# *Exploratory Study to Determine whether Mexico is Able to Reuse Spent Nuclear Fuel*

## Case: Central Laguna Verde


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***Abstract*** *— In this document we conduct an exploratory study in order to know, from an expert opinion regarding nuclear topics such as the future of nuclear power in Mexico, the feasibility of reusing the spent fuel, among others. An online survey has been designed and sent to workers and former workers of Laguna Verde Nuclear Power Plant Units 1 & 2, who expressed their points of view, many in favor, but also some against of continuing generating electricity by nuclear means. The expert's opinions about the results, in a large percentage, support this type of energy generation by 90% in favor; on the other hand, the 70% of the sample believe that Mexico is not ready yet to reuse the nuclear waste.*



***Keywords— Nuclear recycling; nuclear safety; CFE; BWR; nuclear accidents***


## I. INTRODUCTION

25 years after the startup of the ***Laguna Verde Nuclear Power Plant Units 1 & 2*** (LVNPP), and taking into account the energy situation of Mexico, it is convenient to make an analysis from the experts' perception who have worked or are still working there, regarding the future of this kind of plants in our country.

Historically, the Nuclear power has been condemned by environmental groups and communities near the sites where the plants or extraction uranium are. All these derived from the catastrophic events that have caused panic around the world, such as Chernobyl and recently Fukushima.

Currently, it is possible to find online reviews, from people who have worked in LVNPP, referring irregularities in the handling of the facility itself, paradoxically; there are tough measures and policies that protect both, the working staff as well as the equipment used in the process of any nuclear plant **[1].**

Nuclear accidents that have occurred along the history, have caused some scientists strive to provide solutions that protect the integrity, not only of the nearby towns, but also in the entire world, because an accident in this area can bring consequences affecting numerous, or even distant locations to the scene. Therefore, the owner carried out in-depth studies to prevent unexpected power generation situations such as natural disasters.

This exploratory research includes a compilation from expert opinions on nuclear issues, being the ones who have technical knowledge on the subject and can give a founded opinion on a critical topic, which is controversial and continuously attacked by extremists who propagate unfounded opinions.

The following sections include the background information about nuclear energy generation, historical accidents and its current status. In addition, the design methodology to perform the survey is included, and the parameters considered appropriate to perform the study associated to expert's opinion on nuclear topics. Furthermore, the results of the surveys, the conclusions and analysis of them are included in this paper.

## II. BACKGROUND

In recent years, the planet has been suffering various changes, many of them serious, just to mention climate change.

As it is well known, the greenhouse gases, mainly $CO_2$, as waste of fossil fuels used for human activities is one of the main contributors to climate change. As a result, it has raised the need of the creation and use of cleaner and more sustainable sources of energy **[2]**. One of them is nuclear energy, which despite of being considered an alternative source, is part of a debate due to its negative connotations, based on its use as a weapon of mass destruction after the bombs in Hiroshima and Nagasaki, and its relation to diseases such as cancer.


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The "nuclear" issue is controversial, because it is considered an instrument of progress, technology and welfare, but at the same time is considered a potential powerful destroyer. The debate on the use of nuclear power goes from high insecurity regarding the environment by radiation and radioactive waste of high activity **[2]**, as well as the possible damage to health caused from the nuclear accident at the Chernobyl plant.

Another important topic of debate, is the need of uranium production or extraction. Uranium is a natural element that is extracted from the Earth, which positions to nuclear energy as a dependent and unsustainable alternative, because uranium is not an unlimited resource such as the sun or the wind, which hold a limit to its utilization.

The development of nuclear energy, according to reference **[3]**, has experienced a significant obstacle because of the concern of three broad categories of doubts related to their use: reactor accidents, radioactive waste and nuclear proliferation. Arguments regarding economic competition and public opinion, and more recently, terrorist activity, add obstacles facing the civil use of nuclear energy for electricity generation.

These drawbacks have been the main cause of the production of electricity by nuclear means, and have not expanded as widely as decades ago as some experts predicted it.

Unlike its beginnings in the 1960s, when it was introduced as a promising alternative energy and, as it was expected by some experts, to potentially fulfill much of the future energy needs. However, in recent years the debate over the role of nuclear energy has revived, in particular because of current high price of fuels and future potential threats emanating from global climate change. Even after the recent financial crisis, it is likely that there will be an increase in the construction of nuclear power plants around the world for the years to come.

*A. Chronology of nuclear accidents*

Main accidents in nuclear power plants producing electricity before Fukushima and not used for dual use, such as production of military plutonium for nuclear weapons and power generation, have been the following **[1]**.

- 1969 Saint Laurent des Eaux (France). Five fuel assemblies melted. There was no release of radioactivity.

- Dresden 1970 (United States). Due to an error, the turbine stopped. It increased the pressure and there was leak in the building. There were no victims.

- 1972. Surrey (UK). Hot steam leak, there was only one decease.

- 1979 Three Mile Island (Harrisburg, United States). During an inspection, two valves of the cooling system were closed due to forgetfulness. Due to the use of resins in the condensate purification system, a pipe was obstructed. As the cooling system was not operating correctly, there was an increase in temperature and a radioactive leak larger than the allowed limit (2.4 mSv/year).

- 1999. Tokaimura (Japan). An operator JCO company operating in this factory poured 16 kg of enriched uranium in an inappropriate container, reaching super criticality when the permissible limit was 2.3 kg. This could have been avoided if in the uranium transfer area containers had not been equal or greater than the critical mass capacity. There was an inadequate inspection of the Nuclear Safety Council of Japan and the company itself, because there were factory workers who did not received proper qualification and training. In total, 49 people, including factory workers, killing two of them, and nearby villages suffered the effects of radioactivity. Six senior JCO company were sentenced to two and three years in prison.

- Kashiwazaki Kariwa NPS 2007 (Japan). A 6.8 Richter scale earthquake, 16 km from the nuclear power plant with seven BWR reactors with a total capacity of 8.2 GWe. The reactors were stopped safely. There was a fire in the transformer and a leak of water from the pool where radioactive components were cooled, causing contamination of a millionth of the allowed limit.

The most important accident in a nuclear reactor dual civilian use, in the production of electricity and military, to obtain plutonium for nuclear weapons, happened on April 26, 1986 at the Chernobyl nuclear power plant.

The report published on September 5, 2005 (World Health Organization Chernobyl. The true scale of the accident) is difficult to interpret and inconclusive, leaving summarized as follows:

Until mid-2005, fewer than 50 people died of direct exposure to radioactivity, most were workers who died within months of the accident.

- 4,000 cases of thyroid cancer due to iodine 131, mostly among children and adolescents. Considering that the $^{131}I$ has a half life of 8 days, this contamination occurred only during the first months.

Due to medical treatment applied during these 20 years, an estimated of 4,000 cases, only 1% could have been lethal, that is, it would have been about 40 deaths. About 200,000 people, including nuclear plant workers and local residents, 1%, or about 2000 were exposed to high levels of radiation. Although there are no reliable data, it is estimated to have survived 99% over these 20 years, representing about 200 deaths.

*B. Current situation.*

Currently, one of the greatest challenges of the nuclear industry is to determine what to do with the spent nuclear fuel which consists of rods of uranium dioxide mixed with Transuranium elements (Np, Pu, Am, Cm, etc.) and fission products.

After the nuclear accident of Fukushima, opinions remain divided about nuclear power, mostly because of the available information, which agreed to approach society and science, is insufficient and biased. The media as well as the politicians, who must assist in educational tasks, ideologically undermine the reasoning of every day and distance to citizen scientists **[4]**. Surveys and opinion surveys show that not only information but also lack of interest in information, with the result of a public opinion largely little or no sustained.

Today, there are 438 reactors in operation around the world. In 2014 nuclear power generating capacity was 376.2 GWe. The growth in short and long term, remain centered in Asia, mainly in China. From the 70 reactors under construction, 46 are in Asia; the same as 32 of the last 40 which are connected to the grid since 2004, according to the International Atomic Energy Agency.

Thirty countries are currently using nuclear power and a similar number are studying or planning the inclusion of this energy in its energy matrix, or are already working on it. From the 30 countries that have operating plant, 13 new plants are being built or are about to concluded construction projects that had been suspended; 12 other countries are planning the construction of new plants.

Due to a political postponement of the regulatory body on the management of the spent fuel in many States, the amount of global stored spent fuel continued to increase. By 2014 there were downloaded in total, from all nuclear plants, around 10,000 tons of heavy metal, which raised the cumulative amount to, approximately, 380,500 tons, of which about 278,700 tones are stored in facilities located, either inside or outside the reactors.

The investigation of such heavy material has a high cost, as it uses materials from hot laboratories and test reactors, and it is subject to strict safety standards. These specific requirements have contributed to the nuclear reactors to consistently evolve **[5]**.

The reference **[5]** indicates that it is the generation of III light water reactors (for its acronym in English LWR) currently marketed, that operating reactors are designed so that the optimization of nuclear safety and their economic performance. The globalization of research and development, along with improved science research capabilities, has driven more and more refined characterization and numerical simulation techniques to create conditions that improve to make real progress in technologies and processes, and design studies and safety of nuclear systems.

Reference **[6]** mentioned that recycling, by using nuclear fuel is not only interesting for the recovery of these valuable materials, but also responsible for the management of nuclear waste solution, as it occurs in the management of non-nuclear waste in other industries.

The objective of recycling is two folded:

1. To recover valuable materials from spent fuel energy.

2. To separate the real waste of valuable materials and to package them in a safe and compact way for transport, storage and disposal.

Recycling is useful for both, uranium and for other materials. Like other recycling processes (paper, glass, etc.), recycling of uranium provides double advantage of limiting resource consumption and waste production.

The possibility of reusing the raw material is a comparative advantage of nuclear energy to meet the world's energy demands.

### *C. Laguna Verde Nuclear Power Plant.*

In Mexico there is a nuclear power central, located in Punta Limón, near Alto Lucero city, Veracruz State. This plant consists of two units type boiling water reactor (BWR) supplied by the General Electric Company, with a nominal thermal output of 1931 MW.

Using the direct cycle and forced circulation in the generation of steam to drive a turbo-generator set, it is designed to achieve a gross electrical output of 675 MWe and a net capacity of approximately 654 MWe per unit **[7]**.

In Mexico, the National Institute of nuclear research (ININ) is responsible for the management of institutional radioactive waste (not to be confused with spent nuclear fuel), generated in medicine, industry and research.

The ININ collects radioactive waste and takes them to a treatment plant (PATRADER) in the Nuclear Centre, located in Salazar, Mexico State, where it is sorted, treated, immobilized and packed in suitable containers. After that, it is moved to the center of storage of radioactive waste (CADER) near the village of Maquixco, in Mexico State. Both the PATRADER and the CADER have licenses issued by the National Commission of Nuclear safety and safeguards (CNSNS), which is the regulatory body for nuclear safety **[8]**.

The LVNPP manages its own radioactive waste of low and medium levels; these are mainly muds, used resins, filters, gloves, overshoes and contaminated materials.

The LVNPP has a treatment plant where the waste is sorted, treated, immobilized and packaged. For several years, the LVNPP has implemented a successful program to reduce waste generation. The packaged waste is stored in a temporary storage at a site of the Central itself, until the national repository for its disposal is ready. The LVNPP also has an appropriate license by the CNSNS.

However in recent years, some information has been circulating in the press about opinions of former employees who worked at the LVNPP, commenting on containment with its nuclear waste, claiming that, even the way in which it is managed, there was a latent danger, and in the future will affect the performance of LVNPP **[9]**.

On December 2015, Professor of the Faculty of Sciences of the Universidad Nacional Autónoma de México (UNAM), Bernardo Salas commented on the online portal XEU news,

that the LVNPP was sanctioned by the CNSNS by improper confinement of radioactive waste **[10]**.

Likewise, 'plumaslibres', also an online site, published that the already mentioned professor from the UNAM noted that according to the diagnosis of CNSN, wastes had been incorrectly conserved in gallons, for over 15 years. "Since 1996 waste Unit 2, from the reactor 2 has not been addressed and since 1999, they have not treated the waste from the unit 1, and that it is how it has been documented, (...) the reports are not signed, they do not show the values recorded", he said at a press conference in the city of Veracruz **[11]**.

Because of this mismatch of information, the decision to conduct a survey to know the point of view of experts (working or retired) from nuclear LVNPP on these topics were made.

## III. METHODOLOGY

By delving into the recycling information, on the generation of electricity, it is possible to find studies being conducted on the use of nuclear waste used during this process, but these studied techniques are not exploited within Mexican territory. In this exploratory study, the opinions of experts on the reuse of existing spent nuclear fuel within the LVNPP were inquired.

### *A. Data gathering instrument.*

In order to collect data, opinions of people who have not only knowledge but also experience working in the generation of electricity using nuclear material, an online survey was designed.

Looking for answers that offer the possibility to generate graphs, closed multiple choice questions were used to facilitate statistical analysis of the results. In addition, it included a single open question, with the possibility of an extensive review of respondents, in order to know more about their personal view on nuclear energy and recycling of spent nuclear material.

### *B. Survey design.*

The survey was designed online; using Google means, through its package of tools. With the foregoing, the survey was available anytime and anywhere, as they are still available on the network.

Pilot tests were performed, proposing several questions, and increasing them. The final version states, nine multiple-choice questions, an open one that allows the respondent to express their opinions, particularly on the use of nuclear energy to address the energy needs of the population.

### *C. Sampling.*

The selection of the sample, for which the instrument was intended to collect, was delimited according to academic and professional training of the respondents. Particularly, people who has an engineering academic background, with experience with nuclear material. Also, people who has worked or are still working in a department within the LVNPP; it is to this central, where data collection focuses. Therefore, a nonrandom sampling was taken in consultation with people who fulfilled the required profile and have the willingness to be interviewed and share their knowhow on the nuclear topics.

## IV. ANALYSIS OF THE RESULTS

The results obtained are based on the responses of 10 people surveyed, obtaining the following information:

- The educational background of the respondents showed that 50% got an engineering degree, 40% have completed a master's degree and 10% have a doctorate.
- The 20% of respondents worked for 6-10 years at the LVNPP, while 80% worked more than 10 years in the plant.

The respondents have worked in departments such as:

- Licensing and nuclear safety, Engineering and Support, Design, Radioactive Waste Engineering in Water Treatment Plant for the cooling system and the Radioactive Waste Treatment, Start Testing, Operation, Training and Nuclear Safety.

The expert's opinion about the economic and technological status of Mexico, in order to be adequate to recycle nuclear waste on LVNPP is show in figure 1.

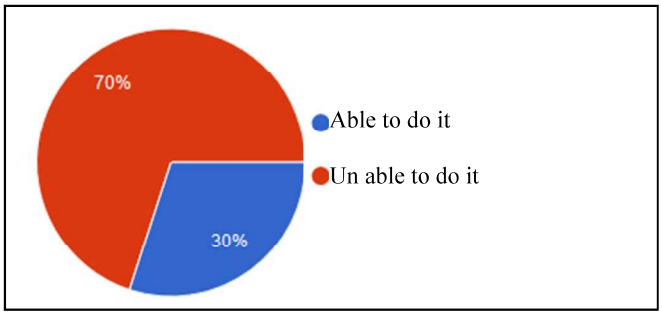


*Figure 1. Percentage of opinion on whether Mexico is in technical and economic conditions for recycling fuel on LVNPP.*

In addition, it was questioned whether nuclear energy in Mexico could be developed and be a source to supply the country's energy demand in the future, 87.5% agreed, in contrast of the remaining 12.5%. From the 87.5% that agreed that nuclear energy has a future, based their response in reasons shown in figure 2.

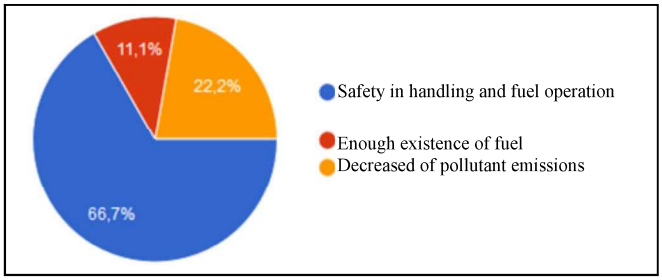


*Figure 2. Reasons to support nuclear power.*

While 12.5% did not believe that nuclear energy could present a promising future in Mexico, was due to a high environmental impact that could occur on a possible accident with nuclear material used in the process of generating electricity.

Regarding question “do you think that it is technically possible to reuse the spent fuel from the LVNPP?”, 70% did not agree, while 30% agreed. Likewise, Figure 3 shows the reasons of the experts to support these results.

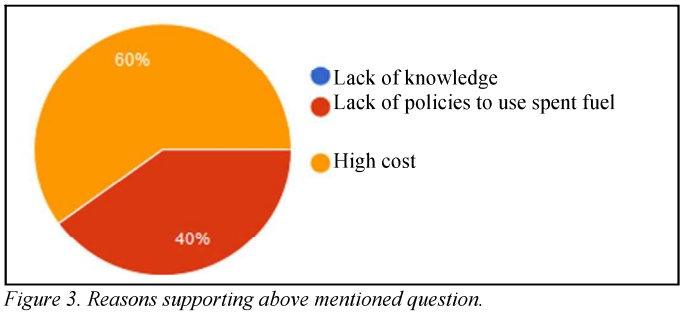


*Figure 3. Reasons supporting above mentioned question.*

According to their experience working on the LVNPP, the survey group were asked if they would support the use of nuclear material recycled to meet energy demand in Mexico. 70% did not support it, while the remaining 30% supported it. Regarding: 'Do you think that Mexico currently has the necessary fonts to meet the popular demand of electricity?' The responses were as shown in Figure 4.

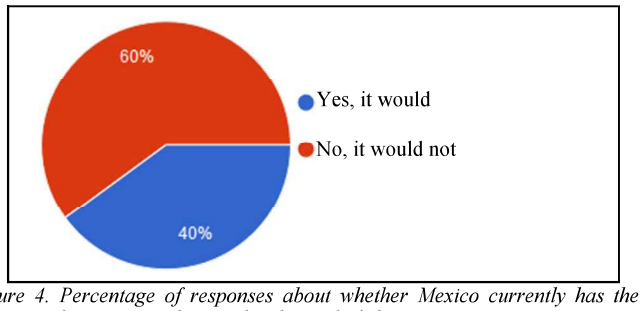


*Figure 4. Percentage of responses about whether Mexico currently has the necessary fonts to meet the popular demand of electricity.*

When its position was asked, for or against, to continue generating electricity using nuclear material, it was possible to obtain a personal and extensive answer from each of the respondents, allowing an open replica. Among the answers found in favor of its use, we mention the following:

- “Because it is required to reduce the emission of polluting gases into the environment”.
- “Yes, it is an energy whose fuel is cheaper than petroleum and does not emit $CO_2$ into the environment”.
- “Yes, it is a source of clean energy profitable and of large capacity”.
- “It is one of the sources that generates less pollution to the environment”.
- “The existence of a security system for expulsion of radioactive contaminants, and operability of the plant, representing a yield of 7% compared with the total of all electricity generation in the country”.
- “It is useful, but is not excluded that in an incident of radioactive leaks into the environment can be a tremendous loss for the country. For this reason, the LVNPP is ruled under strict security and operability policies”.
- “Yes, nuclear power is safe, clean, and reliable. LVNPP has enough experience in the design, construction and operation of this type of energy. It helps to reduce the impact of climate change because it emits no greenhouse gases. It could satisfy large volumes of the increased demand expected for the coming years”.

The responses against nuclear energy were the following:

- "No, I think that the moment in the country to continue with the expansion of new nuclear plants has passed, Mexico lacks qualified personnel on such activities, it is best to look for alternatives such as solar energy among others".
- "Safety is essential and must be applied by people who sticks to the regulation. I know some people on the operation area and when they leave, those who stay must ensure nuclear plant safety and I'm not sure about that".
- “Nuclear power is a culture focused on protecting citizens and the staff of the plant, and a single error in the technical specification can produce an event like Fukushima”.
- “Nuclear power provides for a small percentage of the total production of electrical supply, and there have been changes and "improvements" which have cost have been similar to the combined cycle generating more than the expected power. Only an error and, there will be a scenario similar to the Japanese one”.

Table 1 summarizes the obtained results; showing the percentage of those surveyed who support the use of nuclear energy, as well as the percentage of answers against its use.

| Question | In favor | Against |
|---|---|---|
| Do you think that Mexico is in technical and economic conditions to recycle nuclear spent fuel in LVNPP? | 30% | 70% |
| Do you think that the electric generation using nuclear material in Mexico will be effective in the near future? | 90% | 10% |
| Do you think that it is technically possible that nuclear waste generated at the plant LVNPP can be reused? | 70% | 30% |
| Based on your experience and knowledge regarding the subject, do you support the use of recycled nuclear material to meet current energy needs of our country? | 30% | 70% |
| Do you think that Mexico currently counts with the necessary sources to meet the popular demand of electricity? | 40% | 60% |
| Do you agree on keeping generating electricity using nuclear means? | 70% | 30% |

*Table 1. - Responses in the survey applied*

## V. CONCLUSIONS

Different points of views on the current and future use of nuclear energy in LVNPP were obtained. On the consulted opinions, nuclear energy experts consider nuclear energy generation as an option to meet the energy needs of Mexican society. It is not possible to ignore the protection of the

environment, as historical accidents had shown catastrophical consequences.

Available information on the internet about the treatment of nuclear waste by LVNPP, revealed that the security issue was an area of improvement. However, based on results from the surveys, experts supported the idea that the safe handling and operation of nuclear waste in LVNPP was currently correctly and a consistent energy source.

Some of the consulted sample said, in LVNPP would be technically possible to reuse the spent fuel. This would make LVNPP an ecological plant as other similar industries which reuse their generated wastes; even though a limiting factor for achieving the reuse of nuclear spent fuel is the high cost of the process, coupled with a lack of adequate policies and procedures, looking to achieve a sustainable center in LVNPP.

In a large percentage, a trend was observed in the results indicated by the surveys, which presented that Mexico would need to implement different sources of power generation, stated by the surveyed experts. This was a reason to meet the energy demand in Mexico in a clean, cost-effective and high capacity source as, the nuclear energy generation presented. The safe operation in engineering is essential during the development of this study, and must be applied according to the regulations, the consequences of an error in the processing or handling nuclear material would be disastrous.

It became clear that the prevailing opinion regarding the electric generation by nuclear means in the LVNPP was divided, which could be a solution for the energy needs, but also could be a cause of environmental and health problems in Mexico and for the world population. Mexico still lacks technology and economic status to emulate countries like France, in order to decrease the residue of spent nuclear fuel.

In the LVNPP, there were areas of opportunity to recycle nuclear fuel and decrease the costs arising from its confinement, in addition to reduce the generation of radioactive waste, taking a step to be a sustainable nuclear power plant.

Safety measures must be followed in a exhaustive way because, as Professor Bernardo Sosa stated, sanctions that were imposed on the LVNPP by mishandling nuclear waste was a sign that, before considering a reuse of hazardous materials, such as nuclear waste, the proper application of the current rules are mandatory.

Therefore, the safety and health of the population must be protected above even from an energy need, regardless the sector that has requested it.

The development through scientific research and innovation of different technologies, allow the nuclear power generation in a increasingly, efficiently and safety (as the reuse of spent fuel) way, and derived from the results obtained in this study, LVNPP would present, in the future, an opportunity to implement this technology and to become a sustainable supply central.

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