

## **Extended Essay (Environmental Systems and Societies)**

**“To what extent will the activation of the Akkuyu nuclear power plant  
affect carbon emissions in Türkiye.”**

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**Research Question:** To what extent will the activation of the Akkuyu nuclear power plant affect carbon emissions in Türkiye?

## **Introduction:**

In recent years, Türkiye has been grappling with the challenge of reducing its carbon emissions to combat climate change. In 2020, Türkiye emitted 373.9 million metric tons of CO<sub>2</sub> into the atmosphere<sup>1</sup>, and this number continues to rise. With the country's growing energy demands, the government has recently approved the construction of the Akkuyu nuclear power plant in the southern province of Mersin, in collaboration with Russia. The plant has sparked a heated debate among experts and the public alike.

While proponents argue that nuclear power is a cleaner and more efficient energy source compared to traditional fossil fuels, opponents raise concerns about the potential risks and negative impacts associated with nuclear power, such as the Chernobyl accident of 1986, which devastated Chernobyl and the effects of it are still felt, and the Fukushima disaster of 2011 in Japan. The local population also appears to be against the construction of the Akkuyu plant, and there has been backlash from the anti-nuclear communities.

The debate over nuclear energy is not new, and it has been a subject of global discussion for decades. While nuclear power is often touted as a cleaner alternative to traditional fossil fuels, it is not without its risks and challenges. For example, nuclear power plants require significant capital investment and technical expertise to build and operate, and there is always a risk of

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<sup>1</sup> <https://www.statista.com/statistics/449827/co2-emissions-Türkiye/>

accidents and leaks. In addition, there are concerns about the disposal of nuclear waste, which can remain radioactive for thousands of years.

Despite these concerns, many countries have invested in nuclear power to reduce their carbon emissions and increase their energy independence. For example, France relies heavily on nuclear power and generates over 70% of its electricity from nuclear reactors, while China and Russia are also increasing their nuclear energy capacity. Other countries, such as Germany and Switzerland, have made the decision to phase out nuclear power due to safety concerns, and have focused on developing renewable energy sources instead.

Given the global context of nuclear energy, it is important to consider Türkiye's decision to invest in the Akkuyu nuclear power plant within the wider international discourse. The construction of the plant will have significant implications for Türkiye's energy policy and could impact the country's ability to meet its climate change targets. Therefore, in this extended essay, I will investigate the impact of the Akkuyu nuclear power plant on carbon emissions in Türkiye, considering various factors such as energy demand, electricity production, and the country's climate change goals. In addition to examining the scientific and environmental implications of nuclear power, I will also analyze the political and economic factors that have led to the construction of the Akkuyu plant and compare Türkiye's nuclear energy policies to those of other countries around the world.

## Background Information:

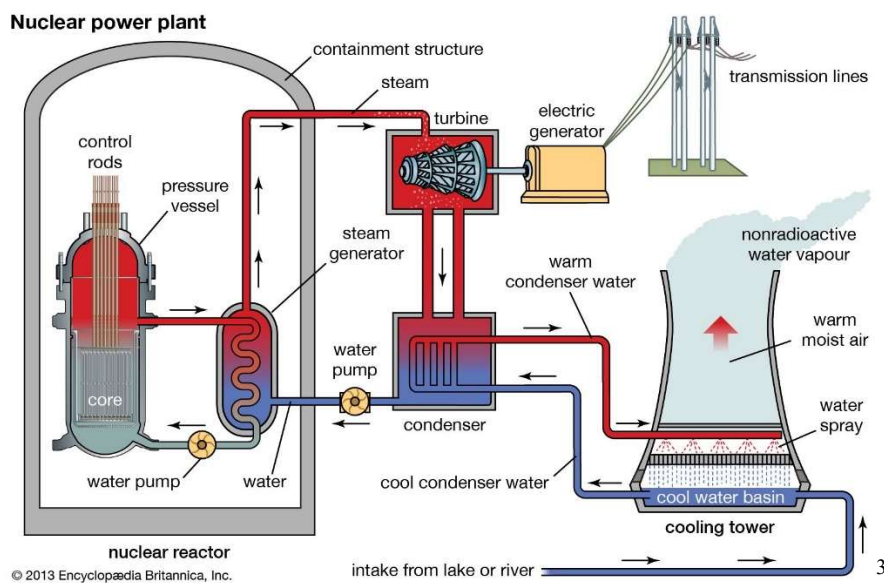
### Nuclear Reactors:

Nuclear power plants generate electricity by using nuclear reactions to heat water into steam, which then drives a turbine to generate electricity. The core of a nuclear reactor is where the nuclear reaction takes place. Inside the reactor core, uranium atoms undergo a process called

fission, where they split into two smaller atoms and release enormous amounts of energy in the form of heat which is later converted into kinetic energy and then converted into electrical energy by the use turbines.

The fission process is carefully controlled in a nuclear power plant to prevent accidents and ensure safe and efficient electricity generation. The core of the reactor is surrounded by a thick layer of concrete and steel, which serves as a radiation shield to protect workers and the surrounding environment from radiation exposure.<sup>2</sup>

The heat produced by the nuclear reaction is transferred to a coolant, which is usually water, and the resulting steam drives a turbine connected to a generator. The generator produces electricity, which is then sent to the electrical grid for distribution to homes and businesses. This process is visualized in the figure below (Figure 2).



There are different types of nuclear reactors, but the most common type used in commercial power plants is the pressurized water reactor (PWR). In a PWR, the coolant is kept under

<sup>2</sup> <https://chat.openai.com>

<sup>3</sup> Figure 2: <https://www.britannica.com/technology/nuclear-power>

pressure to prevent it from boiling and the heat produced by the nuclear reaction is transferred to a secondary loop of water, which then produces steam to drive the turbine.

One of the advantages of nuclear power is that it produces electricity without emitting greenhouse gases such as carbon dioxide, which contribute to climate change. However, the radioactive waste generated by nuclear power plants must be carefully managed to prevent harm to human health and the environment. Additionally, there are concerns about the safety of nuclear power plants and the risk of accidents or nuclear weapon proliferation.

In recent years, advances in nuclear technology have led to the development of new types of reactors, such as small modular reactors (SMRs) and molten salt reactors (MSRs), which are touted as being safer, more efficient, and more cost-effective than traditional nuclear reactors.

### [Akkuyu Nuclear Project:](#)

The Akkuyu nuclear power plant is a controversial project that has been under development in Türkiye since 2010. The project is a joint venture between Russia's state-owned nuclear energy company, Rosatom, and Türkiye's state-owned electricity company, EUAS. The plant is in the Akkuyu district of the southern province of Mersin and is designed to have a total capacity of 4800 megawatts, making it the first ever nuclear power plant in the country since its founding.

Construction of the Akkuyu nuclear power plant began in 2015, and the first unit is scheduled to start operating in 2023, with the other three units to follow in the subsequent years. The project has been controversial since its inception, with concerns about safety, environmental impact, and potential geopolitical implications. Some critics have pointed out that the Akkuyu project has been mired in controversy from the beginning, with allegations of corruption and concerns about the safety of the Russian-built VVER reactors that will be used in the project.

Furthermore, after the earthquakes in Mersin people are further questioning whether Akkuyu is good place for a nuclear power plant.

The Turkish government has defended the project, citing the need for a more diverse and reliable energy mix to meet the country's growing energy demands. The government has also emphasized the potential economic benefits of the project, including job creation and increased investment in the region.

Despite these claims, opposition to the Akkuyu project has remained strong. Environmentalists and anti-nuclear activists have raised concerns about the potential impact on the surrounding ecosystem and the risk of a nuclear accident. Additionally, there have been concerns about the plant's location in an earthquake-prone region, with critics arguing that the plant could be vulnerable to seismic activity citing the events of 2012 earthquake in Iran which devastated damaged their nuclear power plant<sup>4</sup>. This was further proved by earthquakes of that happened in Türkiye in 2023 showing the unreliability of Türkiye's geography for Nuclear Power Plant construction.

Furthermore, there are concerns about the long-term waste management of the nuclear reactors, as nuclear waste can remain radioactive for thousands of years. The Turkish government has yet to announce any concrete plans for dealing with the waste produced by the Akkuyu plant.

In summary, the Akkuyu nuclear power plant is a controversial project that has been under development in Türkiye for over a decade. The project has been subject to criticism and opposition from various groups, including environmentalists, anti-nuclear activists, and political opponents. While the Turkish government has defended the project as necessary for

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<sup>4</sup> [https://en.wikipedia.org/wiki/List\\_of\\_earthquakes\\_in\\_2012](https://en.wikipedia.org/wiki/List_of_earthquakes_in_2012)

meeting the country's energy needs, concerns about safety, environmental concerns it still not apparent whether the construction of this power plant will achieve Türkiye's ambitions.

### Türkiye's CO<sub>2</sub> Emissions

Türkiye is one of the largest greenhouse gas emitters in Europe and is one of the top twenty emitters worldwide. According to data from the Global Carbon Atlas, Türkiye emitted 373.9 million metric tons of carbon dioxide (CO<sub>2</sub>) in 2020. This is a significant increase from the previous year, where Türkiye emitted 364.3 million metric tons of CO<sub>2</sub>.

The energy sector is the primary source of greenhouse gas emissions in Türkiye, accounting for 70% of the country's total emissions. Most of the Türkiye's electricity generation comes from fossil fuels, particularly natural gas and coal. As Türkiye's population and economy continue to grow, the demand for energy is also increasing, leading to a corresponding increase in CO<sub>2</sub> emissions.

To address this issue, the Turkish government has set a goal to reduce the country's greenhouse gas emissions by 21% by 2030. The government has implemented a number of policies and initiatives to achieve this goal, including increasing the use of renewable energy sources, promoting energy efficiency, and investing in clean energy technologies.

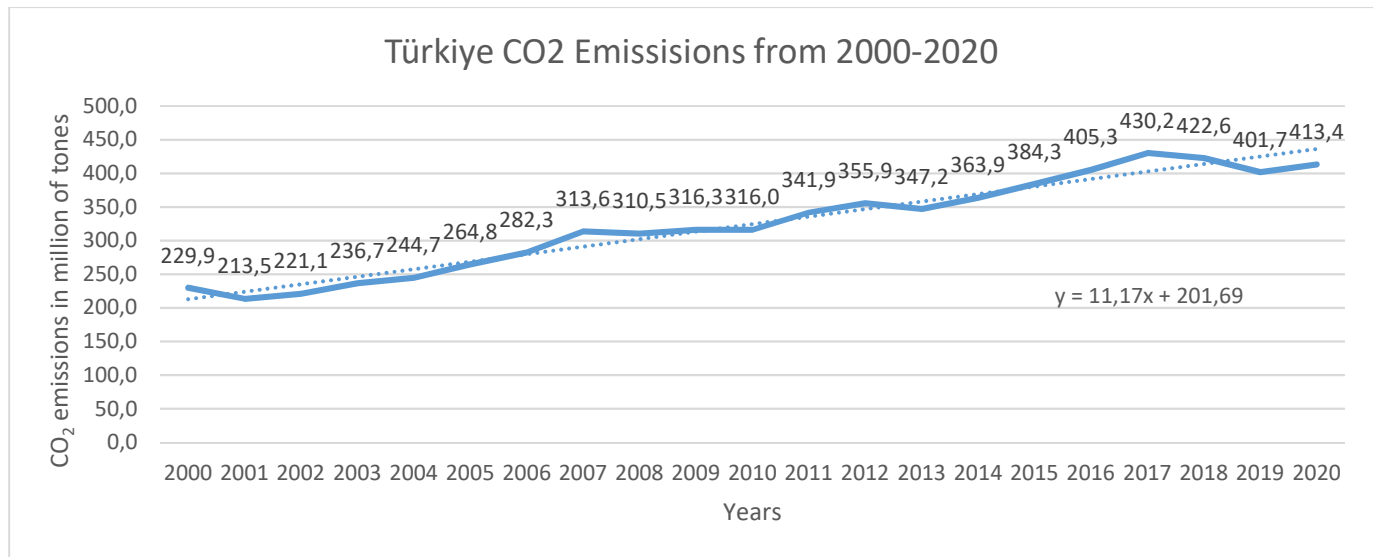


## Methodology:

1. **Research design:** The study will adopt a quantitative research design that will involve the collection and analysis of data on Türkiye's carbon emissions from 2000 to 2020 and the country's energy production. The study will use a linear trend analysis to examine the general trends in CO<sub>2</sub> emissions in Türkiye over the past two decades. The study will also compare the energy production from non-renewable resources with the energy production from the Akkuyu Nuclear Power Plant to determine the extent to which the activation of the plant would affect CO<sub>2</sub> emissions in Türkiye.
2. **Data collection:** The study will collect data from various sources, including government reports, academic articles, and reputable online databases. By using these reputable databases the reliability of the investigation will be increased further. The data collected will cover the period from 2000 to 2020.
3. **Data analysis:** The data collected will be analyzed using a linear trend analysis to examine the general trends in CO<sub>2</sub> emissions in Türkiye over the past two decades. The analysis will also involve comparing the energy production from non-renewable resources with the energy production from the Akkuyu Nuclear Power Plant to determine the extent to which the activation of the plant would affect CO<sub>2</sub> emissions in Türkiye.
4. **Sampling:** The study will use a purposive sampling technique to select relevant data sources. The data will be selected based on their relevance to the study's research questions.

## Data Collection:

### Türkiye's CO<sub>2</sub> Emission from 2000 to 2020:



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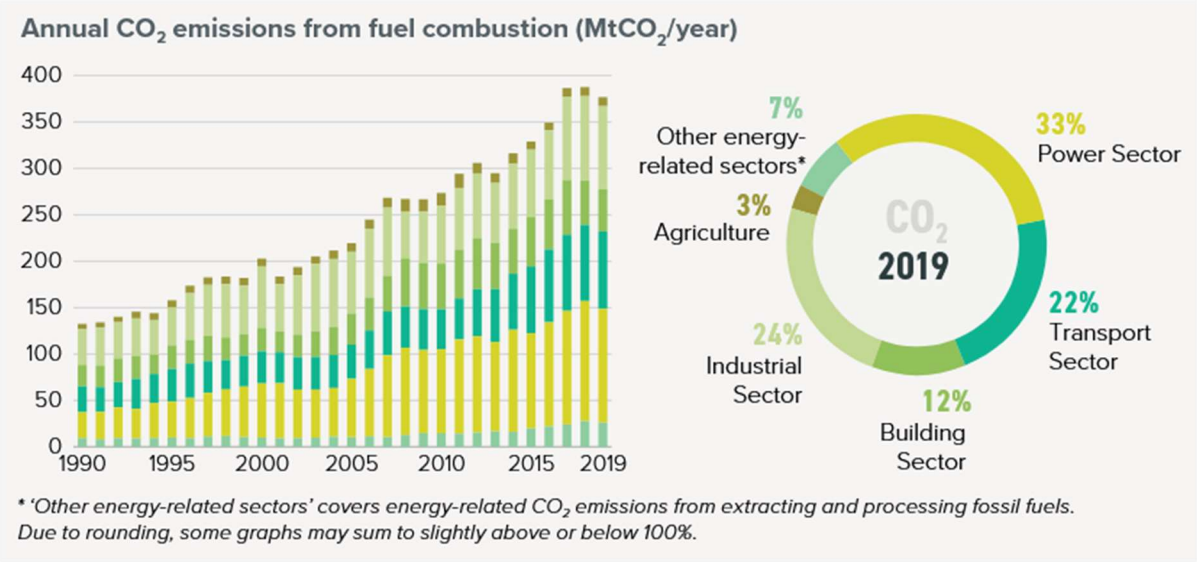
In this graph we see that Türkiye' CO<sub>2</sub> are rising constantly and even though Türkiye signed The Paris Climate which stated that the signatories of this agreement promised to limit their CO<sub>2</sub> and other greenhouse emissions however Türkiye has not been able to oblige with this treaty as seen in this graph, however Türkiye is steadily investing more energy sources that don't require Fossil Fuels as stated by a report from IEA. "Türkiye has made solid progress in recent years in improving the security and diversity of its energy supplies... Türkiye's renewable capacity grew by 50% over the last five years. In 2019, Türkiye had the fifth highest level of new renewable capacity additions in Europe and the 15th highest in the world. The IEA report notes that Türkiye can achieve even stronger growth in renewables – especially solar, wind and geothermal – given its considerable resource endowment"<sup>6</sup>

<sup>5</sup> <https://data.tuik.gov.tr/Bulten/Index?p=Sera-Gazi-Emisyon-Istatistikleri-1990-2020-45862>

<sup>6</sup> <https://www.iea.org/news/Türkiye-s-success-in-renewables-is-helping-diversify-its-energy-mix-and-increase-its-energy-security>

These investments help bring down the CO<sub>2</sub> emissions of Türkiye because Türkiye’s main emissions come from the energy sector in 2019, energy sector was responsible for 33% of Türkiye’s CO<sub>2</sub> emissions <sup>7</sup>as seen in a report from 2020.

**Energy-related CO<sub>2</sub> emissions by sector**



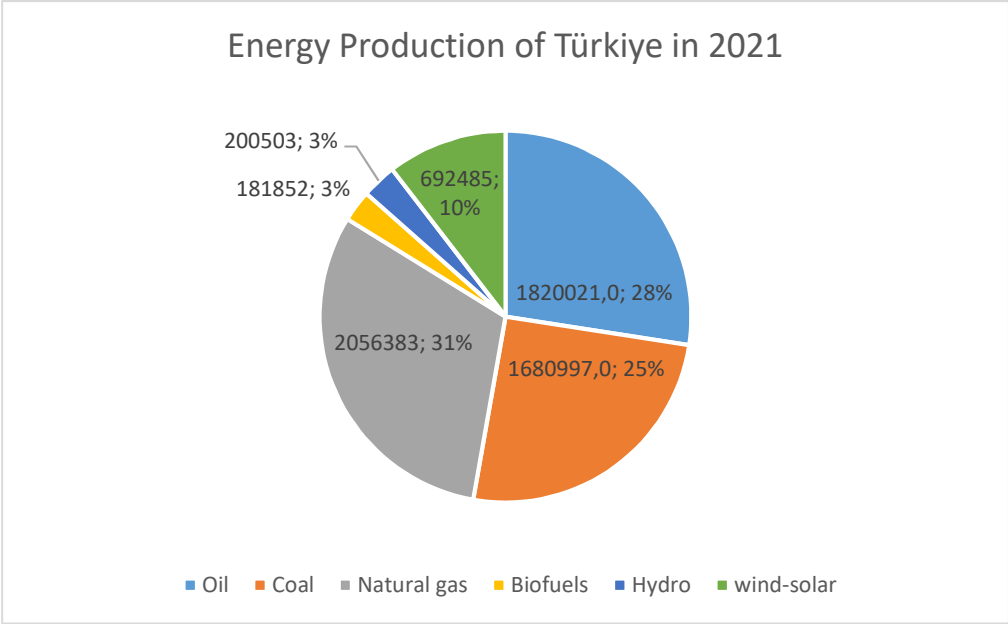
**Türkiye Energy Production**

This reliance on fossil fuels not only poses a threat to the country's energy security, but also contributes significantly to global greenhouse gas emissions, as these sources are highly polluting.

Despite some efforts to diversify its energy mix, Türkiye continues to rely heavily on non-renewable sources such as coal, oil, and natural gas for electricity production. In fact, according to the International Energy Agency (IEA), in 2019, 31% of Türkiye's energy production came from natural gas, 25% from coal, 28% from oil, 10% from wind and solar, and the remaining 6% from other sources.

<sup>7</sup> <https://www.climate-transparency.org/wp-content/uploads/2020/11/Türkiye-CT-2020-WEB.pdf>

This heavy reliance on non-renewable sources has made Türkiye one of the largest carbon emitters in the world, with its CO2 emissions reaching 373.9 million metric tons in 2020 alone. This poses a major challenge for Türkiye, as it is under increasing pressure to reduce its carbon emissions in order to meet its climate change commitments under the Paris Agreement.



According to this graph it seen that 84% of Türkiye’s electrical production came from Fossil Fuels hence it shows how much Türkiye is dependent on non-renewable energy resources.

### Akkuyu Nuclear Power Plant Energy Production

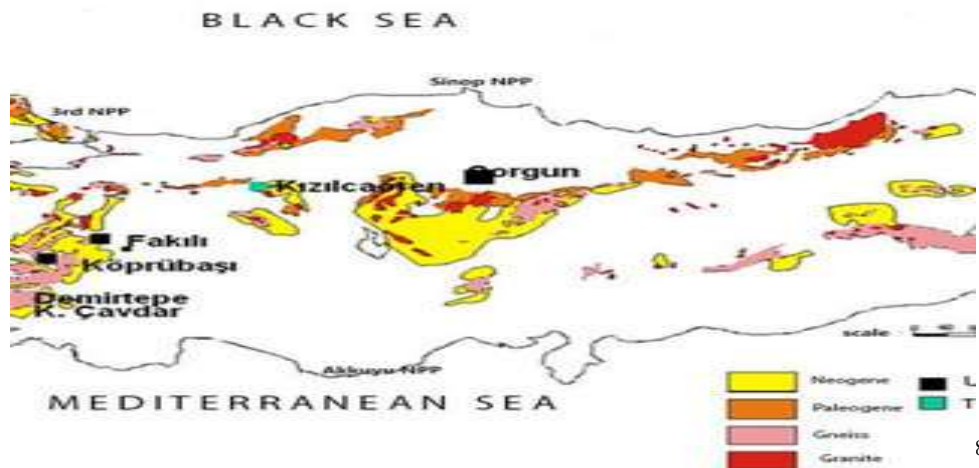
Türkiye aimed to generate 10% of its total energy consumption through nuclear power by constructing two nuclear reactors in 2010. However, the project faced many setbacks, including financing and location issues. Türkiye's energy consumption increased rapidly, making the goal impossible, and the Akkuyu nuclear power plant, the first nuclear power plant in Türkiye, would only cover 2.3% of the country's energy needs. The Akkuyu nuclear power plant project is being implemented in collaboration with Russia and will have four VVER-1200 nuclear reactors, each with a capacity of 1200 MW. The construction of the plant

has been divided into phases, and the first unit is expected to be operational by 2023, but its completion remains uncertain given the project's history of delays and setbacks.

### The cost of running a nuclear plant

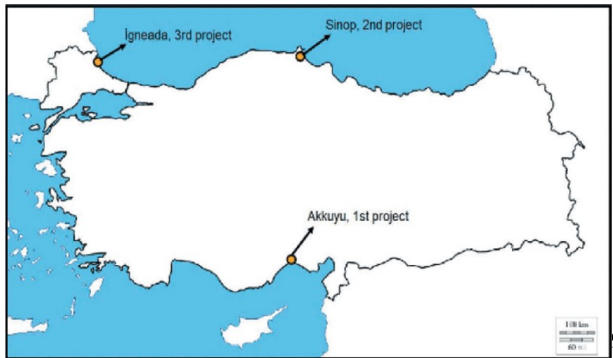
Running a nuclear reactor requires a constant supply of uranium to sustain the nuclear reaction. Unfortunately, Türkiye does not have a significant domestic source of uranium, and thus it must rely on imports or exploit its domestic uranium mines located in Central and Western Anatolia. The Akkuyu nuclear power plant, which is in the south of Türkiye, will depend on these domestic mines for its uranium supply. However, transporting the uranium from Anatolia to Akkuyu poses a logistical challenge that must be overcome. The uranium will have to be transported using trucks or trains, which will increase carbon emissions. As such, the activation of the Akkuyu nuclear power plant may contribute indirectly to the emission of CO<sub>2</sub>. (Figure 3 and figure 4)

Figure 3: Turkish Uranium Reserves represented in black squares.



<sup>8</sup> Figure 3:  
[https://www.researchgate.net/publication/312040305\\_Uranium\\_and\\_thorium\\_production\\_projections\\_in\\_Türkiye](https://www.researchgate.net/publication/312040305_Uranium_and_thorium_production_projections_in_Türkiye)

Figure 4: The map of planned nuclear reactors that would be built in Türkiye.



The transportation of uranium from domestic mines to the Akkuyu nuclear power plant adds another layer of complexity to the logistical challenges facing Türkiye's energy sector. The transportation of nuclear fuel is a highly regulated and carefully monitored process that requires significant investment in infrastructure and transportation equipment. The cost of transportation along with the environmental impact of increased carbon emissions, must be factored into the overall cost of running a nuclear power plant. Moreover, the Akkuyu nuclear power plant has faced numerous setbacks and delays, which may further increase the cost of transporting uranium to the plant site. Despite the challenges Türkiye sees nuclear energy to reduce its dependence on fossil fuels and achieve energy security. However, the sustainability of nuclear energy must be evaluated based on the environmental, social, and economic impacts of the entire nuclear fuel cycle. The cost of running a nuclear power plant, including the cost of uranium transportation, must be weighed against the benefits of reducing CO<sub>2</sub> emissions and achieving energy security. Ultimately, the Akkuyu nuclear power plant must be evaluated based on its overall impact on Türkiye's energy sector and its contribution to the country's energy transition goals.

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<sup>9</sup> Figure 4: [https://www.researchgate.net/figure/Türkiyes-nuclear-power-plants-a-Locations-in-the-country-map-b-Technical-properties\\_fig7\\_332099832](https://www.researchgate.net/figure/Türkiyes-nuclear-power-plants-a-Locations-in-the-country-map-b-Technical-properties_fig7_332099832)

## Comparing Nuclear Energy Production with Renewable Resources

While nuclear energy is generally considered to be less damaging to the environment than fossil fuels, it is still not as environmentally friendly as renewable energy sources such as solar, wind, and hydropower. The use of renewable resources is still in its early stages, and the technologies are not yet optimized, making them expensive and often providing limited results. On the other hand, nuclear power can produce enormous amounts of energy, although it is also quite expensive. To compare the environmental impact and cost-effectiveness of nuclear power to other energy sources, a formula will be used. The formula will consider the cost of producing each type of energy, and the amount of energy produced. This will allow for a comprehensive analysis of the environmental and economic impact of nuclear power, as well as other energy sources.

$$\text{cost coefficient} = \frac{\text{energy yielded per unit (MW)}}{\text{cost per unit}}$$

### Solar Power:

Solar power is often hailed as the poster child of renewable energy sources due to its potential to provide clean, renewable energy. They convert energy of the photons to electrical energy. However, the initial investment costs of installing solar panels are quite high, and the energy yield they provide is relatively low when compared to the costs. This means that although solar energy may be environmentally friendly, it may not always be the most economically feasible option for countries like Türkiye that need to meet their growing energy demands in a cost-effective manner. To study this, I am going to take the biggest of solar farm Türkiye which is the Karapınar solar power plant. This farm has the capacity of generating 628 MW in 2022<sup>10</sup> and the cost of these 1 billion dollars<sup>11</sup>.

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<sup>10</sup> <https://www.aa.com.tr/tr/ekonomi/karapinar-ges-ile-turkiyede-elektrik-uretiminde-gunes-enerjisinin-payi-yuzde-20ye-cikacak/2560636>

<sup>11</sup> <https://www.haberturk.com/gunes-enerjisinde-1-milyar-dolarlik-santralin-lisans-tamam-2793326-ekonomi>

$$\frac{628}{1000000000} = 0.000000628$$

### Nuclear Power:

Nuclear Power plants vary a lot depending on its reactor hence for this investigation we will use the VVER-1200 nuclear reactor. VVER-1200 nuclear reactors generate 1200 MW of power and since the Akkuyu nuclear plant has four of these reactors it can be estimated that the energy production potential would be 4800 MW. This power plant was projected to cost 20 billion to construct.<sup>12</sup>Hence after making these assumptions, we apply our formula we get:

$$\frac{4800}{2 \times 10^{10}} = 0.00000024$$

### Wind Power:

Wind power uses the natural movement of winds to generate electricity, capturing the kinetic energy of the wind and converting that into electrical energy using a generator. For maximum efficiency wind turbines are placed in on top of hills without obstacles preventing the flow air into the turbines. Also, these turbines are placed in areas with a high wind speed to capture more energy. The biggest wind turbine farm in Türkiye is the Soma Wind Turbine Plant. This plant can generate 228.1 MW of energy with a construction cost of 380 million dollars.

<sup>13</sup>Which brings the coefficient to 0,000006.

### Hydropower

Hydropower is a form of renewable energy that harnesses the power of falling or moving water to generate electricity. It's the oldest and most widely used form of renewable energy. The basic principle behind hydropower is to use the force of moving water to spin a turbine,

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<sup>12</sup> <https://www.aa.com.tr/en/energy/nuclear/russia-transferring-15b-for-turkiye-for-akkuyu-npp/35933>

<sup>13</sup> <https://www.polat.com/enerji/polat-enerji/soma-res>



which drives a generator to produce electricity. This can be achieved in several ways, such as: Building dams, run-of-river, and pumped storage. However, for this extended essay I will solely focus on a dam particularly the Ataturk Dam. The Ataturk Dam has a energy generation capacity of 2400 MW <sup>14</sup>with a cost 3.56 billion dollars<sup>15</sup>. With this information it is calculated that the cost coefficient of the dam is 0.000000658.

To visualize

Nuclear Energy	0.00000024	4800MW
Hydropower	0.000000658	2400MW
Solar Power	0.000000628	628MW
Wind Power	0.000006	228.1MW

When looking at the cost coefficients of these energy sources it is clearly seen that wind power is the most cost effective of each of them and nuclear energy is the least of cost-effective of each of them however it should be stated that nuclear energy provides more stable energy than each of these renewable energy resources since it is not affected by the environment, weather conditions and day-night cycles. In case of the renewables, it is seen that in terms of cost-effectiveness the placements of these resources would be Wind power>Hydropower>Solar Power. In case of energy production however nuclear energy seems to be best option as it provides the biggest energy out of the energy resources and the least energy is given by wind power. So therefore, it can be said that if the country is in need for high energy, nuclear energy is the best option however if the country is looking for a cheap alternative energy resources wind power is the best option.

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<sup>14</sup> <https://www.suski.gov.tr/icerik/39/75/ataturk-baraji>

<sup>15</sup> <https://www.insaatmaliyetim.com/post/ataturk-baraji/>

## The environmental impacts of activation the Akkuyu Nuclear Power Plant:

Nuclear Power Plants, by nature don't emit any of the greenhouse gasses we see in non-renewable energy resources such as CO<sub>2</sub>, NO<sub>x</sub> and many more gasses. Instead, nuclear power plants have different environmental impacts. The most notable is the nuclear waste of the nuclear power plant. After the fission occurs inside the nuclear reactor, very dangerous radioactive materials are created such as strontium-90 and cesium-137. If these materials are left unattended and are disposed into the environment; they cause catastrophic damage to environment. As the radioactive materials decay into other elements, they release energy in form radiation which causes harms the environment by harming the DNA and cell structures of living organisms around it. However, this is all preventable by using proper storage and disposal methods. Such as burying the radioactive material underground, surrounded by lead and other protective elements to prevent radiation leakage.

## Conclusion:

In conclusion in this extended essay, I have found many advantages and disadvantages of the activation of Akkuyu Nuclear Power Plant and found alternatives that might have been better. Advantages of activation of the plant included reduction in overall CO<sub>2</sub> emissions. Since 33% of Türkiye's CO<sub>2</sub> emissions come from the energy sector reducing the CO<sub>2</sub> emitted from this sector would dramatically decrease Türkiye's CO<sub>2</sub> emissions and make them more compliant with the 2015 Paris Climate Agreement. By activation the Akkuyu Nuclear Power Plant Türkiye would decrease its reliance on fossil fuels, as discussed 85% of Türkiye's energy is produced via combination of coal, oil and natural gas. If the power plant was able to open in 2012 it would have sufficed 10% of Türkiye's electrical needs however in 2022 that number has dropped to 2.3% because of the increased electrical need in the country, therefore a nuclear power plant that contains 4\*VVER-1200 reactors would not suffice the original vision %10. However according to the original plan 3 nuclear power plants were envisioned with

same characteristics however due to many delays of the construction in Akkuyu the original vision never came to life. Furthermore the construction of the Akkuyu nuclear power plant costed about 20 billion which is a huge number, however this amount was not actually fully covered by the Turkish government but covered by the Russian company Rosatom which has %99.2 stake in the project however in 2019 it sold 49% of it shares to Turkish companies<sup>16</sup> however the Russian company still holds the majority of the stakes and effectively owns the operation which could make Türkiye still dependent on foreign imports just in another way. Another problem with construction of the nuclear power plant is that it stills requires fuel if it becomes operational as discussed in the section “the cost of running a nuclear plant”, the fuels, although not harmful on their own and when used still require transportation and because the transportation system is heavily reliant on fossil fuels in Türkiye it would increase the CO<sub>2</sub> emissions of Türkiye. Another problem for the power plant is its sheer cost as discussed although nuclear power plants yield great energies, they are very expensive to build, which is when investigated turns renewable energy sources are cheaper at it although with the cost of not generating such enormous powers. If Türkiye decided to go towards a more cost-effective way wind turbines are the best option as they yield great power for low cost, however although a bit more expensive dams are great at powering the grid of Türkiye as investigated Dam yields electrical generation half of a nuclear plant with 3/20 the cost of the nuclear power plant. All in all, although the activation of Akkuyu might yield some benefits there much better alternatives available to Türkiye.

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<sup>16</sup> <https://www.rferl.org/a/russia-rosatom-sells-49-percent-stake-akkuyu-nuclear-project-Türkiye-/28565766.html>

## Evaluation

I believe that my extended essay, which focused on the potential impact of the Akkuyu nuclear power plant on carbon emissions in Türkiye, was well-researched and well-written. I made use of various graphs to better illustrate the potential impact of the power plant on carbon emissions. I also tried to present a range of theoretical analysis and practical examples to support my research question.

One of the strengths of my essay was the use of graphs to present data in a more accessible and visual way. I believe that this helped me to better illustrate the potential impact of the Akkuyu nuclear power plant on carbon emissions. Additionally, my essay was well-structured and well-written, making it engaging and easy to follow.

However, there were also several weaknesses in my essay that I would like to acknowledge.

One of the main weaknesses was the fact that it was impossible to accurately calculate the true cost of the nuclear power plant, as it is still under construction. Additionally, when investigating the data for nuclear power plant, I did not include maintenance costs since the plant was not yet online, and for some other sources, the data on maintenance costs was not available. Finally, although I touched on the CO<sub>2</sub> cost of transportation of the uranium, I did not calculate it in my analysis.

Despite these weaknesses, I believe that my essay provided a valuable contribution to the ongoing debate surrounding the Akkuyu nuclear power plant and its potential impact on carbon emissions in Türkiye. I presented a range of data and models to provide a nuanced understanding of the complex relationship between energy production and carbon emissions. However, in future research, it would be beneficial to include more analysis of the limitations and uncertainties of the research and to include a more complete analysis of the costs of nuclear power plants, including transportation and maintenance.

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