

POSITION PAPER:

PUERTO RICO AND THE CASE FOR SMALL MODULAR REACTORS

An Economics and Exports Perspective

**Civil Nuclear Trade Advisory Committee
U.S. Department of Commerce
March 15, 2018**

EXECUTIVE SUMMARY

This Position Paper describes how an SMR project can transform the economy of Puerto Rico, focusing on unleashing the island's potential within the manufacturing, global exports, and research sectors. The paper provides background on the economic potential of an SMR project for Puerto Rico, the opportunity for the people of Puerto Rico to lead a global technological trend, and the benefits the federal government can provide in case Puerto Rico embarks on a First-of-a-Kind (FOAK) project of this magnitude. This paper concludes with a recommendation for Puerto Rico's energy stakeholders to perform a Pre-Feasibility Study to evaluate the viability of a SMR project for the island.

1 INTRODUCTION

Puerto Rico holds a special place in the success of the U.S. nuclear industry across the world. In 1964, with the construction and startup of the Boiling Water Nuclear Superheater reactor (BONUS) in the town of Rincón, Puerto Rico became active in the dawn of U.S. nuclear technology and contributed to the global leadership role of today's U.S. nuclear industry. Engineers and scientists of Puerto Rico, like BONUS chief designer Dr. Modesto Iriarte (Michigan '58), helped launch the nuclear technology of the 60s, which went on to revolutionize the world.

Today, Small Modular Reactor (SMR) Technology promises a technological revolution similar to that of light water reactors in the 1960s, and Puerto Rico is again positioned, not only to contribute, but to lead such a revolution. An SMR project for Puerto Rico can prove the suitability of such technology to address today's energy needs for island-type, natural resource-limited territories around the world. But most importantly, the SMR project in Puerto Rico can demonstrate the potential for transforming the economy of similar territories across the world. This is, in essence, the core message of this paper.

This Position Paper describes how an SMR project can transform the Puerto Rican economy by capitalizing on the island's manufacturing, global export, and research sectors. This core message is presented in three parts: first, it starts by outlining how SMRs are tailored to address Puerto Rico's current energy needs. Second, it follows with the three potential venues an SMR project can lead to economic transformation - manufacturing, research programs, and global exports. Third, this paper ends with an action plan for Puerto Rico's energy stakeholders to perform a Pre-Feasibility Study for evaluating the viability of embarking in a SMR project.

This Position Paper presents the potential for an SMR project to unleash immediate economic revitalization for Puerto Rico and aims to motivate stakeholders from the island's energy sector to seriously consider the viability of such a project. A Pre-Feasibility Study will address such viability from a market and economics perspectives.

Similar to the impact people from Puerto Rico had on the U.S. nuclear industry in the 60s, at CINTAC, we acknowledge that today Puerto Rico has the potential to revitalize its economy through its highly skilled workforce coupled with the advances in SMR technology.

2 HOW SMRs CAN ADDRESS PUERTO RICO'S ENERGY NEEDS

There are currently more than a dozen SMRs and advanced reactors in latest stages of development and design certification. Most SMR designs share unique advances that make them an attractive option for Puerto Rico. As a matter of perspective, it is important to visualize these advances relative to conventional nuclear designs. Table 1 below summarizes a list of SMR design advances compared with conventional nuclear designs.

Table 1: Comparison of SMR advances with conventional nuclear designs

Design Feature	Conventional Nuclear	SMR
Plant Footprint (acres)	830	13 to 74
Fuel cycle (months)	18	>24
Emergency cooling system	Active	Passive
Estimated construction time (years)	6	<3
Emergency Planning Zone	10-mile radius from reactor	Site Boundary
Reactor Output (MWe)	1100-1700	50-300
Typical Plant Output (MWe)	1700-2200	160-600

The design features summarized above contrast the considerable advances in nuclear technology over recent years. For instance, whereas conventional nuclear plants require an average footprint of close to 830 acres, today most SMRs require a footprint of less than 50 acres. Another technological advancement in SMRs is the use of passive safety systems for reactor cooling. Passive safety systems rely on natural driving forces such as gravity flow and natural circulation to cool down the reactor in case of an emergency. This eliminates the dependency on an external source of electricity and active components like pumps for emergency cooling. Although the use of passive safety systems varies among SMR designs, the general design philosophy is maintained to provide cooling for a prolonged period of time without the need of external energy sources. Another aspect has to do with construction time. Whereas conventional reactors required at least 6 years to build, today's SMRs will require fewer than 3 years for construction. This is essential to reducing construction risks and for economy of deployment.

Yet, there are also three specific advances that make SMRs particularly tailored for addressing Puerto Rico's current energy challenges given its island geography. First, most SMR designs have longer refueling cycles (i.e. above 24 months) when compared with conventional nuclear reactors. SMRs would reduce carbon dioxide emissions and dependency on foreign fuels. Currently, almost 90% of Puerto Rico's generating capacity is provided by fossil fuel plants shown here in Table 2.

Table 2: Puerto Rico's Current Generating Fleet [9]

Power Plant	Capacity (MW)	Energy Source
Costa Sur Generation Plant	900	NG/Oil #6
Aguirre Generation Plant	900	Oil #6
Palo Seco Generation Plant	602	Oil #6
Aguirre Combined Cycle Generation Plant	592	Oil #2
Eco Electrica	507	Natural gas
San Juan Generation Plant	400	Oil #6
AES Cogenerator Generation Plant	454	Coal
San Juan Combine Generation Plant	440	Oil #2
Cambalache Generation Plant	247	Oil #2
Mayaguez Generation Plant	220	Oil #2

In 2014, Puerto Rico's existing fleet with a total capacity of about 5,000 MW, consumed 155,000 barrels/day of petroleum products, required 55 billion of cubic feet of natural gas and about 2,000 short tons of coal, producing an approximated 28 million metric tons of carbon dioxide emissions [7]. In contrast, it is estimated that a 1,000 MW nuclear plant requires about 27 metric tons of nuclear fuel each year [10]. This means that an SMR fleet with the same 5,000 MW capacity will require about 135 tons of fuel each year producing zero carbon dioxide emissions. This highlights SMRs potential to drastically reduce Puerto Rico's annual foreign imports in addition to improving air quality and lessening environmental impacts.

The second important technological advance an SMR can offer Puerto Rico is its reliability. SMRs are designed to sustain extreme natural events, thus allowing for the production of electricity 24/7. With a hardened transmission system, SMRs can provide electricity under extreme environmental conditions.

Lastly, the cost of electricity in Puerto Rico is currently about 22 cent/kWh (commercial) and 20 cent/kWh (residential), double that of the U.S. mainland [7]. States like Illinois and South Carolina, where more than 50% of the electricity is produced by nuclear, enjoy electricity costs of about 9 cent/kilowatt hour [8]. Generally, the low cost of electricity generated by nuclear is credited to the very low marginal operating costs counterbalancing the upfront capital investment thus resulting in long term reduced Levelized Cost of Electricity (LCOE). Today's SMR technology presents an even more attractive scenario for reducing cost of electricity for Puerto Rico. Whereas conventional nuclear power required long periods to achieve competitive LCOEs, SMRs simple design and pre-fab modular construction leads to less upfront capital investment. This aims to achieve competitive LCOEs at shorter payback periods when compared with Puerto Rico's decades-long high cost of electricity from imported fuels.

The lower cost of electricity, grid reliability and sustainability offered by an SMR, will address Puerto Rico's energy needs and will have a direct impact on the island's economy. However, the greatest impact of an SMR project on the economy of Puerto Rico rests in its intense reliance on human capital, strong reliance on local manufacturing and export sectors, and support from local academic and research institutions. No other energy source has the capability of addressing energy needs while at the same time transforming the economy over so many sectors.

3 POTENTIAL FOR ECONOMIC TRANSFORMATION

SMR deployment for the replacement of Puerto Rico's retiring electricity generating assets would result in significant growth in domestic manufacturing, the tax base, and high-paying factory, construction, and operating jobs. In an era in which jobs are lost to automation, building an economy on these sectors is of utmost importance, and SMRs represent the foundation for such a vision. Many factors point to the fact that an SMR project would have a significant impact on the economy of Puerto Rico.

Studies have shown that, based upon experience with a 1,000 MWe nuclear facility, a 400 MWe SMR plant is expected to generate over \$377M in direct and indirect economic output annually. This includes over \$181M in the plant's electricity sales, and induced spending at the local and state levels of \$7M and \$32M, respectively. The SMR plant is expected to pay about \$6M in state and local taxes annually [1].

New SMR construction creates demand for skilled labor in Puerto Rico, in positions such as welders and heavy equipment operators, as well as engineers, project managers, and construction supervisors. In addition, major components, subcomponents, fuel, commodities, and consumables are purchased from local manufacturers for safety-related and general commercial applications. Recent studies [2] have shown that a prototypical 100 MW SMR costing \$500 million to manufacture and install on-site is estimated to create nearly 7,000 jobs and generate \$1.3 billion in sales, \$627 million in value-added, \$404 million in earnings (payroll), and \$35 million in indirect business taxes.

During the operational life of the SMR, local vendors in Puerto Rico can provide operations, maintenance, repair, and inspection services. They also supply replacement components and perform plant modifications and upgrades. Ongoing maintenance of an SMR can provide substantial economic benefits for manufacturers in Puerto Rico. Studies show that the annual operation for a 100-MW SMR unit is estimated to create about 375 jobs and generate \$107 million in sales [2].

Both construction and maintenance of an SMR in Puerto Rico will create the demand for local manufacturing services. This presents the opportunity for Puerto Rico to join and complement the U.S. supply chain for fabrication and maintenance of SMR equipment during installation and throughout the lifetime of the plant. Puerto Rico's contribution to the supply chain could be significant and impactful given its strong history in the high-standard medical device and pharmaceutical sector. This presents a strong basis for Puerto Rico to invest in state-of-the-art factories and processes for supplying the high-precision, high-quality components

needed for nuclear technologies. The demand for these commodities, components, and services provides an export opportunity for local manufacturers.

A strong manufacturing sector in Puerto Rico will lead to strong export potential. Recent experience with U.S. nuclear plants built abroad have resulted in export orders in the billions of dollars, for equipment and services, including generators, reactor coolant pumps, and instrumentation, control systems and SMR fuel fabrication facilities including fuel for Advanced Reactors. U.S. businesses are beginning to reap the benefits of reinvestment in the U.S. nuclear supply chain. For example, the four Westinghouse AP1000 projects underway in China support over 15,000 U.S. jobs [3]. These jobs include design and engineering, manufacturing, information technology, and transportation. As an additional example, although the United Arab Emirates (U.A.E.) purchased Korean nuclear technology, it has contracted with multiple U.S. firms to provide program management, regulatory, legal, design, engineering, environmental, oversight, training, and licensing and permitting services.

One of Puerto Rico's greatest assets is its engineering graduates. Graduating more engineers than many universities in the U.S. [4], an SMR project for the island presents an opportunity for employing Puerto Rico's engineering talent in-house. Developing and nurturing in-house talent also presents the opportunity for technological exchanges with developing countries around the world facing similar energy challenges as Puerto Rico. This can translate into direct influence in the developed world. Rather than exporting most of the engineering graduates, perhaps it is time to start investing such talent in Puerto Rico's energy challenges. For an economy to thrive, local talent needs to be harnessed and kept on the island. With an SMR project, this exodus phenomenon can be reversed.

Tourism is one of Puerto Rico's strongest revenue engines contributing millions of dollars each year to the local economy. The reliability provided by a SMR coupled with a sustainable grid would help maintain revenue from the tourism industry. Puerto Rico will secure this profit stream even during hurricane season each year from July to November.

As in the development of any new technology, there is reluctance in the market to being the first customer, due to the First-of-a-Kind (FOAK) risks inherent in these new technology projects. However, an SMR project in Puerto Rico presents the opportunity for incentives from the U.S. Government as an early adopter of this technology to address the risks and paving the way for broader adoption. Incentives will come in the form of subsidies and tax exemptions for manufacturing companies to relocate to the island. Given the global strategic importance of this FOAK project for U.S. national interests, it is conceivable that the Federal government may wish to directly support the engineering, procurement, and construction of one or more of the first SMRs. This program would directly address the near-term aspects of technological uncertainty in deploying SMRs and could

be an attractive value proposition for the Puerto Rican government and first mover customers.

The prospects for an economic revival in Puerto Rico are numerous. Puerto Rico possesses the workforce, momentum, and the energy needs scenario suitable for an SMR project. Now, a Pre-Feasibility Study can be performed to determine the financial and local demand viability of embarking on a SMR project.

4 A PLAN FORWARD: PRE-FEASIBILITY STUDY

CINTAC recommends a Pre-Feasibility Study to assess in detail the viability and economics of an SMR project for Puerto Rico, focusing on market needs and the economic competitiveness for such project in Puerto Rico.

The need for replacing Puerto Rico's old electricity infrastructure and reduce high costs of electricity presents the possibility for a large market for SMRs in Puerto Rico. The Pre-Feasibility study will assess the viability for integrating SMRs with renewables and repower retired fossil plant sites for generating reliable baseload power. The Pre-Feasibility study will also assess the cost of electricity relative to the appropriate private-public investment partnerships, incentives for First-of-a-Kind (FOAK) project, and most importantly, in combination with the technological advances SMRs can offer for electricity rate competitiveness.

With respect to technological advances in SMRs, the Pre-Feasibility Study will emphasize how the "modularity" design aspect will impact financial decisions. For example, the process of modularization allows for converting the design and construction of a monolithic plant to facilitate the factory fabrication of modules for shipment and installation in the field as complete assemblies. SMRs allow investors to make incremental capacity additions at a pre-existing site. This leads to savings where initial investment costs related to siting (e.g., acquisition of land rights, connection to the transmission network) have been carried out. Therefore, certain fixed costs can be saved when installing the second and subsequent units. The modularity aspect also leads to an investment model of proposing several SMRs for the so-called "self-financing" typically encountered in modular investments. It represents the capability of the project to finance itself by re-investing the income from early-deployed nuclear modules operation into the installation of later modules. This approach is common in many other sectors, e.g., in the transportation industry, with toll roads being used to finance the construction of more highways.

The Pre-Feasibility study can follow recommendations and economic models published by the International Atomic Energy Agency (IAEA) "*Approaches for Assessing the Economic Competitiveness of Small and Medium Sized Reactors*" [5]. Therein, a comprehensive guidance is presented for countries currently evaluating the option of SMRs. Over 45 countries are actively considering embarking upon nuclear power programs, ranging from sophisticated economies

to developing nations. This Pre-Feasibility Study could present the opportunity for Puerto Rico to join this international community.

This Pre-Feasibility study aims for a FOAK project with immense value for both U.S. nuclear industry and national interests. This presents the possibility for this study to be eligible for U.S. Department of Energy (DOE) funding via the Funding Opportunities Announcements (FOA) recently offered on December 2017. CINTAC highly recommends that Puerto Rico's stakeholders pursue this funding opportunity in collaboration with staff from the Department of Commerce's (DOCs) Economic Development Administration (EDA) and DOE.

Puerto Rico's ongoing effort to reinvent its energy infrastructure makes this Pre-Feasibility Study a timely and strategic decision. Timing is of the essence and Puerto Rico's energy stakeholders should consider pursuing the Pre-Feasibility Study for an SMR project for the island.

5 CONCLUDING REMARKS

This Position Paper describes how an SMR project can transform the economy of Puerto Rico, focusing on unleashing the island's potential in the manufacturing, global exports and research sectors. Given the information revealed in this Position Paper, CINTAC recommends for Puerto Rico's energy stakeholders to perform a Pre-Feasibility Study to evaluate the viability of embarking in a SMR project.

At CINTAC, we strongly believe that given Puerto Rico's momentum for reinventing its energy infrastructure, the time has come to seriously consider studying the viability of an SMR for the island. SMR's technological advances are particularly tailored to island-type territories that for years have been looking for a self-sustainable and robust energy option. Today, there is a considerable number of Puerto Rican engineers and scientists working in the U.S. nuclear sector, which could lead to a strong grass roots movement aimed at better public acceptance in the island.

A FOAK SMR project coupled with Puerto Rico's human capital could secure Puerto Rico's leadership role in the international nuclear field. Puerto Rico's involvement will lead to global participation with both established and new nuclear energy powers. Puerto Rico will not only participate but could also position itself in a leadership position for next-generation reactors, a trend that is now beginning.

This paper concludes with a historical note: in 1952, the whole world witnessed how the then Honorable Luis Munoz Marin, Puerto Rico's first democratically elected governor, launched a massive economic revival for Puerto Rico, in collaboration with President John F. Kennedy, thus transforming an agricultural country into an industrialized one. At the time, emerging countries like Singapore were sending delegates to learn of the Puerto Rican experience [6]. Today, history can repeat itself, but this time, with Puerto Rico transforming from an industrial

country into a high-tech energy hub poised for global leadership. At CINTAC, we understand that Puerto Rico possesses the skilled labor and the momentum to launch a similar revival. Similar to Puerto Rico's involvement in the dawn of the U.S. nuclear commercial sector with the BONUS reactor, the U.S. nuclear industry today enjoys the support of Puerto Rican engineers and scientists who could pave the way for next generation reactors for the island. This could translate into an unprecedented manufacturing and export revival for Puerto Rico. At CINTAC, we encourage Puerto Rico's stakeholders to capitalize on what constitutes both the nuclear industry's and Puerto Rico's best asset – its people.

6 REFERENCES

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