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ऑफ इंडिया लिमिटेड
(भारत सरकार का उद्यम)
NUCLEAR POWER CORPORATION
OF INDIA LIMITED
(A Govt. of India Enterprise)
एनपीसीआईएल
NPCIL

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रजत जयंती वर्ष
SILVER JUBILEE YEAR
1987-2012

नलिनीश नगाइच
उत्कृष्ट वैज्ञानिक एवं
अधिशासी निदेशक (सी पी एवं सी सी)
NALINISH NAGAICH
Outstanding Scientist &
Executive Director (CP & CC)

D.O. NPCIL/ED(CP&CC)/2012/M/112 July 4, 2012

Sub: Your letter dated March 15, 2012 related to Solar Power/Nuclear Power.

Dear Sir,

1.0 This is in reference to your letter dated March 15, 2012 addressed to Honourable Prime Minister. The said communication, vide PMO ID No.14/3/2012-PMP3/384617 dated 20.03.2012 has been forwarded to us with an advice to respond to you.

We are indeed privileged to be in communication with an eminent personality like you. The atomic energy programme in the country was dreamt as early as 1944 by the great visionary Dr Homi Bhabha, for the benefit of the society. The Department of Atomic Energy, ever since, has been carrying forward this mandate in developing and deploying nuclear energy for societal applications, including nuclear power for electricity generation in the country. While implementing the programme, the safety and welfare of people have been the prime objectives before all other considerations. Sir, we truly appreciate that you have shared your concerns related to power generation in the country.

2.0 In your aforementioned communication, you have suggested large-scale adoption of solar energy as a means to address the energy needs of our nation. India is not rich in traditional resources of energy, while the demand for electricity in the country is growing. So, in India, we need to tap all viable sources of power generation, including solar. Let us assert here that we do not say that nuclear is or should be the only way to go; neither are we opposed to alternative energy sources. Indeed, time and again we have reiterated that India needs to tap all viable sources of energy and that renewable energy resources have a definitive role to play. Nevertheless, given the kind of resources available in the country, nuclear has a vital role to play in the energy mix of the country today as well as in the coming decades and centuries.

2.1 In a sunshine-rich country like ours, solar power has a substantial potential theoretically. However, in practice, realizing this potential on a large scale is fraught with several practical constraints. Indeed, there are limitations of solar that we want to bring out as below.

- ***Statistical stumbling blocks:*** The vast amounts of energy that our planet receives each day from the sun, in the form of solar radiation is, in fact, spread over a vast area globally. Because of this, solar energy is available in a dispersed form. This, in essence, renders solar energy a challenging resource to use practically than what appears possible simply from raw statistics. Quoting theoretical maximum "megawatts" potential and actually converting solar radiation into usable electrical megawatts are two different things involving many technological challenges and practical bottlenecks, some of which are further discussed briefly herein below.

- ***Low conversion efficiencies and Real costs :***
Solar photovoltaic (PV) cells have existed since 1950s. Commercially available solar PV panels have typical efficiencies in the range of 10-15%. Solar energy is a fuel that is available to mankind ***free of cost.*** This 'apparent' advantage of solar diminishes quickly in actual practice, as it is quite costly to physically tap this so-called 'free-of-cost' fuel, primarily because solar energy is not a 'concentrated' resource. A severe limitation of solar power is that there is no power generated during night time and not much on cloudy days, thus limiting its use as a base-load power-generation option. And the moment you think of bringing battery backups into the picture (for nighttime use), solar power becomes ***even more*** uneconomical than what you started with.

  Prima facie, solar power plants appear to entail lower per-MW cost for setting up a given capacity. But this is not entirely true. Let us see how. Solar plants have low capacity factors, and therefore the claimed lower per-MW cost of establishing solar power vis-à-vis nuclear must actually be examined in 'equivalent' terms ***rather than comparing upfront figures only.*** For example, solar photovoltaic panels have a 'maximum' conversion efficiency of only about 15-20% (or even less in many cases). Also, solar power plants remain idle during nighttime and nearly idle on cloudy days. **To make up for this loss in total units (kWh) generated in a given period of time, you are required to set up solar capacity multiple-times (i.e. multiple times the "nameplate" capacity of the plant) in order to reach output 'parity' with an equivalently rated base load plant.**

  Nuclear power indeed has been very cost-effective, consistently generating electricity at affordable prices. For example, NPCIL's nuclear power plants have been generating electricity, for last several years, at an average cost in the range of Rs. 2.25 to Rs. 2.50 per kilowatt-hour (kWh). And the real sterling examples are the Tarapur nuclear power reactors units 1&2, which are generating electricity at a mere 94 paise per kWh.

  The nuclear power plants planned to be set up in foreign technical cooperation will be implemented with a shared scope of work between the vendor country and Indian side in phases. These unique business models will optimize the cost and promote progressively increasing indigenization. Country has gained experience in devising and managing such shared scope of work in implementing Kudankulam nuclear power project. The cost of power from Kudankulam Nuclear Power Plant (KKNPP) is expected to be below Rs. 3.00 per kWh.

- ***Scaling up solar is a major challenge:*** If solar were to make a sizable contribution to the energy mix of India, it would need to occupy extremely large areas of land, spanning in the order of several thousands of square kilometers. Compared to this diffused nature of solar power, nuclear power is extremely concentrated and compact. On a per megawatt basis, the land required for nuclear power plant is about 10 to 20 times lower than that of a solar power plant.

- Distributed power generation is a popular term used in the 'alternatives' communities, especially solar. The term essentially means you have your own private power generation equipment like solar panels installed either on your home rooftops or on the walls of skyscrapers, or even in the form of small-size community solar farms. These types of installations can provide for basic needs like lighting etc., but are grossly inadequate for more intense applications like for industrial use. Also, periodic maintenance of such independent installations would be a costly and tedious affair for individual consumers.

  How green is solar really?: A shocking fact about solar industry pointed out in the book "Green Illusions" by Ozzie Zehner, a University of California–Berkeley visiting scholar, is that solar industry has grown to become one of the leading emitters of hexafluoroethane (C_2F_6), nitrogen trifluoride (NF_3), and sulfur hexafluoride (SF_6). These three potent greenhouse gases, used by solar cell fabricators, make carbon dioxide (CO_2) seem harmless. Hexafluoroethane has a global warming potential that is 12,000 times higher than CO_2, according to the Intergovernmental Panel on Climate Change (IPCC). It is 100 percent manufactured by humans, and survives 10,000 years once released into the atmosphere. Nitrogen trifluoride is 17,000 times more virulent than CO_2, and SF_6, the most treacherous greenhouse gas, is over 23,000 times more threatening. The solar photovoltaic industry is one of the fastest-growing emitters of these gases, which are now measurably accumulating within the earth's atmosphere according to the U.S. National Oceanic and Atmospheric Administration (NOAA). A NOAA study shows that atmospheric concentrations of SF_6 have been rising exponentially. A paper published in the peer-reviewed journal Geophysical Research Letters documents that atmospheric NF_3 levels have been rising 11 percent per year. If photovoltaic production grows, so will the associated side effects. The life-cycle emissions per unit of electricity generated in respect of nuclear are, in fact, about half of that of the solar power.

- ***Demands on raw materials:*** A large-scale implementation of solar infrastructure in the country would put huge demands on raw materials like steel and other metals, and will also involve the use of paints, plastics and other synthetics, etc. Furthermore, settling of dust over mirrors and PV panels also needs to be considered, as this reduces efficiency drastically.
  Sir, India's energy needs are vast and growing and there is no denying that solar can surely play a valuable complementary role at this point of time, especially in far-flung areas not connected to the grid. In future, when significant technological advancements allow greater efficiencies and cleaner manufacturing processes, solar can play even wider role in the energy mix of the nation. In the meanwhile, all that we are suggesting here is that any discussion on solar involving very enthusiastic appraisal of this resource should first take into consideration the aforesaid ground realities.

3.0 Safety in nuclear power plants: by design, not by chance

India has made notable strides in nuclear power development and deployment of commercial nuclear power. From the beginning of nuclear power programme in the country, a strong safety culture has been instilled, with well-established mechanisms for constant review and upgrades to keep the safety at the state-of-the-art level. The principle of 'safety first' is adopted in all activities from site selection (siting), design, construction, commissioning and operation of nuclear power plants. There are continuous internal reviews by NPCIL (operator) and also the regulator. Post-Fukushima, safety review of the existing Indian nuclear power plants in operation and construction by the task forces of NPCIL and an independent committee of Atomic Energy Regulatory Board (AERB) have found that ample safety margins and provisions exist in the design of Indian nuclear power plants for their safe operation even during stressful events. The Indian nuclear power plants are found safe against extreme natural events like severe earthquake and tsunami, and to make them safer, the significant recommendations arising out of the post-Fukushima review have already been implemented.

3.1 Impeccable Safety Record

Sir, as you have rightly mentioned in your letter, over the entire 42 years of commercial nuclear power generation in India, there has neither been an accident in the cumulative 360 reactor-years of nuclear power plant operation, nor has there been any incidence of release of radioactivity in the public domain beyond stipulated regulatory limits.

The robust safety of Indian nuclear power plants during extreme natural events has been practically demonstrated. Kakrapar Atomic Power Station (KAPS) continued to operate safely during the 2001 Bhuj earthquake. Also, in the case of 2004 Indian Ocean tsunami, Madras Atomic Power Station (MAPS) was brought online within a few days without any damage to the plant or involving any release of radioactivity.

It is sad to note that in your letter you have almost trivialized India's remarkable nuclear safety record, but let us reassure you, sir, that this has not been achieved merely because of chance, but actually through sincere, dedicated efforts and a strong safety culture, not to mention world-class technological implementation.

3.2 Nuclear – a clean and green source of power

Unlike fossil sources (coal, oil, natural gas, etc.), a nuclear power plant operates without emitting harmful gases like carbon dioxide CO_2, sulfur dioxide SO_2 or oxides of nitrogen (NOx) like the toxic nitrogen dioxide (NO_2) or its greenhouse cousin nitrous oxide (N_2O).

Even when you consider the entire life-cycle emissions of greenhouse gases associated with the operation of a nuclear power plant operation, they constitute only a fraction of those associated with other power-producing technologies. Indeed, the role of nuclear power as a clean, low-carbon source of power is acknowledged world over.

The radiation from a nuclear power plant is a fraction of the permissible regulatory limits and so extremely low that it is indeed indistinguishable from the background radiation omnipresent in nature.

3.3 Wealth from Waste

India is pursuing the 3-stage Indian Nuclear Power Programme, a closed fuel-cycle policy, involving fuel reprocessing. Nuclear power plants in India use natural uranium, which contains 0.71 % U-235, the 'fissile' isotope in the first stage of Pressurized Heavy Water Reactors (PHWRs) to generate electricity. The balance is U-238, which is a 'fertile' isotope, and a small fraction of this gets converted to another fissile material, plutonium-239 (Pu-239). The waste generated in the first stage is small, equivalent to the fuel consumed. The spent fuel essentially contains unconsumed U-235, U-238 and Pu-239. All these are useful fuels for the next stage, and thus spent fuel is an important and valuable resource for the indigenous nuclear power programme, which is robust and on course.

3.4 Nuclear Waste Management

Nuclear waste refers to waste that has radioactivity in it and is classified into high, intermediate and low levels depending on the level of radioactivity.
India follows a closed fuel-cycle policy, where the spent fuel is reprocessed to obtain fuel for the next stage. The high-level waste is generated at reprocessing plants. Its quantity is very small, of the order of 1-4% by weight of the fuel, which itself is very small in quantity due to its high energy intensity. High-level waste generated from the reprocessing plant is vitrified into a glassy form, contained in multiple barrier containers and stored for an interim period of three to four decades in engineered vaults with necessary surveillance facilities. After cooling down in these storage facilities, waste containers will be stored for long term in deep geological repositories.

At nuclear Power plants, only low- and intermediate-level nuclear waste containing radioactive substances with short half lives are generated and are processed at the site in the following manner:

(i) The generated waste is solidified by fixing this in materials like cement, polymers, glass etc., to ensure that it does not move.
(ii) The solidified waste is then stored in specially fabricated double-walled high-integrity stainless steel container.
(iii) The containers containing the solidified waste are stored inside a high-integrity concrete pit at each of the nuclear power plant site.
(iv) As the waste is fixed in cement, glass, polymer, it is immobilized, and its placement in high-integrity containers inside a pit ensures that the radioactive wastes is completely insulated from the environment.
The radioactivity level of the stored waste reduces with time and, by the end of the plant life, falls to normal levels.

3.5 Decommissioning Costs

As for decommissioning, there is a portion of electricity tariff being set aside (decommissioning levy) to pay towards the cost of decommissioning of nuclear power plants in the future.

4.0 Transparency

Nuclear industry in India, like in the rest of the world, is the best-regulated industry, with high standards that other type of industries aspires to achieve. Every significant event is reported to the regulator in India, Atomic Energy Regulatory Board (AERB). Furthermore, India is a member of several international bodies where the Operating experience is shared for bolstering safety measures and emulating best practices.

India periodically enters into various international agreements on nuclear cooperation, which must follow certain protocols. Nevertheless, these agreements are always in the long-term interest of the country.

DAE and NPCIL are also conducting large public outreach programmes, in which the information about nuclear power and related topics are shared across various sections of the society. Large amount of information is also put on the websites of NPCIL and DAE about nuclear power and our activities.

5.0 Germany's Shutting Down of its Plants

Sir, in your letter, you have also mentioned about Germany's decision of shutting down some of its nuclear reactors. You must have noted that Germany has not abandoned nuclear power! They have closed down only 8 of the 17 reactors that have completed their economic life. The remaining reactors will continue to produce electricity, while the last of their operating reactors will remain in operation till the year 2022. **Had nuclear energy been really unsafe, why would Germany be running the remainder of the reactors at all?**

6.0 Japan Restarts Reactors

6.1 Earlier this month, the Japanese Prime Minister Yoshihiko Noda appealed to the nation, in which he reiterated the crucial role of nuclear power in Japan. Subsequently, two reactors – Ohi 3 and 4 – were given permission to restart operation. The Ohi-3 unit has achieved criticality in the early hours of July 2, 2012.

6.2 After World War II, **multigenerational genetic damage was not observed** due to radiation exposure even in the surviving population of the bomb victims. In this regard you may refer to the 2010 report of United Nation Scientific Committee on Effect of Atomic Radiation (UNSCEAR) based on scientific studies carried out over several decades on the survivors of Hiroshima and Nagasaki. The report has brought out that there has been no abnormal increase in cancer cases or congenital anomalies, among this target group, compared to the natural rate prevalent in the region/country. Based on the scientific evidence of no lingering damage, Japan not only embraced nuclear power but also embarked on its large-scale expansion in the post-war years. Before Fukushima, Japan derived **one-third** of its electricity requirement from nuclear power.

6.3 At Fukushima, more than 15 months after the natural twin disaster of earthquake and tsunami, there has not been a single fatality due to radiation exposure. As a matter of fact, all the reactor buildings and auxiliary structures survived despite the gigantic 9.0-Richter earthquake and the reactors were automatically brought to a state of shutdown, as designed. If this had not been a submarine earthquake, but a land-based earthquake, then the Fukushima accident would not have occurred at all. Also, the displacement of people post-Fukushima was a matter of abundant caution.

Nonetheless, the events at Fukushima have lead to some unfounded apprehensions in the general public, often based on hearsay rather than on scientific facts. The need of the hour is to allay these apprehensions and to address the generally prevalent misconceptions of the public and to provide factual and reliable information on the subject.

6.4 You can get more insight on nuclear safety and the prevalent unfound apprehensions among some people from the work/publications of experts like **Professor Wade Allison, Dr. Akira Tokuhiro and Dr. Theodore Rockwell.** Wade Allison is Emeritus Professor of Physics at the University of Oxford and Fellow of Keble College, Oxford. He is also the author of the book ***"Radiation and Reason: The Impact of Science on a Culture of Fear" (2009)***. Dr. Akira Tokuhiro is a professor of nuclear engineering at the University of Idaho, USA, while Dr. Theodore Rockwell is a member of the National Academy of Engineering, editor of the 1956 handbook, The Reactor Shielding Design Manual, available on the U.S. Department of Energy's website, and the first recipient of the American Nuclear Society's Lifetime Achievement Award, now called Rockwell Award.

7.0 For your ready reference, I am enclosing herewith publications related to nuclear power, radiation, safety and 'Frequently Asked Questions' on Kudankulam nuclear power Reactors. We also request you to visit our web site www.npcil.nic.in for more information.

In the light of these facts, the intelligentsia of the nation can play a constructive role in helping the masses to also understand these facts, so that unfounded fears related to nuclear power can be allayed, and together we can build a strong and prosperous nation.

With warm regards,

Sincerely yours,

(N. Nagaich)

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