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NUCLEAR ENERGY: A SAFE, CLEAN AND COST-EFFECTIVE WAY TO MEET KYOTO TARGETS

Guillermo Velarde, Professor of Nuclear Physics and President of the Fusion Energy Institute at the Polytechnic University of Madrid.

Energy from nuclear fission guarantees our energy supply. It is relatively inexpensive and safe to run. It has been proven to have no negative impact on health and is environmentally friendly- free from CO_2 or greenhouse gas emissions. Technological progress has already provided satisfactory solutions for the disposal of nuclear waste, although further research needs to be carried out within this field. Both Spain's high reliance on energy and the need to abide to the Kyoto agreement simply highlight the benefits this form of energy could have for Spain.

Coal thermal power plant, Spain.

When Albert Einstein claimed in 1932 that obtaining nuclear energy would never be achievable, little did he know that just ten years later, Enrico Fermi and Leo Szilard would build the first experimental nuclear reactor at their laboratory in the University of Chicago.

From the very beginning, one of the main uses of nuclear fission was meant to be the production of electrical energy. With this goal in mind, research was carried out on the main types of reactors that would intrinsically be safe to run and where if in operation should the temperature rise for any reason, the number of nuclear fissions would decrease and the reactor would produce less power. This would lead to a reduction in temperature which would compensate for the initial increase, giving rise to what is technically known as a *negative temperature reactivity and void coefficient*. There are currently 429 nuclear reactors of this kind in operation and 24 under construction: 104 in the United States, 59 in France, 56 in Japan, 8 in Spain, etc. Throughout the European Union, 38% of the generated electrical energy is nuclear energy (79% in France, 55% in Belgium, 47% in Sweden, 31% in Germany, 19% in Spain, etc.). These figures do not contemplate the Chernobyl-type reactors of the former USSR, for reasons explained ahead.

The majority of these 429 nuclear reactors are pressurised light water reactors (LWR) or boiling water reactors (BWR)- strong and compact reactors developed by both the United States and the USSR to power their war-ships, especially their submarines.

Research carried out from the very beginning showed that light water cooled reactors which used solid graphite as a neutron moderator (the type that later on served as the basis for the Chernobyl reactors), were not suitable for the production of electrical energy. They were dangerous during start-up, as that they did not fulfil the prior requirement of any electrical-energy-generating reactor of being intrinsically safe during operation. A potential rise in temperature in this kind of reactors would mean more nuclear fission reactions and a subsequent increase in the reactor's power output. This would lead to an additional rise of the original temperature which the reactor's control systems were meant to compensate. Technically-speaking, these reactors have *positive temperature reactivity and void coefficient*. Nevertheless, this kind of reactor has the special feature of being able to produce highly-enriched plutonium (94% Plutonium-239 and 6% Plutonium-240) used in atomic bombs.

"Nuclear energy is more cost-effective than all types of energy, followed by natural gas, coal and wind-powered energy. It does not generate greenhouse gas emissions"

In order to obtain plutonium for nuclear weapons, both the United States and the USSR built several reactors of this kind, which would disperse the steam produced into the atmosphere. The United States chose a remote site located in Hanford (north-west of the country, within the boundaries of the State of Washington) for its reactors. However, in 1966, once the plutonium required for the majority of its 33,000 nuclear warheads had been obtained, the United States dismantled the reactors. The USSR, despite having produced the required amount of plutonium for the majority of its 45,000 nuclear warheads decided to keep the reactors in order to generate electrical power and also as potential means to increase their nuclear arsenal if required. No nuclear security council in any responsible, democratic country would have ever allowed the use of these reactors to produce electrical energy. Nuclear scientists throughout the world, including Soviet scientists knew they were unsuitable for this purpose. However, the Soviet experts only expressed their concerns in private amongst fear of retaliation.

Nevertheless, the USSR disregarded the experts' advice and created 18 reactors of this kind, allowing the water coolant to boil in order to feed an electrical energy producing turbo-generator. 4 reactors were built in Chernobyl (Ukraine), all of which are currently out of service; 2 were built in Lithuania, one of which is out of service and the second one will be decommissioned in the year 2009, and another 12 were built in the current Russian Federation, all of which are currently operating.

One of the benefits of nuclear power plants is their ability to produce cheaper electrical energy (2.37 euro cents per kilowatt hour) compared to other sources of energy, except for hydro-electricity.

Nuclear energy is the most cost-effective energy currently available followed by natural gas, coal and wind-powered energy. Nonetheless, a number of aspects must be considered. If, in the future, a long-life waste transmutator were to be employed, the cost of nuclear energy would rise to nearly 3 euro cents per kilowatt-hour. In the case of both gas and coal-generated power plants we must bear in mind the purchase of emission rights or the future employment of CO_2 capturing techniques and storage at great depth (sand layers, empty oil wells, empty natural gas pockets, etc), which would bring up the price of the energy 40% raising the cost to 4.6 and 4.3 euro cents per kilowatt hour, depending on whether the power station is fuelled by coal or natural gas. A wind power kilowatt-hour rate worth 5€ equals 2,300 hours usage a year, which is barely achieved in Spain in the areas of greatest wind-generated power potential (Pre-Pyrenees, Galicia, Tarifa). As wind-parks spread to areas of lower potential, the hours of use will diminish, and subsequently an increase in the kilowatt-hour rate will take place. In the year 2005, wind-generated power came to 9,866 megawatts, based on a use factor of 2,100 hours per year. It is predicted that, by 2010, a total of 20,155 megawatts may be produced, which means that the use factor would probably come down to some 1,900 hours per year (2.6 months a year).

"Nuclear power plants offer the enormous advantage of being able to guarantee the supply of electrical energy"

Environmental Benefits: No Greenhouse Gas Emissions

Another very important advantage is that nuclear energy is free from greenhouse gas emissions, unlike thermal and combined-cycle power stations. Those who are concerned with climate change seem to ignore this aspect.

From an economic perspective, this is also a relevant issue for Spain within the context of the Kyoto agreements, the Emission Trading Directive and the cost of acquiring emission rights for the productive sectors.

The Advantage of Guaranteed Supply

Nuclear power plants offer the enormous advantage of being able to guarantee the supply of electrical energy. Other sources such as wind-generated power and solar energy are unable to guarantee this supply, as they rely on weather conditions.

The Debate on Nuclear Proliferation

Anti-nuclear groups tend to associate nuclear energy for electricity production with the bombs that were dropped on Hiroshima and Nagasaki, in the same way as they might link the pharmaceutical industry or therapeutic molecular biology with chemical or biological weapons. These groups base their rejection on the dangers of nuclear proliferation, the Chernobyl accident and the issue of radioactive waste.

According to anti-nuclear groups, the plutonium obtained from either irradiated fuel or waste fuel from a nuclear electrical energy power plant could be used to manufacture Nagasaki-type atomic bombs. However, that is a misconception, as the above-mentioned plutonium is only 60% enriched, which means that, if a bomb made with this material were to explode, in 96% of the cases only a flash would be produced (94% enriched plutonium is required to make a Nagasaki-type with a 90% explosion reliability).

"The reactors of the 18 Chernobyl-type nuclear power plants in the former USSR are not suitable for the production of electrical energy, although they are ideal for producing highly-enriched plutonium that can be used to create nuclear bombs"

The Safety Question: Lessons from Chernobyl

In USSR, the experience of all 18 nuclear power plants similar to the one in Chernobyl has been highly negative, as their reactors are not suitable for the production of electrical energy, although they are ideal for producing highly-enriched plutonium which can be used to create nuclear bombs. Regarding the accident that occurred at the Chernobyl plant, the intrinsic lack of safety of the reactors was compounded by the inexplicable behaviour of the operating team in Unit 4, who sought to demonstrate that nuclear physicists and engineers were mistaken about the dangerous nature of graphite-light water reactors (RBMK or Chernobyl-type reactors). With this objective in mind, the operating team at Unit 4 at this power plant decided to carry out an extraordinarily dangerous experiment which would have never been authorised in a Western country. It is possible that the Head of Chernobyl was aspiring to obtain some kind of special recognition from the Moscow authorities- a common enough occurrence in the former USSR.

As a consequence of this experiment, events unfolded as they inevitably had to unfold. When the temperature rose to the point where it was out of control, some 1,700 tons of solid graphite burned, creating an enormous furnace. This recalls the Spanish saying coined by Eugenio D'Ors: *when experimenting, please use soda-water*

Shortly after the accident, a study undertaken in America, which lacked any kind of scientific basis, estimated that over 200,000 people would die as a result. This figure made a significant impact in the social media, which has not ceased to refer to it ever since. However, following the research carried out since 1986 in order to discover what really happened, the UN published an extensive and exhaustive report on 5th September 2005 (*Chernobyl Forum,* consisting of 3 volumes and 600 pages), which was drafted by over one hundred doctors, biologists and engineers from eight different international organisations. It must be pointed out that some of them were against nuclear energy.

The findings of this report were the following:

1. 56 direct deaths and during the period 1986-2004 (47 accident workers and nine children with thyroid cancer produced by Iodine-131).
2. Some 3,940 people fell ill from exposure to radiation, mostly children and adolescents who developed leukaemia and cancer of the thyroids due to Iodine-131. Thanks to medical treatment these victims have survived over the last 20 years. As Iodine-131 is a b emitter with a half-life of 8 days, a few months after the accident it disintegrated itself and disappeared (only a few traces remain). All of the patients suffering from cancer of the thyroid were exposed to radiation during the first few weeks.
3. A slight increase in minor leukaemia cases was recorded amongst firemen and workers at the plant, all of whom survived thanks to medical treatment.
4. No abortions, malformations or fertility damage has been observed.
5. Traces of Caesium 137, a b emitter with a half-life of 30 years, have been found in lichen and mushrooms in the forests of Finland and Sweden.

"On 17th March 1978, ETA killed the employees Andrés Guerra and Alberto Negro at Lemóniz. On 13th June 1979, the terrorist group killed Ángel Baños. On 29th January 1981, ETA kidnapped José Mª Ryan and murdered him on 6th February. On 5th April 1982, the group murdered the Chief Engineer, Ángel Pascual Múgica"

Of all 3,940 victims of radiation who have survived so far, most of them could die before their time over the next few years, due to delayed-effect metastasis and the side-effects of the medical treatment. If we disregard the cases of spontaneous cancer which are unconnected to the Chernobyl disaster, a 3% rise on cancer rate could still be attributed to the accident. This makes assessing how many out of the 3,940 victims of radiation would really die as a result of the effects of the accident a difficult task. Furthermore, doctors from the Ukraine and Belarus estimate that 99% out of the 3,940 people will survive.

In short, the number of deaths that could have taken place after 1986 would range from 100 to 4,000. Although the maximum estimate is high, it could be compared to other non-nuclear accidents, such as the number of miners who die each year in Chinese coal mines. Therefore, the number of deaths caused at Chernobyl is still one third lower than the number of casualties of the 1984 chemical industry catastrophe of Bhopal (India).

Radioactive Waste

Either irradiated or used fuel is stored in pools located in the nuclear plant for over three months. Afterwards, the waste can be recycled and the plutonium, the impoverished uranium and the rest of the radioactive elements extracted. Alternatively the different components can be extracted and distributed into low-level, intermediate-level and high-level radioactive waste. High-level radioactive waste must undergo a dry method of storage in individual or centralised waste repositories. The final stage of the waste processing can be carried out in deep geological repositories (DGRs), currently under development.

Spain has safe interim storage methods available, for which a decision regarding DGR is best postponed. Also, the fact that both impoverished uranium and the plutonium found in used fuel elements could serve as fuel for further nuclear reactors must also be taken into account.

The creation of a transmutator for long-life radioactive waste is currently at the R+D stage. It is a proton accelerator driven transmutation system which works against a lead target. Each proton produces 15 neutrons in the lead nuclei as a result of spallation and a transmutation of long-life waste into short-life waste is achieved.

There are some 3,000 tons of long-life waste throughout the world (1% of high-level radioactive waste)- with Spain having 60 tons. The transmutator's 99% performance rate would allow to transmute the above-mentioned waste into 30 and 0.6 tons, respectively. Compressed to ten times the initial density, this waste would be reduced to 3,000 litres throughout the world and 60 litres in Spain.

Making use of a transmutator, which is currently at the development stage, would raise the cost of a nuclear kilowatt hour by 20% to 40%.

Spain's energy dependence

The current energy outlook could be outlined as follows:

1. **All petrol extracted in 2003 equals just two days worth of refined fuel.**
2. **All natural gas extracted in 2003 accounted for 1% of national consumption.**
3. **Spain's coal deposits are scarce. It is expensive to extract and produces sulphur emissions (sulphur compound emissions can be reduced by mixing the coal with calcium carbonate).**
4. **There are few wind-powered generation sites with a medium-high use factor (more than 2,100 hours/year).**
5. **Hydro-electric reserves capacity is full to the limit, with space remaining only for mini-hydraulic plants.**

Both Spain's extremely high reliance on foreign energy sources and the high cost of imported energy mean that the decision adopted in 1984 regarding the nuclear moratorium must be reviewed and the announced decisions to close the operating nuclear plants must be reconsidered.

The Spanish Nuclear Moratorium

As a result of the 1973 oil crisis and following the findings of a study on Spain's future energy requirements, the Spanish Government decided to build six nuclear power-stations: Lemóniz I and II (in the Basque Country), Valdecaballeros I and II (in Extremadura), Trillo II (in Castille-La Mancha) and Sayago (in Galicia). However, a number of demonstrations organised by radical anti-nuclear groups took place in the late 1970's. ETA supported the demonstrations and took advantage of the anti-Government feeling. On 17th March 1978, ETA detonated a bomb in the vicinity of the reactor at Lemóniz, killing the employees Andrés Guerra and Alberto Negro. On 13th June 1979, another bomb exploded in the turbine zone of the reactor at Lemóniz, killing Ángel Baños. On 29th January 1981, José Mª Ryan, Chief Engineer at Lemóniz was kidnapped by the terrorist group. He was executed on 6th February. On 5th April 1982, the group murdered Ángel Pascual Múgica, Chief Engineer of the joint venture that was funded to build Lemóniz.

In 1984, the Government approved the National Energy Plan, which had little technical justification and did not favour the interest of the Spanish population. It effectively stopped the development of six nuclear plants which were at different stages of construction. It also prohibited the construction of new ones.

The nuclear moratorium is one of the biggest economic disasters of the Spanish political transition, for it has entailed the following:

1. Compensating the electricity companies involved in the creation of the nuclear plants. The cost totalling 600,000 million pesetas (as of 1984) has been charged to the population's electricity bill.
2. Replacing the nuclear power stations with coal and gas-powered plants has increased the cost of energy supply to 3.2 euro cents per kilowatt hour instead of the nuclear energy cost 2.37 euro cent per kilowatt hour.
3. An increase of greenhouse gas emissions by either 48 million or 24 million tons of CO_2 per year, depending on the coal or gas-fuelled plants replacing the nuclear power stations.
4. The EU granted France the right to implement the experimental ITER nuclear fusion reactors in their site in Cadarache even though the Spanish site in Vandellós, was more cost-effective and technically superior to the French alternative. The nuclear moratorium dismantled the Spanish nuclear industry, leading to a brain-drain of more than 1,000 nuclear physicists and engineers. Despite the general public lack of interest on the placement of the ITER nuclear fusion reactors, the choice of location must be regarded as one the most harmful consequences for the Spanish interests, as the nuclear moratorium will impede and prevent over one thousand physicists and engineers to work in Spain with cutting-edge technologies associated with ITER- what would have provided a considerable boost to the development of Spanish science, so cruelly rebuffed over the years.

"In 1984, the Government passed the National Energy Plan, which had little technical justification and was harmful to Spanish interests, effectively paralysing the six nuclear plants at different stages of construction and prohibiting the construction of new plants"

The Social Response to Nuclear Energy

In a survey carried out in 2001 in the United States (Bisconti, A.S. and Richards, M.D., *Nuclear News* 36, 11, 2001), 74% of the population supported the construction of new nuclear power stations and, within this band of approval, 64% preferred these power stations to be built in former nuclear sites. In Switzerland, 58% of the population oppose the nuclear moratorium and 66% oppose the closure of nuclear power stations, as 33% of the country's electrical energy is generated by them. Finland, a country with extensive tracts of forest and large regions of considerable wind-power potential, nonetheless produces practically no wind-powered energy (just 82 megawatts), with 33% of its electrical energy being obtained from nuclear power stations. The country is currently building a new reactor. A curious note on the French nuclear scenario might be worth telling. When the construction in Framaville of the country's sixtieth nuclear power station was approved, the neighbouring town protested. However, the protest was not against nuclear energy. They demanded that the new nuclear station be built closer to theirs.

In Spain, where the energetic scenario is similar to that of Japan's in terms of insufficient fossil fuels and lack of regions of considerable wind-power potential (based on a use factor of more than 2,200 hours per year), the social perception is different and subject to changes. A number of political leaders, social leaders and trade unionists who formerly opposed nuclear energy are now supporting it.

"A number of prominent political, social and trade union leaders who formerly opposed nuclear energy are now supporting in Spain"

Conclusions

Bearing in mind that the EU has signed the Kyoto Protocol and considering all the points discussed above, we feel that the nuclear moratorium in Spain should be lifted in order to satisfy the country's electrical energy requirements in the medium term. New nuclear power stations should be constructed. Furthermore, the implementation of an effective R+D scheme should be put in place, with a view to developing the following:

1. The capture and storage of CO_2.
2. A long-life radioactive waste transmutator.
3. High-temperature thermal solar energy.
4. Photovoltaic solar energy.
5. The production and use of hydrogen.

However, the final solution to the long-term energy problem (50 to 75 years) will only be available when energy produced by nuclear fusion is marketed, this being the type of energy that is produced by the stars and, in particular, by the Sun- a type of energy that we aim to achieve on Earth.

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www.fundacionfaes.org
papeles@fundacionfaes.org