"The nexus between nuclear energy and climate change"

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Abstract

Focusing on the urgent environmental issue and similarly the increased necessity of energy, this study assesses why nuclear power is not used to its full potential, as an alternative mitigation alternative to climate change. First, it identifies all the factors that frame nuclear power as a non-effective alternate to mitigate climate change, to further discuss about the role on newcomers in the international setting, to providing a safer and secure environment with the usage of nuclear power. Second, it reviews previous literature and various issues to risk perception of nuclear power and misperceived public opinion and concludes that there is a big difference between reality and perception. Third, discusses the case of the United States of America as the country with the highest number of nuclear units, Russia as the highest exporter and the African region as one of the biggest and the most influential newcomer region, financed by Russia. It is concluded that the findings do show that nuclear power is a safe, clean source of energy that has an impact on climate change and reality and perceptions are a gap when it comes to objectively assessments of its role.

CHAPTER ONE - INTRODUCTION

Increased heat, fires, floods, drought, air pollution and loss of ecosystems are only some of the impacts that the climate crisis has on every living being, on their daily lives. According to experts, studies, literature, and what we see to be, one of the main contributors in the greenhouse gas emissions that make an impact on climate change is the energy sector (IAEA, 2016). It has been widely agreed that there needs to be an all-hands all-directions approach to mitigate the effects of climate change. The number of states that has agreed and vowed to revolutionize their energy sector towards renewable, energy sources has increased.

However, the number of states including nuclear power, which is a source of clean energy, in their future plans of energy mix, is low (Burgherr et al, 2019). Due to lack of updated information, the public perception of nuclear energy is negative. Nuclear accidents such as the Fukushima accident have shaped public attitudes toward nuclear power. In some countries public attitudes are so strong that they influence the decision-making process of incorporating this energy source in the country energy mix. Some countries have even decided to decommission early their nuclear power plants.

Nuclear power and climate change are connected as nuclear power can help decrease the effects of climate change. Energy and climate are both important security topics that influence the everyday lives of all citizens of the worlds. As such, this thesis will not focus on only one geographical area. This research aims to address the reasons why nuclear energy is not as widespread as other sources of renewable energies. The analysis is mainly based in the country with the largest number of nuclear reactors in the world, the United States of America, the largest exporter of nuclear technology in the world, Russia and three newcomer countries located in Africa. The implications and effects of nuclear energy are analyzed taking into consideration two different time frames. As an example, the number of deaths avoided by nuclear power is calculated from when nuclear power was first stated to be used to future projections.

This topic addresses a relevant problem that is present amongst the security energy community. It aims to address the reasons as to why nuclear energy, as a clean energy source, is not as relevant as it should in mitigating climate change. The literature analyzed focuses on the reasons why nuclear energy is not chosen by states to be incorporated in their energy mix.

Existing literature fails to compare these reasons with the positive impacts that nuclear power can have in addressing climate change but also considering in the analysis not only states that have or do not have nuclear energy in their energy mix, but also countries that plan to integrate or phase out this energy source. The implications of these different stances are addressed during the discussion and analysis.

This thesis proposes a new understanding of the topic where it aims to address and combine the reasons behind the refusal of nuclear power and also provide a comprehensive picture of how nuclear energy can mitigate the impacts of climate change. To do so, this research paper starts by analyzing reasons behind why nuclear power is not being used to its full potential. The existing literature offers an overview of the connection between nuclear power and climate change. Moreover, it analyses the perception of risk in relation to nuclear power by focusing on the framed risked opinions and continues by looking into the acceptance of nuclear power station.

To analyze the connection between nuclear power and climate change, an overview of the Paris agreement is necessary. Moreover, attention and focus is paid to misconceptions and safety culture issues. Newcomer states are analyzed from a theoretical perspective, in trying to analyze their motivation, but also in a more contextual analysis by offering understanding of several elements that inform their decisions such as their demography, projected impacts of climate change and security impacts.

When discussing the positive implications of climate change towards mitigating nuclear energy, this study focuses on the role of energy in the emission levels, greenhouse emissions and climate change, the implications of nuclear energy in avoiding CO2 emissions and how it has historically contributed to avoiding deaths (Florentina & Dima 2020). On the contrary to the popular opinion and misperception, nuclear energy has historically avoided more deaths than it has caused.

The discussion also focuses on costs deriving not only from keeping or deciding to phase out nuclear power, but also how this energy source contributes to lowering the costs of mitigating climate change.

The discussion also focuses on how informed stakeholders can influence the decision making process and how, new technology and investment in waste management can improve the stance on nuclear power. Finally, it will be presented an overview of three current newcomer countries. It further arguments their decision and chosen path into integrating nuclear power into their energy mix. In doing so, the paper suggests that there are different implications of their decisions. In deciding to include nuclear power in their energy mix, these countries give geopolitical leverage to the country which is exporting the technology. Additionally, security concerns due to their internal and international stability should be taken into consideration as because of the fragile and dangerous nature of nuclear power, can have devastating consequences for others as well. And finally, the positive impact the choice of this energy source will have in climate change but also in their economies.

CHAPTER TWO - LITERATURE REVIEW

1. Introduction

This chapter reviews the theoretical literature by aiming to provide an overview of the importance of the connection between nuclear energy and climate change. It addresses different areas of summarizes previous knowledge on climate change and nuclear energy, its impact, and efforts, which will help understand in depth the nature of the issue and subsequently evaluate the role and importance of this study in the existing literature.

The structure presented as follows, is based on aims of this study and it addresses research related the nexus of nuclear power and climate change. This section will focus on previous studies and discussions about the precepted risk of using the nuclear energy for the benefits of climate change. Moreover, it will analyze misperceptions on nuclear power on its own and its connection to climate change. Previous literature will be addressed in order to interpret the role on nuclear power and its ability to achieve the Paris Agreement goal, on preserving climate change. Selected issues pertaining to the challenges and development potential of nuclear energy are also presented.

2. Precepted risk of using the nuclear energy for the benefits of climate change.

2.1 The risk and nuclear power

When we think of risk, we have the feeling of uncertainty and the possibility that we can be exposed to danger, and directly related to the degree of the consequences (Huang, X, 2008). Generally, the conception of risk is built up differently among different people and countries. Thus, the measures of risk and the generalization could not be possible considering it is perceived differently, based on cultures and also personal beliefs. Moreover, even within one country people perceive risk differently.

Perception studies have often "*determined how the public assesses the risks in order to understand, for example, the differences observed in the positioning of the various social groups", "link perceptions to attitudes and behaviors", and to move from "perceived reality" to an " objective reality"* (Brenot et al., 1996).

The perception of risk of nuclear power makes no difference. The nuclear risk perception is rooted in ideology (Pigeon, 1998). Paraschiv and Mohamad (2020) argue that among non-experts on this issue, greater value is given to negative expectations than benefits. People lean on stronger and much more sensitive feelings to human-made accidents than to natural ones of a similar magnitude.

When it comes to nuclear power, knowledgeable people and non-knowledgeable ones have different models of risk assessment. Previous studies show that experts consider the anti-nuclear public perceptions and attitudes to be irrational. (Hu et al. 2016) Further it is discussed that differences in knowledge, risk perception, and attitudes towards nuclear power between scientists and the general public perception. The authors conclude that among non-experts, negative expectations are given greater value than expected benefits. Moreover, people tend to have stronger and more sensitive reactions to human-made accidents than to natural ones of a similar magnitude. (Sjöberg, 1998)

The public assessment is considered in the academic literature as subjective. (Huang 2008) For example, previous research demonstrated that people living in municipalities in the vicinity of nuclear power plant tend to be more acceptable of nuclear power because they have knowledge of the benefits for their community. On the opposite, people living on areas away from nuclear plant tend to perceive a potential risk negative consequence.

More than 50 countries have already adopted nuclear power, which contributes to over 10% of the world´s electricity production (WNA, 2020). This application it is expected to expand as it has an important role in future of electricity supply.

Shih et al, (2016) clarified that some researchers claimed that nuclear energy has the lowest social cost overall compared to other energy sources, even though it is still a controversial issue for general public. The nuclear industry argues that nuclear energy is clean energy with high efficiency (Haines et al., 2007; Kessides, 2012, Zhou and Zhang, 2010). Similarly, some other experts have clarified that its usage does not include the risk that is caused by potential accidents and the disposal of the radioactive material (Huang et al., 2013).

2.2 Factors that frame opinions on risk of nuclear power related to climate change

What the public thinks and how perceives the risk of nuclear power is essential to its usage as a possibility for climate change issue. The anti-nuclear attitudes and perceptions "explode" after nuclear disasters (Gao et al., 2019) as the Chernobyl accident in the Soviet Union in 1986, and the most recently, Fukushima accident in Japan in 2011 (Ramana, 2011). It is quite important to refer to the perception on nuclear power, from the people and their governments as in many cases it was required to balance the energy security needs, with the climate change threats (Corner et al., 2011; Pigeon et al., 2008).

Previous studies as Cha, (2004); de Groot et al., (2013) consider gender, age, education, marital status, social status, family income, and political ideology as common factors that influence an individual's risk perception of nuclear energy.

Educational level has an important role on acceptance of nuclear energy. The importance of knowledge and education regarding acceptance of the benefits of access to nuclear energy is crucial, despite that there might be recognized hazards on its application. On the other hand, other studies argues that the public acceptance of the risks caused by nuclear power were not affected by educational level or general knowledge of the nuclear power industry due to unaddressed risk perception factors held by a given population and its various subgroups, especially in the existing exposure situations. (Kim et al., 2019)

It is also clarified and previously well documented in the literature that a higher opposition against nuclear power exists among women compared with men and among people with low levels of education compared with others who hold higher levels of formal education. Women are more likely to feel risks from technology and the environment than men (Greenberg and Truelove, 2011).

Prior research also found that female elected officials at each polity level reported greater opposition to nuclear power than their male counterparts (Sundtröm and McCright, 2016). Regarding the education level and nuclear risk perception, certain studies demonstrated that people with a higher level of education are less concerned about nuclear risk and more supportive of nuclear energy (Choi et al., 2000; Mitchel et al, 2007).

Furthermore, people that have knowledge on the nuclear power related accidents are prone to have negative thoughts and reject it. Moreover, trust in the scientists' perspectives alleviates perceived risk and increases perceived benefits of nuclear power.

Nevertheless, different attitudes in the assurance from nuclear power, are all mainly connected to one major reason, trust level and lack of confidence put on the actors who should be responsible on managing nuclear power risk (Baum, Gatchel, Schaeffer, 1983). Authorities should be transparent on new studies and initiatives in order to alleviate the precepted risk on nuclear power. The public's attitude of nuclear power is crucial for establishing nuclear energy policies and programs and determining the investment in energy facilities (Baum, Gatchel, Schaeffer, 1983)

As one of the most important perception risk which has a considerate value is the *transparency and information* on managing of the nuclear power, especially with the attributes of uncertainty (Wachinger et al, 2013). There is a considerate lack of trust in the authorities, how they will manage nuclear power and the possibility of not including the public in the decision-making process (Slovic, Flynn, Mertz, Poumadere, Mays, 2000).

Common perceptions of risk of nuclear power as an alternative for climate change, is mainly attached to nuclear power remains. Many believe that its usage is a danger to health, and it is at the same time a dangerous waste. (Poortinga, Pidgeon & Lorenzoni, 2005) On the other hand, most people perceive wind power as clean, safe, good for the economy and cheap. Coal on the other hand is seen as polluting and as a cause of climate change.

Public perception of nuclear energy is also a *political issue* (Ziegler, 2017) and several researchers have discussed that politics and ideology significantly influence the public's acceptance of nuclear energy (Latre et al., 2019). Nuclear power could be one of the options available for easing the risk of climate change, considering its significant potential contribution to GHG emissions reduction. Again, keeping the nuclear option open in order to realize this potential will require a number of actions by governments and by industries in the nuclear sector (Qi, Han, Veuthey & Ma, 2021).

As previously mentioned, trust in governments, radiation risks, other effects, and threats, affect the public's perception and attitudes toward nuclear power plants.[i] The role of trust

(Earle et al., 2007) is essential because people rely on others as a result of expecting beneficial outcomes from them. As mentioned, people don't always have People do not enough and the adequate knowledge about the risks of any event, in this case nuclear power, for latter to be able to make an informed decision about it. Thus, they appear to rely on their social trust in the relevant actors in order to determine their own risk and benefit perceptions (Siegrist, 2000).

Other researchers as Takebayashi et al. (2011) who often researched on risk perception of nuclear power, included demographics, disaster-related stressors, trusted information, and radiation-related variables and that the effects of radiation risk perception included severe distress, intentions to leave employment or to not return home, as some of the most important factors. They further specified that people's perception is sometimes an issue when it comes to developing and implementing nuclear policies and strategies, requiring substantial subsidies that are not based on the social evaluation of nuclear energy.

Another, meaningful factor that contributes to the acceptance or rejection of nuclear power as a possible solution to the climate change topic is also the transmitted information through different channels, such as mass *media*. On several occasions, as previously discussed in the specific literature, the visual, online and also written media have contributed to influencing people's views, sometimes in a non-natural way. Considering that we live in a digitalized world allows people not only to be selective about which source of information to follow, and how to obtain it, but also to be prone of knowledge which might not be correct and the source not entirely credible. However, the truthfulness, and credibility of information is a wide issue, also considering that sometimes they follow political sides, and consequently being risk tendentious when it comes to delicate topics as nuclear power.

Challenges related to nuclear weapons *proliferation* are also factors that frame nuclear power. The International Atomic Energy Agency's safeguard system under the Nuclear Non-proliferation Treaty (NPT) which literature confers to as a success, has involved cooperation in developing nuclear energy. This cooperation has at the same time ensured that civil uranium, plutonium and associated plants are used only for peaceful purposes and do not contribute in any way to proliferation of nuclear weapons programs.

Many countries have given up on nuclear weapons, in light of the importance that their proliferation would have on the enhancement of threatening the national security rather than protection and enhancing it.

Public's perception on further dissatisfaction to nuclear power, it is due to the misperceived association of nuclear power to nuclear weapons. Yet, to date, peaceful nuclear policies are followed by several countries, which developed ambitious civil nuclear programs without any military policy (United Nation Office for Disarmament Affairs UNODA, 2017). Thus, when the discussion of nuclear weapon proliferation in light, the perception goes beyond economic efficiency and environmental impact level, and out comes the fear of nuclear weapons proliferation. This approach concerns the global power balance, with major impact on the decision making.

The solution to nuclear weapons proliferation is thus political more than technical, and it certainly goes beyond the question of uranium availability (WNA, 2021). To just think about the international pressure that many states have on not acquiring weapons, it should be more than enough to stop most states from developing a weapons program. The major risk of nuclear weapons' proliferation will always be towards the countries which have not joined the NPT and which have significant unsafeguarded nuclear activities, and those which have joined but disregard their treaty commitments (WNA, 2021).

The countries that are considering developing weapon programs but at the same time do not want to face the possible consequences of a formal proliferation are incentivized to initialize a power program which also can function as a covert research program for further development of weapons. Consequently, nuclear power production is a political discussion at the highest level. (Florentina, 2020)

Physical safety is among factors perceived as a risk on nuclear power implementation. Thus, people believe that living close to a nuclear plant might have indisputable risks on them. WNA, 2020, explains that the transfers of nuclear material or equipment would not be diverted to unsafeguarded nuclear fuel cycle or nuclear explosive activities. The governments are to oblige with the delivering of this service as to guarantee the physical protection measures in the transfer of sensitive facilities, technology and weapons-usable materials, and strengthened re-transfer provisions.

2.3 Acceptance of nuclear power stations

As was discussed in the previous section, public's acceptance of nuclear power is an important key factor. Previous researches and studies have focused also in recognition of nuclear power stations and how they perceive the positive and negative effects.

People tend to accept the nuclear power stations focusing on the idea of a secure energy supply but small number relates it to climate mitigation (Siegrist et al., 2007). Nuclear power is considered less an advantage for the climate than it is for a secure energy supply, even though nuclear power stations are often promoted as producing no CO2.

When ask to choose between the lesser bad, people tend to recline a little more on nuclear power stations to mitigate climate change (Bickerstaff et al., 2008), because people put more value on energy supply benefits than on climate benefits.

Climate benefits are not noticed immediately, and more often are perceived as belonging into the future, on the other side energy benefits are immediate, direct. Thus, a secure energy supply is personally relevant, whereas climate change reduction is not (Lorenzoni & Pidgeon, 2006). It is not enough for nuclear power to mitigate as a possibility for climate change, as if it not enough for one country, let alone one person to make an impact by choosing nuclear power and other CO2-neutral energy sources. Leiserowitz, (2006) specifies that this is not an issue of perception of an individual or a country, it's a global cause, and people tend to they easily pass off their responsibility to others.

Nevertheless, nuclear power's contribution to GHG emission reduction, in a longer-term perspective, focusing on non-electrical applications of nuclear energy, could be applied and on their turn these applications could enlarge significantly.

In order to estimate in full, the usefulness of nuclear power´s applications at the industrial level and its economic competitiveness as an alternative to fossil fuels and renewable sources, it would be necessary to invest on research and development, but it won't be impossible. Governments could play an important role by supporting such research and development, and international organizations could assist in this process by promoting and facilitating exchange of information.

3. Misconceptions

The previous section discussed in detail the precepted risks on nuclear power. Together with the risks, misconceptions also have an effect on highlighting its importance and benefits. There is a considerate misconception on nuclear power and on its role on climate change. On several occasions when related to climate preservations, there is a misconception that nuclear won't do.
Many discussions and literature point out that nuclear energy is not safe; on the contrary, nuclear power is one of the most highly regulated industries.

People are influenced by their emotions in accepting the idea of nuclear power stations, especially when they do not feel knowledgeable about the issue, they use, instead, their "gut" evaluation in order to form an opinion about the issue (Dohle et al., 2010).

According to European Commission, (2007b), many report that they feel uninformed about the safety of nuclear power stations. Therefore, they cannot rely on their knowledge about the past performance of the relevant actors as an indicator of the risks of nuclear power; rather, they focus on their social trust in these actors (Earle et al., 2007). Thus, the safety of the nuclear power needs to be addressed with facts and lack of knowledge brings influences in the misconception.

Nuclear energy it is often reviewed as a big contributor to carbon emissions. According to the data retrieved for the article of Visschers, Keller, and Siegris (2011), NP got one of the smallest carbon footprints and will save 9 million tonnes of CO2 per year equal to taking 4 million cars off the road each year (Visschers 2011). Dones et al., (2004), has clarified that *"in the fight against climate change, nuclear power can be seen as one possible mitigation strategy, as this type of energy resource has extremely low carbon dioxide emissions during its life cycle"*.

Unlike fossil fuel-fired power plants, while operating, nuclear reactors do not produce air pollution or carbon dioxide. Dones et al. (2004) went further on explaining that nuclear power plants also have large amounts of metal and concrete, which require large amounts of energy to manufacture. If fossil fuels are used for mining and refining uranium ore, or if fossil fuels are used when constructing the nuclear power plant, then the emissions from

burning those fuels could be associated with the electricity that nuclear power plants generate.

Further, on the safety issue it is often perceived that nuclear reactors can explode like bombs. Whilst that is one of the frequent issues addressed in the literature, it is not possible for a nuclear energy plant to explode like a bomb because the enrichment level of the uranium is too low. Nuclear energy plants are designed to produce electricity safely and reliably.

On its report in 2008 European Commission (2008) suggested that the number of people accept nuclear power seems to have increased in Europe during the last few years, and this is due to increased knowledge on nuclear power possibility to CO2 reduction to mitigate climate change.
One of the biggest misconceptions is regarding waste. Nuclear power is characterized by a large amount of energy produced from a small amount of fuel (Paraschiv & Mohamad 2020), thus the amount of waste produced during this process is relatively small. Nonetheless, much of the waste produced is radioactive and therefore must be carefully managed as a hazardous material.

A major environmental concern related to nuclear power is the creation of radioactive waste. If not handled property, nuclear waste can have unhealthy effects on animals and plant life, and without doubt on people. Florentina, and Dima, sdiscuss on their article on nuclear power dilemma that the waste is usually safely sealed in drums of steel and concrete, but a rare leak can occur. About 97% of the waste is considered low-or intermediate-level waste, which accounts for 5% of the radioactivity.

What is very important when it comes to NP waste is their storage, which involves maintaining it isolated from the environment. Over 90% of the waste produced from nuclear power stations is classified as low or intermediate-level waste. Just a small amount of nuclear waste is classed as high-level waste and does need to be stored long-term.

Most discussed risk of waste management is the hazard with high-level waste, radioactivity, although this diminishes with time.

Now, many advanced technologies have been developed by nuclear industry has developed many technologies, which deal only with waste disposal. At the moment, nuclear waste is stored above ground.

The risk of radiation is among the most discussed issues and often treated as a misconception. Radiation levels during normal operations of NP are below what is considered harmful. However, accidents, can lead to fatal radioactivity levels. Previous literature has discussed that the risk of direct severe accidents for workers and the population nearby from nuclear plant catastrophes is still relatively low.

It has not clearly made a comparison between fatalities from the nuclear power plants and other technologies, but was often concluded that fatality rates are significantly lower for nuclear than for coal, or expected terrorist attacks, if comparing immediate fatalities (Hirschberg, S., et la., 2016).

Thus, to create a full picture of risk of radiation and consequently fatalities that might come as a result of an accident, we should address it case by case. It is important to specify that by giving the weight to different factors of different incidents, as to fatality rates over maximum consequences it can lead to different view on which technology is preferred in terms of accident risk.

Also, several documents specified that people consider nuclear as dirty. The facts show a very different situation. Nuclear energy is one of the cleanest sources of energy, emitting no greenhouse gases when generating electricity. Nuclear power plants don't burn anything. On the contrary they produce uranium atoms to generate heat. The white plume seen rising from nuclear plants with cooling towers is clean water vapor. It contains no pollutants, and it is not radioactive – the nuclear process takes place inside a secure containment building, not the cooling tower.

4. The Paris Agreement key elements and their relevance to nuclear energy

Article 2 of Paris Agreement, clarifies, we cite: *"Holding the increase in the global average temperature to well below 2 °C above preindustrial levels and* pursuing efforts to limit the temperature increase to 1.5 °C above preindustrial levels..."

This study, aims to explain that nuclear power is one possibility, for the yet unaccepted nuclear energy pillar, which contributes on preserving climate change, with the help and of the international contributions under the Paris Agreement.

Nuclear power, together with hydropower and wind-based electricity, is among the lowest greenhouse gas emitters. (IAEA, 2016) and it can be considered as a low-carbon technology. The question that rises is if it will be a suitable alternative to address climate change mitigation. The issue of holding the average temperature levels well below 2°C, as foreseen in the Paris Agreement, which experts believe is a threshold that for worst impact of the climate changes.

Nuclear power, as a technological option, can be effective as a long-term strategy related to climate change. De-carbonization of the power sector also calls on significant use of coal and natural gas with CCS. However, CCS produces higher GHGs emissions than nuclear power and many technical and economic uncertainties remain (IEA 2016).

Nuclear energy is environmentally primal as it not only reduces carbon dioxide emissions, but it also impacts less on different aspects of the ecosystems, such as the usage of land, also maintaining biodiversity of wildlife. There are still some considerate concerns on water use and waste, there is still a possibility to be used as an alternative solution. Also, similar concerns regarding environmental integrity apply to all forms of energy generation and use, thus we should seriously be considering (Schneider, 2020).

Furthermore, some of the advantages in integrating nuclear energy under the Paris Agreement are the clear mitigation outcomes it generates and therefore their relatively easy calculations. Moreover, nuclear power might introduce less legitimacy- related problems as an instrument for reducing carbon dioxide emissions, especially when compared to other ways of generating electricity on a large-scale. Parsons et al. (2019) see nuclear energy essential in meeting the climate goals and the Paris Agreement.

On a positive interpretation nuclear energy could contribute to enabling alternatives for coordination across instruments and relevant institutional arrangements. In case it is deployed

regulations and organizations have to be updated, too, which would be an open window for introducing energy-efficiency, into the market.

At the same time, it could introduce several opportunities for the local economy, such as making it more efficient and less prone to disturbances, opening new economic sectors and activities, or making electrification of households or mobility possible (Hoch, Friedmann, and Michaelowa, 2018).

Lastly, its adoption promotes the international cooperation, focusing different possibilities that could be a direct influence in the climate change issue.

Nuclear energy could be considered as a considered as an alternative, a considerable one, to the environmental integrity, which ultimately makes nuclear able to combine mitigation and adaptation. Nuclear power has potential as all low-carbon energy technologies, and it is needed to meet the Paris Agreement goal of limiting the rise of global temperatures to below 2°C (IAEA, 2016).

5. Newcomers

Statistics of World Nuclear Association (WNA), the main organization representing the interests of the global nuclear industry, show that there is a large number of countries (currently over 30) about to enter the nuclear sector. These new countries have either started planning or are advanced in introducing nuclear power. (Schneider 2020) In the view of discussion of this chapter, this section focuses on the main topics previously discussed and ho the “newcomers” perceive and embrace them on their plans of embracing nuclear power.

5.1 What motivates newcomers in developing Nuclear Power?

The literature has widely interpreted motivations based on which the countries rely on for embracing Nuclear Power. The main motivations identified among the newcomers were the continuously growing energy demands desire to increase energy dependency, increase diversity of sources and mainly mitigation of local and global air pollution.

In the 2000's there was a considerate increase of interest on nuclear power and it was positively related to climate change and stronger global markets. According to the International Energy Agency, electricity generated by nuclear energy is currently the second most important low-carbon source in the world, with 443 GW in global capacity in 2019.

Milko Kovachev, head of the IAEA's nuclear infrastructure development section explained that the "Newcomer countries have a key role to play in the global transition to clean energy". The need for low-carbon energy both to power economic growth and to meet climate goals are the main reasons and motivations that includes them in the picture of nuclear power as a mitigate for climate change crisis.

5.2 Safety Culture Issues, and the Need for an Improved International Safety Regime

No nuclear-power industry is successful if there Is no safety culture in place, for which countries already implementing it and newcomers are continuously working for. (IAEA, 2016c)

Literature has previously identified the attributes of a strong safety culture (Morrow et al., 2014) in relation to operations, management and political environments. Strong safety measures include, but not only: rigorous operator training, a cultural environment that allows any individual to raise safety (and security) without boundaries, a weak or unstable political and social atmosphere in the country, a non-dominating "top-down" Nuclear power management approach, a strong national nuclear regulatory institution and so on.

In order to achieve a high level of safety, it is required a high level of a well-designed and well operated nuclear power station, that meets all applicable codes and standards (IAEA, 2006b).

New comers are working more towards creating the safety culture by focusing specifically on socio-cultural aspect, which involves the organizational, communication and operational procedures that account for the cultural environment and collective preferences for certain values over others and on political-cultural aspect. The latter must include the political support of the government and policy makers, focusing on providing a national security

which is independent for the politics. Without all these attributes, it will be unlikely to achieve on a national level an accepted application of the nuclear power.

CHAPTER THREE - METHODOLOGY

This paper focuses on providing an answer to the question as of "Why isn't nuclear power used to it full potential to mitigate climate change and how could it contribute to advert its impacts." To answer the research question and achieve the objectives, this study used qualitative research methodology, focusing on a narrative analysis. To facilitate the analysis, the question is divided in two parts. The literature review section focuses on the first part of the question and explores relevant existing literature to explore why nuclear energy is not being used to its full potential as a mitigating energy resource for climate change. The discussion and results section focuses on exploring how nuclear power could contribute as a mitigator for climate change.

For the purposes of the qualitative review, qualitative research was defined as research that investigates phenomena in their natural settings, by describing and/or interpreting meanings people give to them. It encompasses a diversity of data gathering techniques such as already existing document and literature analysis. Other qualitative approaches are embedded in a number of different theoretical and methodological frameworks, such as, case studies, ethnography, phenomenology, grounded theory, action research, content analysis, and others (Noyes, Popay, Pearson, Hannes and Booth, 2008). This study in order to answer its question, analyzed a real-time phenomenon within its naturally occurring context with the consideration that context will create a difference (Kaarbo & Beasley, 1999).

The already available data that was collected and used in this research, from various nuclear energy stakeholders helped illustrate not only lessons learnt and good practices in the development of nuclear energy, but mainly, it provided insight on how they will impact geopolitical implications, such as international energy relationships as means to influence other nations. It also provides insight as to what security concerns are associated with the decision of these newcomer countries to include nuclear energy in their energy mix. These findings will be collected from analyzing cases of newcomer countries who are part of the international group implementing nuclear power. Later, the collected data will be compared, and it will provide the reader with a picture of gains from the implantation of nuclear power projects and the risks associated and security implications that they bring with them.

This study used a descriptive, narrative style, by providing a particular benefit that allows examining different forms of knowledge that might otherwise be unavailable, thereby gaining new insight.

3.1 Advantages of using qualitative method

This study uses secondary data from previous literature, as an advantage in providing a nuanced, empirically-rich, holistic account of the importance of newcomers in balancing the global transition to clean energy.

This method design will allow having a wide understanding and a better grasp how important is the international political support is utterly important for the successful development of nuclear power for the climate change benefits. This area of information is little explored and an extensive analysis of the various variables will contribute in explaining the safety, security and non-proliferation concerns associated with newcomer countries.

Flyvbjerg (2006) states that: "The advantage of the case study is that it can "close in" on real-life situations or phenomena and explain views directly in relation to the phenomena as they unfold in practice", by comparing country-by-country analysis of implementation on nuclear power, based on the findings and the data available.
The question of this study, why is nuclear power not being used to its full potential as an alternative energy source to adapt to climate change, could be better understood by introducing both the in-depth, contextualized, and natural but more time-consuming insights of information's from the already existing data. Data is composed by documents, previous studies, publications, reports of international organizations statistical data from national and international institutions etc., to help explain the current situation of already existing and newcomers in the nuclear power market.

3.2 Criteria for selecting the literature

Each identified and utilized records in this study were assessed according to the criteria that they were peer-reviewed literature and the information was official. Each of the publications addressed several issues and aspects of the nuclear power to specific countries ultimately related to its possible impact in climate change.

It exclusively aimed to use existing articles and data from official sources to make conclusions on the research question and does not include any direct contact with the research object.

The literature on country-specific analysis is structured based on their relation to nuclear power as being the countries with nuclear power, countries with a major nuclear industry that have not sought economies of scope, countries that use nuclear power to generate electricity but have not developed a national industry themselves, countries that do not correspond to any of the previous categories, also newcomers and potential newcomers to the sector.

This study excluded quantitative research methods due to the circumstances on the pandemic; nevertheless the findings from existing quantitative research have been crucial for the analysis of this study. To achieve a strong qualitative analysis, findings from existing quantitative research retrieved form e official documents and public statements are compared with the relevant scientific literature.

Further, the study had a broad unit in focus, taking into analysis countries as the United States which currently has the largest number of nuclear units, Russia, which is the global top exporter of nuclear technology and expertise and three newcomers located in Africa. Namely, Algeria, Egypt and Nigeria are used as study cases to discuss the geopolitical implications of buying and importing nuclear technology and the security implications of these decisions. This study did not focus on a specific region, because it evaluated nuclear power and its relation to climate change, as a global issue, although it conducted detailed interpretation on power countries on nuclear power.

3.3 Research material

The information and the data gathered were retrieved from several sources as, documents, reports, literature and the media.

Reports, documentation and data as well as the literature were the main of data for this study. They involve official reports from governmental and companies' webpages such as Nuclear Regulatory Commission, European Commission, International Atomic Energy Agency, International Energy Agency, World Nuclear Association, on national and international

energy issues, official strategies, and other policy documents. The literature used and evaluated is focused more on scientific papers on the nuclear energy and its relation to climate change. There was not a timeframe for the referred literature considering that the research on nuclear power in in a continuous development.

Lastly, data gathered from the media, although not a very broad use is applied to get a broader overview of the countries' plans, taking in consideration that many of the government's decisions on nuclear power are not officially documented or the information is inaccessible. Also, these data are mainly used to argument the literature review chapter, on misconception.

Based on this data, the study provides misconceptions and economic, social and other dimensions why nuclear power is not used, based on illustrative results of the studies reviewed. Further it proceeds with specific arguments on the important linkage between climate change and nuclear energy.

CHAPTER FOUR - DISCUSSIONS

According to IEA about 10.4% of the world's electricity was generated by nuclear power plants in 2016. (IEA, 2018) It is estimated that in December 2017, globally, distributed amongst 30 countries in the world, there were 448 nuclear reactors which accounted for 391.7 GWe of installed capacity. (IAEA, 2018)

Countries have adopted different policies and rules when it comes to the use of nuclear energy. The commitment towards maintaining nuclear power as a future option in the energy mix is dependent on specific characteristics. Depending on these specific countries are categorized in three groups, countries that are gradually lowering its usage or immediately abandoning it, countries that are keeping the use of nuclear energy constant and, finally, countries that are expanding their use of nuclear energy. To illustrate, France is a country that falls under the third category of countries that are gradually lowering its usage. In 2017, France held the first place in Europe for the country with the highest number of nuclear power plants. 58 nuclear power plants accounted for about almost 72% of the country's total electricity production or 631 30 MWe net capacity. (IAEA, 2018) (IAEA, 2020) France was producing electricity at a low cost and it this benefit contributed towards making France hold the first place on a global scale of electricity exporter. (IEA, 2017a) In the light of the European Union's countries decisions for the mitigation of GHG emissions, and incorporating more renewals in their energy mix, France ratified a law which states that nuclear participation in the energy mix in generating electricity should be reduced from 75% to 50% by 2025. (Banet and Wettestad 2017)

4.1 Greenhouse Gas Emissions and Climate Change

The United Nations Intergovernmental Panel on Climate Change has established the consequences of greenhouse (GHG) gases in the global climate change. (IPPC 2019) If GHG emission trends continue, the impacts, as we have started to witness, bring devastating consequences for human lives and ecosystems. (IPCC 2007; Hansen et al. 2013) In the light of these established global changes in climate, 190 countries signed in Paris in 2015, at the United Nations Conference, an agreement which underlines the urgent need to limit the global average temperature increases to 1.5 °C by 2050 through the redocument of GHG emissions. (Young 2015; Joeri & Rogelj, 2015) IAEA estimates that in achieving the above mentioned target, several changes must be made, amongst other fields, it is imperative to

focus and action in the energy field. It is estimated that by 2050, 80% of electricity must be produced from a combination of different types of low carbon dioxide emission technology energy generation plants. (IAEA, 2017)

The main contributors in the world energy mix are fossil fuels. According to IEA (2017), fossil fuels in 2017 account for 81% of the world energy mix and it is also the main source of GHG emissions. (IEA 2019) Most of the GHG emissions worldwide are caused by the electricity production sector. Electricity produced from coal account for 85% of CO2 emissions worldwide. Countries who are the largest emitters by the use of coal-fired power plants are China, the United States (USA), India, Germany, Russia, Japan, South Africa, Australia, South Korea and Poland. These countries are responsible for 84% of the total emissions mentioned above. (Finkenrath et al., 2012)

Fossil fuels are used heavily in electricity generation because their abundance, firm energy generation and access to plants with available technology and rapid construction. (IEA 2016) Still, these plants have a high contribution towards CO2 emissions and the concentration of GHG released in the atmosphere. Some countries have been working towards minimizing the negative impact of their coal based electricity production technology by investing in new coal-fired power plants by using supercritical technologies. These technologies and their lower emission indexes have been proved attractive to countries such as Japan, Germany and South Korea. (Finkenrath et al., 2012)

In this context, nuclear energy, an energy source which does not emit carbon dioxide while generating electricity, is an important alternative for electric power generation. As such, it has an important role in mitigating climate change (WNA, 2016; IAEA, 2017). IEA estimates that nuclear power, a low carbon energy source, generated a third (31.5%) of the world's energy. (IEA, 2017a)

In the scenario of limiting the temperature rise by 1.5 °C until 2050, nuclear power must be included in the energy producing mix. Moreover, its power plant installed capacity needs to increase and make nuclear power accountable for the production of 17% of the world's electricity production. However, there are some serious obstacles that need to be taken into consideration when setting these goals. Firstly, some countries, such as Germany, have completely shut down their nuclear power plants since the Fukushima accident. Secondly, it is worth noting, that if we assume that the maximum life length of a nuclear reactor is 60

years, almost half of the existing nuclear power plants will be decommissioned by 2050 and more than a third will be at the final stage of their life. More specifically, in 2014, 146 units raged between 21 to 30 years of age, 133 units from 31 to 40 years and 39 reactors with more than 40 years. (Schneider2015) In the present situation about two thirds of all the world's nuclear capacity are through half of their official lifespan, they have been in operation for more than 30 years. Some countries are considering investing in programs for long term operation for their nuclear capacity. (IAEA 2018) All the data suggests that to achieve the 17% target for nuclear generation by 2050, there is a strong need for investment from public and private sectors towards the nuclear power production chain. (IEA 2019)

Countries which currently have nuclear energy in their power mix need to think in advance about their life expectancy. Reactors in some of these countries have an estimated life expectancy of 30 to 40 years. If these countries plan to continue including nuclear energy in their power mix it is imperative that when the reactors are decommissioned, they can be replaced by new ones. The new technology of nuclear reactors called Generation III and III + are being designed to operate for up to 60 years. This technology will result in low GHG emissions for a long time.

4.2 Energy and Emission levels

The largest source of GHG emissions in recent years, around two thirds of total emissions, is the result of the production and use of energy. (International Energy Agency, 2019; EDGAR, 2019; Friedlingstein, 2019) Emissions from electricity generation have more than tripled since 1970 now accounting for one third of total emissions from energy production and use. Coal and gas fired power plants account for close to 95% of direct CO_2 emissions from electricity generation. (International Energy Agency, 2019) The emissions would have been higher if it had not been for the use of low carbon nuclear power. Low carbon generated electricity has been provided vastly by hydroelectricity and nuclear power with the latter supplying close to 50% in the 1990s assessed to having avoided a total of 74 gigatons of carbon dioxide (Gt CO_2) between 1971 and 2018. (International Energy Agency, 2014) This highlights the critical importance in the role low carbon electricity production and use has in climate change mitigation and the substantial larger role these sources will play in the future in decarbonizing electricity generation worldwide.

4.3 Nuclear Power and CO2 Emissions

How can nuclear power contribute to mitigating climate change? Nuclear power plants are a clean electricity source which does not release CO2 in the atmosphere during the production process. Siquera (2019) estimates the potential of nuclear power plants in avoiding CO2 emissions based on present and future nuclear generation by country and groups of countries. In estimating the potential of nuclear power plants to avoid CO2 emissions the generation prospects of groups of countries are considered. Tint he analysis the main driver of the study is the level of investment in electric energy generation by nuclear power for the years 2020, 2030 and 2050.

In the low investment scenario, the projections of the future of nuclear energy are conservative and plausible. In this scenario few changes happen in laws, policies and regulations and the trends in the market, technology and resources continue. On the other hand, in the high investment scenario the projections are more ambitious. In this scenario, economical and electric demand growth in countries will be achieved by technical feasibility together with changes in national policies regarding nuclear power and climate change.

The model used by Siqueira (2019) estimates that in 2015, due to nuclear power, CO2 emissions avoided worldwide range from 1.86 to 2.41 billons tons. This estimate was further supported by IAEA (2016b). The organization reports that for the same period, nuclear plants contributed to reducing 2 billion tons of CO2 emissions from entering the atmosphere.

According to the model used by Siquerira (2019) compared to the numbers presented for 2015, the CO2 emissions levels tend to be reduced for a low investment scenario. For 2020 the projection tends to be reduced by 4.5%, 28.4% for 2030 and 45.8% in 2050. Variously, in the high investment scenario, the level of CO2 emissions avoided by the use of nuclear power increase in comparison to those of 2015. Respectively, the levels of CO2 avoided will increase by 4.1% in 2020, 11.1% in 2030 and 17.4% in 2050.

The USA is the largest producer of electricity by nuclear power plants globally. As of 31 December 2019, the USA has 96 operational power reactors, the highest number of operational reactors in the world. However, the low investment scenario is strongly influenced and based by the US nuclear policy which opts for investment in other energy producing sources and technology, such as gas. Still, the installed capacity of nuclear power

plants is expected to have a growth of 4.8%. (Zummo 2015) According to NEA/OECD (2017) by 2030 the USA will be generating 789TWh electricity by nuclear power plants. Based in these predictions, the country's part of contribution in the North American group in non-CO2 emission will vary between 106.6 and 79.5%.

According to IAEA (2018) in 2017 nuclear reactors in Russia were generating 17.79% of the country's electricity. The future projections result in having nuclear power generate 20.8% of the county's electricity by 2030 or 239 TWh. (EIA 2016) Meanwhile, other projections, such as the one by NEA/OCDE (2017) indicate that Russia's nuclear reactors will be producing more electricity than what IAEA predicted, specifically 288.6 TWh. If these forecasts will be contextualized, it would correspond to 48.3% for the lo investment scenario and 60.8% for the high investment scenario. Also, it should be highlighted that by being the largest exporter of nuclear power plant technology in the world, Russia promotes electricity generated by nuclear power and indirectly contributes to non-emissions of CO2 from other countries in the world.

Globally, in a low investment scenario avoided CO2 emissions will remain at similar levels to the current ones, hence, this scenario will not be a high contributor in the much-needed change to achieve the Paris agreement goals. However, this scenario will not tip the other side of the scale, as in the scenario where the contribution towards the avoided CO2 emitting will be null in the scenario of early decommissioning of nuclear power plants. The high investment scenario will be more efficient by avoiding higher levels of CO2 emissions in the atmosphere.

4.4 Prevented mortality

Climate change due to greenhouse gas (GHG) emissions from burning fossil fuels will have catastrophic impacts for natural ecosystems and human society. Several studies analyse the impacts of man-made climate change. However, we have been able to see for ourselves these effects as recently as last month. Individuals from across the globe are experiencing first-hand extreme weather events. The key time frame to mitigate climate change is the next decade.

During the month of June and July 2021 unprecedented rain falls followed by killing floods devastated central China and Europe. Floods represent an immediate risk of death or injury

and are deeply traumatic for the ones affected. Wildfires and record drought have become yearly occurrences in the US. Extreme temperatures as high as 49 degrees Celsius have been recorded in Canada and the heat tropic embarked in Ireland and Finland. (Januta, 2021)

Since these occurrences are very recent and studies haven't been conducted yet, we still don't have empirical results as to the consequences. However, studies have concluded that the 2018 heatwaves in UK show that the high temperatures have led to 8,5000 heat-related deaths. Additionally, more recently, in 2020 16 tropical nights were recorded in the UK with temperatures remaining above 20 degrees Celsius. These conditions are rare for the UK and are associated with harmful health conditions. Between 2004 and 2018, heat related mortality in persons older than 65 increased by 21%. (Watts et al. 2020)

It is estimated that these extreme weather events were made 30 times more likely due to of anthropogenic gas emissions. (UK Met Office 2018) These extreme experiences are shown to lead to heightened risk of mental health issues. (Walker-Springett et. al. 2017) The extreme weather events described above are characterized as direct. The global atmosphere is 1.2 degrees Celsius warmer than the preindustrial average and today we are experiencing for ourselves the projections that scientists have long predicted and that we have been only reading about in the past.

Moreover, climate change is impacting human health in indirect as well via ecosystems by the means of air pollution and infectious diseases. It is estimated that outdoor air pollution due to fossil fuel burning has caused over 1 million deaths annually worldwide. These severe issues that derive from climate change are a reminder of the urgent need to reduce GHG emissions. (Tom Levitt, 2021) Amongst other low-carbon or carbon free energy sources, nuclear energy could help mitigate the consequences of climate change.

In the next decade or so, the future of global nuclear power will be decided, mainly by choices made by major energy-using countries. (IAEA 2011) As previously discussed, the Fukushima accident has impacted the plans of some nuclear countries. While some highly dependent nuclear countries have decided to continue developing and using nuclear technology, other countries have decided to not pursue plans for new plants or phase out existing plants. (OECD 2011)

To calculate an estimated number of deaths prevented, data for global annually electricity generation by energy source must be collected and analyzed. Mortality and GHG emissions factors are applied to these numbers. These latest are defined as “deaths per unit electric energy generated depending on the energy source”. (Kharecha & Hansen 2013) The authors estimated the total of deaths avoided by the use of nuclear power for the projection period from 2010 to 2050 based on statistics and data by IAEA. In estimating a number for their analysis, the authors assume that the electric energy produced by nuclear power would have been produced by fossil fuel sources such as coal and natural gas.

Results of the study conclude that the number of human deaths prevented by nuclear power production from 1971 to 2009 is 1.89 million. The average number of prevented deaths from 2000 to 2009 is 76 000 deaths/year. After the Fukushima accident Germany decided to phase out nuclear power and shut down all its nuclear plans by 2022. It is estimated that from 1971 to 2009 by using nuclear power, Germany has prevented an estimated of 117 000 deaths. (Kharecha & Hansen 2013)

The number of human deaths caused by nuclear power for the same time period is 370 times lower than the number of deaths avoided. The calculations show that globally 4900 deaths were caused by nuclear power. (Kharecha & Hansen 2013) From 2009 to 2011 the top 5 CO2 emitters were China, the United States, India, Russia, and Japan. These top emitters together account for 56% of global emissions in the above-mentioned period. In regard to number of deaths caused by nuclear energy, approximately, 1800 is the number of those for Europe, 1500 for the United States, 540 in Japan, 460 in Russia including in the calculation all the 15 former Soviet Union countries, 40 in China and 20 in India. As to the reasons for these deaths, 25% of the total number is due to occupational accidents and about 70% are due to air pollution related effects, such as fatal cancers from radiation fallout. (Markandya & Wilkinson 2007)

Based on empirical evidence demonstrate that the Chernobyl accident from 1986 is the world’s only source of fatalities from nuclear power plant radiation fallout. As of 2006 the conclusive number of deaths attributed to radiation from Chernobyl is 43, where 28 were plant staff and first responders and 15 were from the 6000 cases diagnosed with thyroid cancer. (UNSCEAR 2008) Apart from inconclusive reports of an increased number of leukaemia cases among recovery workers, there has been no further evidence of other health related effects among workers or general population.

What's more, there is no scientifically validated evidence proving that the other two major nuclear accidents, Three Mile Island in March 1979 and the Fukushima Daiichi in March 2011 are responsible for deaths due to radiation. A 20 year comprehensive scientific health assessment was done for the March 1979 accident. (Talbott et al. 2003) Although it is too early for a conclusive analysis on the long term health impacts of the Fukushima Daiichi accident, preliminary findings from scientific health assessments suggest that the general radiation annually threshold for fatal disease development was not exceeded. (Kinoshita et al. 2011)

For the projection period of 2010 to 2050 Kharecha & Hansen (2013) conclude that deaths prevented globally by nuclear energy power production is an average of 4.39 million for the low-end projection of IAEA and 7.04 million deaths prevented for the high-end projections of IAEA. (IAEA 2017) However, limitations are present in the projections and calculations of deaths avoided for the above mentioned period. The study doesn't consider in the mortality factors the impacts of ongoing or future anthropogenic climate change. (Markandya & Wilkinson 2007)

Finally, the false division between reducing air pollution and stabilizing the climate, as argued by some, must stop. (Hansen 2000) (Shindell 2012) If the two issues are considered as separate, governments might decide going for near future solutions that will decrease air pollution such as starting large scale production and of "syngas", gas derived from coal. This alternative is possibly a climate impacting electric fuel switching. This option could be a good alternative for reducing air pollution and consequently the deaths associated to air pollution. However, the GHG factor for emissions from syngas is between ~5% and 90% higher than coal, which can have more serious impacts towards climate change deriving from GHG emissions in the long term.

4.5 Energy Infrastructure and Climate

Global warming is associated with many risks. Amongst the five reasons for concern, according to IPCC, are extreme weather events. (Masson-Delmotte, 2018) World leaders are concerned as over the last decades societies face more frequent and extreme weather events which cause power outages and damages to infrastructure. (WEC 2020) (AON 2016) (SRG 2017) As referenced by Obolensky (2019) in the USA 44% of power outages stemmed from natural disasters which shook the financial stability of states not only by increasing the

vulnerability of the poor, but also by having very large costs of repair as high as billions of dollars. (Zamuda 2018)

The frequency and severity of environmental conditions such as storms, floods, heatwaves, and water stress are expected to increase in the future. These events will threaten, test, and impact the energy infrastructure. (IAEA 2019) Renewable energy sources are vulnerable to weather conditions depending on their location or initial design. In the future, NPPs may be affected by extreme weather events. More than 40% of NPPs are located near shorelines and they might be particularly exposed to storm intensity and sea level rise. (IAEA 2020) Inland NPPs can be affected by wildfires and increasing fresh water temperatures. (IAEA 2018) Additionally, in periods of extreme hot weather, power outages may be mandatorily initiated to avoid plant damage.

It is important to build durable energetic infrastructure that won't be impacted by the future severe environmental conditions. These extreme weather risks should be considered in future energy panning and introduce resilience-by-design when planning for energy transition projects. Resilience and adaptation need to complement each other in the transition towards low carbon electricity generation technologies.

4.6 Financing Nuclear Power

Over the next decades there needs to be a considerable growth in the number of new reactors built and functioning for nuclear power's potential to be realized. But the deployment of new nuclear capacity is challenging to finance. The typical timeframe for the construction of an Nuclear Power Plant (NPP) is seven years, and it is considered the time between the first physical act of construction and the connection of the plant to the grid. (IAEA 2020) However, shorter construction times have been realized in the past. These examples have been observed in countries with large ongoing nuclear programmes such as Japan. (WNA 2019)

Building a NPP requires a vast number of resources such as thousands of qualified workers, materials, specialized components, equipment and systems which must be inspected, tested and of the highest standard and quality. (Shin 2018) These projects are also characterized by long and complex regulatory processes which include public consultations, impact assessments and political risks. In regard to the building new nuclear projects, in the recent

decade there have been cases of delays and cost overruns in Europe and USA, but also examples of delivery on time and budget in the Russian federation, China and the Republic of Korea.

The cost of building an NPP is specific depending on the region, country, and site. It has been seen that the total capital construction cost with interest for recent nuclear new build projects is higher in Western European countries than it is in Asia. (Gogan 2019) Some key factors at the local level that affect the costs and delivery on time can be shipments, site preparation and the capabilities of the supply chain. According to studies, experience gained over time by plant developers, vendors, work crews and regulators is the main route to lowering costs of nuclear construction by building an efficient supply chain. (IAEA 2012; Shakhkarami 2017) Additionally, when it comes to successful project competition, factors of importance are effective planning and collaboration and partnerships by shared commitment. (Solzhenitsyn 2018)

As seen above, financing new nuclear plans is pricy. The owner or operator which could be a private or public entity is accountable for financing the project, however, governments can contribute to de-risking the financing of NPP. They can fund and establish legal frameworks and set up institutions to implement nuclear power programmes which could be responsible for creating emergency responses and funding radioactive waste disposal and NPP decommissioning. The de-risking has done by the government can attract funding as investors are attracted by projects which are considered sustainable and profitable.

Multiple benefits were shown to be generated in countries hosting NPPs. Investment programs in nuclear power tend to bring benefits also in cases of joint projects between countries. For countries engaging with foreign suppliers, especially in the cases of newcomer countries, increased employment in close proximity to a NPP are benefits of the country where the NPP is being constructed. Also, the hosting country can benefit from the construction sector and manufacturing of equipment and machinery depending on the standards of the industrial companies. (IAEA 2016; RASIEF 2017) On the other hand, the supplier country benefits the most during the construction phase of the NPP. However, some countries engage in contracts that require patenting for the use of technology or paying debt with interests. In that case the supplier country continues to earn even after the construction phase.

The longlines of life of a nuclear plant depends in many factors such as profitability, outdated technology, public acceptance and opinion, operating incidents, or political reasons. To maintain their presence in the energy market nuclear power plants must not only increase in number, but they must also make up for and substitute the numbers of the nuclear power plants that will soon be decommissioned or those that have been permanently shut down. (IAEA, 2017) Here it is worth noting that the number of nuclear plants who will need an extension in their operating licenses to continue operation is increasing. (IAEA, 2018) Additionally, as reported by the IAEA (2020), as of 31st December 2019, 186 reactors with an overall capacity of 82083 MWe have been permanently shut down, including 2 units (1208 MWe) in China. (IAEA, 2020) As of today, Europe has 129 reactors in operation, 50 of those units are planned to be shut down by 2025. (European Commission, 2017)

Concerning the costs included in the investment in nuclear power plants states interested should not only include the economic costs but also take into account the costs related to the social and environmental impacts generated during the whole life of the project. (IAEA, 2017b) Prior to construction, an extensive and expensive is dedicated to project planning and obtaining the necessary permits and licenses. The estimated cost for Engineering, Procurement and Construction (EPC) management of nuclear reactors varies from 4.5k to 5.5k USD/kW, which is considerably higher than the capital cost for other electricity producing resources such as natural gas or renewables. (WNA, 2020) (EIA, 2018)

The construction time of nuclear power plant is estimated from the first physical act of construction to the power plant connection to the grid. Stricter regulations are to be taken into consideration when considering the high capital of investment necessary for a nuclear power plant construction project. The worldwide public opposition increases the risk of delays in construction, licensing, and long commissioning time. All these are contributing factors in the raising financing costs of nuclear power plants project. (Chu, 2012) (Deutch et al., 2003) IAEA (2018) estimates that the current time of construction for a nuclear power plant is 68 months. The above-mentioned projected time of construction has decreased since 2001, this is due to greater experience with project management and standardization of projects of the reactors.

Electricity generating costs are estimated by the levelized cost of electricity (LCOE) method. This method calculates all the costs for the construction and operation of a new plant from the commencing of the project with start-up capital, return in investment, continuous operation,

fuel, maintenance, life expectancy and estimated time of construction. (IPCC, 2015) One of these factors, fuel prices influence the total cost of electricity generation. Consequently, changes in the total cost of electricity generation are influenced by changing fuel prices. Nuclear power plants require fuels fabrication for each type of reactor. The processing of nuclear fuel includes exploration and mining of uranium and processing, conversion, and enrichment. (European Commission 2016) Nonetheless, uranium account for only 14% of the cost of operation and maintenance of nuclear power plants, hence, the floating fuel price does not drastically impact the electricity generation cost. This positions nuclear power plants in a favourable place in comparison to other electricity generating technologies such as coal and gas. Since fuel has a share of 78% and 87% respectfully in the total cost of operation and maintenance, coal and gas are highly dependent on the fuel price variations.

Another reason for the low share of participation in the value of operation and maintenance of nuclear fuel is the high energy density related with uranium processing. The difference is notable where for every 1kg of fuel, fossil fuels, oil and coal produce respectively 0.004 MWh and 0.003 MWh of electricity, whereas 1kg of nuclear fuel accounts for the production of 50MWh of electricity. (IAEA, 2015) Additionally, uranium resources are spread geographically and in relatively large quantities which reduce the possibility of the monopolisation of the international market and the price fluctuation. Moreover, the ease in securing uranium along with the high energy density, guarantee diminishing logistic problems such as ensuring supply, transportation, and storage.

The nuclear power plant costs include a reserve of funds for the decommissioning, dismantling and final disposal of radioactive waste. These funds should be accumulated during the operation of the plant and are a responsibility of the operators of the nuclear power plants. The decommissioning phase is overseen by the regulatory agency. (WNA, 2016) The estimated decommissioning cost for each plant is 500 million USD. (Chu, 2012) Included in this cost is the used fuel cost and site restoration. The cost of managing the fuel used accounts for a 10% share of the total cost involved in the electricity production. (WNA, 2021) In December 2014, it was estimated that until 2050, nuclear power plant decommissioning would cost 123 billion EUR and 140 billion EUR spent for the management of fuel and radioactive waste, including deep geological disposal. (European Commission 2017)

4.7 Financing Climate Mitigation

It is argued that nuclear energy can reduce the costs of climate change mitigation relatively. So much so that developing nuclear power can be seen as returning investment in the high climate change mitigation costs. Lehtveer, (2014) used the Global Energy Transition and Monte Carlo models to estimate if and how much this energy production technology could reduce the cost of climate mitigation. The authors analysed three scenarios. In the first scenario, called advanced nuclear, there are no restrictions to nuclear expansion or technology use. In this scenario Light Water Reactors (LWR) and Fast Breeder Reactor (FBR) are allowed to be used. The second one is called conventional nuclear, supposes that only technologies that are currently available will be used in the future. Hence, FBRs aren't included in the energy mix and uranium extraction from seawater is not allowed. This diminishes the resource base of production for nuclear power. In the third scenario, called no nuclear, it is assumed that due to different challenges in relation to nuclear power the technology is phased out globally. There are no new reactors built after 2020 and the existing ones are retired by 2040.

In the projection of the first scenario of advanced nuclear, when the nuclear energy expansion is allowed, the share of electricity produced by nuclear in the supply is significant and reaches almost a third of the whole by 2050. Several delays are taken into consideration when projecting this scenario. Building of FBRs starts from 2030 but they start becoming economically competitive around 2050. This is mostly due to high investment costs in the beginning of nuclear energy projects and on the time dependent investment cost decline. Additionally, in this scenario, the expansion of LWR and FBR technologies continues thought the end of the century. It is estimated that in this scenario the number of reactors will grow tenfold. (Vaillancourt et al. 2008)

The other scenario where nuclear power is present, in the conventional nuclear scenario, also agrees with the conclusions and projections about electricity production by nuclear power. However, in this scenario it is estimated that nuclear power gradually gets eliminated by the end of the century due to the exhaustion of uranium resources and it is replaced by solar power.

The role of solar power is also highlighted in the third scenario, that of the phase out of nuclear power. In this scenario solar power reaches 32% of electricity production. In terms of

mitigation costs, it is estimated that in this scenario the discounted mitigation cost is 9 trillion US$. (Lehtveer, 2014) However, in the two previous scenarios this cost if furtherly reduced by 20% in the advanced reactors one, and by 10% in the baseline scenario for conventional reactors. These conclusions correspond with the assessments of the EMF27 study that concludes that nuclear power can reduce mitigation costs by 30%. (Sang-Wook Kim, 2014)

According to the numbers above, developing or keeping on utilizing nuclear power can be used as an insurance against the high climate mitigation costs. The option of building new nuclear power plants will be cost effective after 2040 and the cost saving efficiency will start to show in the second half of the century. In the phase out or limiting nuclear technology scenarios, the saving benefits in mitigation cost from this technology will be reduced.

In a phase out like scenario, Roth and Jaramillo (2017) analysed the economic impacts or premature decommissioning of nuclear power plants. Deciding to do so would greatly Impact the electricity prices in the USA. Nuclear power plants are put in the light of a machinery used to avoid increases in CO2 emissions from the power generating sector. It is argued, that considering any of the EIA natural gas price pathways, preserving nuclear power plants through 2040 has a lower economic cost than the social cost of carbon.

Moreover, several negative impacts are associated with the effects of nuclear energy policies, and most specifically, early decommissioning. According to the results of Bauer's "REMIND-R" multiregional model of nuclear energy policies, early decommissioning of nuclear power plants affects negatively the overall gross domestic product (GDP) by 0.07% by 2020. Furthermore, it is estimated that in the absence of a detailed investment plan in nuclear power plants, these losses could double. Bauer et al. (2012) argue that if governments decide to decommission existing nuclear capacities the global power market will suffer from a shortfall in electricity production. The energy gap left by decommissioning of nuclear power plants will not be effectively covered by other renewables.

New nuclear projects take time to be profitable due to their long construction time and also due their high financing costs. One way of reducing the cost of transition to clean energy is by extending the operational lifetime of existing NPPs. Prolonging the lifespan of NPPs beyond the original designed timeframe also represents a cost-effective opportunity for low carbon energy production for countries with existing nuclear fleet. As estimated in the latest report of IEA, lifetime extensions of nuclear power plants contribute directly to the mitigation

of climate change and are crucial to getting the energy transition back on track. (IEA 2019) This report also indicates that the level of investment in new NPPs and in long term operation programs directly affects emissions, costs and energy security.

In the decarbonization and mitigation era that we live in, low-carbon electricity sources are essential and as the only non-hydro form of dispatchable low-carbon power, nuclear power plants should be preserved as a carbon avoidance strategy. Hence, it is logical to compare the costs of building new wind and solar generation to that of keeping already existing nuclear power plants operational. Roth and Jaramillo (2017) in their analysis based on the Monte Carlo method, conclude that according to the costs observed, keeping nuclear power plants in operation, more so those with multiple reactors would be more profitable economically than investing in wind power.

When the use of renewables is incorporated in the energy mix and their expansion is legitimized to be implemented completely, the cost of electricity for the end user is estimated to vary from 80 to 95 EUR/MWh. Whereas when nuclear is used as 50% of the source of energy production the price varies from 70 to 80 EUR/MWh and in the case of its usage as 70% of the electricity production source, and with extended plant life, the price is estimated to be even lower, and it varies from 50 to 65 EUR/MWh. (Percebois and Mandil 2012)

The country with the highest number of nuclear power plants in the world is the USA. However, their reactors are also the oldest in operation with the highest average age of 37.1 years. (Schneider, 2017) Nuclear power plants near decommissioning age are no taking into consideration requests for extension of the operation period due to the high costs associated with the decision. In the scenario where North America is considering renovating its nuclear park, immediate action should be considered. In this scenario two things are to be taken into consideration. Firstly, that the average time necessary to build a nuclear reactor is 15 years and 10 months (IAEA, 2016a). Secondly, the increase of new plants and the capacity of their reactors will be lower than that of those which will go into decommissioning.

Considering the long time needed to build nuclear reactors, the project of renovating North America's nuclear park should start being implemented by the end of 2020 and with a clear roadmap of investment for the upcoming decade so that new nuclear plant capacity can be installed by the end of 2030 and 2040. Based on the current USA policies on nuclear energy a figure projection shows that nuclear generating capacity will increase by 2.2 GW for new

plants and 3.8 GW for upgrading processes. However, around the same time frame, the generation capacity from nuclear will decrease by 26.2 GW due to decommissioning. This will result in the reduction of North American nuclear generation capacity by 20.3%. (EIA, 2018)

According to IAEA (2018) in 2017, Russia had a gross output of 187.5 TWh which equals to 17.8% of the country's electricity production. In terms of numbers, Russia has 37 potentially operating reactors and 6 more under construction. Based on these numbers, Russia is in the fifth place in a globally scale regarding the number of reactors. An optimistic scenario predicts that by 2050, Russia's nuclear capacity will expend by 90 GWe. (WNA, 2018) In comparison to other countries of the world, Russia has a noticeable and recognized upper hand globally in all the phases of nuclear cycle, hence making it the largest producer and exporter or nuclear power plants in the world. (WNA, 2018)

4.8 Long term operation

About two thirds of the global nuclear capacity has been in operation for more than 30 years, which is the average operation age of an NPP. Today, many countries in the EU, USA, the Russian Federation, Canada, China and Japan are deciding whether they should invest in long term operation programs for their nuclear capacity. (IAEA 2018) Increasing the investment and the attention towards Long Term Operation (LTO) programs will avoid a decrease in the global nuclear capacity. Several countries have already adopted programs to extend the lifetime of NPPs and they provide general know-hows and technical experience that can be exported.

In reference to the technical aspects of the long-term operation of NPPs it is acknowledged that an NPPs doesn't have a predetermined technical lifetime. An NPP is made of several components, all of which have a design lifetime, but at the same time each of them can be replaced. Additionally, the design lifetime was estimated when the NPPs was constructed. Since then, several technical advancements have been achieved that couldn't be foreseen during the design and construction phase. The technical advances include adopting operational procedures to reduce thermal stress pipping, adopting core loading and fuel management strategies and better monitoring capabilities for vessel embrittlement and concrete degradation. (IAEA 2020) NPPs lifetime extensions require considerable

investments and are carefully planned and performed. After the LTO programming and implementation the NPP lifespan prolongs with three decades and the output increases.

Extending the lifetime of NPP has a double factored positive impact. They are cheaper than new build projects and they are projected to be cost competitive with all carbon generating technologies until at least 2040. (Credit Suisse 2018) In comparison to new build nuclear projects, LTO projects present an opportunity to reduce costs by having a shorter construction time, limiting construction delays, and featuring shorter payback times. By adding an additional 20 years to the original lifetime LTO projects reach the same operational lifetime of wind and solar PV projects. These are contributing aspects that reduce the project risk and financial cost by providing attractive economics in the long term.

However, despite the attractive benefits that Nuclear Energy represents, countries are prematurely shutting down NPPs and are undecided whether or not to adopt LTO projects. Barriers in considering the technology include low electricity prices, insufficient carbon prices, failure to assess the value of the services provided by nuclear power and political uncertainty.

Small Modular Reactors (SMR) are an emerging category of NPPs with smaller power level and with smaller construction financial costs in a shorter period of time. SMRs represent an alternative mode of contribution of nuclear power towards climate change mitigation. They supply low carbon energy in market less suitable for conventional NPPs. While large NPPs consist of multiple units, small NPPs can be built using a single SMR. (Mignacca & Locatelli 2020)

Identified markets for SMRs include markets that can accommodate traditional NPPs with large reactors and those that are less appropriate for large reactors. Markets that can accommodate traditional NPPs benefit from SMRs modularization such as faster construction schedule and savings on average of 15% in construction costs and 38% in schedule costs while also benefiting from the possibility of further additions and the learning effect. (Mignacca & Locatelli 2020) (Mignacca 2018) (IAEA 2018) Another potential market where SMRs perspective could be exploited is the markets which are inadequate or less accessible for large NPPs. These markets could have financial limitations such as the capital needed to sustain conventional NPPs construction and maintenance, geographical limitations such as

small islands and areas with limited access to cooling water or even technical such as small grids. In terms of capital costs, easiness of financing, shorter construction time and a lower risk profile in comparison to conventional NPPs, developing economies present possible arenas for SMRs.

However, even though SMRs complement conventional NPPs and appear valuable and represent a promising mitigation potential in the light of the urgency of the climate crisis, one persistent factor that affects their uptake is the level of public and political acceptance.

Government driven projects for SMRs have been finalized and represent successful stories and significant development. However, these projects have been planned and developed for longer than ten years.

In December 2019, in Pevek in the Russian Federation, the Akademik Lomonosov was connected to the electricity grid. A floating 70 MW power unit made of two compact pressurized water reactor modules. In January 2021, in Shidao Bay China, functional testing began for the 210 MW high temperature pebble bed modular reactor with operational startup planned for later in 2021. (Power Technology 2012) In Argentina, CAREM project is developing, designing and constructing an advanced simple and small NPP. (The project is currently at an advanced stage. (Magan et al. 2021) Multiple new SMR designs have been proposed.(IAEA 2018)

Still, even though these projects appear promising in the research and design phase, it is unclear how they will be demonstrated and commercialized. It is critical for the project to have a successful demonstration so that the proof of concept can be seriously taken into consideration as an option by the industry. Several governments are leading initiatives in the demonstrating projects. The Canadian Nuclear Laboratories are aiming in demonstrating at least one prototype by 2026. So far, four companies, Global First Power, StarCore Nuclear, U-Battery Canada, and Global Terrestrial Energy have answered the call for proposals for an SMR demonstration unit. Each of them will submit a different SMR design. (CNL) NuScale Power is working with the US Department of Energy in developing Joint Use Modular Plant (USDE 2020).

The IAEA has developed a set of deployment indicators to help support Member States in making informed decisions on supporting SMRs and evaluating their potential in regard to their national energy portfolio. (IAEA 2020)

4.9 Stakeholders Involvement

Legitimate concerns of stakeholders and the public in regard to nuclear power and its role in mitigating climate change should be addressed through the culture of transparency and openness. Particular concerning issues for the stakeholders that are specific to nuclear power generation are such as severe accidents, radioactivity, nuclear security and radioactive waste management.

In engaging stakeholders, a clear strategic approach should be considered. It should follow steps such as identifying, researching and organizing stakeholders, their interests, needs expectations and concerns. Environmental groups should be engaged, and plain language, clear narratives and strong visuals should be used to efficiently communicate about nuclear energy. Only this way can the misperception around nuclear power and the crucial role it plays in climate change mitigation can be addressed. Finally, stakeholders should be involved in the decision-making process.

New nuclear programs should engage not only with the local public but also with representatives from, the media, vendors, government authorities, professional groups, environmental groups and most importantly established anti-nuclear groups. (IAEA 2017) Environmental organizations have evolved over the years and their focus varies in a variety of causes, including combating nuclear power, whereas that is the sole focus of anti-nuclear groups.

Nuclear power is a low carbon energy source and as such plays a key role in climate change mitigation. The nuclear community needs to position itself within the environmental community. The practice of openness and dialogue needs to be put into place, especially with organizations that are also working to mitigate climate change. Participating in challenging conversations and answering difficult questions will help build trust and finding common grounds.

Being part of these groups will enhance the acceptance of nuclear energy and will inform communities on the low carbon nature of this energy source. Studies have shown that disinformation and information shortage is preliminary when it comes to nuclear energy. 51% of Americans think nuclear power is damaging to climate change while 60% of Canadians and 70% of French are unaware of the fact that nuclear power is a low carbon energy source (English 2019).

Governments considering nuclear power programs can adopt and use the guidelines developed by the IAEA on strategic environmental assessment. (IAEA 2018) The strategic environmental report, classifies engagement, participation and mapping of stakeholders groups. Moreover, the IAEA offers Safety Standards by communicating and consultation with interested parties by the regulatory body. It promotes the safety culture by providing guidance to the regulatory body on how to make informed decisions and how to develop awareness of safety among interested parties. (IAEA 2017) These initiatives provide a solid base not only for the understanding and acceptance of nuclear energy as a low carbon source, but also for the planning and achieving of the transition.

4.10 Capacity Factor

In terms of energy security, an energy source is considered secure by its uninterrupted availability at an affordable price and one of the factors by which the secureness of an energy source is measured by the capacity factor (IEA, 2014). This factor represents the intensity of the plant energy generation. According to EIA (2014), when the plant intensity is being used at 100% to produce electricity it means that it is generating energy at full time.

Nuclear power plants are a source of safe electricity delivery. Also, typically they only put on hold their long year operation almost exclusively for fuel replacement which improves the reactor performance and benefits them in reaching higher capacity. In some regions, the high-capacity factor reaches 90%. The high score percentage of the capacity factor favours nuclear plants in comparison to other electricity generation technologies. Another favourable factor of nuclear power plants is their capacity consistency. Differently from other electricity production technologies, nuclear power plants' capacity factor remains constant throughout their lifetime.

Apart from having high performance, nuclear reactors are an effective technology for the long-term mitigation of climate change. (IAEA, 2016) This is due to their ability of generating electricity without emitting carbon dioxide in the atmosphere. It is worth noting that nuclear power generates one third, or 31.5%, of the world's electricity by a low carbon source. (IEA, 2017) IAEA (2015) estimated the GHG emissions of different electricity producing technologies. By analysing and comparing the different life cycles of these technologies in the study it was concluded that the lowest CO2 emissions were produced by nuclear power and hydroelectric plants. Also, the higher emitters were estimated to be technologies using fossil fuels and natural gas.

For low carbon generation options to be serious contributors towards the 1.5°C goal by playing a key role in transitioning into the path of decarbonized electricity, they must fulfil the dispatchable technologies criteria. Variable renewable energy (VRE) sources energy production is highly dependent on seasonal patterns. This impacts the reliability of the system as a whole in these resources and also the requirements for flexibility.

4.11 Nuclear Waste

The misperception and general unacceptance of the public opinion towards nuclear energy is closely linked to nuclear waste. For the public to accept nuclear power plants they must be made aware of the existing solutions in place to safely and sustainably isolate the radioactive waste of nuclear power plants so that its effects on biological systems are kept to a minimum. (Sartori 2013)

Materials that are categorised as radioactive waste are materials that are radioactive per se, or materials that have been contaminated by radioactivity, hence regarded as material that cannot be of further use. Depending on the level of the radioactivity, the material can be classified as low-level waste (LLW), intermediate-level waste (ILW), or high-level waste (HLW). (WNA 2018e) HLW makes up for a low amount of share in terms of mass, only 3% of the total radioactive waste, but is highly radioactive by making up for 95% of the total radioactivity released. Whereas LLW is a large amount in terms of mass, 90% of the total mass of the waste, but in terms of radioactivity, it only accounts for 1% of the radioactivity releases of all radioactive waste. Essentially, HLW is strongly radioactive, making a small amount highly radioactive. However, LLW is comparatively not as radioactive. (WNA 2018f) Most countries with nuclear power plants have in place disposal facilities for LLW

and ILW. In contrast, not all countries with nuclear power plants have HLW disposal facilities. (European Commission 2017)

The radioactive liquid residue from the first solvent extraction cycle in reprocessing of the spent fuel makes up the distinctive feature of HLW. (IAEA 2016c) Two options are available for the spent fuel; it can be a valuable resource for reprocessing or radioactive waste, encapsulated and stored temporarily on-site facility or in a deep geological disposal. (European Commission 2017; IAEA 2018; Ji et al. 2017).

Although nuclear energy has seen several technological advancements, there has yet to be a breakthrough in research and findings in effective final disposal of HLW. (Yano et al. 2018) (Suman 2018) However, it is estimated that between 2020 and 2030 the first HLW definitive deep geological disposal sites will start up in Finland, Sweden, and France. (European Commission 2017)

Accumulation of heavy metal from nuclear fuel and its storage on site is an ongoing problematic. It is estimated that during the life cycle of a nuclear power plant it produces between 9 and 11 m^3/GWh of HLW. (Kröge 2001) In 2010 it is estimated that Europe and the USA had each accumulated respectively, 53,300 tons and 65,000. The waste is stored on site, in the same location as the reactors and in temporary storage. Additionally, it is estimated that each year in Europe 3200 tons of heavy metal are generated on a yearly basis from nuclear fuel , while, 2000 tons are accumulated in the USA. (Tollefson 2011) (European Commission 2016)

Deep geological projects have encountered political, economic and technical problems. As an example, the Yucca Mountain repository in the USA was shut down after 15 billion USD of investment. In 2014 the facility was shut down due to a leak. Radioactive plutonium and americium leaked out of the Waste Isolation Pilot Plant (WIPP) near Carlsbad, New Mexico. Whoever, the leak was reported to not have had any serious environmental or health impacts. The project went through several political decisions and stalling and at the present is not active and there are no plans of reopening it. Experts testify that the retirement of the respiratory is due to political reasons and growing concern of the public and not technical issues. (Tollefson, 2014)

There are several alternatives currently being used for the storage of nuclear waste. One of these alternatives is reprocessing the fuel to produce mixed oxide and another is using current fast reactors technology which is able to consume plutonium and uranium more efficiently than conventional nuclear reactors. However, in terms of cost efficiency, France is opting out of the mixed oxide of uranium and plutonium (MOX) option and using fresh uranium fuel and disposing the waste in geological repository, which is a cheaper option. (Hippel et al. 2012) On the other hand, the U.K. has decided on closing the program of separating and recycling plutonium until 2018. (European Commission 2017) A final decision in the implementation of reuse is not required in the close future. However, the residue of the of MOX fuel will require geological disposal facility in the end. Future decision-making and implementation will be based and informed on considerable programs of research leaded by universities and commercial organizations. (Hyatt, 2020)

In general terms there is not a consistent and common perception or best solutions and technology for disposing of nuclear waste. There is lack of long-term program management objectives and sufficient funding to achieve a sustainable solution for the accumulated and future nuclear waste. (Yano et al. 2018)

4.12 Construction and planning of new nuclear power plant

At the end of 2019, 19 countries were constructing 52 reactors. Considering that the construction time of a Nuclear Power Plant (NPP) varies between five and seven years and it's calculated as the time between the decision to construct a NPP and the start of operation, these NPP are expected to enter service by the end of the 2020s. These new reactors will account for 54.7 GW of net electrical capacity, which is over 13% of the total current global nuclear capacity. (IBRD 2020)

Some of the 19 countries developing nuclear projects in 2019 are characterized by growing populations and an increasing electricity need. As an example, China has 10 reactors under construction and India 7. These countries see nuclear power as a reliable source of energy that can improve living standards not only by providing electricity services doe underserved communities but also by contributing to improving air quality particularly around rapidly urbanizing areas. (IAEA 2018; ENERDATA 2020)

Moreover, countries constructing their first NPPs are likely to play more significant roles in the next decades. However, these 'newcomer' countries usually face longer lead times when it comes to technical requirements and steps. It takes longer for them to establish the supporting infrastructure, technical expertise, and institutions.

Another challenge encountered by 'newcomer' countries is securing funds for the development of a nuclear program. The IAEA Milestones approach offers an approach for the support of newcomer and countries with well-established programs. (IAEA 2015)

The contribution of low carbon technologies towards a reliable electricity system varies. Electricity generation amongst low carbon technologies differs especially in their dispatchability and variability. All thermal power plants using nuclear are fully dispatched and their production can be adapted to the system's needs. (IAEA 2020)

4.13 Newcomers

Countries experiencing rapid developments and where the effects of climate change are causing great and irreparable damage to environment and the economy are opting and have to rely on sustainable courses of energy. At present, globally, 26 countries who do not have nuclear energy in their energy mix, are planning to develop future nuclear plans. Countries falling under both categories described above are concentrated in Africa. The majority of countries developing nuclear power plans are located in Africa. The continent's industry if beginning to grow rapidly and the demand for power is increasing rapidly. Additionally, Africa is the continent with the fastest population growth rate, with urbanization rates predicting a population increase of double by 2050 with 65% growth occurring in urban areas. (Saghir & Santoro 2018) These elements are making Africa one of the largest centres of economic growth.

Countries planning to incorporate nuclear power in their energy mix are called newcomers. Such countries have signed agreements to develop nuclear power infrastructure or are already in the developing process. Some of these countries have already begun the construction for nuclear power plants. Algeria, Egypt and Nigeria are included in the list and are two amongst the fastest growing and developing countries in Africa on the top of the list for their GDP value. Other countries in the region have a developed interest in the possibility of

implementing nuclear power projects, but do not have yet nuclear policy plans. Niger is one of the countries interested, but that have yet to establish formal agreements or plans.

Newcomer countries which show the most progress in implementing and advancing their nuclear plans, are countries located in regions with established infrastructure and technology, developed and stable financial markets and with investment proposals, plans or agreements with international supplying partners. Egypt is one of the countries well developed with already committed plans, agreements and investors plans and also is getting ready or has begun to the nuclear power plants construction.

The process of developing adequate infrastructure, putting in place safeguards and creating and implementing legal frameworks all while securing investors is vital and while it cannot be bypassed, it takes time. The whole process is fundamentally conditioned by necessary investment in infrastructure, government investment in policy, legislation and international agreements. Moreover, stakeholder engagement through public support can make or break the progression towards nuclear energy. When deciding to adopt nuclear energy these newcomers bring with their decision new security considerations. These countries and their level of political stability, the presence of violence and terrorism, transitional conflicts and general national security concerns come into the global attention. The IAEA (2009) assists newcomers by providing a list of criteria for the introduction and implementation of safe and controlled nuclear energy programs.

As the climate crises progresses and makes itself more relevant in the populations of many countries and in the ecosystem of the world, countries opt to transition to renewal energy sources and reduce the reliance on fossil fuels and natural gas. Wealthy industrialized states, particularly in Europe with developed infrastructure represent the biggest number of countries with renewable energy programs. On the other hand, other less economically developed countries decide for nuclear energy. These countries can perceive the ability of this energy producing source to reduce socio-economic gaps by providing increased access to electricity at favourable prices by also helping mitigate climate change. Hence, nuclear energy becomes an alternative energy source with the potential of reaching the UN Sustainable Development goal of universal access to reliable and affordable energy.

Newcomer countries constitute a new market and demand for nuclear energy. This new market challenges geopolitical power dynamics by amplifying the competition between

supplier countries such as the United States and Russia. Supplier countries target newcomers as a source of income to export technology and expertise, but not only. By offering assistance, infrastructure, technology and fuel services the supplier countries also leverage their geopolitical presence. Finalizing nuclear energy agreements with newcomer countries secures a leveraged position of the supplier country in the global power through proxy issues. Russia has significantly increased its presence in the world energy markets in an attempt to gain leverage in the global marketplace.

State owned power companies in Russia allow for greater financing of nuclear projects, making it easier to secure regional geopolitical influence by financing international nuclear projects. Russia is the most influential nuclear supplier in the world with existing agreements and contracts with 23 countries and 18 Memorandums of understanding signed with 18 African countries. (Elabssoussy 2021) The Russian-African Forum has played an imperative role in facilitating agreements and understandings between Rosatom, Russia's power company, and individual African countries that want to transition or incorporate nuclear power in their energy mix. Rosatom operates under a unique Build-Own-Operate-Decommission model, and as such is able to provide newcomer countries without robust nuclear infrastructure, governance, security measures or financial independence with the opportunity of incorporating nuclear power in their energy mix. Moreover, Rosatom is in agreement with the African Commission on Nuclear Energy to cooperate on future nuclear projects, and this gives leverage to Russia in regard to maintaining its influential supplier status in the future. Currently, Rosatom has initiated the building of nuclear plants in Egypt and is actively engaged in planning and implementing projects in eight African nations.

This shift in nuclear technology supply on the eastside of the world has positioned the United States in a less dominant actor in the nuclear energy market. Private nuclear energy cooperation in the United States are struggling to compete with the state sponsored companies such as Rosatom. The private companies are not in a favorable position to shoot ahead of the financing and technology that the state owned companies can provide to foreign customers. However, the United States is making an effort at maintaining geopolitical influence and leading global markets by rehabilitating projects such as the U.S. International Development Finance Cooperation and ending its prohibition of funding nuclear energy projects.

4.14 Africa

4.14.1 Algeria

Algeria is a country located in North Africa and has a current population of 43.8 million and a growth rate of 1.85%. Due to its semi-arid climate, Algeria is highly vulnerable to climate change. Over the past 50 years, extreme weather events have increased. The country has had to counter torrential rainfall, cyclones, and drought, heatwaves and sand storms. Scientists predict that temperature will increase with an average of 3 degrees Celsius by 2050, and that in the close future there is expected a 20% decrease in rainfall. (Caritas 2011) Additionally, water security, desertification and erosion of beaches are of particular concern due to the country's high water stress ranking. (WBK 2015)

In terms of energy generation, the country relies on its own oil and natural gas production. Natural gas is the energy source of electricity by producing 98% of the electricity production needs. In 2017 the country signed a Memorandum of Understanding with Rosatom for the transfer of nuclear technology. (Lefevre 2017) As of now Algeria is developing plans for a 1200 MW nuclear power plant. (IAEA 2018) The end date of the project was 2022, but it has faced several delays. Nonetheless, it is projected that for the period between 2030 and 2050, the base load of the national electric energy generation capacity will be mainly generated by nuclear power.

Algeria has signalled a commitment to its nuclear power plants by taking action towards committing to nuclear security and non-proliferation. In cooperation with IAEA, the country has adhered to the organization's safeguards and signed the third Country Programme Framework (CPF) with IAEA in 2017. This cooperation is a frame of reference for the medium-term planning of technical cooperation between the organization and the country. Moreover, Algeria has ratified the Non-proliferation Treaty (NPT) and the Treaty of Pelindaba. Internally, the country is drafting national laws on nuclear energy and establishing bodies to safeguard nuclear safety and security. The country currently operates two test reactors, one of which is a heavy water, 15 MWt reactors, constructed by China.

As a newcomer country Algeria represents a major challenge to nuclear security. This challenge is the potential for theft or sabotage of nuclear materials and technology by terrorist groups like al-Qaeda in the Islamic Maghreb (AQIM). In 1990s this terrorist group attempted developing biological weapons in the Algerian territory, hence, the presence of nuclear

materials in the country raises proliferation concerns. (NTI 2018) Other security challenges faced by Algeria that raise concerns are the growing political instability and civil unrest, violence, and recruitment by AQIM in Islamic State (IS) affiliates, and sectarian clashes between Sunni Arabs and the Berber minority.

4.14.2 Egypt

With regards to population Egypt's 100 million is projected to continue rising, up to double the current number, reaching 150 million by 2050 and 200 million by 2100. (Schwartzstein 2017) Consequently, the energy demand is projected to rise with the population number and density and the country lacks the ability to meet these demands. At present, 91% of the country's energy demand is met by fossil fuels. (Eia 2018) By 2035 Egypt hopes to that their installed energy mix includes 3.3% of nuclear energy.

The large population number also makes the country more vulnerable to climate change. Higher temperatures are predicted accompanied by changes in rain patterns, rising sea levels, erosion in the Nile River and extreme water shortage. (FAOUN 2016) (Khalil 2019)

Egypt has received site approval in April 2019 for the El-Dabaa project by the IAEA. Rosatom, Russia's state energy company will develop the plant and 85% of the project will be financed by Russia. On 2026 unit 1 is expected to launch and the other three are expected to be completed within 2028-2029. Currently, Egypt has one research reactor in operation, the ETRR-2, 22000kW open pool light-water reactor.

Egypt has demonstrated willingness to cooperate with the IAEA. Ahead of beginning construction the country has included all relevant IAEA safety standards in its regulations used as part of the basis for the site studied carried out at El-Dabaa. The Egyptian government requested an Integrated Nuclear Infrastructure Review (INIR) mission which was completed in November 2019. (WNN 2019) The review concluded that Egypt is ready and well placed for the construction phase of its first nuclear power plant.

A matter of concern is the fact that Egypt hasn't yet signed several security and safety agreements like the Additional Protocol and the Convention on Nuclear Safety. Additionally, the risk of theft or sabotage of nuclear materials and technology by IS and its affiliates is a matter of concern. Prolonged political instability, economic and social discontent, the

presence of violence and terrorism add fuel to the existing concerns. Moreover, the rise of unemployment amongst youth can increase the terrorist recruitment possibility and risk. Egypt has an estimated number of 800-1200 IS fighters in Egypt and the attacks have increased since 2013. (CFR 2021)

4.14.3 Rwanda

As part of its vision to become a high-income country by 2050, Rwanda plans to construct and connect to the grid a nuclear power plant by 2024. (WNN 2019) In 2018, Rwanda signed a deal with Russia to set up a Centre of Nuclear Science and Technologies. In 2019, this agreement was expanded to include cooperation on constructing a power plant with the year 2024 as the end date goal. This country is characterized by poor energy infrastructure with an electrification rate of 30% and unreliable electricity. (World Bank 2019)

In the interest of preparation for the integration of nuclear energy in its energy mix, the country has engaged with IAEA and in 2017 the government signed the first CPF with IAEA. (IAEA 2017) In 2019 IAEA sent legal experts to Rwanda to instruct and train officials on the international legal framework on insuring nuclear safety, security, and civil liability for nuclear damage. (Kwibuka 2019) Rwanda is part on important non-proliferation treaties, but they have not signed yet the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management and the Convention of Nuclear Safety. Moreover, there is no legal framework in place for radiation protection.

In terms of national security, the 1994 genocide created internal security challenges of ethnic division and high poverty. There are also external security challenges stemming from tensions with neighbouring states. The risk of terrorist attacks in Rwanda is low, but transitional terrorist organizations still pose a threat. (CRS 2021)

Scientists predict an increase in temperatures by 1.4 – 2.3 degrees Celsius by 2050. These changes in the temperature will be characterized by longer heat waves and drought. Water and food shortage as a result of drought are increasing in the East of the country, which is considered particularly vulnerable.

In summary, a common ground point amongst the above mentioned new comers is they will need to import the technology and manpower expertise required from nuclear operators to get

their programs starting. However, while nuclear power can help in avoiding the price fluctuation of gas and coal, it is worth taking into consideration that nuclear energy is one of the energy industries with the most concentrated supply chains. The suppliers in this market are just a few, in contrast with other major energy sources.

Additionally, the countries analyzed above lack political and economic stability. In fact, Nigeria and Egypt rank in the top 50 most unstable countries in the world. In this climate, there is a risk of the initiation of a nuclear power project that eventually concludes with the pursuit of nuclear weapons, falling under the three big concerns related to the spread of nuclear technology.

CHAPTER FIVE - CONCLUSIONS

5.1 General Conclusion

This study does not assume that it can completely explain people's approval, the risk and misconception on using nuclear power as an alternative for the climate change issue. However, it explained that based on well-known results from previous studies, it can be an alternative for the mitigation of climate change.

As discussed, nuclear power is a greener production source than coal, oil, or natural gas, with reduced negative consequences on human health. (Paraschiv & Mohamad 2020) Furthermore, taking in consideration that the risk of accidents from nuclear power is lower, thus their health and environmental impact is lower than that of fossil-fueled power. As well, the radiation levels from nuclear power plants are lower than the natural radiation and much lower than the deliberate radiation we are exposed to through medical procedures.

At the same time, waste management, even though it is challenging, it has enough, technologies in place to correctly administer them. Lastly, it comes to the conclusion that it a matter of countries decisions to invest in the safe and efficient long-term storage facilities.

Usage of nuclear power requires a high public understanding and acceptance. Their opinion not always is objective or balanced, because it is indisputably related to the health concerns, due to lack of information, knowledge, transparency or also influence from the biased media.

Thus, literature and knowledge from experts should be considered in defining future energy policies on nuclear power, in order to diminish the blank misperceptions and reality. Thus, for the potential of nuclear power to be fully understood and therefore used, there should be a balance of public opinion, making a difference when it is based on knowledge and when not.

While we are facing severe challenges with climate change issue because of the energy needs which influence negatively, it can be argued that this crisis will be much harder and expensive to overcome without making use of nuclear power (Visschers, Keller, Siegrist, 2011). Nuclear power is a viable, available, and reliable power source and this fact cannot pass unobserved. (Florentina & Dima 2020) Like so, prejudice against nuclear it is not about

technical issues or either related to impacts on health or environment, or even market design. As reviewed in this chapter, many countries have already implemented it with high and positive results. By negatively addressing nuclear power, it only creates room to use the public misperception as an excuse, rather than not making data-driven decisions.

Nuclear power has the potential to play a significant role in achieving these mitigation goals and, as a large scale, reliable, dispatchable (ICCCRNP 2019), and concentrated source of energy, can also contribute to broader economic and social dimensions of sustainable development.

This study, makes a contribution to the literature, because developed a thorough interpretation of the adaptation–mitigation dilemma on the ability of nuclear power to mitigate climate change and the potential for nuclear power operation to hinder climate change mitigation. The current literature discusses mainly advantages and disadvantages of nuclear power on its own, and also its relation to climate change. Whilst this study discusses why it is not used on its full potential, making its statements that nuclear power is for sure a possibility to climate change.

Beckjord, concludes that the climate crisis will be much harder and expensive to overcome without making use of nuclear power. (Beckjord et al. 2003)

5.2 Research question and recommendations

This study had one question, as the core of the research: “Why is Nuclear Power not being used to its full potential as an alternative energy source to adapt to Climate Change and how could it contribute to advert its impacts?”. Based on the findings from the analysis, that do answer the question as to what the limitations of usage on NP to its full capacity are, as follows are specified several recommendations.

5.3 Environment and nuclear power

Regarding to several findings on perception of damages that nuclear power does on environments, the nuclear electricity generation chain does not release gases or particles that cause acid rains, urban smog, or depletion of the ozone layer. Nuclear power contributes

already to the lowering of carbon intensity in the energy sector. Comprehensive analysis of GHG emissions from different electricity generation chains shows that nuclear power is among the less carbon intensive generation technologies. (IAEA 1996)

As a low-carbon technology, nuclear power is an important energy producing alternative in meeting the climate change long-term CO2 emission reduction targets. In conclusion, nuclear power's potential in helping to avoid GHG emissions is significant. New strategies in addressing global GHG emissions and the mitigation of climate change should include nuclear power.

5.4 Costs and policies

In most cases, existing nuclear is a cost-efficient provider of low-carbon electricity. Premature closures of existing plants undermine efforts to reduce carbon dioxide and other power sector emissions and increase the cost of achieving emission reduction targets. Governments should focus on future research, development, and also fundings that prioritize that lower the costs, including construction costs.

The investment cost in nuclear energy is high. However, when implemented, their operational cost is much lower than that of their fuel sources. Nuclear energy is importantw in minimizing costs such as imports of fuels like natural gas and coal. An additional benefit of nuclear power is its sustainability in regards to the area it requires to be built in, unlike renewable generation plans which require bigger geographical surfaces and very specific climatarian conditions.

The time of installation in many countries is long. Hence, for projects to get into operation in the desired time, the planification should be realized well in advance.

Decisions to freeze or phase out nuclear energy should be considered with extreme caution. When countries decide to withdraw nuclear energy from their power mix, they should consider the extensive amount of time this energy needs to be put back into operation. If countries who decide to put a pause in the nuclear plants energy production and operation decide to go back, their decision can seriously impact local economies.

5.5 Public attitudes

Public acceptance of nuclear power is based on several topics. For example, waste management has an important role to play in public acceptance of nuclear energy in some countries. Public concern about radioactive waste is a critical issue for nuclear energy. Nevertheless, it is important to highlight that the public acceptance goes beyond technical issues of the application of nuclear power. So, what is recommended is a transparent information sharing with the public based on data and research and also include public opinion in the decision making as much as it is possible, in order to demise the non-acceptance. The inclusion or exclusion of nuclear energy in the energy mix is highly impacted by popular opinion. The latter is used as a means of influence towards the governments in regards to the inclusion of this energy source in the energy mix. Hence, popular opinion influences the decision related to the control of emissions of effects of GHG. Governments and the scientific community have to be open about nuclear energy, build trust with the public and provide accurate and complete information about the technology used, as well as the benefits and the risks involved.

5.6 Safety measures

As explained throughout this study, the safety matters are one of the most important reasons why people do not perceive nuclear power as a safe solution to climate change. Thus, there is a requirement for regulations that should be coordinated and aligned internationally to enable international deployment of nuclear power and to standardize and ensure a high level of safety worldwide. The differences between national safety regulations and their cultural practices make it difficult to develop a universally accepted regulatory regime. But certain basic standards for nuclear safety should be maintained internationally due to the far-reaching environmental and social/political effects of nuclear plant operation. (MIT 2019) Also, considering the low risk of accidents related to nuclear power plants, their overall health and environmental impact is lower than that of fossil-fueled power. (Dones 2004)

5.7 Newcomers

Being a basic electricity generation source, its incorporation and withdrawal from a country's energy mix can directly impact CO2 emissions. Nevertheless when focusing on the analysis of the current situation of three African countries; Algeria, Egypt and Nigeria, this study

concludes that newcomer countries should be well prepared before deciding to include nuclear power in their energy mix. Whereas nuclear power has positive impacts in mitigating climate change, from which not only the three newcomers analyzed suffer the consequences of, it can bring further security implications concerns that could have global impact.

5.8 Limitation of the study

The literature on nuclear power and specifically its relation to climate change is a continuum of research and still there is broad information available to provide enough knowledge on the topic. This study focused on determining why nuclear power is not being used to its full potential to adapt to the ongoing climate crisis. Moreover, it investigated how the decision of using or not using nuclear power affects different aspects of the global security.

This study provided a restricted number of case studies taken into consideration as examples in the analysing democratic states choosing not to use or invest in nuclear power and newcomer countries adopting the energy source.

The study focuses also in newcomers and the competition Russian and the U.S.A compete for the role of exporter of nuclear technology. This study does not focus on the future implications of the advantageous position that Russia holds, but however, it recognizes the importance of future research on the topic.

Taking account of the reduced case study data prevents an exhaustive analysis. Additionally, in the light of the recent events caused by climate change, future work may include more detailed analysis based on updated data from all reasons explained in this study why nuclear power is not used on its full potential.

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