Bad Choice: The Risks, Costs and Viability of Proposed U.S. Nuclear Reactors in India

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Executive Summary

The Government of India has proposed through the Nuclear Power Corporation of India Limited (NPCIL) to enter into contracts with Toshiba-Westinghouse (Westinghouse) and General Electric-Hitachi (GE) to build a total of 12 new nuclear power plants on two separate sites in India using new and untested technologies.

Six of these new plants, to be sited at Mithi Virdi in Gujarat, would use a new Westinghouse AP1000 reactor design. In the few locations where this design is under construction, the projects have run into technical problems and significant cost increases and schedule delays. Construction has not been completed at any plant with this design anywhere in the world, and there are no operational AP1000 plants in the world.

The other six new plants, proposed for Kovvada in Andhra Pradesh, would use GE's Economic Simplified Boiling Water Reactor (ESBWR) design. This design is not under construction anywhere in the world. If approved, India would be the first country to experiment with its construction and operation.

An assessment of the projects by the Institute for Energy Economics and Financial Analysis (IEEFA) finds that:

- Given that both projects are first-of-a-kind designs, the government's plan to invest in 12 units of untested GE and Westinghouse nuclear plants will entail significant and unnecessary economic, financial and technological risks. Even the conservative "best-case" scenarios we have considered reveal that the capital costs of building the new power plants and, consequently, the costs of power from them, would be far higher than solar sources of electricity. Given that the reactor designs are untested and that there are other risks associated with land acquisition and nuclear accident liability, cost- and schedule-overruns are a near certainty.
- Even if no significant problems are experienced during construction, IEEFA estimates that the first-year tariffs for Mithi Virdi in 2029 likely would range from Rs. 11.18 to Rs. 22.12 per kilowatt hour (KWH), with levelized tariffs of Rs. 9.05 to Rs. 17.75 per KWH. This range reflects the substantial uncertainty in the actual cost of building the plants.
- The first-year tariffs from Kovvada would be between Rs. 19.80 and Rs. 32.77 per KWH, with levelized tariffs of Rs. 15.85 to Rs. 26.04. As at Mithi Virdi, this range reflects the significant uncertainty in the actual cost of building the new plants at Kovvada.
- These tariffs would mean significantly higher electricity prices for consumers unless the Indian government provides long-term and probably unsustainable subsidies.
- As shown in Figures ES-1 and ES-2, the power generated at each of the new plants will be very expensive and far more costly than electricity from renewable solar resources. By the time the first new reactors at Mithi Virdi and Kovvada are completed, the cost of new solar tariffs would be well below Rs. 3.00 per KWH, with prices continuing to fall over subsequent

years. This is lower than the lowest cost of power from the Mithi Virdi and Kovvada plants by a factor of 3 to 6.

- As shown in Figure ES-3, solar tariffs in India have declined by 65 percent since 2010. IEEFA has concluded that this trend will persist, and that solar tariffs in India will decline by 5 percent to 8 percent annually over the next two decades.
- Based on the actual history of new AP1000 reactor construction, the first new reactors at Mithi Virdi and Kovvada will take 11 to 15 years to build if approved, even assuming no delays. This means that if licensing were completed and site preparations were to begin in 2017—an optimistic assumption in itself—none of the new reactors at Mithi Virdi and Kovvada would generate any power for the electric grid until sometime between 2029 and 2032. The remaining units at each project are unlikely to be completed, if approved, until late in the 2030s.
- Even without time-and-cost overruns, both projects will be very expensive to build. Based on IEEFA's assessment of the currently estimated costs of building new Westinghouse and GE reactors around the world, the "overnight" cost of building the first two units at Mithi Virdi will be between Rs. 20 crore and Rs. 40 crore per Megawatt (MW). The likely "overnight" cost of building the first two units at Kovvada will be even higher, within the range of Rs. 30 crore to Rs. 50 crore per MW. However, these ranges may well be too low, given the uncertainty associated with the projects' status and the problems that are typical of other first-of-their-kind power plants. These "overnight" costs do not include any escalation or financing costs.
- Construction of both the Mithi Virdi and Kovvada projects would require massive investment over the next two decades, ranging from Rs. 6.3 lakh crores (US $95 billion) to 11.3 lakh crore rupees (US $170 billion). It is questionable whether the Indian government will be able to finance such amounts while continuing to pursue its current investments in coal mines, coal-rail freight, renewable resources and energy efficiency.
- IEEFA's analyses are based on low risk scenarios where no significant delays are experienced by the Mithi Virdi and Kovvada projects due to technological challenges, public opposition to land acquisition and legal question such as the issue of liability for nuclear accidents. Any delays associated with these issues will only drive up capital costs, and consequently, the per KWH costs of electricity from the new reactors.
- However, IEEFA believes that the following risks can be expected to lead to substantial, and perhaps indefinite, delays and significant increases in capital costs, possibly even far beyond those we have assumed in our analyses:
    - **Land Acquisition Delays**: Land acquisition is a politically fraught process as landowners and land-users in India are not known to part easily with their properties. Existing land-acquisition laws require public consultations based on social impact assessments and the informed consent of land-losers. Westinghouse has said that it hopes to have a signed contract to build the six units at Mithi Virdi by the end of 2016. However, land acquisition has not yet begun at either the Mithi Virdi or the Kovvada site.
    - **Liability issues**: Disagreements over liability for nuclear accidents create significant uncertainty about when construction actually might start at Mithi Virdi and Kovvada. GE has announced that it is ruling out any nuclear investments in India under the current nuclear liability law. Any changes in the law to make it acceptable to equipment

suppliers would transfer the financial and other risks of accidents to local communities and taxpayers.

- **Construction and technical delays**: Neither of the proposed reactor designs for Mithi Virdi and Kovvada has been completed or is in operation anywhere in the world. The history of first-of-a-kind power plants show that they are far more expensive and take substantially longer to build than governments anticipate.
- **Make in India delays**: The cost- and schedule-uncertainties associated with the Mithi Virdi and Kovvada projects will likely be even more pronounced if the Government of India pushes ahead with its Make in India program with respect to procurement of specialized components and/or erection and commissioning of the plants.[1] Some of the components are so specialized and first-of-their kind that even vendors in the United States are having difficulty meeting the design and quality specifications.

Conclusion

The proposed Mithi Virdi and Kovvada nuclear projects are not economically or financially viable, they would take much longer than expected to build, they would result in higher bills for ratepayers, and, if they are built, they might not work as advertised. Investing in new solar photovoltaic (PV) capacity would be a much lower-cost, significantly less environmentally harmful and far more sustainable alternative to the Mithi Virdi and Kovvada projects.

[1] http://scroll.in/article/802861/former-atomic-energy-regulator-explains-why-india-needs-to-pause-its-nuclear-power-plants.

Figure ES-1: The Range for Likely Annual Tariffs for Power from the First New Reactors at Mithi Virdi Compared to Solar-Energy Tariffs

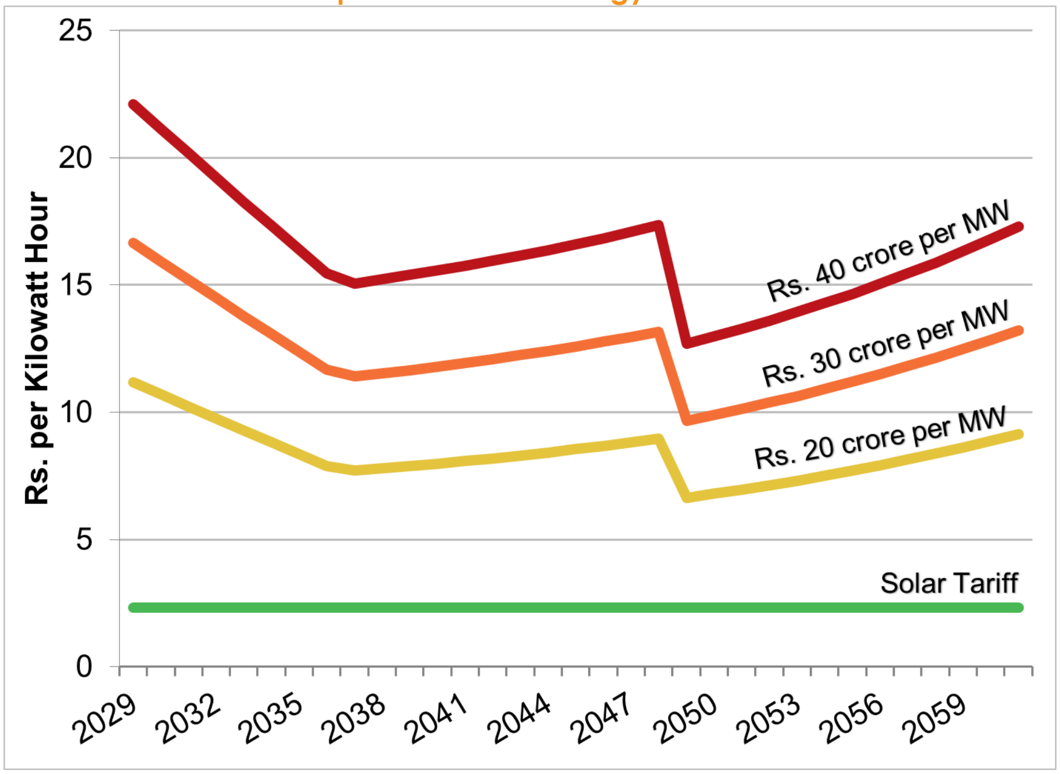


Figure ES-2: The Range for Likely Annual Tariffs for Power from the First New Reactors at Kovvada Compared to Solar-Energy Tariffs

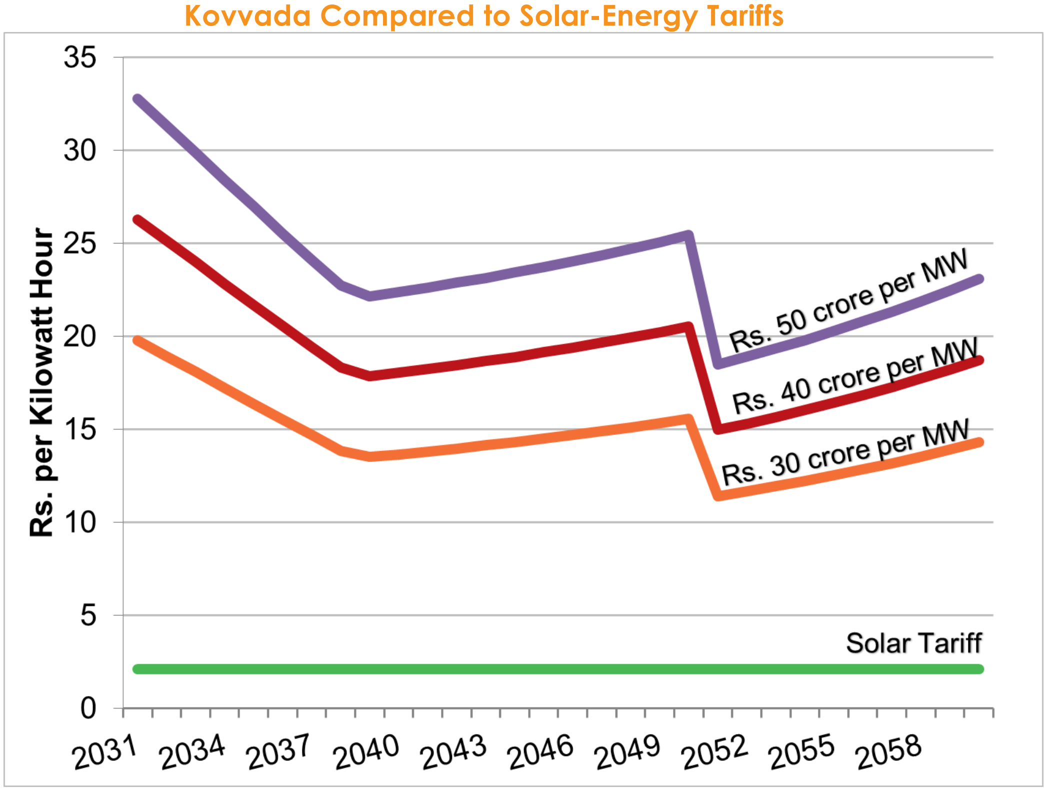
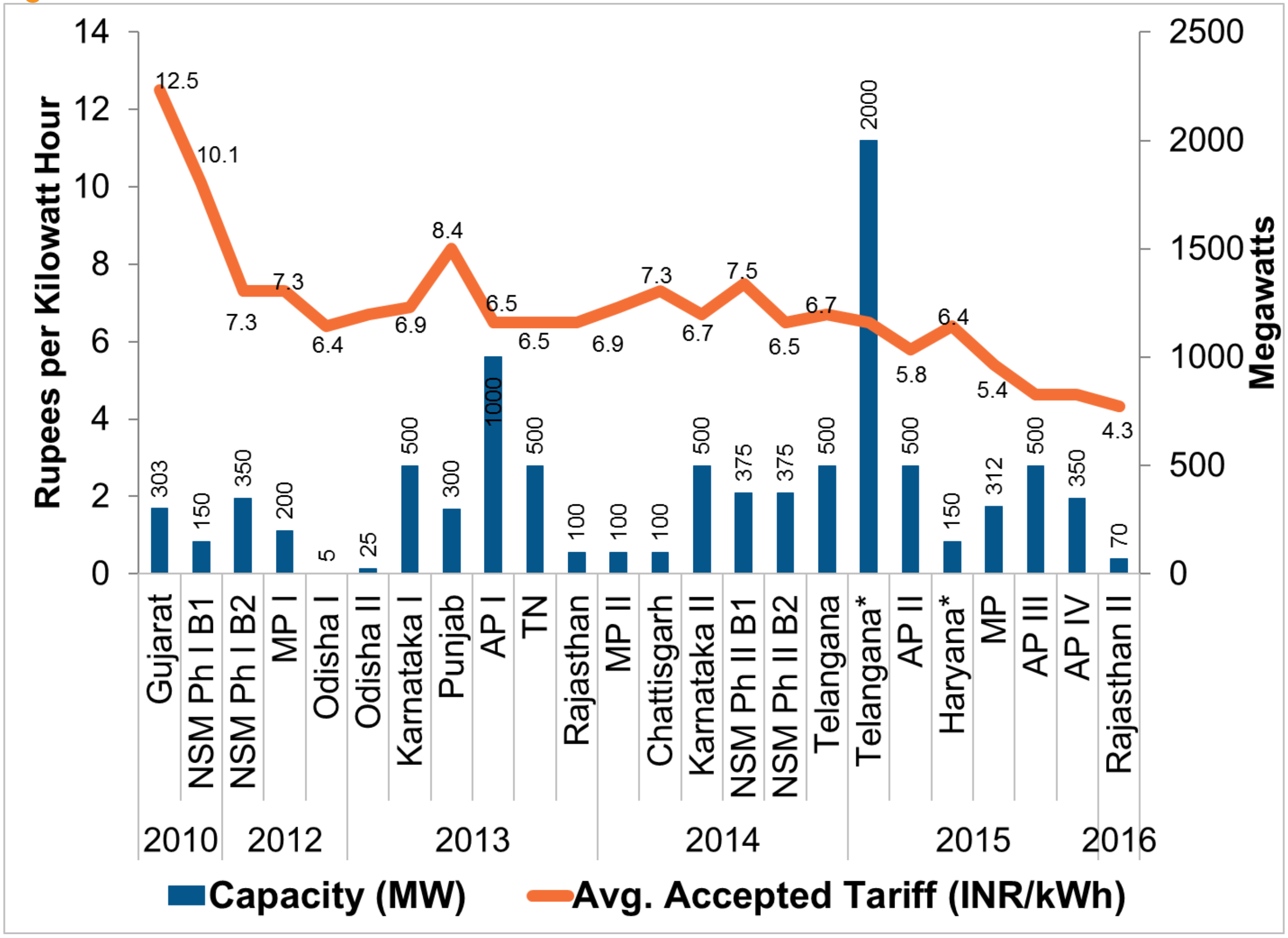


Figure ES-3: 65 Percent Decline in Solar Tariffs Since 2010[2]



[2] Source: Deutsche Bank, Abhishek Puri, 19 July 2015, CERC, State ERC, media reports

Section I. Nuclear Power in India

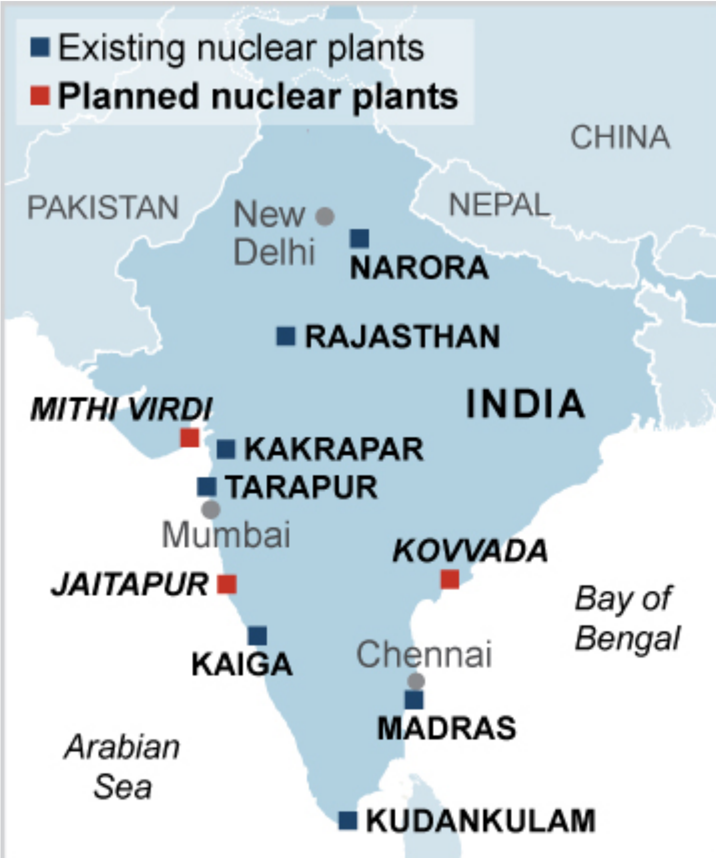
India currently has 21 nuclear units in operation at 7 power plant sites.[3] These 21 nuclear units have a total 5,780 megawatts of capacity. The oldest units, Tarapur 1 and 2 in Maharashtra, are 56 years old. The newest unit, Kudankulam 1 in Tamil Nadu, began commercial operations in December 2014. An additional five nuclear units, with 3,800 MW of capacity, are under construction. These units are scheduled for completion by 2017.[4]

The Indian government says that it is planning to reach about 13,500 MW of nuclear capacity by about 2022[5] and to ultimately add 18 reactors over the coming decade or so, all of which would use new and untested reactor designs. In addition to the projects described here at Mithi Virdi and Kovvada, six new reactors would be built at Jaitapur by Areva, a French company. The Jaitapur reactors would use a new European Pressurized Reactor (EPR) design.[6] No operating examples of this design exist anywhere in the world. The cost of electricity from the proposed Jaitapur nuclear power plant already has been examined by Suvrat Raju and .V.

[3] http://npcil.nic.in/main/PowerPlantDisplay.aspx Downloaded March 23, 2016.
[4] http://npcil.nic.in/main/ProjectConstructionDisplay.aspx Downloaded March 23, 2016
[5] http://articles.economictimes.indiatimes.com/2015-11-17/news/68356324_1_india-ltd-kudankulam-nuclear-power-project-cost-escalation
[6] http://www.rediff.com/news/report/india-france-to-build-6-nuclear-reactor-units-at-jaitapur/20160125.htm

Ramana.[7] This report focuses on the cost of power from the proposed Mithi Virdi and Kovvada projects.

Figure 1: Existing and Proposed Nuclear Reactor Plant Sites in India



[7] http://www.princeton.edu/~ramana/SA_XLVIII_26-27_290613_Suvrat%20Raju_M%20V%20Ramana.pdf

Section II. Current Status of the Proposed Mithi Virdi and Kovvada Nuclear Projects

The status of the Mithi Virdi project is uncertain. NPCIL and Toshiba-Westinghouse (Westinghouse) signed a preliminary commercial contract in September 2013. Recently, Westinghouse said that it expects to sell nuclear reactors to India by the end of 2016.[8] However, there has been no announcement of when construction would start. Although the Mithi Virdi project has environmental clearances, the clearance under the Coastal Regulation Zone Notification, 2011, has been challenged in the National Green Tribunal.

The Kovvada project appears to be stalled, perhaps for the long-term, after the September 21, 2015 announcement by the head of General Electric-Hitachi (GE) that he was ruling out any nuclear investments in India under the current nuclear liability law.[9] This announcement came only months after the Project Director for the Kovvada Nuclear Power Park had indicated that the first pour of concrete, an important milestone in the building of a new nuclear power plant, would be achieved in late 2016, with the first of the six new units expected to go online by 2021.[10] Clearly, GE's announcement will delay that plan substantially.

Section III. Risks of the Proposed Mithi Virdi and Kovvada Nuclear Investments

The proposed nuclear projects are subject to six major risks:

- A technology risk – the history of the nuclear industry clearly shows that plants with new designs, that are untested through the construction and actual operation of other reactors with the same design, typically experience significant unanticipated delays and major cost increases during construction, as well as unexpected problems when they begin commercial power operations.
- A land acquisition risk – power plants need land. If the land for a proposed plant can't be acquired, the project either is not built or it is moved to another location where the land can be obtained. Even if land can be acquired, the cost of the project can be increased if the land is more expensive than expected and the project schedule can be delayed, perhaps quite significantly, if the land acquisition process takes longer than planned.

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[8] Bloomberg News, December 24, 2015, http://www.bloomberg.com/news/articles/2015-12-24/westinghouse-expects-to-sell-india-nuclear-reactors-by-end-2016.
[9] http://www.cnbc.com/2015/09/21/ges-immelt-no-india-nuclear-investment-unless-laws-changed.html
[10] http://www.thehindu.com/news/national/andhra-pradesh/kovvada-nplant-work-likely-by-2016-official/article7168278.ece

- A construction cost risk – the "overnight" estimated cost of a plant includes the projected cost of building the plant without any escalation or financing costs. This "overnight cost" includes the expenditures for the elements of typical nuclear construction projects:

    - Vendors and contractors to design and engineer the plant and its main components and equipment;
    - Vendors to fabricate the larger, long-lead-time components (e.g., the reactor vessel, reactor coolant pumps, turbine generator);
    - Labor to build the plant;
    - Commodities such as concrete, steel, piping, wire and conduit;
    - Quality assurance and quality control personnel and activities; and finally
    - Pre-operational and start-up testing.

  If the "overnight cost" of building the plant increases, the accompanying escalation and financing costs also grow.

- A construction schedule risk – the total escalation costs incurred in building a new nuclear power plant increase the longer it takes to build the plant because purchases and activities are pushed further into the future. The total cost of financing the construction of the plant also grows as the length of the construction schedule is extended.

- An operational risk – As noted earlier, many new nuclear power plants, especially those with new untested designs, experience unanticipated problems that lead to both planned and unplanned plant outages, during their initial years of operations, if not longer. The plant downtime from these outages reduces the amounts of power (KWH) that the plant generates. Most of the costs associated with operating a nuclear plant are fixed (interest on debt, equity return, fixed operating & maintenance costs), meaning that they must be paid regardless of how much, if any, power the plant generates. However, the cost of the power from the plant, on a Rs. per kWH basis, is lower if these fixed costs can be spread over a larger number of KWH. Conversely, the costs of power from the plant, again on a Rs. per KWh basis, will be higher if it generates fewer KWH.

  At the same time, maintenance costs typically go up when a plant is shutdown for planned or unplanned outages and expensive capital expenditures may be required to replace non- or poorly performing plant equipment.

- A nuclear accident liability risk – nuclear plant vendors, like Westinghouse and GE, are risk adverse. At the same time that they argue that their plants are extremely safe, they don't want to bear even a small financial liability for the costs of a nuclear accident. But if the vendors don't bear any of the risk, then the government or its citizens may be responsible for all of the socio-economic costs of an accident.

These risks will be addressed in the following sub-sections of this report.

A. Land Acquisition Risk

Both the Mithi Virdi and the Kovvada projects appear to face significant issues in acquiring the land they need for the proposed reactors.

Mithi Virdi

The process of acquiring the 520 hectares of private land needed for the reactors at Mithi Virdi (out of a total of 777 hectares) has not yet started. The new land acquisition act sets forth many conditions that must be satisfied before acquisition, including a social impact assessment for the project. If Mithi Virdi ever gets to the stage of land acquisition, the requirements under the new land acquisition law can be expected to significantly delay the project.

Kovvada

No applications have been made for permits for the Kovvada Project. A ballpark estimate suggests that about 2,000 acres of land will be required, of which 1,400 acres are privately owned. However, land acquisition, always a complicated exercise, has not yet commenced. Any land acquisition will now need to be conducted under the new Right to Fair Compensation and Transparency in Land Acquisition Act, 2013. This requires that 70 percent of the private landowners will have to consent to the purpose for which the land is being acquired. Thus, the announcement that construction would start by the end of 2016 is overly optimistic.

B. Technology Risk

No plants with either the Westinghouse AP1000 design proposed to be built at Mithi Virdi or the GE-Hitachi Economic Simplified Boiling Water Reactor (ESBWR) reactor design proposed for Kovvada have been completed and none is operating anywhere in the world. While a few AP1000 reactors are under construction, no GE-Hitachi ESBWR is even under construction anywhere worldwide. Both designs represent new first-of-a-kind technologies that, like other new designs, can be expected to experience unanticipated delays, costs and problems during both construction and the initial periods of operations, if not longer.

Consider this:

Eight nuclear units -- four in the U.S. and four in China – are currently being built using the same AP1000 reactor technology that would be used at Mithi Virdi. Publicly available information shows that the four AP1000 reactors under construction in the U.S. have experienced significant cost overruns and construction delays. Although there is no detailed public information on what it is costing to build the four plants in China, there are reports that the cost has increased by at least 30 percent since the projects were first announced.

With no other ESBWR reactors under construction or in operation, Kovvada will clearly be the first-of-a-kind plant involving this new plant design. Without any actual experience with the

ESBWR, given the history of the nuclear industry, the Kovvada project is likely to be extremely expensive to build, with a very long construction schedule.

The first power plants with new generating technologies, both nuclear and non-nuclear, also typically experienced problems during their initial years of operation that lead to lower-than-expected operating performance and higher-than-expected operating costs. There is no reason to expect that the Mithi Virdi and Kovvada projects will be any different.

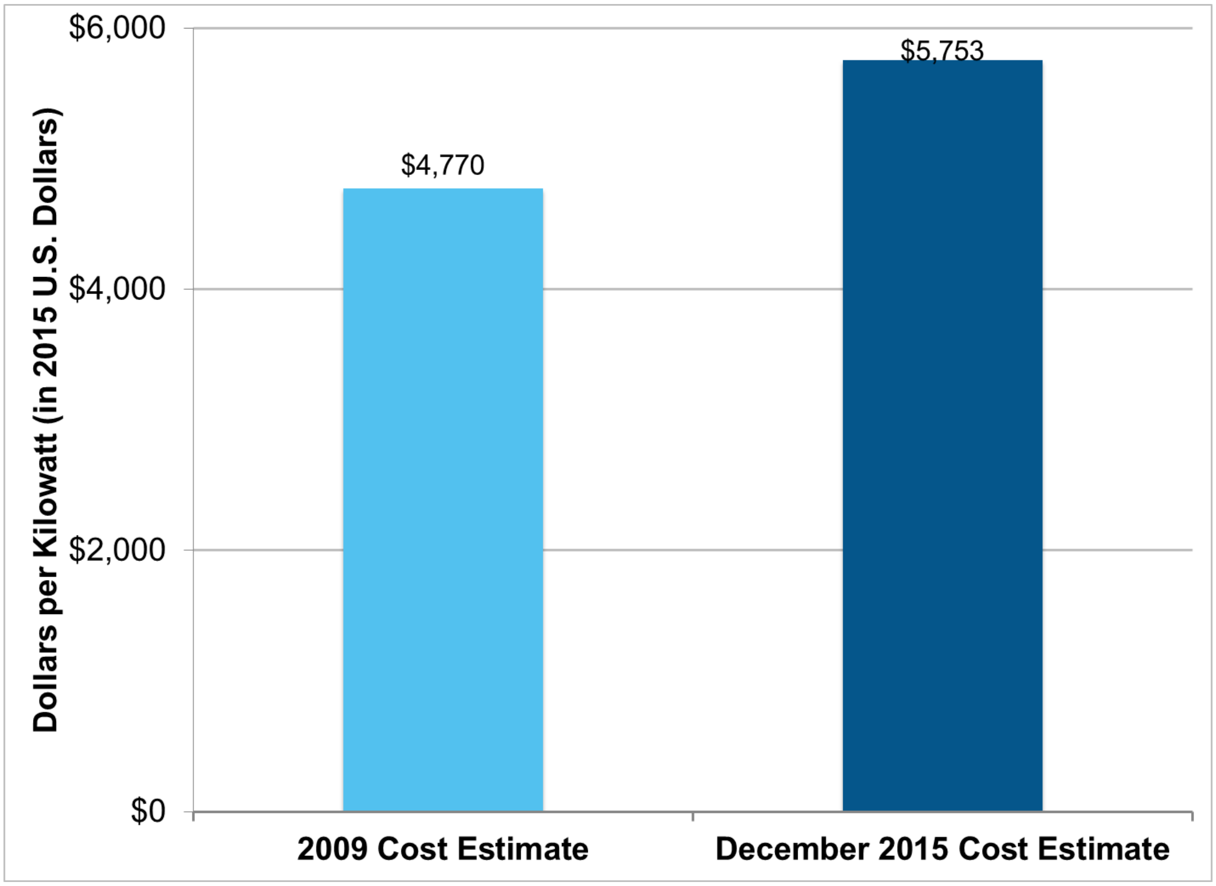
C. Construction Cost Risk – How Much Will it Cost to Build the Reactors at Mithi Virdi and Kovvada?

Westinghouse AP1000: Mithi Virdi

Both the construction periods and the costs to build reactors with new AP1000 reactor designs in the U.S. have increased significantly since utilities actively began to develop the projects.

As noted earlier, the "overnight" cost for a nuclear plant is the estimated expenditure needed to build the plant without including any escalation or financing costs. As, shown in Figure 2, below, the estimated overnight cost of building the Summer 2 & 3 AP1000 plants in the U.S. has increased by more than 20 percent since the construction of the reactors first was approved in 2010. At an exchange rate of 67.5 rupees per U.S. dollar, this translates into an increase in Summer's overnight cost from Rs. 32.2 Crore per MW to Rs. 37.2 Crore per megawatt (MW), in 2015 rupees.

Figure 2: Increase in Estimated Overnight Construction Cost for Summer 2&3 AP1000 Reactors.



At an exchange rate of 67.5 rupees per U.S. dollar, the currently estimated overnight cost of the Summer 2 & 3 reactors shown in Figure 2 translates to more than Rs. 37 Crore per MW.

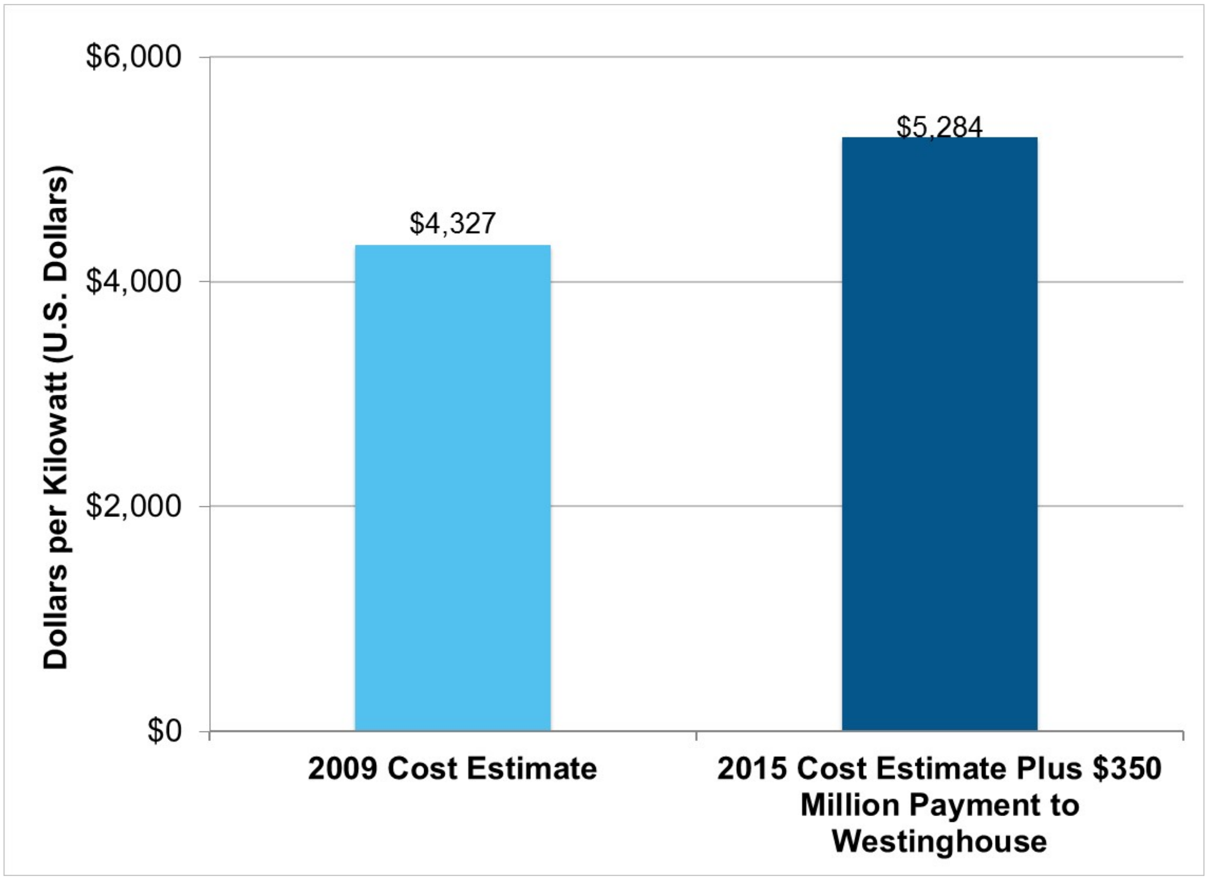
Georgia Power Company originally estimated in 2009 that the construction and capital cost for its 45.7 percent share of the Vogtle 3&4 AP1000 reactors would be $4.418 billion, or $4,327 per KW.[11] The Company has since increased its estimated construction and capital cost for its share of Vogtle 3&4 by $647 million, an increase of 15 percent.[12]. However, this cost does not reflect the $350 million in additional costs that Georgia Power owes Westinghouse under a recent legal settlement. As shown in Figure 3, below, including this additional $350 million payment to Westinghouse would mean that the currently estimated construction and capital cost for Georgia Power's share of Vogtle 3 & 4 is almost $1 billion, or approximately 22 percent higher,

[11] Unlike Summer 2&3, the only available construction cost estimate for Vogtle 3&4 includes escalation for certain key items including Quality Assurance and Design Scope Changes.

[12] Georgia Power Company's January 2016 Monthly Status Report for the Plant Vogtle 3&4 Project, Georgia Public Service Commission Docket No. 29849, at page 2. Available at http://www.psc.state.ga.us/factsv2/Docket.aspx?docketNumber=29849.

than the original cost estimate in 2009.[13] As shown in Figure 3, below, this translates into an increase in the construction and capital cost from $4,327 per KW to $5,284 per KW.

Figure 3: Increase in the Estimated Construction & Capital Cost for Vogtle 3 & 4 AP1000 Reactors.



Further cost increases are certainly possible, if not probable, at both Summer 2&3 and Vogtle 3&4, given that four to five years, or longer, of further construction and testing still remain to be completed before the new units are currently projected to be in service.[14]

GE ESBWR Design: Kovvada

As noted earlier, there are no reactors with ESBWR designs under construction. However, a U.S. utility, Virginia Electric and Power Company, has estimated that building a single unit ESBWR

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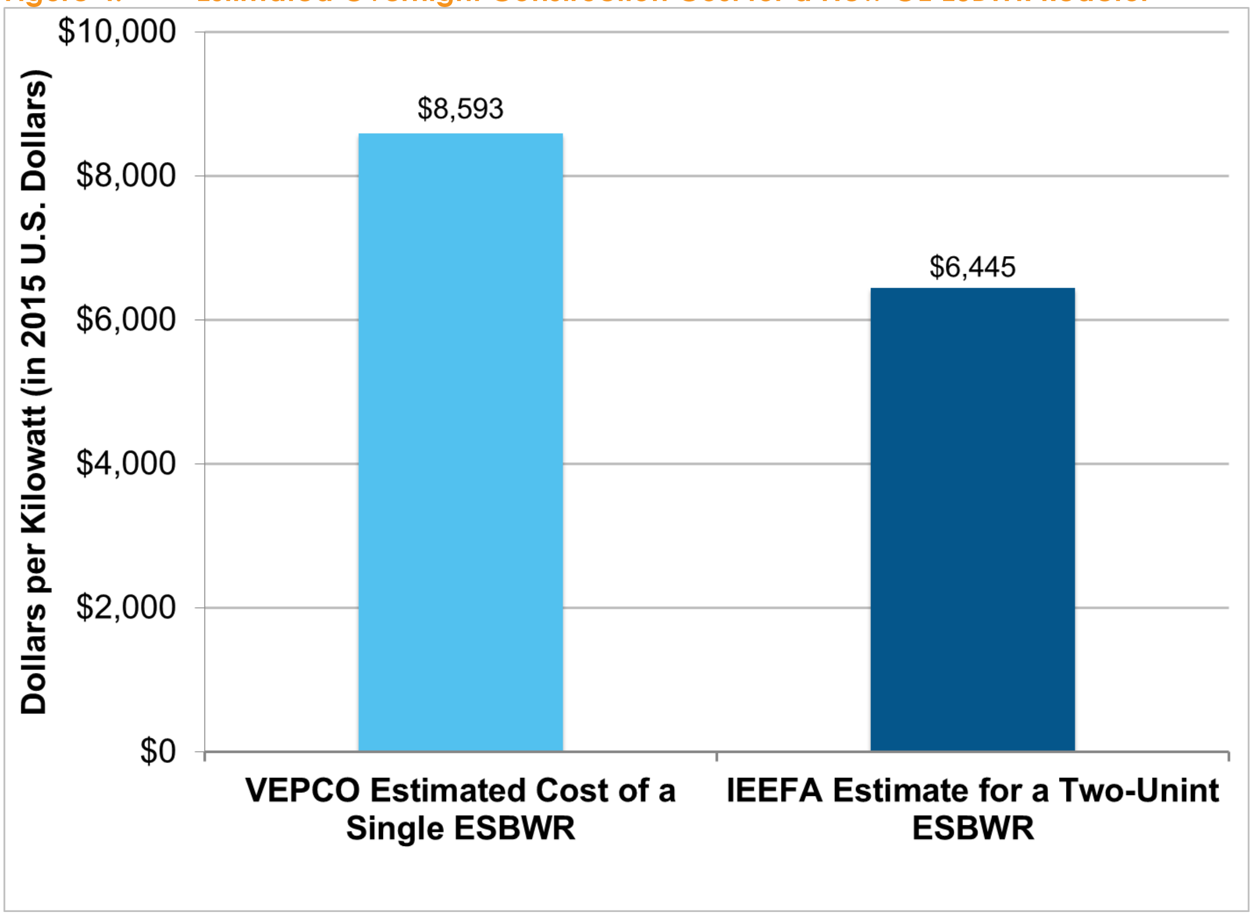
13 The estimated cost of financing Georgia Power Company's share of Vogtle 3&4 also has increased by more than $700 million since 2009. If this increase is considered, the total cost of the project has grown by more than 27 percent (from $6.113 billion to $7.083 billion) since 2009.

14 The cost of building the Vogtle AP1000s may even have increased already. See 'Vogtle Costs May Have Reached $21 Billion', *Nuclear Intelligence Weekly*, 11 December 2015: http://www.energyintel.com/pages/login.aspx?fid=art&DocId=909334

plant will cost $8,593/KW, in 2015 U.S. dollars.[15] As shown in Figure 4, below, based on this estimate for one unit, IEEFA estimates that the cost of building a two-unit set of ESBWRs would be in the range of $6,450 per KW, in 2015 U.S. Dollars. This suggests that the overnight cost of building an ESBWR reactor will be about 10 to 15 percent more expensive than for an AP1000 reactor. This is an extremely conservative assumption, as the cost of the Kovvada ESBWRs would likely be much more expensive than that, given that they would truly be "first of the kind" reactors with that design not having been previously built (and operated) anywhere in the world.

Figure 4: Estimated Overnight Construction Cost for a New GE ESBWR Reactor



[15] Virginia State Corporation Commission Case No. PUE-2015-00035, Virginia Electric and Power Company response to Question No. 87 of the Second Set of Interrogatories and Requests for Production Propounded by the Office of the Attorney General.

Areva's EPR Design: Jaitapur

Other nuclear plants being built with new technologies also are experiencing significant construction cost increases. The estimated cost of building the Olkiluoto 3, the first plant with the new European Pressurized Reactor (EPR) design, has more tripled since construction began in 2005.[16] The Flamanville EPR was originally scheduled to cost approximately 3.3 billion euros but its estimated construction cost has since tripled to 10.5 billion euros.[17]

Estimated Costs for Building Mithi Verdi and Kovvada

Experience suggests that it is cheaper to build new nuclear plants in India than in the United States. For example, based on the cost advantage claimed by a former managing director of the NPCIL in 2010,[18] Suvrat Raju and M.V. Ramana have estimated that the cost of a new nuclear plant in India could be about 25% to 30% lower than the cost of building the same plant in the United States.[19] This would mean an overnight cost of approximately $4,000 per KW, in 2015 U.S. dollars, for a new plant in India, like Mithi Virdi and/or Kovvada.

At the same time, the International Energy Agency projects an approximate $3,000 per KW, in 2015 dollars, overnight cost for a new nuclear plant in India.[20] This is about 40 percent below the IEA's estimated overnight cost for a new nuclear plant in the United States.

As shown in Figure 5, below, IEEFA's analyses have assumed two separate ranges of possible overnight costs for Mithi Virdi and Kovvada. These wide ranges reflect the great uncertainty both in the cost of building new generation nuclear plants and the cost savings that would be achieved by building the plant in India as opposed to the United States or Europe. The lower range of overnight costs for Mithi Virdi also reflects the savings that might be achievable at that project given the lessons learned during the construction of the eight AP1000 reactors currently being built in the U.S. and China.

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[16] http://www.nytimes.com/2015/05/08/business/energy-environment/france-nuclear-energy-areva.html

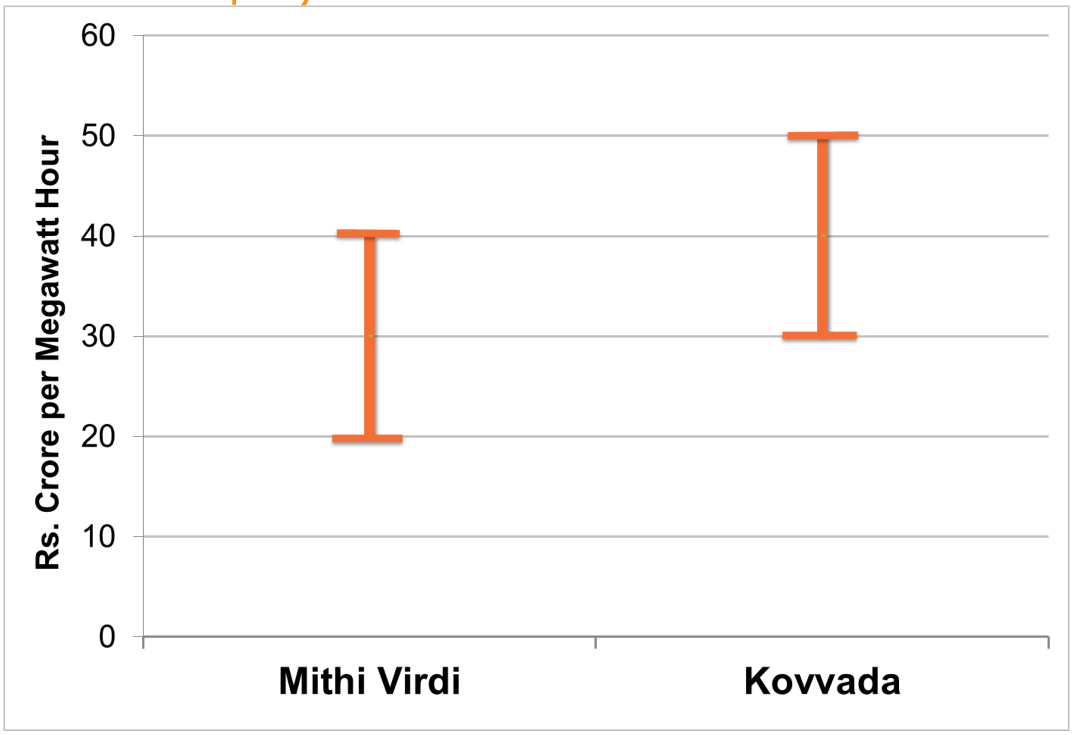
[17] http://www.wsj.com/articles/edf-postpones-flamanville-nuclear-reactor-startup-to-2018-1441293024

[18] *India's Nuclear Renaissance*, Economic Times, 12 December 2010. Available at http://articles.economictimes.indiatimes.com/2010-12-12/news/27575189_1_heavy-water-reactors-areva

[19] *Cost of Electricity from the Jaitapur Nuclear Power Plant*, Suvrat Raju and M.V. Ramana, Economic & Political Weekly, June 29, 2013, at page 54. Available at http://www.princeton.edu/~ramana/SA_XLVIII_26-27_290613_Suvrat%20Raju_M%20V%20Ramana.pdf

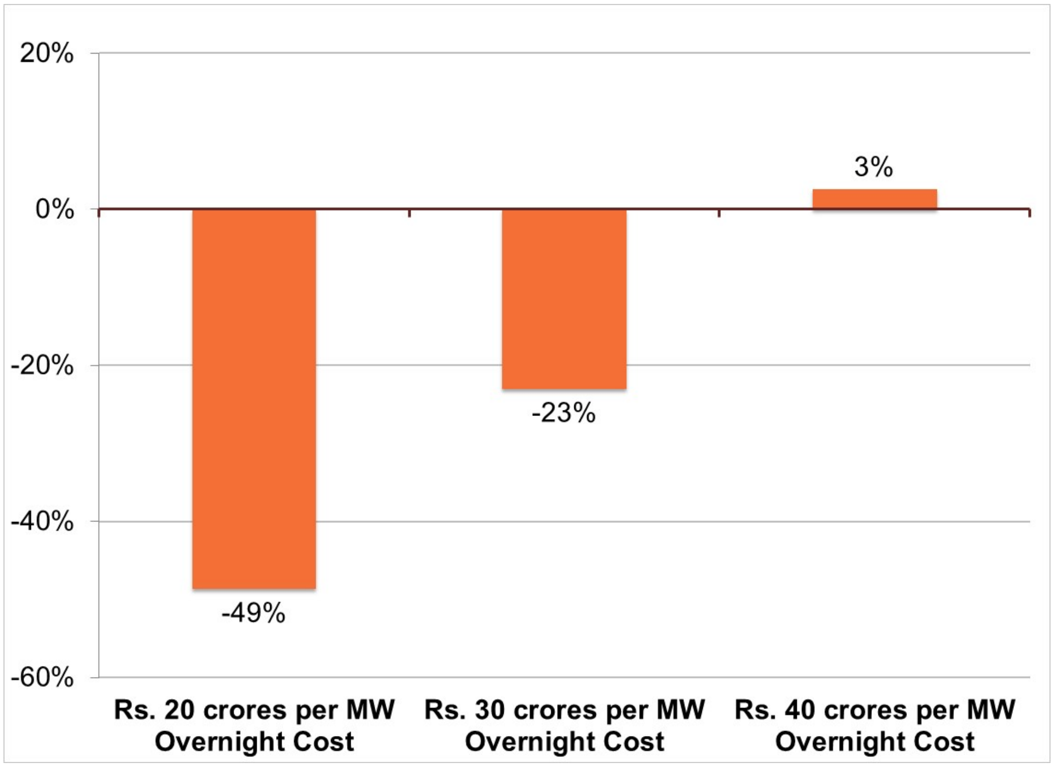
[20] See http://www.worldenergyoutlook.org/weomodel/investmentcosts/

Figure 5: Ranges of Assumed Overnight Costs for Mithi Virdi and Kovvada Reactors (in 2015 Rupees)



The Rs. 20 crore to Rs. 40 crore per MW (in 2015 Rs.) range of overnight costs we have used for Mithi Virdi converts into a range of $3,000 to $6,000 per KW, in 2015 U.S. dollars. As shown in Figure 6, below, this range of assumed overnight costs for Mithi Virdi would be between 49 percent lower and 3 percent higher than the current estimate for the overnight cost for the Summer 2 & 3 AP1000 reactors.

Figure 6: Difference in Assumed Overnight Costs for Mithi Virdi vs. Current Overnight Cost for Summer 2 & 3 AP1000 Reactors Under Construction in the U.S.[21]



The Rs. 30 crore to Rs. 50 crore per MW range of costs we have assumed for Kovvada would be between 31 percent lower and 15 percent higher than IEEFA's estimated cost of building a two-unit ESBWR in the U.S.

IEEFA's analysis uses a higher range of estimated overnight costs for Kovvada of Rs. 30 crore to Rs. 50 crore, in 2015 rupees.[22] This translates to a range of $4,400 to $7,400 per KW in 2015 U.S. dollars, using an exchange rate of 67.5 rupees per U.S. dollar. However, this range may well be too low, given the uncertainty surrounding the project's status and the problems experienced building other new first-of-a-kind power plants that have led to substantial schedule delays and significant cost increases. For example, lead units using first-of-a-kind technologies have experienced the following schedule delays and cost increases:

- As noted earlier, the schedule for the Vogtle 3 & 4 AP1000 reactors under construction in the U.S. has been extended by 39 months and the reactors' estimated construction and capital cost has been increased by $1 billion, or 22 percent.
- Construction of Olkiluoto 3 in Finland, the first plant using the new EPR technology, is taking at least nine years longer than originally planned and the project's cost has tripled since construction began in 2005.

[21] Using conversion rate of 67.5 Rupees per U.S. Dollar.
[22] The Rs. 30 crores to Rs. 50 crores per MW range of costs we have assumed for Kovvada would be between 31 percent lower and 15 percent higher than our assumed cost of building a two-unit ESBWR in the U.S.

- The Kemper County plant in the U.S. which uses a first-of-a-kind Integrated Coal Gasification Combined Cycle (IGCC) technology is now estimated to cost $6.49 billion, or approximately 2.7 times the $2.4 billion cost initially claimed for the plant in 2010. And its construction is taking at least two years longer than originally planned.

Even the nuclear industry has acknowledged that the actual costs of building new reactors typically are higher than the estimated costs: "Nuclear power plant construction is typical of large infrastructure projects around the world, whose costs and delivery charges tend to be under-estimated."[23]

D. Construction Schedule Risk - How Long Will it Take to Build the Proposed Mithi Virdi and Kovvada Reactors?

NPCIL has not released official information about the current status and schedules for the proposed Mithi Virdi and Kovvada nuclear plants. The Project Manager for the Kovvada Nuclear Power Park has recently indicated that the first pour of concrete[24] for the Kovvada project would be achieved by the end of 2016, with the first of the six new units likely to go online by 2021.[25]

Westinghouse AP1000: Mithi Virdi

Westinghouse initially claimed a short three-year construction schedule for its new AP1000 reactors.[26] But this schedule is not realistic given the actual experience of the nuclear industry, both in India and with the new AP1000 reactors under construction in the U.S. and China.

For example, as illustrated in Figure 7 and Table 1, the originally projected construction schedules for the four AP1000 reactors in the U.S. and the first AP1000 under construction in China were short – between 3 and 5 years. However, in each case, the projected construction schedule has been delayed. Each of these projects is now projecting a 6 to 7.5 year construction schedule, or more than two years longer than originally estimated.

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[23] http://www.world-nuclear.org/info/Economic-Aspects/Economics-of-Nuclear-power/

[24] The first pouring of concrete is considered an important milestone in the construction of new nuclear power plants. This milestone is known in the United States as the first placement of structural concrete.

[25] *Kovvada N-plant work likely by 2016: Official*, The Hindu, May 4, 2015.

[26] http://www.nei.org/News-Media/News/News-Archives/Us-Vendor-Westinghouse-Launches-Ap1000-Build-In-Ch

Figure 7: Estimated Westinghouse AP1000 Construction Schedules

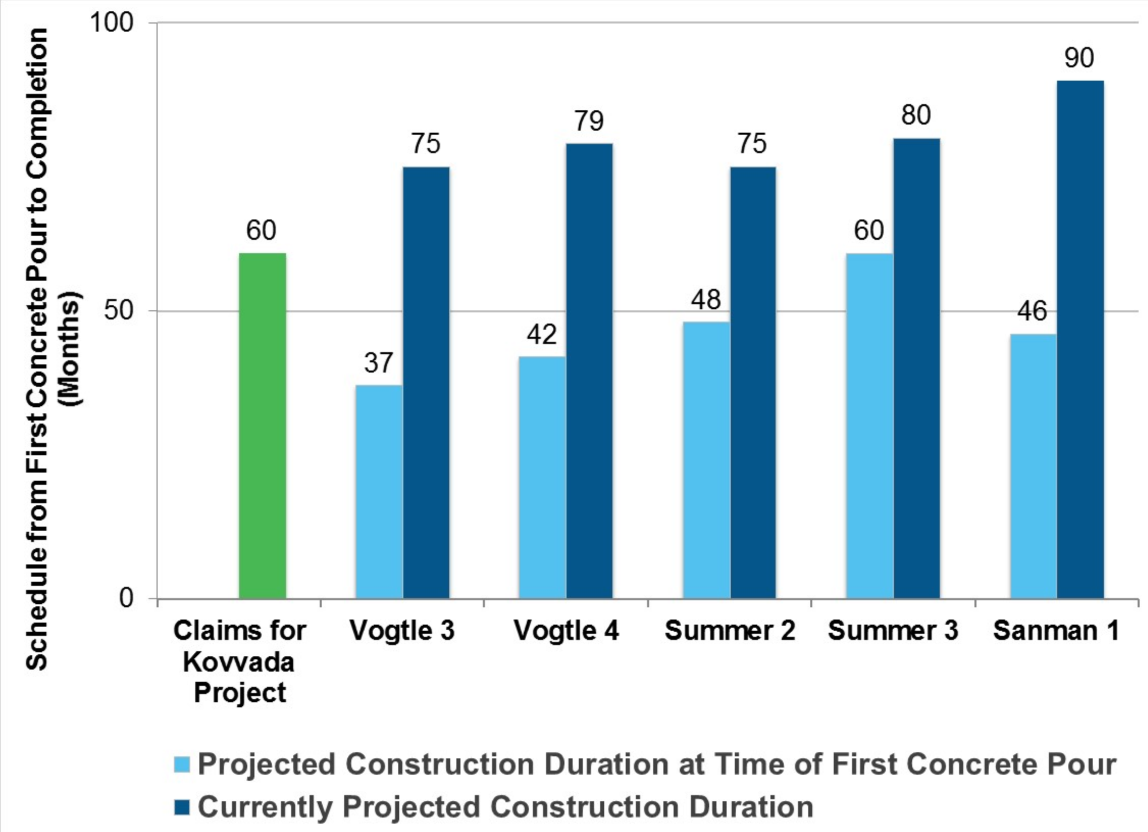

Table 1: Estimated Westinghouse AP1000 Construction Schedules.[27]

	Date of First Pour of Structural Concrete	Projected In-Service Date at Start of Construction	Currently Projected In-Service Date	Status
Claims for Kovvada Project	End of 2016	2021		Project Uncertain
Vogtle 3	March 2013	April 2016	June 2019	Further delays expected by independent monitor
Vogtle 4	November 2013	April 2017	June 2020	Further delays expected by independent monitor
Summer 2	March 2013	March 2017	June 2019	Further delays expected
Summer 3	November 2013	November 2018	June 2020	Further delays expected
Sanmen 1	March 2009	January 2013	September 2016	
Kudankulam 1	March 2002			Went on-line in the fall of 2013

The significant schedule delays shown for the Summer and Vogtle reactors in the US, shown in Figure 7 and Table 1, are due, in part, to design, fabrication, and delivery problems associated

[27] Id.

with the production of the modules being used in the units' construction. The ease of building the new modular design had been one of the claimed benefits of the new Westinghouse AP1000 reactors, but this claim has not proven to be true. Delays also have been caused by quality control problems, late and substandard quality work by equipment vendors and sub-contractors,[28] and an inexperienced workforce.[29] Vogtle, in particular, also has been plagued by the lack of an integrated project schedule.[30] Startup testing, and the resolution of problems identified during startup, also is expected to take longer than the plant owners expected.[31]

It is quite possible, perhaps even inevitable, that the actual construction schedules for the new Summer and Vogtle AP1000 reactors will be even longer than shown in Figure 7 and Table 1. More than three to four years of additional construction remain to be completed at each of these reactor sites. This is plenty of time during which new, currently unanticipated, problems can be discovered and further delays can be experienced. In fact, the schedule for completing Summer 2&3 is currently under review and delays of at least several months appear likely.[32] The nuclear engineers who work for the Georgia Public Service Commission as construction monitors at the Vogtle construction site have said that there is a "high probability" that there will be further delays in the project[33] because some components for the AP1000 units represent first-of-a-kind designs that have never been built before.

The construction durations shown in Figure 7, above, represent only the time between the first pouring of concrete and completion of the reactor. In addition, another three to seven years are spent on each project for licensing, land acquisition, site preparation, project initial design and engineering work, which includes the contracting for and fabrication of the large and expensive equipment such as the reactor vessel and reactor coolant pumps that require long lead times. This would mean it would ultimately take some ten to fourteen years to complete each of the new reactors starting when the initial decision was made to build them.[34]

For example, the owners of the Summer 2&3 reactors (which they now estimate will be completed in 2020) began spending money on the project back in 2007.[35] In fact, the owners spent approximately $1.6 billion, or approximately 30% of the anticipated overnight cost[36], by the time that the first pouring of structural concrete was achieved in March 2013.[37] This $1.6

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28 http://news.wabe.org/post/growing-concern-further-delay-and-cost-vogtle-nuclear-expansion

29 *Vogtle nuke project at risk for delay, but changes being made, monitors say*, SNL Financial, December 10, 2015.

30 http://news.wabe.org/post/growing-concern-further-delay-and-cost-vogtle-nuclear-expansion

31 http://www.powermag.com/delays-and-more-costs-for-plant-vogtle-nuclear-expansion/

32 *Quarterly Report to the South Carolina Office of Regulatory Staff Submitted by South Carolina Electric & Gas Company for the Quarter Ending December 31, 2015,* Appendix 1, at pages 9 and 10 of 11. Available at https://www.scana.com/docs/librariesprovider15/pdfs/blra-status-reports/2015-q4-blra-quarterly-report.pdf?sfvrsn=2

33 *More Delays Possible for Plant Vogtle Reactors*, Ray Henry for the Associated Press, May 14, 2015. http://chronicle.augusta.com/news/metro/2015-05-14/regulators-more-delays-possible-plant-vogtle-reactors

34 The assumption that a new plant, with preliminary design and site work underway in 2017, would not be in service until sometime between 2029 and 2032 also is consistent with the estimated construction schedules for proposed new U.S. new nuclear units other than the Summer and Vogtle projects. For example, a 2015 Feasibility Analysis prepared by Florida Power & Light Company for its planned Turkey Point 6&7 AP1000 project assumed that the first new unit, with preliminary work starting in 2014, would not be online until 2027, with the second new unit following in 2028. http://www.psc.state.fl.us/library/FILINGS/15/02473-15/02473-15.pdf, at Exhibit ROB-1.

35 *Quarterly Report to the South Carolina Office of Regulatory Staff Submitted by South Carolina Electric & Gas Company for the Quarter Ending December 31, 2015,* Appendix 2. Available at https://www.scana.com/docs/librariesprovider15/pdfs/blra-status-reports/2015-q4-blra-quarterly-report.pdf?sfvrsn=2

36 As noted earlier, the 'overnight' cost for a nuclear plant is the estimated expenditure needed to build the plant without any escalation or financing costs.

37 *Quarterly Report to the South Carolina Office of Regulatory Staff Submitted by South Carolina Electric & Gas Company for the Quarter Ending December 31, 2015,* Appendix 1, at page 5 of 11 and Appendix D. Available at https://www.scana.com/docs/librariesprovider15/pdfs/blra-status-reports/2015-q4-blra-quarterly-report.pdf?sfvrsn=2

billion had been spent on the design, engineering, licensing and site preparation work that needed to be completed before concrete could be poured.

Very little information has been made public about the four AP1000 nuclear units under construction in China other than at the time of the pouring of structural concrete in 2009, the start of operations of the first new unit, Sanmen 1, was planned for late 2013.[38] This planned in-service date has since been delayed to late 2016 or 2017, at the earliest. A significant delay has been attributed to problems with the reactor coolant pumps and to problems discovered during testing.[39]

GE ESBWR Design: Kovvada

There is no actual experience with building a new reactor project using a GE ESBWR design. The best information available is an estimate by Virginia Electric and Power Company that it would take sixteen years or longer to engineer and build a new ESBWR reactor.[40]

Areva's EPR Design: Jaitapur

It is also worth noting that multi-year delays and massive cost increases have been incurred during the construction of the new EPR reactor design that is proposed for the Jaitapur site.[41]

Construction began at the Olkiluoto 3 EPR plant in Finland in 2005, with a scheduled completion date of 2009.[42] As a result of what appears to be a never-ending series of problems, Olkiluoto 3 is now projected to be in service in 2018, or nine years later than initially scheduled. [43]

The Flamanville EPR, under construction in France was originally scheduled to open in 2012.[44] However, the plant's scheduled in-service date has been slipped to late 2018, or more than six years late.[45]

Summary

Given this history with the new generation of nuclear plants with new reactor designs, it is unrealistic, if not impossible, that the first units at either Kovvada or Mithi Virdi will be in operation in 2021 or anytime close to that. Instead, it is more reasonable to expect that the first units at either site would not start full time commercial operations until sometime in the 2029-2032

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[38] *China's First Advanced Nuclear Reactor Faces More Delays*, Wall Street Journal, January 15, 2015. Available at http://www.wsj.com/articles/chinas-first-advanced-nuclear-reactor-faces-more-delays-1421297393

[39] http://www.neimagazine.com/news/newsdesign-issues-resolved-for-china-ap1000s-4378966

[40] Virginia State Corporation Commission Case No. PUE-2015-00035, Virginia Electric and Power Company response to Question No. 87 of the Second Set of Interrogatories and Requests for Production Propounded by the Office of the Attorney General.

[41] http://sputniknews.com/business/20160125/1033669328/india-france-nuclear-reactors.html

[42] http://www.world-nuclear-news.org/NN-Olkiluoto-3-start-up-pushed-back-to-2018-0109147.html

[43] Id.

[44] http://www.energiedata.be/nieuws/edf-to-postpone-the-flamanville-reactor-to-2018.html

[45] http://www.world-nuclear-news.org/NN-Flamanville-EPR-timetable-and-costs-revised-0309154.html

timeframe. Even this timeframe might be very optimistic given the uncertainty surrounding when construction actually will start at either project, the problems that have been experienced during the construction of the new generation nuclear plants using AP1000 and EPR technologies, and the fact that Kovvada would be the very first plant built using GE's ESBWR technology.

E. Operational Risk - Lessons from the Kudankulam Nuclear Project

In addition to construction delays and large cost increases, nuclear power plants with new and untested designs also typically experience unanticipated operating problems that lead to unplanned and planned maintenance outages and reduced generation. In fact, the history of the recently completed Kudankulam nuclear plant in southern Tamil Nadu raises serious warning signs for the Mithi Virdi and Kovvada projects.

Kudankulam is the first commercial power plant with a foreign reactor design to be built in India in more than 40 years. At the time that the first pour of concrete was achieved in March 2002, Kudankulam 1 had a projected construction schedule of about 67-69 months, a little longer than has been claimed for the new reactor designs proposed for Mithi Virdi and Kovvada.[46] But instead of starting in 2007, Kudankulam did not achieve initial criticality until July 2013, and was not connected to the electric grid until October 2013 – 11.5 years after the start of construction.[47] The unit was not declared to be in commercial operations until December 2014.[48]

The construction of Kudankulam 2 has been similarly delayed. At the time of the first pour of concrete in July 2002, the unit was expected to startup in late 2008. And as recently as August 2013, expected to be started in mid-2014.[49] Criticality (startup) is now expected in April 2016, or nearly 14 years after construction began.[50]

At the same time that construction took longer, the cost of building Kudankulam rose more than 31 percent, from an original estimate of Rs. 13,171 crore, to a revised cost of Rs. 17,270 crore.[51] And that revised cost was released in 2013, so the first two units at Kudankulam probably were even more expensive to build than the Rs, 17,270 crore would suggest.

Moreover, the cost of building the two next units at Kudankulam has soared, with an estimated cost of Rs. 39,000 crore for Units 3 and 4.[52] Even if they were actually completed at this estimate,

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[46] http://www.frontline.in/the-nation/ready-to-run/article4944731.ece?homepage=true
[47] Id.
[48] http://www.business-standard.com/article/economy-policy/launch-of-unit-3-4-of-kudankulam-nuclear-power-project-in-2015-16-115022501046_1.html
[49] http://www.frontline.in/the-nation/ready-to-run/article4944731.ece?homepage=true
[50] http://articles.economictimes.indiatimes.com/2015-11-17/news/68356324_1_india-ltd-kudankulam-nuclear-power-project-cost-escalation
[51] http://www.frontline.in/the-nation/ready-to-run/article4944731.ece?homepage=true
[52] http://www.business-standard.com/article/economy-policy/launch-of-unit-3-4-of-kudankulam-nuclear-power-project-in-2015-16-115022501046_1.html

a cost of Rs. 39,000 crore would mean that Units 3 and 4 would be more than two-and-a-quarter times more expensive to build than Units 1 and 2. With a schedule of 69 months from an expected first placement of concrete in early 2016, Unit 3 is not expected to startup until sometime in 2022 – but that schedule must be considered extremely optimistic given the actual construction history of Units 1 and 2.

Unit 1 has had serious operational problems since it started up in 2013. Most significantly, the unit shut down for its first refueling and maintenance outage in June 2015, with an expected restart in late August. Restart kept being delayed however, and the unit did not resume commercial operations until the end of January 2016.[53] The unit was then shut down for an additional 11 days on February 4, 2016, barely 4 days after it had restarted from the seven month-long outage.[54] The chairman of India's Atomic Energy Commission has attributed the long outage to "teething problems" at a "first of its kind" reactor in India using new equipment and a new technology.[55]

F. Nuclear Liability Risk

The Indian Supreme Court established an "absolute liability" principle after the Bhopal disaster. Under this principle, both the operator and supplier would be jointly liable for damages from an accident, with no limit on their liability.

However, in 2010, the Indian parliament adopted the Civil Liability for Nuclear Damage Act. This law indemnifies the supplier of the nuclear technology and transfers the liability to the Nuclear Power Corporation of India Limited (NPCIL), whose liability is capped at $250 million. In other words, the Indian victims of a nuclear accident and Indian taxpayers would be entirely responsible for the damage from the accident, with no way of holding the supplier to account.[56]

But the 2010 law also contains a clause that allows NPCIL a "right of recourse," which it can use to reclaim some of the cost of the damage from an accident from the supplier if the accident was caused by a design defect. Even the minimal risk from this limited liability (as compared to the billions of dollars that companies like Westinghouse and GE can earn by selling nuclear plants to India) apparently is too much for the suppliers. GE has announced it will not make any nuclear investments in India until the current nuclear accident liability law is changed.

However, the Indian government appears to be eliminating even this limited liability. Last year it created a 15 billion rupee insurance pool that would provide coverage to nuclear operators and would shield suppliers (including Westinghouse and GE) from liability under the "right of recourse."[57] Then, in early February 2016, the government ratified the International Convention of Supplementary Compensation for Nuclear Damage that seeks to establish a uniform global

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[53] http://www.ndtv.com/tamil-nadu-news/kudankulam-nuclear-plant-restarts-generation-1277488.
[54] Id.
[55] http://articles.economictimes.indiatimes.com/2015-11-17/news/68356324_1_india-ltd-kudankulam-nuclear-power-project-cost-escalation
[56] *The Impasse over Liability Clause in Indo-U.S. Nuclear Deal*, M.V. Ramana and Suvrat Raju, New York Times India Ink Blog, October 15, 2013. http://india.blogs.nytimes.com/author/suvrat-raju/
[57] http://articles.economictimes.indiatimes.com/2015-11-17/news/68356324_1_india-ltd-kudankulam-nuclear-power-project-cost-escalation

regime for compensating victims in the event of a nuclear accident.[58] The government hopes these steps will open the doors to investments by foreign reactor suppliers including Westinghouse and GE.[59]

Even if the Indian government reduces the liability of Westinghouse and GE under the 2010 Law, the issue of liability for nuclear accident costs already has delayed and continues to create uncertainty for the Mithi Virdi and Kovvada projects.

Section IV. The Cost of Power from Mithi Virdi and Kovvada

Background: Nuclear Plant Tariffs

The process through which the Indian government determines the actual tariffs (that is, the prices) paid for the power from nuclear plants in India is opaque and not disclosed to the public.[60] There also is no external oversight of how the tariffs are set. And unlike solar power, there is no auction process through which nuclear tariffs are set.

Furthermore, there is no evidence of whether the actual tariffs for the power from nuclear plants fully recover from customers the total costs of producing that power. If they don't, the difference between the full cost of producing power from a nuclear plant and the tariff being charged for that power represents a hidden subsidy by the Indian government, ultimately borne by taxpayers.

Analytic Methodology for Estimating the Cost of Power from Mithi Virdi and Kovvada

Although the process of setting nuclear tariffs is opaque, a 2008 paper by Sudhinder Thakur, who at that time was the Executive Director (Corporate Planning) for NPCIL, does list the factors

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[58] http://timesofindia.indiatimes.com/india/India-ratifies-nuclear-liability-convention-hopes-to-win-foreign-investment/articleshow/50860762.cms

[59] http://articles.economictimes.indiatimes.com/2015-11-17/news/68356324_1_india-ltd-kudankulam-nuclear-power-project-cost-escalation

[60] Ramana, M. V. 2012. *The Power of Promise: Examining Nuclear Energy in India*. New Delhi: Penguin India, available at https://books.google.com/books?id=5m8Atq0ncrwC&printsec=frontcover&dq=inauthor:%22M+V+Ramana%22&hl=en&sa=X&ved=0ahUKEwj2ir__gtXKAhUEHh4KHcsAAzYQ6AEIHTAA#v=onepage&q&f=false

that the Indian government says its considers when it calculates to calculate nuclear power plant tariffs.[61]

According to Thakur, nuclear plant tariffs include both capacity and energy charges. The fixed components of the capacity charge are return on equity, interest on borrowed funds, and depreciation. The variable capacity charge includes operations and maintenance (O&M) costs. The energy charge is comprised of the variable fuel charge.

Mr. Thakur's calculations also include charges for the recovery of the initial fuel load and for interest on working capital. To be conservative, and because these charges are comparatively small, they have been excluded from IEEFA's analysis.

The following assumptions were taken from Mr. Thakur's 2008 paper:

1. The new plants will be funded through a 70:30 debt/equity ratio. The first year of investment is all equity.
2. The debt borrowed for the construction of the plan would be repaid in eight years.
3. The initial year O&M costs are assumed to be 2% of the estimated cost of building the new plants and escalate at a 5% annual rate after that.
4. Construction costs and fuel costs are escalated at a 5% annual rate.
5. Each new plant would operate at an average annual 80% capacity factor, with seven (7) percent of each reactor's output consumed by running on-site equipment.

Other key assumptions include:

6. Overnight construction cost – As shown in Figure 6 above, a range of overnight construction costs between Rs. 20 crore and Rs. 40 crore per MW, in 2015 Rs., has been assumed for Mithi Virdi and a range of Rs. 30 crore to Rs. 50 crore per MW, also in 2015 Rs., has been assumed for Kovvada.
7. Construction Schedule. For Mithi Virdi, IEEFA has assumed that work on licensing, land acquisition, site preparation, project initial design and engineering work, the contracting for and fabrication of the large and expensive long-lead-time equipment such as the reactor vessel and the reactor coolant pumps, will begin in early 2017 and that the project will start commercial operations in early 2029. This construction schedule is consistent with the experience at the AP1000s already under construction.

   IEEFA also has assumed, based on the actual experience at Summer 2 & 3, that approximately 30 percent of the total estimated overnight cost of Mithi Virdi will be spent in the years 2017-2020, prior to the first pouring of structural concrete. The construction expenditures for the remaining years of the project, 2021-2028, are assumed to follow the same annual expenditure curve as is being used for Summer 2 and 3.

   The annual and cumulative construction expenditures IEEFA has assumed for Mithi Virdi (as a percent of the total overnight cost) are shown in Table 2, below:

[61] *Economics of Nuclear Power in the Indian Context*, Atoms for Peace, 2008, available at http://www.inderscience.com/info/inarticle.php?artid=19891

Table 2: Assumed Annual and Cumulative Expenditure Pattern (as % of Total Overnight Cost) for Mithi Virdi.

Year	Annual Expenditure (%)	Cumulative (%)
2017	7.70%	7.70%
2018	7.70%	15.41%
2019	7.70%	23.11%
2020	7.70%	30.81%
2021	8.56%	39.37%
2022	7.98%	47.35%
2023	11.20%	58.54%
2024	15.07%	73.62%
2025	13.51%	87.13%
2026	7.98%	95.11%
2027	3.86%	98.97%
2028	1.03%	100.00%

This accelerated schedule for Mithi Virdi conservatively assumes that some planning and design for Mithi Virdi has already been completed prior to 2017 under the initial agreement with Westinghouse and that some of the work being performed for the eight AP1000 reactors under construction in the U.S. and China is readily transferable to India.

Because Kovvada is expected to truly be a first-of-a-kind plant using the new GE-Hitachi ESBWR technology, IEEFA has assumed a full fourteen-year construction schedule will be required. This would mean that the first two units at Kovvada would not be completed and start commercial operations until early 2031, under the optimistic assumption that work on the project actually begins in 2017.

The annual and cumulative expenditures assumed for Kovvada (as a percentage of the total overnight cost) are shown in Table 3, below.

Table 3: Assumed Annual and Cumulative Expenditure Pattern (as % of Total Overnight Cost) for Kovvada.

Year	Annual Expenditure (%)	Cumulative (%)
2017	0.41%	0.41%
2018	1.86%	2.27%
2019	6.08%	8.35%
2020	7.14%	15.50%
2021	6.00%	21.50%
2022	9.31%	30.81%
2023	8.56%	39.37%
2024	7.98%	47.34%
2025	11.20%	58.54%
2026	15.07%	73.62%
2027	13.51%	87.13%
2028	7.98%	95.11%
2029	3.86%	98.97%
2030	1.03%	100.00%

8. Return on Equity – 15.50%.
9. Debt Cost - 12.50%.
10. Discount Rate – 13.40%, based on a 70-30 debt/equity ratio and the assumed return on equity and cost of debt.
11. Annual depreciation rate – 5%.

IEEFA's Projected Costs of Power from Mithi Virdi and Kovvada

Total Investment

The total investment that would be needed to build and finance the twelve proposed nuclear reactors at Mithi Virdi and Kovvada would be massive, ranging from a total of Rs. 6.7 trillion to Rs. 11.9 trillion ($99 billion to $175 billion in U.S. dollars, at a conversion rate of 67.5 Rupees per U.S. Dollar).

Tariffs

The average cost of generating electricity in India is approximately Rs. 3.00 to Rs. 4.00 per KWH.[62] The annual and levelized tariffs for power from Mithi Virdi and Kovvada will be significantly more expensive, as shown below.

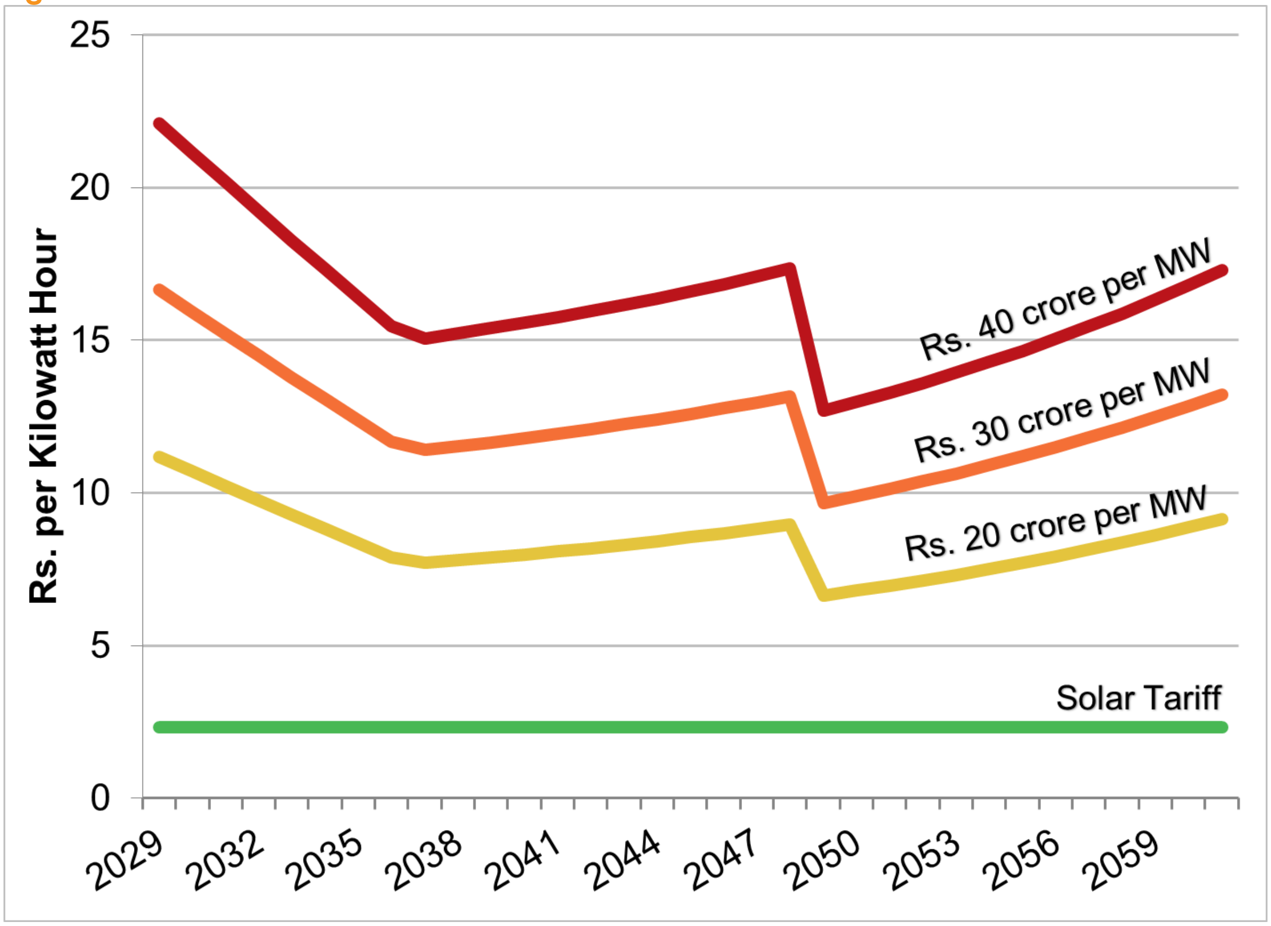
Each of the figures below compares the estimated costs of power from Mithi Virdi and Kovvada with estimated solar tariffs. A more detailed explanation of solar tariffs can be found in the next section of the report.

Cost of Power from Mithi Virdi

As shown in Figure 8, below, the first year tariffs for the power from the first new units at Mithi Virdi likely will range between Rs. 11.12 and Rs. 22.12 per KWH, and then will decline over time as the debt is repaid and the annual collections for depreciation end. After twenty years, however, the tariffs will again rise due to the impact of the annual escalation of operating and fuel costs.

62 *India's Electricity Sector Transformation: Global Capacity Building*, Tim Buckley and Jai Sharda, November 2015. Available at http://ieefa.org/wp-content/uploads/2015/11/IEEFA-India-Electricity-Sector-Transformation_Global-Capacity-Building_11112015.pdf

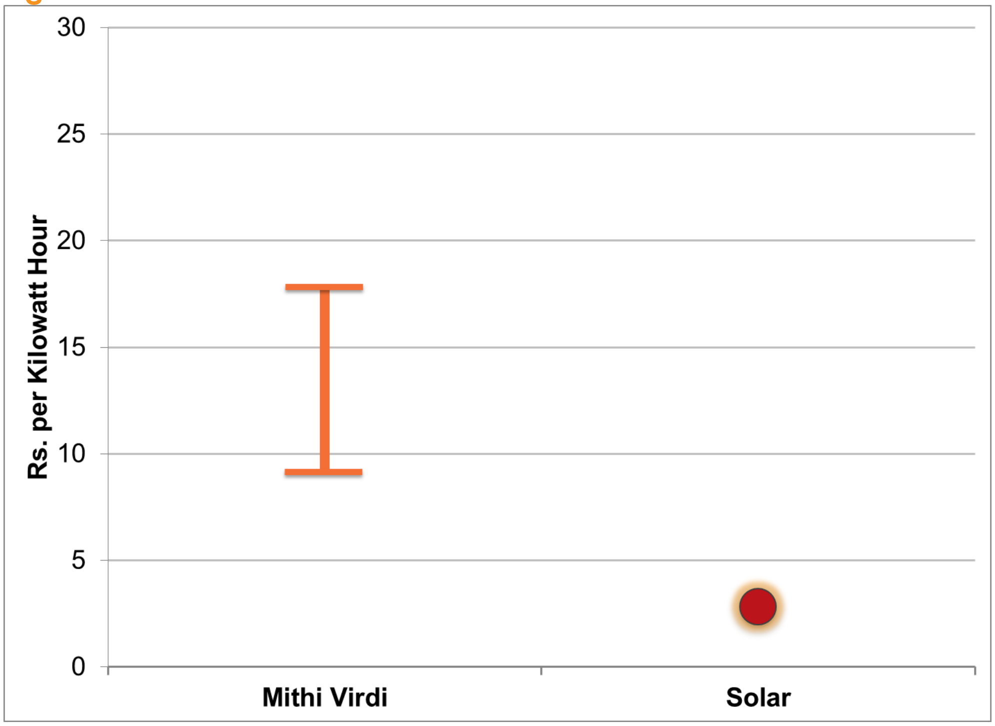
Figure 8: Annual Tariffs for Power from the First New Reactors at Mithi Virdi



These first year tariffs for the power from Mithi Virdi translate into a range of Rs. 5.92 to Rs. 11.73 per KWH, in 2016 rupees.

The levelized tariffs for the power from Mithi Virdi can be expected to be somewhere between Rs. 9.05 and Rs. 17.75 per KWH, in 2029 Rupees, over a thirty-year lifetime, as shown in Figure 9, below.

Figure 9: Levelized Mithi Virdi Tariffs vs. Solar Tariffs.



Due to escalation, the annual and levelized costs of power from the subsequent units at Mithi Virdi are likely to be higher than those for the initial units, unless substantial economies of scale are achieved.

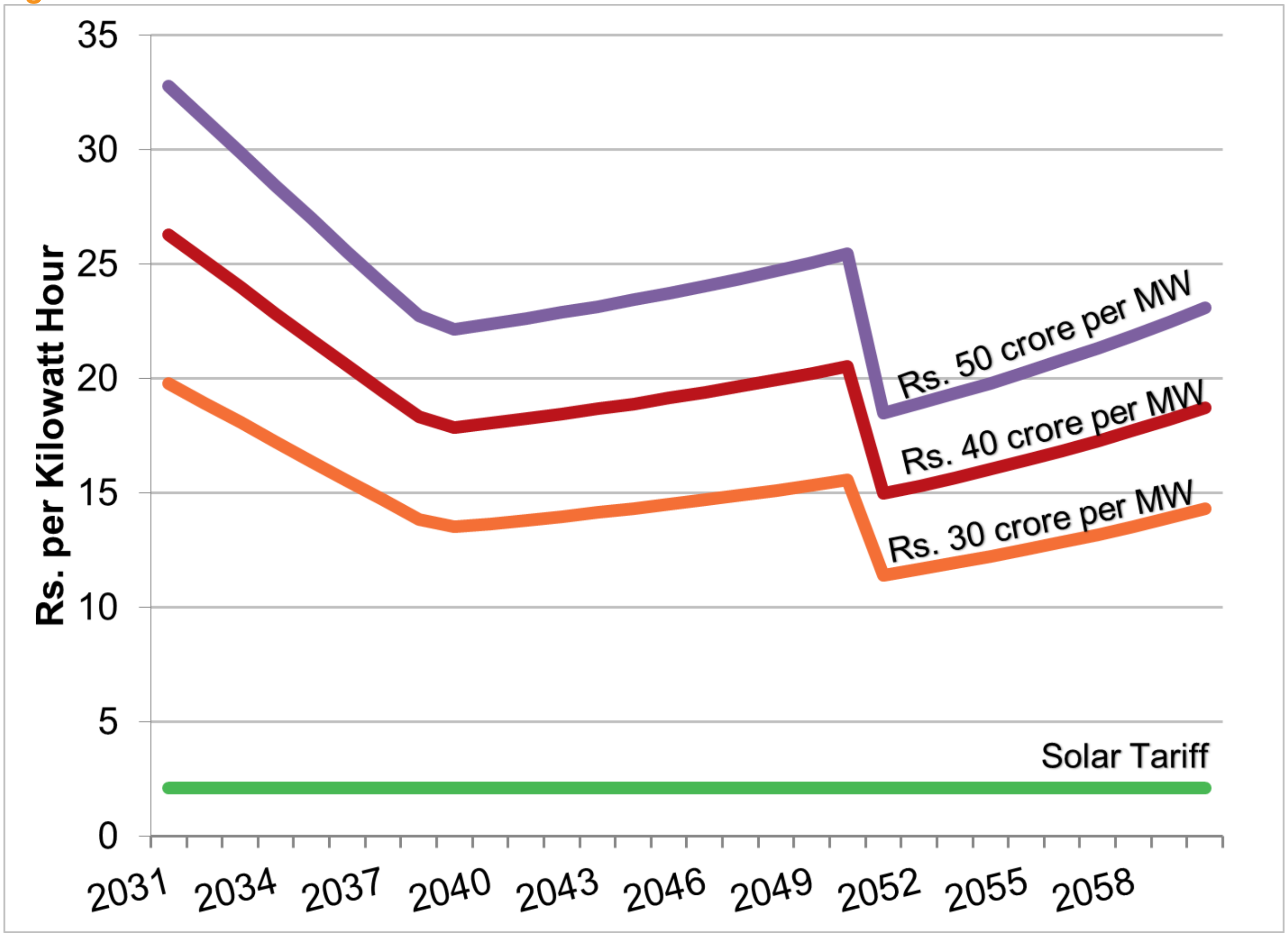
This range of potential power tariffs is substantially higher than the "around Rs. 12" per KWh that the Indian Department of Atomic Energy (DAE) has estimated for the cost of power from Mithi Virdi.[63]

Cost of Power from Kovvada

As shown in Figure 10, below, the first year tariffs for the power from the first new units at Kovvada likely will range between Rs. 19.80 and Rs. 32.77 per 9KWH, and then will decline over time as the debt is repaid and the annual collections for depreciation end.[64] After twenty years, however, the tariffs will again rise due to the impact of the annual escalation of operating and fuel costs.

[63] *Cost of nuclear power proving high, DAE in a* fix, The Times of India, December 25, 2013.
[64] The first year tariffs from Kovvada are much higher than those from Mithi Virdi because (1) we expect that the new units at Kovvada are likely to be significantly more expensive to build and (2) they will be entering service years after the first units at Mithi Virdi.

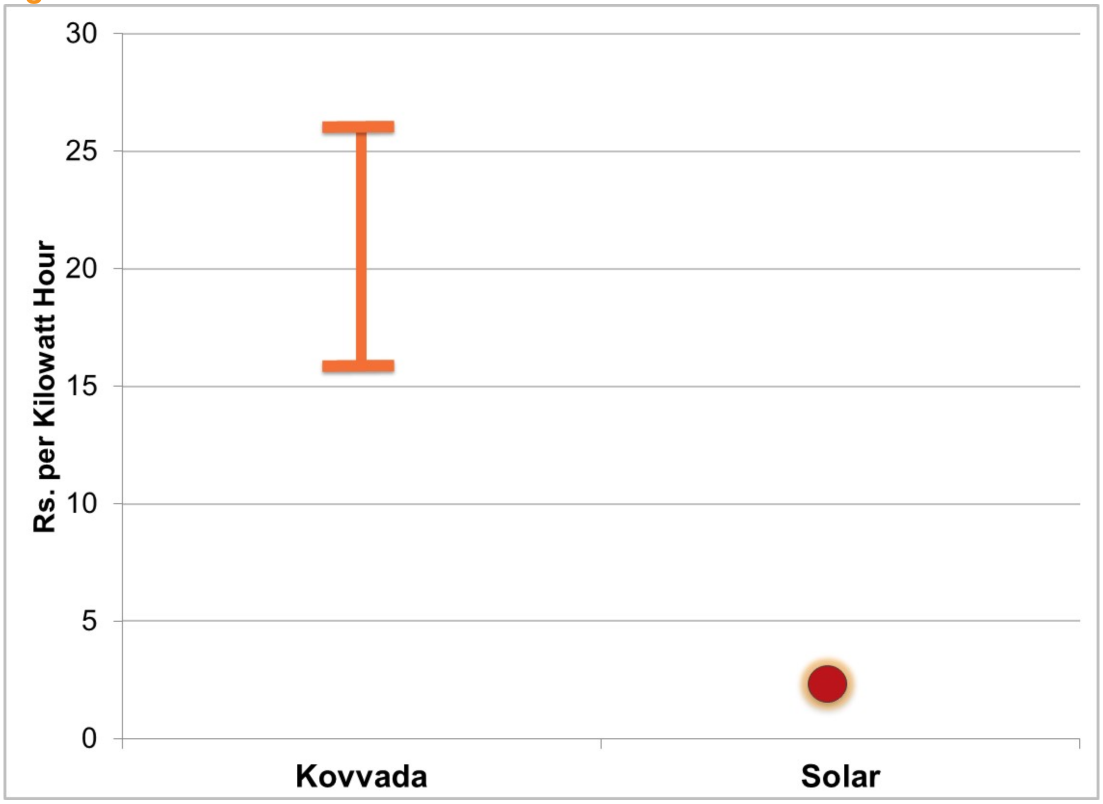
Figure 10: Annual Tariffs for Power from the First New Reactors at Kovvada.



These first year tariffs for power from Kovvada translate into a range of Rs. 9.52 to Rs. 15.76 per KWH, in 2016 rupees.

The levelized tariffs for the power from Kovvada can be expected to be somewhere between Rs. 15.85 and Rs. 26.04 per KWH, in 2031 Rupees, over a thirty-year lifetime, as shown in Figure 10, below.

Figure 11: Levelized Kovvada Tariffs vs. Solar Tariffs.

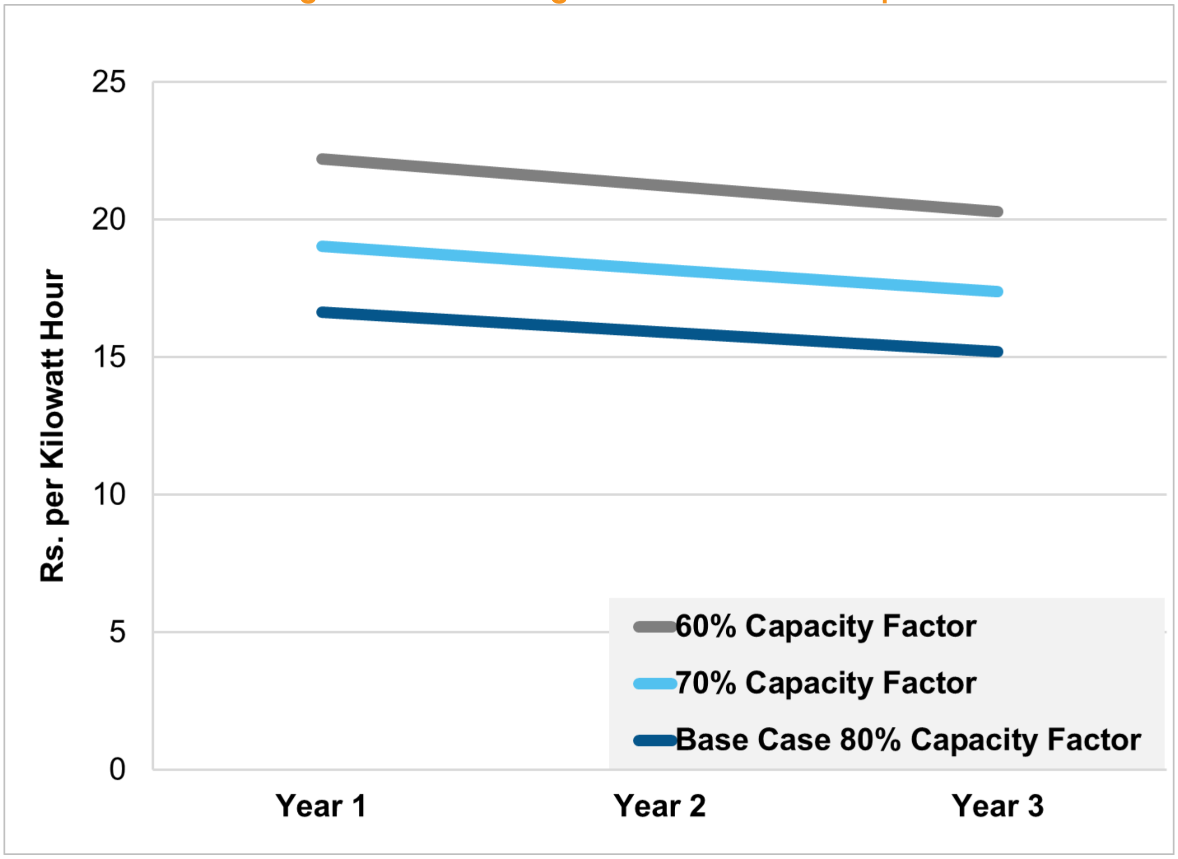


As at Mithi Virdi, due to escalation, the annual and levelized costs of power from the subsequent units at Kovvada are likely to be higher than those for the initial units, unless substantial economies of scale are achieved.

But the tariffs shown in Figures 8 through 11 could be even more expensive if the actual costs of building Mithi Virdi and Kovvada are higher than we have assumed, if the new nuclear reactors do not achieve the 80 percent annual capacity factors assumed in our analyses, and/or if their operating costs are higher than we have used.

Figure 12, below, for example, shows that the annual tariffs for the power from Mithi Virdi would be significantly higher if the reactors experienced "teething problems," to use the words of AEC Chairman Sekhar Basu, and achieved only 70 percent or 60 percent capacity factors during their first three years of operations.

Figure 12: Annual Tariffs for Power from the First New Reactors at Mithi Virdi Assuming "Teething Problems" during Their Initial Years of Operations.

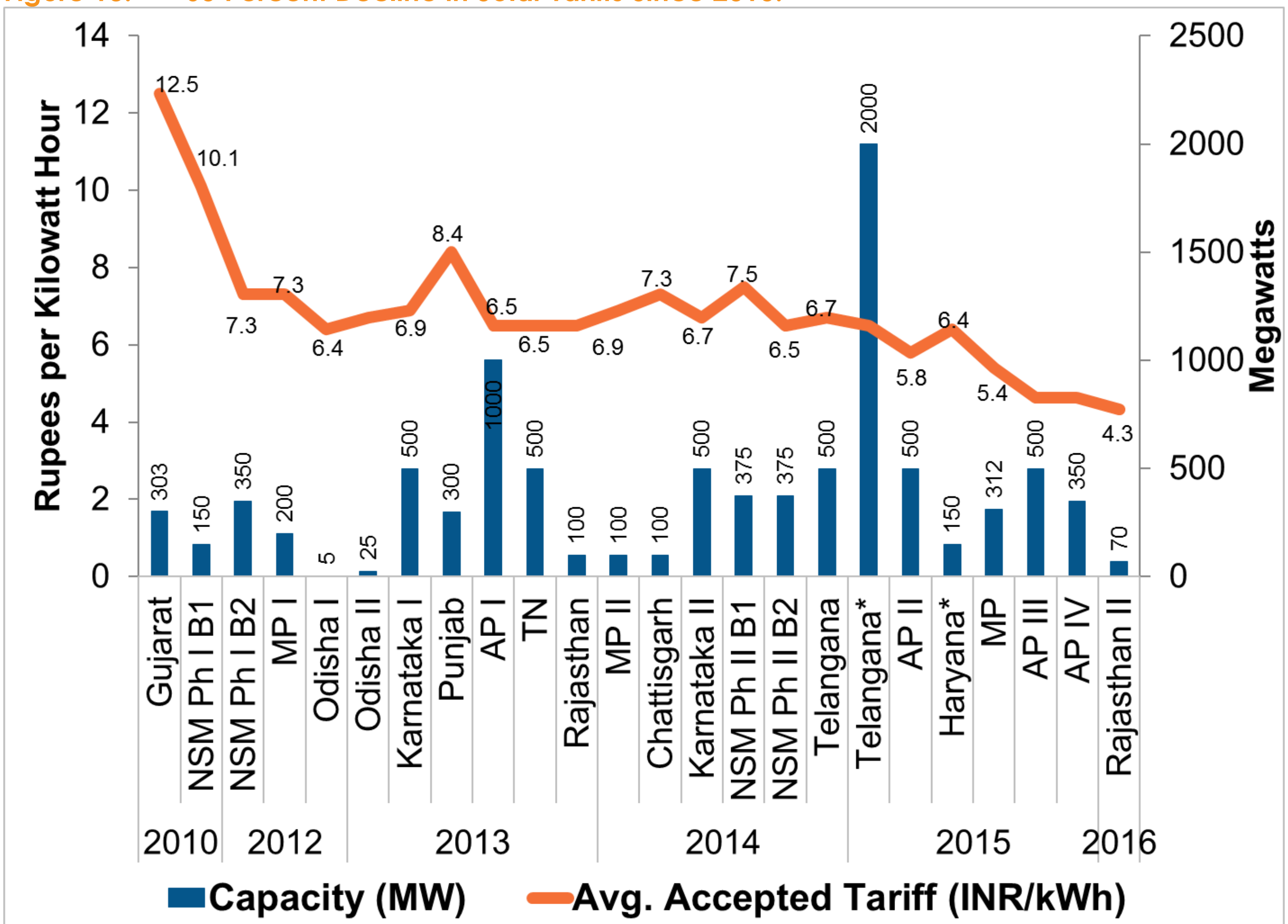


The only way NPCIL and the Indian government can prevent these very high tariffs is either to not build the Mithi Virdi and Kovvada projects or to subsidize the tariffs for the power from the new nuclear plants. However, that would increase the government's financial and fiscal risks and limit its ability to carry out other aspects of its energy and economic plans.

Section V. Solar Photo Voltaic (PV) Investments Produce More Significant Benefits than Spending on Mithi Virdi and Kovvada

As shown in Figure 13, below, solar tariffs in India have declined by 65 percent in the last five years:

Figure 13: 65 Percent Decline in Solar Tariffs Since 2010.[65]



[65] Source: Deutsche Bank, Abhishek Puri, 19 July 2015, CERC, State ERC, media reports

Because the tariffs in Figure 13 are fixed prices for 25 years, they decline each year in real terms. This is an important benefit of renewable energy, and particularly solar energy. Once systems are installed, their tariffs do not increase. As a result, the real price of electricity generation declines over time. Thus, with no fuel risks, renewable energy is deflationary.

IEEFA forecasts that installed solar tariffs will decline at an annual 5-8% rate in the next two decades. This forecast is based on continued double-digit growth in global solar installations that will drive economies of scale in manufacturing. At the same time, advances in solar technologies will continue to increase solar-conversion efficiencies.

As a result, IEEFA anticipates that a 25 year fixed rate solar tariff will be approximately Rs. 2.30 per KWh in 2029 and Rs. 2.09 per KWh in 2031. Thus, new solar tariffs will be much lower (perhaps, as low as one-third to one-seventh) than the cost of power from the proposed Mithi Virdi and Kovvada nuclear projects, as shown in Figures 8 through 12, above.

In addition to lower costs, solar PV investments also have other significant benefits compared to building the Mithi Virdi and Kovvada nuclear plants:

- Unlike nuclear, solar PV has no fuel cost, so there is no uncertainty regarding fuel availability or prices;
- Solar PV resources can be installed in much less time (about a year) than the 12-14 years it takes to build a new nuclear plant. Therefore, solar PV resources can be producing electricity years over a decade before any of the proposed units at Mithi Virdi or Kovvada;
- Solar PV has a small footprint, with significant environmental and health benefits. In particular, there would be no concern about the storage of radioactive spent nuclear fuel for over 100,000 years;
- There is a reduced need for new capital investments in the transmission and distribution systems as the solar generators can be placed closer to the communities where the power will be used and there would be lower transmission and distribution system losses;
- The production from solar PV is not very strongly dependent on geography unlike nuclear which has to be close to large water bodies;
- Solar PV has significantly lower annual operations and maintenance costs than nuclear and, unlike nuclear, has no need for substantial annual capital expenditures.

Solar PV is not a baseload resource, like nuclear. However, along with wind, hydro, energy efficiency, and existing baseload capacity in India, it can be part of a smart grid that would reliably provide energy all day, all year-round. Moreover, the intermittency of solar PV resources only becomes a concern when its share of electricity generation becomes higher than it is, or likely in the nearly future, will be in India. Given the technological developments around the world, it is reasonable to expect that cost-effective storage can be employed as part of the smart grid in India by the time that either Mithi Virdi or Kovvada would be likely to come on-line.

Section VI. Conclusion

The proposed Mithi Virdi and Kovvada nuclear projects will be very expensive to build and the tariffs for their power will be very high. Investing in new solar photovoltaic capacity represents a lower-cost, less environmentally harmful and more sustainable alternative to the Mithi Virdi and Kovvada projects.

Institute for Energy Economics and Financial Analysis

The Institute for Energy Economics and Financial Analysis (IEEFA) conducts research and analyses on financial and economic issues related to energy and the environment. The Institute's mission is to accelerate the transition to a diverse, sustainable and profitable energy economy and to reduce dependence on coal and other non-renewable energy resources. More can be found at www.ieefa.org

About the Author

David Schlissel, director of resource planning analysis for IEEFA, has been a regulatory attorney and a consultant on electric utility rate and resource planning issues since 1974. He has testified as an expert witness before regulatory commissions in more than 35 states and before the U.S. Federal Energy Regulatory Commission and Nuclear Regulatory Commission. He also has testified as an expert witness in state and federal court proceedings concerning electric utilities. His clients have included state regulatory commissions in Arkansas, Kansas, Arizona, New Mexico and California. He has also consulted for publicly owned utilities, state governments and attorneys general, state consumer advocates, city governments, and national and local environmental organizations.

Schlissel has followed developments in the nuclear industry for more than 40 years, including the reasons for nuclear power plant construction cost increases and schedule delays.[66] He also has accurately predicted the increased costs experienced by new generation Westinghouse AP1000 reactors under construction in the U.S.[67] In addition, Schlissel has conducted reviews of the management of more than fourteen nuclear construction projects and over 100 nuclear plant outages.

Schlissel has undergraduate and graduate engineering degrees from the Massachusetts Institute of Technology and Stanford University. He has a Juris Doctor degree from Stanford University School of Law. He also has taken nuclear engineering and project management courses at the Massachusetts Institute of Technology.

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66 http://schlissel-technical.com/docs/reports_36.pdf
67 http://schlissel-technical.com/docs/testimony/testimony_26.pdf