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Double Energy Input IV, a proposal for a novel source of energy.

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ABSTRACT

In order to slow down adverse global anthropogenic effects such as global climate change and the destruction of ecosystems, alternative energy sources that are clean, renewable, and efficient are needed to replace the existing energy sources.

Double Energy Input is a novel invention that gathers two renewable energy resources: hydro-electric and geothermal. This invention utilises the sea as a coolant, the geothermal heat to heat pressurised water and another chamber to run the steam power plant.

This model provides an alternative means for producing clean and renewable energy with two natural energy sources, heat and pressure.

1. INTRODUCTION.

1.1 Greenhouses gases effect on our planet

According to the statement of the Joint Science Academies (2005), greenhouse gases positively affect life on our planet. Without them, the Earth would have temperatures 30 degrees centigrade below the current temperatures. But the problem is with human activities that have resulted in a large concentration of greenhouse gases in our atmosphere, with an increase from 280 ppm in 1750 to more than 375 ppm today. The temperature of the Earth increased by about 0.6 degrees centigrade in the twentieth century.

The Intergovernmental Panel on Climate Change (IPCC) estimates that global surface temperatures will increase between 1.4 degrees centigrade and 5.8 degrees centigrade above 1990 levels by the end of this century.

Historically, the energy requirements of humankind have increased sharply from time to time, and the rate of this growth is also growing. Power demand tremendously increased with the advent of industrialisation, and fossil fuels relatively quickly displaced traditional energy sources. But the increase in demand did not stop with the industrial revolution; the aerospace age requires more and more energy. The standard of living of every country is improving, and more power is needed to fulfil the requirements of all citizens.

Increasing production requires new ideas for developing more renewable energy production. Solar and wind power production are upward trending technologies, and there is essential growth in developing such renewable sources of energy. Renewables are taking more importance in producing energy, and clean energy is required to fight the problem of global warming, pollution, and the destruction of ecosystems.

1.2 Comparison of greenhouse gas production by source

Energy production is essential for humankind. The way of living requires a high energy output, and the demand is increasing over time. More utilities, industrial production, and food are needed with increasing population. According to Vaclav (2017), by 2018, more than 80% of energy production was from non-renewable resources.

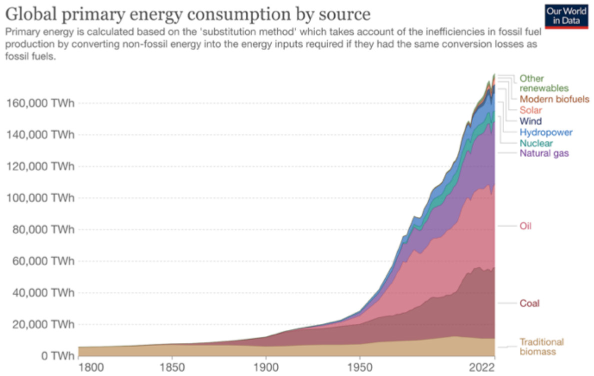

Figure 1: "Energy consumption by source, World" According to the Energy Institute Statistical Review of World Energy (2023) and Vaclav Smil (2017), this chart shows the proportion of the sources of energy.

In Figure 1, we can appreciate the gradual reduction in oil and coal use. But the rate of decline in the use of fossil fuels is slow, and the demand for more energy is growing at a very fast pace. New sustainable energy sources are required to compete against the infrastructure and versatility of coal and oil.

The need for sustainable energy has become increasingly critical due to several interconnected reasons. Firstly, sustainable energy sources, such as renewable energy, help mitigate the adverse effects of climate change. Fossil fuel-based energy generation is a major contributor to greenhouse gas emissions, which trap heat in the Earth's atmosphere and lead to global warming. By transitioning to sustainable energy sources like solar, wind, hydro, and geothermal power, we can significantly reduce carbon dioxide emissions and limit the impact of climate change. This is crucial for preserving the health of our planet and ensuring a sustainable future for generations to come.

Secondly, sustainable energy promotes energy security and independence. Many countries heavily rely on imported fossil fuels, which can be subject to price volatility and geopolitical tensions. By diversifying our energy sources and investing in sustainable alternatives, we can reduce our dependence on finite and often unreliable fossil fuel reserves. Sustainable energy technologies are often decentralised and can be harnessed locally, providing communities with greater control over their energy supply and reducing vulnerability to disruptions in global energy markets.

Furthermore, according to Nassar et al. 2019, sustainable energy offers numerous economic benefits. The renewable energy sector has experienced significant growth in recent years, creating jobs and stimulating economic development. Investing in sustainable energy technologies and infrastructure can drive innovation, attract investments, and foster the growth of a green economy. Additionally, sustainable energy sources have the potential to provide affordable and accessible energy to underserved communities, improving energy equity and reducing energy poverty.

In conclusion, the need for sustainable energy is driven by the urgency to combat climate change, enhance energy security, and promote economic growth. By transitioning to sustainable energy sources, we can mitigate greenhouse gas emissions, reduce our reliance on fossil fuels, and create a more resilient and prosperous future. Embracing sustainable energy is not only an environmental imperative but also a pathway towards a more sustainable, equitable, and prosperous society.

2. DEI PREVIOUS MODELS AND CHALLENGES.

2.1 DEI previous models.

The previous models (DEI I, II and III) combined Hydro-Electrical and Geothermal electricity production, using the sea as a reservoir and the geothermal heat located at the bottom of a vast pit as a source of thermal energy. The difference between the level of the sea and the bottom of the pit allows this model to produce energy from the kinetic energy of the reservoir and the interaction with gravity.

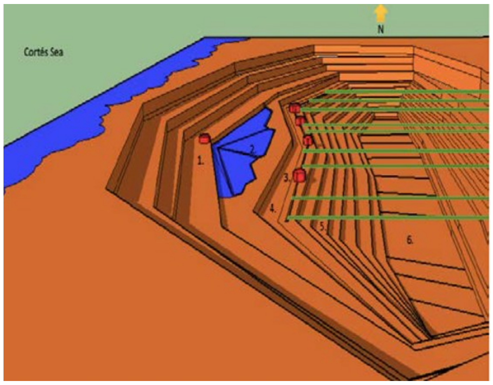

Figure 2: DEI II, Open pit model, was proposed to produce energy using the sea, gravity and geothermal energy.

2.2 Challenges with the previous DEI models.

Previous DEI models proposed a new source of energy that combines Hydro-Electrical and Geothermal electricity production, using the sea as a reservoir and the geothermal heat located at the bottom of a vast pit as a thermal energy source.

The difference between the level of the sea and the bottom of the pit allows this model to produce energy from the kinetic energy of the reservoir and the interaction with gravity.

A significant challenge in drilling and digging is the high-pressure environment encountered at greater depths. As drilling goes deeper, the pressure exerted by the surrounding rock formations and fluids increases significantly. This can lead to well-control issues, blowouts, and other safety hazards. To mitigate these risks, drilling companies employ advanced well control systems, including blowout preventers and mud circulation systems. These systems help maintain pressure balance and prevent uncontrolled releases of oil, gas, or other fluids from the wellbore.

Digging and drilling are costly, according to Ghanizadeh Zarghami et al. (2019); the cheapest way to dig a pit for the previous models is open-cast mining. One of the primary challenges in open-cast mining is the significant environmental impact it can have on the surrounding ecosystem. Removing large quantities of soil and rock can result in habitat destruction, soil erosion, and the disruption of natural drainage patterns. Additionally, according to the Environmental Law Alliance (2019), exposure of water to minerals and ores during mining operations can lead to the release of harmful chemicals and heavy metals into the environment, polluting nearby water bodies and affecting the health of local flora and fauna.

Also, the pit's dimensions for the previous model are larger and deeper than the largest mining pit ever constructed. Another challenge was the risk of having groundwater leaks. The previous models were not ideal for a landscape like those we have in New Zealand. The first models were designed for countries like Mexico and areas like the Sonora desert. Therefore, the investment was huge, and the time for constructing the pit was too long.

2.3 Conclusions of the previous studies.

For any energy model, the first step is to prove the science behind the project; after reaching the demonstration of the proposal.

The second step is to determine the costs, the ROI (return on the investment) and the applicability in considering the environment. Only after these studies can we figure out if our model can be presented as a project that helps our environment or if it is only an academic improvement.

The previous models were scientifically feasible, but finding the ideal conditions required and building the required infrastructure to achieve the goal of the model was extremely difficult, and the risk involved in the operation was high.

3. DEI IV, FINAL STAGE MODEL.

3.1. Evolution of the DEI model, working with natural pressure and heat.

The evolution of the previous models brought me the idea to pick the natural pressure and natural heat and use them in another way rather than hydroelectric and geothermal power plants. We found that we can use the pressure of the bottom of the sea without building a gigantic infrastructure, and we can deal with the natural pressure allocated at the bottom of the sea and the heat that we expect to reach from the collision of the tectonic plates under the sea.

3.1.1 Water column natural pressure from the bottom of the sea.

The pressure at 2000 meters (or 2 kilometres) below sea level can be calculated using hydrostatic pressure, which is the pressure exerted by a fluid due to the weight of the overlying column of the fluid. The pressure increases with depth due to the increasing weight of the water above.

For every 10 meters of depth in seawater, the pressure increases by approximately 1 atmosphere (atm) or 101,325 pascals (Pa). Therefore, at 2000 meters below sea level, the pressure would be about 200 atmospheres (atm) or 20.2 megapascals (MPa). This is equivalent to approximately 2940 pounds per square inch (psi) or 206.8 times atmospheric pressure at sea level.

It's important to note that this calculation assumes a standard average density of seawater and does not account for other factors such as temperature, salinity, or variations in water density. Additionally, the pressure at any given depth can vary depending on the specific location and conditions of the underwater environment. Still, we can assume we will have this amount of pressure at a depth of 2000 metres.

3.1.2 Geothermal heat from the bottom of the surface.

On the other hand, we have the natural resource of geothermal heat. The Earth's crust is cold on the surface, but it is well known that the deeper we go, the higher the temperatures we reach.

Geothermal gradient refers to the rate of increase in temperature with increasing depth within the Earth's crust. It measures how the temperature changes as one moves deeper into the Earth. The geothermal gradient is typically expressed in degrees Celsius per kilometre (°C/km) or degrees Fahrenheit per mile (°F/mi).

The geothermal gradient is influenced by various factors, including the Earth's internal heat flux, thermal conductivity of the rock, and the heat flow within the Earth's crust. Generally, the geothermal gradient is positive, meaning the temperature increases as you go deeper into the Earth. The rate of increase can vary depending on the specific geological conditions of a region.

The geothermal gradient is an important parameter in geothermal energy exploration and development. It helps determine the potential for harnessing geothermal heat for energy production. Higher geothermal gradients indicate the presence of greater heat sources, which can be utilised for geothermal power generation or direct-use applications such as heating and cooling.

3.1.3 Finding heat is complicated; high pressure is complicated to manipulate.

In the previous models of DEI, we figured out that the infrastructure required to obtain heat from the geothermal source and bring water to produce more energy is very expensive.

Finding geothermal heat in the tectonic plate joints presents several challenges due to the complex nature of the Earth's crust and the variability of geothermal resources. One of the primary challenges is the identification and characterisation of suitable locations for geothermal exploration. Tectonic plate intersections are areas where the Earth's crust is fractured, allowing for the movement of fluids and the potential for geothermal heat. However, these intersections are not evenly distributed, and their presence and characteristics can be difficult to determine accurately. Geologists and geophysicists employ various techniques, such as seismic surveys, magnetotelluric surveys, and gravity measurements, to map and analyse the subsurface structures and identify potential geothermal reservoirs.

Another challenge in finding geothermal heat in tectonic plate intersections is the depth and accessibility of the resources. Geothermal reservoirs are often located at significant depths, requiring drilling operations to reach them. Deep drilling can be technically challenging and expensive, especially in areas with complex geological formations. Additionally, the presence of high temperatures and pressures at depth can pose safety risks and increase wear and tear on drilling equipment. To overcome these challenges, drilling technologies and techniques, such as directional drilling and advanced wellbore design, are employed to reach the target reservoirs efficiently and safely.

Furthermore, the variability of geothermal resources within tectonic plate joints presents a challenge in accurately estimating the potential heat output. The productivity and temperature of geothermal reservoirs can vary significantly, even within a single tectonic plate intersection. This variability is influenced by factors such as the permeability of the rocks, the presence of fractures, and fluid characteristics. Geoscientists conduct detailed reservoir modelling and simulation studies to assess the potential heat output, incorporating data from exploration wells and geophysical surveys. This helps in understanding the reservoir characteristics and optimising the design and operation of geothermal power plants.

3.1.4 Looking for hotspots between the Australian and Pacific plates.

The geothermal gradient under the sea in the intersection area of the Australian and Pacific plates can vary depending on the specific location and geological characteristics. In general, the geothermal gradient in this region is influenced by tectonic activity and the presence of underwater volcanic systems. The Pacific Plate is known for its subduction zones, where one tectonic plate is forced beneath another, resulting in intense heat generation and volcanic activity. These subduction zones can contribute to a higher geothermal gradient under the sea in the joint area, indicating the potential for significant heat sources.

The Australian plate, on the other hand, is relatively stable and has less volcanic activity compared to the Pacific plate. As a result, the geothermal gradient under the sea in the intersection area of these plates may be lower compared to regions with more active tectonic processes. However, it is important to note that the specific characteristics of the underwater volcanic systems and the proximity to geothermal hotspots can influence the geothermal gradient in this region. Further exploration and research are necessary to accurately determine the geothermal gradient under the sea in the intersection area of the Australian and Pacific plates and assess the potential for geothermal energy extraction.

As this model is designed for the New Zealand landscape, we are looking for geothermal "hotspots"; the desired temperature to reach is close to or above 300 degrees Celsius. We think such hotspots can be found close to New Zealand, North Island, the northeast coast, and the Taupo Volcanic Zone.

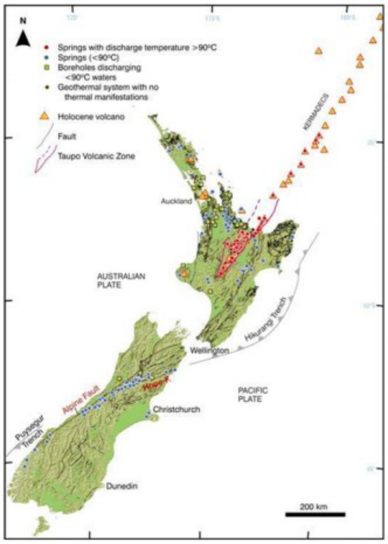

Figure 3: New Zealand geothermal gradient map. This map shows the higher geothermal gradient zones in New Zealand.

Once the hotspot is located, the model proposes to build some infrastructure that can allow us to have the chance to use the high pressure of the environment and the heat allocated underground.

3.2 Introduction of the model.

The first element that we are using in this model is the natural pressure located at the bottom of the sea; we are using the pressure of the water column from 1900 to 2000 metres; such pressures can be found in a place located about 1900 to 2000 metres under the sea, that results from a pressure of 20 MPa or 197.38 atm.

The second natural element is geothermal heat. Finding a hotspot of geothermal heat that exceeds 250 degrees Celsius is crucial.

The third natural element is the cold water allocated at 2000 metres under the sea. This element will cool down the system once the steam is used at the end of the process.

3.3 Model Description.

This model has several advantages over the previous models and less infrastructure is required. But this model will challenge the actual technology of directional drilling and the resistance of materials.

The two main elements of this invention are:

1. The Heat Chamber and its heating system.
2. The Steam power plant and cooling process.

3.3.1 Heat Chamber and the heating system.

This model is designed to use the underground heat and the pressure to obtain super-critical water and heat at a high pressure. That will allow us to heat water, transport it to another chamber with less pressure, and move a steam turbine.

Dealing with high pressure under the sea is a big challenge because the structures made by man have limits in their resistance.

The first component, the heating chamber, will have the same pressure from inside and from the outside, eliminating the differentiation of the pressure and having a system that will not produce pressure stress on the walls of the structure.

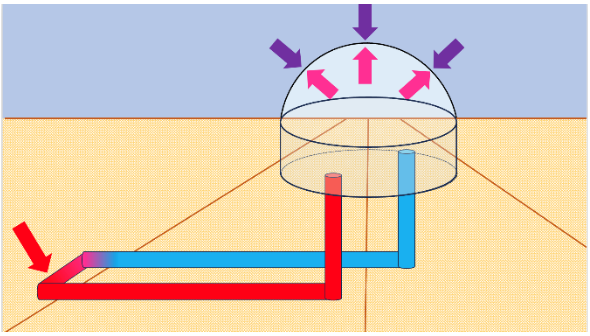

Figure 4: Heat chamber. This figure represents the first part of the model.

The first component is a structure with a peculiar shape that will allow us to have the top, high-pressure air and the bottom fresh and pure water that will be affected by a pressure of about 20 MPa. This amount of pressure will not be letting the water boil. We will be obtaining "supercharged water".

Isolating the heat from the heat chamber is crucial not to lose heat in the system. Pressurised air will help to improve the isolation, and the bottom of the chamber shall be allocated underground. Only the dome (filled with air) will be facing the sea.

The pressure inside the structure will be the same one we will find outside the structure. In Figure 4, the external pressure is represented with the purple arrows and the internal pressure is represented with the pink arrows. The red arrow represents the place where the "hotspot" will be found.

The model will take heat from the "geothermal hotspot" and transport the heat to the heat chamber. We are looking for heat resource of 2000 cubic metres at 350 degrees Celsius.

Having a reserve of 2000 cubic metres allows us to provide enough heat for the next stage of the power plant. High pressure will prevent the water from evaporating, and it will be heated, flowing through the system.

The pressurised air will allow us to isolate the chamber from the undersea cold water, and it will allow us to regulate the pressure from the system and protect it from external pressure. Otherwise, the maintenance of a prominent structure is challenging under such high-pressure conditions.

3.3.2 Steam cycle and cooling.

The other components shall be allocated in underground chambers, where they will be excluded from the undersea pressure. This construction of this kind of chamber is complex, requiring several safety steps.

Figure 5. is a modification of a typical pressurised water reactor; this modification changes the Nuclear Turbine for the Heat Chamber. The parts of the model with the blue background are allocated at the bottom of the sea, and the parts in the grey background are allocated in an internal chamber underground. This chamber will protect from excessive pressure and possible underground heat, so the components and the personnel shall be protected from the extreme environment.

Another change from the original model is the condenser and cooling water; it will be using seawater as a coolant, not a cooling tower.

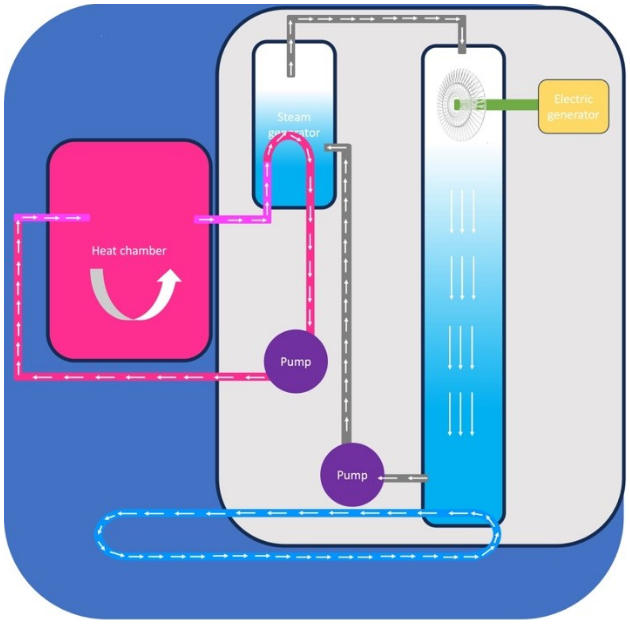

Figure 5. Electricity production diagram. This diagram is a modified pressured steam reactor.

The heat chamber will be connected to the chamber where the steam turbine is allocated. For a 1 GW turbine, it is common to have a steam flow rate of around 680 to 907 metric tons per hour. This estimate assumes a typical steam turbine efficiency of around 35-40%, which means that only a portion of the thermal energy in the steam is converted into mechanical work.

The steam turbine shall be allocated in a chamber that protects it from underwater pressure. So this model has a chamber allocated inside the ground and connected to the surface with a tunnel.

All the components connected to the exterior require special care for the isolation of the pressure and some safety measures in case of failure.

3.4 DEI IV Model in steps.

The following steps are proposed in this model.

a. Heating of the pressured water with geothermal heat underground around 300 Celsius.
b. Pumping the super-critical water into the steam generator.
c. Produce high-pressure steam (16 MPa at 250 degrees Celsius).
d. The steam will spin the steam turbine, and it will generate electricity with the electric generator.
e. The steam will be condensed and cooled with the seawater.
f. The model will have a loop for cooling and heating the water and steam.

3.5. Considerations about this model.

This model seems to be cheaper than the previous DEI models. Also, it seems to have a lesser environmental impact on the ecosystem.

Once the underground chamber is built, it will be accessible to the personnel who will be operating the steam power plant.

Given maintenance of the heat chamber is complex, considering the extreme pressure at the bottom of the sea; therefore, the elements of the Heat Chamber must be simple and easy to fix or change.

Finding hot spots close to 300 Celsius is a challenge, but it is possible to find such hot spots because we are working at a 2000 metres depth.

Working with extreme conditions, studying material resistance and engineering and structural costs is crucial.

Directional drilling will be required to construct the chamber that will protect the steam power plant components.

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The safety conditions of the personnel shall be assured. Automated processes are crucial to have less personnel in the chambers.

Further studies are crucial to calculate the heat that this model will send to the ocean floor. And if this heat could harm the ecosystem close to the shore.

4. Conclusions and further studies.

This innovative model is specifically crafted to harness natural resources, namely pressure and heat, thereby presenting an alternative avenue for the acquisition of clean and plentiful energy. Despite demanding fewer resources in comparison to its predecessors, meticulous examination of the investment is imperative.

Conducting a comprehensive study, inclusive of modeling, is essential to elucidate the potential risks posed by seismic activity and its plausible ramifications on structural integrity.

REFERENCES

Alpiq. (n.d.). Grande Dixence SA. Retrieved from https://www.alpiq.com/power-generation/hydropower-plants/storage-power-plants/grande-dixence/

Environmental Law Alliance. (2019). 1.1 phases of a mining project - ELAW. https://www.elaw.org/files/mining-eia-guidebook/Chapter1.pdf

Flores-Armenta, M. (2011). Geothermal activity and development in Mexico. Presented at the Short Course on Geothermal Drilling, Resource Development and Power Plants. Santa Tecla, El Salvador.

Ghanizadeh Zarghami, A., Shahriar, K., Goshtasbi, K., & Akbari, A. (2018). A model to calculate blasting costs using hole diameter, uniaxial compressive strength, and joint set orientation. *Journal of the Southern African Institute of Mining and Metallurgy, 118* (8), 869-877. https://dx.doi.org/10.17159/2411-9717/2018/v118n8a10

Grande Dixence. (n.d.). The Bieudron power station. Retrieved from https://web.archive.org/web/20100225031738/http://www.grande-dixence.ch/energie/hydraulic/switzerland/bieudron-power-station-altitude.html

Mining Technology (2019). The top ten deepest mines in the world. Retrieved from https://www.mining-technology.com/features/feature-top-ten-deepest-mines-world-south-africa/

Ministry of Business Innovation and Employment of New Zealand. (2023). Geothermal energy generation. **Ministry of Business, Innovation and Employment.* https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/energy-generation-and-markets/geothermal-energy-generation/

Nassar, I. A., Hossam, K., & Abdella, M. M. (2019, November 1). Economic and environmental benefits of increasing the renewable energy sources in the power system. *Science Direct.* https://doi.org/10.1016/j.egyr.2019.08.006

Posch, G. (2014). Manufacturing of turbine blades by shape-giving CMT-welding. Paper presented at the *Metal Additive Manufacturing Conference.* Vienna, Austria.

Prol-Ledesma, R. M., & Morán-Zenteno, D. J. (2019). Heat flow and geothermal provinces in Mexico. *Geothermics, 78*, 183–200. doi:10.1016/j.geothermics.2018.12.009

Simon, J., Beisner, E., & Phelps, J. (1995). *The state of humanity.* Oxford: Blackwell.

Tunnel Intelligence (2008). Safety. Retrieved from https://web.archive.org/web/20110717113025/http://www.tunnelintelligence.com/safety-in-detail-167.html

U.S. Department of Energy (2016). *Combined Heat and Power Technology Fact Sheet Series.* Retrieved from https://www.energy.gov/sites/prod/files/2016/09/f33/CHP-Steam%20Turbine.pdf

United Nations. (n.d.). Ensure access to affordable, reliable, sustainable and modern energy. Retrieved from https://www.un.org/sustainabledevelopment/energy/

United States Nuclear Regulatory Commission. (2021). Pressurised-water reactor (PWR). *NRC Web.* https://www.nrc.gov/reading-rm/basic-ref/glossary/pressurized-water-reactor-pwr.html

Vaclav Smil (2017). *Energy Transitions: Global and National Perspectives.* & *BP Statistical Review of World Energy.* http://vaclavsmil.com/2016/12/14/energy-transitions-global-and-national-perspectives-second-expanded-and-updated-edition/

Vaclav, S. (2023). *Energy Transitions: Global and National Perspectives* (second expanded and updated edition). Chart of energy by origin. https://vaclavsmil.com/2016/12/14/energy-transitions-global-and-national-perspectives-second-expanded-and-updated-edition/

Vlaar, N. J., van Keken, P. E., & van den Berg, A. P. (1994). Cooling of the Earth in the Archaean: Consequences of pressure-release melting in a hotter mantle. *Earth and Planetary Science Letters, 121* (1-2), 1–18. [doi:10.1016/0012-821x(94)90028-0](doi:10.1016/0012-821x(94)90028-0)