Article **Journal Renewable Energy**
June, 2022 Vol.6 No.16 15-23

Nuclear energy as backup to renewable energies

Energía nuclear como respaldo a las energías renovables

JIMÉNEZ-ROANO, Guadalupe†*, CRUZ-GÓMEZ, Marco Antonio, MEJÍA-PÉREZ, José Alfredo and JUÁREZ-ZERÓN, Tomás Aarón

Benemérita Universidad Autónoma de Puebla; Facultad de Ingeniería, Grupo de Tribología and Transporte, Cuerpo Académico 189 (Prevención de Desastres and Desarrollo Sustentable, Tribología), Edificio de Posgrado, Primer nivel, Cubículo Núm. 16, Blvd. Valsequillo esq. Av. San Claudio, Ciudad Universitaria, Col. San Manuel, CP. 72570, Puebla; México.

ID 1st Author: *Guadalupe, Jiménez-Roano* / **ORC ID**: 0000-0001-7316-5015, **Researcher ID Thomson**: AGC-4811-2022, **CVU CONACYT ID**: 1190772

ID 1st Co-author: *Marco Antonio, Cruz-Gómez* / **ORC ID**: 0000-0003-1091-8133, **Researcher ID Thomson**: S-3098-2018, **CVU CONACYT ID**: 349626

ID 2nd Co-author: *José Alfredo, Mejía-Pérez* / **ORC ID**: 0000-0002-4090-8828, **Researcher ID Thomson**: G-3354-2019

ID 3rd Co-author: *Tomás Aarón, Juárez-Zerón* / **ORC ID**: 0000-0002-9796-0540, **Researcher ID Thomson**: S-3099-2018, **CVU CONACYT ID**: 295058

DOI: 10.35429/JRE.2022.16.6.15.23 Received March 30, 2022; Accepted June 30, 2022

Abstract

Due to climate change, the use of nuclear energy for electricity production has been presented as a backup alternative to renewable powers to reduce CO2 emissions while maintaining energy stability. Currently, the carbon dioxide emissions produced related to the energy sector increased by 6% by 2021, reaching 36.3 billion tons (their highest level in history), the cause of this event is due to the global economic recovery after the COVID-19 crisis, which relied heavily on coal to fuel its increase. The main problem with nuclear energy lies in the waste produced by the nuclear fission reaction, therefore, the objective of this research was to gather information on why nuclear energy is considered clean energy, the current management of nuclear waste, and public opinion, with information obtained from the most recent articles on the production of electrical energy through nuclear energy.

Nuclear power, Fission, Clean energy

Resumen

Debido al cambio climático el uso de la energía nuclear para la producción de electricidad se ha presentado como una alternativa de respaldo a las energías renovables para reducir las emisiones de CO2 manteniendo una estabilidad energética. Actualmente las emisiones producidas de dióxido de carbono relacionadas con el sector energético aumentaron un 6% para 2021, alcanzando los 36300 millones de toneladas (su nivel más alto en la historia), la causa de este acontecimiento se debe a la recuperación económica mundial tras la crisis de COVID-19, la cual dependió en gran medida del carbón para impulsar su crecimiento. De acuerdo con un estudio realizado por la comisión europea, las emisiones de CO2 producidas por la energía nuclear son similares a las energías verdes, a diferencia de estas últimas, la energía nuclear puede producir grandes cantidades de electricidad de manera estable y continua. La principal problemática sobre la energía nuclear radica en los desechos producidos por la reacción de fisión nuclear, por lo tanto, esta investigación tuvo como objetivo recabar información sobre por qué la energía nuclear es considerada una energía limpia, el manejo actual de los desechos nucleares y opinión pública, con información obtenida de los artículos más recientes sobre producción de energía eléctrica a través de energía nuclear.

Energía nuclear, Fisión, Energía limpia

Citation: JIMÉNEZ-ROANO, Guadalupe, CRUZ-GÓMEZ, Marco Antonio, MEJÍA-PÉREZ, José Alfredo and JUÁREZ-ZERÓN, Tomás Aarón. Nuclear energy as backup to renewable energies. Journal Renewable Energy. 2022. 6-16: 15-23

*Correspondence to Author (e-mail: jmnzrnluu@gmail.com)
† Researcher contributing as first author.

Introduction

Energy demand is increasing, so it is necessary to find a viable solution to maintain stable and sustainable energy consumption, which is why nuclear energy has been presented as an option to make the energy transition to renewable energies. A system is sustainable if it can survive or persist over a time scale that is conscious of its spatial scale. There are 3 pillars for sustainability, these are the economy, the environment, and society. (Andrea Bersano, 2020)

Misinformation and historical events surrounding this type of energy are the main reason why people oppose its use. There are divided opinions within the scientific community, the strongest argument as to why we should not use nuclear energy is its waste, however, there is an increasing number of experts who agree that nuclear energy should be part of the solution to combat climate change, it already emits few greenhouse gases and has had no negative consequences for health during normal operation and even has limited consequences after accidents. (Anne-Sophie Hacquin, 2022)

It is a fact that a decrease in dependence on fossil energies is required, which is why nuclear energy is sought after as transitory energy because it produces large amounts of stable energy compared to renewable energies. Over time, society has experienced exponential growth, causing high energy demands, and depleting resources. As a society develops, greater energy consumption is generated, leading to negative consequences, mainly of an environmental nature. (Orozco, 2022)

Nuclear energy is what keeps the subatomic particles in the nucleus (protons and neutrons) together and is responsible for giving them stability. (Marcos, 2022). Plutonium, uranium, and other radioactive elements are used as fuel because "they are considered unstable". The energy is obtained or caused through a method called nuclear fission, when hitting the nucleus of unstable atoms with other neutrons, a colossal burst of energy is produced. At the end of the process, the so-called "nuclear waste" remains, are the plutonium and uranium atoms that are unused, these remains emit large amounts of radiation and are toxic to living beings and the environment.

Currently, deep geological repositories in vaults with specific characteristics are considered the most durable way to dispose of high-level radioactive waste and aim to transform much of the accumulated nuclear waste into innocuous compounds over time. (Rohini C.Kale, 2021)

Methodology

This research was carried out under a mixed, quantitative, and qualitative methodology with a mixed approach based on scientific articles, as well as interviews, international reports, and videos on nuclear energy. Due to the difficulty of access to this topic, information was collected on why nuclear energy is considered clean energy? the current management of nuclear waste, and public opinion, with information obtained from the most recent articles on nuclear production. of electrical energy through nuclear energy.

The application of the qualitative method allowed us to obtain comparison graphs between the types of energies and their effects in different ecological environments. From the results obtained, a discussion of results will follow on the use of nuclear energy as a support for green energies.

1 What is nuclear energy and how is it produced?

Nuclear energy is a form of energy that is released from the nucleus (central part of atoms) consisting of protons and neutrons. This source of energy can be produced in two ways: through the fission (when the nuclei of atoms are divided into several parts) or through fusion (when they merge). (Galindo, IAEA Organismo internacional de energía atómica, 2021)

Fission receives this name because when a nucleus is bombarded by neutrons it subdivides into more neutrons, which in turn bombard other nearby nuclei causing a chain reaction. This is the science that nuclear power plants use for the production of energy. (Marcos, 2022)

To achieve a nuclear fission reaction, elements that can be easily altered and that release thermal energy are required. Uranium is the most widely used element as nuclear fuel. Not all cores of a given element are built the same.

ISSN 2523-2881

An element is defined by the number of protons within the nucleus, and varying the number of neutrons in the nucleus can cause it to behave differently. Natural uranium is mostly made up of uranium-238 (99.3%), with uranium-235 (0.7%) and a very small amount of uranium-234 (0.0055%). Most reactors require a higher percentage of uranium-235, which is why to maintain nuclear fission reactions, uranium enrichment processes are usually used. (Enciclopedia de energía, 2021)

1.1 Nuclear reactors

Nuclear reactors produce electrical energy from the thermal energy that is produced through fission reactions and is found inside nuclear power plants, these are industrial facilities that produce electrical energy. The fuel used for the fission reactions is found in the reactors and they have systems capable of starting, maintaining, and stopping the reactions caused to release large amounts of thermal energy. It is estimated that 11% of the total energy around the world is produced by reactors in nuclear power plants. (Hermosilla, 2022)

1.1.1 Operation of a reactor

Pressurized water reactors are the most widely used. When the heat produced by the fission reaction increases, the coolant begins to rise in temperature, producing the steam responsible for turning the turbines. The thermal energy produced is transformed into kinetic energy, then it is transformed into mechanical energy and finally, it is converted into electrical energy. Figure 1 shows the cycle of a pressurized water reactor. (López, 2019) (Galindo, IAEA Organismo internacional de energía atómica, 2021).

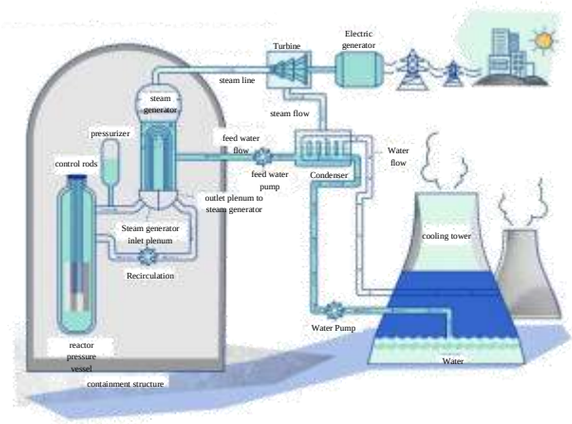


Figura 1 Cycle of a pressurized water reactor (PWR) *(Galindo, IAEA Organismo internacional de energía atómica, 2021)*

The process can be simplified into four phases;

1) The fission reaction is carried out in the reactor, and the water that works as a coolant is heated and transported to the steam generator to produce steam.
2) Steam is transported to the turbine, followed by a secondary circuit to the generator.
3) In the turbine, the blades rotate by the action of steam and the turbine shaft moves the alternator, transforming mechanical energy into electricity.
4) The vapor is sent to the condenser through a secondary circuit to be transformed into a liquid again.(SectorElectricidad, 2021).

1.2 Types of reactors

Some of the existing reactors are:

CANDU Reactors (Canadian), Boiling water reactors, pressurized water/prismatic reactors, molten salt reactors, modular reactors, supercritical water-cooled reactors, and research reactors, currently, Actually, no fusion reactor allows obtaining electrical energy, however, if there are research centers that study fission reactions. (Adetunji, The conversation, 2022).

2 Nuclear energy as clean energy

It is important to know the difference between green, clean and renewable energies to understand why, according to the European Commission, nuclear is considered clean energy. The definition of green energy says that it encompasses all clean, non-polluting energy that comes from 100% renewable sources. All renewable energy is clean, but not all clean energy is renewable. Renewable energy is defined as one whose energy source is based on the use of inexhaustible natural resources, such as the sun, wind, water, or biomass. Renewable energies are characterized by not using fossil fuels, but natural resources capable of unlimited renewal. (Garrett, 2022)

Non-renewable clean energies are those that consist of energy production systems that exclude any type of pollution, mainly due to the emission of greenhouse gases, such as CO2, which cause climate change.

ISSN 2523-2881

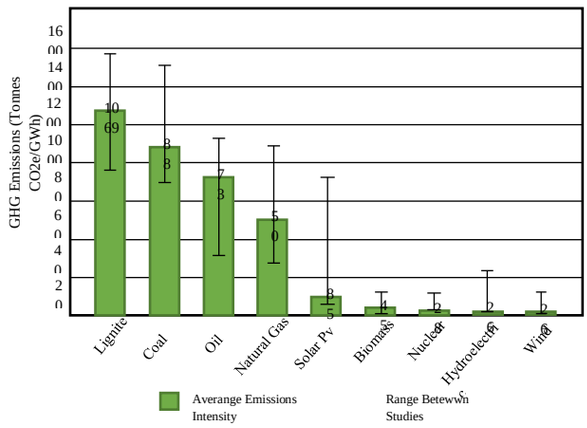
They promote advances to preserve the environment and reduce the crisis of exhaustible energies. (IBERDROLA, 2022). Nuclear energy according to the configurations fits as clean energy, this is because it is decarbonized and "does not emit" greenhouse gases compared to fossil energies, however, it is not considered renewable energy because the Uranium (a component used to carry out nuclear fission) is a limited resource.

To label nuclear energy as green, the European Commission establishes that those energies that can play a crucial role in decarbonizing our economies during the coming decades can be classified as such. (Gallo, 2022) (Petten, 2021)

According to the technical report published by the European Commission on the ecological impact of nuclear energy, this is one of the sources of electricity production that generates fewer greenhouse gases throughout its cycle.

As can be seen in graph 1, the source of electrical energy that generates the most tons of CO2 for every gigawatt-hour (GWh) of production is lignite (fossil coal) with 1069 tons for every GWh and natural gas as an energy source. electricity generates an average of 500 tons of CO2 for each GWh produced, this data is significant because the strategy that governments such as Spain or Germany are following is to use gas as complimentary electrical energy for renewable energy sources, the idea is to replace coal plants by plants that use natural gas since coal emits much more CO2 into the atmosphere, however, natural gas is still a source of electricity production that emits large amounts of CO2 (Gallo, 2022).

In comparison, nuclear energy can be seen with a considerable minimum production of greenhouse gases, reaching an amount not so separate from that emitted by renewable energies.



Graph 1 The intensity of GHG emissions of the life cycle of electricity generation technologies *(Petten, 2021)*

From the broader perspective, the European Commission argues that nuclear power further contributes to climate change mitigation through synergy with renewable energy technologies. Nuclear is the main source of manageable low-carbon electricity next to hydroelectricity. When used as a baseload technology, it provides flexible operation to supplement intermittent renewable energy sources.

Therefore, wind and solar energy are deployed more efficiently. This avoids, on the one hand, the use of highly carbon-intensive generation technologies that are often used as a backup or main source of energy. On the other hand, this integration, together with the storage of electricity, brings benefits to the electricity grid, by minimizing short-term interruptions.. (Petten, 2021)

The report also compares the precursor compounds of acid rain, sulfur dioxide (SO2), nitrogen oxide (NOx), nitrogen monoxide (NO), nitrogen dioxide (N2O), and various other substances. Emissions of these acidifying substances can persist in the air for a few days, undergoing a chemical conversion into acids (sulfuric and nitric), causing changes in the chemical composition of the soil and surface water, contaminating jungles and forests, and in turn, damaging the flora and wildlife.

Graph 2 shows the grams per kilowatt-hour (kWh) of electricity that is generated by the different sources that produce electricity. (Petten, 2021)

ISSN 2523-2881

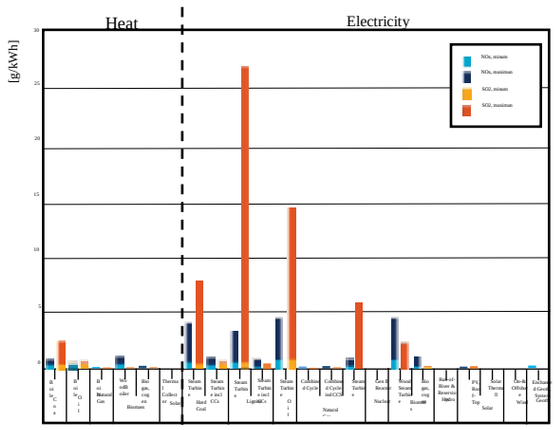


Gráfico 2 Cumulative life cycle emissions of NOx and SO2 per unit of energy for current heat and power supply technologies *(Petten, 2021)*

It can be seen that fossil energies stand out as the most harmful, coal, oil, and, to a lesser extent, natural gas. On the other hand, renewable energies have a minimum production like nuclear. Another factor taken into consideration in the report is the abiotic depletion potential (ADP). This indicator refers to the depletion of non-living (abiotic) resources such as metals, minerals, and fossil energy (Graph 3). The scarcity of the different natural resources used is a factor in the calculation of the indicator and is measured in kilograms of Antimony (Sb).

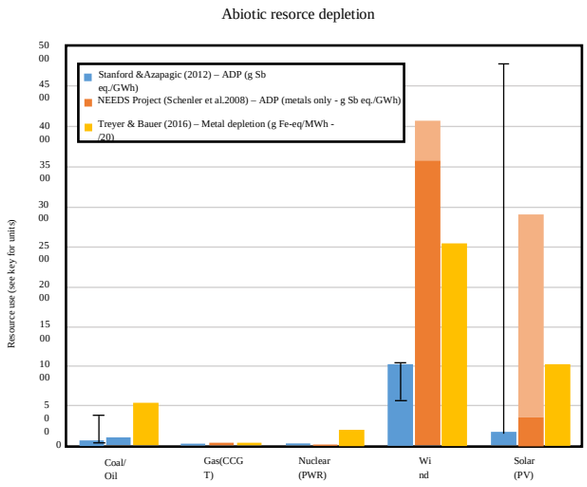


Gráfico 3 Use of natural resources *(Petten, 2021)*

These maximum and minimum values correspond only to national differences in the implementation of the different technologies, except for photovoltaic solar energy. (Petten, 2021). Nuclear energy consumes the fewest metallic and non-metallic mineral resources. The graph shows that the potential for abiotic depletion with nuclear energy is much lower than with solar or wind energy.

To complement the energy transition through renewable energies such as solar or photovoltaic, a brutal increase in the mining extraction of the entire planet would be necessary, since these energy sources consume many mineral resources. The available scientific evidence allows nuclear energy to be classified as green, that is, it does not have a significantly negative impact on the environment across the production. (Gallo, 2022).

Despite its drawbacks, a large number of experts consider that they are not enough to rule out this source of energy, in an article in "The Conversation" they conclude that "there is no science-based evidence that nuclear power causes more damage to humans or the environment than other electricity production technologies".(Marcos, 2022) (Adetunji, The conversation, 2022).

According to José Pardo de Santayana in Energy security in the transition towards clean energies, the proposal to integrate nuclear energy as green is defended, stating that to meet the objectives of the energy transition, the European Union must include nuclear energy, implying an investment in new reactors between now and 2050. In Construction and positioning of the sociotechnical imaginary: "Energy 2050" by Juan Carlos Imio, it is stated that planning is necessary due to the importance of sociotechnical phenomena in promoting the energy transition to sustainability. (Imio, 2022)(de Santayana, 2022)

3. Waste radioactive

Radioactive waste is defined as any material derived from the peaceful use of nuclear energy that contains radioactive isotopes for which reuse is not anticipated. Most of the nuclear waste generated comes from spent nuclear fuel in nuclear power plants. (Planas, 2022).
Each country has its policy and strategy for the management of its waste, they are important since they guarantee the position and plans agreed upon at the national level for the management of said materials. In Mexico, radioactive desire is considered to be any material that contains or is contaminated with radionuclides in concentrations or levels of radioactivity greater than those indicated in NOM-035-NUCL-2013, and for which no use is foreseen. (SEGOB secretaria de gobernación, 2021) (IAEA, 2022)

ISSN 2523-2881

3.1 Radiation levels and types

There are levels of medium, low and high activity, this classification depends on the concentration of radionuclides. Short-lived waste has radionuclide contamination with a half-life of less than or equal to 30 years, and long-lived waste with alpha-particle emitters has a decay period greater than 30 years. Medium-level waste is generated in the fission process in small quantities and is placed in steel drums for treatment. Low-level waste is also added to drums. High-level waste can be active for thousands of years and its treatment consists of three stages: initial storage, intermediate storage, and final storage. (Planas, 2022).

In turn, radiation is divided into ionizing (capable of ripping electrons from atoms and molecules) and non-ionizing (of lesser intensity). In the case of non-ionizing radiation, its energy is not enough to remove the electrons from the atoms or molecules that make up matter, however, it is capable of generating heat through the vibration of said molecules. Ionizing radiation can produce changes at the atomic level and in high doses, it can be lethal, however, the reality is that with controlled and adequate doses, in addition to protection measures, it has positive uses such as energy production and the treatment of diseases stories like cancer. (Galindo, IAEA Organismo internacional de energía atómica , 2022)

In the case of nuclear power plants, the type of radiation is ionizing and is emitted naturally by the uranium and during nuclear fission, despite this, it does not represent a danger outside of the radiation emitted by the waste. (Galindo, IAEA Organismo internacional de energía atómica, 2021)

4. Countries and their opinion

According to the International Electric Power Agency by the end of 2020, the world's total nuclear power capacity amounted to 392.6 GW(e)[1] produced by a total of 442 functional reactors in 32 countries. In the same year, nuclear power supplied 2,553.2 terawatt-hours of GHG-free electricity, about 10% of the electricity generated globally and one-third of the world's low-carbon output. (General, 2021).

In Latin America, the first country to build and commit to nuclear energy was Argentina. Julian Gadano, the former Argentine undersecretary for nuclear energy, says that he is convinced that there is no solution to climate change in the short term without nuclear energy, since "This one is clean and at the same time, somehow, it's always available." He also talks about the fact that, in addition to public opinion, another challenge he faces is cost, due to the search for clean, permanent, and safe energy that is also found at competitive costs.

Germany currently has six nuclear reactors in operation that produce 8,113 MWe, previously 25% of the country's electricity was produced by 17 reactors and this percentage was reduced to 10%. Germany has stated that it does not have construction planes for future reactors and has closed a total of 30 that have a production capacity of 18,262 MWe. (Español, 2021).

Countries such as France and the United States are in favor of the production of electrical energy through nuclear power, the latter being the largest producer in the world with 93 active reactors and an average production of 95,523 MWe per year, in addition to having reactors under construction. France, for its part, has been openly in favor of the energy transition, supporting renewable energies through nuclear due to the scarcity of resources such as gas, coal or oil. It has 56 reactors with a production of 61,370 MWe equivalent to 70% of its electricity and about 17% of its electricity is generated through recycled nuclear energy. (Español, 2021). Mexico has two nuclear reactors that produce 1,552 MWe, covering 4% of the country's electricity, but there are currently no plans to build more reactors. (Portillo, 2022)

5. Métodos de eliminación de desechos nucleares

Proper disposal of nuclear waste requires strict guidelines to ensure proper handling from start to finish. There are different methods, including incineration, storage, burial at shallow, medium and deep depths, and even recycling. The most common way to eliminate high-level waste is deep burial, countries with resources use this method, creating "bunkers" with strict characteristics for proper storage accompanied by laboratories that monitor the use and storage of materials. (Mundial, 2022)

ISSN 2523-2881

5.1 Bunkers de almacenamiento

Specifications for nuclear waste storage bunkers are extremely limited, however, the basic principle of disposal is the use of multiple barriers designed specifically for the area. (Rodney C.Ewing, 2021)

"Waste Isolation Pilot Plant" (WIPP) is one of the pilot nuclear cemeteries located in New Mexico, EU. Since the beginning of the 21st century it has received highly radioactive waste and it is expected to receive containers until the year 2070. This cemetery stores 185,000 containers of radioactive waste 660 meters below ground. The Hanford complex in Seattle is one of the largest, storing 177 tanks containing 200,000 cubic meters of waste. It is not known for sure how many cemeteries there are, however, it is understood that they are desolate places that cannot be accessed, even on the surface, since people can be exposed to harmful chemicals such as radioactive cesium – also known as isotope cesium 134 or 137. (Avramow, 2022)

6. Waste management

There is no single solution to develop a waste management program, each country has taken its path to deal with the problem, most technological development refers to waste storage, however, this is not the end of waste management. waste, the next step is to put said waste to use to obtain an efficient life cycle. Achieving the closure cycle is the essential factor to guarantee sustainability, the fissile material of the spent nuclear fuel can be recovered to produce non-irradiated fuel. Few water-cooled reactors are currently licensed to use recycled fuels. (General, 2021)

Countries like Japan have invested in reprocessing infrastructure, thereby recycling as much plutonium as possible. The socio-economic aspects and environmental ratios are expected to be a guide to the emerging market for the nuclear industry, which tends to adhere to the "wait and see strategy" for nuclear waste management but will soon struggle with nuclear waste management. (Lim, 2016) (Jung WooSuh, 2020).

Results

According to the Director-General of the International Atomic Energy Organization, nuclear power can help address pressing global issues. However, misconceptions about nuclear power continue to outpace public acceptance and policy making. Public perception of the benefits and risks associated with nuclear energy and, in particular, concerns about radiation risks, radioactive waste management, safety and security remain the aspects that most influence public acceptance. As public opinion plays a critical role in how governments choose to produce their energy, understanding the views, perceptions, and knowledge of stakeholders regarding nuclear power is important for the programs for nuclear power. Establishing strong, positive and long-term relationships with stakeholders is a key factor for existing, new and future nuclear power programs. (General, 2021)

Discussion of results

Implementing waste treatment plans and providing active knowledge to society about the benefits and safety measures of nuclear power production is essential to opening up its acceptance. It is not about moving from fossil to nuclear energy, but about giving priority to clean energy in general, renewable or not. The benefits of nuclear power are obvious, there can be no transition to green energy without support because renewable energy, such as solar or wind, is intermittent. The constant and growing energy demand, together with the depletion of fossil resources and the worrying environmental situation, make the need to use this type of energy evident. Furthermore, prioritizing waste treatment plans, primarily waste recycling, maybe the method to achieve a full cycle for nuclear power.

Conclusions

It has been verified with statistics that the environmental impact on the ozone layer is much lower with nuclear power, maintaining a high energy production capacity. Nuclear reactors are safe, they are controlled at all times by trained personnel and each radioactive waste has a process for its containment or elimination. Public opinion influences how countries manage this sector, a firm and informed decision is required more than the public.

ISSN 2523-2881

Acknowledgments

- To the Benemérita Universidad Autónoma de Puebla; Engineering Faculty for the support in the use of its infrastructure.
- To the Tribology and Transport Group, BUAP, for their support in the analysis and development of the work.
- To 189 Disaster Prevention, Sustainable Development and Tribology Academic body, BUAP.

References

Adetunji, J. (2022, 03 27). *The conversation*. Retrieved from The conversation: https://theconversation.com/es-hora-de-decir-si-a-la-energia-nuclear-179395

Adetunji, J. (2022, 01 19). *The conversation*. Retrieved from The conversation: https://theconversation.com/fusion-nuclear-la-cuenta-atras-ha-comenzado-174285

Anne-Sophie Hacquin, S. A. (2022). Disgust sensitivity and public opinion on nuclear energy. *Journal of Environmental Psychology*, 1-9.

Avramow, M. (2022, 02 14). *EOL*. Retrieved from EOL: https://www.energiaonline.com.ar/cementerios-nucleares-que-se-hace-con-los-desechos-radioactivos/

de Santayana, J. R. P. (2022). Seguridad energética en el tránsito hacia unas energías limpias. bie3: Boletín IEEE, (25), 7-9. Recuperado de: https://www.ieee.es/Galerias/fichero/docs_analisis/2022/DIEEEA03_2022_JOSPAR_Seguridad.pdf

Español, C. (2021, 06 14). *CNN*. Retrieved from CNN: https://cnnespanol.cnn.com/2021/06/14/energia-nuclear-mundo-cuantas-reactores-plantas-tiene-cada-pais-orix/

Galindo, A. (2021, 11 03). *IAEA Organismo internacional de energía atómica*. Retrieved from IAEA Organismo internacional de energía atómica: https://www.iaea.org/es/newscenter/news/que-es-la-energia-nuclear-la-ciencia-de-la-energia-nucleoelectrica

Galindo, A. (2022, 05 13). *IAEA Organismo internacional de energía atómica* . Retrieved from IAEA Organismo internacional de energía atómica : https://www.iaea.org/es/newscenter/news/que-es-la-radiacion

Gallo, J. R. (2022, 01 2022). *Youtube*. Retrieved from Youtube: https://www.youtube.com/watch?v=NMDwmc6vFFc&list=PL0wJx-UFqWezl52wwJ3090ISV7DEkx_Ue&index=13

Garrett, C. (2022, 03 25). *Climate CONSULTING Selectra*. Retrieved from Climate CONSULTING Selectra: https://climate.selectra.com/es/que-es/energia-verde#:~:text=Se%20define%20como%20energ%C3%ADa%20verde,las%20energ%C3%ADas%20limpias%20son%20renovables.

General, D. (2021, 08 03). *IAEA Organismo Internacional de Energía Eléctrica.* Retrieved from IAEA Organismo Internacional de Energía Eléctrica: https://www.iaea.org/sites/default/files/gc/gc65-inf6_sp.pdf

Hermosilla, I. (2022, 03 04). *bbcl Aquí Tierra*. Retrieved from bbcl Aquí Tierra: https://www.biobiochile.cl/especial/aqui-tierra/noticias/2022/03/04/como-funciona-una-planta-nuclear-y-cuales-son-las-mas-grandes-del-mundo.shtml

IAEA. (2022, 03). *IAEA*. Retrieved from IAEA: https://www-pub.iaea.org/MTCD/Publications/PDF/PUB1396_S_web.pdf

IBERDROLA. (2022). *IBERDROLA*. Retrieved from IBERDROLA: https://www.iberdrola.com/sostenibilidad/energias-limpias#:~:text=DEFINICI%C3%93N%20DE%20ENERG%C3%8DAS%20LIMPIAS,CO2%2C%20causantes%20del%20cambio%20clim%C3%A1tico

Jung WooSuh, S. Y. (2020). Patent clustering and network analyses to explore nuclear waste management technologies. *Energy Policy*, 14-20. Retrieved from https://www.sciencedirect.com/science/article/abs/pii/S0301421520305152

López, J. C. (2019, 04 2). *Xataka*. Retrieved from Xataka: https://www.xataka.com/investigacion/reactores-nucleares-pequenos-limpios-seguros-baratos-esto-que-nos-promete-fision-nuclear-cuarta-generacion

Marcos, L. (2022, 04 16). *Esquire*. Retrieved from Esquire: https://www.esquire.com/es/ciencia/a39690430/energia-nuclear-limpia-sostenible-peligros/

Mundial, A. N. (2022). *Ecológico Sostenible*. Retrieved from Ecológico Sostenible: https://ecologicosostenible.com/cuales-son-los-metodos-de-eliminacion-de-desechos-nucleares/

Ortiz Orozco, M. F. (2022). Propuesta para la implementación de baldosas piezoeléctricas como alternativa energética para el Centro Comercial Santafé en Bogotá DC. Recuperado de: https://repositorio.unbosque.edu.co/bitstream/handle/20.500.12495/7830/Monografia-piezoelectricas%20CC%20Santafe.%20Cod.%202101-035.%20Final.pdf?sequence=1

Petten. (2021). *Technical assessment of nuclear energy with respect to the 'do no significant harm' criteria of Regulation (EU) 2020/852 ('Taxonomy Regulation').* Europa: European Commission Joint Research Centre.

Planas, O. (2022, 01 28). *Energía Nuclear*. Retrieved from Energía Nuclear: https://energia-nuclear.net/que-es-la-energia-nuclear/residuos-nucleares#:~:text=Los%20residuos%20radiactivos%20se%20definen,gastado%20en%20las%20centrales%20nucleares.

Portillo, S. R. (2022, 01 20). *Ecología verde*. Retrieved from Ecología verde: https://www.ecologiaverde.com/cuantas-plantas-nucleares-hay-en-el-mundo-3356.html

Rodney C.Ewing, S. (2021). The Concept of Geological Disposal of Highly Radioactive Nuclear Waste. *Sustainable Cities and Society*, 588-602.

Rohini C.Kale, K. (2021). A review on the impact of thermal history on compacted. *Environmental Technology & innovation* , 1-13.

SectorElectricidad. (2021, 08 26). *SectorElectricidad*. Retrieved from SectorElectricidad: https://www.sectorelectricidad.com/35136/como-funciona-una-central-nuclear/

Imio, J. C., & Fonseca-Prieto, F. (2022). Construcción y posicionamiento del imaginario sociotécnico:"Energía 2050". Revista Austral de Ciencias Sociales,

SEGOB secretaria de gobernación. (2021, 10 11). *SEGOB secretaria de gobernación*. Retrieved from SEGOB secretaria de gobernación: https://dof.gob.mx/nota_detalle.php?codigo=5632219&fecha=11/10/2021#gsc.tab=0

ISSN 2523-2881