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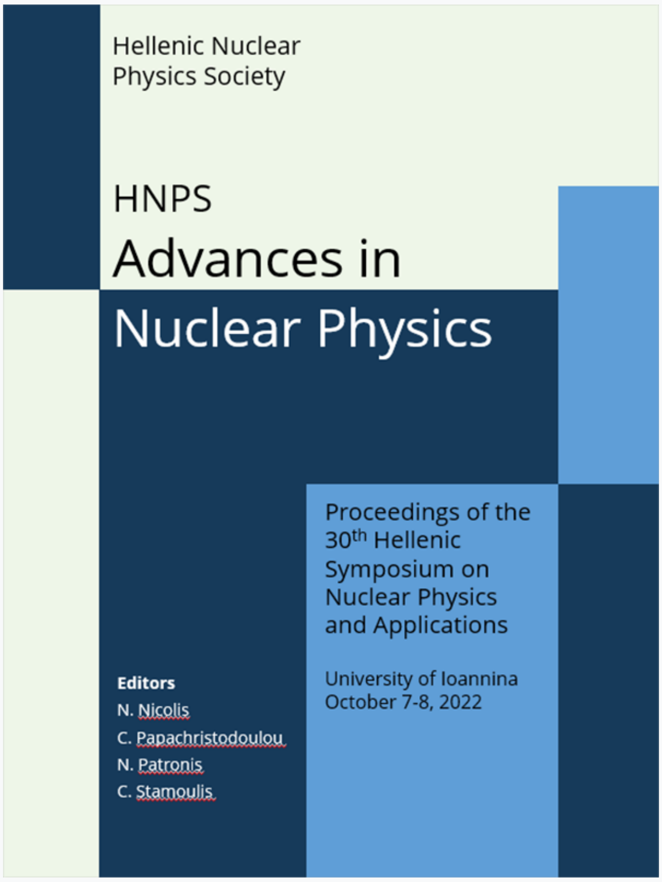

Nuclear power as part of the Greek energy mix: Far better to be cost effectively proactive than unconditionally inactive

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Nuclear power as part of the Greek energy mix: Far better to be cost effectively proactive than unconditionally inactive

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Abstract This position paper advocates preparatory actions for the incorporation of fission energy into the Greek mix, should this be necessary within the foreseeable future. To this end, and first of all, a concise understanding of the current Greek energy mix and its perspectives is essential in connection to the potential problems due to the expansion of renewable energy. Present and future inefficiencies could be avoided to a manageable extend, mainly by energy savings, mostly applicable for buildings consumption and also by upgrades towards a much denser grid, capable of reversing flows, along with energy storage facilities. In parallel, an assessment of the introduction potential of nuclear power could be examined. The assessment could involve political parties, scientists and other stakeholders, pro and against, and might reasonably result to justified arguments capable of raising public awareness. The country's preparedness to go nuclear could depend more or less on the degree of local energy market regulation framework, on the local and broader investment and financial environment, on the power plant construction and operation insurance possibilities, on the review and introduction of applicable law for licensing and regulating nuclear power and on the local scientific potential in the nuclear engineering field. Parameters like construction of related major engineering parts locally should also be examined along with compensatory benefits to the domestic economy and the local societies in the vicinity of the reactor sites. It is proposed that this work could be accomplished by an adequate task force without particular costs and within reasonable time.

Keywords nuclear power, nuclear reactor, Greece

INTRODUCTION

The incorporation of a nuclear power reactor (or even reactors) in the Greek energy mix is certainly possible from the technical point of view. If the cost of such an option could be deemed manageable, then, it seems that, adding such a component is a probability that should be considered in the foreseeable future. Reasons regarding this consideration are: zeroing the green house gas emissions, increasing the grid stability, supporting the base load, securing electricity energy independence, promoting the country as an electricity hub interconnector in SE Mediterranean, keeping fossil fuels as strategic reserves, abstain from natural gas imports etc. The arguments against such a choice are: cost considerations, site selection problems, waste disposal problems, societal concerns, urban myths and misconceptions and others. It is of importance for Greece to reach a decision on this matter, either positive or negative, independently of any external influence, based on its own experts opinion. Additionally, and well before any final action, both social and political consensus should be reached. The means to this end are: knowledge, expertise, discussion and persuasion based on scientific and financial facts. There exists a pool of scientific and business resources, from which one could draw consulting personnel with adequate knowledge and expertise for energy matters and capable on consulting on the nuclear question. Components of this pool might be: the Public Power Corporation S.A., the Regulating Authority for Energy, the Independent Power Transmission Operator S.A., the Hellenic Electricity Distribution Network Operator S.A., the Public Gas Corporation of Greece S.A., the Hydrocarbons and Energy Resources Management Company S.A. and similar entities. Last but certainly not least, people coming from universities and research centers could contribute with their educated opinion and expertise.

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Unfortunately, instruments like the National Energy Council, which was thriving as a State consultant in the '70s does not exist anymore. Nor it exists, its short-lived successor: the Council for the National Energy Strategy, which concluded its life in 2009 [1].

FEASIBLE SOFT ACTIONS WORK

On the public, social and political perception field

The urban myths regarding immeasurable numbers of victims due to nuclear accidents should be discarded using available hard data coming from well acknowledged international organizations like the United Nations and the International Atomic Energy Agency. In fact, and according to data found in well esteemed on-line publications [2], deaths per nuclear electric PW-hour are approximately 0.03 in an energy environment that produces 2.5 nuclear electric PW-hours annually, that is practically "zero", especially if compared to the deaths resulting from the fossil fuels cycle including those from the gas cycle: 80 per electric PW-hour in an energy environment that produces 27 fossil fuel electric PW-hours annually [3]. The situation is much like deaths per mile travelled in air; these are also "zero", or, actually, 0.04×10^{-8} mile^{-1}, despite the publicity effect that might be produced by any rare flight accident [4]. In addition, it should be reminded that industrial accidents or toxic contamination situations, for example, the BHOPAL [5] and LOVE CANAL [6] cases, had significant numbers of victims and led to affected areas evacuations, but are largely ignored and forgotten. A total of 15000 died because of the BHOPAL accident, while several thousands of others suffered malignant diseases. In the LOVE CANAL case, ~250 families were permanently relocated. Furthermore, millions or even billions liters of toxic industrial and urban wastes are being dumbed daily and without any preprocessing in the environmental air, land and water without raising any massive and certainly justified concern. It has to be realized that nuclear wastes per reactor are of minimum volume, culminating to about some 10 – 100 m^3 yearly. It should be also stressed that the emissions using the nuclear way, at least for the EU, are at the absolute minimum, if compared to other energy sources, over the life cycle of a nuclear reactor and today (2022) estimated to about 6 g CO_2 per electric kWh. In terms of life time costs, decommissioning included, a nuclear reactor is quite competitive.

Peaceful applications of nuclear technology should be disconnected from weapons in any public or political mind. Nuclear technology has been useful and applied in industry and medicine in Greece and elsewhere without connection to any weapon technology whatsoever. Talking of "elsewhere", it can be further communicated that almost all our neighboring countries already have nuclear power reactors, or they are going to have soon, namely: Bulgaria (4), Romania (2), Slovenia (1), Turkey (4 under construction, 8 more planned), Egypt (4 under construction, several more planned). The reactor types in these countries are far more safer than the Chernobyl type, since they, inherently, cannot catch fire.

On the other hand, one should not forget, and this should be widely understood, that any nuclear accident involving some considerable reactor core damage creates an almost impossible to handle cost.

On identifying the Greek potential

An appropriate census could be held to find out how many Greek individual engineers and other scientists exist locally and internationally with the capability and willingness to be involved in the preparation of a Greek nuclear reactor project. Further, within the same census, it could be identified the existing scientific personnel with suitable or close knowledge within the Greek public and private sector, including universities and research centers. It is difficult to assess this potential by simplistic calculations, since the outcome of the Greek Higher Education Institution in the nuclear engineering relevant scientific fields has been severely disturbed due to the recent austerity crisis and the resulting brain drain. It is worthy to mention, that, currently, the university laboratories capable of providing relevant engineering education are down to just two or barely three. In parallel to the census, the capacity of the Physics, Chemistry, Medical and Engineering Departments of the Greek tertiary education system to produce graduates with relevant capabilities should be investigated. A plan should be proposed to increase these capacities, if this is deemed as needed. A search could be also conducted for the suitable law makers, either individuals or within law firms, interested in investigating the applicable law aspects. Last, but not least, the investment scale of a reactor could call for a serious consideration on the relaxation of investment laws and prerequisites regarding "large and beneficial capital investments".

Last but not least, arguments presented publically, stress that most Nuclear Power Plants accidents strongly relate to human mistakes, thus making the case that in a non-nuclear country, there is always a know-how gap and lack of expertise when engaging energy producing reactor environments, possibly leading to accident prone situations. However, this is not a real issue since Greece efficiently and productively operates high-tech installations and devices; prominent examples are (a) the maintenance of well-populated civil and defence aviation fleets at an insignificant incident rate and (b) the operation of facilities supporting cardiac transplantations or other equally complex medical practices. Therefore, bridging this gap is a pure matter of education and training only.

On law and regulation aspects

It could be examined which nuclear law system available within the EU could be translated, transferred and adjusted for the Greek needs. In this frame, the licensing scheme of a nuclear reactor and all of its associated facilities could be suggested. Outsourcing licensing to internationally available, well recognized licensing services could be a time saving option. Changes in regulating authorities might also be considered. The questions to be answered culminate to: (a) Should the existing Radiation Protection Regulator assume the duties of a Nuclear Regulator? or (b) Should the Nuclear Regulator be new and independent? Attention should also be paid on the possibility of smooth introduction of fast track procedures in deploying the nuclear option. It seems appropriate to spend 8-10 years from decision day "zero" to first grid connection, rather than to consume 25 years for the same purpose. For example, following the good practices of nuclear fast track countries, like South Korea and United Arab Emirates, could be a favorable option.

TECHNICAL AND FINANCIAL ASPECTS EXAMINATION

In terms of energy economics, effort should be put to compensate any future energy needs by incorporating more and optimal energy savings especially for the old buildings stock, which has to be heated, vented and air-conditioned at a substantial energy cost. Such an investment could be much more effective and far less questionable than the nuclear way. The time for a nuclear reactor investment would be at the point when the benefits of such policies become marginal. However, work has to be done in parallel to establish the country's initial readiness for the nuclear option. Since such initiatives are now missing, some relevant considerations are summarized as follows:

Effort could be first put on identifying the international and local consultants interested in supporting any Greek nuclear projects. Beyond the identification stage, a preparation of the basics of an international call for tender for consultants could subsequently start. Nevertheless, before the engagement of any consultant, initial reactor siting considerations have to be made. The considerations should accept the fact that, in most well developed European countries, reactors are part of the agricultural or even suburban environment. The engaged consultants could be able to investigate siting or this task could be an object of a different international call for tender for a siting study. It would be far better and effective, if all consultants and studies could focus on a beforehand prepared reactor technology choices short list. If the list is to emphasize on what could be produced in EU or broader

Europe, the technology and reactor sizes designed in France could be an option. Regarding the small modular reactors choice, UK companies seem to lead the race both in Europe and internationally, thus making such a selection easier.

On the financial side, two are the main problems: Capital investment and insurance. The regulation of the local energy market should be carefully adjusted to adopt a nuclear energy component in the percentage range between 4 and 10%. The Greek state, as every state that operates reactors, should also examine an appropriate subsidizing scheme. Subsidizing and fast track could make the capital investment attractive in the long term and as far as capital depreciation at a convenient interest rate is involved. The fact remains that the capital cost of the initial investment for a reactor is huge and is usually contributed by a willing yet sole investor or by a small group of investors available to undertake all risks. It is evident that reaching out to investors groups early enough is key to successfully pull the reactor project through. In view of a revival of new built reactors in the EU, investors might be engaged in other reactor projects in different EU countries, before even thinking of any investment in Greece. Further, the investment on nuclear should be adjusted to a size that could keep the local electricity system stable, address the stability issues of projects of Greece's international interconnections (like the proposed EUROASIAN Interconnector) without abolishing previous investments in other forms of electricity production. Small reactors incorporating into the system could benefit from a dense and smart grid, soon to be developed for the accommodation of renewable energy production and the close introduction of energy storage facilities. One should not forget that, according to data such as those in [7], the local installations of renewable energy sources are now (2022) at about 10 - 12 GW. At an onshore installation cost in the range of 1.0 - 1.5 million EUROS per GWe [8], this investment, given the difference of the capacity factors between renewables and nuclear (~25% and ~85%, respectively), is now similar to two large size reactors of 2 GWe total power. The difference is that this investment has been distributed to many small businesses. The basics for a relevant study should be also prepared. Observing things macroscopically, and if the technology choice is set to small reactors, two units of 250 – 350 MWe each, may be the investment size preferable. For the insurance and counter insurance front, things could evolve to be more complicated than the investment front. Insurance companies are not that willing to get involved in such or similar projects due to previous bad experiences, like construction delays, costs readjustments and accidents, even if the latter is of miniscule probability. The basics for an international call for tender for insurance should be prepared on an attractive insurance fee basis.

ACTIONS INITIATION AND EVOLUTION

Private or state initiatives could be set to found a *Discussion Forum*, aiming to address the nuclear energy perception difficulty. Local and international experts could be invited and join, on a temporary or even regular basis, to participate in the discussion. Publicity actions involving opinion makers and influencers may be launched, in order to provide arguments useful for the debate. Debate possible outcome and final statement, either in favor or against a nuclear reactor, should be based on objective facts. All substantially different or opposite opinions should be welcome to contribute in the discussion.

Should the outcome of the *Discussion Forum* be positive and acceptable, both politically as well as socially, then the *Forum* could evolve to a *Task Force* of experts. The *Task Force* could assume the legal entity of a Non-Governmental Organization. The *Task Force's* administration could be provided by own means, or by major sponsors. The *Task Force's* mandate would be to prioritize and address previously mentioned and other necessary soft and harder actions. Funding might be secured by the electrical energy providers, according to their share in the market on a volunteer base encouraged by the state; after all, the annual sum of funded activities should and would be rather moderate. The *Task Force's* deliverables could be set after discussion with state representatives and the funding sponsors.

Reporting on deliverables would be both to sponsors and to interested state agencies. All reports should not adopt interventions neither by the sponsors, nor by the state. A concise Memorandum of Understanding should warrant and secure liberty of statements and actions. Sponsors or even external auditors could assess all deliverables in terms of quantity and quality. Sponsors auditors could examine the, anyhow limited, expenses flow. Effectiveness of the *Task Force* could be enhanced by a short mandate duration to last between minimum 2 years and maximum 4 years. Involvement of universities and research centers in the *Task Force* would be by any means welcome.

ROLE OF UNIVERSITIES AND RESEARCH CENTERS

It has to be mentioned that the nuclear industry and products environment of this century is vastly different than the corresponding environment of the '80s, when Greece decided to abandon any thoughts of developing one or more nuclear reactors. Globally, and due to the lack of capital investments availability, the current reactor versions belong to the mature technology of Generation III+, while, soon to arrive technologies designated as Generation V or as small modular reactors are envisaged to demonstrate even greater maturity. The reactor versions of the '80s mostly belonged to Generation II, where there was still room for evolution and optimization coming from independent scientists in universities and research centers. Given this situation, the role of educational and research institutions beyond the onset decision would be limited, taking also into account that major reactor selling and constructing corporations seem not in favor of third party involvements. Therefore, some, since long expected, outsourcing of research items could be very limited unless supported by some kind of compensatory benefits. Further, job chances for our graduates would not be as many as one might think; after all, a reactor operational environment is not labor intensive. Therefore, the introduction of nuclear reactor(s) in the Greek system will not create as many opportunities as anticipated in the past. It is not to be forgotten, that in most new built reactor cases *"parthenogenesis of the involved personnel is largely preferred"*, in order for the selected technology not to be questioned by comparison to other non-selected technologies.

FURTHER THOUGHTS

Direct Greek investments in nuclear reactors within the Greek state is certainly an option, which, given an, even marginal, political and social consensus, could reach maturity within reasonable time. However, Greece is now a part of a broader integrated energy environment evolving EU and non-EU countries in the Balkans and EU neighbors in the west of the country. Consequently, there exist other types of such energy investment options that do apply within the EU, i.e. Greece could partly finance a reactor developed beyond its borders, in order to benefit by buying some of its electrical energy production at reasonable, well before agreed prices. Such investment discussions have been into the making with Bulgaria about 20 years ago. There is the possibility that these discussions might reconvene in the near future.

Moreover, authors believe that, independently of any decision on the matter, Greece has the potential to be involved in the small nuclear reactors vessels construction industry and evolve to be a reactor parts construction hub. Parts "made in Greece" could be commercially propagated in the international market. After all, the idea behind the small modular reactors is that their smaller size would allow construction in industrial installations, rather than in the actual operation site. Plenty of ready and housed construction sites near seaports are already available to accommodate the necessary specialized machinery, which is nowadays commercially available and non-classified. Vessels and other engineering parts could be CNC machined to specifications. Finalized products could be then rather easily transferred to final customers. Of course, patents and proprietary designs will strictly remain with original designers and owners. However, there could be created significant knowhow transfer chances.

Safety and security necessary could be assured in collaboration with original designer's home country or countries. Greece, in this case, will not be involved in fuel or fuel related production. These items and any other nuclear materials will be the responsibility of other international providers. The technological, political and even geostrategic benefits of such a development are more than obvious.

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