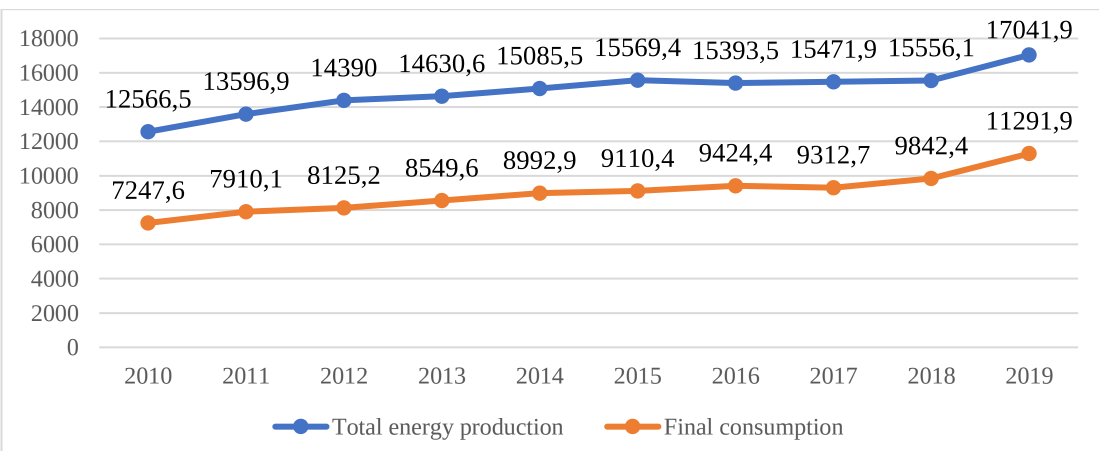
Graph 2.2 Share of renewable energy in total energy production and consumption (in percent)



Source: Energy of Azerbaijan 2020 (State Statistics Committee, 2020)

Nonetheless, it should be noted that the reason for the decrease is related to the increasing energy production and consumption, but not to the overall shrinking of the renewable energy industry. The energy production and consumption for the same period kept increasing significantly as the overall economic and social development continued even during global economic turmoil and the collapse of oil prices (see Graph 2.3). Though hardships related to mentioned external factors slowed down the pace of the development.

Graph 2.3 Total energy supply and final consumption (thousand TOE[8])



Source: Energy of Azerbaijan 2020 (State Statistics Committee, 2020)

[8] TOE – tons of oil equivalent

The current situation with renewable energy production in Azerbaijan

The efforts allocated to the development of the renewable energy industry and its results for today are not at the same level if to say softly. The initiation of the development of this sector came back in 2004 when the State Program on the Use of Alternative and Renewable Energy Sources in the Republic of Azerbaijan (2004 Program) was approved by the President. The 2004 Program put forward the following goals:

- To determine the potential of alternative energy sources in Azerbaijan;
- To increase the efficiency of utilization of the energy sources of the country by incorporating renewable energy sources;
- To open new workplaces by creating new energy production plants;
- To increase the energy security of the country.

Source: 2004 Program (The State Program on Use of Alternative and Renewable Energy Sources in Azerbaijan, 2004)

The 2004 Program specifically listed wind, solar, hydro, biomass, and geothermal power accentuating existing privilege in terms of the abundance of mentioned resources. The program put forward a clear-cut action plan with relevant state entities responsible for implementation and set timeframes for each of them. At the time, the whole industry was under the supervision of the Ministry of Industry and Energy (MIE) without any specific body operating in this sector. The necessity to establish an exclusive organization that would boost the utilization of alternative and renewable energy sources and development of the industry led to the establishment of the State Agency for the Alternative and Renewable Energy in 2009 operating under auspices of the MIE. Historically, in 2009 the first windmills generated power in Azerbaijan. In 2011, President Ilham Aliyev signed another decree on the preparation of the 2012-2020 State Strategy on the Utilization of Alternative and Renewable Energy Sources (2012-2020 Strategy). To achieve the realization of ambitions in a more efficient way, in 2013 the SAARE was transformed into a fully independent agency whose sole mission was to manage smooth integration of renewables into power generation in Azerbaijan. In 2014, another presidential order was signed to approve the 2015-2020 State Program for the Development of Industry in Azerbaijan. The program envisaged the development of the alternative energy production industry too, highlighting its strategic importance in the development of the country.

Though a lot has been carried out towards the shift to green energy, results are dragging down the enthusiasm related to it. To start with, although more than 7 years have passed since the signature of the decree on the preparation of the 2012-2020 Strategy, it is yet to be finalized. In spite of achievements, the activities of the SAARE were not considered as satisfying, and hence, the agency was dismissed in early 2019. The President ordered the re-organization of the activities of the agency as a public legal entity and asked the Cabinet of Ministers to submit a related plan to the President in three months. In 2020, the agency started operating as Alternative and Renewable Energy Agency under the auspices of the Ministry of Energy. Nonetheless, since the 2018 SAARE report submitted to the International Renewable Energy Agency remains the latest reliable source of information for current and future projects, thus this study will consider the report as valid and build its analysis using the data presented there along with other sources. Moreover, most of the projects indicated in the report are approved by the government and are already under construction which makes it highly probable that the newly established entity will continue the path laid by the SAARE, though in a much effective and efficient way.

Up to the first quarter of 2019, water remained the most significant renewable energy source in Azerbaijan with several hydropower plants generating power for various districts. According to the Azerenergy OJSC (the major energy-producing state entity), the following hydropower plants are currently operating contributing to the renewable energy production:

Table 2.1 List of hydropower plants and their output capacity

No	HP Name	Output capacity
1	Mingachevir HP	402 MW
2	Shamkir HP	380 MW
3	Yenikand HP	150 MW
4	Fuzuli HP	25 MW
5	Takhtakorpu HP	25 MW
6	Yenichay HP	25 MW
7	Varvara HP	16.5 MW
In the Nakhchivan Autonomous Republic		
8	Araz HP	44 MW
9	Bilav HP	22 MW
10	Arpachay-1 HP	20,5 MW
11	Arpachay-2 HP	1,4 MW
12	Ordubad HP	36 MW

Besides enlisted HPs, the Azerenerji OJSC also provides a list of Small Hydropower Plants (SHP) with an output capacity of less than 5 MW mainly supplying energy to small communities or industries exclusively.

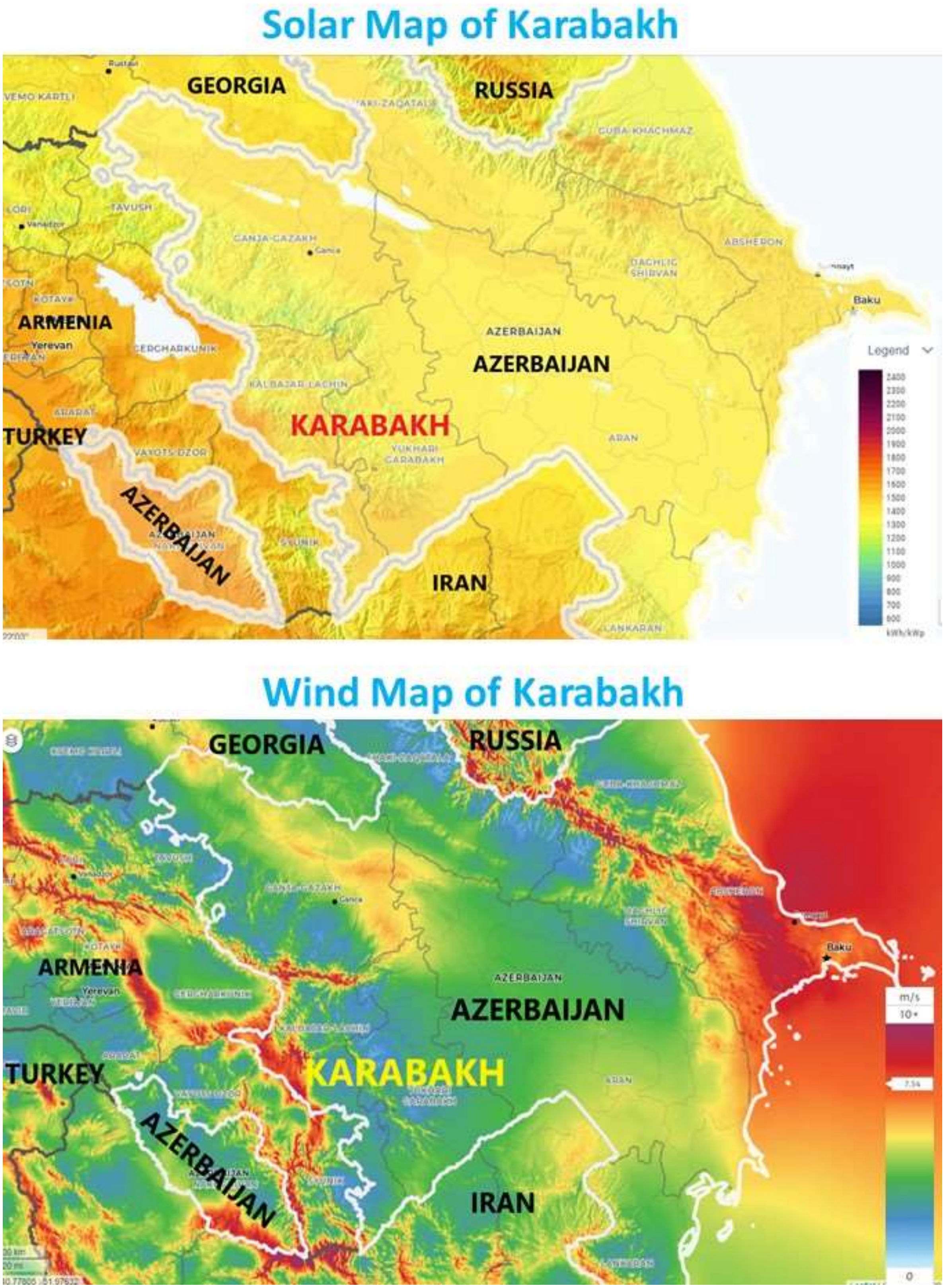
Table 2.2 List of SHPs and their output capacity

No	SHP Name	Output capacity
1	Goychay SHP	3,1 MW
2	Ismayilli-1 SHP	1,6 MW
3	Ismayilli-2 SHP	1,6 MW
4	Balaken-1 SHP	1,5 MW
5	Gusar HSP	1,0 MW
6	Astara-1 SHP	0,260 MW
In the Nakhchivan Autonomous Republic		
7	Vaykhir SHP	5 MW

Total hydro energy production levels and their share in the overall energy generation of Azerbaijan can be found in Graph 2.1.

Nonetheless, as already several times mentioned, water is not the only source for the renewable energy industry in Azerbaijan, though up to now, it has remained the most utilized one. The country possesses the significant potential of generating wind and solar power thanks to abundant resources. The 44-day war that resulted in the liberation of the territories of Azerbaijan has revealed a huge potential for green energy generation in Karabakh. As per information provided by the Ministry of Energy, approximately 30 small-scale hydropower facilities are located in those territories. Besides, initial observations revealed the estimated solar potential of 4,000 MW and 500 MW of wind power (Ismayilov, 2021). The findings have stimulated the government to announce the Green Zone concept to be developed in Karabakh (see Figure 2.1). The initiative has already been shared with the international organizations and reportedly will be developed together with IRENA and with the companies of other countries. Besides, the government has also allocated resources to boost biomass and waste utilization in energy production.

Figure 2.1. Solar and Wind Map of Karabakh.



Source: (The World Bank Group, 2020)

The structural reforms carried out in early 2019 accelerated the development of the renewable energy industry. Agreements were reached with foreign companies on the construction of renewable energy plants (discussed in detail in Chapters 2.2, 2.3, 5.1 and 5.2) and first ever Renewable Energy Potential Assessment of Azerbaijan was completed at the same year. Relevant legal base is being formulated to launch the first ever tender announcement in 2021 to attract private capital into the industry (Babayeva, 2021). Dialogue with Turkish officials was put in place to learn the experience of Turkey's liberal energy market and assess its applicability in Azerbaijan (The Ministry of Energy, 2021).

The next paragraphs will try to focus and analyze the mentioned resources, and their potential for development in Azerbaijan.

Chapter 2.2. The perspectives of the wind power production

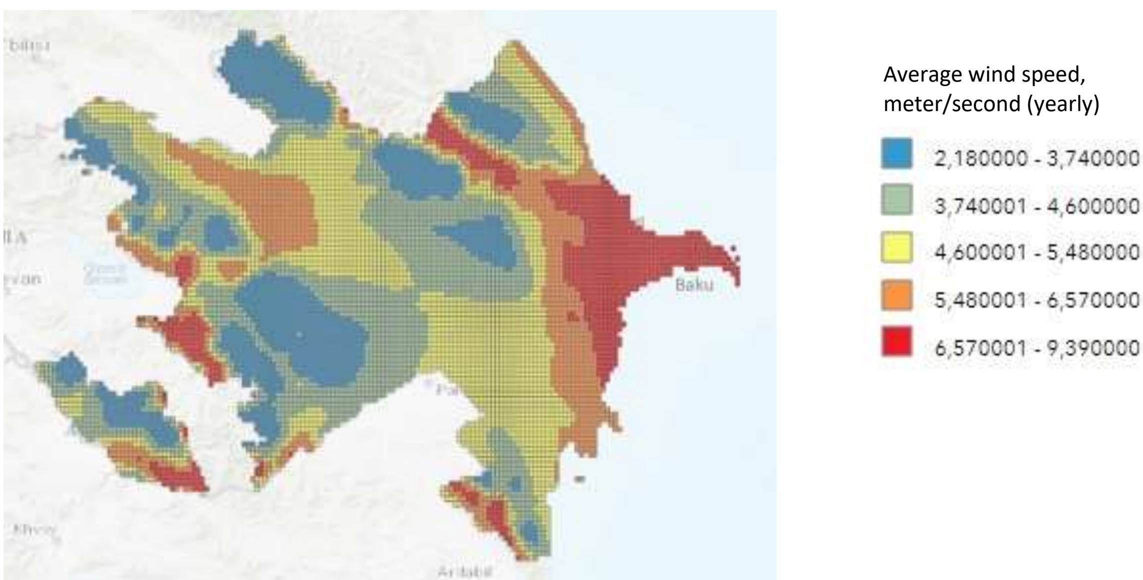
Wind power is among the most promising renewable energy types for Azerbaijan as the country enjoys a vast amount of this resource and its production cost went lower than that of energy from fossils for the first time in history, reported Forbes in 2018 (Sharma, 2018). Focusing on Azerbaijan, this chapter will try to find out followings:

- Is there enough wind to achieve sustainable production?
- What are the pros and cons of power generation through windmills?
- Does it have the potential to play a significant role in total energy production?

Before exploring the situation with the capacity of Azerbaijan in terms of wind power generation, it is essential to briefly describe how wind energy is produced. Wind energy is basically generated by converting the movement (kinetic) energy of the wind into mechanical energy using wind turbines (US Department of Energy, 2019). The uneven solar heating of the earth creates winds that start rotating blades of the turbines and triggers its shaft. As a result, the turbine starts to generate electricity. To prevent possible crashes and incidents turbines are equipped with brakes that step in when the wind speed exceeds 22 meters per second (m/s). In fact, there is no turbine as such and the system stands on a tall tower with an anemometer for speed measuring, and a controller for starting and stopping the whole thing (Silbajoris, 2017). Historically, windmills are considered as the first installations for obtaining energy from the wind. With the development of the industry two groups of turbines - Vertical Axis Turbines and Horizontal Axis Turbines are now available in different sizes and capacities. Production power varies between 200 watts and 6000 kW depending on the diameter of the blades. The bigger the blade, the more energy it produces as the interception area with the wind increases (Gipe, 2009). Horizontal Axis Turbines are the most commonly used type everywhere in the world. To reach maximum effectiveness, the blade should rotate at least 10 meters above the ground. In bigger turbines, the distance between the ground and the blade can reach 50 meters. To rotate the blade of a small turbine minimum of 2 m/s wind speed is required, whereas to produce energy the speed should be 3,5 m/s minimum (The Authority on Sustainable Building, 2019). This thesis will not go deeper into the process and technicalities of wind power generation since it is not the primary purpose of the study. An extensive library is available both online and offline focusing on this matter.

Azerbaijan is lucky to situate in a favorable geographical location which ensures plenty of windy days per year as per reports of the SAARE.

Figure 2.2 Wind map of Azerbaijan (by SAARE)



Absehron, Aran, Daghlig Shirvan, Ganja-Gazakh, and Kalbajar-Lachin economic districts[9] possess more favorable conditions for wind energy production as the average annual wind speed constitutes 6,57-9,39 m/s, more than enough to generate energy using mid and even large-sized

[9] Azerbaijan is divided into 10 *economic districts* which encompass districts with similar economic specifications.

turbines. The first assessment of the wind resources and their energy capacity was carried out in 2002 revealing 800 MW annual reserves in 0-30-meter height. The second assessment was carried out in 2009 after the establishment of the SAARE which delivered an estimation of 4,500 MW yearly capacity considering 0-50-meter space above the ground (Imamverdiyev, 2014).[10] The most recent assessment carried out together with the Ministry of Energy of Azerbaijan and IRENA revealed wind potential of 3,000 MW (Assessment of the Renewable Energy Sources of Azerbaijan, 2019). Despite the availability of significant capacity, the SAARE report expresses a goal of 402 MW annual wind energy production up to 2030 (Yusifov, 2018). The difference between total capacity and planned output can be explained with the territorial limitations. Installation of wind turbine grid requires the vast size of free space with relevant geographical specifications, and at the same time needs to be located not far from the settlements for easier transportation of the energy. Though the area with suitable wind conditions is not small in Azerbaijan, the windiest areas are either densely populated or unusable due to the uneven surface (mostly mountainous areas) which produces unsustainable and often aggressive wind. Though the gaps and open spaces in mountainous terrain are advantageous for wind flow, at the same time this wind may be unreliable, relatively turbulent, and outside of the speed range for which most of the current turbines are designed. Thus, it might lead to frequent and significant maintenance costs arising from fatigue damage and premature failure (Dorminay, 2012). Thus, despite the high level of a natural and renewable resource, not all reserves are favorable for full utilization.

The SAARE implemented a number of projects aimed at the construction of wind energy plants (WEP) and delivered the following results as of 2014.

Table 2.3 List of operating and envisaged WEPs in Azerbaijan (as of 2014)

Name of the WEP	Output Capacity (MW)	Location
Gobustan	2,7	Gobustan
Shurabad	15	Khizi
	25	Khizi
Pirakushkul	60	Pirakushkul 1
	150	Pirakushkul 2
Shurabad	33	Khizi
Sitalchay	25	Khizi

[10] The Ministry of Energy's reports indicates 3,000 MW of wind energy potential.

Khizi	3,6	Khizi
Mushfiq	9	Mushfiq settlement
Pirallahi Wind Park	15	Caspian Sea
New Yashma	50	Khizi
Ecological Park	0.04	Baku
Clean City	9.6	Zira
Samukh Agro-Energy Complex	5	Samukh
TOTAL	**402,94**	

Source: Azerbaijan's Wind Energy Potential and its Utilization Perspectives (Imamverdiyev, 2014)

The latest SAARE report presented below primarily focuses on six projects that were aimed to be completed by 2020 with an overall output capacity of 350 MW per year.[11]

Table 2.4 Perspective WEP projects to be implemented up to 2020

Project title	Output capacity (MW)	Required investments (AZN, million)
Khizi-1 (Shurabad)	56,1	134,5
Khizi-2 HES	69,0	190,1
Khizi-3	135,0	371,9
Absheron HES	55,2	152,1
Lokbatan	26,7	73,6
Gobustan HES	8,0	22,0
TOTAL	**350**	**944,1**

Source: Overview of the renewable energy developments in Azerbaijan, 2018 (Yusifov, 2018)

It should be noted that significant efforts of the SAARE are directed at enlarging existing infrastructure rather than founding new grids from scratch. Four out of six WEPs (Khizi-1; Khizi-2; Khizi-3; Gobustan HES) mentioned in Table 2.4 are already functioning and more than USD 411.8 million is expected to be directed at the development of these projects located in Khizi and Gobustan districts. Statistics on the share of wind energy in total power production presented by the State Statistics Committee prove not all ambitions are fully delivered. According to the latest statistics provided by the State Statistics Committee, the total capacity of wind energy production in Azerbaijan was equal to 66.1 MW in 2019 (State Statistics Committee, 2020). The data available in State Statistical Committee reports reveal the below contribution portion of wind energy to the total supply from 2015 to 2019.

[11] Projects are yet to be fully completed.

Table 2.5 Share of wind energy in total electricity supply (million, kW/h)

	2015	2016	2017	2018	2019
Total energy supply	24,688.4	24,952.9	24,320.9	25,229.2	26,072.9
of which wind energy	**4.6**	**22.8**	**22.1**	**82.7**	**105.4**

Source: (State Statistics Committee, 2019)

Despite the low level of output up to now, the above analysis portrays a very enthusiastic prognosis for the future perspectives of the wind energy from a technical point of view. Azerbaijan is located in a favorable location with enough annual wind speed for sustainable energy production. If significantly realized, 4,500 MW capacity is handy to reduce fossils utilization, decrease carbon emissions into the atmosphere, strengthen energy security shifting towards infinite natural resources. However, its economic feasibility is a significant concern at this stage as the establishment of renewable energy plants require enormous investments, and analysis into its production cost should be conducted in order to find out whether the end product, e.g. the electricity will be competitive enough in price terms. The higher production cost will inevitably result either in higher sales prices or bigger state subsidies, both of which are undesirable.

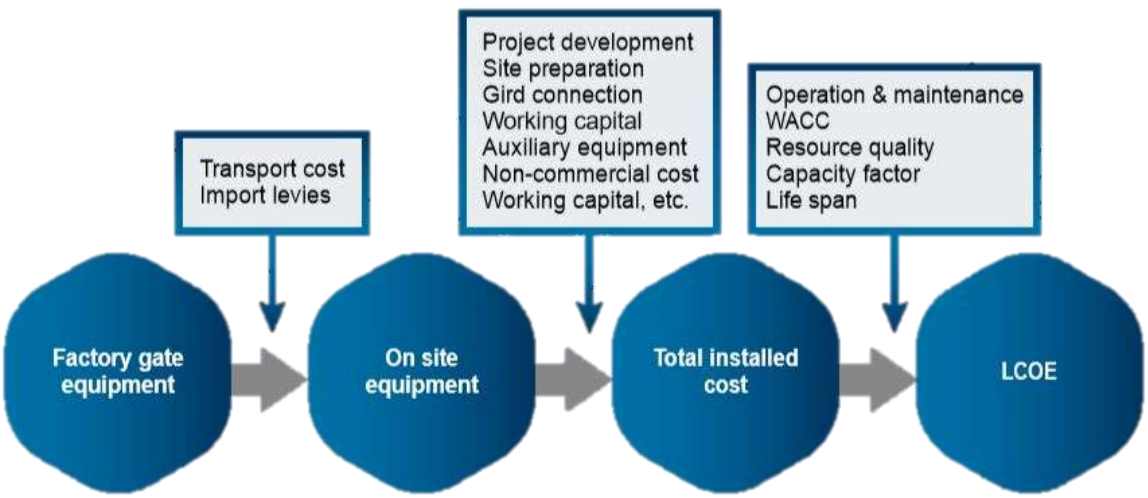
Financial requirements for the establishment of wind turbine plants are among the most burdensome aspects of the whole shift to wind energy. Turbine prices are the most expensive single expenditure items for the whole project. It has fluctuated notably since early 2000 peaking in 2008-2009 with USD 2000-2100/KW in the United States and USD 1900/KW in Europe. Starting from 2010 prices went down and saw an average of USD 1000/KW in 2017 (International Renewable Energy Agency, 2018). The total onshore wind farm installation costs averaged at USD 1477/KW, reports IRENA. The SAARE report, however, indicates a slightly higher installation cost estimating AZN 944,1 million for 350 MW in total (onshore farms only) (Yusifov, 2018). Respectively, 1kW wind energy will amount to AZN 2697,4 which converts to USD 1586,7 as of April 21, 2019.[12]

The total installation cost of offshore wind farms is significantly higher reaching USD 4697/KW in Europe in 2016. The sharp difference between onshore and offshore farms can be explained with operational and technological costs arising from building the farm in the water.

[12] The calculation is carried out based on the exchange rate provided by the Central Bank of Azerbaijan for April 21, 2019. 1 USD – 1.7000 AZN (The Central Bank, 2019)

The calculation of the average cost of 1kW energy sold to end user includes several factors like turbine prices, installation costs, operational and maintenance costs, debt costs (interest rate), wind quality, etc. To find out the end price of the renewable energy, for example, the kW/h price of the electricity derived from wind, the Levelized Cost of Electricity (LCOE) term is introduced into the subject. One of the largest international organizations in the renewable energy industry, the International Renewable Energy Agency (IRENA) modelized LCOE calculation in the below form.

Figure 2.3 LCOE calculation cost metrics



Source: Renewable Power Generation Costs 2017, IRENA (International Renewable Energy Agency, 2018)

The most widely used mathematical formula for the LCOE calculation is (The U.S. Department of Energy, 2020):

$$\frac{\sum_{t=1}^{n} \frac{I_t + M_t + F_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}}$$

where:

I_t = Investment expenditures in year t (including financing)

M_t = Operations and maintenance expenditures in year t
F_t = Fuel expenditures in year t
E_t = Electricity generation in year t
r = Discount rate
n = Life of the system

It should be noted that LCOE of renewables yielded downwards notably thanks to technological advancements. The very important factor here is the capacity which is determined by the wind quality and technology applied at the farm. The IRENA reports a 45% capacity rise in onshore wind farms from 1983 to 2017, and 56% in offshore. The total weighted average capacity factor increased by 42-43% by 2017, states the Agency's report for 2017 (International Renewable Energy Agency, 2018).

Unfortunately, there are no data available about the LCOE of renewables, including wind energy, in Azerbaijan. Therefore, this study will carry out a price comparison of green and conventional energy based on international market prices of the former with current prices set in the country. According to various sources, the LCOE of the onshore wind energy differs from one country to another one, though not significantly. The average prices vary between USD 0.01-0.06 KW/h for onshore wind energy, and USD 0.14-0.17 kW/h for offshore (International Renewable Energy Agency, 2018; Renewable Energy Sources, 2019). The 2017 Greenpeace report portrays more or less the same picture stating that "current wind power costs in some of the G20 countries are lower than costs of fossil and nuclear power. These countries, which include the USA, China, Brazil, Argentina, Australia, and most parts of Europe, have excellent wind power resources that have contributed to the rapid cost decline. This trend has continued with recent power auctions resulting in a volume-weighted average bid of 0.057 €/kWh (ranging from 0.042 to 0.058 €/kWh) for onshore wind power in Germany. In Spain, the resulting cost was 0.043 €/kWh (Manish Ram, 2017).

At this point it should be noted that the price of energy (produced from hydrocarbons) sold to consumers in Azerbaijan is lower than the LCOE of renewables discussed above:

- For residential use:
    - Up to 300KW – USD 0.04/kWh
    - More than 300 KW – USD 0.06/kWh

- For non-residential use, 1KWH – USD 0.05[13]

  Source: **Tariff Council** (Tariff Council of the Republic of Azerbaijan, 2019)

Hence, increasing the share of wind energy production in overall power generation might result in sale price yielding or require more subsidy toughening the burden on the budget. Though the Greenpeace 2017 report indicates that the LCOE of wind energy is now equal or even lower than the LCOE of fossils, it is not indicated whether the report assumes fossils as bought from third parties or as extracted in-house. Considering that not all of the G20 countries (Greenpeace report includes G20 countries only) possess natural gas or other hydrocarbons for energy production, it can be assumed that the LCOE of energy obtained from natural gas in Azerbaijan is lower than that in Europe or America (USD 0.05 kW/h on average (Renewable Energy Sources, 2019)). The latest reliable report produced in 2015 indicated that the LCOE of energy obtained through conventional sources in Azerbaijan is equal to USD 0.035 kWh (Inventory of Energy Subsidies in the EU's Eastern Partnership Countries: Azerbaijan, 2015). Thus, it is highly probable that the production cost of wind energy can drive sale prices up. Such probability is also reflected in the SAARE's report according to which, the retail tariff of the wind and solar power might increase up to AZN 0.17/kWh, that is USD 0.10/kWh (Yusifov, 2018). This is a very sensitive aspect as the government might be hesitant for the price increase considering economic policies.

Pros and cons of wind energy have been vastly discussed with a general overview that green energy, including wind energy, should be the future of the planet due to several reasons:

- Green and renewable source;
- Little to zero harm on the environment;
- Leads to the opening of new job places;
- Resilience to large scale incidents (failures) that could bring to big energy cut-outs;
- Close to zero operational cost.[14]

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[13] Ibid.

[14] According to IRENA 2017 report, fixed operational and maintenance cost for wind energy production in the United States constituted USD 53/KW/year, while in Europe this figure varied between USD 41-66KW/year. In terms of variable operational and maintenance cost, the figure averaged at USD 0.01 kW/h in the United States, and at USD 0.01-0.05 kW/h in Europe, in the same year (International Renewable Energy Agency, 2018). The SAARE reports AZN 0.04 kW/h operational and maintenance cost for total output capacity without indicating separate numbers for wind and solar energy plants.

However, some disadvantages of wind energy are not overseen either:

- Expensive installation cost;[15]
- Occupies large territories;
- Has noise and visual pollution;
- Blades constitute a danger for birds and other flying creatures, thus could harm nature;
- Dependence on the wind.

One of the most important cons of wind energy is that it is not possible to store unless special batteries are installed. Thus, besides the necessity to be located in areas close to the settlements, it also requires batteries to back up energy in case of low wind or other unpredicted situations.

Despite enlisted disadvantages, wind energy production is growing rapidly all over the world as countries demonstrate more commitment to taking care of our planet. As mentioned at the beginning of this paragraph, a lot of countries are converting to green energy, and the wind is an essential part of the whole process.

Recent developments in the energy sector of Azerbaijan hints at the government's will to pursue the footprints of a global trend, and wind energy is among key priorities for development efforts together with solar power. Recently, the SAARE together with the IRENA representatives introduced in Baku the Renewable Readiness Assessment Report for Azerbaijan which prioritizes 8 renewable plants with a total output capacity of 750 MW. Five out of eight plants envisaged to be windmill plants. During the introduction event, the representatives of both organizations also shared results of discussions on possible policies aimed at supporting the development of the RES (Ministry of Energy of the Republic of Azerbaijan, 2019). A couple of days after the presentation, it was revealed that Baku is eyeing for the implementation of tendering procedures to stimulate the growth of the renewable energy industry. The Ministry of Energy plans to have 5-year tenders implemented as of 2020 considering it as the most transparent and effective policy (Ismayilov, Tendering Program in the Renewable Energy Industry of Azerbaijan will Cover the Period of 2020-2025, 2019). At the end of 2019, the government has signed a contract with "ACWA Power" company of the United Arab Emirates

[15] Though number of variables can affect the installation cost of wind turbines, in general, the literature and studies on this agrees that this figure will be somewhere between USD 1.3-2.2 million per MW (Windustry, 2016).

on the construction of wind energy plant with the output capacity of 240 MW. Anticipated yearly electricity output of the project is equal to 1 million MW/h. The construction cost is estimated to be around USD 280 million. Locations of the wind turbines, necessary legal and administrative procedures have already been finalized in 2020. Estimated launch date of the project is not revealed.[16] The LCOE of electricity generated in these plants will approximately equal to AZN 0.055 per kWh.

The next paragraph will analyze whether solar energy possesses the same potential and attention of the government to capitalize on it.

Chapter 2.3. The perspectives of the solar power production

Following wind energy, solar energy is probably the most promising and feasible renewable source for power generation. The infinite resource comes from the Sun, the strongest source of energy itself. The amount of sunlight touching the surface of the planet in 24 hours is enough to supply the whole world with energy for 24 years. NASA estimations claim the Sun has enough potential to continue providing the same amount of energy for 5 billion years more (Maeda, 2011). With such an enthusiastic picture one cannot doubt the potential of the sunlight in becoming the cornerstone of the renewable energy industry.

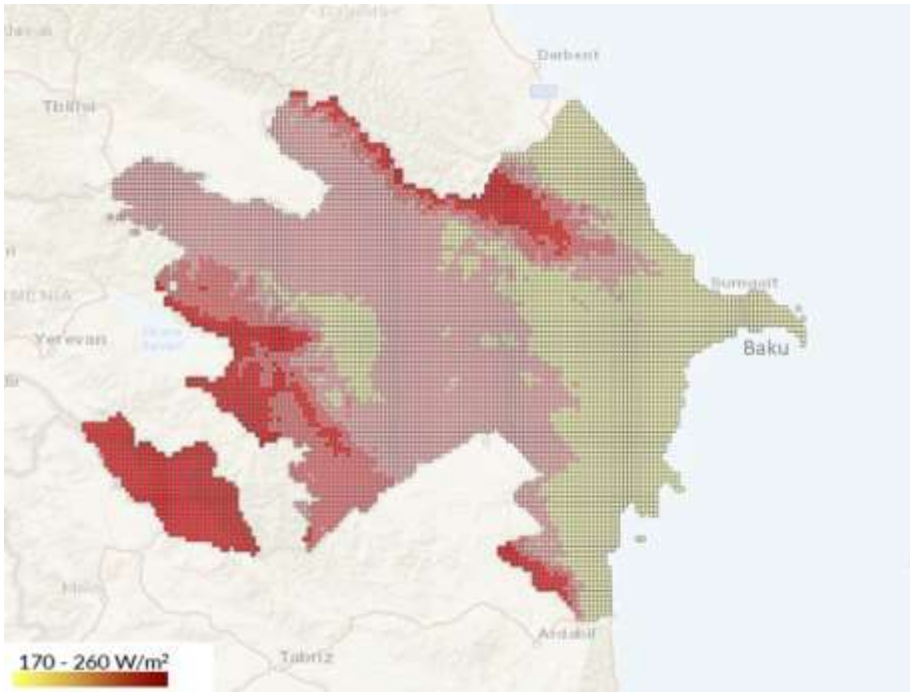
Sun’s energy has been used as of ancient times when Greeks and Romans used glass lenses for starting fire utilizing the sunlight. Modern solar energy is produced by converting sunlight into electricity using solar cells, also known as photovoltaics (PV) (National Renewable Energy Laboratory, 2019). The history of solar energy goes back to 1839 when Edmund Becquerel discovered that hitting a surface, sunlight can generate electric current. The founding was later developed by Albert Einstein in the early 1920s and Bell Labs who introduced silicon (obtained from sand) cells in the mid-1950s increasing the efficiency of the PVs (Maeda, 2011). Today, the same silicon cells are utilized in big solar farms, though with technological advancement, their output capacity increased significantly. As a result, humankind is able to benefit from the sunlight much efficiently converting it into energy.

Azerbaijan is not spared from such a generous gift of nature and enjoys annual sunbath enough to produce power. According to the official data, the amount of solar energy per square

[16] More details about the projects are available at Chapter 5.1.

meter equals 1.5-2.0 MW/h (Ministry of Energy of the Republic of Azerbaijan, 2014). The SAARE presented the following solar map of Azerbaijan according to which, the amount of W/m^2 radiation varies between 170 – 260.

Figure 2.4 Solar map of Azerbaijan (by SAARE)



Unfortunately, less amount of sunlight comes to the most settled areas including the Absheron peninsula, where approximately 3 million people live (State Statistics Committee, 2019). Nonetheless, the overall solar energy capacity of Azerbaijan is estimated at 23,000 MW by the Ministry of Energy and IRENA, which is way more than the wind energy capacity (Yusifov, 2018).

Despite promising sunlight amount, the government's intentions towards solar energy were notably weaker in comparison with the wind. Solar power capacity is projected to reach 150 MW in 2025 (wind – 440 MW), and 190 MW in 2030 (wind – 465 MW) reports the SAARE. The total amount of investments is estimated at AZN 107.2 million, whereas, the same figure for the wind energy plants constitutes AZN 944.1 million (Yusifov, 2018). Following PV farms were designed to be delivered by 2020.[17]

Table 2.6 Solar plants projected up to 2020 (by the SAARE)

Project	Capacity (MW)
Surakhani	1.7
Sumgait	1.8
Pirallahi-1	2.2
Pirallahi-2	7.2
Samukh-1	0.4
Samukh-2	7.2
Gobustan HES (solar component)	5.0
Khizi-2 HES (solar component)	10.0
Absheron HES (solar component)	10.0
Siyazan	4.5
TOTAL	**50**

Nonetheless, the reason for such a sharp difference between aimed wind and solar energy capacities is understandable. It is not a secret that wind energy is much feasible and easier for production rather than solar for two main reasons:

- Sunlight is available during the daytime only;
- Solar panels generate much less electricity than wind turbines. In fact, depending on the size, the output capacity of one turbine can equal the capacity of 48 704 panels taken together (Redlitz, 2016).

Though the output capacity of a single PV is way less than that of a single turbine, the total installation cost per kW can’t be said to differ hugely. Surprisingly, in some parts of the world, the weighted average installation cost per KW solar energy is even lower than that of wind. Though the range between the lowest and the highest prices differ significantly, as per data retrieved from different sources. According to the IRENA, for Q1 of 2017, this figure varies in-between USD 1,050/kW and USD 4,550/kW depending on the region with California being the most expensive place. At this point, it should be noted that these prices are approximately 47-

[17] Not all projects were delivered by 2020.

48% less in comparison with 2007 Q1 prices (USD 6,700/kW and USD 11,100/kW) (International Renewable Energy Agency, 2018). Energy Sage reports that in the United States, solar energy costs per W/h averaged at USD 3.05 with 6 kW of sunlight electricity system costing around USD 12,810 after tax credits in 2019 (Matasci, 2019). Azerbaijan's plans included achieving power of installations equal to 50 MW for AZN 107.2 million which equals AZN 2,144/kW, that is, USD 1,261/kW.[18] The existence of "Azguntex" LLC which produces solar panels reduces costs significantly as the import of PVs from abroad will have additional expenditures related to the shipping, import duties, etc. Data shows that PV constitutes approximately 30% of overall solar panel farm installation costs (International Renewable Energy Agency, 2018). Reducing allocations on this item helps Azerbaijan to maintain solar energy installation costs at even below level than that of windfarm setup (USD 1586.7/kW as of April 21, 2019). The annual output capacity of the Azguntex LLC is equal to 50 MW (Ministry of Energy of Azerbaijan, 2019). Besides the cooperation with the government, the company announced public sales of panels as of 2013 (Azguntex LLC, 2012). The initial plans were upgraded significantly in 2019, when the government had struck a deal with the "Masdar" (Abu Dhabi Future Energy Company) on the construction of solar energy plants with a total output capacity of 200 MW. Annual electricity generation capacity of the projects constructed jointly with "Masdar" is estimated to be around 410,000 MW/h. Preliminary legal and administrative works, including allocation of territory for setting plants, are finalized. The estimated cost of the project is USD 120 million. The LCOE of solar electricity generated in mentioned projects will approximately be equal to USD 0.031 per kWh, as per available information.[19]

Just like the case with wind energy, capacity factors play a determinant role in installation cost and LCOE of solar energy. Advanced improvement and tracking system, together with highly efficient inverters, enhanced total installed farm capacities by 79% in the United States in 2017 (Mark Bolinger, 2018). Though details are not revealed, Azguntex LLC reports the utilization of the highest standards which allows to reach the capacity factor possessed in Europe and America and bring down per watt installation cost in Azerbaijan.

[18] The calculation is carried out based on the exchange rate provided by the Central Bank of Azerbaijan for April 24, 2019. 1 USD – 1.7000 AZN
[19] Ibid.

The determinant factors for the calculation of solar power LCOE includes the same parameters indicated earlier for wind energy. Nonetheless, different sources provide slightly different LCOE values per watt of solar energy. Solar Power World editor-in-chief reports USD 36MW/h, that is, 0.036 kW/h LCOE for unsubsidized utility-scale solar energy cost, claiming this figure is identical for per watt energy price of coal as well (Pickerel, 2018). Energy Sage reports significantly higher prices USD 0.07 – 0.13 kW/h in the United States depending on the capacity factor (EnergySage, 2018).[20] International Renewable Energy Agency states that the global weighted average LCOE amounts to USD 0.10 kW/h (down from USD 0.36 kW/h in 2010). Nonetheless, this figure can reach USD 0.31 kW/h in some places, adds the report (International Renewable Energy Agency, 2018).

Another interesting and promising way of utilizing the sunlight is concentrating solar power onto a receiver and then converting it into heat. This heat is further used as industrial process heat or transformed into energy by driving a turbine using the steam created with it. This technology uses mirrors for reflecting and concentrating the light coming from the sun onto a single point. These systems are usually used for utility-scale projects with an output capacity of 10 MW and more (The US Department of Energy, 2013). The most widely used type of concentrating solar power systems are linear concentrator systems, dish/engine systems, and power tower systems (National Renewable Energy Laboratory, 2019).

The complexity of systems and storages drag up the levelized cost of such energy though. The IRENA reports USD 0.14-0.35 kW/h LCOE for concentrating solar power systems forecasting these values to go under USD 0.10 in the near future (International Renewable Energy Agency, 2018).

Operational and maintenance costs of solar photovoltaics are estimated in the range between USD 10-18/kW in the United States for utility-scale plants. This indicator amounts to USD 0.02-0.03/kWh for concentrating power plants, reports IRENA (ibid). For Azerbaijan, the SAARE reports AZN 0.04/kWh, that is USD 0.023/kWh (AZN 10.4 million, that is USD 6.12 million per year) operational and maintenance cost for a total 420 MW capacity.[21] Thus, it remains unclear

[20] EnergySage report classified three different price groups depending on system sizes: 3 kW; 5 kW; 10 kW. The LCOE varied between USD 0.07-0.09 and USD 0.09-0.13 depending on the location.

[21] The calculation is carried out based on the exchange rate provided by the Central Bank of Azerbaijan for June 9, 2019. 1 USD – 1.7000 AZN

whether this figure changes depending on the type of green resource utilized for energy production (Yusifov, 2018).

Despite obvious pros, solar energy does not come without cons too, which are high initial installation costs, dependence on the weather, expensive storage systems, territory requirements (utility-scale solar farms use a lot of open space) and though not high, association with pollution. Surely, the environmental hazard of solar power is far much less in comparison with conventional sources, nonetheless, utilization of some toxic materials during PV production, and emission of greenhouse gases during transportation and installation are associated with an indirect negative effect on the environment (GreenMatch, 2019).

Nonetheless, Azerbaijan is keen on pushing forward the solar energy industry as it was part of the programs put forward in the Renewable Readiness Assessment Report discussed earlier. Three plants are foreseen to be set up starting from 2020 through tendering procedure where the government intends to find private actors interested in investing in solar energy production. A strong advantage at this point is the availability of internal PV production by Azguntex LLC. Cutting down transportation and customs duties will be an additional point to build on much efficient solar plants.

The next chapter will analyze the RES supporting mechanisms in a select group of countries with best practices in terms of the renewables penetration into energy consumption.

Chapter 3. Research of the international best practices in renewable energy introduction to energy systems

This chapter will explore the best practices of various countries around the globe focusing on:

- Installation of renewable energy capacity;
- Renewable vs. hydrocarbon balance in power generation;
- Law, policies, regulatory framework in place for supporting the industry.

The aim is to explore the environment and conditions which led to the development of the renewable energy industry in various places. For this purpose, short analyses will be carried out to learn the experiences of universal best practices in the world, and the best practices in the countries with geographic and climate conditions similar to Azerbaijan. Collected findings will be thoroughly analyzed and scaled based on quantitative data gathered for this purpose. This study will look for the support the industry is receiving in different countries, and at later chapters try to see possibilities for implementation of best experiences in Azerbaijan.

Before proceeding with the analysis, it is essential to define main terms which are mentioned above and will be used throughout the study:

- **"Best practices".** The best practices can either be defined as countries with the most installed capacity or with the best green-to-hydrocarbon balance in energy production. Due to very purpose of this study the notion of "**best practice"** is defined as countries with the best green-to-hydrocarbon balance with minimum of 5,000 MW installed capacity;

- "**Climate and geographical conditions similar to Azerbaijan**". The literature, be it scientific or rather economic, gives various definition to the climate zone understanding and categorizes it in different models. Hence, some sources divide the world into five climate zones, others into six; nine; or even twelve. This paper will not engage in geographic debates trying to understand how many climate zones there are and what countries share the same zone. Instead, the notion of "**climate conditions same to Azerbaijan**" is defined as countries which are located at the same or close latitude. Also, the study will consider average temperature, sunlight and wind resource data for identifying countries close to Azerbaijan in terms of climate conditions. Saying "**geographical conditions same to Azerbaijan**" the study means countries with likewise landscape terrains and biodiversity, including territory size and useful lands for renewable energy plants. Azerbaijan's territory size is 86.6 km^2. Nonetheless, as the study focuses on best practices, insignificant deviation might be applicable as not all countries with likewise climate and geographical conditions are successful in the development of the renewables.

3.1. Best practices in selected countries: case studies

The dynamics of the development of the renewable energy industry saw historic upsurge during last decades. This approach can be explained with: 1) the need to enhance the energy security reducing dependency on depletable (and in various cases imported) hydrocarbon resources, and 2) decrease hazardous impact of energy generation on the environment leaning towards efficient sources like wind and sunlight.

According to the International Energy Agency's (IEA) *Global Energy Review 2020* report, the share of renewable electricity in total electricity production in the world has climbed to 28.0% in 2020 from 26.0% in 2019. The IEA anticipates that this figure will reach 29.4% by 2023 (Global Energy Review, 2020). In the EU, share of renewables in total energy production amounted to 19.7% in 2019, only 0.3% short of the 2020 target of 20%.[22] The leading EU member country in this list is a Sweden where more than 5% of total final energy consumption is derived from fossil-free sources (Renewable energy statistics, 2020). The leading country in Europe though is Norway. With hydropower being the main source of green energy, Norway produced 98% of all its electricity from renewable sources in 2016 (Norway Government, 2016).

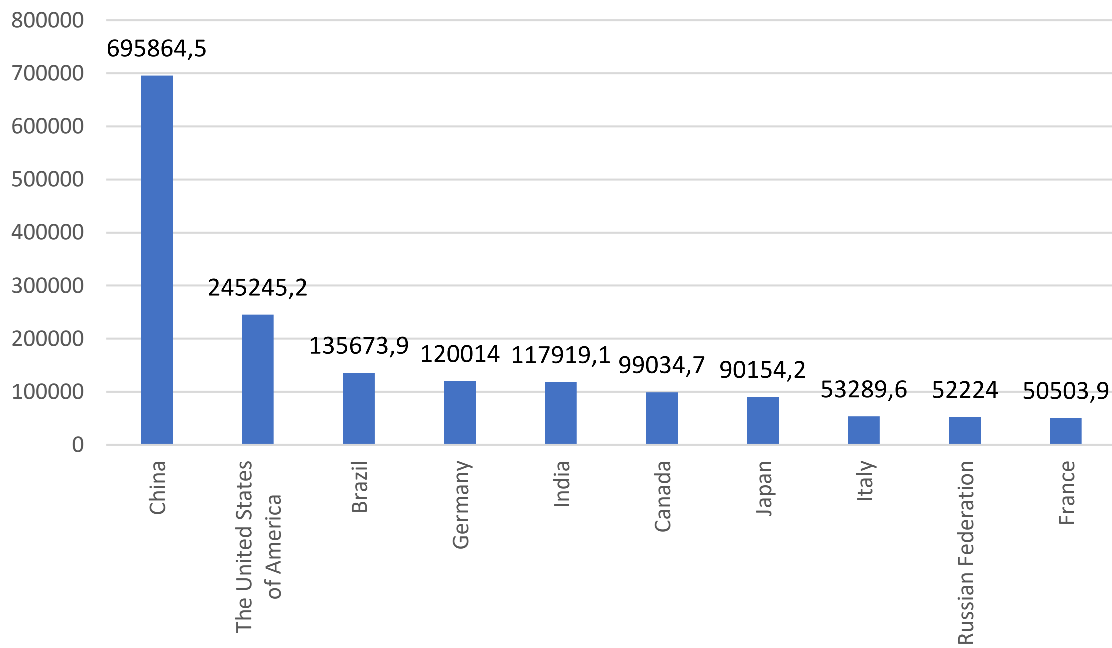
Countries with the most installed capacity

The shift to fossil-free energy is viewed in two different perspectives in world literature. The IRENA provides the list of countries with the most installed capacity where China, Russia and Brazil lead the scene. According to the data, in 2018, China's installed capacity reached 695,000 MW with the USA (second in the list) hitting 245,000 MW (International Renewable

[22] Results for 2020 were not revealed at the time of writing this thesis.

Energy Agency, 2019). Top ten included Germany, Canada, India, Japan, Russian Federation and France (see Graph 3.1). Nonetheless, despite staggering achievements, these amounts constitute smaller portion of energy (or even electricity) consumption in those countries due to extremely big demand and market. Despite being the first in terms of installed capacity, only 26.4% of total energy consumption of China was derived from green resources in 2017 (Wenjuan Dong, 2018). In the USA, this figure constituted 11% only in 2018 (U.S. Energy Information Administration, 2018). Thus, despite significant efforts directed at zero emission energy production, these countries' shift towards efficient sources still have a solid room for improvement considering internal demand levels.

Graph 3.1 Country rankings by installed capacity (MW)



Source: (International Renewable Energy Agency, 2021)

Countries with the best renewable to hydrocarbon balance in energy generation

On the other hand, there are smaller countries on our planet where economy size, population and demand does not stand anywhere close to those of major economies. Nonetheless, favorable geographical conditions, supportive regulatory policies, and strong will aligned with political and economic necessity produce 80-to-20, 90-to-10 or even higher ratio of green to hydrocarbon driven energy production levels. Profound examples of small economies vowing renewable revolution can be Costa Rica, Uruguay and Nicaragua with all three generating more than 70% of in-house demand from resources like water, sunlight or wind. According to the Climate Council, Australia based climate change communications organization, Costa Rica has produced 95% of its electricity from hydro, geothermal, solar and wind power with aim to go completely emission free in 2021 (Climate Council, 2019). Uruguay went even further with 97% indicator which was as low as 40% back in 2012. The U.S. Department of Commerce's International Trade Administration reports that sometimes production of green energy in Uruguay exceeds internal demands and thus country exports surplus to Brazil and Argentina (International Trade Administration, 2018). Nicaragua is another small, yet powerful green energy country producing 75.2% of internal demand from environmentally friendly sources in 2020 (Jones, 2020).

Best practice countries with similar to Azerbaijan geographical and climate conditions

Numerous conditions and variables affect the development of the renewable energy industry in a given country. Thus, comparative analysis of Azerbaijan with big powers like China, the United States and Brazil would be inappropriate due to major differences in resource potential, economy size, business environment, etc. Therefore, this study will rather focus on selected countries which demonstrate advanced results in terms of renewable energy industry (REI) development, and at the same time share with Azerbaijan likewise climate and geographical conditions. Nonetheless, discussed regulatory policies and frameworks hereinafter will also be compared to the very same factors analyzed previously for major economies.

The world is big and hosts nearly two hundred countries at the moment with dozens of them located approximately at the same latitude with Azerbaijan. Similarly, numerous countries have close to Azerbaijan weather conditions, including sunlight and wind resources for production purposes. Trying to look for the countries with the best REI, this study will focus on the ones with not only close to Azerbaijan climate and geographical conditions, which directly affects the amount of sunlight and has an impact on the wind potential, but also considers factors like population and territory size. Though deviation, especially in relation to the latest two indicators are present. Nonetheless, the whole purpose of this analysis lies behind defining the legal framework approach in support of renewable resources. Thus, the geographical location remains the major factor for selecting the countries, along with achieved successes in the penetrating the green energy into utilization. The reason for considering territory size and population is to avoid a possible level of analysis problem. In the below analysis the following countries will be take into consideration:

Table 3.1 Best practice countries selected for this study[23]

	Geographical location	Territory size (km^2)	Population (million)
Azerbaijan	40.1431° N, 47.5769° E	86,600	10.0
Austria	47.5162° N, 14.5501° E	83,879	8.58
Norway	60.4720° N, 8.4689° E	385,207	5.3
Romania	45.9432° N, 24.9668° E	238,397	19.0
Portugal	39.3999° N, 8.2245° W	92,226	10.0
Greece	39.0742° N, 21.8243° E	131,957	10.7
Croatia	45.1000° N, 15.2000° E	56,594	4.0

Sources: (LatLong, 2021; Living in the EU, 2019)

Norway is the only country which is not located in the same geographical zone as Azerbaijan. The reasons for inclusion of Norway into the study are its outstanding results in terms of integrating renewable energy into the consumption, and high utilization of hydropower resources (note that Azerbaijan has a significant hydropower capacity and operating infrastructure as discussed in Chapter 2).

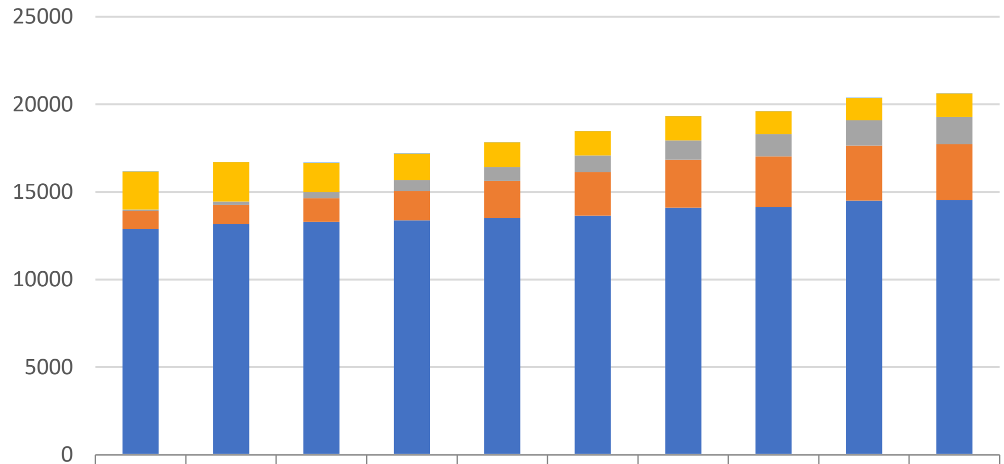
The detailed analysis of the selected countries' renewable energy industries are presented in the following paragraphs.

Austria

Austria is one of the leading countries not only in Europe but in the world in terms of renewables penetration into energy consumption with more than 33% result (European Union, 2020). Total installed capacity is higher than 20,000 MW as per IRENA report of 2019 (International Renewable Energy Agency, 2021) with hydropower being the major contributor (14,194 MW (ibid.)). Below table demonstrates the country's installed capacity trend by years and types.

[23] Achievements of the selected countries in renewable energy generation and utilization are discussed in separate paragraphs in detail.

Graph 3.2 Installed Renewable Power Capacity in Austria (MW)



	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Geothermal	1	1	1	1	1	1	1	1	1	1
Bioenergy	2176	2249	1672	1507	1411	1396	1393	1290	1271	1336
Solar power	89	174	337	626	785	937	1096	1269	1438	1578
Wind power	1016	1106	1337	1675	2110	2489	2730	2887	3133	3159
Hydropower	12895	13177	13309	13383	13532	13650	14116	14150	14516	14554

Hydropower Wind power Solar power Bioenergy Geothermal

Source: (International Renewable Energy Agency, 2021)

Austria is a landlocked country located in the center of Europe with a total area of 83,879 km^2 (About the EU, 2019). It has population of 8.58 million (Statistics Austria, 2018).

Located in mountainous areas, Austria has very close to Azerbaijan solar and wind statistics. According to the World Bank, the Global Horizontal Irradiance (GHI)[24] per year is equal to 1192 kWh/m^2. The yearly temperature averages to 10.0 °C. Wind density is 1201 W/m^2 (WB Global Solar Atlas, 2019; WB Global Wind Atlas, 2019). In terms of REI development and share of carbon free energy in total consumption, Austria is the fifth most successful EU country as per 2017 statistics. Being far ahead of the 2020 target set for the EU countries, Austria is able to provide 60% of electricity supply through sustainable resources. Like most other countries, hydropower is the leading renewable source type with impressing wind and solar sectors. In

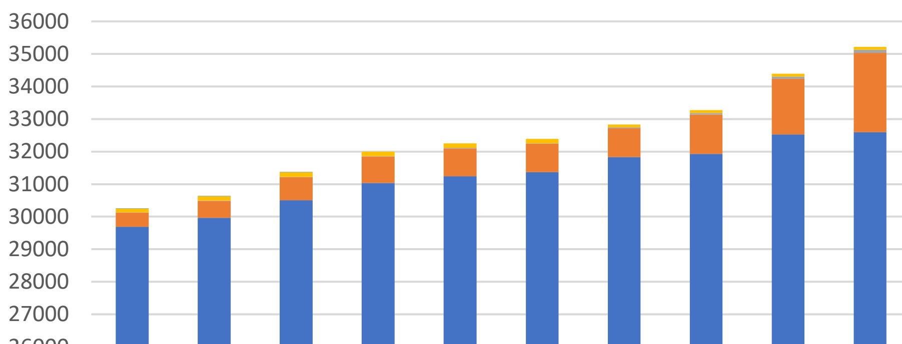
[24] The radiation reaching the earth's surface can be represented in a number of different ways. Global Horizontal Irradiance (GHI) is the total amount of shortwave radiation received from above by a surface horizontal to the ground. This value is of particular interest to photovoltaic installations and includes both Direct Normal Irradiance (DNI) and Diffuse Horizontal Irradiance (DIF) (Vaisala Energy, 2019).

2016 alone, 95% of all solar systems installed in the European Union were produced in Austria, national investment promotion agency reports (ABA Invest in Austria, 2019).

Norway

Norway is one of the leading countries in the world in terms of REI development. In 2019, 74% of gross final energy consumption came from green sources (European Union, 2020). Total installed capacity reached staggering 35,214 MW in 2019, reports IRENA. The lion's share of the renewable energy comes from one single source though – total installed hydropower energy capacity constitutes more than 30,000 MW. Installed wind energy capacity went slightly over 2,444 MW, while installed solar capacity amounted to 90 MW only in 2019 (International Renewable Energy Agency, 2021). Below table summarizes Norway's installed renewable capacity for the period of 2010-2019.

Graph 3.3 Installed Renewable Power Capacity in Norway (MW)



	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Marine	2	2	2	0	0	0	0	0	0	0
Bioenergy	122	140	140	140	140	140	87	87	87	87
Solar	9	10	10	11	13	15	27	45	68	90
Wind	425	512	705	818	859	867	883	1207	1710	2444
Hydropower	29693	29969	30509	31033	31240	31372	31834	31930	32530	32592

Hydropower Wind Solar Bioenergy Marine

Source: (International Renewable Energy Agency, 2021)

Hosting nearly 5.3 million population, Norway is located in the north of the continent within an area of 385,207 km^2 (Statistics Norway, 2019). The mother nature bestowed this Scandinavian country with abundant hydrocarbon resources making it one of the riches in the globe. Relying extensively on sustainable resources, Norway is accumulating the wealth generated from hydrocarbon resources in its Pension Fund which now oversees more than 1 trillion US dollars being the richest sovereign wealth fund in the world (Sovereign Wealth Fund Institute, 2018).

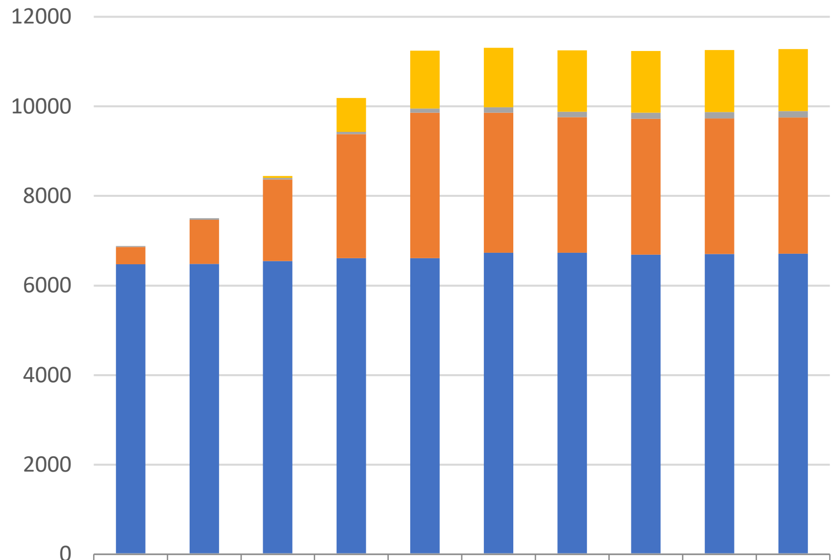
As already mentioned, Norway's REI heavily relies on hydropower plants. Unlike other countries discussed in this study, Norway can't be considered privileged in terms of solar potential. Average yearly GHI is equal to 822 kWh/m^2, whereas average wind density in 10% of the windiest areas exceeds 1,300 W/m^2 which is a pretty fine indicator (WB Global Solar Atlas, 2019) (WB Global Wind Atlas, 2019). Nonetheless, hydropower alone was enough to provide almost 98% of the total electricity consumption of the country in 2016 (Norway Government: Ministry of Petroleum and Energy, 2016).[25]

Romania

Romania is another successful, yet not making the headlines country when it comes to the development of the renewable energy industry. By 2019, the country was able to reach 24% green energy share in its gross final energy consumption with an installed capacity of 11,190 MW (European Union, 2020; International Renewable Energy Agency, 2021). Hydropower is leading renewable energy source (RES) in this country either. Total installed hydropower capacity tops 6,600 MW with production results of 14,853 GWh in 2017 (International Renewable Energy Agency, 2021).

[25] Both Norway and Austria benefit from the specific geomorphological features: they have high mountains with narrow valleys and intensive rain and snowfall all year round. It is easy and relatively cheap to build dams there. It facilities the production of hydroenergy all the year. To big extent those two countries benefit from nature.

Graph 3.4 Installed Renewable Power Capacity in Romania (MW)



	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Solar	0	0	41	761	1293	1326	1372	1374	1386	1386
Bioenergy	20	30	35	46	94	118	123	140	141	142
Wind	389	988	1822	2773	3244	3130	3025	3030	3032	3040
Hydropower	6474	6483	6548	6610	6613	6730	6734	6692	6701	6713

Source: (International Renewable Energy Agency, 2021)

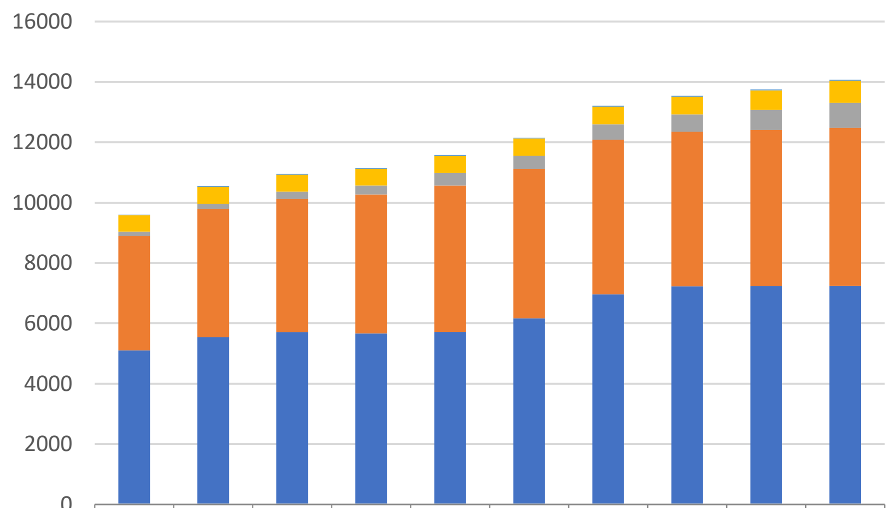
Romania's territory and population size are significantly bigger in comparison to Azerbaijan as the country sit in 238,397 km^2 of area with more than 19 million population (Living in the EU, 2019).

Romania's solar and wind potential statistics interestingly differs from the country's vision for developing the REI. According to the World Bank data, Romania has an average annual GHI indicator of 1367 kWh/m^2 and only 684 W/m^2 of wind density. Average yearly temperature is 12.0 °C and average wind speed is equal to 7.8 m/s (WB Global Solar Atlas, 2019; WB Global Wind Atlas, 2019) However, the government announced ambitious plan of 35% renewables penetration rate into total energy consumption, where significant portion of attention is devoted to development of wind farms. The same plan projects that wind farms alone should provide 23% of total electricity consumption by 2030. (Romania Insider, 2018).

Portugal

Portugal has successfully utilized abundant renewable resources into developed industry surpassing the EU targets by far. Renewable sources constituted 30% of gross final energy consumption in 2019 (European Union, 2020). Unlike other cases in Europe, Portugal is one of the rare cases where relatively new mean of renewable energy source like wind now constitutes the largest portion of the renewable energy output. Out of 14,068 MW of installed renewable capacity in 2019, wind energy amounted to 5,233 MW, whereas hydropower energy remained at 7,249 MW (International Renewable Energy Agency, 2021).

Graph 3.5 Installed Renewable Power Capacity in Portugal (MW)



	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Geothermal	25	25	25	25	25	25	25	29	29	29
Bioenergy	546	560	568	551	561	577	587	582	648	729
Solar	134	172	238	296	415	447	513	579	667	828
Wind	3796	4256	4412	4610	4857	4937	5124	5124	5172	5233
Hydropower	5106	5535	5712	5661	5715	6168	6960	7226	7236	7249

Hydropower Wind Solar Bioenergy Geothermal

Source: (International Renewable Energy Agency, 2021)

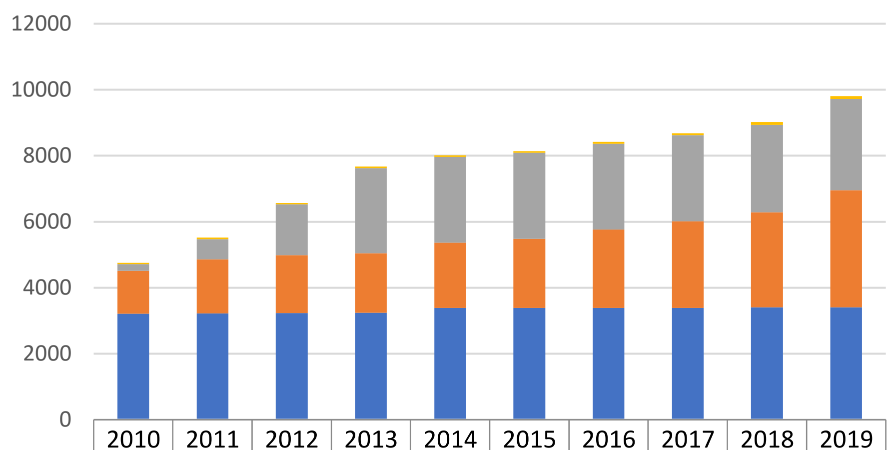
Portugal has a territory of 92,226 km^2 where approximately 10 million of its population are inhabited (Living in the EU, 2019). Its located on the coast of Atlantic Ocean and enjoys a vast amount of sunlight thanks to its geography and climate. Average yearly GHI tops 1722 kWh/m^2 (WB Global Solar Atlas, 2019). Portugal is a very special case for analysis as the average wind density is pretty low at 323 W/m^2 in 10% of its windiest areas (WB Global Solar Atlas, 2019).

Despite this fact, 24.3% of Portugal's electricity demand was met by wind farms only in 2018 (Renewables Now, 2018). At this point, research into the success of wind farms in producing energy despite low levels of wind energy density and average wind speed needs to be carried out. Considering low wind density indicator in most territories of Azerbaijan, Portugal's case could be useful for implementation.

Greece

Greece is one of the countries with fast growing renewable energy industry which continued evolving despite the major economic turmoil. Its renewable capacity topped 9,800 MW in 2019, reports IRENA (International Renewable Energy Agency, 2021). The below table demonstrates Greek green energy evolution during 2010-2019.

Graph 3.6 Installed renewable power capacity in Greece (MW)



	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Bioenergy	41	45	45	46	47	51	58	64	82	86
Solar power	202	612	1536	2579	2596	2604	2604	2606	2652	2763
Wind power	1298	1640	1753	1809	1978	2091	2370	2624	2877	3547
Hydropower	3215	3224	3236	3238	3389	3392	3392	3392	3409	3409

Source: (International Renewable Energy Agency, 2021)

Greece's total area is 131,957 km^2. It has a population of 10.7 million (Living in the EU, 2019). The installed capacity of renewable energy by different sources is as follows (as of 2019) (International Renewable Energy Agency, 2021)

- Hydropower 3,409 MW;

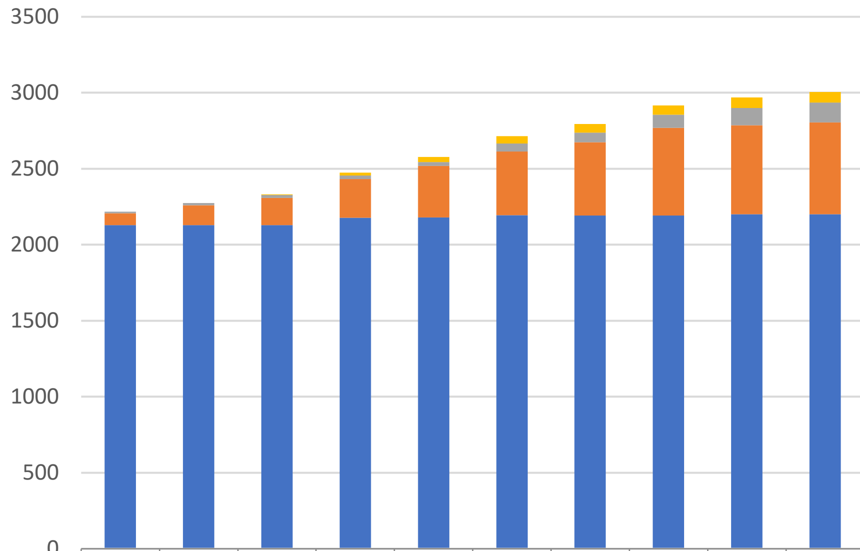
- Wind power 3,547 MW;
- Solar power 2,763 MW

Greece is located in a favorable location where abundant sunlight and wind resources are available for energy generation. The amount of GHI per year is equal to 1,620 kWh/m^2. Average air temperature is 14.6 °C. The mean wind speed in 10% of the windiest area averages to 8.72 m/s with wind power density of 786 W/m^2 (WB Global Solar Atlas, 2019; WB Global Wind Atlas, 2019) Being privileged with solar and wind resources the country not only is successful at achieving renewables related targets set by the European Union (currently 18% green energy penetration in gross energy consumption) but also looks beyond them aiming to reach 20% carbon free energy penetration rate in the gross energy consumption. The information of the Regulatory Authority for Energy (RAE) claims the country is running for 40% carbon free energy penetration into the gross electricity consumption. If achieved, this would be one of the best results in the European Union (Apostolos, 2017).

Croatia

Croatia's advancement in terms of REI can be classified as quiet, yet powerful. The country does not always make the headlines in topics related to renewables, nonetheless, comfortably sits among top ten EU countries in terms of renewables' share in gross final energy consumption far beating the 2020 target with 28% result in 2017 (European Union, 2020). Nonetheless, it should be noted at this point that statistics on installed renewable energy capacity of Croatia provided by the IRENA and the EU differs as the first institution provides figure of approximately 3,000 MW where the European Union and the official Zagreb itself claims installed capacity of 4,500 MW (International Renewable Energy Agency, 2021; Zuvela, 2018).

Graph 3.7 Installed Renewable Power Capacity in Croatia (MW)



	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Solar	0	0	4	19	33	48	56	60	68	69
Bioenergy	10	15	19	24	25	53	63	87	115	130
Wind	79	130	180	254	339	418	483	576	586	606
Hydropower	2129	2129	2129	2178	2180	2195	2192	2193	2200	2200

Source: (International Renewable Energy Agency, 2021)

Croatia is favorably located in the south of Europe with its approximately 4 million population inhabiting 56,594 km^2 of territory (Living in the EU, 2019).

Croatia’s solar resources, along with hydropower potential, are what helps this country to boost the renewable energy industry. The average yearly GHI equals to 1279 kWh/m^2, whereas wind density indicator is 859 W/m^2 (WB Global Solar Atlas, 2019). The newest member of the European Union aims to allocate USD 1.85 billion into the development of the renewable energy industry, told the country’s state-run utility HEP. This funding envisions the construction of two solar and two wind farms (Zuvela, 2018). Minister of Environmental Protection and Energy Tomislav Coric announced that Croatia has a target of increasing its wind energy capacity by three times, and solar energy capacity by 20 times during the next ten years (Jovanovic, 2019).

Table 3.2. Installed renewable energy capacity by countries and source types (2019, MW)

	Hydropower	Solar	Wind	Bioenergy	Geothermal
Austria	14,554	1578	3,159	1,336	1
Norway	32,592	90	2,444	87	-
Romania	6,713	1,386	3,040	142	-
Portugal	7,249	828	5,233	729	29
Greece	3,409	2,763	3,547	86	-
Croatia	2,200	69	606	130	-

Source: Consolidated from above paragraphs

3.2. How countries support renewable energy development: regulatory frameworks and implementation

Excellence in the development of renewable energy industry does not come only with being privileged to have a lot of sunny days, winds or other kinds of resources. Dozens of countries have at least the same if not more luck to have preferable climate and geographical conditions, and they yet lack the properly developed renewable energy industry. All successful examples mentioned above share some common patterns contributing to shifting towards green energy. Besides, the size of economy, energy demand levels, power generation potential and etc., in all above cases dedicated will grounded with number of regulatory policies in place supporting the renewables industry and effective implementation paved the way to transforming the industry.

Instruments directed at supporting the REI deployment can be classified in many ways. One of the very first classifications which are still largely used in literature came from Reinhard Haas et al. in 2001 with the Report on Promotion Strategies for Electricity for Renewable Energy Sources in EU Countries. The below table summarizes the classification which will also be used as a basis for this study.

Table 3.3 REI support instruments classification

		Direct		**Indirect**
		Price driven	**Quantity driven**	
Regulatory	Investment focused	Investment incentives Tax credits Low interest loans	Tendering system for an investment grant	Environmental taxes Simplification of authorization procedures Connection charges,

				balancing costs
	Generation based	Feed-in tariffs Fixed premium systems	Tendering system for long term contracts Tradeable Green Certificate System	
Voluntary	Investment focused	Shareholder programs Contribution programs		Voluntary agreements
	Generation based	Green tariffs		

Source: *A historical review of promotion strategies for electricity from renewable energy sources in EU countries* (Haas, et al., 2011)

Before proceeding with the analysis of support instruments in place for the countries discussed in this study, it is important to explain briefly the above table. This study will rely on the study carried out by (Haas, et al., 2011) for an explanation of abovementioned policies. REI support instruments can be broadly classified into two groups: *direct* and *indirect* policies. *Direct* policies are introduced for immediate stimulation of the deployment of renewables and can be either *price driven* or *quantity driven*, while indirect policies are not divided into sub-groups and focus more on long-term framework. Both direct and indirect instruments can be of *regulatory* and *voluntary* nature. *Regulatory policies* envision measures defined by the government or utility and applied to all private actors of the energy market. *Voluntary policies* are only applicable if the private actors demonstrate independent will to participate in the scheme.

Regulatory and voluntary policies are classified into two groups: *investment focused,* and *generation based*.

Regulatory price driven strategies allow energy generators to receive financial support or subsidy from the government per installed capacity or per kWh of produced and sold energy. This sub-group itself can be divided as investment and generation focused. Investment focused instruments are low rated loans or subsidies, tax credits, and other investment incentives. The generation focused are mainly comprised of *feed-in tariffs* (FIT) and *fixed premium systems* (FIT premium). Both systems envision the government's or legal utility's obligation to purchase the renewable energy produced by the eligible party. The difference is that, in *feed-in tariffs,* the end price of the energy per unit is fixed. In *fixed premium systems,* the add-on to the per unit of energy is fixed. Nonetheless, the end price of the energy depends on external factors. The second scheme has a greater potential for the fair competition since the production costs are not always the same.

Regulatory quantity driven schemes mainly include two instruments: *tendering* (or *bidding*) and *Tradeable Green Certificate systems* (TGC). In both instruments, the government sets minimum amount of energy to be produced. Using *tendering* system, government announces auction for pre-determined renewable energy capacity to be installed. The winner of the auction receives a contract with guaranteed amount to be purchased by the government (or legal utility) and tariffs for specified years. The TGC is well-known system in Europe, where energy producers, wholesalers or distributors are obliged to penetrate certain renewable energy share to the overall supplied amount. Actors involved in TGCs can either produce green energy themselves or buy it from other generators.

Indirect instruments include measures which are not directly targeted at the stimulation of the renewable deployment but do so via, for example, setting taxes for per unit of fossil-based energy production or simplifying procedures for renewable plants to join the grid.

Voluntary instruments supporting the REI are harder in nature for implementation as the will of those who will join the policy is vital. Shareholder and contribution programs are dependent on investors' decision to invest into the development of green plants. Green tariffs are implemented when end users, are willing to pay extra for the green energy as its generation cost might be higher than of conventional energy.

The Council of European Energy Regulators (CEER) prepared a report on Status Review of Renewable Support Schemes in Europe for 2016 and 2017 which concludes that the most commonly used support instruments in Europe are:

- Feed-in-Tariffs;
- Feed-in-premiums (also referred to as FIPs);
- Tradeable green certificates; and
- Investment grants (Council of European Energy Regulators, 2018).

Case study: Austria

Austria is among the top five countries in the EU in terms of renewable energy share in overall energy consumption. The share of green energy in overall consumption was well beyond 25% already in 2008. This figure topped 32% in 2017 making Austria one of the most experienced in terms of REI development (European Union, 2020). Austria's interest in deployment of renewables dates back to 1995 when the country invested 32% of its energy research and development budget specifically to the renewables. This figure went down to under 25% in 1996 but still was surpassing the IEA average by three times (International Renewable Energy Agency, 2019). The *Electricity Act 2000* obliged electricity distribution systems to purchase pre-determined amount of green energy from recognized generators. During 2001-2003, Austria shortly practiced green certificate scheme which was later replaced by FIT. In 2012, the last version of *Green Electricity Act* was adopted which set FIT and investment subsidies as the main supporting schemes and obliged end users to contribute to the green electricity funding (ibid). Investment subsidies are projected to be directed at small size off-grid solar systems and hydropower plants (RES LEGAL Europe, 2019).

Table 3.4 Overview of support schemes in Austria by technologies in place

	Support type			**Solar**	**On-shore wind**	**Off-shore wind**	**Bio energy**	**Hydro power**	**Support duration in years**
Austria	Regulatory	Generation based	FIT	+	+		+	+	13-15
		Investment focused	Invest ment subsidi es	+				+	N/A

Source: (Council of European Energy Regulators, 2018; RES LEGAL Europe, 2019)

Austria submitted its National Renewable Energy Action Plan (NREAP) to the EU in 2010 where below targets for 2020 were set in line with the Directive 29/2008/EC:

- Minimum of 34.2% RES penetration into the gross final energy consumption;
- Minimum of 70.6% RES penetration into the gross final electricity consumption;
- Minimum of 32.6% RES penetration into the energy consumed for heating and cooling; and

- Minimum of 11.4% RES penetration into the energy consumed for transportation (NREAP Austria, 2020).

Despite undisputed success in REI development, Austria is still to reach the target of overall RES share in gross final energy consumption. This figure constituted 33.63% for 2019 (European Union, 2020). Nonetheless, Austrian authorities are confident that the 2020 target would be reached on due time (Austrian Biomass Association, 2018). Though the overall target not reached, the target for electricity consumption was exceeded in 2016 with 72.6% result. RES-H&E target was also reached with 33.8% in 2019, whereas RES-T target implementation amounted to 9.77% in at the same year (European Union, 2020).

Case study: Norway

Being one of the most successful countries in terms of renewables penetration into the gross final energy consumption and hosting complex system of renewables (which includes all major types like hydro, solar, wind, geothermal, biomass and others), Norway yet has one of the simplest supporting policy frameworks. The kingdom calls its instrument a quota scheme which is equal to TGC and largely relies only on it (Legal Sources on Renewable Energy, 2019). The quota obliges certain producers and consumers to purchase a pre-determined amount of green energy per year. If not fulfilled, parties are subject to fines under the legislation. This kind of scheme has been introduced in 2012 (Smelvær, 2015). At the same year, Norway teamed-up with Sweden establishing joint green certification scheme - the first ever TGC implemented jointly by two countries. *Norway-Sweden Green Certificate Scheme for Electricity Production* set target of achieving 26,4 TWh of electricity generation by 2020. Just like national green certificates, this joint scheme also includes penalties for failing to achieve set targets. According to Smelvær, no single certificate holder ever failed to achieve targets (ibid.). This kind of certification policy has an advantage over national schemes because it allows the investment to take place in a location with better profitability and other conditions. The CEER report indicates that Norway supports REI through green certificates for solar, on-shore wind, off-shore wind, bioenergy and hydropower types. The duration of support is 15 years (Council of European Energy Regulators, 2018).

Table 3.5 Overview of support schemes in Norway by technologies in place

	Support type			**Solar**	**On-shore wind**	**Off-shore wind**	**Bio energy**	**Hydropower**	**Support duration in years**
Norway	Regulatory	Generation based	Green Certificates	+	+	+	+	+	15

Source: (Council of European Energy Regulators, 2018)

Though in small scale, Norway supports the hydrocarbon free energy production through investment driven policies like incentivization of non-electricity heating technologies, investment aid and conditional loans to innovate energy and climate technologies. Before shifting to green certificates, the country used tax incentives scheme for accelerating the wind power generation up to 2003. (International Renewable Energy Agency, 2019).

Norway presented its NREAP to the EU with targets of:

- 67.5% RES penetration into the gross final energy consumption (already achieved according to the EU data);
- 43% RES penetration into heating and cooling;
- 114% of electricity demand to be met by RES;
- 10% of energy demand in transportation to be met by RES (Ministry of Petroleum and Energy, 2012).

The NREAP puts green certificates as the main scheme of supporting the Plan.

RES shares in electricity generation amounted to staggering 110% in Norway in 2019 yet remaining behind the target of 114%. RES-H&C indicator is also to be reached in the future as the result for 2019 amounted to 35.81%. Green energy penetration into the transport is far exceeded with 27.33% result compared to 10% target set by the NREAP (European Union, 2020).

Case study: Romania

Though not very known for its green achievements, Romania was among the most successful EU countries in 2019 for RES penetration into gross final energy consumption records. Already in 2008, Romania introduced initial policies aiming at the development of the renewable energy industry supported by green certificates. The *Law on Establishing the Promotion System of Energy Production from Renewable Energy* (Law 220/2008) was a cornerstone of framework creation which ultimately supports the country in reaching the targets determined by its NREAP. Choosing quantity driven support scheme, Romania set first quota obligations for electricity generated from green sources up to 2020 (Law 220/2008, 2008). It was amended several times, the latest in 2014. Law 220/2008 also interposed green certificate system between the Energy Regulatory Authority (ANRE) of Romania and green energy producers. In line with the law, ANRE started granting green certificates to eligible generators. These certificates could also be traded in the market operated by the Electricity Market Operator.

RES LEGAL Europe informs that Romania started investment focused support scheme as of January 2019 for photovoltaic systems. The scheme is designed to cover up to 90% of total installation costs. This mechanism projects support to "rooftop-sized" solar systems aiming at the development of the off-grid consumer systems (RES LEGAL Europe, 2019).

Table 3.6 Overview of support schemes in Romania by technologies in place

	Support type			**Solar**	**On-shore wind**	**Off-shore wind**	**Bio energy**	**Hydro power**	**Support duration in years**
Romania	Regulatory	Generation based	Quota	+	+		+	+	15
			TGC	+	+		+	+	
		Investment focused	Investment loans	+					N/A

Source: (Council of European Energy Regulators, 2018; RES LEGAL Europe, 2019)

Romania's NREAP set below target for 2020:

- Minimum of 24% RES penetration into the gross final energy consumption;
- Minimum of 42% RES penetration into the gross final electricity consumption;

- Minimum of 22% RES penetration into the energy consumed for heating and cooling; and
- Minimum of 10% RES penetration into the energy consumed for transportation (NREAP Romania, 2010).

The target for overall RES share in energy consumption was already exceeded in 2017 with 24.5% and amounted to 24.29% in 2019. Targets for RES share in heating & cooling and electricity have also been achieved with 25.74 and 41.72% results respectively. Romania is only yet to reach its target set for transportation energy, as the indicator demonstrates 7.85% share as of 2019 versus targeted 10% (European Union, 2020).

Case study: Portugal

Portugal's history of renewable energy framework has gone a long history of development accompanied with ups and downs. It is one of Europe's most successful wind energy producers. As back as in 1988, first regulatory act on guaranteeing grid access for small-scale independent hydropower producers was adopted which in 1995 was amended to include wind power generators as well (IRENA, 2013). It was that legislation which also introduced FIT as the main supporting scheme, though the tariffs were revised several times afterward. Portugal launched *Energy Efficiency and Endogenous Energies* (E4) program in 2001 which set ambitious target of achieving 39% RES penetration into electricity consumption. The target was later increased to 45%. As of 2005, tendering scheme was applied to accelerate deployment of the renewables, mainly focused at wind energy. The apace development of the renewables industry was hit by economic crisis the country underwent in 2011. The bailout resulted in the government change and as of 2012, the National Renewable Energy Association canceled all new allocations to the renewable plants indefinitely (ibid.). Introduction of new FIT tariffs broke the stalemate restarting the new phase of RES development.

Table 3.7 Overview of support schemes in Portugal by technologies in place

	Support type			Solar	On-shore wind	Off-shore wind	Bio energy	Hydropower	Support duration in years
Portugal	Regulatory	Generation based	FIT	+	+	+	+	+	15-25
			Quota/ Tendering	+	+	+	+	+	N/A
		Investment focused	Investment subsidies		+			+	N/A

Source: (Council of European Energy Regulators, 2018; RES LEGAL Europe, 2019)

In 2015, the country adopted *Green Growth Commitment 2030* strategy which set a target of reaching 31% in 2020 and 40% in 2030 RES penetration rate into the gross final energy consumption (Green Growth Commitment 2030, 2015). Portugal's NREAP submitted in 2010 set following targets for 2020:

- Minimum of 31% RES penetration into the gross final energy consumption;
- Minimum of 55.3% RES penetration into the gross final electricity consumption;
- Minimum of 30.6% RES penetration into the energy consumed for heating and cooling; and
- Minimum of 10% RES penetration into the energy consumed for transportation (NREAP Portugal, 2010).

As per 2019 data, RES share in overall energy consumption constituted 30.62%. RES-E equaled to 53.77, RES-H&C 41.65%, and RES-T 9.09% (European Union, 2020). Though Portugal is yet to reach its RES overall target, with only H&C indicators fulfilling set target.

Case study: Greece

Greece started constructing its legal framework, including support schemes, for the development of REI back in the early 2000s. In 2004, *Development Incentives for Renewable Energy Sources* (Law 3299/2004) was adopted to accelerate the RES deployment. The law foresaw financing of 20-40% of initial investments made into the renewables industry. An alternative for the investment financing was 100% tax exemption for the plant installation cost

(The Law 3299/2004, 2004). The law itself introduced price driven and investment focused support scheme. In 2006, the law on *Generation of Electricity using Renewable Energy Sources* (Law 3468/2006) introduced first feed-in tariffs for electricity generated from green sources (The Law 3468/2006, 2006). Four years later, Greeks introduced the law on *Accelerating the development of Renewable Energy Sources* (Law 3851/2010) which set following targets for 2020 under the 2009 EU Directive, supported with FIT scheme:

- Minimum of 20% renewable penetration into the gross final energy consumption;
- Minimum of 40% renewable penetration into the gross final electricity consumption;
- Minimum of 20% renewable penetration into heating and cooling; and
- Minimum of 10% renewable penetration into transportation (The Law 3851/2010, 2010).

Greece submitted its NREAP to the EU in 2010 with a slight change in targets as renewable penetration into the gross final energy consumption was reduced to 18%. In 2019, Greece already delivered the target with 19.68% total penetration rate, as per the EU data (European Union, 2020). The NREAP included as many as 34 policies and measures for supporting REI development and reaching the targets (NREAP Greece, 2010).

The main REI supporting instrument in Greece is feed-in tariffs combined with investment incentives (Haas, et al., 2011). The CEER report indicates that Greeks use both FIT and FIT premium in four different forms. The below table is obtained from the CEER report and summarizes FIT and FIT premium schemes applied in Greece for supporting different renewable types.

Table 3.8 Overview of support schemes in Greece by technologies in place

	Support type		**Solar**	**On-shore wind**	**Off-shore wind**	**Bio energy**	**Hydro power**	**Support duration in years**
Greece	Regulatory	FIT	+	+				20-25
	Generation based	FIT Premium	+	+				
		FIT	+	+	+	+	+	

		FIT Premium	+	+	+	+	+	

Source: (Council of European Energy Regulators, 2018)

Considering Greece's results in terms of energy generated from renewable sources, implementation of policies and measures in place seem to be out of concern. As already mentioned, Greek's outperformed set target for overall share of renewables in the supply with 19.68% in 2020 exceeding the target by 1.68%. RES penetration into the electricity, H&C and transport amounted to 31.30%, 30.19%, and 4.05% respectively. Thus, only RES-H&C target was reached on due time with other targets being pursued currently (European Union, 2020).

Case study: Croatia

CEER report indicates two main REI support schemes in-place in Croatia: these are FIT and FIT premiums (Council of European Energy Regulators, 2018). However, Croatian NREAP indicates that the country also provides soft investment loans for projects in the field of the renewable energy industry through the Environmental Protection and Energy Efficiency Fund (EPEEF) (NREAP Croatia, 2013).

Table 3.9 Overview of support schemes in Croatia by technologies in place

	Support type			**Solar**	**On-shore wind**	**Off-shore wind**	**Bio energy**	**Hydro power**	**Support duration in years**
Croatia	Regulatory	Generation based	FIT	+	+		+	+	14
			FIT Premium	+	+		+	+	
		Investment focused	Investment loans	+	+		+	+	

***Source*:** (Council of European Energy Regulators, 2018; NREAP Croatia, 2013)

One of the very first acts regulating the energy production from RES in Croatia came in 2007 the *Regulation on the Minimum Share of Electricity Produced from RES and Cogeneration* was adopted. The act announced that minimum RES share in energy production in incentivized projects cannot be smaller than 5.8% (International Renewable Energy Agency, 2019). In 2009, Croatia finalized its Energy Strategy which was in line with the EU Directive 2009/28/EC and later used as a basis for submitting its NREAP. The strategy set below RES targets:

- Minimum of 20% RES penetration into the gross final energy consumption;
- Minimum of 39% RES penetration into the gross final electricity consumption;
- Minimum of 19.6% RES penetration into the heating and cooling; and
- Minimum of 10% RES penetration into the energy consumption in transportation (NREAP Croatia, 2013).

The primary supporting policies in NREAP are of financial and legislative nature. In the Energy Act of 2012, first FIT tariffs were introduced, which were later amended by the 2014 *Tariff System for the Production of Electricity from RES and Cogeneration* plan. The plan provided a comprehensive FIT scheme and shifted the related costs to the shoulders of end consumers. FIT premium was introduced in 2016 with the *Act on Renewable Energy Sources and High-efficiency Cogeneration* (International Renewable Energy Agency, 2019).

Croatia is successfully implementing policies in place which allowed the country to exceed the NREAP target of 20% RES penetration into the gross final energy consumption by 8.47% in 2019 with 28.47% result. The EU statistics indicate a 27% rate achieved in 2017 (European Union, 2020). The country reached 49.78% RES penetration into electricity consumption and 36.79% in heating and cooling by 2019 (European Union, 2020). Both results are far exceeding the set targets in NREAP for 2020. Only the target for renewables share in transportation is short of the target as only 5.85% results was achieved in 2019 versus targeted 10%.

3.3. The energy market of countries: demand and supply

The energy market of countries analyzed in this chapter varies mostly in regard to energy related statistics. Though they all have specific actors (generators, distributors, retailers, etc.), privatization level, authority overseeing the market and policies in place regulating the process, the general chain of the market remains unchanged: generators convert the resource (fossil, renewable, nuclear, etc.) into the energy -> produced energy is transmitted to transformers where it is adjusted for different types of usage -> retailers/distributors sell it to end users (households, businesses, industries, etc.)

Figure 3.1 Energy market chain

All these processes are what makes the energy market. Population, economy size, demand/consumption and supply levels, dependency on import of resources, actors at different stages, support mechanisms and regulatory framework are factors that affect the market and its operation mode.

One of the important aspects of the European countries' energy markets is very high liberalization level which started with the UK pioneering the field in early 90s. The trend was picked up by Norway and by middle of 2000s became a standard for all. The liberalization of the market meant allowing private actors to participate in generating and distributing energy to retailers and consumers (Pepermans, 2018).

Figure 3.2 Market liberalization illustration

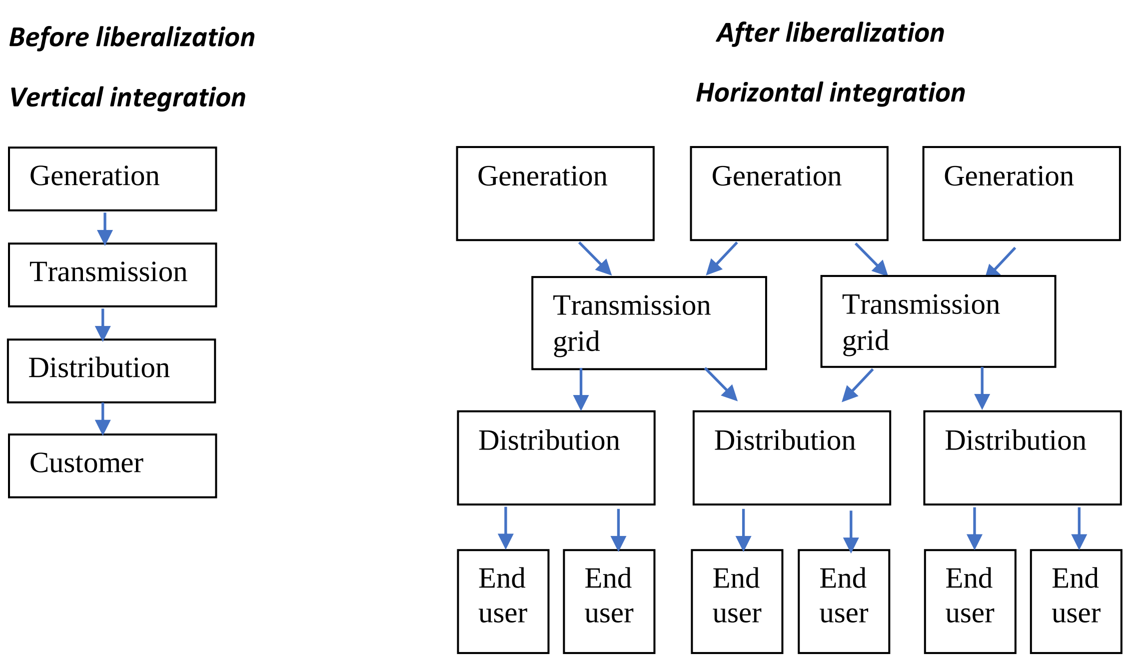


Figure based on (Pepermans, 2018)

As the figure portrays, in terms of the chain, there are no differences in-between illiberal and liberal markets. The difference comes with the allowed number of actors participating in various phases. Liberal markets allow private businesses to enter the energy market which contributes to a) competition among actors which fosters development; b) attraction of investment which shifts the financial burden from the state to the private entities; and c) generation of more renewable energy in a regulated market. All these factors are what drive the development of REI in selected countries too.

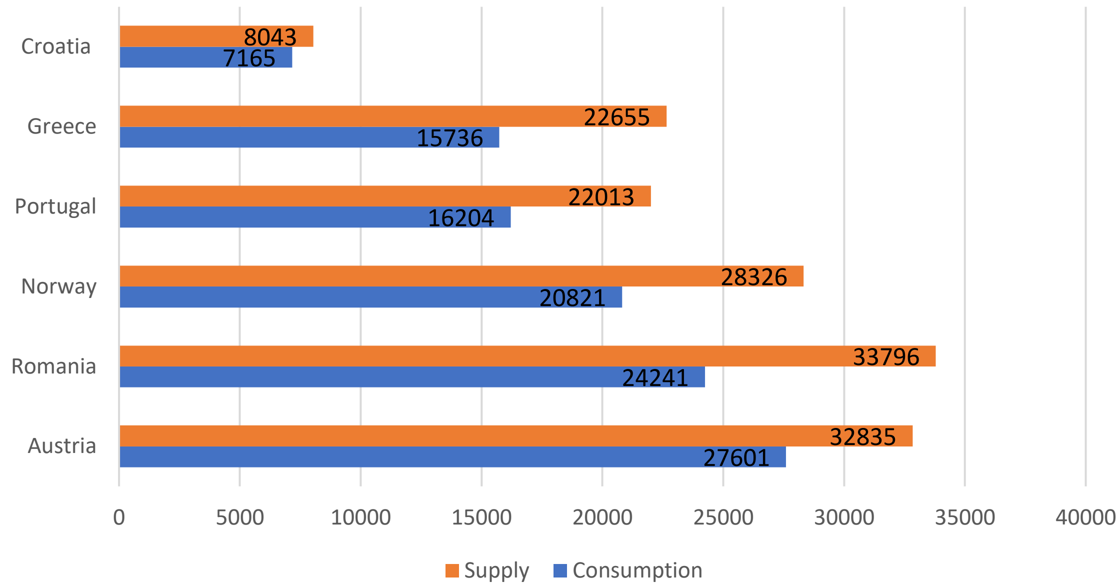
Nonetheless, all the countries have one national authority overseeing and managing the process. They ensure that demand is met, and actors are operating in line with the regulatory framework set by the government. In cases where FIT or quota support schemes are applied, national utilities are taking a role in defining the tariffs and purchasing renewable energy from eligible producers.

The model of the market in analyzed countries are very similar to what is described above. With differing support schemes and actors in place, the markets are operating in similar highly liberalized and privatized environments where actors in generating and distributing the energy carry out activities complying to the general guidelines controlled by the national utility.

What differs across mentioned countries though are the internal dynamics of the market, consumption and supply levels, prices and regulatory frameworks (which is discussed earlier).

Below this study will portray the situation in regard to the energy markets of countries based on the statistics about various indicators. All the data are obtained from the International Energy Agency's database for 2018 (International Energy Agency, 2019). Conceptualization and measurement of the indicators mentioned in below tables refer to the IEA Database Documentation (IEA Database Documentation, 2019).

Graph 3.8 Total final consumption and energy supply by countries (2018, in Ktoe)[26]



Source: (International Energy Agency, 2019)

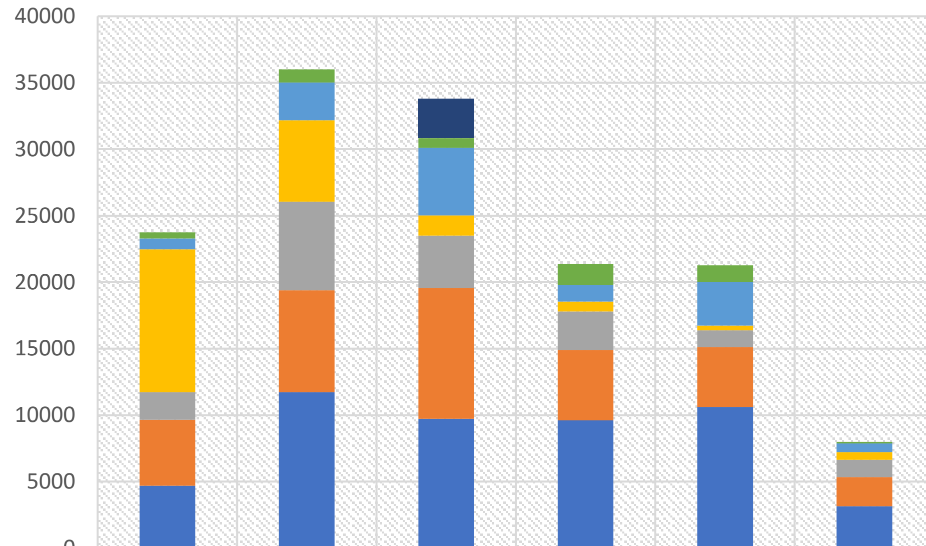
The above table is actually an indication of a possible issue related to the shift to green energy. As it can be observed, all countries except for Croatia have significant supply - consumption imbalance. RES became one of major contributors in this regard. When hydrocarbon resources are utilized for power generation, the government is able to use the necessary amount to meet the demand which is not the case with renewables. Unlike fossil driven energy, generation of renewable power is dependent on weather, especially in cases with wind and solar generation, rather than on demand. Therefore, in several cases, countries do face situations when more than needed energy is produced at some point. This problem is especially observable in electricity production based on renewables. Insufficient advancement of batteries for saving surplus production leads to problems of managing excess energy. Although countries carry out import and export operations of energy, sometimes these measures are not able to solve the issue. Export of energy needs contracts to be signed or amended and the whole procedure of transfer to be completed. Unexpected period of sunny or windy days leave no time and room for holding export negotiations and concluding agreement. This is when governments start 'to pay' households for the electricity used in determined timeframes (e.g. holidays, weekends, etc.).

[26] The tonne of oil equivalent is a unit of energy defined as the amount of energy released by burning one tonne of crude oil. – this is a measure used by all int organizations and even countries to showcase huge numbers.

Though utilities do not directly pay by cash to individuals, households receive lower bills where incentivized electricity usage is deducted (Berke, 2018).

Despite related issues, RES penetration into the energy keeps growing with hydro, solar, wind power and biofuels being the major focal points.

Graph 3.9 Total primary energy supply by sources (2019, in Ktoe)



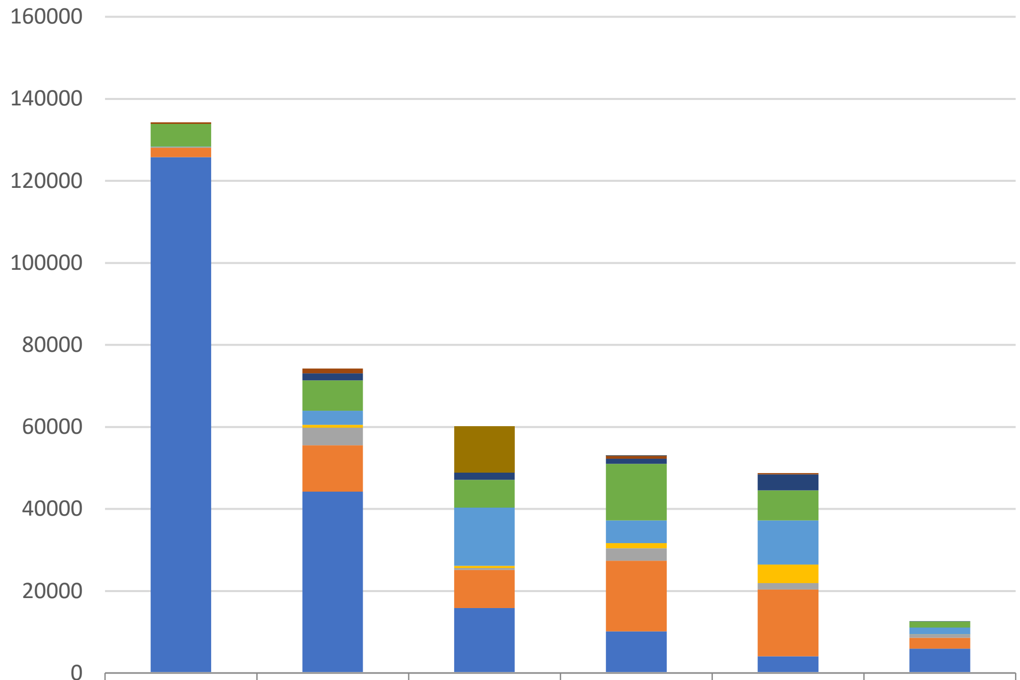
	Norway	Austria	Romania	Portugal	Greece	Croatia
Nuclear	0	0	2964	0	0	0
Solar, wind, etc.	477	994	736	1575	1261	113
Coal	801	2819	5065	1252	3285	651
Hydro	10741	6127	1519	752	346	589
Biofuels and waste	2090	6681	3953	2886	1262	1309
Natural gas	4959	7668	9843	5284	4503	2171
Oil	4685	11713	9716	9616	10613	3160

Oil Natural gas Biofuels and waste Hydro Coal Solar, wind, etc. Nuclear

Source: (International Energy Agency, 2019)

REI development is much significant in electricity supply as major industries and businesses are still using fossil driven energy which pulls hydrocarbon indicators up. If to look at electricity supply delivered to households and small to medium sized businesses, the share of renewables is much higher. The minimum RES-E penetration rate in analyzed countries is 42% with Norway getting close to 100 marks. The below table provides insight into the source types used for electricity generation.

Graph 3.10 Electricity generation by source (2019, GWh)



	Norway	Austria	Romania	Portugal	Greece	Croatia
Nuclear	0	0	11280	0	0	0
Geothermal	0	0	0	216	0	0
Waste	412	1146	0	625	286	0
Solar	13	1702	1777	1275	3961	83
Wind	5536	7421	6773	13738	7278	1438
Coal	163	3414	14157	5594	10805	1644
Oil	17	694	585	1210	4471	35
Biofuels	37	4300	468	3014	1579	877
Gas	2332	11321	9308	17249	16303	2623
Hydro	125796	44223	15811	10165	4059	5932

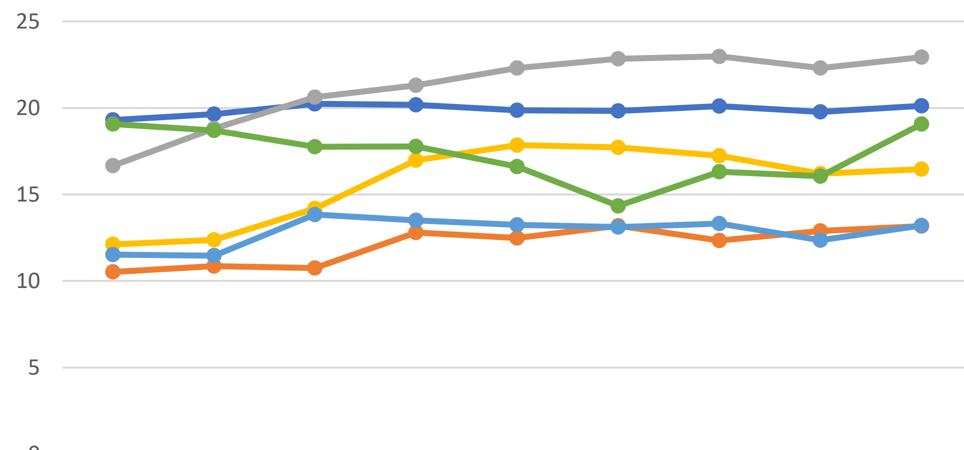
Source: (International Energy Agency, 2019)

Along with other support mechanisms implemented, high liberalization and privatization levels of renewables in analyzed countries is one of the main factors lowering hydrocarbon driven electricity generation. Especially, with the development of solar PV systems, individual households are installing panels on their properties which significantly decreases, or abolishes at all electricity bills, and contributes to the PV penetration to the indicators. Wind plants are more useful for small or mid-sized farms is privately used. Otherwise, the wind is generally preferred by generators who acquired necessary certificate and produces electricity for distribution to households. Nonetheless, despite not being suitable for individual use, its impact on the household and prices of electricity is of same significance.

Despite the progress, Graph 3.10 shows wind and solar power still has a big space for improvement. The scene is still dominated by hydropower when it comes to the renewables as fuel type. Water's potential in meeting the demands for energy generation aligned with its relatively low cost and reliability puts this resource at the center of REI. Nonetheless, wind power development in Portugal, Greece, Romania and Austria signal positive perspective for future.

Electricity prices are another important aspect of the energy market and are significantly affected by the development of the renewable energy industry.

Graph 3.11 Electricity prices in countries (Euro cents, per kWh)[27]



	2010	2011	2012	2013	2014	2015	2016	2017	2018
Austria	19,3	19,65	20,24	20,18	19,87	19,83	20,1	19,78	20,12
Romania	10,52	10,85	10,75	12,79	12,48	13,19	12,33	12,89	13,17
Portugal	16,66	18,81	20,63	21,31	22,31	22,85	22,98	22,3	22,93
Greece	12,11	12,38	14,18	16,97	17,85	17,71	17,23	16,2	16,46
Croatia	11,53	11,46	13,84	13,5	13,24	13,12	13,31	12,36	13,21
Norway	19,07	18,7	17,75	17,78	16,61	14,34	16,31	16,05	19,07

Source: (Eurostat, 2020)

[27] Statistics demonstrate average year-end prices for 2,500 kWh < Consumption < 5000 kWh all taxes and levies included.

Impact of renewables on the electricity market and prices in separate or individual cases might be significant due to the de-centralized supply-demand scheme and off-grid plants feeding households directly. Nonetheless, the same can't be said about the REI impact on average electricity prices for the country. This phenomenon is yet to be explored to full extent, but early studies show electricity market reforms and regulatory frameworks has higher impact on average electricity prices than green energy generation development (Limura & Cross, 2018; Mulder & Scholtens, 2013; Maekawa, Hai, Shinkuma, & Shimada, 2018).

To conclude, all countries under focus have highly privatized and liberal energy market where the national utility oversees the de-centralized in nature supply and demand cycle. Internal consumption is fully met with most countries generating surplus energy which is sent to the international market or stored in batteries. Renewable energy generation is developing with a fast pace with electricity needs majorly met by green fuels.

3.4. Variables affecting the development of the renewable energy industry

The study has already discussed selected practices of the development of renewables in countries, support mechanisms in place pushing the green evolution ahead and the market overview, including fossil-free energy share. Nonetheless, contributing factors to the renewables industry development are not limited to mentioned ones. REI development depends on various factors which can be labeled as independent variables (renewables industry being the dependent variable). Although this study focuses on the regulatory policies applied in countries with the developed renewable energy industry, other components of the economic environment affecting the shift towards green energy cannot be disregarded.

Number and scope of factors impacting the renewables industry are vast, and they come with different impact extent. Some major variables for consideration are analyzed below:

- **Renewable energy potential.** The empirical link between the potential and development of the sector is evident: no resource, no power generation. Serving to the purpose of this study, data on wind, solar and hydropower potential will be considered for analysis. For wind and solar potential, indicators of the World Bank's solar and wind atlases will be used. For hydropower, installed capacity will be considered.

- **Economy size: GDP.** The size of the economy is crucial, yet not a decisive variable. Yet, generalized pattern demonstrates that the larger the economy, higher REI development indicator. Several conditions are necessary for development of the economy, like liberalization of the environment, strong emphasis and protection of property rights, etc. All these factors are also contributing to the establishment of private businesses generating and distributing the energy from green resources. Thus, the empirical link between these two variables is indubitable. To prevent the analysis from getting extremely complex, the economy size will be measured by the current GDP – the most commonly referred indicator for this purpose.
- **Territory size.** The logic behind introducing this variable is that the larger the territory, the higher the chances of encompassing windy or sunny areas, and hydropower resources.
- **Existence of hydrocarbon resources.** Hydrocarbon resources are in many cases the main obstacle hindering the development of the renewables industry. As discussed in earlier chapters, the average LCOE of green energy is getting closer to the fossil driven power, but there is still a room, especially if the necessary equipment for plant installation is imported. Thus, countries with hydrocarbon resources are in many cases not supportive of REI. However, this argument is broken by Norway who despite being one of the largest owners of natural resources has developed significant renewable industry. This is a nominal variable with yes or no categories.[28]
- **Supportive policies and their types.** As the case studies of best practices put it clearly, high liberalization of the green energy market with private businesses participating in power generation and distribution is one of main traits leading to success. For private businesses to enter the energy market, besides liberal environment, it is essential to have in place support schemes designed to attract investment into the industry. The type of those mechanisms can differ based on strategies pursued by governments, but all of them serve to the very same goal. Besides, penetration of individuals into the process also leads

[28] The hydroenergetic potential of Norway was developed before the discovery of crude oil and natural gas reserves. Electricity in Norway was traditionally more available than road access, especially in the mountain areas. Norway did not developed hydroenergy because it was green. It developed this source because it was cheaper and more available in the most of the country areas. The same is the case for Sweden and Austria

to technical innovation as businesses constantly seek to decrease the production costs and increase the revenues.

- **Easiness of doing business.** Easiness of doing business is directly linked with the availability of the investment capital. This variable is essential as the conducive business environment is what needed for investors to be interested in investing in the industry. To introduce this variable, the World Bank Doing Business Report, Ease of Doing Business (EODB) scores will be taken as basis.

Surely there are other factors too contributing to the development of the renewable energy industry. Production of necessary details for installing green plants, custom duties and procedures for export of equipment, availability of territory for settlement of plants are essential factors for consideration before entering the renewables market. Nonetheless, in a case when selected indicators in place are positive in any given country, lately mentioned factors' roles decrease in decision making.

Table 3.10 Overview of selected variables by countries

	Renewable capacity	GDP current (USD, billion, 2018)	Territory size (km^2)	Hydrocarbon Resources	Supportive policies	Business environment (EODB score)
Norway	1347 W/m^2 900 GHI 32 502 MW	434 751	385 207	Yes	Yes	82.95
Austria	1220 W/m2 1200 GHI 14 194 MW	455 737	83 879	No	Yes	78.57
Portugal	323 W/m2 1714 GHI 7248 MW	237 979	92 212	No	Yes	76.55
Romania	357 W/m2 1368 GHI 6692 MW	239 553	238 397	Yes	Yes	72.30
Croatia	859 W/m2 1500 GHI 2206 MW	60 806	56 594	Yes	Yes	71.40
Greece	786 W/m2 1700 GHI	218 032	131 957	Insignificant	Yes	68.08

	3392 MW

Source: *Data indicated at the table are derived from multiple sources*[29]

The general reading of the table is simple, yet important. In all selected countries where renewables industry is developed, along with green resources, we can see the existence of supportive policies, compelling business environment and strong economy. At this point, the impact level of selected independent variables on the dependent variable can be a topic for a very comprehensive quantitative research. Trends of changing GDP, improving business environment or adopted supportive policies and its correlation with development of renewables (measure in installed capacity or produced energy) can produce results of utmost importance for consideration in Azerbaijan, which this thesis strives to come up with. Nonetheless, if to try to accommodate all abovementioned factors and come up with recommendations based on findings derived from quantified analysis, we will need much larger study, or even a book to publish. This paper rather focuses on supportive policies implemented by the states and their implications. Hence, various schemes, mechanisms and incentivization methods are what put under magnifier. Based on case studies, several recommendations for Azerbaijan can be made for future implementation. Therefore, as already mentioned, qualitative method focusing on comparative analysis of different cases better suit the purpose here. Nonetheless, variables indicated above will be considered at later chapter while analyzing possibilities of taking measures aimed at boosting the REI.

3.5 Conclusion

Efforts and resources spent on increasing the share of renewables in energy consumption in all best practice countries selected for this study are undeniable. Nor it is possible to pass by neglecting the success gained in this regard. Minimum share of energy originated from renewable sources in final gross energy consumption of countries tops 20%. Besides this factor, all analyzed case studies have several points they share commonly:

[29] Sources are (The Authority on Sustainable Building, 2019); (WB Global Solar Atlas, 2019); (International Energy Agency, 2019) (WB Global Wind Atlas, 2019)

- Share of renewables in electricity consumption tops the indicators of all countries with minimum of 23% penetration rate. Greece is the only case spoiling the overall scene with low indicator in this term. The rest of countries outperformed Greek's by at least 10 percent;

- Transportation remains the major sector where countries struggle to increase the energy efficiency in terms of carbon emissions;

- Hydropower is the major renewable energy source extensively utilized by all analyzed countries. Although Portugal, Greece and Romania progressed in utilization of wind for energy production purposes, the overall situation depicts fairly large room for further development of wind and solar energy industries;

- All analyzed countries possess liberal market conditions which stimulates private actors to strive for excellency in reducing costs and increasing effectiveness;

- All analyzed countries implement series of instruments which support reduction of carbon emissions in energy production and consumption. Generation based regulatory tools such as FIT and FIT Premium are the main schemes implemented widely. Voluntary tools are not particularly popular in any of countries.

- Investment focused schemes are also constantly observed where governments apply various means of supporting the flow of capital to the industry.

Application of generation based regulatory schemes has proved to be effective way of supporting the renewable industry. Nonetheless, there are several aspects that should be considered before opting for such mechanisms:

- FIT and FIT Premiums proved to be effective in boosting the green energy generation. Investors continuously deploy technological advancements in order to increase the production efficiency. However, serious regulation is necessary for newbie countries in managing the liberal market. Although we have observed that the liberal market with private players is a common characteristic for countries with successful carbon free power production, apace shift to renewable sources with strong supporting measures will lead to many investors' interest to fill the niche. Thus, it might have possible implications such as:

- More than necessary energy will be generated. As already discussed, the storage of green energy is not an easy task to handle and its rapid export in case of necessity also remains an issue.
- Both FIT and FIT Premiums rely on governmental or legal entity who should buy the energy from private actors either at fixed price per unit of kW or fixed add-on per unit of kW plus the production cost. Excess energy generation fueled with high enthusiasm, unmanaged support and motivation will lead to increased expenditures of the governmental body. In the new setup of the energy market part of end users will purchase the energy from private actors directly. Thus, the legal entity will lose some portion of its revenues. Moreover, the expenditures will yield as that organization will also need to purchase the energy from the private actor. This scenario will add extra financial burden to the government.
- Investment related supporting mechanisms can also be burdensome as the level of such support depends on the availability of private capital and its volume. Availability of capital for investment into such projects in Azerbaijan is not as much as in the countries discussed above.

To sum up, FIT and FIT premiums might have drawbacks too along with potential to stimulate the RES. Obviously, a perfectly fitting support tool for one country can lead to failure if applied in the very same way in another country. Thus, comprehensive analysis highlighting opportunities and risks of any given support tool should be carried out before opting any scheme. The very purpose of the next chapter is to run comparative analysis of abovementioned policies and to see possibilities of their implementation in Azerbaijan. Considering that Baku is building an eye on implementing tendering mechanism together with investment incentives as discussed previously (see Chapter 2), special focus will also be devoted to this support tool as well. Since tendering is not among preferred tools in analyzed countries this study will also run comparative analysis of this mechanism with FIT/FIT premiums, TGCs and investment grants as those schemes are much common for countries with high level of green energy penetration into the overall energy consumption.

Chapter 4. Implementation of selected international best practices in Azerbaijan

4.1. Comparative analysis of the legal framework and supportive policies in selected international best practices

EU level legal acts regulating the renewable energy industry

The most prominent characteristic of the legal framework which can be considered as a commonality for five EU member states discussed in this study and difference from Azerbaijan is that the renewable energy markets of Austria, Greece, Croatia, Portugal, and Romania are regulated by the EU directives at the top level. Although Norway is not an EU member, it complies with the Union's directives in the renewable energy sphere. As per the EU regulations, the directives are documents that set targets to be reached by the member states without imposing binding measures, strategies, or tools. These documents ask to reach a certain level of the renewable energy penetration into different spheres and implementation of the supportive mechanisms, but does not limit member countries in possible paths, but rather describes bottom line and limitations. The most important legal act regulating the renewable energy industry in the EU member states is the DIRECTIVE (EU) 2018/2001 on the Promotion of the Use of Energy from Renewable Sources, originally adopted in 2009 and revised in 2018 (Directive 2018/2001, 2018). Norway has adopted the Directive as well and hence follows its requirements. The Directive is highly comprehensive and encompasses all vital aspects of renewable energy in detail. The Table 4.1 summarizes important points on what targets the Directive sets for countries to accomplish, including five countries studied in this thesis.

Table 4.1 Summary of the main targets the Directive (EU) 2018/2001 sets for the member countries

Article 4. Support schemes	4.2. Supportive measures should incentivize the integration of the electricity derived from renewable sources into the energy market; 4.3. Supportive measures should ensure that renewable energy producers' market revenues are maximized; 4.4. Supportive measures should be granted in an open, competitive, non-discriminatory, cost-effective and transparent manner; etc.

Article 5. Stability of financial support	5.1. Financial support granted to renewable energy projects should not be revised in a manner that would worsen the conditions of the actors or hurt their economic viability; 5.2. The effectiveness of the support should be assessed at least every five years.
Article 15. Administrative procedures, regulations, and codes	15.1. Member states should ensure that: b) authorization, certification and licensing related rules are transparent, proportionate and objective. Those rules should fully accommodate any particularities of separate renewable energy technologies. d) procedures related to authorization are simplified. Simple notification systems should be in place for decentralized devices and for generating and storing renewable energy. 15.3. Integration of the renewable energy generation should be ensured at the national, regional or local levels during early spatial planning, building or major renovating of residential, commercial or industrial areas. 15.4. Building regulations and codes should be drafted or amended in a way to ensure an increase of renewable energy share in electricity consumption, heating or cooling. The required minimum level of renewable energy for these categories should be defined. 15.8. All unjustified regulatory and administrative barriers for long-term energy purchase agreements should be eradicated.
Article 16. Organization and duration of the permit-granting process	16.1. Focal points should be assigned who would guide through and facilitate the entire administrative permit application and granting procedure upon request by applicants. These persons should guide the applicant in a transparent and effective manner up to the delivery of decisions by authorities.
Article 17. Simple notification procedure for grid connection	17.1. Notification for grid connection should be simplified in a way that renewable energy market actors send a notification to one contact only through the single window for cases of 10,8 kW or less capacity. For higher capacities, it is up to countries to decide on how simplified the notification procedure should be considering grid stability, reliability, and safety. 17.2. Relevant authority can reject the request for grid connection only for safety concerns or technical incompatibility.
Article 18.	18.1. All actors of the renewable energy industry should have easy access to

Information and training	information on support measures. 18.6. Citizens should be attracted to awareness-raising, guidance or training programs in order to inform them about the benefits and practicalities of using energy derived from renewable sources.

Source: (Directive 2018/2001, 2018)

In 2019, the EU adopted the Clean Energy Package which set forward additional targets for reaching carbon neutrality by 2050. Along with defining priorities for increasing the shift to renewables, setting at least 32.5% renewable energy penetration into overall EU consumption by 2030, the package also sets a task for member countries to further enhance the rights of consumers, simplify shift among suppliers and stimulate self-generation. The Package also seeks to increase the energy security of the EU improving the cross-border market integration and developing tighter and better collaboration between energy regulators and transmission system operators in the EU member countries. As per the agreement, the Center for Cooperation for Energy Regulators should guide actors of the market presenting them best practices implemented in a series of areas, including the legal regulations at the national level. Five dimensions are presented as part of the new approach:

- Energy security, solidarity, and trust;
- Energy efficiency;
- Decarbonization of the economy;
- Research, innovation and competitiveness; and
- A fully integrated internal energy market (Clean Energy Package, 2019).

The last point is of crucial importance as it can significantly strengthen energy security and diversify the range of actors available to end-users, thus increasing the competition. The act aims to simplify procedures required for cross-border energy supply for independent generators operating at a regional level.

The Package also requires countries to put consumers in the center of the thinking process while designing or developing the renewable energy industry. The legal framework of the countries should enable households to have increased access to a variety of suppliers, easily change suppliers, go through minimum administrative burden for self-generation and have easier access to the market for selling excess energy generated individually. According to the package, by

2050, at least 50% of the EU households are expected to be producing renewable energy. This kind of approach should further stimulate energy generators and suppliers to have increased efficiency and offer better services. The EU should support all actors, including consumers, by providing necessary support and guidance in the process. Nonetheless, as mentioned above, the requirements set forth by the Directive and the Package are defining the overall direction of the development of REI and countries do come up with their legal acts and implementation measures. Prioritizing the goals, the Package set a task for member countries to submit their National Energy and Climate Plan for 2021-2030 to the EU for review. Thus, an updated legal framework around discussed targets is yet to be prepared by countries. The next paragraph will dive deeper into the country-level legal framework and support schemes in countries selected for this study.

Comparative analysis of the country-level legal framework and supporting measures in selected countries

Since all selected countries do comply with the EU directives and regulations, this study accepts below legal framework commonalities for all of them:

- Selected countries do have liberal energy markets with private actors;
- Selected countries do implement support schemes for stimulating REI growth;
- Selected countries do take measures to reduce bureaucratic barriers and administrative burden for energy market actors.

The countries selected for this study take necessary actions to transpose the targets and requirements set forth by the European Union into the national legislation during one-two years. For this purpose, governments carry out through assessment of the current situation around the renewable energy industry which acts as a basis for designing policies. This aspect defines the differences between legal frameworks applied in various countries.

Legal framework and major trends

Interconnected wholesale energy markets

Considering that the general principles of the design of the energy markets in European countries are defined by the EU directives and regulations (which are discussed above in detail), this study will not carry out a deep analysis of initial legislative acts adopted by countries for liberalization of the energy markets. Instead, the focus will be concentrated on a recent legal framework employed by governments to increase the efficiency of the market, counter any arising or potential issues, introduce new policies, and further develop the energy industry, including the REI.

The market liberalization in EU countries, including the selected countries, developed in a way that each of them not only opened the market for local private actors but also created cross-boundary access for generators or suppliers from abroad. The creation of integrated wholesale energy markets is the most prominent and fast developing trend in the continent. The idea of establishment of the single electricity market (which later included other energy types) was initiated with the EU Regulation 2015/2222 on Establishing a Guideline on Capacity Allocation and Congestion Management (CACM Regulation, 2015). This model is also known as market coupling. [30] All countries analyzed in the thesis are already part of various market coupling schemes. Norway is included in the Nordic market (Norway, Sweden, Finland, Denmark). Portugal established the Iberian market together with Spain. Romania is in the list of countries that are covered by the Central Eastern Europe Capacity Calculation Region (CEE CCR). Central Western Europe (CWE CCR) includes Austria, Belgium, France, Germany, the Netherlands, and Switzerland. Croatia and Greece are in South-Eastern Europe (SEE CCR) along with Bulgaria and Serbia. The ultimate goal for the EU is the establishment of the single integrated energy market for all member countries (Quarterly Report on European Electricity Markets, 2018).

One of the core ideas behind the establishment of the interconnected energy market is the enhancement of the energy security (CACM Regulation, 2015). The approach is that the producers of the electricity should have independent access to energy markets of several countries which would serve to:

- Increase the competition:
    - thus, achieve higher service quality; and
    - ensure that all consumers have access to energy at a competitive price.
- Increase the electricity supply stability, as the market would have a larger pool of energy generators.

[30] Market coupling is the agreement between countries for establishment of interconnected electricity market where various control tools are deployed to harmonize different electricity exchange systems and price differences (Ondrich, 2014)

- Increase liquidity (for example, easing the quick energy sale without affecting the price);
- Increase the risk appetite related to the unexpected electricity outage and consumption changes.
- Provide new incentives for investing in new sources of energy generation, including renewable sources.

The CACM Regulation introduced single day-ahead and intraday coupling (a.k.a single intraday coupling – SIDC) as an implicit cross-zonal capacity allocation mechanism. Under this mechanism suppliers and consumers of energy are able to collaborate through a common IT system on the day the energy is needed (Single Intraday Coupling, 2020).

Along with introducing a number of advantages, measures aimed at liberalization, the establishment of cross-border collaboration, the emergence of companies operating in two or more countries, the creation of integrated markets bring challenges as well. An example can be an economic situation (or price difference) between countries which might potentially lead to destabilization of the market with intentions of private actors to increase revenues by selling in a country where prices are higher. Governments try to address such challenges by adopting legislative acts at the national level or by reaching an agreement with participating states. An issue brought by market coupling emerged in the Iberian energy market where electricity generators started making windfall profits thanks to the taxation system adopted in Spain. Higher pool prices in Spain attracted suppliers which in turn led to price yield in the overall market. The scheme was halted in 2018 with a temporary suspension of taxes. In 2019, additional measures were taken to permanently harmonize the market (Sousa, Cascao, & Sanches, 2020).

Being part of the Nordic energy market, Norway tries to eradicate potential issues arising from different economic conditions where energy generators operate, through strict regulation of the grid and monopolizing electricity transmission and distribution. In such a scheme, a grid operator, which is a public company, keeps track of how much electricity the generator is supplying to the grid and how much each end-user is consuming (Energy Facts, Norway, 2017). End users pay for their consumption and producers are paid for the volume they have supplied. This kind of scheme is common for other integrated markets as well where the generator sells the power in another country.

Energy efficiency in buildings

Another commonality for six countries analyzed in this study is the implementation of measures ensuring the penetration of renewable energy into the consumption in buildings, most importantly residential ones. This approach to energy efficiency is also backed up by the recast EU Directive on the Energy Performance of the Buildings 2010/31 (later amended in 2018).[31] The Directive requires the states to introduce minimum energy efficiency standards, including standards for utilization of renewable energy sources, considering local conditions, climate and the environment (The EU Directive 2010/31 on Energy Performance of Buildings, 2010). It distinguishes three main parameters of energy efficiency in buildings:

- Energy-saving – designing and constructing buildings in a manner that would minimize energy needs for heating, cooling and electricity purposes;
- Increasing energy efficiency – combined efficiency of building installations for heating, cooling, electricity and hot water;
- Utilization of renewable energy sources – installation of PVs, or other means, to utilize renewable sources for heating, cooling, electricity and hot water (Joint Research Center, 2020).

The primary green energy source for buildings is solar energy, which can be classified in three main directions:

- Passive solar – design and construction of buildings considering the utilization of the direct sunlight for light and/or heating purposes;
- Solar electrical – PV installations on roof-top of buildings; and
- Solar thermal – utilization of solar collectors for heating and hot water (Joint Research Center, 2020).

Except for Norway (where the vast majority of renewable energy comes from hydropower plants), other countries analyzed in this study have already embraced measures for energy efficiency, including installation of roof-top PVs. Though no comprehensive data is available about the current share of roof-top generated electricity in overall consumption in separate

[31] The predecessor of the 2010/31 Directive is the European Parliament and the Council Directive of 2002 December 16 on the Energy Performance of Buildings.

countries or the EU, the obvious trend is hard to bypass. According to researches, the potential of solar electricity penetration into consumption is as much as 25% in Europe (of consumption for 2019). Portugal is among the top countries in these terms with a potential economic share of 51.8% (Bódis & Kougias, 2019).

Table 4.2 Roof-top electricity potential and its share in final electricity consumption in selected countries (2016 data)

Country	Current technical roof-top potential (GWh/year)	Final electricity consumption (GWh/year)	Technical roof-top potential share (%) of final electricity consumption
Portugal	24,259	46,353	52.3
Greece	17,090	53,463	32.0
Austria	12,854	61,852	20.8
Romania	35,877	43,569	82.3
Croatia	7,769	15,300	50.8
Norway[32]	-	-	-

Source: Extraction from (Bódis & Kougias, 2019)

In 2019 Croatia adopted Renewable Energy and High Efficiency Cogeneration Act which eradicated bureaucracy and simplified administrative procedures for self-generation (Res-Legal, Croatia, 2018). Authorities assume that households should be able to produce up to 75% of electricity needs in-house thanks to PVs and suitable climate conditions.

Romanian government took a similar path empowering prosumers financially through rebate scheme and administratively easing the procedures. In 2019 authorities launched a policy that would subsidize up to 90% costs of installation of PVs for self-utilization. This measure was aimed at increasing the number of prosumers and de-carbonization of electricity consumption. To eradicate the administrative burden, official procedures for electricity generation were eased down.

The only exception in terms of roof-top PV employment in Norway which generates approximately 90% of its renewable energy from water resources (International Renewable Energy Agency, 2019). Nonetheless, this country has adopted its approach to energy efficiency in buildings introducing *powerhouse* and *passive house* concepts. Both concepts employ various

[32] No reliable data available at the time of writing this chapter.

measures implemented during the construction phase to increase energy efficiency (i.e. better insulation, better utilization of sunshine, an increase of airtightness, etc.). The *powerhouse* concept also envisages the installation of roof-top PVs for electricity generation if the climate conditions are favorable (Torstensen & Brandal, 2016).

Installation of PVs for solar power utilization in buildings is considered as one of the significant measures to reach the targets related to the REI penetration into the final electricity consumption set by the EU directives. European countries, including those studied deeply in this thesis, have an amended legal framework regulating the planning and construction of buildings to ensure the energy efficiency, including possible installation of roof-top PVs, is considered during spatial planning.

Supportive policies aimed at the development of the renewable energy industry

The adoption of various policies or schemes for the development of the renewable energy industry is one of the most important steps each country took in order to gain significant achievements. The guidelines regulating the state support to the renewable energy industry are set by the EU in 2014 with the respective document. The purpose of setting the guidelines is to avoid potential market distortions due to the received support volume and promote a gradual transition to market-based support model. Moreover, the guidelines also provide a basis to switch from FITs to FIPs and apply for tax or surcharge exemptions in relation to renewable energy sources. The document's maturity date was the end of 2020 (Erbach, 2016).

Different policies adopted at countries analyzed in this study have already been explored earlier (see Chapter 3.2.). Thus, this chapter will not only focus on six selected countries but will go beyond them to explore the most commonly used means for supporting the REI.

According to the latest report of the Council of European Energy Regulators, starting from 2016, four main supportive policy types were in place in Europe (Council of European Energy Regulators, 2018):

- Feed-in tariffs (FITs);
- Feed-in premiums (FIPs);
- Green Certificates (GCs); and
- Investment grants.

All four support policies fall under regulatory policies explored in Chapter 3.2.

Table 4.3 Comparative summary of main support schemes applied in selected countries

	Regulatory					
	Price driven				Capacity driven	
	Investment focused		Generation based			
	Investment grants	Tax incentives	FITs	FIPs	Green certificates	Bidding
Austria	✓		✓			
Croatia			✓	✓		
Greece			✓	✓		
Norway					✓	
Portugal			✓			
Romania					✓	

Source: *Extraction from* (Council of European Energy Regulators, 2018)

The popularity of FITs and FIPs can easily be seen, and not only in countries mentioned in Table 4.3. As per the CEER report, 17 out of 27 member countries have adopted FITs or FIPs since 2016. A tradeable green certificates scheme is the runner up with 6 countries preferring it. Investment grants are adopted in 5 out of 27 countries. It should also be noted that 15 countries adopted two or even more supportive policies, often in combination with FIT schemes (ibid).

The lion shares of support provided by governments go to small or middle-sized producers of electricity. According to the CEER report, the total amount of green electricity production which saw support reached 603 TWh in 2017 (538 TWh in 2016).

Table 4.4 The total amount of produced renewable electricity that received support (2017, in MWh)

Country	Bioenergy	Geothermal Energy	Hydropower	Solar	Wind energy – Onshore	Wind energy – Offshore	Others	Total (MWh)
Austria	2 532 736	76	1 624 634	574 295	5 745 938	-	-	10 527 679
Croatia	464 750	-	15 867	73 996	1 178 211	-	-	1 732 824
Greece	280 300	-	586 000	3 991 500	5 515 400	-	-	10 373 200
Norway	-	-	6 360 000	-	690 000	-	-	7 050 000
Portugal	1 036 439	-	611 568	540 368	11 943 204	-	1 913 898	16 045 476
Romania	453 411	-	854 861	1 702 270	6 357 586	-	-	9 368 128

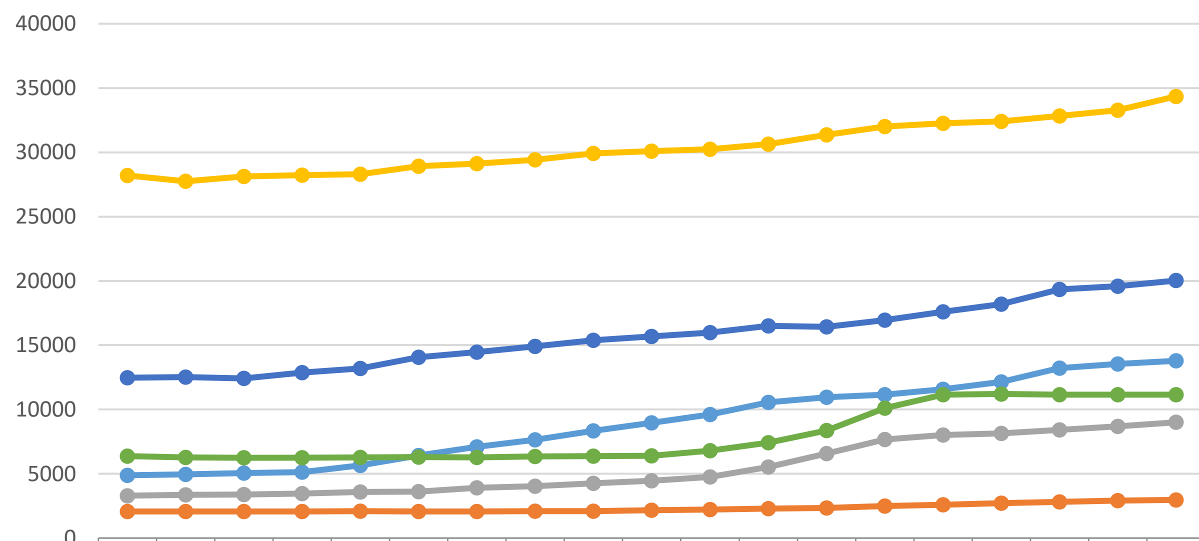
Source: *Extraction from* (Council of European Energy Regulators, 2018)

The necessity to support renewable energy production is evident. History of implemented policies goes as back as to late 1970s when investment subsidies were realized for the first renewable energy projects. The late 80s were the period when the first FITs were introduced in Denmark. Austria introduced investment subsidies together with FITs in 1992 (Haas, et al., 2011).

Effectiveness of applied policies

Though initial observations do allow to safely say that supportive policies implemented by countries are effective for promoting the renewable energy industry, to ground it with statistics, we can look at a total installed renewable energy capacity and total investments made into this industry and try to see whether any correlation with applied schemes can be observed.

Graph 4.1 Installed renewable energy capacity in selected countries (by years, in MW)



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Austria	1247	1251	1241	1287	1318	1407	1446	1490	1539	1567	1598	1651	1642	1695	1759	1819	1933	1959	2002
Croatia	2082	2082	2069	2079	2092	2071	2082	2097	2099	2170	2230	2286	2344	2487	2588	2726	2806	2927	2969
Greece	3299	3369	3388	3473	3594	3622	3912	4044	4250	4458	4756	5521	6570	7672	8010	8138	8424	8686	9006
Norway	2819	2774	2812	2821	2829	2891	2910	2942	2992	3008	3025	3063	3136	3200	3225	3239	3283	3326	3435
Portugal	4885	4947	5058	5128	5666	6417	7088	7653	8344	8958	9607	1054	1095	1114	1157	1215	1320	1354	1378
Romania	6371	6273	6245	6250	6280	6292	6285	6350	6383	6389	6791	7410	8354	1009	1115	1121	1116	1114	1114

***Source*:** (International Renewable Energy Agency, 2019)

Considering the submission year of the National Renewable Energy Action Plans by countries as the point when governments declared the supportive policies which will be applied for the promotion of the REI (Austria, Croatia, Greece, Portugal and Romania submitted NREAPs in 2010, Norway in 2012), we can see that the growth in terms of installed capacity has higher development rates as of 2010 in Austria, Greece, Portugal and Norway. These countries have opted for FITs and FIPs as the main supportive policies. Croatia is the only country which has declared FITs and FIT Premiums as the main supporting tools but has very modest installed capacity growth. There might be a wide array of possible causes for such a deviation from the general trait visible in other countries.

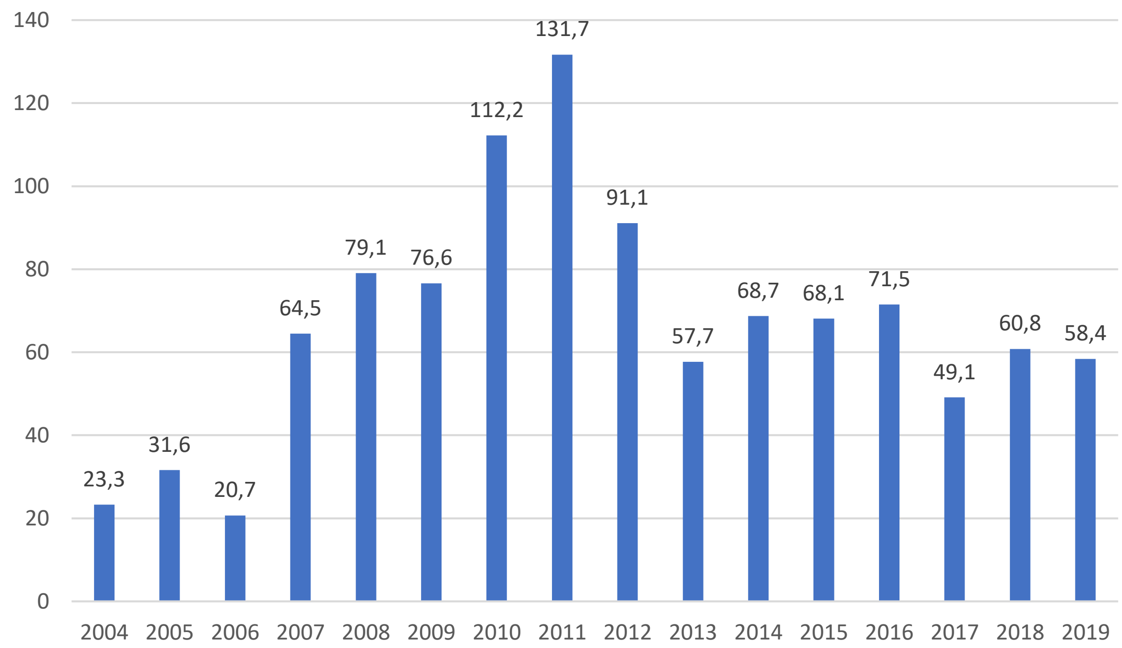
Romania have not relied on FITs and FIT Premiums and their trend line has no obvious traits. Initial upward slope stops in 2014 and reverses downward. It should be noted that Romania has decreased the level of support over the years and decided to stop as of 2017 (Res-legal, Romania: Summary, 2019).

Norway is another country which has not relied on the FITs and FIT Premiums. Nonetheless, historically strong background of the renewables industry and efficient state support plays crucial role in the development of REI. The 2012 NREAP further enhanced the development temps which can be observed in Graph 4.1.

Surely, installed capacity can be associated with various factors, most importantly with the submission of NREAPs where countries undertook responsibilities to reach the required level of renewables penetration into overall energy consumption. However, all NREAPs' general guidelines and targets were in line with the EU Directive. Moving on from this point, a considerable difference in the growth volume of installed capacity in Austria, Greece, and Portugal can be associated with implemented supportive policies. In this regard, though not directly, FITs and FIT Premiums can be considered as schemes with a higher impact on the development of the REI.

The impact of the implementation of supportive policies can also be observed in statistics on investments attracted to the REI. Not to limit the analysis to the statistics of six countries only, and increase the reliability, total investments into the REI in Europe during 2004-2015 will be analyzed.

Graph 4.2 Investments in the renewable energy industry in Europe (by years, in USD billion)



Source: (Value of renewable energy investment in Europe from 2004 to 2019, 2021)

Investments in the REI increased dramatically from 2009 reaching a peak in 2011 with USD 131.7 billion. Not surprisingly, this period coincides with the adoption of NREAPs and the implementation of supportive policies in European countries.[33]

Effectiveness of supportive policies on the development of the renewable energy industry has been deeply studied by (Haas, et al., 2011) in the paper named *A historical review of promotion strategies*. The study builds a strong relationship between the applied policies and achieved results in terms of energy generation from renewable sources. The study has also found out that FITs and FIT Premiums are the best mechanisms to reduce the risks for investors. Similar research has also been conducted by Harmelink Mirjam in the paper named *Analyzing the effectiveness of renewable energy support policies in the European Union* who also found a strong cause-result relationship (Harmelink, Voogt, & Cremer, 2006).

[33]This data does not allow to observe potential impact of separate support mechanisms. Overall assumed impact can be associated taking into consideration that during 2009-2010 most European countries submitted their NREAPs and started implementing supportive policies indicated plans.

The attraction of private investments into the REI is of fundamental importance under the liberal market conditions. The Figures 28 and 29, and studies conducted by (Haas, et al., 2011) and (Harmelink, Voogt, & Cremer, 2006) give good grounds to claim the positive effect of supportive policies in attracting investment and increasing installed capacity. FITs and FIT Premiums are widely accepted as the most effective policies and applied in the vast majority of European countries, including the cases selected for this study.

The next chapter will explore the opportunities for application in Azerbaijan the legal framework and supportive policies analyzed in this paragraph and come up with recommendations on how Baku could stimulate the development of the renewable energy industry.

4.2. Current legal framework, government regulations and government incentives for the production of renewable energy in Azerbaijan

Azerbaijan's current legal framework regulating the renewable energy industry cannot be considered extensive. Nonetheless, a number of strategies, laws, policies are in place and successor of the SAARE, the Azerbaijan Renewable Energy Agency (AREA) operates under the auspices of the Ministry of Energy. The situation with the availability of supportive policy has a bigger room to improve though. Most of the acts regulating the REI serve to development of the production capacity without offering any specific supportive policy. In most of the cases, the government managed utility or body is defined as the sole responsible for carrying the industry forward.

The Ministry of Energy is the key actor regulating and managing the renewables industry in Azerbaijan. The AREA continues implementation of the projects started by the SAARE.

The Ministry of Energy enlists four primary laws that regulate the energy market of Azerbaijan, including renewable energy production and sale:

1. The Law on Energy (Law 541-IQ, 1998);
2. The Law on Electricity Power (Law 459-IQ, 1998);
3. The Law on Electricity and Thermal Power Plants (Law 784-IQ, 1999);
4. The Law on Utilization of Renewable Sources in the Electricity Production (Law 339-VIQ); and

5. The Law on Efficient Use of Energy Resources and Effectiveness of Energy (Law 359-VIQ, 2021).[34]

In 1998, the *Law on Energy* declared the directions of the energy policy of Azerbaijan, which, along with several points, included:

- Concentrating focus on the utilization of renewable energy sources; and
- Minimizing the carbon footprint in the energy industry (Law 541-IQ, 1998).

The *Law on Energy* also defines the state as the sole actor who possesses the right to grant any individual or legal entity a right to participate in the energy market through electricity generation or supply. The conditions required for getting the right are defined in the *Law on Licenses and Permissions*.

The laws 541-IQ and 339-VIQ are accepted as the cornerstone of the state will to develop the renewable energy industry.

The potential contribution of the *Law on the Electricity Power* to the development of the energy market, including the renewable energy market, is much substantial as it specifically underlines the right of private companies to generate the energy and sell it to the end-user or the official utility (Law 459-IQ, 1998). Touching the renewables, the law even encourages the participation of private actors. This aspect is the very much needed liberalization nuance for the successful development of the REI, and the law does not limit sources that can be used by private generators. The Law 459-IQ defines the following energy market actors:

- **State utility**;
- **Energy supply companies**. These are the companies which do not generate electricity, but can participate in supply through buying from the generators or the state utility and selling to end-users;
- **Private energy generators**. These are the companies that are completely independent and run by private actors. Receiving necessary licenses and rights from the relevant authorities, these actors can generate electricity and sell it to the state utility, or the energy

[34] This law has replaced the The Law on the Utilization of Energy Resources (Law 94-IQ, 1996);

supply companies. The excess energy generated by them should be bought by the state utility on special terms and conditions defined by the relevant authorities; and

- **Energy consumers** (end users).

To summarize, the law allows private actors to either generate electricity or sell it. Unfortunately, the legislation does not create conditions for private companies to establish a plant and sell the generated energy directly to end-users. Private supply companies need to receive a special license from the government to connect to the power grid. Nonetheless, the existence of the conditions for the participation of the private actors in the energy market is indeed a good opportunity to explore. In accordance with the Law 459-IQ, the state takes responsibility to de-monopolize the energy market. Considering the fact that fossil fuels are strictly managed by the government, it is out of doubt that the most relevant sources for energy generation by private actors are renewable sources like wind, sunlight, water or the bio sources (e.g. waste). Though it should be noted that Azerbaijan is yet to catch up with the level of higher degree of market liberalization, like in countries discussed in earlier chapters. The legal framework has a number of areas that need to be improved and managed properly to achieve the desired results. According to the *Law on the Electricity Power*, followings are still regulated by relevant authorities:

- Electricity generators and distributors need to acquire special licenses from the government in order to operate;
- Electricity distribution in a given region should be carried out based on a special contract signed with a relevant governmental entity;
- Electricity generators and suppliers should sell the energy based on tariffs established by the government.

If properly managed, the abovementioned tools can be effective to regulate the market. Moreover, private actors have to be trained on the requirements, eligibility criteria and other necessary conditions to acquire licenses, sign contracts and get information on a variety of policies. There should be more publicly available information on those directions.

The *Law on Electricity and Thermal Power Plants* also include paragraphs allowing private actors to participate in the energy market as electricity generators or suppliers with the following provisions:

- Any individual or legal entity can install and operate electricity or thermal power plant in a territory which legally belongs to that person, or a full right for exercising property rights over a territory is granted by the third party (§ 2)
- Any individual or legal entity with a granted right to participate in an energy market can install and operate small electricity plant without any license or permission if the generated electricity will be utilized in the property which belongs to that individual or legal entity, or enjoys full property rights granted by a third party (§ 3.2.;) (Law 784-IQ, 1998).

Among others, small electricity plants defined by the law include a) solar power plants generating electricity or thermal power; b) wind plants generating electricity in the volume of 10-100 kW; c) hydropower plants generating electricity in the volume of 50-10,000 kW.

The Law 784-IQ also stimulates the electricity generation through renewable sources:

- Announcing possible state dotation for the construction of green energy plants;[35]
- Providing a guarantee to buy the electricity produced through renewable sources without any volume limitation.

The fundamental improvement to the legislative framework was made in 2021 with two newly adopted laws. In May 2021, the *Law on Utilization of Renewable Sources in the Electricity Production* (Law 339-VIQ) was adopted with a clear focus on the development of the REI. The Law 339-VIQ outlines the roles, responsibilities and entitlements of the state and generators in green electricity production. This is the very first law which explicitly describes mechanisms in support of the development of the REI. Nonetheless, the Law 339-VIQ also has a room for improvements. First and foremost, it should include more provisions about the private generation. Besides, the list of incentivization mechanisms is very narrow and the only specific scheme named in the document is FITs. Rest of the list on support mechanisms include several statements about the need to support active market players (Law 339-VIQ, 2021).

[35] Terms, conditions and procedures for state dotation are not clarified by any legal act.

In July 2021, the *Law on Efficient Use of Energy Resources and Effectiveness of Energy* (Law 359-VIQ) has replaced 1996 *Law on the Utilization of Energy Resources* (Law 94-IQ). Contribution of the Law 359-VIQ to the development of the renewables is way less in comparison to the provoked Law 94-IQ since the renewables are only mentioned twice in the document, and those are among general statements only. No specific regulation is brought to the REI, although the law talks about the efficient and effective use of energy resources (Law 359-VIQ, 2021).

Analyzing these five laws and their role in regulating and supporting the REI following conclusions can be drawn:

Table 4.5 Main opportunities and obstacles for the development of the REI in main legal acts

Opportunities	**Obstacles**
Laws create a positive environment for the liberalization of the market.	The state remains the major and sole actor who has a right to provide a contract for participation in the energy market. Terms and conditions necessary for acquiring the contract are not concrete.
Laws provide support for the penetration of renewable sources into the electricity generation.	Private participation in the energy market is mostly accessible for small scale projects.
Laws do mention the necessity for supportive policies and the state responsibilities on boosting green energy.	The same entity cannot generate and sell electricity. Distribution and connection to the grid are processed via special licenses and permissions.
Laws do introduce the possibility of individual green energy production and utilization in properties owned by the producer.	Definitions of terms used in legal acts are vague and/or hardly accessible. Thus, interpretation of possibilities is always ambiguous and has potential to create misunderstandings or disagreements between the actors.
Legal base defines main directions of the	Overall legal base for the development of the

development of renewable energy industry.	renewable energy industry has a room to improve (especially in comparison with successful states in these terms discussed at this study) and implementation level is low.

Own elaboration

The participation of private actors in the energy market of Azerbaijan is extremely low, if not close zero, up to now. The reasons behind such a low development, despite the intention to liberalize the market, can include the obstacles mentioned in Table 4.5 and not only. Nonetheless, legal acts discussed above are good fundaments to build the industry on.

Another milestone in the development of the RES came in 2004 with the adoption of the State Program on Utilization of Alternative and Renewable Energy Sources in Azerbaijan (mentioned in Chapter 2.1.). The 2004 Program defined a number of activities with responsible bodies and timeframes to complete. Most of the activities were of technical or practical nature with the aim to boost green energy production, while two projected actions went beyond the Program to create a practice and base for the future. Those tasks are:

1. To come up with suggestions on establishing the legal framework for the development of the renewable energy industry, including supportive mechanisms. The responsibility for this action was laid on the Ministry of Industry and Energy (now the Ministry of Energy), the Ministry of Economy and Industry[36], the Ministry of Ecology and Natural Resources, the Ministry of Justice, and the State Construction and Architecture Committee; and
2. To take measures for speeding up the privatization of the small hydropower plants. The Ministry of Energy and Industry, the SAARE and local administrative powers should have proceeded with this action.

These two points carried strategic importance as:

- The first action should have served to enhancing and strengthening of the legal framework around the RES which was considered as a weak point in the early 2000s; and

[36] The Ministry of Economy and Industry was restructured into the Ministry of Economy in 2016. Later, responsibility of the Ministry of Economy was transferred to the SAARE (operating as the AREA currently).

- The second action should have established the real-life practice of liberalization of the renewable energy production industry which is the key characteristic of all countries with outstanding green energy records discussed in this study.

Nonetheless, the goodwill once again was hurt by a weak implementation, as neither of the abovementioned targets was achieved despite the deadline for both matured more than ten years ago.

One more attempt to revive the industry was hurt by weak implementation in the early 2010s. In 2011, the decree was signed on the preparation of the *2012-2020 State Strategy on Utilization of the Alternative and Renewable Energy Sources in Azerbaijan*. In 2012, two additional decrees were signed to speed up the process. Nonetheless, organizations responsible for drafting the strategy failed to do so as the document has never been officially announced.

One of the very important potential factors hindering the shift towards green energy sources can be the rich reserves of fossil fuels which were being sold at a very attractive price at those times. Starting from 2004 (USD 36 per barrel), crude oil prices yielded intensively seeing highs of USD 109 per barrel in 2012 (Statista, 2020). It is obvious that the country leaving its teenage years at the time could not miss the golden opportunity of realization of vast hydrocarbon resources. The revenues from the sale of natural resources brought macroeconomic flourishing to Azerbaijan in a short span of time. It is not surprising that extracting so much fuel, a lot of concentration was allocated in its domestic utilization as well.

In 2012, the government adopted *Azerbaijan 2020: Look into the Future* concept, where for the second time (after 1998, the *Law on Energy*) it was mentioned that policies aimed at supporting the renewable energy industry should be prepared and implemented by 2020. The excerpt from the concept says:

> *"During the period covered by the concept, it is planned to carry out stimulating measures to speed up the use of alternative (renewable) energy sources, develop the institutional environment, strengthen the scientific-technical potential, continue training specialists and enlighten energy consumers. Along with projects carried out by the state in this field, the close involvement of the private sector in this process will be promoted and the quick regulation of alternative energy tariffs will be ensured."*

Two critical aspects – supportive policies and privatization of the energy market – are existing in the concept as an aim.

In 2016, the SAARE adopted 2016-2020 Strategic Plan envisioning very ambitious plans in regard to the development of the renewable energy industry. The strategy defines the development of the RES and its intensive penetration into electricity consumption as the core mission, together with increasing the energy security of the country. The Strategy announced support to:

- Establishing “one house - one electricity generation plant” principle according to which every building, regardless of its type and purpose, will be able to have its own small electricity plant;
- Developing the “Samukh” Agro Energy Complex, including the Hybrid Electric and Thermal Power Stations (HETPS - where two or more renewable resources are utilized at the same time for energy generation) as an Azerbaijani brand and introducing it to the world;
- Establishing separate and decentralized electricity grids in districts (or regions) of Azerbaijan which will be provided with energy thanks to the HETPS;
- Establishing industries with smart grids sourced by plants operating with renewables;
- Opening new job places thanks to enlarging the renewable energy industry;
- Developing the existing legal framework to create conditions for long-term sustainable development of the industry;
- To prepare a package of supportive policies for private actors operating in the renewable energy market; etc. (SAARE Strategic Plan, 2016)

The list of the projections introduced with the strategy can further be prolonged. Nonetheless, the real-life results of targets do not overlap with plans. The de-jure liberal energy market is still waiting for its first private actors to generate or supply energy. In some minor cases only, private organizations established independent electricity generation installations, including solar panels which are used locally. However, a number of such cases are insignificant for consideration. The situation is the same as the deployment of the policies to support the development of the renewables industry.

Dynamics in the renewables industry changed significantly only as of the second half of 2019. The Ministry of Energy announced several activities aimed at enhancing the legal framework regulating the renewables, researching opportunities for establishing individual electricity generation plants and grids in rural areas of the country (Ismayilov, Azerbaijan started to research opportunities for deploying renewable energy in rural areas, 2019). To develop the industry, Azerbaijan seeks to learn from the experience of the leading countries in the world in terms of renewable energy. For this purpose, a contract was signed with the Norway located international company DNV Energy Advisory Ltd. to develop the legal framework a) to regulate the attraction of private capital into the renewables industry; b) to prepare supportive policy packages for private actors; c) to work on special tariffs on renewable energy; c) to increase the penetration of the green energy into overall consumption (APA, 2019). Another important aspect of the cooperation was the design of the tendering scheme as a supportive policy for private actors. At the end of 2020, the Ministry announced that tenders would take place in the first half of 2021 for the attraction of private capital to set up and operate 5 wind and 3 solar plants in 8 different parts of Azerbaijan.

Recent dynamics in this sector is expected to bring long-awaited strengthening of the legal framework and implementation of supportive policies. Considering the announcement of tenders to attract private actors, this tool can be accepted as the main supporting tool, at least for the initial period of activities. The next paragraph of the study will carry out a comparative analysis of the selected international best practices in terms of the legal framework and supportive policies to come up with recommendations for Azerbaijan.

4.3. Applicability of the legal framework and supportive policies of selected best practices in Azerbaijan

No doubt, the legal framework regulating the REI in Azerbaijan has a room for improvement. The fact that the whole industry is mentioned only in five legislative acts, and sometimes with abstract and blurred regulations, can be a significant factor in the relatively slow development of renewables. This sub-chapter will try to come up with recommendations for Azerbaijan to develop the legal framework and supportive policies to boost the generation of carbon-free energy. For this purpose, the study will explore the applicability of experiences discussed earlier or the adaptation of local acts to them.

The legal acts regulating the development of the renewables can be broadly classified into two groups:[37]

1. **The first phase acts**. These are the acts that are necessary to move ahead the industry from the current point. The purpose of such acts is to achieve immediate impact directed at the green energy generation. It can include liberalization of the energy market, the introduction of minimum standards and requirements in energy supply, simplification of administrative burdens for private actors and implementation of supportive policies.
2. **The second phase acts**. These are the acts that can be implemented after the industry is boosted and generation levels are high enough to be open for new horizons. Examples can be, but are not limited to, the establishment of integrated energy markets, creation of renewable communities, implementation of joint REI projects and support schemes together with other countries in the region, organization of training and information sessions, etc.

Considering very low green energy output levels and insignificant penetration of carbon-free energy into overall consumption, Azerbaijan's first response to the current situation should be the adoption of a comprehensive strategy with a multifaceted approach to the development of the legal framework.

[37] This classification is the product of this study and is not indicative of vastly accepted methodology.

The first phase of amendments to the legal framework

Regulation of the energy market

As explored in earlier chapters, a liberal energy market with the participation of private actors is the cornerstone of every success story. The foundations of the liberal market in Azerbaijan are put in legal acts discussed in Chapter 4.2. Nonetheless, the requirements and eligibility criteria for acquiring licenses remain vague and blurry. Most of those requirements and criteria are not available for the public. And whenever, those documents are less unclear, they contain provisions that give the floor for executive bodies to make decisions based on subjective interpretation of the situation, rather than rational methodology, procedures and requirements found by legal acts. Moreover, all provisions envisaging the liberal market are focused on small-scale projects designed for self-consumption or distribution within very limited boundaries. Thus, to launch the new phase of development of the REI, it is important to:

- Ensure easy access to receive information on obtaining a license or a contract for green energy generation;
- Simplify administrative procedures, ease down requirements and eligibility criteria, though not giving up on safety and security related matters (both energy and physical);
- Broaden the scope of opportunities to include mid-sized or large businesses which would generate and distribute the green energy to end-users;
- Decrease the number of governmental entities each generator should deal with for passing administrative procedures and receiving a license or a contract. Appoint a single state entity that would accept inquiries and deal with the case throughout the process until granting a license or a contract. Deployment of electronic services should further smooth the communication process and eliminate bureaucracy minimizing the contact between the applying actor and the responsible entity.

The laws 541-IQ and 459-IQ discussed earlier contain provisions on the participation of private actors in energy markets. Nonetheless, the inexistence of private actors in the market might raise a question: what is the reason for such a low implementation level despite the availability of a legal base? Are there actors who hinder the liberalization of the market? Who are key stakeholders in the energy market and what are their positions regarding the entrance of private actors? The below table brings together key stakeholders of the energy market in Azerbaijan and gives insight into their roles in the market.[38]

Table 4.6 Key stakeholders of the electricity market, their roles

	Stakeholders	**Role**	
		Direct	**Indirect**
1	Cabinet of Ministers		Adopts and oversees the implementation of legal acts and activities of the executive entities
2	Ministry of Energy	Regulates the market; acts as the main body responsible to implement the legal acts	
3	Azerenerji OJSC	Produces electricity	
4	Azerishiq OJSC	Sells and distributes electricity	
5	AREA	Responsible for the development of the REI	
6	Consumers	End-users	

Source: own elaboration

Note: Azerenerji and Azerishiq are not competing organizations. Azerenerji produces energy, whereas Azerishiq carries out distribution and supply to consumers. The main shareholder of both organizations is the state.

The list can surely be prolonged with other state entities, like the Ministry of Economy, Ministry of Ecology and Natural Resources, etc. Nonetheless, it can safely be said that no other organization plays a significant role in the implementation of the legal acts mentioned above. Talking about the positions of the key stakeholders in regard to the liberalization of the market, Azerenerji and Azerishiq might be the only organizations favoring the current state of being. Cabinet of Ministers, the Ministry of Energy, the AREA would surely be for the liberalization of the market and penetration of the renewable sources. The position of the consumers would most probably depend on the retail price of energy.

Considering Azerenerji, Azerishiq and consumers have a minimum, if not zero, impact on the formulation of the state will in regard to the liberalization of the market, and the state itself,

[38] The stakeholder list focuses mainly on the electricity market actors considering the purpose of the study.

including its entities, should ideally be interested in the participation of independent actors and development of the REI, the answers to the questions raised earlier apparently are not related to the position of stakeholders. The less liberal nature of the market does not give much say to the actors in the adoption and implementation of important decisions. As it was discussed in Chapters 1 and 2, Azerbaijan has long been very much focused on fossil fuels considering rich resources. State control over oil and gas resources which were the main sources of energy generated in the country remains the major reason why the liberalization of the market was out of focus up to date. Nonetheless, new global trends, development of the economy, dropping extraction levels of oil and gas will inevitably push the government to shift towards a more liberal energy market, attract independent actors, and involve the green resources in energy generation. By keeping the state production levels constant and providing opportunities to meet the demand of the growing economy and population, a lot of investors can be attracted to the energy market. Besides these, the measures enlisted above can effectively enhance opportunities for private actors to generate and distribute green energy if properly integrated into the legal acts.

Introduction of standards and minimum requirements

The introduction of standards and minimum requirements for buildings in terms of green energy utilization is one of the widely deployed legal framework developments helping to boost carbon-free electricity utilization. Azerbaijan could adapt the below measures to address the electricity performance of buildings:

1. Make mandatory to include green electricity supply for several types of buildings (e.g. high-rise residential buildings, business/office buildings, public buildings, etc.) during the spatial planning phase. Include minimum levels in terms of the percentage of total forecasted electricity utilization. Unless the planning would not satisfy the green requirements, relevant authorities should not grant construction permission. Exceptions to this plan could be individual houses and constructions in areas where utilization of green energy is not technically possible or feasible.
2. Special standards and requirements should be put in place to ensure thermo-isolation helping to reduce the energy utilization for heating and cooling of buildings.
3. Analysis of existing buildings should be carried out to assess where small-scale green electricity generation plants or roof-top PVs can be helpful to reduce hydrocarbon-based

electricity usage. Surely, this process needs a huge volume of work. However, the gradual implementation of relevant projects can deliver substantial results in the long-term. Installation of heat pumps or solar heating installations are another widely used practices applied in European countries. Those systems help to reduce the heating and cooling costs.

If properly regulated, the management of electricity performance of buildings has a big potential to increase penetration of green electricity into household utilization.

Simplification of administrative procedures for green energy generation

Azerbaijan has adopted legislative acts to simplify bureaucratic and administrative procedures in a number of spheres bringing services of dozens of governmental entities to the internet or uniting them under a single roof – ASAN Service. This attitude should be directed at procedures related to participation in the renewable energy industry too. According to current regulations, actors intending to generate or distribute energy should communicate and deal with a number of public entities. In many cases, requirements and conditions are vague and thus processes can take months, if not years to complete. The factor of uncertainty hinders private actors to engage in the industry.

Azerbaijan could also adapt the EU approach in this term. According to the Directive (EU) 2018/2001, Article 16.1, countries should introduce single focal points to guide private actors in the process of permission granted. A similar approach, but in a broader context can be applied to:

- Help private actors to understand the specifics, conditions, and requirements of the industry (for example, organize information sessions);
- Guide private actors through all processes – from collecting necessary documents at the inception of the project, up to collecting the permission granted by authorities;
- Assist private generators in continuous dialogue with authorities during operations.

Information sharing and training

The establishment of information sharing and/or training centers for the public is another useful way to support the development of the REI and increase awareness among people on the benefits of green energy. This strategy can be employed at two levels.

First level. Information and training centers for individuals who seek to become an actor in the energy market. Such centers can be established within the Ministry of Energy and operate in the ASAN Service offices throughout the country. Individuals, RECs, businesses interested in the generation and/or distribution of energy, or electricity would get initial information from such centers. In the second stage, those who decide to start a renewable energy project would get enrolled in training obtaining necessary knowledge on the administrative procedures, and also on renewable energy generation. At the third stage, staff members of this center could be appointed as focal points to guide the investors through all administrative procedures up to obtaining a certificate or a contract.

Second level. Independent from the first level, the second level of information sharing entails awareness increasing campaigns at a nationwide scale. Azerbaijani public is yet to be familiarized with renewable energy systems and its benefits. In many cases, the public lacks understanding of the side effects of hydrocarbon-based electricity. Long-time legacy of energy generation and distribution by the state engraved a perception that this industry is not for individual actors. Thus, individuals and businesses do not even realize the opportunities for getting involved in energy generation and distribution. Less certain legal framework scares off private actors. Therefore, the government should spare no efforts to change the mindset and behavior of the public in this direction. A comprehensive communication strategy needs to be developed and employed to pass messages and reach target audiences to drive more interest and capital into the renewable energy industry.

Supportive policies

Liberalization of the market is one of the dimensions of the multifaceted approach. Besides creating suitable conditions for private actors to enter the energy markets, it is also important to motivate and support them through supportive policies.

Although the analysis conducted in the Chapter 4.1. helped to identify FITs and FIT Premiums as the most preferred and effective supportive policy, it should not be overlooked that the initial stages of supporting the REI included investment-oriented tools and tax incentives too in a number of successful countries (Haas, et al., 2011). These two measures can especially be useful in the initial phase of the support process when it is important to attract capital from investors.

Therefore, Azerbaijan would benefit from a complex support strategy that would envisage the implementation of various schemes.

Investment subsidies or grants. Financial support to construct new renewable energy generation plants would be a useful tool to attract private capital. Investment subsidies are applied in Austria and Portugal as main supportive policies. Amount of support, requirements and eligibility criteria for getting funding must be explicitly defined without a room for subjective decision making. Information on this should be made publicly available through various online and offline means. Various opportunities, requirements, and eligibility criteria should be established considering the type of the planned project (wind, solar, small hydropower, etc.), output capacity and additional installations to accumulate the energy or transmit it to the grid. Besides offering financial support directly through governmental entities, private banks could be stimulated and supported by the Central Bank to finance green projects. It could further attract businesses into the REI.

Taxation regulations.[39] As it was analyzed previously, LCOE of the green electricity worldwide is slightly higher than the price of fossil-based electricity sold to end-users in Azerbaijan. Therefore, measures need to be taken to ensure the generators could offer green electricity at competitive prices. It is highly unlikely that the government could go with an artificial increase in the price of electricity sold domestically considering its social and economic policy. In this kind of scenario, one of the measures could be [at least] temporary reduction of tax duties or even complete exemption from it. This measure would also mean simplification of administrative procedures – a further significant motivating factor.

Custom duty regulations.[40] Though “Azguntex” LLC produces photovoltaic panels domestically, necessary materials to produce it, and devices necessary for installation of wind or other types of plants require import operations. To help investors with reducing the costs, government could introduce various custom duty schemes that would stimulate investors.

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[39] Due to the purpose of this study, analysis will not go deeper into designing the exact schemes for taxation regulations in renewables industry, but rather will introduce the overall idea potentially useful for boosting the generation levels.
[40] Ibid.

FITs and FIT Premiums.[41] The methodology behind these two schemes and their success in terms of application scale have already been discussed previously. Their contribution to the increase in green energy output is obvious. The most important aspect of these policies that drives interest and capital is the assurance that the generator will be able to sell the produced energy, at least at contracted volume. Not surprisingly, FITs and FIT Premiums are applied as supportive policies in 4 out of 6 countries analyzed in this thesis – Austria, Portugal, Greece, Croatia. Policies discussed before FITs and FIT Premiums are mostly directed at the physical installation of plants and their operation. However, what will the generator do with the output remains to be covered. FIT schemes jump in at this stage acting as a minimum guarantee for private actors. Nonetheless, guaranteeing high FITs might result in issues arising from desire to earn more. Thus, careful calculations should be made to introduce an adequate level of FIT that will not destabilize the market.

A support strategy comprised of all abovementioned policies implemented simultaneously, yet at different volumes and levels, a present comprehensive approach aimed at three main purposes:

1. Offer financial support to attract private capital for constructing renewable energy plants.
2. Offer support through taxation and import schemes to reduce construction, operation and maintenance costs, thus, help to reduce the LCOE of the green electricity which is slightly higher than the price of electricity derived from hydrocarbons domestically and sold to end-users.
3. Present commitment to purchase green electricity from private generators to motivate them.

Apparently, Azerbaijan has adopted tendering as the scheme to support the renewable energy industry. At the end of 2019, citing the officials of the Ministry of Energy of Azerbaijan, local media outlets reported that in 2020, the Ministry would launch a tendering scheme to attract private investors to the REI. In general, tenders and auctions are carried out to attract private investors to realize projects. As a matter of practice, in auctions, the price is the only indicator that plays a role in bid selection. In tenders, the bidder can refer either to installed capacity or electricity production. The owner of the selected offer can receive support through various schemes like FITs, FIT Premiums, TGCs, investment grants, etc. The tendering scheme comes

[41] Ibid.

with its pros and cons. On one hand, this tool is considered to be a cost-efficient way of promoting the green energy industry. Tendering stimulated competition contributes to revealing the optimal cost of technologies, and helps to prevent overcompensation. Nonetheless, this method of support is highly dependent on the participation of private actors. Participation related costs and uncertainty about the results can demotivate small or mid-sized businesses which will lead to having expensive offers only. The only way to counter this possibility is to announce compensation of participation related costs. Nonetheless, tenders also come with risks like getting no suitable offer, unrealized projects due to underbidding for various reasons, collusive behavior of bidders to yield up the prices, etc. It is yet to be seen how Azerbaijan will manage the tendering process and what kind of policies will be in place to support participating and winning bids.

The second phase of the amendments to the legal framework

Renewable energy communities

The practice of best-case countries selected for this study shows that reaching satisfactory levels in the penetration of green energy into overall consumption is not a reason to stop the development of the REI. Thus, after taking initial measures and relevant amendments to the legal framework, Azerbaijan can adopt a number of beneficial experiences to further develop the industry.

The establishment of renewable energy communities (REC) is one of the novelty methodologies to achieve green, sustainable and inclusive development. By definition, the renewable energy community involves:

> *"… groups of citizens, social entrepreneurs, public authorities and community organizations participating directly in the energy transition by jointly investing in, producing, selling and distributing renewable energy."* (European Regional Development Fund, 2018)

To put in simple terms, REC is a group of people who jointly generates energy for own consumption. Supporting the creation of renewable energy communities could help bring the utilization of carbon-free electricity in districts of Azerbaijan, including rural areas. According to the EU Policy Paper, RECs can be beneficial in increasing the acceptance of renewable energy (ibid). Nonetheless, these types of projects require leadership, upfront investments, legal and administrative knowledge. Hence, government support at least in the initial phase is of vital importance.

Regional energy markets, REC projects, and support schemes

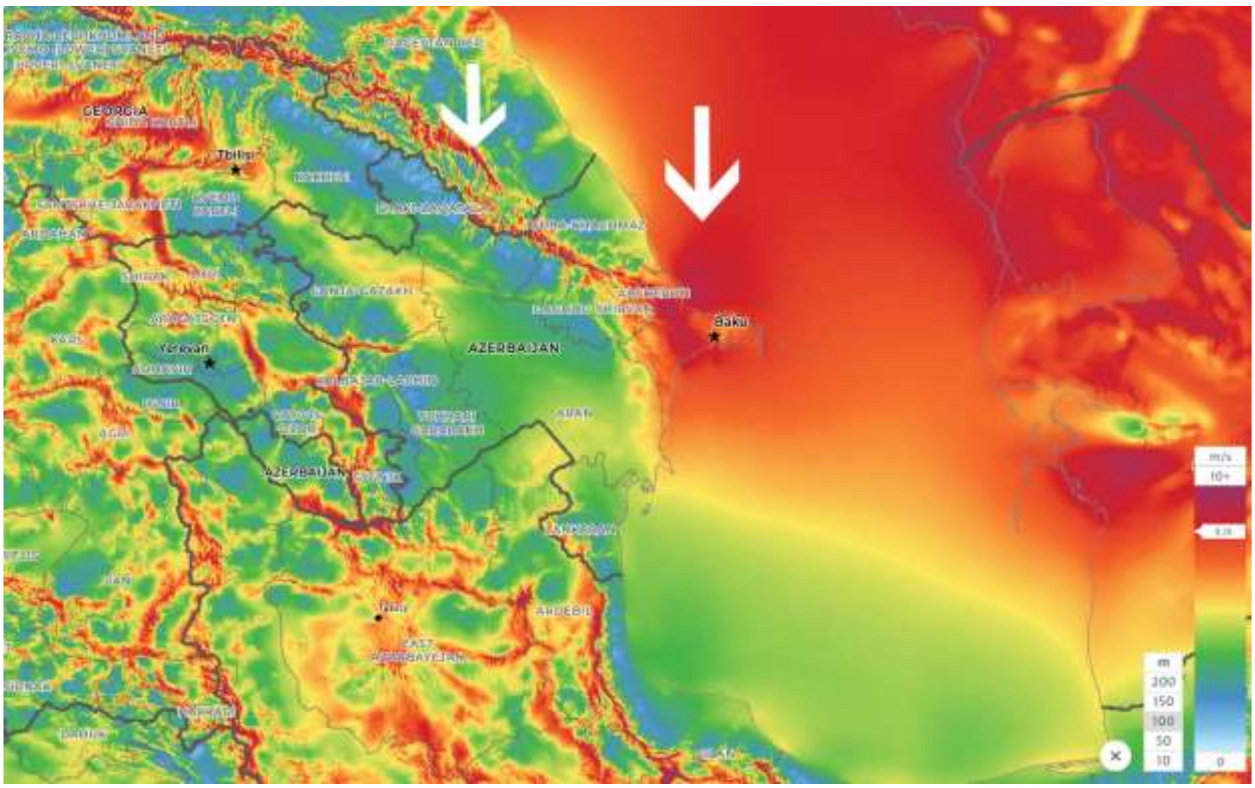
The establishment of the regional energy market(s) is a new dimension of development where governments open the borders of the national energy market to the companies operating in other countries. No doubt, this strategy comes with a lot of nuances and aspects to consider, work on, and regulate. Nonetheless, if employed, integrated energy markets are able to level up the liberalization level of the market, deliver better service and quality to the end-users, increase efficiency, drive-in innovations, expertise, and knowledge, increase energy security, enhance business level cooperation between countries which would also serve the strengthening of political and economic relations.[42]

In the region, Azerbaijan has opportunities to build a number of integrated renewable energy markets with neighboring countries. Promising project can be implemented jointly with Turkey on the western border of Azerbaijan, especially taking into account suitable geographical conditions for solar power in Nakhchivan. Also, as per the Global Wind Atlas provided by the World Bank, bordering areas of the Russian Federation with Azerbaijan has the same wind potential in both countries. These territories are in the northern part of the country where the government seeks the utilization of wind for renewable energy generation. Mountainous areas of Russia have even higher wind potential. Though such areas are not always useful for wind power plants in terms of geographical location, examples of utilization of uneven territories are not rare. Considering the potential, an integrated renewable energy market can be viable in the northern part of the country.

[42] The findings of the research on the *Benefit of an integrated European electricity market: the role of competition* conducted in 2013 demonstrated that integrated energy markets through market coupling is able to increase efficiency and deliver other benefits (Bockers, 2013).

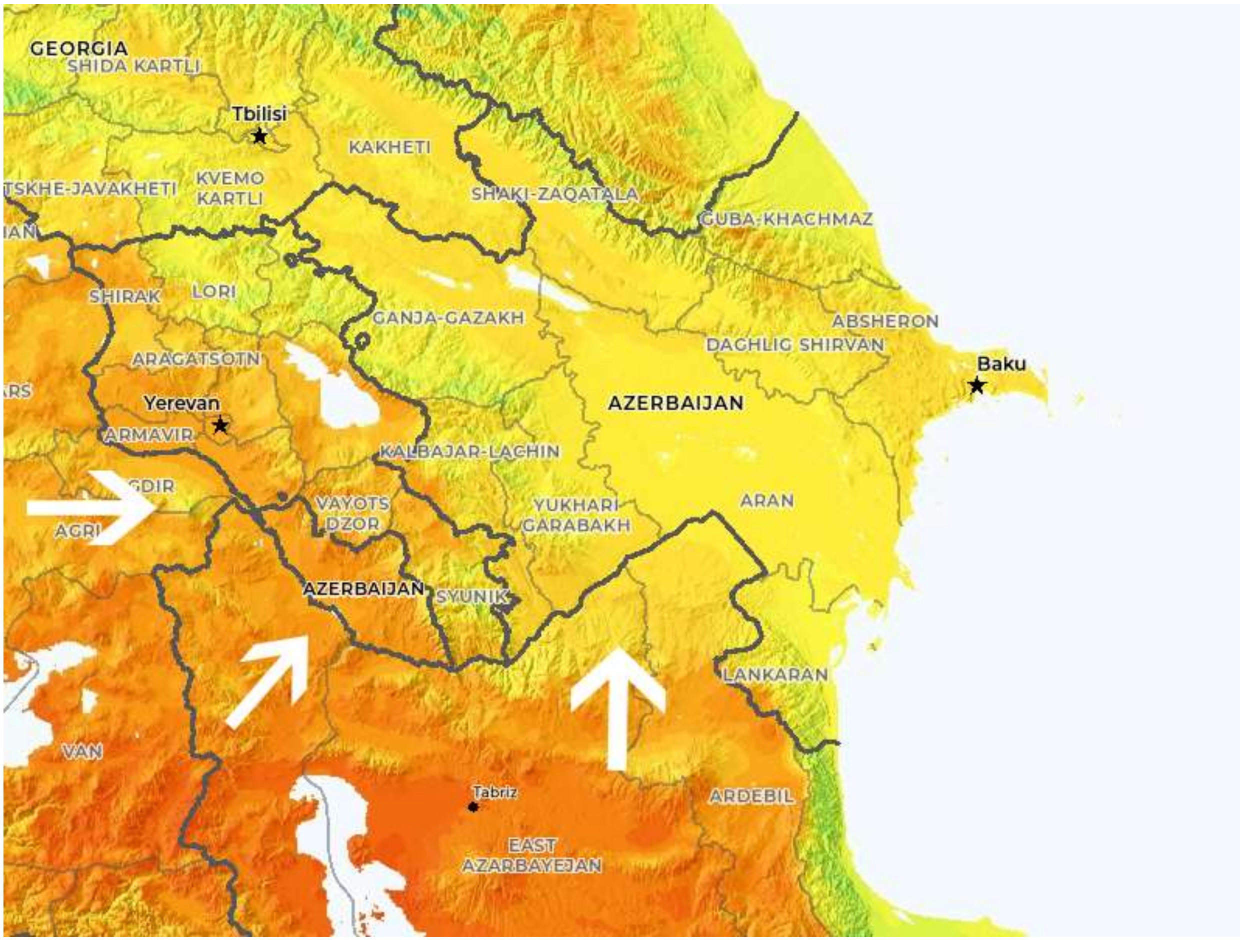
The same approach can be applied to the southern part of the country – the bordering areas with Iran. According to the Global Solar Atlas, the average solar potential of northern Iran is approximately the same as the solar potential of the south of Azerbaijan. To increase the competition, service, quality, and thus strengthen the energy security of the southern part, Azerbaijan could negotiate with Iran the establishment of the integrated renewable energy market.

Figure 4.1. Suitable territories for potential Azerbaijan-Russia wind energy cooperation



Source: (WB Global Wind Atlas, 2019)

Figure 4.2. Suitable territories for a potential solar energy cooperation with Turkey and Iran



Source: (WB Global Solar Atlas, 2019)

Together with integrated renewable energy markets, Azerbaijan could also explore opportunities for stimulating companies from different countries to implement joint renewables projects. This approach is effective to attract more investments, establish cross-border projects, and strengthen economic relationships with [at least] neighboring countries. A similar approach is also introduced by the EU Directive 2008/2001 which calls the government to expand collaboration through joint renewables projects.

Along with integrated renewable energy markets and projects, Azerbaijan could also employ joint support mechanisms, as a cohesive approach to the overall framework in this direction is inescapable.

Establishment of the integrated energy markets and joint renewables projects is a burdensome approach that needs a comprehensive strategy, policymaking, strong legal framework and an excellent relationship between cooperating countries. Thus, ideas generated in this section of the study are more subject to the further elaboration and analysis to find out feasibility and viability of opportunities. Harmonized electricity (energy) regulations, strong management of the distribution operations, cohesive pricing, taxation regulations (or any other regulations which would affect the generation and sales prices) are necessary to prevent potential misuse and issues discussed earlier (see Chapter 4.1.). Considering the number of markets could vary (e.g. Azerbaijan-Russia Renewable Energy Market, Azerbaijan-Iran Renewable Energy Market), including the participating countries in each, it is important to also consider the opportunities for applying different regulations at the different parts of the country, which is not the case currently and even is hardly imaginable at this point of time. Nonetheless, the applicability and effectiveness of joint projects and integrated markets are undeniable considering the experience of European countries, including the best cases selected for this study.

Since this thesis focuses on the renewables as the dimension of the energy security of Azerbaijan, and this Chapter focuses more on the immediate development of the legal renewable energy framework, suggestions under the *Second Phase of the amendments to the legal framework* will not be elaborated and analyzed in detail. These ideas require additional studies and research to come up with a much clear picture of policies. Instead, these keynotes could be a useful takeaway for additional material to work on.

The next chapter will focus on the feasibility studies of the renewables for Azerbaijan and see whether the development of the REI could be as effective and efficient as anticipated.

Public-Private Partnerships

Public-Private Partnerships (PPP) have successfully been employed in a broad number of industries and proved to be highly effective in boosting development levels. The energy industry, including renewables, has benefitted a lot from this kind of scheme as it has attracted a lot of investment into the industry. According to the World Bank data, the total PPP investment in the energy sector in 2019 constituted more than USD 30 billion (The World Bank, 2020). PPPs have several advantages over traditional all-government or all-private business models. Advantages of PPPs are, (but not limited to):

- Effectiveness in attracting private capital, especially in pre-mature liberal markets, since the cooperation with the accountable government increases the confidence level for private companies.
- Potential to bring in additional funding for the government and necessary expertise and knowledge for private actors.
- Division of overall burden in-between public and private actors makes investment opportunities even more interesting.

The starting point to apply PPP schemes in Azerbaijan is the relevant update of the legal base, the introduction of its definition, and the framework for mutual cooperation of public and private entities. Depending on context conditions, PPPs are defined and managed differently. For example, South Korea approaches PPPs as schemes to tap private funding and business efficiency in classically government-run projects, while the United Kingdom has a much broader concept (Public-Private Partnerships in the Middle East and North Africa, 2019).

Although earlier mentioned legislative acts in Azerbaijan facilitate the operation of independent actors in the energy market, those regulations are limited to small-scale producers/sellers and do not envisage the framework for public-private partnership models. As per the experience of a broad range of countries, a number of PPP agreements can be concluded in the energy sector. These are:

- Built-Operate-Transfer (BOT)
- Power Purchase Agreements (PPA)
- Fuel Supply Agreements (FSP)
- Land Lease Agreements (LLA)
- Joint Implementation Agreements (JIA)
- Grid Connection Agreements (GCA)[43]

BOT, JIA, and PPA schemes can be a good starting point for Azerbaijan to start attracting private capital into the renewable energy industry. Rural electrification activities can significantly benefit from PPP agreements where independent actors, backed with the support and expertise of the public actors, can generate electricity using renewable sources like water, sunlight, and wind and distribute it to renewable communities.

[43] ***Source*** (Public Private Partnership Legal Resource Center, 2020)

Though PPPs have a number of advantages to benefit, it does not go without drawbacks as well. The "*Public-Private Partnerships in the EU: Widespread shortcomings and limited benefits*" report prepared in 2018 by the European Court of Auditors, have revealed a number of problems with the PPP projects. Insufficient competition, significant project delays, cost overruns, inappropriate 'enthusiasm' and the realities on the ground, inadequate legal framework were among mostly observed issues with the PPP projects (Grassi & et, 2018). Considering EU's richer PPP experience and well-developed institutions and infrastructure, the occurrence of such problems as recently as in 2018 hints at the need to have a realistic and well-developed approach to public-private partnership projects.

The most beneficial aspect of PPPs for Azerbaijan is the obvious attraction of private investors into the renewables industry. Nonetheless, careful and comprehensive strategy should be in place to avoid possible issues mentioned above.

Chapter 5. Estimation of the renewable energy potential of Azerbaijan

In the earlier chapters, topics like the current energy system and energy security of Azerbaijan, best practices around the world, the applicability of those practices in the country have been assessed in a thorough manner. The Chapter 5 will focus on the estimation of the renewable energy potential of Azerbaijan, coming up with draft projects on wind and solar farms, and carry out financial feasibility analysis.

The 'estimation of potential' will include in itself an analysis of the resource availability and basic proposals for setting up wind and solar farms in different regions of the country depending on various factors.

Chapter 5.1. Estimation of potential for wind power in Azerbaijan

Based on the same altitude and territories, the IRENA and the Ministry claim that Azerbaijan has the potential of 3,000 MW of wind energy production (IRENA, 2019; Ministry of Energy, 2020). None of those organizations have publicly available data on the long-term wind data and power density statistics in separate regions.

The only available data was collected back in 2014 by Nijat Imamverdiyev for the National Academy of Sciences of Azerbaijan (NAS).

Table 5.1 Average annual wind speed in m/s and number of windy days in the coastal settlements of Azerbaijan

Settlement	January	February	March	April	May	June	July	August	September	October	November	December	Annual average
Shubani	8.1/14.2	8.8/12.8	8.7/14.5	8/11.2	7.4/10.7	8.5/12.5	8.9/14.1	8.1/12.2	8.2/11.5	7.5/11.3	6.9/9.8	7.2/10	**8/145**
Sumgait	7.2/13.2	7.2/13.9	7.7/14.6	7/12.9	6.3/9.8	6.4/9.1	7/10.4	6.9/9.5	6.9/10.7	7.2/11.6	6.8/10.5	6.8/13	**7/139**
Puta	6.4/8.7	7.4/9.5	7.2/10.8	7/9.9	6.6/10.1	7.3/10.8	7.7/12.2	7.2/10	6.4/9.5	5.9/8.3	5.3/7	5.5/7.5	**6.7/114**
Pirallahı	6.9/7.5	7.1/7.5	7.2/8.6	6.4/5.6	5.9/3.8	6.2/4.2	6.6/4.6	6.5/4.9	6.5/5.8	6.7/7.3	6.6/5.7	6.6/6.2	**6.6/72**
Bina	6.3/8.2	6.7/8.7	7.3/11.5	6.7/9.5	6.6/8.9	6.7/7.5	7/8.9	6.3/7.1	5.8/7	6/7.6	5.8/6.8	5.8/7.8	**6.4/100**
Sangimughan	6/5.7	7/7.1	6.9/7.3	5.6/9.5	5.4/4	5.6/5.1	5.9/5.8	6.7/5.6	6.9/6.9	6.5/7.3	7.2/7.2	6.7/6.3	**6.4/73**
Baku	6.1/4.9	6.6/6	6.9/7.5	6.5/6.8	6.2/5.2	6.5/6.2	6.8/6.6	6.3/5.2	6.2/4.7	6.1/5.3	5.7/4.3	5.6/4.8	**6.3/67**
Chilov island	6.6/5.3	6.7/4.8	6.6/5.3	5.5/3.8	5.3/3	5.8/4	6.5/4.1	6.2/4	6.3/4.1	6.4/5	6.7/5.2	6.3/5.2	**6.2/54**
Oil rocks	6.3/5.3	6.8/5.6	6.9/6.9	5.2/3.8	4.7/2.2	5.3/3.3	6.3/4.5	5.8/3.8	6.4/4	6.1/4.7	7.2/4.5	6.7/4	**6.2/52**
Mardakan	6/6	6.4/7.5	6.6/7.4	6/6.1	5.7/3.8	5.8/4.7	6.1/6	5.6/5.1	5.4/5.2	5.6/5.7	5.5/5	5.6/4.6	**5.9/67**
Mashtaga	6.2/6.7	6.4/6.1	6.7/7.9	6.1/6	5.6/4.9	5.7/4.2	6.1/5.1	5.6/3.6	5.3/4.7	5.4/5.6	5.3/4.7	5.4/5.4	**5.8/64**
Davachi	4.3/3.1	4.2/2.7	4.6/4.8	5/6.2	4.3/4.6	4.6/4.2	4.6/3.8	5/5.8	4.6/5	4.2/4	4.3/3.8	4.1/3.4	**4.5/51**
Neftchala	3.7/1.9	4.1/2.3	4.8/3.8	4.4/2.5	4.4/2.1	4.4/2.3	4.3/2.5	4.3/2.3	4.2/2.9	4/2.8	3.9/2.3	3.7/1.9	**4.2/30**
Sara island	3.3/1.6	3.5/2.5	4.4/4.3	4.7/5.5	4.8/3.5	4.5/4	4/1.2	4/19	3.9/3.3	3.8/2.7	3.5/3.3	3.2/2.1	**4/36**
Alat	3.3/2.9	3.9/2.8	4/4.1	3.7/3.4	3.9/2.6	4.1/2.8	4.1/3.7	4.1/3.2	4.2/3.3	3.6/2.6	3.4/2.8	3.3/2.5	**3.837**
Astara	3.1/1.8	3/2	2.8/1.3	2.8/0.7	2.7/0.5	2.7/0.5	2.7/0.2	2.7/0.2	2.7/0.3	2.7/1	2.7/0.9	2.7/1.1	**2.8/30**
Khachmaz	2.1/0.8	2.3/0.9	2.4/0.9	2.5/1.8	2.4/1.1	2.5/0.9	2.3/0.9	2.4/2.3	2.3/1.2	2.1/0.6	2/0.5	2/0.6	**2.3/13**
Guba	1.7/0.5	1.7/0.9	1.8/0.8	1.9/0.6	2/0.6	2.1/0.4	2.1/0.1	2.1/0.2	1.9/0.2	1.8/0.4	1.7/0.4	1.7/0.4	**1.9/6**
Lankaran	1.5/0.7	1.7/0.4	1.7/0.5	1.9/0.2	1.9/0.2	1.9/0.3	1.9/0.1	1.8/0	1.8/0.2	1.8/0.3	1.9/0.1	1.4/0.2	**1.8/3**

***Source*:** (Imamverdiyev, 2014)

Territories within the Absheron peninsula and close proximity around it have suitable conditions for generating wind energy. Average yearly wind speed varies from 6 to 8 m/s with up to 145 windy days per year. These are favorable conditions for setting up a wind farm. The suitability of the Absheron peninsula for wind generation can also be verified with Global Wind Atlas data. The mean wind speed and power density at the Absheron peninsula and its surroundings (including the off-shore territories) amount to 8 m/s and 810 W/m^2 respectively at 50-meter height. At 100-meter altitude, the indicators reach 9.1 m/s and 1026 W/m^2 (WB Global Wind Atlas, 2019).

Apart from the Absheron peninsula, there are three more regions in Azerbaijan with suitable conditions for wind energy generation. These are the flatlands of northern Sumgait and Khizi districts, Kalbajar-Lachin districts, and the Ganja-Qazakh economic zone. Wind speed and power density figures of Khizi district and areas in its close proximity are almost the same as the figures of the Absheron peninsula. At 100 m altitudes, the mean wind speed is close to or higher than 9 m/s and the power density indicator reaches 1000 W/m^2. In the Kalbajar-Lachin area, mean wind speed is around 8 m/s and power density is above 700 W/m^2 (ibid.). However, Kalbajar and Lachin districts are located in mountainous areas, and thus setting up industrial-size wind farms is challenging but not impossible. A Swiss experience of successful utilization of mountainous areas for wind energy generation can be a good base to explore possibilities for the Kalbajar-Lachin zone.

The fourth area suitable for farming wind characteristics – Ganja-Qazakh economic zone is located on the foothills of Greater Caucasus mountains and thus is not favorable for setting up an industrial size generation plant. However, with 5.45 m/s mean wind speed, the zone can be used to set up small to mid-sized wind plants or provide services for individual wind energy generation (ibid.).

Below are the mean wind speed and power density maps of Azerbaijan provided by the WB.

Figure 5.1 Mean wind speed in Azerbaijan at 100-meter altitude

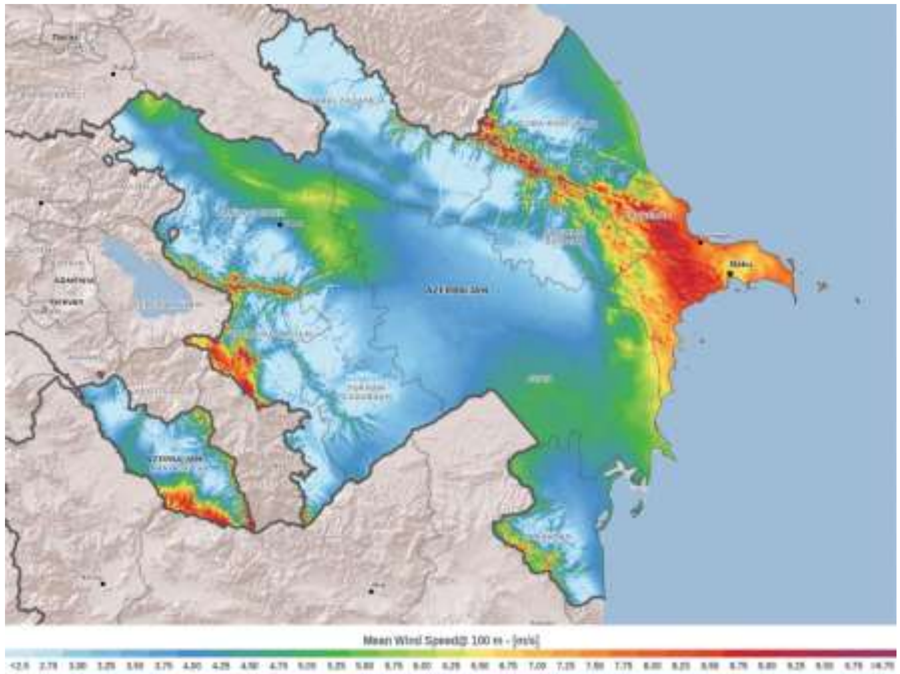
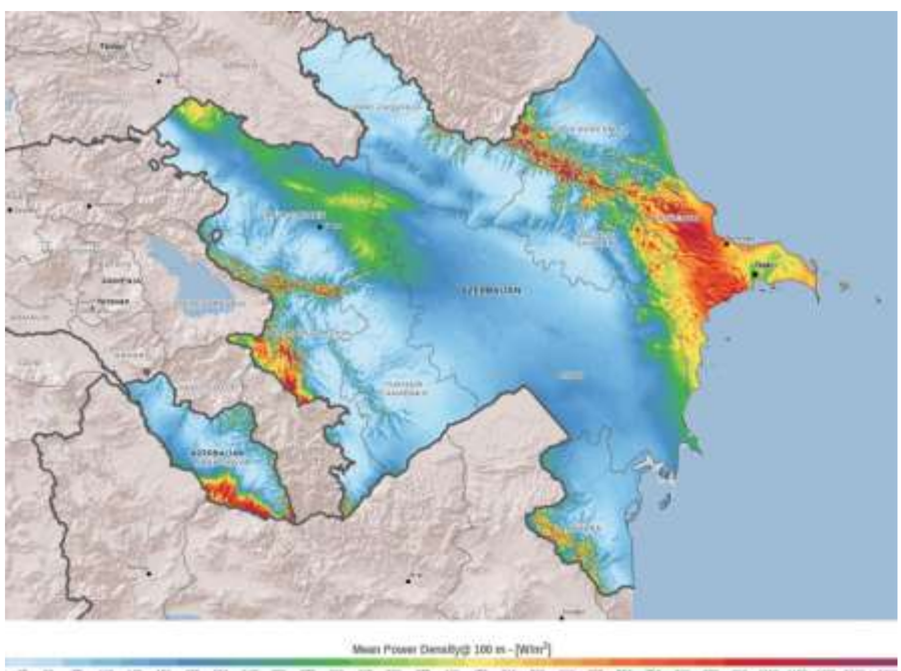
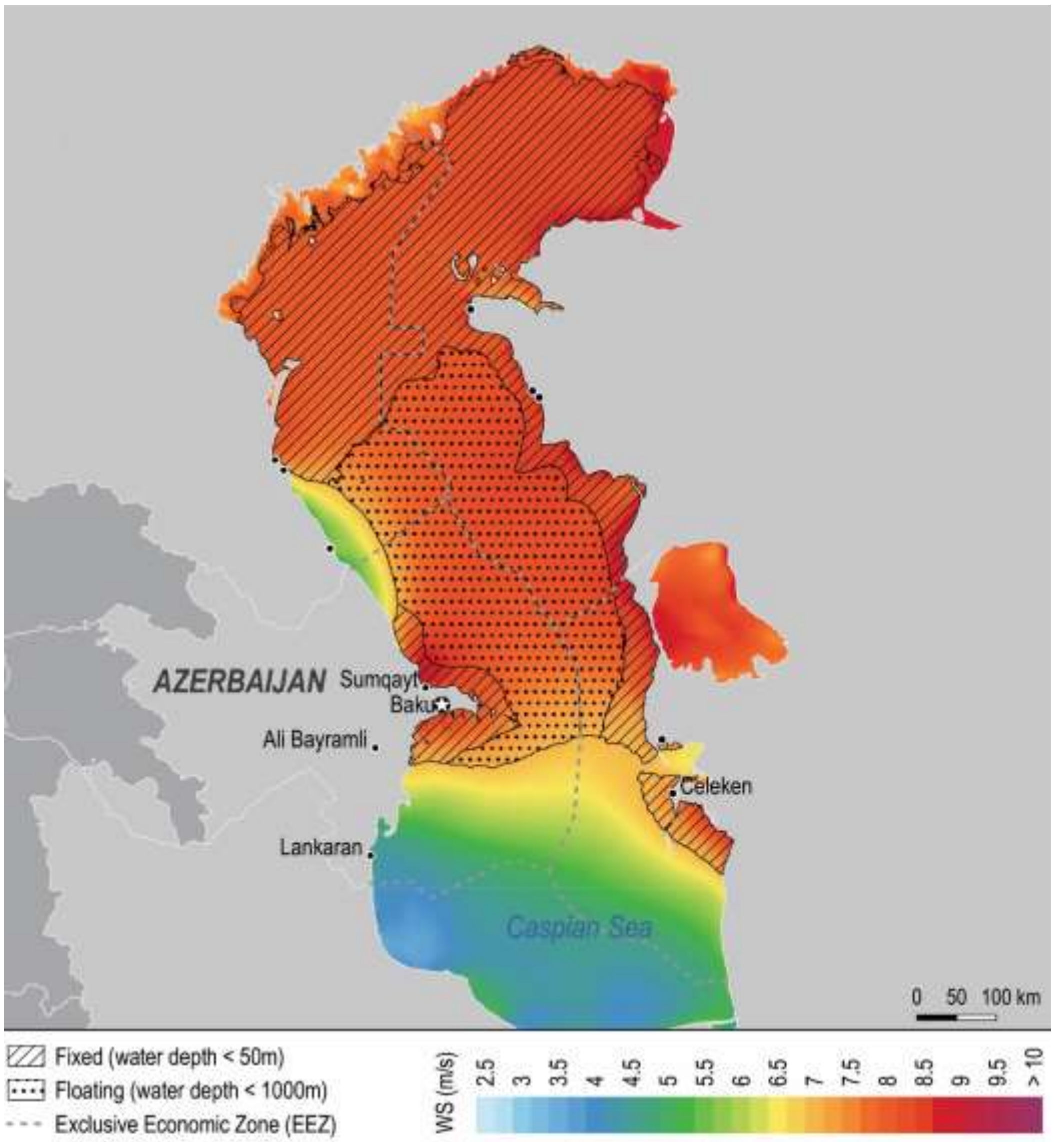


Figure 5.2 Wind power density in Azerbaijan at 100-meter altitude



Besides on-shore resources, the Caspian Sea provides appealing off-shore potential thanks to its suitable wind atlas.

Figure 5.3 Wind Atlas of the Caspian Sea



Source: (Offshore Wind Technical Potential in the Caspian Sea, 2020)

The mean wind speed in the Caspian Sea around the Absheron peninsula is above 7.5 m/s which means a good generation can be achieved from a fixed wind turbine farm at the depth of <50 m. For deeper areas floating wind turbines can potentially be a good solution. Nonetheless, the utilization of floating wind turbines is still in the early phase and can not be considered as a reliable project at the time being. According to the World Bank, the fixed potential of the Caspian Sea amounts to 509 GW (ibid.).

It should be mentioned that a 2019 study conducted by Florin Onea and Eugen Rusu has concluded that the area of the Caspian sea around Baku is not much attractive for a wind farm project (Onea & Rusu, 2019). The study was based on the data obtained from the European Centre for Medium-Range Weather Forecasts and the AVISO+ (Archiving, Validation, and Interpretation of Satellite Oceanographic Data). Onea and Rusu considered a variety of turbines which included models from Siemens, Vesta, Envision, Adven, and Areva. Nonetheless, the study concluded that with the utilization of a single Siemens SG type turbine (140-meter height) annual electricity production assessment showed a 19.29 GW/h result which can be considered as acceptable (ibid.). The academic study in this direction was made by the NAS back in 2004. The study concluded that 1800 MW of wind energy can be generated from 180 km^2 area in the Caspian Sea from an off-shore wind energy plant of 3000 turbines. Nonetheless, the validity of the results today is under question since the NAS considered the older generation of turbines in their calculations.[44] The AREA also considers the Caspian Sea as a favorable place for setting up a wind plant. Back in 2016, the organization envisaged a USD 300 million project to set up an off-shore wind plant along the coastal line (Wind Energy and Electric Vehicle Magazine, 2016). However, the project was not implemented due to reasons not related to the availability of a renewable resource. Moreover there are several uninhabited islands, such as Chilov, in close proximity to the Absheron peninsula that can be used to install off-shore wind plants on their shores, with the cost similar to on-shore plants.

Moving on from the available data and results for Azerbaijan, the first and most appealing territory for setting up a wind farm is the areas around Khizi district and the northern part of Sumgait. Not surprisingly, the mentioned territory is already considered by the Ministry of Energy and the AREA for promising wind energy plants. The envisaged wind energy plant projects discussed in Chapter 2.2 of this study (see Tables 2.3 and 2.4) has been updated by the Ministry of Energy in 2020.[45] The Ministry has introduced a plan of setting 5 plants with a total

[44] The study was considered construction of 0.6 MW capacity turbines with 3-5 hectares of distance between each unit at 100 m altitude (National Academy of Sciences, 2004). An average off-shore turbine nowadays is capable producing 3 MW electricity at the same altitude (IRENA, 2020).
[45] Envisaged projects in Tables 2.3 and 2.4 remain identical but with different output capacity that can be associated to the utilization of different turbines and calculation methods.

output capacity of 442.5 MW and an estimated yearly generation of approximately 1,334 million MWh of electricity. Table 5.2 provides detailed information about the projects.

Table 5.2 Selected areas for the development of wind energy plants (Development of the Renewable Industry in Azerbaijan, 2020)

Project name	Planned output capacity	Estimated generation
Khizi 2	69 MW (20 turbines x 3.45 MW)	192,000 MWh/year
Khizi 3	135.3 MW (41 turbines x 3.3 MW)	414,000 MWh/year
Absheron-Garadagh	55.2 MW (16 turbines x 3.45 MW)	198,000 MWh/year
Area-1	78 MW (26 turbines x 3.0 MW)	225,000 MWh/year
Area-7	105 MW (35 turbines x 3.0 MW)	313,670 MWh/year

To analyze the technical feasibility assessment of a given wind farm the annual electricity production (AEP) levels indicator is the most important factor to look at. Long-term wind data, technical characteristics of the wind turbine, and Weibull probability density are among the variables to calculate the AEP for a given project. The formula for the AEP can be considered as the following:

$$AEP = T \int_{cut-in}^{cut-out} f(u)P(u)$$

Where *AEP* is the number of MWh of generated energy, *T* is the number of hours in a year, *f(u)* is Weibull probability density of the mean wind speed and power density, and *P(u)* is a power curve of the considered wind turbine. Cut-in and cut-out times represent the minimum and maximum speeds at which the turbine starts to operate and automatically brakes to prevent an accident (or is manually stopped for the same purpose). The lack of long-term wind data to feed the Weibull probability density factor prevents carrying out of an academic and reliable AEP data calculation. This deficiency can also explain why the total considered output of the projects presented by the AREA is far from the estimated electricity generation per year. With a very basic conversion formula, it can be said that for all 5 projects, the AREA roughly expects to generate electricity in the amount of 30 percent of the total envisaged output capacity.[46]

A similar approach can be applied to draft wind generation plants for Ganja-Gazakh and Kalbajar-Lachin economic zones. Referring to the international experience, it can be concluded that an average of 20-30 hectares needed for the installment of 1 MW output (Paul Denholm, 2009). Another general rule for wind farm spacing is that turbines should be about 7 rotor diameters away from each other (Gaughan, 2018). In mountainous areas (especially actual for Kalbajar-Lachin district) the volume of the area allocated for a wind farm can go higher due to the terrain. Taking into account that the mean wind speed and power density in both zones are in medium-range, Siemens SG 3.4-145 or Vestas V117-3.45MW turbines with respective output capacity of 3.45 MW and 3.45-4.0 MW can be utilized (Siemens, 2020; Vestas, 2020). Both turbines can start generating electricity at as low as 3-5 m/s wind speed. Considering the mean wind speed in the Kalbajar-Lachin and Ganja-Gazakh zones and referring to the average productivity figures obtained from the AREA projects following wind farm projects can be drafted.

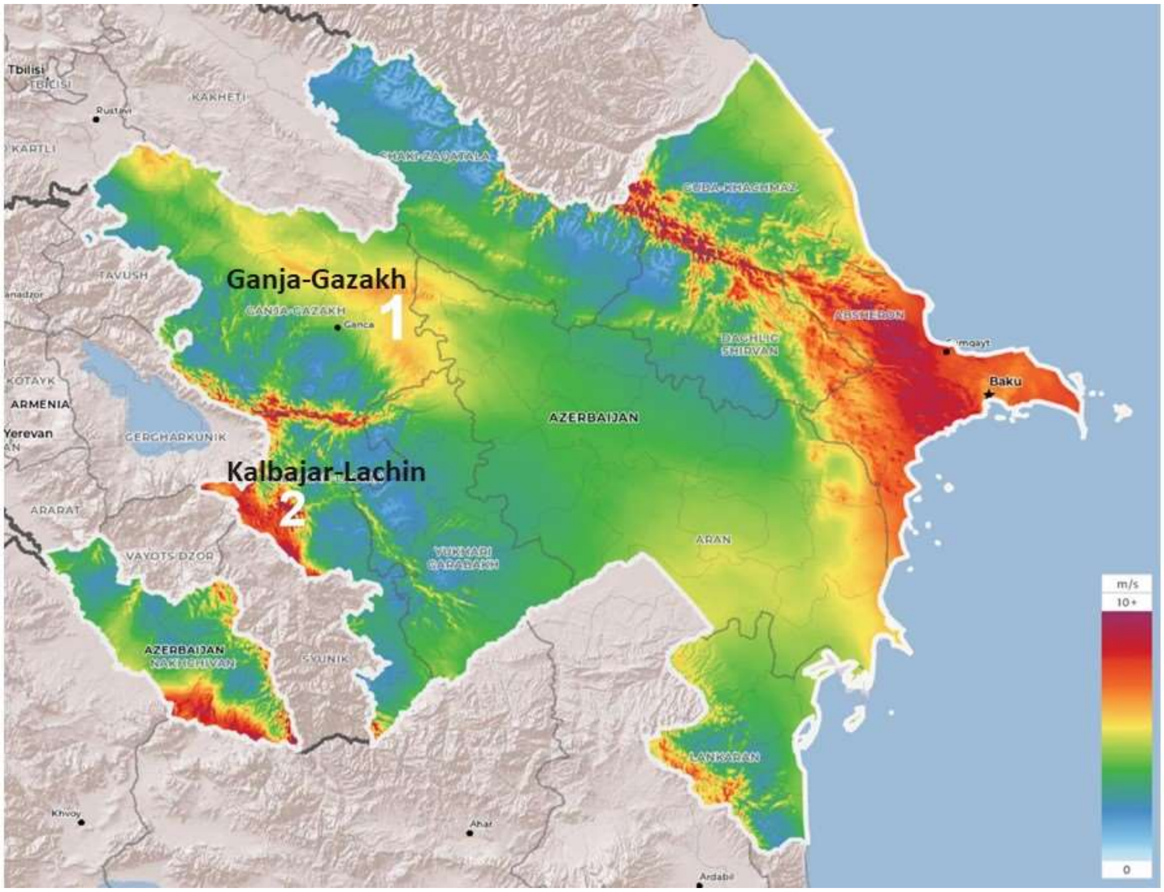
Table 5.3 Draft wind farm projects for Ganja-Gazakh and Kalbajar-Lachin zones

Project name	Planned output capacity	AEP
Ganja-Gazakh (at a projected area of ≈3235 ha)	138 MW (40 Siemens SG 3.4 turbines x 3.45 MW)	≈362,000 MWh/year
Kalbajar-Lachin (at a projected area of ≈1617 ha)	69 MW (20 Siemens SG 3.4 turbines x 3.45 MW)	≈181,000 MWh/year
Total	207 MW (60 Siemens SG 3.4 turbines)	≈543,000 MWh/year

Own elaboration

[46] Assumption is based on the convertion formula of *MWh = MW x Hours*.

Figure 5.4. Draft wind farm projects for Ganja-Gazakh (1) and Kalbajar-Lachin (2) zones



Undoubtedly, suggestions made in Table 5.3 are based on rough estimations and conclusions. The purpose of this study is to analyze the overall potential of renewable sources and their contribution to the energy security of Azerbaijan, rather than to conduct a detailed feasibility assessment for separate projects, and therefore scientific analysis of the mentioned zones can deliver slightly different results. However, the availability of suitable conditions, including large empty areas in both zones, allows saying that Ganja-Gazakh and Kalbajar-Lachin territories are reliable places to farm wind energy. The current development conditions between the two zones differ significantly. Ganja-Gazakh economic zone has a highly developed infrastructure, including energy infrastructure and grid connection points. Hence that zone can be considered as a much favorable location to generate wind power. Though, lower mean wind speed (≈5 m/s) can potentially reduce the AEP, utilization of high-efficiency turbines and splitting wind plants in between different zones within the Ganja-Gazakh zone instead of having one or two big plants can help to maximize the penetration of wind energy into the daily consumption in smaller green energy communities. The situation in the Kalbajar-Lachin zone is much different. The territory had been under occupation for more than 27 years and has a very weak development level, including energy infrastructure. The envisaged generation level can be achieved in a long-term perspective though since the zone has good mean wind speed and power density indicators (please, see figures 6 and 7). The terrain challenges can be overcome with the adoption of the small green community model which was applied successfully in the mountainous areas of Switzerland.

To conclude, maximum utilization of the available wind resources (estimated to be at least 3,000 MW) is not possible in the short to mid-term due to a variety of reasons. Nonetheless, three on-shore and one off-shore spot can be utilized successfully to generate approximately 1,000 MW of energy (estimation based on total capacity of units in Tables 2.3, 5.2, 5.3.).

Cost and benefit analysis of wind power generation

The literature on justifying the advantages of renewable energy over a conventional one is significantly rich. Arguments like support to the reduction of unemployment, environmental benefits of zero-emission generation and its long-term positive impact, deeper liberalization of the energy market, and development of private generation are putting green energy in a favorable position in comparison to hydrocarbon-based energy. Nonetheless, in countries new to this journey, the financial aspects of the development of renewable industry, the economic viability of the projects are sometimes questioned a lot due to huge capital investments, and research and development investments. Fossil rich countries are especially careful in this regard since the domestic natural resources mean lower LCOE and a satisfactory level of energy security. On the other hand, given the state monopoly over the energy market and abundant fossil resources in Azerbaijan, the utilization of renewable sources can significantly impact the export of oil and gas products through savings of fossil fuel and thus result in increased cash inflow. This chapter will analyze the financial aspects of green energy development and its implications for the economy of Azerbaijan. To do so, wind and solar energy generations will be analyzed separately since both industries have their own specifics.

Cost and benefit analysis performed under this section will only cover the projects proposed in Table 5.3 of this study. Calculations mentioned for the Ministry of Energy projects have been carried out by the relevant authorities and can be found in the indicated sources.

The installed cost of a renewable power plant can be divided into three major groups:

1. Upfront capital cost. Often referred to as CAPEX, it is the most expensive stage of any project and includes the construction of the site, including the administrative buildings inside the plant, civil works, control systems, etc.
2. Grid connection costs.
3. Operation and maintenance costs.

As per official information of the Ministry of Energy, the projected investments into the construction of wind farms with a total capacity of 240 MW is equal to USD 280 million (see Chapter 2 for wind energy project agreed with ACWA Power company). Though the breakdown of the costs is not publicly available, the project cost allow to say that the government calculations are based on USD 1.17 million per MW of capacity. Based on similar per MW estimation, the projects drafted for Ganja-Gazakh and Kalbajar-Lachin sites would approximately cost USD 161.5 million and USD 80.7 million.[47]

Since there is no precedent of private wind farms connecting to the state-controlled grid in Azerbaijan, related costs will be calculated based on the grid connection costs for businesses as indicated below.

Table 5.4 Grid connection costs of businesses (AZN)[48]

For agriculture businesses	For industrial-type businesses	For services and other types of businesses
21,240 + kW x 72 (after 125 kW)	23,600 + kW x 80 (after 125 kW)	28,320 + kW x 96 (after 125 kW)

Source: (Akbarov, 2019)

While the grid connection costs for large scale wind farms can differ from the same costs for businesses, the above data hints at pretty high investment requirements. Calculations based on tariffs for industrial type businesses result in approximately USD 6.5 million (AZN 11 million) for an envisaged project in the Ganja-Gazakh zone and USD 3.3 million (AZN 5.5 million) for the project drafted for Kalbajar-Lachin zone. Considering construction and grid connection costs and their rate to the AEP, we get construction and grid connection cost of USD 0.023/kWh for

[47] All estimations from now on are based on the Siemens SG 3.4 turbines.
[48] Above costs include administrative expenditures only. Thus, costs related to ensuring technical and safety requirements are assumed to be part of construction costs estimated by the Ministry.

both projects. According to the data of the Ministry of Energy, the LCOE of the wind power produced in drafted projects should constitute USD 0.032/kWh (AZN 0.055/kWh). The difference of USD ~0.01/kWh is operational and maintenance cost which is close to the one in OECD countries where the figure varies between USD 0.01 to USD 0.03 per kWh for on-shore wind farms (Renewable Power Generation Cost, 2018). In 20 years, the total operational and maintenance cost of wind power would be USD 72.4 million for Ganja-Gazakh project and USD 36.2 million for Kalbajar-Lachin project.

The following assumptions are considered in the calculations:

The assumption 1 is that the same company is a producer and a distributor of energy.

The assumption 2 is that there are not the wholesale and retail prices – there are only end retail prices.

The assumption 3 is that there is not a loss of renewable energy production sales due to limited demand.

The assumption 4 is that in the competition of renewable and fossil fuels energy production, the renewable energy has the priority and is sold first.

The following formulas help to calculate full investment rate per year and for total of 20 years (average lifespan of a wind turbine).

$$FIC(WF20) = UCC(WF20) + GC(WF20) + MOC(WF20)$$

where:

FIC(WF20) – Full Investment Cost of Wind Farm Installation for 20 years;

UCC(WF20) – Upfront Capital Cost for Wind Farm Installation for 20 years;

GC(WF20) – Grid Connection Cost for Wind Farm Installation for 20 years; and

MOC(WF20) – Maintenance and Operation Cost for Wind Farm Installation for 20 years.

Ganja-Gazakh FIC(WF20) = 161.5 mln. + 6.5 mln. + 72.4 mln. = USD 240.4 million

Kalbajar-Lachin FIC(WF20) = 80.7 mln. + 3.3 mln. + 36.2 mln. = USD 120.2 million

Thus, putting numbers in place FIC(WF20) equals to USD 240.4 million for the Ganja-Qazakh wind farm project, and USD 120.2 million for the Kalbajar-Lachin project. The FIC(WF20) can be divided by the average lifespan of the wind turbine (20 years) to find the annual value of full investment cost for a wind farm AFIC(WF):

$$AFIC(WF) = \frac{FIC(WF20)}{20}$$

Thus, AFIC(WF) for the Ganja-Qazakh project equals to USD 12 million. And AFIC(WF) for the Kalbajar-Qazakh project equals to USD 6 million.

Average electricity retail price is around USD 0.053/kWh[49] in Azerbaijan. Taking into account average retail price, LCOE and annual production levels envisioned in Table 5.3, Annual Profit (AP) of both projects can be estimated as the following:

AP of wind farms in Ganja-Gazakh zone:

362 million kWh/year x (USD 0.053/kWh – USD 0.032/kWh) = USD 7.6 million/year

AP of wind farms in Kalbajar-Lachin zone:

181 million kWh/year x (USD 0.053/kWh – USD 0.032/kWh) = USD 3.8 million/year

To conclude, the cost and benefit analysis of wind power generation in Azerbaijan demonstrates that the development of this industry is beneficial from a financial perspective. Tax and other incentives could make wind power generation even more attractive field for investors.

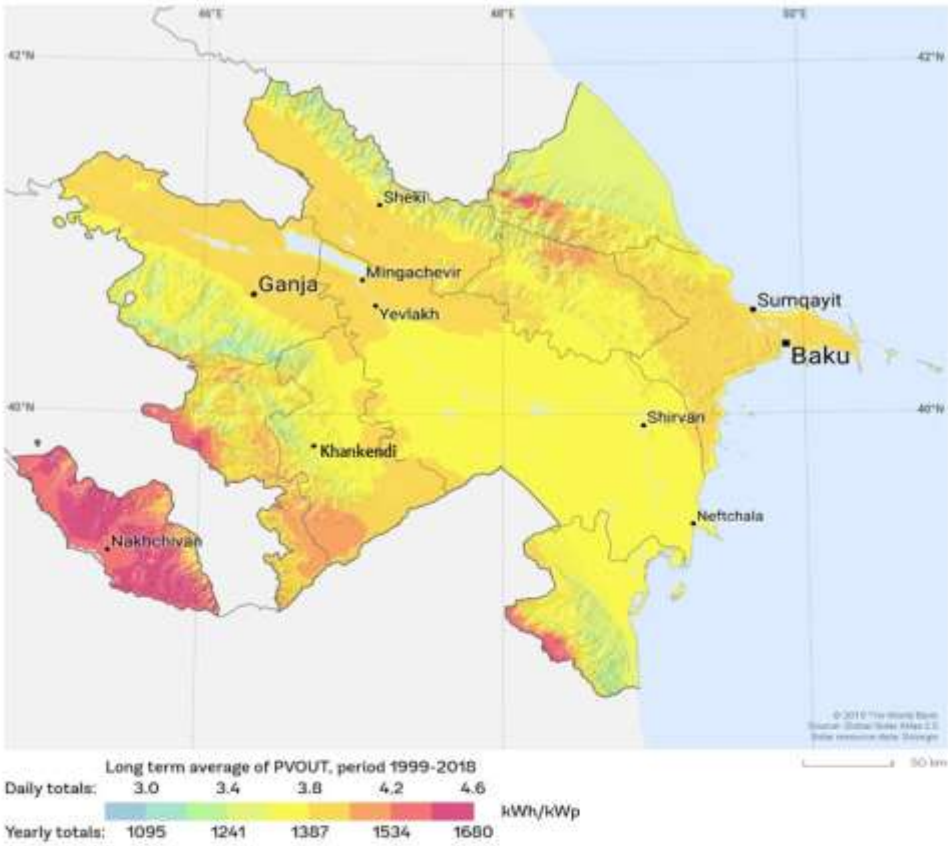
Chapter 5.2. Estimation of solar power potential in Azerbaijan

The situation with the sunlight availability is much better in comparison with the wind reserves as the IRENA estimates Azerbaijan's solar capacity to amount to 23,000 MW (IRENA, 2019). The total amount of sunny hours per year reaches 3000 leaving behind the USA (2500) and Russia (2000), claims the Ministry of Energy of Azerbaijan (Perspectives of Renewable and Alternative Energy Sources in Azerbaijan, 2014). Another study claims this number even reaches 3200 hours per year which is considered as one of the best indicators in the climate zone in which Azerbaijan is (Mahmudgizi, 2010). The World Bank's Global Solar Atlas confirms local

[49] Per kWh electricity price for households varies between AZN 0.07 and AZN 0.11 and for business it is 0.09 AZN. An average price of AZN 0.09 (USD 0.053/kWh) is considered for calculation.

claims about the rich solar potential. According to the available data, specific photovoltaic power output (SPPO) indicator for Azerbaijan ranges between 3.21 – 4.48 kWh/kWp.[50]

Figure 5.5 The photovoltaic power potential of Azerbaijan (WB Global Solar Atlas, 2019)



According to the World Bank, the DNI indicator varies in-between 2.71 – 4.84 kWh/m^2 per day. GHI indicator ranges from 3.44 to 4.80 kWh/m^2 per day (ibid.). These indicators are close to or even better in comparison with the similar indicators from best practice countries selected for this study.

[50] Specific photovoltaic power output indicates how much electricy can be produced for every kWp of the module capacity over a course of year (Zhang, 2017).

Figure 5.6 Global Horizontal Irradiation map of Azerbaijan (WB Global Solar Atlas, 2019)

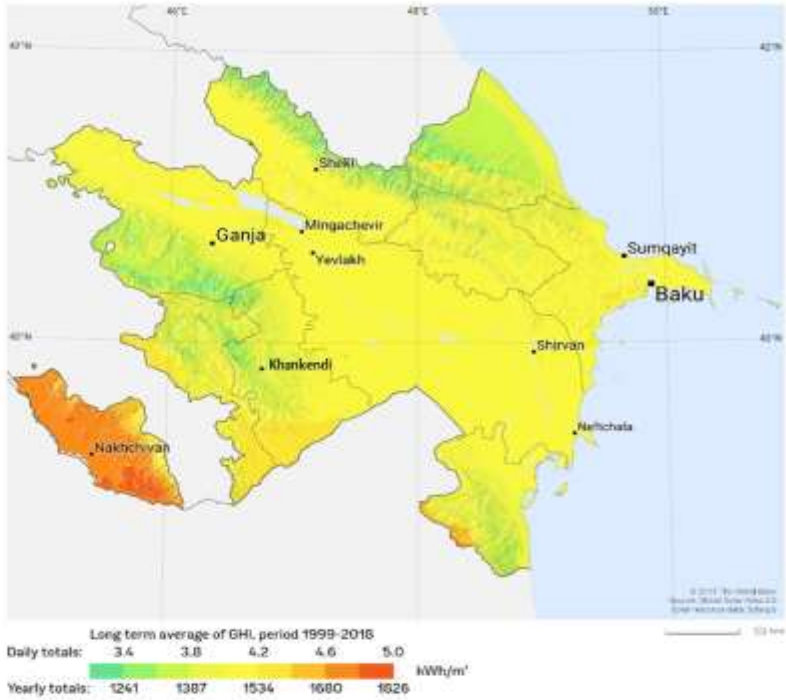
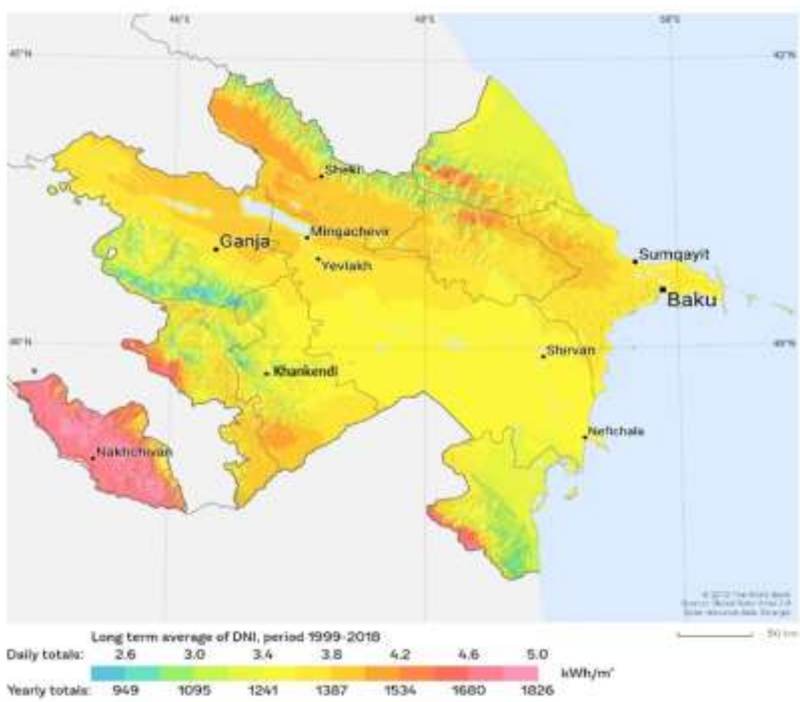


Figure 5.7 Direct Normal Irradiation map of Azerbaijan (WB Global Solar Atlas, 2019)



Despite resource abundance, the share of solar power in annual generation level is below 1% (44,200 MWh in 2019 (State Statistics Committee, 2019)). Also, in comparison with the wind energy industry, there are much fewer researches and studies to evaluate the solar potential of the country.

As per SPPO, GHI, and DNI maps, almost the whole territory of Azerbaijan is suitable for farming a power from sunlight. This factor, together with the specifications of solar panels can mean the followings:

- Unlike the situation with wind energy generation, there are many more potential zones to farm solar power.
- Instead of constructing industrial-size solar farms that require huge capital expenditures and possesses more business risks, a focus can be allocated on the development of private use or small solar communities.
- There is no need for allocation of large areas for solar power plants since private use or establishment of small solar communities will mean the utilization of areas such as rooftops, yards, private territories, etc.

It should be noted that in the majority of countries with developed solar energy generation, (including the best practices selected for this study) the roof-top installment of solar panels, integration of solar electricity generation into requirements for obtaining construction licenses, private or individual use of solar panels are among usual practices.

The technology of solar panels has evolved significantly allowing to generate even more electricity from the same territory or panel array size. The introduction of bifacial photovoltaic panels boosted the possibilities of its installation in places where conventional panels would not fit. Factors like technological advancement in the industry, average of 7-8 sunny hours per day throughout most parts of the country (based on the Ministry of Energy data), less burdensome construction process, easy private setup allow saying the chances of better utilization rate out of total capacity is higher than the same indicator for wind power.

For sure, construction of medium and large size solar plants can also be considered as the natural conditions are more than suitable for this. Projects on solar energy plants have been designed by the Ministry of Energy together with wind plants. Territories targeted by the Ministry overlap with the territories selected for wind power generation.

Table 5.5 Solar energy plant projects envisaged in Azerbaijan (The Ministry of Energy, 2020)

Project name and location	Planned output capacity	Estimated generation
Project 1 – 2200 hectares in Hajigabul district	1100 MW (4.4 million panels x 250 W)	1.46 million MWh/year
Project 2 – 850 hectares in Absheron peninsula	425 MW (1.7 million panels x 250 W)	579,000 MWh/year
Project 3 – 2600 hectares next to Alat settlement	1350 MW (5.4 million panels x 250 W)	1.725 million MWh/year

It should be noted that much more space beyond the total surface area of panels is considered for industrial size solar power plants. For example, though total surface area of typical panels make 704 hectares in the first project, 2200 hectares are allocated to host roads, administrative buildings, transmission systems as well.

Taking into account relatively easier private use or establishment of private solar communities, penetrating sunlight energy into the consumption at smaller sized projects is much attractive. This approach will also diminish or eliminate financial, technical, and administrative burdens related to the grid connection.

Focusing on large scale solar plants, a promising site can be Nakhchivan Autonomous Republic (NAR). As can be seen from Figures 5.5, 5.6, and 5.7, NAR's SPPO, GHI, and DNI indicators are much higher in comparison to the remaining part of the country. Thus, these territories can potentially accommodate a higher efficiency solar plant. The map below presents three potential areas for setting solar plants.

Figure 5.8 Potential solar plant zones in Nakhichevan (own elaboration)

There are three high potential zones in close proximity to the center of NAR, the Nakhichevan city. The total area of all three zones constitutes 1,724 ha. According to the Global Solar Atlas, annual GHI and DNI indicators are as follows:

- GHI: 1633 kWh/m^2
- DNI: 1553 kWh/m^2.

As per general experience (also based on the projects drafted by the Ministry of Energy presented in Table 5.5), approximately 30% of the total allocated plant area is covered by the photovoltaic panels. Taking into consideration all the abovementioned details and indicators, the following estimated output capacity and annual generation levels can be calculated for the projected zones in Figure 5.7. All calculations are carried out on the public PV power calculator.

Table 5.6 Potential solar plants in Nakhichevan, their output capacity and estimated generation levels (own elaboration calculated on a publicly available calculator (Photovoltaic Software, 2020)**)**[51]

Project name and location	Planned output capacity	Estimated generation
Area 1 – 794 ha	372.5 MW (1.49 million panels x 250 W)	385,000 MWh/year
Area 2 – 514 ha	240 MW (963 000 panels x 250 W)	250,000 MWh/year
Area 3 – 416 ha	195 MW (780 000 panels x 250 W)	202,000 MWh/year

To put the above figures into perspective, monthly average electricity consumption in the whole territory of NAR roughly constitutes 28,000 MWh, which translates into an annual approximate consumption rate of 336,000 MWh (NAR Energy Department, 2020).[52]

The territory of Nakhichevan has a lot of potential zones that can be utilized for generating solar power. Higher solar indicators and availability of flat terrains create possibilities for expanding the industry in the future and establish joint energy markets with neighboring countries. An example here can be a solar project implemented jointly with Turkey in the western border. Successful practices of European countries in this regard (discussed in Chapter 3) can be a good starting point to learn, adapt, and implement in the region.

Besides Nakhichevan, the flatlands of the Aran zone (territories of Yevlakh, Aghdash, Mingachevir districts) and southern Azerbaijan can also be utilized for generating solar energy as the main indicators demonstrate favorable conditions. Nonetheless, considering slightly lower population density (and hence, less consumption) large-scale projects implemented in those territories can give back more value if connected to major transmission grids. Penetration of solar power into private use or establishment of small solar communities can be much effective.

Transformation of sunlight into electricity is only one way to utilize solar power out of several ones. Solar power can also be included in daily consumptions in the following ways:

- Solar water heating;
- Solar heating of premises;

[51] The calculations have been carried out with the following values: inverter losses – 15%; temperature losses – 15%; DC cable losses – 3%; AC cable losses 3%; shading – 20%; weak irradiation losses - 7%; and losses due to snow, rain, dust and ect. – 2%. These values were set slightly higher than automatically set values of the calculator in order to prevent deceivingly high estimated generation levels.

[52] The rough annual consumption is calculated by finding an average monthly consumption and multiplying by 12.

- Solar ventilation of premises; and
- Solar lighting (especially street lamps, the lighting of road signs, etc.).

The abovementioned methods of the utilization of solar power are among the most widely used methods in the world (Energy Sage, 2020). With the development of technology, new means of the usage of solar power have emerged lately. Farming of sunlight for storage in portable batteries (individual scale usage), solar wearables, and even solar vehicles (though in many cases prototype but with promising results) are amongst means that enter the daily life of the habitats of the planet at a fast pace. The technology behind the solar industry and the relatively easy process of penetrating it into the daily individual use is promising in terms of increasing the share of sunlight generated energy in overall consumption levels.

The next chapter will discuss the integration of renewable energy into the energy system of Azerbaijan and energy storage prospects.

Cost and benefit analysis of solar power generation

The cost and benefit analysis of solar power generation has a similar methodology to the wind power generation. The CAPEX, grid connection costs, and operational and maintenance costs constitute the major expenditures before and during the operation of a solar plant. Taking this into consideration, the annual estimated generation rate, revenues from its sales, and expenditures will be analyzed and compared to the annual construction and maintenance costs to assess the profitability. Like was the case in the previous section, this section will try to conduct the cost and benefit analysis for the proposed projects in Table 5.6 based on the financial indicators derived from solar projects prepared by the Ministry of Energy.

According to the available information on the solar project carried out together with "Masdar", 200 MW capacity plant will cost USD 120 million with an estimated electricity generation of 410,000 MWh/year. These figures translate into USD 600,000 construction cost per MW output capacity. Based on these numbers, Table 5.6 can be further developed accordingly.

Table 5.7 Potential solar plants in Nakhichevan, their output capacity, estimated generation levels, and construction costs (own elaboration)

Project name and location	Planned output Capacity	AEP	Estimated construction cost (USD)
Area 1 – 794 ha	372.5 MW (1.49 million panels x 250 W)	385,000 MWh/year	223,500,000
Area 2 – 514 ha	240 MW (963 000 panels x 250 W)	250,000 MWh/year	144,000,000
Area 3 – 416 ha	195 MW (780 000 panels x 250 W)	202,000 MWh/year	117,000,000
Total	**807.5 MW (3.233 million panels x 250 W)**	**837,000 MWh/year**	**484,500,000**

Considering that the grid connection costs are stable for any kind of power plant, the figures indicated in Table 5.4 applies to the current calculations as well:

- Area 1: USD 17.5 million (AZN 29.8 million)
- Area 2: USD 11.3 million (AZN 29.2 million)
- Area 3: USD 9.2 million (AZN 15.6 million)

From the above figures, we can infer that construction and grid connection costs for every kWh would be USD 0.025 for all three projects (annual costs divided by AEPs). According to the Ministry of Energy, the LCOE of solar power should approximately constitute USD 0.034/kWh (AZN 0.057/kWh). The difference of USD ~0.01/kWh is operational and maintenance cost. In 25 years, the total operational and maintenance cost of solar power would be USD 96.3 million for the Project 1, USD 62.5 million for the Project 2 and USD 50.5 million for the Project 3.

The same assumptions for the cost and benefit analysis of the wind power projects in Chapter 5.2 are considered in the below calculations as well.

The following formulas help to calculate full investment rate per year and for total of 25 years (average lifespan of solar panel).

$$FIC(SI25) = UCC(SI25) + GC(SI25) + MOC(SI25)$$

where:

FIC(SI25) – Full Investment Cost of Solar Installation for 25 years;

UCC(SI25) – Upfront Capital Cost for Solar Installation for 25 years;

GC(SI25) – Grid Connection Cost for Solar Installation for 25 years; and

MOC(SI25) – Maintenance and Operation Cost for Solar Installation for 25 years.

Area 1 FIC(SI25) = 223.5 mln. + 17.5 mln. + 96.3 mln. = USD 337.3 million

Area 2 FIC(SI25) = 144 mln. + 11.3 mln. + 62.5 mln. = USD 217.8 million

Area 3 FIC(SI25) = 117 mln. + 9.2 mln. + 50.5 mln. = USD 176.7 million

Thus, putting numbers in place FIC(SI25) equals to USD 337.3 million for Project 1, USD 217.8 million for Project 2, and USD 176.7 million for Project 3.

The FIC(SI25) can be divided by the average lifespan of a solar installation (25 years) to find the annual value of full investment cost for a wind farm AFIC(SI):

$$AFIC(SI) = \frac{FIC(SI25)}{25}$$

Thus, AFIC(SI) will be USD 13.5 million for Project 1, USD 8.7 million for Project 2, and USD 7 million for Project 3.

As mentioned in the Chapter 5.1, Average electricity retail price is around USD 0.053/kWh in Azerbaijan. Considering all the above figures, we can draw the following Annual Profits (AP) for the projects:

AP of Area 1:

385 million kWh/year x (USD 0.053/kWh – USD 0.034/kWh) = USD 7.3 million/year

AP of Area 2:

250 million kWh/year x (USD 0.053/kWh – USD 0.034/kWh) = USD 4.8 million/year

AP of Area 3:

202 million kWh/year x (USD 0.053/kWh – USD 0.034/kWh) = USD 3.8 million/year

To sum up, the analysis displays that solar power generation in Azerbaijan also offers positive returns for investors. Another research on specific wind and solar projects could be done to estimate payback period (PB), internal rate of return (IRR), net present value (NPV) and other capital budgeting tools to see whether investments in renewables are competitive with the investments in other sectors of the economy.

Chapter 5.3. Macro level contribution of renewable energy to the economy

On Macro Profit of Renewable Energy Production level-1 (MPREP-1), estimation of profits are based only on the benefits derived from the generation of electricity. Total profit of all wind and solar power projects is calculated as below:

(AP for **Ganja-Gazakh** USD 7.6 million/year + AP of wind farms in **Kalbajar-Lachin** USD 3.8 million/year) x 20 years lifespan of wind power turbines = USD 228 million

(AP of **Area 1** USD 7.3 million/year + AP of **Area 2** USD 4.8 million/year + AP of **Area 3** USD 3.8 million/year) x 25 years lifespan of solar panels = USD ~ 398 million

MPREP-1 = USD 228 million + USD 398 million = USD ~ 626 million

From the cost and benefit analyses in chapters 5.1 and 5.2, we can get the total profit of USD 626 million in all five wind and solar projects.

Savings in hydrocarbon resources arising from the penetration of renewable energy into consumption should also be considered in overall benefits. On Macro Profit of Renewable Energy Production level-2 (MPREP-2), both the pure profit from the five REI projects and the amount of income earned from the sale of saved oil is summed up.

The proposed two wind power projects could generate 543,000 MWh/year electricity and three solar power projects could generate 837,000 MWh/year electricity as indicated in the tables 5.3 and 5.7 respectively. The 20 years lifespan of wind projects offer 10.9 million MWh, whereas 25 years lifespan of solar projects offer 21.9 million MWh electricity. In total, five projects in both wind and solar have the potential to yield 31.8 million MWh green energy.

As per the US Energy Information Administration, 0,08 gallons of petroleum is used to generate 1 kilowatt-hour (KWh) of energy (EIA, 2020). Therefore, 60.6 million barrel of oil is required to obtain the abovementioned 31.8 million MWh.[53]

MPREP-2 = 60.6 million barrel x USD 35/barrel[54] *=USD 2 121 million*

The Macro Profit of Renewable Energy Production would be the sum of MPREP-1 and MPREP-2, which is approximately USD 2.75 billion.

MPREP = USD 626 million + USD 2 121 million = USD ~ 2.75 billion

Effective management of revenues from the sales of saved crude oil resources can either be invested in research and development of REI or be utilized to develop various industries and spheres.

Chapter 5.4. Integration of renewable energy into the energy system of Azerbaijan and prospects for energy storage capacity

Integration of renewables into the energy system is an ongoing process even in countries with very rich experience in terms of generating fossil-free energy. The majority of countries are seeking the support of expert organizations in drafting a strategy, program, or action plan to smoothly integrate renewables into the existing energy system. Not surprisingly, one of the leading actors in this market is IRENA. As per the 2019 report of IRENA, the organization has provided assistance to Japan in recent years and continues an active work with G20 countries in this direction (Solutions to Integrate High Shares of Variable Renewable Energy, 2019). Azerbaijan can also work with IRENA to develop a strategy to get prepared for a well-planned integration of renewables into the existing energy system. This chapter will focus on factors for consideration and perspectives, including energy storage capacity prospects.

Integration of variable renewable energy (VRE)[55] into the energy system requires consideration of several factors which are:

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[53] 42 gallons equal 1 barrel and thus 1 barrel of oil contains 525 KWh or 0.525 MWh energy

[54] 20-year average crude oil price is taken as USD 35/barrel and obtained from the data provided by the OPEC (Organization of the Petroleum Exporting Countries, 2019).

- Integration to the grid
- Balancing supply and demand
- Creating storage capacity
- Establishing the necessary legal base[56]

Integration of green energy into the grid is itself a complex and challenging process that contains the following factors for consideration as elaborated by Leisch and Cochran in their report.

- New renewable energy generation
- New transmission
- Increased system flexibility
- Planning for a high REI future (Leisch & Cochran, 2015)

In Azerbaijan, the most favorable places to generate solar or wind power create electricity transmission and distribution challenges since some sunny locations are not close enough to the densely populated cities and some windy locations are right in the center of the area with the most concentration of population. As per the wind map of the country (Figure 2.1), the windiest area is Absheron peninsula and its close proximity where the concentration of population is very high (approximately 25 percent of the overall population, as per official data) which may challenge installation of large plants in those areas to generate a significant amount of energy. Another option would be settlement of off-shore wind plants though may lead to cost-related problems. A possible solution can be technical development and construction of efficient windmills to offset the mentioned challenges. Similar problems could be experienced in installing solar power plants, as mostly sunny areas are not close enough to densely populated cities (see Figure 2.3) which in its turn would create a need for improved electricity transmission system. Considering those factors, the connection of renewable electricity into the grid in Azerbaijan requires the development of complex transmission systems and storage batteries. As discussed in Chapter 1.3, the vast majority of electricity in Azerbaijan is generated in 13 PPs and TPPs, and 17 HPPs and SHPPs. The transmission system of the electricity is set up around those plants and is currently in a complicated state. Thus, in 2018, the Cabinet of Ministers approved

[55] Variable renewable energy (VRE): "electricity generation technologies whose primary energy source varies over time and cannot easily be stored. VRE sources include solar, wind, ocean, and some hydropower generation technologies." (Leisch & Cochran, 2015)

[56] Enlisted points are elaboration of author and are derived from the research of the existing literature.

the *Master Plan on Rehabilitation and Development of the Electricity Transmission Systems in the cities and districts of the Republic of Azerbaijan* (The Ministry of Energy, 2017). However, the Master Plan does not mention opportunities for flexibility to connect renewable electricity into the grid. The technological advancements have not bypassed electrical grid systems. Introduction of smart grids has significantly improved the accessibility and functionality, especially for private generators. With the help of such systems, prosumers can easily reach the market to sell the surplus electricity generated through private means.[57]

Another important point in the shift to renewable energy is ensuring a balance between supply and demand. According to the practice of other countries, the development of the REI is usually taking place at high speed and thus results in the generation of energy volume exceeding the current demand. This kind of scenario took place in Japan and Italy where apace development led to energy congestion and curtailment actions, as per the IRENA report (Solutions to Integrate High Shares of Variable Renewable Energy, 2019). With current transmission systems, high volumes of generation can create significant problems in Azerbaijan, especially in the absence of storage capacity. To avoid possible issues, the IRENA recommends the employment of flexibility strategies that would harness all components of the energy system (ibid). The flexibility of the demand-side has historically been hard to manage as consumers are much unresponsive to the implemented actions. Thus, conventionally, the supply side, especially the generation process has been the number one target to adjust to the demand. Nonetheless, the technical development, transmission, distribution, and storage of energy are also considered to be enablers of flexibility. The final energy consumption in Azerbaijan has been steadily increasing since 2010 (see Graph 2.3) and has reached 9 636.7 TOE in 2018 (State Statistics Committee, 2019) with continuous economic development. Hence, there is an obvious room for integrating the renewable energy system in rational volume to the consumption, resting assured of the demand side. Nonetheless, ensuring a comprehensive approach to flexibility mechanisms in generation and distribution is essential to avoid potential problems that were recorded in other countries.

[57] Smart grids employ advanced communication and IT systems that allow detailed analysis of electricity flow to reduce the waste, increase efficiency, and allow private generators an easier grid connection. Large definition of smart grid systems is provided by the U.S. (Energy Independence and Security Act of 2007).

Chapter 4 of this thesis has comprehensively described the current situation around the legal base regulating the REI. Obvious challenges do exist in regard to the regulation of integration of renewables into the energy system. The legal ecosystem lacks programs, documents defining the goals, and setting targets in this regard. Though a number of documents, including the earlier, mentioned Master Plan, envisages integration of renewables into the energy system the legal literature lacks sources describing how the process should develop (The Ministry of Energy, 2017). With proposed legal base regulations in Chapter 4 of this study, the integration of renewables into the energy system should also be comprehensively encompassed.

Storage of energy is one of the strongest tools in balancing supply and demand, and one of the most important aspects to consider when developing the renewable energy industry. The "sun doesn't always shine, and the wind doesn't always blow" reality acts as an impediment to the REI, but also should act as a solid impetus to develop means for storing the renewable energy to use when needed. For the time being, Azerbaijan lacks serious means of storing energy due to two main reasons:

- The fuel for generating energy is extracted and stored domestically and hence there is no need to generate energy and store it; and
- To balance the supply and demand, the country uses a conventional and reliable system of decreasing the generation when the supply starts to exceed the demand. Moreover, excess energy is sold to foreign countries.

The development of the REI requires parallel development of storage means, especially in cases where and when the renewables will be the major source of energy in separate communities. As the whole REI, the storage means are also currently in active development stages with over 700 projects being developed in this direction (Hicks, 2020). Mostly developed projects are:

- Installation of batteries (lithium-ion, lead-acid, sodium, Redox Flow, etc.)
- Pumped storage hydropower (PSH)[58]
- Compressed air energy (CAE)[59]

[58] PSH is a "is a configuration of two water reservoirs at different elevations that can generate power (discharge) as water moves down through a turbine; this draws power as it pumps water (recharge) to the upper reservoir." (The US Department of Energy, 2020).

There are other projects like flywheels, ultracapacitors, power-to-gas technologies with bioreactors and so on forth, but none of them have been developed enough to be considered in this thesis since the purpose is to analyze means that can be applied in a short term period (ibid.).

Energy storage can be broadly classified into three main groups depending on the time period. These are short-term storage (up to 5 hours), long-term storage (10 to 100 hours), and seasonal storage (longer than 100 hours). As per storage capacity, battery storage can vary from 10 kW up to 100 MW, whereas PSHs and CAEs can have a capacity up to 1000 MW (Patrick T. Moseley, 2015).

Currently, lithium-ion (Li-ion) batteries serve as the main tool used globally for short-term storage. This electrochemical mean of energy-storing is used when enough sunlight is available every day during the daytime and accumulated energy is used during evenings and early mornings. PSHs and CAEs are used for long-term purposes, but both come with disadvantages. The PSH project can last up to 10 years to finish which seriously impacts the willingness of private investors to participate in the project. CAE technology is still under development and not well applied in any country (ibid.). Another important point for consideration is the cost of stored electricity and operation and maintenance costs of the discussed technologies. Though defining the storage cost is a very difficult task and there is no universally accepted methodology for doing so, K. Mongird and V. Viswanathan have prepared the *Energy Storage Technology and Cost Characterization Report* where a group of experts has come up with a reliable approximation of storage and O&M costs of different technologies. According to the report, total project cost for the mostly preferred technologies are as below:

- Li-Ion Battery – USD 1,876 per kW;
- PSH – USD 2,638 per kW; and
- CAE – USD 1,669 per kW. (K. Mongird, 2019)

Considering the abovementioned, Azerbaijan can opt for installing li-ion batteries for a short-term solution (especially storing energy for the night and early morning times) and at the same time launch PSH projects in a few places to reserve energy for longer time periods. The

[59] CAE is a technology used to convert electrical energy into high-pressure compressed energy which can later be released to generate electricity (GreenAge, 2020).

government has recently adopted an action plan to ensure the water supply to consumers. According to the plan, 11 water reservoirs are planned to be constructed in near future (Action Plan for 2020-2022 on Ensuring Effective Utilization of Water Resources, 2020). Water reservoir design can be adapted to make those projects suitable for hydro based energy storage. Nonetheless, the financial aspects of PSH and CAE projects can impede the development of such projects considering their impact on the final LCOE of renewable electricity. As already mentioned in earlier chapters, the LCOE and retail prices of hydrocarbon-based electricity produced using domestic fuel are lower than the current average LCOE of renewables. The impact of storage prices will further increase the total price of green energy and make it difficult to sell to local consumers. Thus, thorough analysis and dedicated government support are needed to implement projects in this direction.

The next chapter will analyze the potential contribution level of renewable energy resources to the overall energy security of Azerbaijan.

The next chapter of this study will dive deeper into the impact of renewables on the economy and energy security of Azerbaijan and come up with recommendations.

Chapter 6. Transition to renewables: Energy security and implications on the economy of Azerbaijan

Chapter 6.1. Contribution of renewables to the energy security of Azerbaijan

The present stage of the energy security of Azerbaijan has already been analyzed in Chapter 1.3. using the MOSES methodology prepared by the IEA. Besides the MOSES framework, there are a few studies trying to measure energy security in a quantitative way. Colin J. Axon, Christian Winzer, and Richard C. Darton have tried to summarize existing literature on this topic and contribute to their *Measuring Energy Security* article (Colin J. Axon, 2013). Reviewing the existing literature, it can be safely noted that measuring the energy security using indicators offered by various authors is largely applicable for countries that import the fuel to generate power. Considering the fact that Azerbaijan extracts oil and gas domestically, indicators used for quantification and measurement of energy security is not well applicable in this context. Only a few concepts like the fuel prices, 'reserve to production' ratio (R/P ratio) are used to analyze the potential contribution of renewables to energy security.[60] Nonetheless, not to deviate from the initial energy security assessment framework, those indicators will be considered within the MOSES framework discussed in Chapter 1.3.

Operational definition. The definition of energy security defined for the purpose of this study is "*non-stop supply of energy at an affordable price able to withstand possible risks and threats posed by natural, geopolitical and economic circumstances*" (see Chapter 1.3.) Renewable energy sources will obviously contribute to the notion of "*non-stop supply*" in terms of resource availability. Though the existence of domestic fossil fuels eliminates the dependency on foreign imports and related risks, wind and solar resources will add to the diversification of sources, de-centralization of infrastructure systems, and the reduction of huge dependence on a few large energy generation units. The 2018 incidents in Mingachevir city, where the largest energy generation infrastructure is located, clearly demonstrated that most of the country is dependent on one plant, thus is very fragile for any possible physical damage, including possible military or terrorist attacks. Although measures were taken after the incidents, including the opening of plants in other territories, overall dependency on the infrastructure located in Mingachevir remain high. On another hand, though Azerbaijan enjoys large reserves of oil and gas, they are not inexhaustible. According to the BP report, the R/P ratio of oil in Azerbaijan is equal to 24.1 years and the same figure for natural gas is equal to 117 years, as per 2020 statistics (Statistical Review of World Energy, 2020). Considering the error rate in the calculation of reserves and extraction levels, and increasing natural gas exports with the full operation of the SGC natural gas project, the R/P ratio of both reserves are expected to be significantly less. From this perspective, the contribution of renewable energy sources to the maintaining of non-stop supply of energy is out-of-doubt. According to the statistics provided by the State Statistics Committee of Azerbaijan and Azerenerji OJSC, final energy consumption constituted 9 636.7 TOE in 2018 and that volume was generated in 30 generation plants (including thermal and hydropower plants) with a total capacity of 6 590.2 MW (State Statistics Committee, 2019) (see Table 1.2). The wind and solar potential constitute approximately 26,000 MW, according to the

[60] 'Reserve to production' ratio: "if the reserves remaining at the end of any year are divided by the production in that year, the result is the length of time that those remaining reserves would last if production were to continue at that rate" (BP, 2020)

IRENA report (Assessment of the Renewable Energy Sources of Azerbaijan, 2019). Chapter 5 of this thesis have proposed 5 projects that could utilize the mentioned potential. Comparing the total capacity of all current plants and the potential capacity of solar and wind power, it can safely be said Azerbaijan has the opportunities to become a fossil-free energy country in long-term perspectives. With economic development, consumption figures will surely yield which means instead of substituting the current need, renewables can also be used to meet the future demand. On the other hand, management of demand-side can be helpful to reduce the current dependency on hydrocarbon-based energy (shifting transportation system to the electric-based vehicles, upgrading old infrastructure with modern technologies which allow efficient use of energy, and etc.).

The *affordable price* notion of the above definition is the only aspect that might be potentially impacted negatively. As was already discussed throughout this study, the current LCOE of electricity generated with domestic fuel in Azerbaijan is lower than the average LCOE of green electricity generated worldwide. It is out-of-doubt that increasing research and development investments in renewables is dragging that figure down. Nonetheless, under current conditions and context, the penetration of fossil-free electricity might have a negative contribution to the energy security of Azerbaijan based on the concept of *energy security* defined in this thesis. However, recent contracts signed with "ACWA Power" and "Masdar" on the construction of wind and solar plants target to have the LCOE of AZN 0.055 and 0.053 per kW for wind and solar electricity respectively. These contracts reduce down the risks associated with the *affordable price* notion of energy security. **Identifying energy systems.** As it was mentioned during this study, there are approximately 30 power plants where the total consumption is generated (see Table 1.2). A number of relevant infrastructure objects are installed in each city and district. Along with conventional energy generation plants, there are also a number of operating wind and solar power plants, though they do not contribute much to feed the consumption (see Tables 2.3 and 2.4). Development of the REI and relevant systems will lead to diversification of infrastructure which is a clear-cut positive contribution to energy security as a whole. A fundamental contribution of renewables in this regard will be the de-centralization of the generation. Household level electricity production, small-sized renewable communities will decrease the role of separate facilities and thus the risks associated with physical protection of those.

Identifying risks and resilience capacity. A number of internal and external risks to energy security have been identified in Table 1.3. Development of the renewable energy industry will support to increase the resilience capacity in the following terms:

- **Internal risks**
    - **Resource supply**. Development of the REI means utilization of inexhaustible sources. The positive contribution of renewables to energy security in this context is self-explanatory.
    - **Emergency situations.** The REI contributes to the reducing of risks related to emergency situations and increasing resilience capacity through the diversification of energy infrastructure, reduction of dependency on central units, increasing of the number of independent renewable energy communities which serves to the reduction of loads on central units. Nonetheless, together with a positive contribution, REI also comes with risks associated with supply and demand balance, higher financial costs, and physical damage risks related to the renewable plants and energy storage infrastructure.
    - **Affordability.** Affordable price is another aspect where penetration of renewable energy into final consumption might have a negative 'contribution' due to higher LCOE and project costs. While more and more evidence is available according to which the renewable energy LCOE is in many cases equals or even goes below the LCOE of hydrocarbon-based energy, this aspect is still a concern for Azerbaijan, especially due to the availability of domestic fossil resources at lower costs. Implementation of major wind and solar projects mentioned earlier (see Chapter 2.2. and 2.3.) and results in terms of final LCOE will provide a concrete answer to this uncertainty.
    - **Utilization of renewable energy sources.** Integration of renewables into the energy system will allow to significantly diminish or even eradicate the dependence on large-scale generation units, eliminate the dependency on raw material supply, create opportunities to decentralize the generation process, thus reducing the risks associated to the dependency only on public utilities.

- **External risks**
  - **Physical attacks**. Increased number of energy generating plants inevitably leads to the higher risks associated with possible physical attacks. Thus, more steps and measures need to be taken to ensure the physical security of sites. From this perspective, the development of the REI means higher relevant risks and increased security costs. Nonetheless, this risk can be significantly brought down through the reduction of dependency on big facilities and stimulation of individual generation. Embracing individual generation will lead to minimalization of the scale of consequences of possible external/physical attacks.

Another risk beyond the scope of analysis carried out in Chapter 1.3. are financial risks as the renewable energy industry requires a huge amount of investments. As per experience discussed in Chapter 5.3. a number of projects, especially in storage capacity projects, remain unfinished or becomes non-profitable. Government support will mean an additional burden on the state budget and allocations in this direction risks to be expenditures rather than investments. Hence, the development of the REI, energy storage capacity, and integration into the system poses financial risks as well. This risk is especially higher at the initial stage of the development due to a low level of experience and issues related to the cooperation with private investors (poor expertise level, high expectations, etc.).

Interpretation. The topic of the potential contribution of renewable energy to the energy security of Azerbaijan is a coin with two sides. Positive side effects of the development of the REI from an energy security perspective are:

- diversification of resources;
- reduction of load on major sites;
- utilization of renewable resources;
- liberalization of the market (which leads to its development); and
- reduction of dependency on hydrocarbon resources.

The other side of the coin - increased energy security risks associated with the development of the REI are:

- financial risks;

- physical attack risks associated with the increased number of energy generation plants; and
- the risk of increased electricity prices due to higher LCOE of renewables.

To sum up, the abundance of domestic hydrocarbon resources has always meant lower energy prices and close to zero external dependence in terms of energy security. Thus, the positive contribution of renewables to the energy security arising from their integration into the energy systems is surely not at the same level as countries that import fuel to generate power. Moreover, the current energy price is also less dependent on global market prices and related external and geographical factors.

All in all, the development of the REI will undoubtedly serve the enhancement of a number of aspects discussed in this chapter. Reduced dependency on major energy generation sites, diversified sources, and utilization of inexhaustible resources to generate power are important elements of energy security. It is extremely hard to measure or quantify the contribution level of the REI to energy security in terms of numbers. And it surely has its own challenges that need to be extensively analyzed. However, with successful integration and management, the REI has substantively enhanced energy security in a number of successful countries. Azerbaijan will surely not be an exception by any means. Shifting to renewable sources will open opportunities to create hydrocarbon reserves for the future or bring in cash from its sales to other countries. These will serve to the strengthening of the overall security of the country, including energy security, through enhanced political and economic relations with regional countries and international organizations.[61] On the other hand, REI's undeniable positive impact on the liberalization of the energy market, decrease of carbon footprint, potential to attract private investments (including foreign capital), reduction of state burden on production and supply of energy are factors acting in favor of implementing green projects. As it has been analyzed in previous chapters, existing financial risks are not paramount and can be offset with proper market liberalization, support mechanisms, and research and development activities.

The next chapter of this thesis will come up with recommendations on how Azerbaijan can develop the REI, integrate it into the energy system, and enhance energy security.

[61] The role of the development of relations with regional countries and international organizations in enhancing the national security, including energy security, is defined by the (The National Security Concept of the Republic of Azerbaijan, 2007).

Chapter 6.2. Expected added value of renewables to the economy

The expected added value of the development of renewables to the economy has been studied extensively by individuals and organizations. Findings are that it significantly contributes to the overall economic growth and welfare, as per the outcomes of many studies. According to IRENA, doubling of renewables in the global energy mix can potentially increase the global GDP from 0.6% up to 1.1% by 2030. The positive effect of green energy on welfare is well beyond those figures, as the increase of the same amount can lead to a 2.7-3.7% increase in the welfare of the population (Renewable Energy Benefits: Measuring the Economics, 2016). The effect is obtained through positive impact to economic dimension (through investments and consumption), social dimension (through employment and increased spending sectors like education and health thanks to the reduced expenditures to purchase or generate fossil-based energy), and environmental dimension (reduced carbon emission, healthier environment). Development of the REI is especially beneficial from the employment perspectives since increasing demand means more jobs to manufacture bigger volumes of equipment, more jobs to enhance the supply chain, and more jobs to improve the service sector. Indisputably, the world is yet far from full abandonment of hydrocarbon-based energy. Thus, the job losses related to the decreased share of conventional energy in the global or country-level mix do not stand at the same level as the newly created job places in quantitative terms. Panel investigations conducted for the OECD countries and the United States resulted in similar conclusions (Matei, 2017; Xiarchos, Nondo, & Kahsai, 2014).

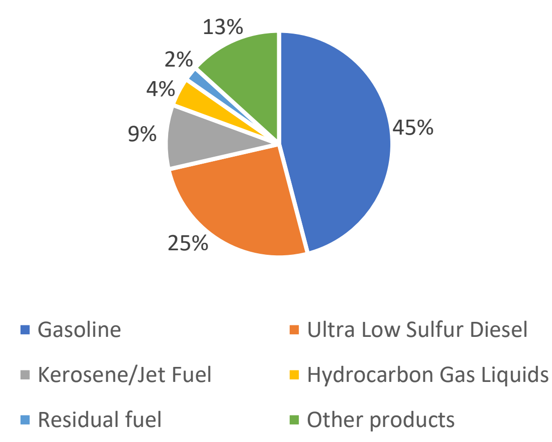
A similar study considering the economy of Azerbaijan has never been carried out. Next, the thesis will dive into the perspectives of renewables from the macroeconomic aspects focusing on its impact on economic growth, employment, and social welfare in Azerbaijan.

Renewables and economic growth

Scientific studies analyzing the relationship between the development of the REI and the growth of the economy converge at the point that green energy boost has a positive impact on the economy. A similar conclusion is also made by the IRENA in its (Measuring the Economics, 2016) report. An increase in GDP, employment upturn, creation of new job places, improvement in social welfare are indicators of growth of which are strongly associated with the development of the REI, along with other factors. Furthermore, Azerbaijan will also benefit from crude oil and natural gas savings thanks to the increasing share of green electricity penetration to consumption.

The scale of the increase in GDP associated with the growth in renewables differ across countries due to various reasons. Nonetheless, the research conducted among the OECD countries has determined that the positive correlation at significant levels between two variables is true at 57% of analyzed cases (Singh, Nyuur, & Richmond, 2019). The amount of saved oil and gas resources is one of the crucial factors affecting economic growth as it can be invested in many directions contributing to economic growth. The projects envisaged by the government totaled 121 million MWh and the projects proposed in this study offer an extra 32 million MWh green energy (solar and wind projects taken together). As discussed in Chapter 5, one barrel of oil contains 0.525 MWh electricity and the abovementioned projects translate into the total of 291 million barrels of oil saved over 20 and 25 years, lifespan of wind and solar plants respectively. If sold as a crude oil based on a 20-year price average that would generate more than USD 10 billion of associated revenues. However, crude oil is also cracked into various petroleum products, like diesel fuel, jet fuel, Liquified Petroleum Gases (LPG), bitumen, asphalt, etc., and sold as separate products at price points sometimes exceeding the profitability of crude oil sales.

Graph 6.1 Breakdown of a barrel of crude oil into petroleum products



Source: (Muenster, 2020)

Most of the products obtained from crude oil are sold at varying prices connected due to many factors. Thus, estimating the price of all products derived from one barrel of crude oil and comparing it to its per barrel price is not easy and does not constitute the main goal of this study. Nonetheless, it is safe to say that the potential earning of Azerbaijan through saved crude oil thanks to the increased share of green energy in consumption can be much higher. A project similar to the Jurong Island of Singapore set up in the Caspian Sea would enormously boost the petrochemical complex of Azerbaijan.[62] Very good potential locations are already available to create a petrochemical community in the Caspian Basin (see figure 6.1) . An option can be the area around Pirallahi and Chilov islands where three more smaller islands are located: Boyuk Tava island, Tavaalti island, Koltis island. Besides, a few smaller unnamed islands are also located nearby. Chilov island is already housing several oil and gas related facilities and located very close to the *Neft Dashlari* complex (Oil Rocks complex). Another location can be the area near Alat settlement, a newly growing hub housing multimodal transport intersections and logistics centres. Gil island, Khara-Zira island, Duvanny island are located in close proximity and can fully be transformed into petrochemical oasis. Moreover, as per the government's initiative, Alat Free Economic Zone is to be created in the area that would stimulate businesses to invest starting from mid-2022. The experience of the Jurong Island is extremely useful in understanding the overall potential. A similar project in Azerbaijan would mean foreign investments into the economy, new job places, additional revenue streams. Besides, the relocation of existing facilities around the chosen spot could help to reduce the environmental hazard spread to the residential settlements.

[62] Singapore Jurong Island is a project set up in 7 amalgamated islands where dozens of big companies like BP, BASF, Exxon, etc. are producing petrochemical products. More about the project can be read here: https://www.jtc.gov.sg/about-us/our-journey/Pages/default.aspx

Figure 6.1 Caspian Basin

Source: *(Google. (n.d.). Caspian Sea. Retrieved September 17, 2021)*

On the other hand, the re-allocation of the revenues and its effective management will define the real level of contribution of renewables into the economic growth of the country. Considering the net exports as one of the components of GDP, growing trade share related to saved hydrocarbon resources automatically converts into the GDP growth as well. Additional benefits incoming from the hypothetical petrochemical community of Azerbaijan could further add up to the benefits of shifting towards zero carbon energy generation.

Renewables and employment

The development of the renewable energy industry affects employment levels in three main ways. These are:

- *Direct effects* that imply jobs created in connection with the development of the industry. An example can be employees producing the items, selling manufactured items, installing renewable plants, etc.
- *Indirect effects* imply jobs created in industries that supply various goods and services to companies in the renewables sector. E.g. companies supplying steel and other necessary materials, companies carrying out logistics works, etc.
- *The induced effect* includes the implications of the development of renewables on trade operations, including international trade, expenditures in the other sectors of the economy using the financial capacity generated through the development of green energy, etc.

The global perspectives analyzed by IRENA and separate studies conducted for various countries indicate a high potential of green energy in creating new job places (for IRENA findings refer to Chapter 5.4.). According to the research conducted by R. Pollin and et al, USD 1.0 million investment in renewables has the potential to create 16.7 new job places in the United States (includes indirect and induced jobs). This number outperforms the same indicator for fossil-based energy by almost three times (5.3 jobs for oil, gas, coal investments) (Pollin, Wicks-Lim, & Peltier, 2009). The employment boom associated with renewables can also be observed in Eurozone where more than 1.5 million jobs are accounted for green energy generation in 2018 (calculations included direct and indirect jobs only) (Czako, 2020).

The general employment per industry information provided by the State Statistics Committee hints at the fossils being a significant shareholder in this regard (Distribution of employed population by economic activities, 2020). According to the latest numbers, the oil and gas sector accounts for 35 thousand job places, excluding indirect and associated jobs (Banker, 2019). Adding indirect and associated jobs, the figure can be estimated to be well above 60k. Thus, the development of renewables in Azerbaijan will be accompanied by the diminishing of the scale of the oil and gas industry which will inevitably lead to lay-offs, in direct, indirect, and associated activity fields. Hence, the contribution level of the REI to the employment in Azerbaijan will not be the same as in the European countries, especially in ones without domestic hydrocarbon resources. Another challenge to overcome for Azerbaijan is the incompatibility of a variety of skills and knowledge across two industries. Many employed in the oil and gas sector, especially those working in mining and related fields will need to acquire a new set of skills and knowledge to find a job outside of the industry. To balance potential negative impacts, comprehensive and complex strategy should be put in place.

Development of the renewables industry has the potential to create a broad array of job places within the educational continuum - starting from management, finance, legal works requiring higher education, down to drivers, carpenters, insulation workers with high school or even lower education level. One of the main differences of renewables from the hydrocarbons in terms of employment needs is the higher labor intensity. Unlike conventional energy generation, where the lion's share of investments and expenditures are allocated to developing and purchasing machines, installing high-cost platforms (on-shore or off-shore), green energy requires more budget for research and development and labor force. In 2011, the International Labor Office has prepared a detailed report on the employment status in renewables. The findings indicate at 6.96 – 11.01 jobs per megawatt of average capacity in solar photovoltaics and 0.7 – 2.78 jobs in wind power (direct employment only) (International Labor Office, 2011).

Table 6.1 Average employment over the life cycle of the facility (jobs per MW)

	Construction, installation	**Operating and maintenance, fuel processing**	**Total**
Solar plant	5.76 - 6.21	1.20 - 4.80	6.96 - 11.01
Wind plant	0.43 - 2.51	0.27	0.70 - 2.78
Coal energy plant	0.27	0.74	1.01
Natural gas plant	0.25	0.70	0.95

Source: (International Labor Office, 2011)

As can be seen from Table 6.1 average per MW employment rate for solar and wind power exceeds the same indicator for conventional energy generation. The positive difference in this regard allows forecasting that the development of the REI and jobs created in relation to it will off-set the number of closed-down job places. Employing a gradual, yet continuous shift to renewables have all the potential to outperform fossils' contribution to the labor market while ensuring enough adaptation and reintegration time for those who lost their jobs in the oil and gas sector due to the shrinking of the industry. Five wind plant projects drafted by the Ministry of Energy with a total output capacity of 442.5 MW (see Chapter 5.1.) has the potential to house 300 workers with open-ended contracts (excluding indirect and induced effects). The lay-off levels associated with the shrinking of the same scope for the oil and gas sector would be approximately the same. The situation with solar energy is different. The photovoltaic plants designed by the Ministry with a total output capacity of 2,825 MW could accommodate 5,000 workers (considering permanent job places only). These figures do not include indirect and induced effects of the development of REI. Given the estimations, the total green energy capacity of Azerbaijan can provide jobs for dozens of thousands (see Chapter 5 for total renewables capacity). The 2013 study conducted by C. Juchau and D. Solan found out that each MW capacity of conventional energy generation creates approximately 0.2 jobs only (Juchau & Solan, 2013). Thus, it can be concluded that the replacement of fossil-based energy generation facilities with renewable plants will overall has positive impact on the employment levels in Azerbaijan.

The financial parameters of the projects are discussed in Chapter 5.4. lead us the following results:

- For wind power generation, allocation of USD 1.171 million (per MW cost) will result in 0.7 – 2.78 new job places.
- For solar power generation, allocation of USD 617.7 thousand (per MW cost) will result in 6.96 – 11.01 new job places.

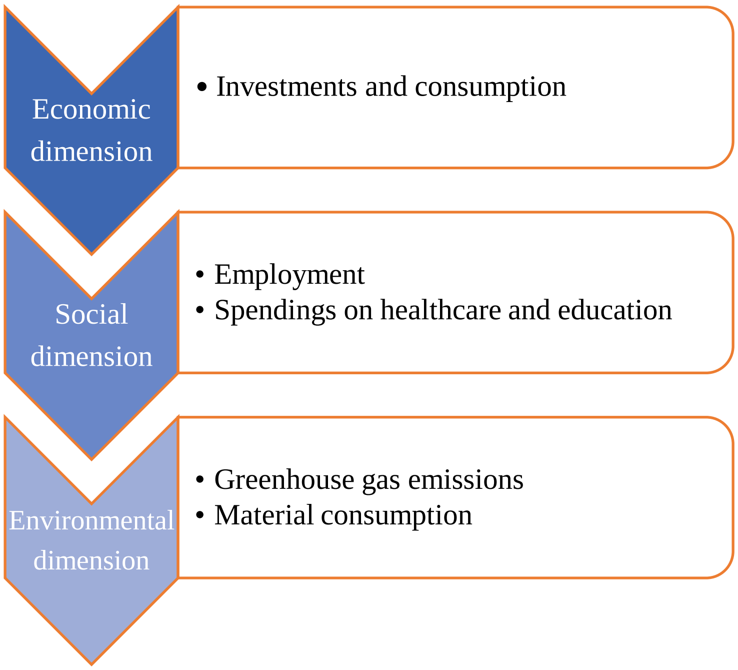
As can be seen, investments in solar power have better results in terms of employment impact. Combined with indirect and induced effects, the positive impact of wind and solar power generation on employment will only grow.

Renewables and social welfare

The positive impact of the REI's development to the economic growth and employment has a direct connection with the improvement of social welfare. The term social welfare includes three main dimensions which are economic, social and environmental. Altogether, these are accepted as important factors affecting the welfare of population.[63]

[63] The conceptualization of the social welfare term is based on the conclusions of discussions by many international organizations summed up at the (Measuring the Economics, 2016) report.

Figure 6.2 Social welfare dimensions and components



Source: (Measuring the Economics, 2016)

According to the empirical findings, doubling the share of renewables in the consumption can potentially increase the social welfare 2.7 - 3.7% (Measuring the Economics, 2016).

The components of the economic dimension are mainly fed by the financial capacities created due to the savings from expenditures on the purchasing of fossil reserves for energy generation or sales of saved domestic fossil reserves. Allocation of a share of generated money into education and healthcare is one of the primary ways how renewables can enhance social welfare in Azerbaijan.

The positive impact of renewables on employment has already been analyzed in the previous paragraph. Besides the creation of new job places and higher labor intensity, green energy generation is much suitable for the labor force with lower education levels. College or high school graduates have higher chances of getting employed in the renewables industry rather than the conventional energy generation field. Hence, lower layers of the population in terms of social wellbeing are better supported which translates into an overall benefit to the social welfare of the country.[64]

Additional financial capacity accumulated with the development of the REI might also increase expenditures allocated to the education and healthcare which are primary components affecting social welfare in any country. Estimated savings thanks to the green energy constitute approximately USD 2.75 billion for 20 years considering revenues generated from the sale of crude oil only. With effective management of investments, their value (and not only monetary value) can be upfolded by many times. Below are a few specific directions that can boost social welfare through additional investments in education and healthcare:

- Investments in research and development are also related to renewables.
- Investments into the development of the local education system through the improvement of the livelihood of teachers, scientists and others working in the education sector (especially those living in districts and rural communities).
- Boosting the state programs on education abroad (successfully implemented throughout 2007-2015 and continues currently in a modified format).
- Investments into renovating healthcare facilities in districts and rural communities, including the benefits of healthcare workers.

Reduced greenhouse gas emissions and reduced material consumption are direct effects of the transition from hydrocarbon-based energy to zero carbon energy.[65]

Chapter 6.3. Recommendations

Research of the existing experience of the development of REI, together with analysis of practice and methods in a select list of countries with relevant indicators close to Azerbaijan allow to confirm that the shift to renewable energy will play a crucial role in the strengthening of the energy security, along with its positive impact on the economic growth, social welfare, and employment levels. Due to historic and geographic reasons, the abundance of hydrocarbon

[64] Assumptions are made based on the findings of the *Green Prosperity: How Clean Energy Policies Can Fight Poverty and Raise Living Standards in the United States* study by (Pollin, Wicks-Lim, & Peltier, 2009).

[65] Material consumption is defined as the amount of materials (in terms of weight) used in an economy (Material consumption, 2020).

resources, Azerbaijan has developed an extensive oil and gas industry which plays a crucial role in feeding the economy and maintaining energy security. Nonetheless, green energy has gradually become a topic on par with oil and gas with relevant developments and reforms accompanied with a strong state will. The analysis of the current situation and potential for the development of renewables revealed a number of decisions taken towards enhancing green energy production but at the same time a number of shortcomings to overcome. This study presents the below recommendations that would complement the successful development of the REI in Azerbaijan.

1. One of the key shortcomings in the path for the transition to green energy is the relatively weak legal framework. A comprehensive document should be available defining the development objectives and strategic approach. Detailed analysis of the current situation in Azerbaijan in these regards has revealed a necessity to adopt a document that would establish fundamental principles, a long-term vision of the industry, and strategic objectives. An example of the National Renewable Energy Action Plan submitted by the EU countries can play a good role model in setting short, mid, and long-term objectives.

   Laws and other legal acts regulating the development of the REI need to be adopted (or current acts should be updated) to:

   1.1. Liberalize the energy market;

   1.2. Stimulate private green energy generation and consumption;

   1.3. Incentivize and support the creation of independent small-scale renewable communities (especially in mid to small size districts and rural areas);

   1.4. Update necessary legal framework to enforce utilization of renewable energy sources in buildings (e.g., consideration of minimum share of renewables in the design phase to acquire construction permission).

2. Allocations to the research and development (R&D) in renewables will create conditions to employ advanced technologies and fill in data necessary for setting up effective green plants. It will also pay off with the creation of new job places, scientific findings contributing to non-energy related fields, gaining expertise in renewables that can add value to international cooperation and trade (selling knowledge). Major R&D investment directions for Azerbaijan can be the development of sustainable technologies, upgrading transmission grid systems to create conditions for private integration, employing smart

grid systems allowing prosumers to utilize privately generated electricity and sell the surplus, enhancing of the legal framework regulating the REI, etc.

3. Upgrading the transmission grid systems is of pivotal importance, especially for private generators, including household level generators to increase efficiency. The application of smart grids will ease the life of private generators, and at the same time increase the efficiency. A relevant legal framework should be adopted to allow the burden-free procedure to access smart grids.
4. Awareness raising about the renewables, its advantages and possibilities of private generation, combined with proper training on this, should be another target to achieve. As a result of abundant hydrocarbon reserves and the long-lasting history of its utilization for energy generation through public means, the population in Azerbaijan is yet to understand and embrace the notion of individual electricity generation. Besides, the awareness of the environmental hazards of fossil-based energy generation, climate change, and overall environmental sensitization in Azerbaijan have a generous space to improve. A comprehensive strategy should be adopted by relevant governmental bodies to change the mindset of people, prepare them for the ownership of green energy, stimulate private generation, increase the knowledge on the legal, technical, and administrative aspects of this activity, including the support policies put in place by the state.
5. At the end of 2020, the government announced a conceptual project of Green Zone to be implemented in Karabakh (see Chapter 2.1.). Similar projects can successfully be implemented in various economic zones where green resources have potential to provide enough supply to feed the local demand through ‘in-house’ generation. De-scaling the ownership level to individuals or prosumers provided with appropriate access to connect to transmission grid will help to transfer the burden of supplying energy from the public utilities to self-organized, yet properly supported individuals, private companies, or renewable communities. This will provide additional benefits to the development of the energy market, technologies, and attraction of capital investments.
6. The energy security concept of Azerbaijan is one of the main documents to be revised to integrate an increased role of renewables. In 2007, the *National Security Concept of the Republic of Azerbaijan* was adopted where the energy security paragraph mainly includes notions about hydrocarbon reserves, facilities to extract, save and transport oil and gas

resources, including local and international pipelines, energy generation facilities, and physical security of all mentioned. The renewables are mentioned in only one line where the government takes accountability to develop the REI focusing on solar and wind resources (The National Security Concept of the Republic of Azerbaijan, 2007). The collapse of the global oil market, lowering oil prices accompanied with lower demand and extraction levels, developing trend to embrace carbon-free resources supported with decreasing costs, and electricity LCOE are important factors to consider and integrate into the current energy security concept. Besides, joint green projects that can potentially be established in southern, northern and western territories of Azerbaijan with neighboring countries might further increase the energy security at a local scale through increased interdependency, boost cooperation, trade and contribute to the enhancing of political relations. These developments will further strengthen national security.

7. The shift to carbon-free energy generation will have the following direct financial impact:
    - The amount of oil and gas resources exported to the international market will increase as the local demand will be met by renewable sources. It means more associated revenues will inflow to State Oil Fund of the Republic of Azerbaijan.
    - The amount of hydrocarbon reserves available to store for future use will increase (if saved resources are not immediately sold at the global market).
    - Revenue accumulation of the main energy producer and distributor – Azerenerji OJSC – will significantly decrease with the stimulation of private generation and use. The development of prosumers will further add to this factor. It will translate into more dependency on direct financial allocations from the state budget.

    These are the immediate results that will be followed up by the impact on GDP, employment, and social welfare as discussed above.

The shift to renewable energy sources is a demand of now and the future. The advantages of green resources over conventional natural reserves used for energy generation are obvious. The benefits of carbon-zero energy generation are not only financial and economic, but it also plays a crucial role in the strengthening of energy security. Azerbaijan has recently joined the global trend, albeit in lower temps initially. Introducing a robust legal framework, solid and balanced support policies, employing a proper and comprehensive strategy to embrace green energy and technologies, reforming current utilities as private electricity generation is stimulated, Azerbaijan can in a short time period significantly enhance its energy security, develop its relations with neighboring countries and enjoy benefits in terms of added value to the economy. Besides economic and environmental benefits, development of REI can create new energy collaboration schemes adding up to the regional cooperation and trade. Huge reserves in terms of solar, wind, and hydropower allow to extensively enlarge the share of carbon-zero electricity in the total consumption. Nonetheless, shift to green energy is not a one-sided coin for Azerbaijan. There are some dilemmas too since the abundance of domestic fossil fuel is already ensuring the energy security. Billions of dollars have been invested into related infrastructure and facilities up to date. On the contrary, renewable energy industry is a completely new endeavor that requires huge investments and solid expertise on the matter. It is not surprising that no information is publicly available about the outcomes of projects planned (discussed in Chapter 2). Despite a number of projects implemented, the penetration of green energy into consumptions is insignificant. Development of the REI is accompanied in practice by the liberalization of energy market which will lead to the loss of state control over the related industry. Possible electricity price increase, necessity for developed and adapted transmission grids and relevant investments are among factors residing on the other side of the coin.

The findings of this study reveal that the development of renewable energy industry will have positive security, economic, and social impact on the life of Azerbaijan. Despite aspects weighing in favor of hydrocarbon-based energy generation, added value of renewables to the energy security, economy and social welfare is overweighing concern. Combined with the environmental benefits of green resources, the shift to REI is the best alternative to go for. The 2021 and the following years will likely to be cornerstone period in the development of the REI in Azerbaijan, as President Ilham Aliyev announced “clean environment and ‘green growth’ country” to be one of five strategic objectives to be reached by 2030 (Azerbaijan 2030: National priorities on the socio-economic development, 2021).

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List of Graphs

List of Tables

List of Figures