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ASSESSING THE ATTRACTIVENESS OF SMR: AN APPLICATION OF INCAS MODEL TO INDIA

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ABSTRACT

Small Modular Reactors (SMRs) have the potential to be an important component of the worldwide nuclear renaissance. Whilst requiring more diluted investment than Large Reactors (LRs), SMRs are simpler build and operate as well as being suitable for deployment in harsh environmental conditions. In addition, useful by-products such as desalinated water and process heat are generated. The economic competitiveness of SMRs with respect to LRs must be carefully evaluated since the economies of scale label these reactors as not economically competitive. As such, a variety of financial and economic models have been developed by the scientific community in order to assess the competitiveness of SMRs. One of these, the INCAS model (Integrated model for the Competitiveness Assessment of SMRs), performs an investment project simulation and assessment of SMR and LR deployment scenarios, providing monetary indicators (e.g. IRR, LUEC, total equity invested) and not-monetary indicators (e.g. design robustness, required spinning reserve). The work in this paper investigates the attractiveness of SMRs for a given scenario, the Indian state, through application of the INCAS model. India is the second most populated country in the world with rapid economic growth and a huge requirement for energy. There is also both good public acceptance and political support for nuclear power in India, important factors favoring the deployment SMRs in particular. India seems particularly suitable for SMR deployment because (i) its energy intensive industrial sites are located far from existing grids, (ii) rapid growth in the region and (iii) the requirement for plants to provide fresh water for the population, as well as for agriculture and industry. The results show that SMRs have roughly the same financial performance of LRs, however they have a competitive advantage as a result of non-financial factors such as co-generation application, higher local content and better management of the spinning reserves in a country with an electricity deficit.

INTRODUCTION: THE INDIAN SCENARIO

India envisages increasing the contribution of nuclear power to overall electricity generation capacity from 3.7% to 9% within 25 years. By 2020, India's installed nuclear power generation capacity will increase to 20000 MW [1]. The per capita electricity consumption is expected to double by 2020 with 3.4% annual growth [2]. The Nuclear Power Corporation of India Limited (NPCIL) is responsible for design, construction, commissioning and operation of nuclear power plants. Its funding model is 70% equity and 30% debt financing. However, it aims at involving other public sectors and private corporations in future nuclear power expansion, notably National Thermal Power Corporation (NTPC). NTPC is largely government-owned, and the 1962 Atomic Energy Act prohibits private control of nuclear power generation, though it allows minor investment.

India's nuclear industry has been largely without IAEA safeguards. However, in October 2009 India's safeguards agreement with the IAEA became operational, with the government confirming that 14 reactors will be put under the India Specific Safeguards Agreement by 2014 [3].

India's situation as a nuclear-armed country excluded it from the Nuclear Non-Proliferation Treaty for 34 years. In 1974 India tested its first nuclear weapon and the IAEA decided that India had to be isolated from world trade by the Nuclear Suppliers' Group. A clean waiver to the trade embargo was agreed in September 2008 in recognition of the country's impeccable non-proliferation credentials [4]. Now, foreign technology and fuel are expected to boost India's nuclear power plants considerably [3]. In the last few years India has been able to enter into the world nuclear market, starting with trade involving uranium and nuclear technology, which has led India to be a leader in the nuclear field.

For the large extent of the country and the economic-geography context, the SMRs may be a very interesting option for India. It has so far built 220 MWe and 540 MWe plants using their indigenous technology PHWR. Furthermore in recent years it has opened up new possibilities arising from companies that were willing to introduce nuclear to supply own power requirements. They can approach with SMRs that better fit their needs [5]:

- Indian Railways have approached NPCIL to set up a joint venture to build two 500 MWe nuclear plants on railway land for their own power requirements.
- Steel Authority of India Limited SAIL and NPCIL are discussing a joint venture to build a 700 MWe plant.

Quite interesting India has (i) energy intensive industrial sites that are remote from existing grids, with rapidly growing area that need electricity and (ii) plants that provide by-product as water desalination for population, agriculture and industries. The country's conformation requires particular attention to earthquakes, tsunami, floods and other external events.

In recent years, joint ventures and new agreements have been established to develop new plants with technologies from other countries. NPCIL had meetings and technical discussions with three major reactor suppliers start in 2009: Areva, GE-Hitachi and WEC Electric Corporation for supply of reactors.

In December 2011, over 300 million Indian citizens had no access to electricity. Over one third of India's rural population lacked electricity, as did 6% of the urban population. Of those who did have access to electricity in India, the supply was intermittent and unreliable. In 2010, blackouts and power shedding interrupted irrigation and manufacturing across the country [6]. With an electricity demand growth of 3.4% per year, Indian energy policy has focused on gas, nuclear and renewable energy to reduce the dependence on coal. In making this decision, India is very similar to China. The two most populated countries of the world aim to expand their nuclear share. Public acceptance, opinion and political consent are vital to decide on issues like nuclear policy. Compared to other countries, in India nuclear energy does not cause any serious worry to the public opinion and the NIMBY syndrome has not been found except for a few episodes in the Post-Fukushima days. However nuclear power has a broad agreement within the country and SMRs would have no problem of public acceptance in overall and also local population's attitude since they present considerable advantages and improvements in safety.

"Nuclear energy is the present and future of Indian energy needs. With government employing efforts to make the best use of the opportunities proposed by this modern platform of power generation, even the citizens are now joining hands and accepting it more openly." [1]

This paper aims to assess the competitiveness of SMR in the Indian scenario. Therefore Table 1 shows, as benchamrk, the existing power plants and their cost of generation (Levelised Unit Electricity Cost LUEC); SMRs will be competed with these power plants.

Technology	Name of Power Plant	Installed Capacity [MW]	LUEC [$/MWh]
Coal	Anpara, Uttar Pradesh	1000	26.8
	NTPC, Ramagundam, Andhra Pradesh	2600	25.9
	NTPC, Dadri, Uttar Pradesh	840	40.5
	NTPC, Tanda, Uttar Pradesh	440	44.7
	Panipat Thermal Power Station (2 x 250)	500	44.4
	Indraprastha Power Station, Delhi	247	66.2
	Faridabad Thermal Power Station	165	86.7
	Panki, Uttar Pradesh	220	59.3
	Obra, Uttar Pradesh	550	59.3
	Ennore, Tamil Nadu Electricity Board	450	68.3
Hydro	Bhakra Complex, Punjab	1480	2.3
	Chamera, NHPC, Himachal Pradesh	300	26.8
	Ranganadi, North- Eastern Electric Power Corp., Arunchal Pradesh	405	21.8
	Tehri 1, Tehri Hydro Development Corporation, Uttarakhand	1000	63.1
Gas and Naphtha	Dadri Gas, NTPC, Uttar Pradesh	830	51.8
	Kawas, NTPC, Gujarat	656	99.7
	Rajiv Gandhi Kayankulam, NTPC, Kerala	360	136.7
Nuclear	Rajasthan (200 + 2 x 220)	640	31.8
	Madras (2 x 220)	440	25.0
	Narora (2 x 220)	440	32.0
	Kaiga (2 x 220)	440	37.4

Table 1 Cost of electricity generation from some of the operating power plants in India, [7]

METHODOLOGY AND INPUT

The Indian scenario is assessed from three main perspectives:

- characterization of country energy sector with particular emphasis on the nuclear power;
- analysis of the financial factors relevant to a new nuclear power plant construction;
- analysis of the external non-financial factors (technical, social, market and political factors) impacting the decision-making process for an investment in nuclear technology.

The sizes of SMR are representative of 7 design proposed by international vendors (see Figure 1). The size is the only difference among the designs and other specific features has not been investigated. The 7 selected reactors are used to meet the 3 target scenarios (i.e. overall power installed):

- SMALL: 600-675 MWe
- MEDIUM: 1100-1350 MWe
- LARGE: 2200-2475 MWe

Every scenario will have a different number of units that depend on the type of reactor used to achieve the required output power. Figure 1 shows the number of units of each type of reactor deployed in the three scenarios. The deployment of SMRs in multi-unit configuration leads to a construction of units in parallel

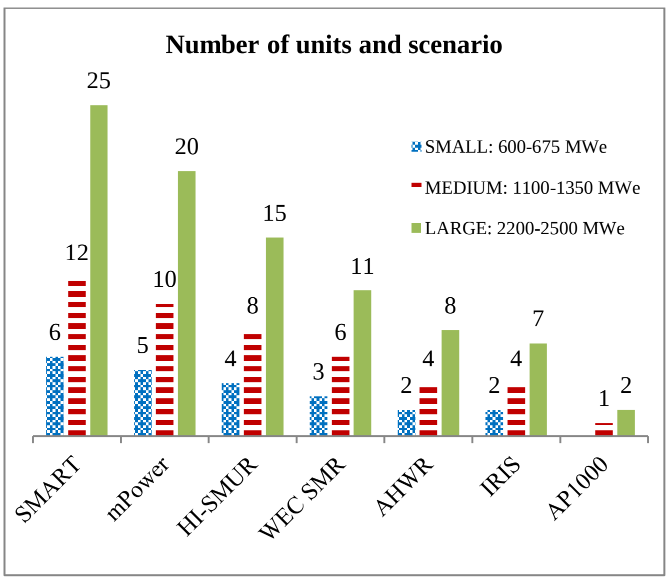

Figure 1 Rector types, scenarios and number of units considered

The following sections summarise the most relevant data for the analysis

✓ Debt interest rate

In India, for these kinds of investments the debt interest rate is 11.5% [8]. This value could be different according to certain loan conditions, for instance the interest of the government. In the sensitivity analysis we will evaluate the effect of the change on final result.

✓ Cost of equity capital

With an equity risk premium of 5.5%, the cost of equity is 17% [8].

✓ Debt-Equity ratio [9]

Capital structure of nuclear power projects:

- Debt Equity ratio for the plants constructed so far: 1:1
- Debt Equity ratio in future: 2:1

So we assume for the financing mix: 30% equity and 70% debt. This is the initialization value of debt-equity ratio that varies over the useful life of the plant depending on the cash flow.

✓ Annual escalation rate for construction cost

According to [10] we assume 8%.

✓ Inflation rate

The inflation rate in India was recorded at 7.23 % in April of 2012. Historically, from 1969 until 2012, Indian inflation rate average was 8.03 % [11], but this data is referred to the wholesale price index. [12] provides inflection rate for several industrial sector (see Table 2) According to these source a reasonable inflation rate is therefore 7%.

	Inflation rate	
Fuel & Power	0.025486	
Non Food Manufactured		
- Rubber & Plastic Products	0.000932	
- Chemicals & Chemical Products	0.016699	
- Non-Metallic Mineral Products	0.003256	
- Basic Metals, Alloys & Metal Prod	0.020400	
- Machinery & Machine Tools	0.004170	
- Transport, Equipment & Parts	0.003184	
	0.07	7%

Table 2 Inflation rate, elaborated from [12]

✓ Corporate tax rate

Only domestic companies can manage nuclear plants in India, so we assume the standard corporate tax rate of 32.445%. [13]

✓ Overnight costs of reactors as reported by Atomic Energy Commission (AEC):

Different labour rates, standardised design and increased localisation (or local content) are all significant factors in India, which contribute to reduce overnight capital cost. The overnight cost consists of the construction cost, and the costs of the initial loading of fuel and, if PHWR, heavy water. Overnight cost does not include the Interest During Construction (IDC). The benchmark capital cost sanctioned by DAE for imported units is quoted at $1600 per kW (Table 3). The Atomic Energy Regulatory Board (AERB) approved Rajasthan 7 & 8 in August 2010. First concrete was in July 2011. Construction is then expected to take 66 months to commercial operation. Their estimated cost is $2.6 billion that means 1300 $/kW.

Plant	Size	Overnight cost	Years
Tarapur 3 & 4 PHWR	540 MW	$ 1200/kW	2000-2006
Kaiga 3 & 4 PHWR	220 MW	$ 1300/kW	2002-2007
PHWR 60-year life	700 MW	$ 1700/kW	2011

Table 3 Overnight costs reported by AEC

✓ Other Nuclear life cycle costs

India has developed PHWR technology but in the last years LWR gained a growing attention. [14] and [7] provide data about LWR (the typical technologies of SMR), a summary is in Table 4.

The conversion among the currencies is: 1 India Rupee (INR) = 0,017990 US Dollar (USD) as average 2011-2012 exchange rates [15].

Plant Size	1000 MWe PWR		Koodankulam NPP 2 x VVER-1000/412 (AES-92)
Overnight construction cost	$ 1600 per kWe	Rs 88935	
Weighted Average Cost of Capital	10%		Assuming 70:30 debt equity ratio
Decommissioning Charge	$ 81 per kW	Rs 4502	Considered into Capital cost
Plant Load Factor	85%		
Interest during construction	20%		5 year construction period
Fuel cycle Costs	$ 2.9 per MWh	Rs 161.2	Fabricated LEU cost of $ 1.5 Million per Ton
O&M Costs	$ 12.1 per MWh	Rs 672.6	
Waste Disposal Cost	$ 1.3 per MWh	Rs 72.3	
Total Operating Cost	$ 16.3 per MWh	Rs 906.1	

Table 4 Economics of imported Light Water Reactors, from [14] and [7]

✓ Wholesale electricity price

The electricity reforms were initiated in India with the goal of promoting competition in the electricity market. In order to promote competition, the Electricity Act 2003 was enacted and various policy initiatives were taken by the Government of India. The Central Electricity Regulatory Commission (CERC) facilitated competition through the regulatory framework of availability based tariff, Indian Electricity Grid Code, open access in inter-state transmission, inter-state trading and power exchanges. Despite these initiatives, electricity prices increased in the Wholesale Electricity Market in India (WEMI). However NPCIL sold electricity at an average price of Rs 2.44 kWh, in 2011-2012, that correspond at 43.9 $/MWh. This price is very low in comparison with wholesale electricity price of other entities [16]. The Kudankulam NPP will sell power to the state utilities at around Rs 2.65 kWh that correspond at 47.6 $/MWh. [17]. The wholesale electricity price of new plants, both indigenous and imported, is expected to be about Rs 2.6 kWh that correspond at 47 $/MWh. [5]

✓ Electricity price annual increase rate

During 2011 and 2012 the tariff of electricity prices had a consistently rise due to the adjustment at the wholesale price [18]. The State Electricity Regulatory Commission (SERC) establishes the power tariff. From 2002 to present there were two substantial hikes in power price. In 2002 there was an increase of less than 43% and in 2012 of 22% [19]. We assume an annual increment of 7%.

RESULTS

The following graphs show the most significant parameters for the understanding of the profitability of SMRs in different scenarios.

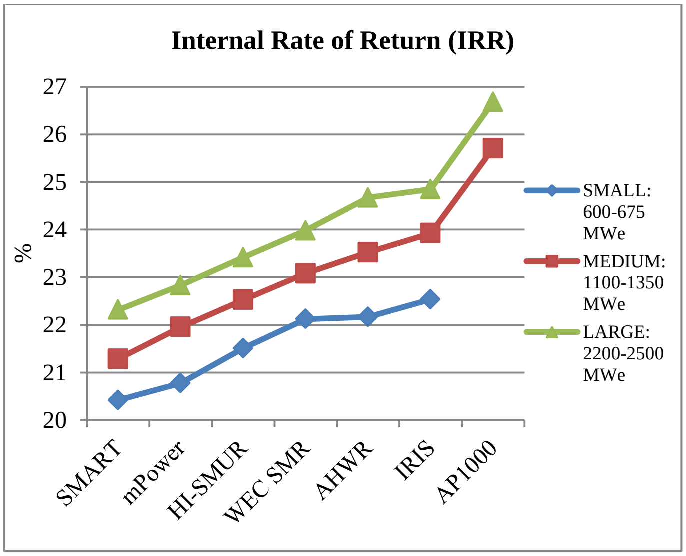

Figure 2 Investment profitability in different plant configurations

Figure 2 shows the correlation between IRR and reactors size. LARGE scenario is associated to a large number of units SMR that thanks to the effects of learning and modularization allows to reach a greater profitability. This is the result of the so called economy of multiples ([20], [21], [22]). The IRR also increases with increasing size of the reactor showing an advantage for the LR respect to SMR. Analysing the percentage change between the values of IRR of the same reactor between the different scenarios, there is an increase of about 5% for all reactors between scenarios SMALL and MEDIUM. Among the scenarios MEDIUM and LARGE however this increase is less than the previous and equal to about 3-4%.

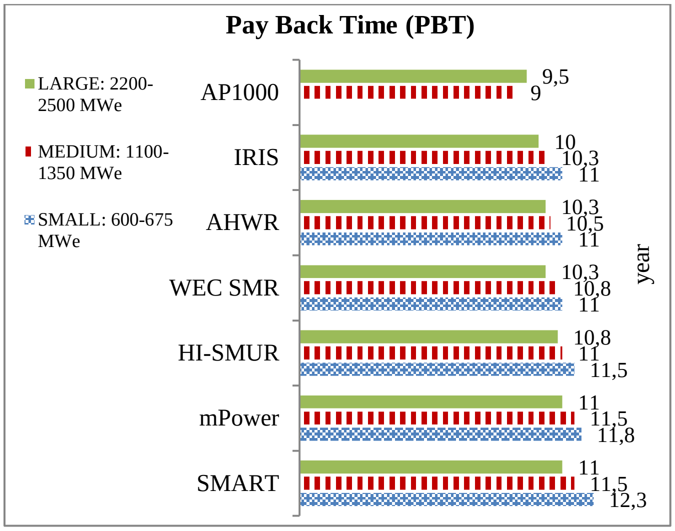

Figure 3 Pay Back Time in different configuration plants in India

In Figure 3 the PBT is reported for the single unit and not to the plant payback time. INCAS consider a new debt whenever a SMR starts the deployment. So the PBT for the SMRs are very similar in all scenarios considered with a range of up to one year, between the three scenarios of market output by fixing the reactor and also between the 6 SMRs. The LR AP1000 has the lower value of PBT.

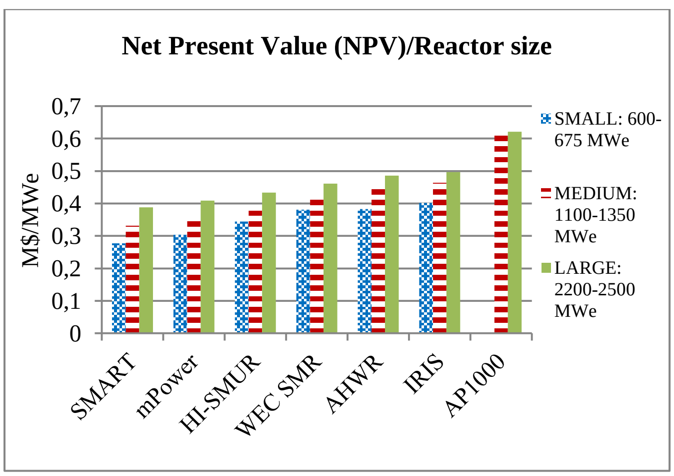

Figure 4 NPV divided by power plant for different configuration plants in India

The Net Present Value (NPV) (Figure 4) is presented scaled to the corresponding power plant. It is necessary to normalize the values to the power to compare the outputs with different orders of magnitude. It is possible to see a significant difference within each reactor between the 3 scenarios. This difference is less evident within the specific setting of the SMRs while the LRs have a higher value by 20-25%. Interestingly, the performance notably of AP1000 with the equal value of scenario MEDIUM and LARGE. This is explained by the different time horizons in the construction of two plants, the first with a schedule of 17 quarters and the second of 24 quarters like all other plants. It shows us the importance of the schedule in the profitability of these investments with very long construction times and highest costs.

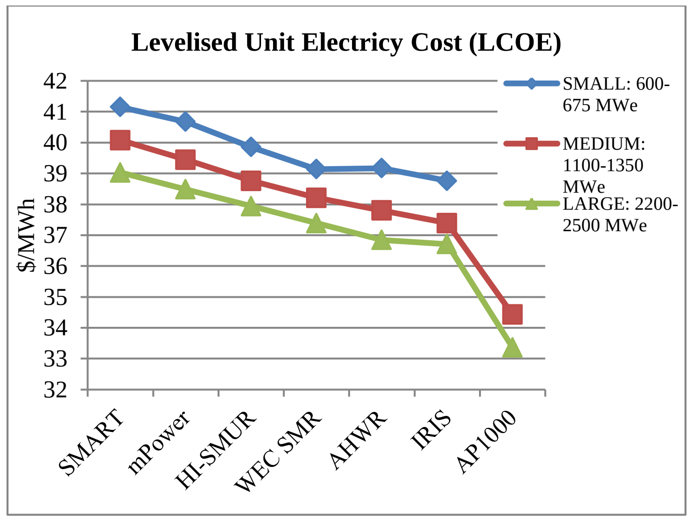

Figure 5 LUEC for different configuration plants in India

Figure 5 shows the LUEC of LR and SMR for the three scenarios and the seven reactors. LUEC is the minimum ee_{price} needed to cover capital remuneration and all the life cycle cost. SMRs deployment has higher LUEC than LR: LUEC value increases with decreasing size of the reactor mainly because of the higher capital cost. INCAS shows that SMRs deployment is slightly less cost-effective than LR (higher LUEC). It is interesting to see how, given the same total reactor fleet size, the Economy of Multiples helps to decrease LUEC in large site scenarios, as compared to small site scenarios. If the same total number of NPP is concentrated in few sites, then learning and multiple units economies on fixed costs may be exploited in order to gain cost-effectiveness. The doubling of the units SMRs for each type of reactor, the variation of the scenarios considered (SMALL to MEDIUM and MEDIUM to LARGE), leads to a reduction of the LCOE of 2-3%. As it is a key parameter in the profitability of the plants, this aspect is not negligible.

Figure 6 presents the results related to the Overall Capital Expenditure (OCE) for the SMRs. Quite surprising the values are comparable, since the economy of scale is balanced by the economy of multiples.

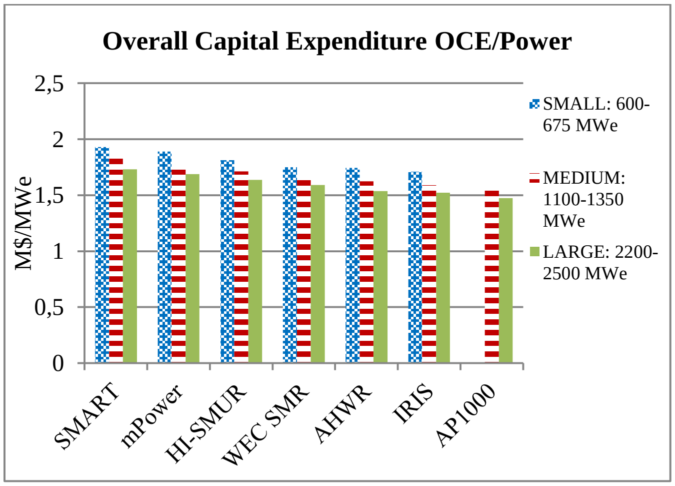

Figure 6 Overall Capital Expenditure divided by Power for different configuration plants in India

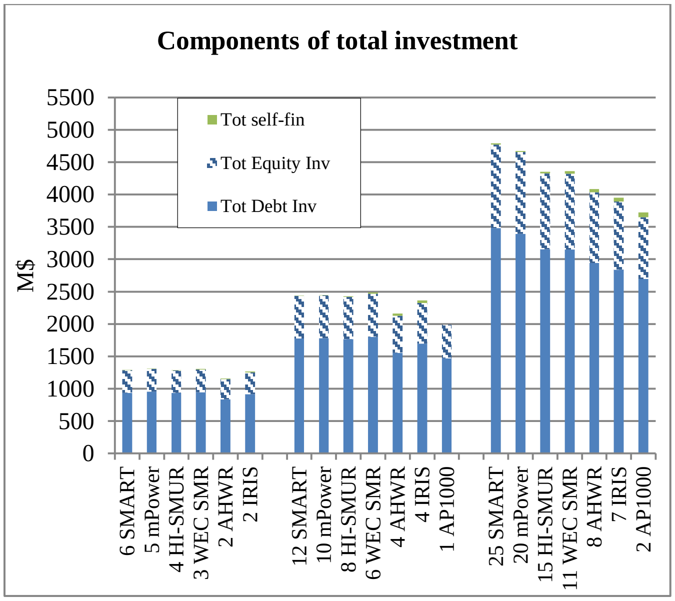

Figure 7 Components of total investment for different configuration Plants in India

Figure 7 presents the effect of self-financing (as described in [23]). The use of self-financing mitigates the up-front capital investment, but represents a higher recourse to equity funds, that is a more expensive capital source than debt, so with a less efficient financial leverage. Usually the values of total self-financing are only a small percentage of the overall capital expenditure to around 1-2%. Self-financing generation may be fostered by diluting SMRs construction schedule over a longer period of time. This is considerably favoured in the construction of many units SMRs thanks to their reduced construction time and thus more rapid generation of profit that can then be used as self-financing. The LR with 2 units can produce more self-financing of the SMRs with a time horizon of construction of 6 years. This outcome would be different if the schedule was long where would observe a significant advantage for the SMRs built in multi-unit. The applied schedule is very compressed and this aspect is not emerged.

Sensitivity analysis

The sensitivity analysis is performed on the base scenario, considering the configuration: 4 x 300 AHWR. We use this configuration as a base scenario because it has the same output of the plants in operation and construction in India. Moreover, the AHWR is an Indian SMR with chances to be deployed in the next years. In Figure 8 we evaluate the deviation of the value of IRR according to a ± 10% change in the input parameters.

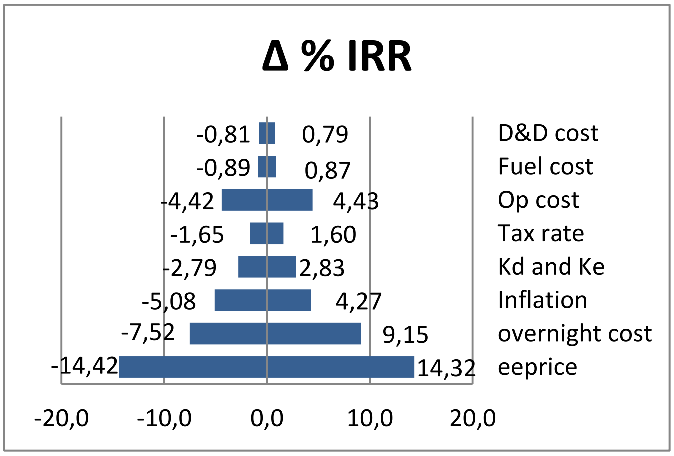

Figure 8 Sensitivity of project profitability (IRR) to main parameter input data variation for the base case India

The IRR variation is assessed as a percentage of its base value equal to 23.5 %. The most critical parameters for the variation of the IRR are:

- ee_{price}
- Overnight cost
- Inflation
- Operation cost

The other parameters contribute very little to the change in the value of the IRR. The ee_{price} is the most critical parameter and the change of 10% of its value leads to a variation of the IRR in excess of 14%. The ee_{price} is free to float according to electricity market price dynamics and it is essential to deepen and predict its performance over time in order to obtain reasonable results with the real scenario.

Figure 9 shows the LCOE variation according to a according to a ± 10% change in the input parameters. The LCOE variation is assessed as a percentage of its base value equal to 37.803 $/MWh. The most critical parameters for the variation of the LCOE are:

- Cost of debt K_d and Cost of Equity K_e
- Inflation
- Overnight cost

- Operation cost

Other parameters are quite irrelevant to the final result of investment profitability.

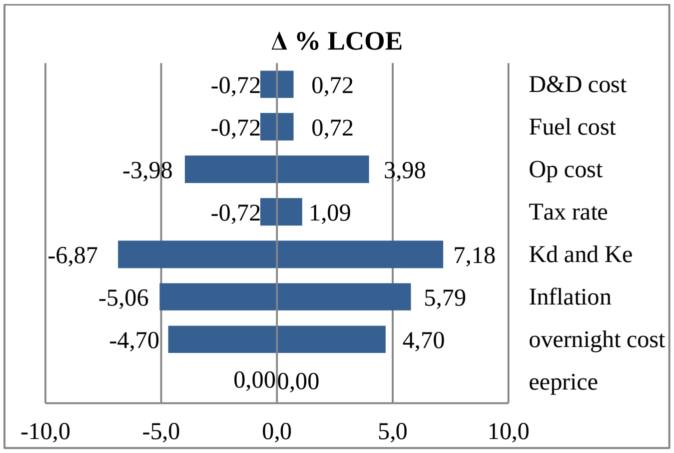

Figure 9 Sensitivity of LCOE to main parameter input data variation for base case India

External factors analysis

[24] presents a list of the external factors (i.e. not financial factor), providing, for each one, the rationale and the quantification procedure. [24] is a general framework therefore it is possible to add other factors country-specific. Here examine those factors that are relevant for Indian scenario. Each of the following bullet point represents an "external factor" specific for the indian scenario.

- Spinning reserves and electric grid vulnerability

In 2012 India experienced its worst-ever power crisis, leaving more than 650 million people without electricity [25]. Figure 10 shows the areas affected.

Figure 10 Areas affected by the power outages [25]

The massive power failure for two straight days has turned the spotlight on India's electricity deficit. Analysts have long said that the country's power requirements have failed to keep pace with the demands of an expanding economy and a growing population. As a result, outages for several hours a day are routine across much of the country [25].

The spinning reserves and the grid failure can be greatly improved by the installation of SMRs in stand-alone configurations or with multiple facilities located in those territories where node connectivity is already busy. A few LRs complicate the management of the grid and they do not allow a complete resolution of blackouts due to cascading failures of a large number of transmission lines.

- Public acceptance

"Public acceptance, opinion and diligence of policy makers and planners as well as political consensus are vital for deciding on issues like energy mix for India, its nuclear policy and its nuclear contribution to the energy mix" [26]. In India there have been few public protests against the nuclear plants and the NIMBY (Not In My Back Yard) effect is not strong [27]. In the post-Fukushima scenario this trend has been maintain and a significant proportion supports nuclear energy [28]. The SMRs can then be installed in multi-unit single site or in multiple sites to optimize the electricity distribution in the vast territory.

- Technical siting constraints

Nuclear Power plants are design against expected natural disasters including earthquake, tsunami and floods. The sites where NPPs will be located will be first approved by MOEF (Ministry of Environment & Forests) and then by AERB (Atomic Energy Regulatory Board), each taking care of safety and security issues within their jurisdiction. AERB has issued a code on siting and all stipulations are mandated in this. During the application for site, preliminary safety details of the NPP need to be submitted including a guarantee that all AERB limits and requirements will be adhered to. This includes several requirements including checking for natural disasters. During the period between authorizations for excavation to commissioning, a detailed three tier review of each design detail is performed.

Most of the areas in India are in seismic zone. The SMRs facilitate the use of seismic isolators similar to those used for conventional buildings [29] therefore it is possible to standardize their seismic protection. Furthermore according to the Indian requirements, all safety equipment has to be located above maximum flood level or tsunami levels [26]. In conclusion SMRs result in a more flexible siting than LRs in the Indian scenario.

- Political aspects and risks associated to the project

India's Prime Minister, Manmohan Singh, said that his country's Department of Atomic Energy would review all safety systems at India's nuclear plants, particularly with a view to ensuring that they would be able to withstand the impact of large natural disasters such as tsunamis and earthquakes [30]. Even after the nuclear disaster in Japan, Indian government said they would move ahead with ambitious nuclear plans. India plans to spend an estimated $150 billion in new NPP. Its forecast calls for nuclear power to supply about a quarter of the country's electricity needs by 2050 [30]. In a scenario with this outlook, the SMRs may find their space and we must therefore demonstrate their advantages and competitiveness. India is open to new technologies and there are no restrictions to install FOAK plants.

About FOAK risks, [24] states: "*FOAK risks have the same probability of occurrence for both SMRs and LRs, but they have differential magnitude in the two cases. In fact, these risks impact on the capital employed in the single FOAK: it is smaller for SMRs, therefore size does not reduce probability, but reduces the impact of risks.*" This aspect therefore benefits the SMRs.

- Impact on national industrial system

Industrial Production in India increased 2.4% in May of 2012. Historically, from 1994 until 2012, India Industrial Production averaged 7.35% reaching an all-time high of 20% in November of 2006 and a record low of -7.2 % in February of 2009 [31]. The main limit for national industries to become suppliers of new NPPs is related to the capacity of their production systems. The technical feasibility of NPPs' components depends on dimension and complexity. However Indian industrial system is one of the more productive and efficient worldwide and it is ready to address requests for the construction of SMRs. In recent years it has greatly invested in the nuclear sector and consequently also in the industrial system which must support this development.

- Nuclear fuel cycle and radioactive waste management

Radioactive wastes from the nuclear reactors and reprocessing plants are treated and stored at each site. Waste immobilisation plants are in operation at Tarapur and Trombay and another is being constructed at Kalpakkam. Research on final disposal of high-level and long-lived wastes in a geological repository is in progress at BARC [3]. India is one of the few countries to have developed expertise in all areas of the nuclear fuel cycle and allied fields covering mineral exploration, mining, heavy water production, fuel fabrication, fuel reprocessing and the management of nuclear waste at the back end of the cycle. So India has adopted a closed nuclear fuel cycle policy that has been revealed a convenient option to maintain low costs. [32]

- Co-generation

India has a great need of potable water for civil usage but also for agriculture irrigation and industrial usages. Nuclear desalination plants could be real opportunities in the Indian scenario that could give to SMRs a substantial advantage in comparison with LRs. India's hybrid Nuclear Desalination Demonstration Plant (NDDP) at Kalpakkam comprises a Reverse Osmosis (RO) unit of 1.8 million litres per day commissioned in 2002 and a Multi Stage Flash desalination unit of 4.5 million litres per day, as well as a barge-mounted RO unit recently commissioned, to help address the shortage of water in water-stressed coastal areas. It uses about 4 MWe from the Madras nuclear power station. [3]

CONCLUSION

The analysis shows that the construction of nuclear power plants in India is a sustainable investment; the IRR values are high when compared to the cost of equity equal to 17%. The final decision about the best configuration plant to deploy will have to take into account the matching between demand for electricity and the plant output size. India is moving towards the LRs that appear very profitable. Nevertheless SMRs can play an important role to serve more isolated areas and reduce the risk of blackouts, or seismic areas subject to environmental risks covered by the innovative design of the SMRs. A good political support and public acceptance allow the deployment of SMRs in several sites. In conclusion SMRs are a viable and profitable solution for Indian electricity share as power generation with an option on co-generation.

The SWOT analysis (Table 5) is a compact method to show the results obtained by this study in a strategic way. The Strengths and Weaknesses of the SMRs in the Indian scenario are reported to internal factors and they are mainly determined from INCAS evaluation. Indeed the Opportunities and the Threats are reported from external factors evaluation.

In India the SMRs have collected five strengths of considerable importance for the competitiveness and profitability of an investment. As for the weaknesses there is the negative effect of economies of scale and the direct consequence of this factor: the lack of competitiveness of the SMRs compared to LRs. This is, however, offset by the advantages in terms of external factors. These opportunities are very relevant and, although they cannot be quantified and valued, provide a strategic advantage that adds competitiveness to a possible deployment of the SMRs. The threats are opposed to the opportunities also concerning an investment in LRs. The threats stem from the external environment and particularly from investments less capital-intensive. The instability of the financial parameters in India does not allow long-term visions and makes the final result less deterministic.

Internal factor	S • Modularity • Self-financing • Low value of LCOE • Short PBT and high IRR • Competitiveness compared to many power plants currently existing in India	W • Competitiveness compared to LR • Economy of scale
External factor	O • Co-generation: nuclear desalination, district heat • Grow of the national industrial system • Spinning reserves • Good political support on FOAK plants • Good public support • Delocalized plants and flexible siting • Low nuclear capital cost	T • Increase of nuclear costs • High inflation rate • High cost of debt and equity

Table 5 SWOT Analysis: India SMR

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