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CARBON FREE ENERGY DEVELOPMENT AND THE ROLE OF SMALL MODULAR REACTORS: A REVIEW AND DECISION FRAMEWORK FOR DEPLOYMENT IN DEVELOPING COUNTRIES

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Abstract

Global energy demand is projected to continue to grow over the next two decades, especially in developing economies. An emerging energy technology with distinct advantages for growing economies is small modular nuclear reactors (SMRs). Their smaller size makes them suitable for areas with limited grid capacities and dispersed populations while enabling flexibility in generating capacity and fuel sources. They have the ability to pair well with renewable energy sources, the major source of increased energy capacity for many developing economies. Further advantages include their passive safety features lower capital requirements and reduced construction times. As a result, SMRs have potential for overcoming energy poverty issues for growing economies without increasing carbon emissions.

This study reviews the features and viability of SMRs to meet increasing energy capacity needs and develops a decision support framework to evaluate the market conditions for SMR deployment to emerging economies. The focus is on identifying countries best suited for domestic deployment of SMRs rather than vendor countries with ongoing or future SMR development programs for export. We begin by examining the characteristics of over two hundred countries and identifying those that satisfy several necessary economic, electrical grid capacity, and nuclear security conditions. Countries satisfying these necessary conditions are then evaluated using the Analytical Hierarchy Process (AHP) using criteria related to the economic and financial conditions, infrastructure and technological framework, and governmental policies within each country. The results find that countries with increasing GDP and energy demand that possess a robust infrastructure, energy production from high GHG sources, and governmental policies favorable to foreign investment are well-suited for future SMR deployment.

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Carbon Free Energy Development and the Role of Small Modular Reactors: A Review and Decision Framework for Deployment in Developing Countries

1. Introduction

Global energy demand is growing and projected to rise by more than fifty percent by 2040, with most of this growth occurring in developing economies [1], [2]. Recent projections forecast a ninety percent increase in energy use in countries outside the Organization for Economic Cooperation and Development (OECD) while energy use in OECD countries is expected to rise by only seventeen percent over this time frame [2]. The use of fossil fuels as the primary sources of energy production is projected to continue into the foreseeable future, especially in China and India which are projected to account for seventy-five percent of increased coal usage [3]. However, there are likely to be significant changes in the supply mix. Given that electricity production is the largest source of greenhouse gas (GHG) emissions globally, and especially in developing economies [4], [5], [6], increasing concerns with climate change will result in growing demand for low-carbon and renewable energy sources. This is already evident in the dramatic growth in energy production from renewable energy sources over the past several years with ongoing increases projected through 2040 [1], [7]. In addition to renewable energy sources such as solar, wind, hydroelectric, biomass, and geothermal, the growing demand for low-GHG energy sources will likely increase the demand for nuclear energy. A recent article in this journal by Amponsah et al [8] notes that, on a life-cycle basis, nuclear ranks second behind offshore wind as the lowest source of GHG emissions of electricity generation methods, with about one-third of the GHG emissions from hydroelectric, less than twenty percent of GHG emissions from solar and onshore wind production and less than five percent of GHG emissions from biomass and natural gas energy production. Indeed, the recently released International Energy Outlook states that renewables and nuclear power are the fastest growing sources of global energy [9].

Although the projected demand for new energy is greatest in developing countries, the use of large nuclear power plants (NPPs) is not often a viable option for many emerging economies given the large grid sizes, concentrated populations, and high capital costs required for NPPs. A new technology currently being developed with the potential to make significant contributions to meeting both future energy demands and carbon reduction targets is small modular nuclear reactors (SMR). As former U.S. Secretary of Energy Steven Chu stated in 2010:

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> "If we are serious about cutting carbon pollution, then nuclear power must be part of the solution. Countries such as China, South Korea and India have recognized this and are making investments in nuclear power that are driving demand for nuclear technologies. Our choice is clear: Develop these technologies today or import them tomorrow…..one of the most promising areas is small modular reactors (SMRs)." [10]

One question, raised in several recent articles in this journal and elsewhere, is the relationship between carbon reduction, through the increased use of renewable energy sources, and economic growth. Farhani and Shabaz [11], for example, find that reductions in CO_2 emissions may be associated with slower economic growth in some developing regions. Park and Hong [12] find similar results for South Korea. Halkos and Tzermes [13] find a negative correlation between electricity consumption from renewable sources and economic growth in developing countries, but they note that the relationship is positive for developed economies. At the same time, Terrapon-Pfaff [14] find access to energy to be a crucial element in reducing poverty in developing nations and that small-scale renewable energy projects can lead to sustainable economic growth in emerging economies.

In order to foster economic development while addressing carbon reduction concerns, the adoption of SMRs is a viable policy option. This emerging energy technology has distinct advantages for growing economies. They are able to pair with renewable energy sources, have significantly lower capital costs compared to large nuclear power plants (NPPs) or coal facilities, and are better able to match the lower energy outputs and less developed energy infrastructures of emerging economies. In addition, SMR designs incorporate high levels of passive safety systems and security features and offer the flexibility to support electrical generation as well as cogeneration, industrial heat, desalinization, and other uses particularly important to developing countries. SMRs are of particular interest to government officials, industry, international organizations, and environmental groups because of their potential impacts on economic growth, climate change mitigation, non-proliferation efforts, and waste disposal. In short, SMRs have significant potential for supplying a meaningful portion of rising energy demand over the coming decades, especially in emerging economies, while reducing the demand for fossil-fueled sources of energy production.

This study addresses the suitability of SMRs to meet part of the growing demand for carbon-free energy. It begins by reviewing the features of SMRs as described in a small, but growing, literature on this new technology. SMRs are less than one-third the size of conventional

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NPPs and are designed to be modular in construction, thus enabling them to be transported by truck, rail, or ship. Their modular components are assembled on-site. These features make them suitable for locations with smaller grid size and lower capacity needs than those where larger nuclear, coal, or other conventional power sources are appropriate. Similarly, their smaller size and modularity allow for increased flexibility to accommodate gradual increases in demand and require lower capital costs and construction times than large conventional power plants. SMR designs incorporate passive safety features that, along with their modularity, require fewer trained personnel for on-site deployment and operation. Further, most SMR designs have the ability to pair with renewable energy sources, such as wind and solar, where the ability to load-follow promotes both energy production and grid stability. In addition to these advantages for electricity production, some SMR designs are suitable where cogeneration and non-electrical industrial applications are needed.

Given these features and advantages, SMRs are well poised to meet part of the future demand for carbon-free energy production not only in developed economies but also, especially, in developing nations. However, very little research has taken place on the potential markets for this new technology.[1] Therefore, following the review of SMR designs and features, this study examines the economic, technological, energy, and political characteristics of nations in order to identify those countries where SMR adoption is most likely to be advantageous. This study begins by evaluating all two hundred fourteen countries listed by income classification by the World Bank [15] and uses a series of necessary conditions and ranking criteria to assess countries in terms of their suitability for SMR deployment. The result is the creation of a decision support framework for SMR adoption that provides a means for evaluating those countries best suited for meeting future energy demands and economic growth needs through domestic SMR deployment. By doing so, opportunities can be identified and policies developed for regulating, promoting, and financing the adoption of SMRs, especially in developing countries.

The perspective taken here is that of countries considering which energy production options should be part of their future energy development strategy rather than vendor countries considering the development of a domestic SMR manufacturing industry for export to global

[1] One published study is the 2011 report by the U.S. Department of Commerce [16]. The present study significantly extends this work both in the number of countries examined and the methodology employed.

markets. As a result, countries with ongoing SMR development initiatives may not rank highly in this study. Similarly, this study includes not only economic and infrastructure conditions but also includes governmental and regulatory measures often used by multilateral lending institutions.[2] As a result, some countries with an expressed interest in SMR industry development may not be highly ranked in terms of domestic deployment of SMRs. Further, because SMR commercialization is not expected to be widespread until at least the latter part of the decade, considerations of the current political or social attitudes toward nuclear development are not included.

2. SMR Features, Benefits, and Projected Deployment

Small and medium reactors are defined by the International Atomic Energy Agency (IAEA) as those producing less than 300 MWe, in contrast to conventional nuclear power plants that produce in excess of 700 MWe [17] and newly constructed NPPs that produce in excess of 1,500 MWe. While there are a number of designs and operating reactors globally that fall into the range of less than 300 MWe,[3] they do not have the characteristics associated with the new SMR designs. SMRs are differentiated not only by their size but also by their features including integrated design, modularity of manufacture and installation, passive safety and heat removal systems, underground containment, and reduced fuel requirements. SMRs currently being developed for commercial deployment within the next decade are Light Water (LW) reactors with development underway in several countries including the United States, Russia, South Korea, India, China, and Argentina [18], [19]. In order to promote US-based SMR deployment, the United States Department of Energy initiated a 6-year $452 million SMR Licensing Technical Support program and awarded financial support to two US designs and partnerships [20]. The first SMRs to reach the market will be used primarily for power generation. These and other design sets that may arrive later for commercial use, such as high temperature reactors, have additional potential for hybrid, manufacture, desalination, and process heat applications [21], [22], [23], [24], [25]. This section reviews the literature on the design features and

[2] As case in point is the World Bank's Ease of Doing Business Index, one of the criteria used in this study
[3] There are one hundred thirty-one operating reactors globally that fit this size range with a power output of 59 gigawatts electric [21].

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characteristics of SMRs and their advantages for developing economies in terms of meeting their projected increases in energy demand.

2.1 SMR Design Features

There are several design features that make SMRs substantially different from existing nuclear power plant designs. The modularity referred to in the name of small modular reactors refers to the fabrication of the major components of the power unit, including the reactor vessel, steam supply, and cooling system in centralized manufacturing facilities and shipped in component parts via rail, truck, or ship for on-site installation [26]. Modularity has several advantages, including standardization of both components and design and resulting economies of mass production. Significant economies of scale have long been attributed to the construction of large nuclear plants (see, for example, [27], [28], [29]). At first glance, scaling down from gigawatt-sized NPPs to small nuclear power plants would appear to result in a significant loss of scale economies and a concomitant increase in unit electric costs. However, as noted by Rosner and Goldberg, cost estimation for SMRs are significantly different than those of NPPs in that scale economies are gained "through 'economies of mass manufacturing' where economy is achieved in the capacity and throughput at a dedicated SMR manufacturing facility rather than in the size of the fully deployed reactor site" [30, p. 54]. Scale economies from modularization stem not only from mass manufacturing of component modules, but also from lessons learned during the manufacturing process that result in productivity and efficiency gains in successive modules [23]. Therefore, the initial loss of scale economies compared to NPPs are offset by the modularity effects of SMRs [31], [32] so that SMRs are economically competitive with conventional nuclear facilities as a result of mass manufacturing and learning economies. This has recently been described as the SMR's 'economy of multiples" counterbalancing the loss of 'economy of scale' [32].

While being comparable to NPPs in terms of estimated initial capital costs on a per-megawatt basis, SMRs have several unique characteristics that provide advantages compared to large nuclear and fossil fuel plants over a wide range of markets. They require lower capital costs on an absolute basis and, due to their modularity and factory manufacturing features, significantly reduce construction times. This reduction in capital requirements and risk is important for large utilities, but is especially important for developing economies where financing an NPP of at least five to seven billion dollars poses significant challenges. Further, SMRs are expected to have much shorter construction and installation times than NPPs. This results in reductions in both financing costs and risk levels. These advantages on the part of SMRs extend beyond the initial capital costs in that SMRs are subject to much lower fuel price sensitivity risk than large coal or natural gas facilities because fuel costs comprise a much lower share of operating costs than is the case for fossil fuel plants [33], [34]. As a result, relatively large increases in fuel costs for SMRs result in relatively small increases in operating costs. This contrasts with the findings of recent studies that establish the dramatic sensitivity of fuel prices on the cost of producing electricity for coal and natural gas plants. For example, Pratson, Haerer, and Patiño-Echeverri [35] demonstrate the changes in competitiveness of gas and coal plants to both fuel prices and environmental regulations. As a result, utilities in both advanced and developing countries can better diversify fuel portfolios to mitigate the risk of fuel cost volatility associated with coal and natural gas electrical generation facilities.

A key feature of SMRs is that modules can be used individually or in groups with the possibility of sequential installation, thereby providing the ability to match increases in demand over time. This provides significant advantages in terms of operational flexibility [36]. The smaller size of SMR modules and their ability of sequential deployment allows for improved coordination between grid capacity and plant generation capacity. In many developing economies, grid capacities are often small and demand is dispersed rather than concentrated as they are in large urban areas. Further, a lack of grid interconnectivity and infrastructure maturity may not allow for the construction of large generating facilities. In these cases of distributed energy markets and limited grid capacity, where the viability of large nuclear or coal generating plants is low, SMRs are capable of providing electric power to foster economic development.

In addition to the advantages associated with their small size and modular nature, SMRs have important design features related to passive safety, passive heat removal, design simplicity, and non-proliferation. Passive safety features enable SMRs to shut down automatically while remaining cool without outside water or power and without human intervention for a period of time. Passive heat removal enables the reactor to remain cool by allowing cooling to take place through gravity and evaporation and without the use of active pumps to circulate cooling fluid. Design simplicity is realized through a dramatic reduction in components compared to large power facilities and the incorporation of primary systems into a single reactor vessel [18]. SMRs will reduce proliferation risks by having the reactor vessel, associated components, and fuel storage below grade.

2.2 SMR Advantages for Developing Economies

As described above, the role of renewable energy sources is projected to increase over the next decades, with electrical generation from solar and wind technologies becoming increasingly important [1]. In addition to addressing concerns relating to carbon emissions, these technologies have advantages similar to SMR deployment in terms of smaller grid capacities and sequential increases in energy production. One disadvantage for electricity grid managers, with regard to these renewable technologies, is their variability in energy production. This is especially problematic when trying to meet base load energy demand. Utilities that incorporate large amounts of solar and wind sources need generation sources that can reliably ramp up or down during prolonged or incorrectly forecasted periods of high or low winds or sunlight. A key advantage of SMRs and multi-unit plants is their potential to balance fluctuating energy supply on the grid. This is done by increasing electric production during times of low generation from renewable sources, and to reduce production when conditions are optimal for wind or solar production. This is different from traditional nuclear load following as practiced in countries that currently allow it, such as Germany and France, in which nuclear reactor output is adjusted in a tight operational envelope to follow the demand load that is predictable by time of day [37], [38]. This load following characteristic of SMRs may be particularly important for developing countries where increased generating capacity from renewables is projected to increase more rapidly than in advanced economies. Given that this type of load following will require a new operational envelope for more rapid and sustained cycling, regulatory agencies will require substantial safety margins and more modeling before approval for operations [39].

The design and security features of SMRs, described above, are of particular relevance to developing economies and enable SMR operation in markets that would not be suitable for large nuclear or fossil fuel plants. For example, the water required for cooling is significantly reduced, thereby facilitating operations in locations other than near large rivers or bodies of water. In addition, the passive safety systems that allow SMRs to operate without external power or water sources and without human action for extended periods enable them to operate in locations where infrastructure and support systems are not well developed. Similarly, given the enhanced

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security features of SMR designs, the security requirements are much less than for NPPs because the nuclear reactor modules and safety systems are located underground rather than on the surface, making them much less susceptible to theft or disruption.

Finally, while large nuclear and fossil fuel plants are used almost exclusively to produce electricity, SMRs have potential additional applications well matched for developing economies. Principal among these are cogeneration applications, district heating applications, and desalination. The latter is particularly important in that SMRs can provide power for desalination in order to help alleviate water scarcity, especially in the developing world. This has been championed as a leading use for the emerging SMR industry. As noted by the International Atomic Energy Administration:

> Currently 2.3 billion people live in water-stressed areas and among them 1.7 billion live in water-scarce areas, where the water availability per person is less than 1000 m3/year. Statistics show that by 2025 the number of people suffering from water stress or scarcity could swell to 3.5 billion, with 2.4 expected to live in water-scarce regions. Water scarcity is a global issue, and every year new countries are affected by growing water problems [40, pp. 2-3].

Desalination is an energy intensive process and several studies demonstrate that the cogeneration of desalinated water and power using nuclear energy is an attractive option in developing countries and in grids where desalination plants can utilize off-peak power [41]. However, most of the more than 7,500 desalination units worldwide use fossil fuels but, according to the IAEA, a future desalination strategy based only on the use of fossil fuel systems is not desirable and that:

> … Small and Medium Reactors (SMRs) offer the largest potential as coupling options to nuclear desalination systems in developing countries. The development of innovative reactor concepts and fuel cycles with enhanced safety features as well as their attractive economics are expected to improve the public acceptance and further the prospects of nuclear desalination. [17, p. 4).

Other cogeneration applications for which SMRs are particularly suited are the provision of process heat for industrial applications and for district heating. The residual heat from electrical production, over a wide range of temperatures, is usable for a variety of industrial applications, including the production of glass, plastics, steel, synthetic fuels, and chemicals [22]. A recent study indicates that SMRs are well suited for many European industrial processes [42]. In developing economies, the modularity and relatively small size of SMRs offer advantages where

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process heat is needed but not in the quantities associated with large nuclear or fossil fuel plants. Where high temperatures are not needed for industrial applications, SMRs are amenable to district heating applications. Heat from cogeneration nuclear plants have been used for large scale district heating projects for space and water heating applications in several Baltic and Eastern European countries, including Bulgaria, the Czech Republic, Hungary, and others [43].

2.3 Future Deployment of SMRs

Previous projections of SMR deployment are limited. In 2010, a study by the Center for Advanced Energy Studies (CAES) assessed the global market potential for SMRs as part of a study to estimate the impacts on the U.S. economy stemming from the manufacturing and deployment of domestically produced SMRs through 2030 [22]. In addition, two studies for the International Atomic Energy Agency estimated SMR deployment over the same time period [44], [45]. Finally, the U.S. Department of Commerce (DOC) evaluated potential global markets for SMR deployment [16]. Unlike the other studies mentioned, the DOC study evaluated and ranked prospective markets for SMRs under current market conditions and did not project SMR deployment over a future time horizon. These studies are briefly summarized here.

The CAES study [22] used four scenarios for projected growth for SMRs through 2030. The scenarios were based on projections of growth in nuclear power capacity, SMR share of nuclear capacity growth, and the market penetration of U.S. SMR manufacturers. According to vendor estimates at the time of the study, SMRs were expected to arrive on the global market in the 2015-2020 timeframe, as opposed to the 2022-2025 timeframe estimated by the US Department of Energy [46]. The study used forecasts of nuclear capacity additions by the U.S. Energy Information Agency, the Electric Power Research Institute, and the IAEA to construct scenarios for SMR deployment over the 2010 - 2030 time horizon. Four scenarios for growth of SMR deployment globally were constructed: Low, Moderate, High, and Disruptive. In the Low Adoption scenario, SMRs were projected to supply 15.3 GW of U.S. and international power capacity additions. The Moderate, High and Disruptive scenarios projected 75.8 GW, 83.5 GW, and 206.7 GW of SMR capacity additions through 2030, respectively. The study assumed SMR additions for power generation only and assumed no added demand for additional applications such as load balancing, cogeneration, or desalination. Further, no assumptions about the specific SMR technology were adopted. The study made projections regarding the share of SMR deployment internationally – undifferentiated by country – in order to estimate the number of SMR units manufactured in the U.S. The study used these projections to estimate the economic impacts from SMR manufacturing and deployment. It did not incorporate an analysis of potential SMR markets globally.

Two recent studies were performed for the IAEA on the potential for future SMR deployment. In a presentation to the IAEA's Planning and Economic Studies Section, Kuznetsov [44] projected SMR deployment by constructing two scenarios. In the High adoption scenario, twenty-two countries were projected to adopt SMRs over the 2010 – 2030 time horizon, yielding a total electric capacity addition of 38 GW from SMR units. In the Low adoption scenario, ten countries were projected to adopt SMRs with a total electric capacity addition of 16.8 GW. This study did not incorporate an analysis for identifying the most likely global markets for SMRs. More recently, the IAEA presented an initial estimate of SMR deployment [45]. In this study, SMR producing countries were estimated to have 20.6 GW of increased nuclear capacity from SMRs. Only a relative small share, 4.68 GW, was projected to be deployed to smaller countries without existing nuclear experience. Specific market characteristics influencing SMR deployment were not addressed. This study assumed that the demand for SMRs stems from electric production only. A subsequent ongoing study identifies specific countries for manufacture and deployment, incorporating electricity balancing, cogeneration, and other uses [47].

3. Decision Framework for Global Deployment of SMRs

The previous section reviews some of the most important design features and applications of SMRs that enhance their potential for meeting part of the increased global demand for low-carbon energy production. While features such as enhanced safety and security, deployment flexibility, and decreased capital costs, construction times, and risk are applicable to both developed and developing countries, many of these characteristics are especially well-suited for developing countries. In this section, we evaluate the use of SMRs by developing a decision support framework for adopting SMRs, globally.

The only previous study to specifically analyze the suitability of SMRs in individual markets was performed by the U.S. Department of Commerce [16]. This study identified twenty-seven countries as markets of interest for new nuclear additions. Some countries have existing nuclear power capacity and others were identified as being at the preliminary stages of nuclear readiness. The countries were analyzed according to six criteria which were used to rank-order them in terms of SMR market potential. For four criteria - low population density, growth in carbon emissions, economic growth, and growth in energy consumption - countries were assigned a score of one to four depending on their quartile ranking in each criteria.[4] A country ranking in the upper quartile in growth in CO2 emissions, for example, would receive a score of four for this characteristic. The remaining two characteristics are scored according to whether a country is an energy importer and whether a country has existing nuclear capacity. A net importer of electricity is given a score of one, while a net exporter is given a score of zero. Similarly, a country with existing nuclear capacity is given a score of one, while the absence of existing nuclear capacity yields a zero score. The DOC study then calculated the total scores for all twenty-seven countries and determined that those with the highest total scores are ideal candidates for SMR deployment.

In assessing the available studies on potential SMR deployment, the authors of the current study determined that a more comprehensive and systematic approach was needed to more fully determine potential SMR markets. The following section sets forth a decision framework for identifying potential markets for domestic SMR installation. It should first be noted that there are several key differences in the approach taken in the DOC study [16] and the present study. First, countries were not pre-selected for inclusion in the present analysis. As described above, the DOC study identified twenty-seven countries of interest to include in the study. In contrast, the aim of the present study is to comprehensively review all potential countries, beginning with an initial sample of two hundred fourteen countries, and utilizes more extensive quantitative measures. We begin by first identifying five necessary conditions that first must be met before countries are further analyzed. For countries meeting these conditions, this study then considers fifteen criteria in the areas of financial and economic, technology and infrastructure, and government policy and regulatory conditions. Quantitative measures are used to evaluate countries across each criterion using the Analytic Hierarchy Process with empirical data from the World Bank, the U.S. Energy Information Agency, and other data sources. The necessary conditions, the criteria used, and the analytic process are described in more detail in

[4] Countries were rank ordered in each of the four categories and given a score of one to four depending on which quartile they were classified.

the following subsections.

3.1 Necessary Conditions

There are five necessary conditions for a country to be considered and ranked for possible SMR deployment. First, the Gross Domestic Product (GDP) must be sufficiently large. For countries whose economies are too small, the necessary demand and financial conditions necessary for utilizing SMRs are likely to be insufficient. The country with the lowest GDP of all countries with a nuclear program under development is Armenia, with a GDP of $16.7 billion in 2010, measured in Purchasing Power Parity (PPP). Thus, countries must have a GDP of more than $16 billion (PPP) to be included in the rankings.[5] Similarly, a country must have a sufficient level of per capita income, measured by per capita GDP (PPP). The cutoff country for this measure is Bangladesh, with a per capita GDP of $1,649 (PPP) in 2010, the lowest of any country with a nuclear power development program. For countries to be included in the rankings for this study, 2010 per capita GDP must exceed $1,600 (PPP). The third necessary condition concerns the size of the electric grid in a country. The IAEA issued guidelines for the size of electric generation units relative to total grid size [49]. Under these guidelines, the SMR unit size should be less than ten percent of total grid capacity. For a smaller 150 MWe SMR, the electric grid capacity should exceed 1.5 GW. Thus, the necessary condition for a country to be included in the rankings is Total Electrical Grid Capacity exceeding 1.5 GW.[6] The final necessary condition is that a country must be a signatory to the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) or a member of the IAEA. Signatories to the NPT agree to undertake safeguards to prevent the spread of nuclear weapons. Annual update reports on membership are issued by the United Nations [51]. As of 2013, a total of one hundred ninety countries have joined the treaty.[7] Similarly, a country must be a member of the IAEA in order to be considered a viable SMR market. The IAEA is an independent intergovernmental organization that conducts inspections to verify that Member States comply with their commitments under the Non-Proliferation Treaty and reports to the UN General Assembly and the UN Security Council.[8]

[5] Data source: World Bank DataBank [48].
[6] Data source: U.S. Energy Information Administration [50]
[7] The treaty text and status of adherence are available from the United Nations at [51].
[8] Data source: Member States of the IAEA [52].

Countries that have met the necessary conditions are then evaluated according to several criteria concerning financial, economic, technological, and infrastructure conditions, and government policy and business setting. The criteria and associated data source are described below.

3.2 Evaluative Criteria

Fifteen criteria were identified for which data are available from well-respected sources such as the World Bank, U.S. Energy Information Agency, the International Atomic Energy Agency, and others. The criteria were analyzed to evaluate countries in terms of their suitability for domestic SMR deployment. The method used here is the Analytic Hierarchy Process (AHP), described in the following subsection. For descriptive purposes, it is useful to consider three general categories of criteria, described below.[9]

Financial and Economic Criteria. There are five criteria that evaluate a country's economic and financial conditions. The first of these measures countries according to their GDP (PPP), as described above. This criterion captures the notion that larger economies have larger power requirements, are more likely to require multiple SMRs, and are better able to finance their purchase. Second, the previously described criterion of Per Capita GDP is used as a measure of economic activity and addresses the corresponding rise in energy demand with higher levels of income. The third criterion is the Rate of Real GDP growth. This addresses the issue that more rapidly growing economies are more likely to have a commensurate increase in demand for new energy capacity.[10] The fourth criterion is International Trade as a Percentage of GDP. This criterion serves as a proxy for the openness of a country's economy and the degree to which it is integrated into the global economy. As noted by the OECD, small countries are generally more integrated, as indicated by a higher share of international trade relative to GDP.[11] The fifth criterion is the Growth Rate of Energy Consumption. This measure indicates the relative change in demand for electricity. Countries with higher rates of energy consumption are more likely to need increased access to energy and are, therefore, more likely to be receptive to new energy sources such as SMRs. This indicator was constructed here by calculating the year-

[9] In the analysis using AHP, the criteria were not grouped into categories or sublevels but evaluated individually. The comparison matrix with weight calculations and ranked eigenvalues were determined in the AHP analysis.
[10] Data source: World Bank Databank, GDP Growth [53].
[11] Data source: OECD, Trade as a Percentage of GDP [54].

to-year growth rates of Total Primary Energy Consumption (quadrillion BTU) from 2002 to 2009 and averaging those growth rates over that period.[12]

Electric Grid, Technology, and Infrastructure Criteria. In addition to the above criteria used to measure economic and financial conditions, there are five criteria that evaluate the size and type of a country's electric grid and the state of technology and infrastructure. Regarding grid characteristics, given the generating unit size restriction imposed by grid size limitation [49], larger electric grids are capable of integrating more SMRs into their system. However, it is also the case that more decentralized electric generating capacity systems are better suited to SMR deployment than centralized grids. To evaluate these considerations, we begin with the criterion Total Electric Grid Capacity, one of the necessary conditions described above. Grids smaller than 1.5 GW are not considered to be capable of accepting even a relatively small SMP generating 150 MWe. Once that threshold is passed, larger grids indicate an increased ability to accept SMRs. At the same time, given the characteristics of SMRs, systems with a more dispersed electric generating capacity are more likely target markets than more centralized systems. The criterion Percentage of Population in Rural Areas is used here to measure market dispersion. It is calculated using the difference between total population and urban population in a country as a percentage of the total population.[13] Similarly, a country with a dispersed population with limited access to electricity is more likely to adopt smaller generating units, especially those with the capability of working in concert with renewable energy sources. Further, areas with limited access to electricity are likely to have needs for the additional applications that SMRs provide, such as co-generation, desalination, and district heating, as described above. Thus, countries are evaluated using the criterion of Access to Electricity,[14] with the country ranking having an inverse relationship to the underlying data.

In terms of the suitability of a country's technological conditions for SMR utilization, we specify two criteria, Infrastructure Ranking and Technology Readiness. The Infrastructure Ranking[15] criterion measures a country's infrastructure on the basis of its transportation, communications, and electrical distribution networks. The Technology Readiness criterion

[12] Data Source: US Energy Information Administration, Total Primary Energy Consumption [55]. The years 2002 through 2009 were chosen due to the completeness of the data compared to more recent years.
[13] Data Source: World Bank DataBank, Rural Population (% of total population) [56].
[14] Data source: World Bank DataBank, Access to Electricity [57].
[15] Data Source: World Economic Forum, Global Competitiveness Report, Infrastructure Ranking [58].

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measures the ability of an economy to adopt existing technologies that enhance productivity.[16] For these two criteria, countries are ranked in descending order, with one being the highest ranking. Thus, as with the criterion of Access to Energy, a country's score has an inverse relationship to the underlying ranking for these two criteria used in this study.

Government Policy, Regulatory Framework, and Emission Reduction Criteria. It is also important to consider the regulatory and institutional framework in a country. To this end, this study uses two criteria, the Doing Business Index and the Corruption Perceptions Index. In the Doing Business Index, reported by the World Bank,[17] countries are scored according to conduciveness of the regulatory environment to starting and operating a business in each country. As stated by the World Bank [60], this index averages the country's percentile rankings on ten topics, giving equal weight to each topic, including: the ease of starting a business, obtaining construction permits, protecting investors, obtaining credit, and enforcing contracts. Economies are ranked with a higher ranking indicating greater ease of doing business. The second criterion used here is the Corruption Perceptions Index.[18] In this index, countries are ranked based on how corrupt a country's public sector is perceived to be on the basis of surveys and assessments by both national and international institutions. With more corrupt nations receiving higher scores for this criterion, there is an inverse relationship between a country's score for use in this study and the underlying data.

Finally, it is important to assess the incentives for a country to adopt SMRs and the risks relating to energy security and climate change from continued fossil fuel and import dependence. Three criteria are used here; Oil, Gas, and Coal as a Percent of Total Electricity Capacity, Energy Imports as a Percent of Energy Use, and Per Capita CO2 Emissions. The first of these addresses the issue that countries heavily reliant on high carbon sources of electricity production may be more likely to implement fuel-switching, or at least increase their electricity production using low carbon sources, because of the long-term need to address climate change and pollutants. This could be renewables, such as wind and solar, as well as nuclear. Given that SMRs are both low-carbon emission sources and have energy balancing capability to complement renewable sources, a criterion measuring the reliance on high-carbon fuels is important. The measure used in this

[16] Data Source: World Economic Forum, Global Competitiveness Report, Technology Readiness [45].
[17] Data source: World Bank, International Finance Corporation, Doing Business Index [60].
[18] Data Source: Transparency International, Corruption Perceptions Index, 2012 [61].

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study is Oil, Gas, and Coal as a Percent of Total Electricity Capacity.[19] This criterion measures the following inputs used to generate electricity: oil (crude oil and petroleum products), natural gas (excluding natural gas liquids), and coal (both primary and derived coal fuels). The criterion Energy Imports as a Percent of Energy Use[20] addresses the notion that countries that import a large percentage of their energy are more likely to be interested in developing domestic energy production and are thereby more likely to be potential markets for SMRs. In this measure, net energy imports are estimated as the difference between energy use and energy production.[21] A country with a positive value uses more energy than it produces and is, therefore, a net energy importer. In the present study, countries are scored according to their percentage value. Countries that are large energy importers receive high positive percentage values and are ranked in the upper quartiles. Countries that are large energy exporters will receive large negative scores and be ranked in the lower quartiles. The final criterion in this category assesses a country's motivation for adopting low-carbon emissions energy production by using the measure of Per Capita CO_2 emissions.[22] Countries with high levels of greenhouse gas emissions are deemed more likely to be amenable to SMR adoption.

4. Analysis and Results

This study utilizes the Analytic Hierarchy Process (AHP), a Multi-criteria Analysis (MCA) method used for decision-making involving several criteria. The following subsections describes the analytical process used to rank qualifying countries in terms of their likely suitability for domestic SMR deployment and the results of the analysis. The remaining subsections contain a comparative analysis of the other study of country rankings of SMR market potential, performed by the U.S. Department of Commerce [16], followed by concluding remarks.

4.1 Analysis

[19] Data Source: International Energy Agency, Energy Balances of Non-OECD Countries [62], Energy Statistics of Non-OECD Countries [63], Energy Statistics of OECD Countries [64] and Energy Balances of OECD Countries [65]. This criterion is based on 2009 data due to its being more complete than subsequent years.
[20] Data Source: World Bank, DataBank, Energy Imports, net (% of energy use) [66].
[21] Both of these measures are given in oil equivalents.
[22] Data Source: World Bank DataBank, CO2 emissions (metric tons per capita) [67].

The AHP method was developed by Saaty [68] and has been used extensively in research on decision-making involving energy development, including project evaluation, facility siting, and energy source selection (see recent overviews in this journal by Stein [69], Wang, et al [70], and Kurka and Blackwood [71] and application research in this journal by Lee, et al [72], and Heo, et al [73]). The AHP method begins by identifying the criteria relevant to the decision at hand. The criteria, criteria symbols used in the AHP analysis, and data sources are listed in Table One below.

Table One: Evaluative Criteria

Financial and Economic Criteria	
Gross Domestic Product (Purchasing Power Parity basis). Symbol: GDP Data source: World Bank DataBank. GDP, PPP (Current international $) 2009-2013	International Trade as a Percentage of GDP Symbol: ITPGDP Data source: Organization for Economic Cooperation and Development. Trade as a percentage of GDP 2010
Per Capita Gross Domestic Product (Purchasing Power Parity basis). Symbol: PCGDP Data source: World Bank DataBank. GDP, PPP (Current international $) 2009-2013	Growth Rate of Energy Consumption. Symbol: GREC Data Source: US Energy Information Administration, Total Primary Energy Consumption 2010
Rate of Real GDP Growth. Symbol: RGDPG Data source: World Bank Data Bank, GDP Growth (annual %) 2013	
Electric Grid, Technology, and Infrastructure Criteria	
Total Electric Grid Capacity Symbol: TRGC Data source: U.S. Energy Information Administration. International Energy Statistics 2012	Infrastructure Ranking Symbol: IR Data source: World Economic Forum, Global Competitiveness Report, Infrastructure Ranking 2012
Percentage of Population in Rural Areas Symbol: PPRA Data source: World Bank DataBank. Rural Population (% of total population) 2011	Technology Readiness Symbol: TR Data source: World Economic Forum, Global Competitiveness Report, Technology Readiness 2012
Access to Electricity Symbol: AE Data source: World Bank DataBank. Access to	

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Electricity 2009	
Government Policy, Regulatory Framework, and Emission Reduction Criteria	
Doing Business Index Symbol: DBI Data source: World Bank, International Finance Corporation, Doing Business Index 2013	Oil, Gas and Coal as a Percentage of Total Electricity Capacity Symbol: OGC Data sources: International Energy Agency. Energy Balances of Non-OECD Countries 2012 International Energy Agency. Energy Statistics of Non-OECD Countries, 2012 International Energy Agency. Energy Balances of OECD Countries 2012 International Energy Agency. Energy Statistics of OECD Countries, 2012
Corruption Perceptions Index Symbol: CPI Data source: Transparency International, Corruption Perceptions Index, 2012	Energy Imports as a Percent of Energy Use Symbol: EIP Data source: World Bank, DataBank, Energy Imports, net (% of energy use), 2012
CO_2 Emissions Per Capita Symbol: CO2 Data source: World Bank DataBank, CO_2 emissions (metric tons per capita), 2012	

After the identification of criteria, AHP involves making pair-wise comparisons of each element relevant to a decision-making problem. By so doing, the relative weights of each criterion are estimated in order to arrange the criteria into a hierarchical structure. AHP then synthesizes the results of the structure and the values of each criterion to determine the overall ranking of possible outcomes. For the criteria in this study, the data are quantitative in nature. Therefore, the calculation of the relative weights for each criterion is straightforward relative to other studies using AHP where criteria are more qualitative in nature and AHP methodology has been adapted using fuzzy set theory (see, for example, Heo, et al [73] and van Laarhoven and Pedrycz [74]). The pair-wise comparisons for the fifteen criteria are assessed using a 15 x 15 matrix which is then normalized to determine the relative weight for each criterion. The Country Score is then determined by summing the products of each criterion times its weight, as shown by:

Score = GDP (wt_1) + PCGDP (PCGDP wt_2) + RGDPG (wt_3) + ITPGDP (wt_4) + GREC (wt_5) + TRGC (wt_6) + PPRA (wt_7) + AE (wt_8) + IR (wt_9) + TR (wt_{10}) + DBI (wt_{11}) + CPI (wt_{12}) + CO2 (wt_{13}) + OGC (wt_{14}) + EIP (wt_{15})

Where:

Score = Country AHP score for SMR suitability

Wt_i = Weight for Criterion i, determined by AHP

This analysis utilized AHP analysis was carried out using the Analytic Hierarchy Process Template developed by SCB Associates [75]. This software allows the user to enter data for each criterion directly from spreadsheets. This was useful for this study in that the data used are available to download into spreadsheets and either used directly or calculated (for example, in the cases of GREC and OEC). After entering the data, the SCB software makes pair-wise comparisons and calculates ratio scale priorities and normalizes the matrix in order to weight the criteria and calculate the total score for each country.

4.2 Results

In order to be ranked according to the criteria described above, countries first had to meet the necessary conditions of having the requisite levels of GDP, GDP per capita, grid capacity, and non-proliferation conditions. This study began with a sample of two hundred fourteen countries for which data on all the criteria could be obtained. Of the initial two hundred fourteen countries, one hundred seventeen were eliminated for failing to meet the necessary conditions. Nearly all of the countries that failed to meet the necessary conditions failed on the basis of two or more conditions. For example, many small countries with grid capacities less than the minimum requirement of 1.5 GW also failed to meet the minimum GDP requirement of $16 billion (PPP). For many countries, economic conditions are not sufficient to provide viable markets for SMRs.

The World Bank classification of countries by income provides a useful framework for characterizing market viability. The World Bank classifies all countries with populations exceeding thirty thousand according to income. The two hundred fourteen counties classified by the World Bank fall into four principal income groups: low income ($1,025 or less), lower middle income ($1,026 - $4,035), upper middle income ($4,036 - $12,475), and high income ($12,476 or more). The measure of income used in this classification system is Gross National Income (GNI) per capita, adjusted to reduce the impact of exchange rate fluctuations across countries by using the World Bank Atlas Method conversion methodology [5]. It should be noted that, while the World Bank classification is based on GNI, this study uses GDP as a measure of income. Exchange rate fluctuations were accounted for using the purchasing power parity (PPP) measure for both GDP and GDP per capita.

Many of the countries that failed to meet the necessary conditions are those classified as low-income and low middle-income countries by the World Bank. Of the thirty-six countries in this sample classified as low income, Bangladesh and Kenya were the only two that met all necessary conditions. Of the remaining low-income countries, most lacked both sufficient grid capacity and the economic conditions, as measured by GDP and per capita GDP, to be considered for further study.[23] The results are somewhat similar for countries in the World Bank lower middle-income category. Twenty-two of the fifty-three countries in the sample with this classification failed to meet the necessary conditions, with most failing to meet both the grid capacity and GDP conditions. Thus, a large majority of countries classified by the World Bank as low-income and lower middle-income nations failed to meet the necessary conditions to be considered for further study.

Countries classified by the World Bank as being in higher income groups were more likely to meet the necessary conditions. For the upper middle-income countries, thirty-three of the fifty-four nations in this group met the necessary conditions. Of the ones failing to meet the necessary conditions, some had sufficient economic conditions, based on GDP and per capita GDP, but lacked sufficient electric grid capacity. These include Botswana, Grenada, and Gabon. Several others, including Antigua, Dominica, Montenegro, Namibia, Saint Lucia, and the Seychelles, do not qualify because of their small size, as measured by both grid capacity and GDP. One of the upper middle-income countries, Turkmenistan, met all of the necessary conditions except membership in the IAEA and was, therefore, not considered further. Of the high income, non-OECD nations, many were rejected because of their small size. Several are small island nations such as the Bahamas, Cayman Islands, Grenadines, and the Seychelles. These, along with several other countries in this income group, did not meet grid capacity and GDP requirements. Other non-island nations in these income groups that did meet the conditions necessary to be ranked in this study include Bahrain, Croatia, Oman, and Singapore.

[23] Both Ethiopia and Congo had sufficient grid capacity, but failed on the basis of GDP per capita.

For the thirty countries classified by the World Bank as high-income OECD nations, all but two met the conditions necessary for further evaluation in this study. Iceland is included in the World Bank's classification because of its relatively high per capita GNI. However, its GDP of $11.3 billion (PPP) was not large enough to meet the necessary condition and is, therefore, not considered a viable market for SMRs. The other country classified as a high-income, OECD nation that was not included in the rankings is Israel, which is a member of the IAEA and meets all of the economic and infrastructure conditions but is not a signatory to the Non-Proliferation Treaty.

For the countries that met the necessary conditions, their rankings are based on their total score as calculated in the AHP process described above. The overall findings from the AHP analysis are listed in Tables Two and Three, with the following conditions characterizing the countries with the highest potential to use SMRs: high per capita income, growing economies, relatively dispersed populations, a reliance on high carbon emission sources of energy, and sufficient grid capacity and infrastructure to accommodate SMRs, and whose policies accommodate new business ventures and exhibit a low degree of corruption. Table Two shows the rankings for the top two quartiles of the evaluated countries and Table Three shows the rankings for the third and fourth quartiles.

Table Two: Country Rankings for First and Second Quartiles

Rank	**Country**	**AHP Score**		Rank	**Country**	**AHP Score**
1	Singapore	2.122023041		26	United Kingdom	1.632284483
2	Qatar	1.918976363		27	Denmark	1.632231696
3	Luxembourg	1.896379938		28	Sweden	1.600693732
4	Ireland	1.85890528		29	Australia	1.59745136
5	Korea, Rep.	1.846920284		30	Czech Republic	1.589776492
6	Netherlands	1.846780032		31	Poland	1.58762984
7	United Arab Emirates	1.816532153		32	Canada	1.582118418
8	Oman	1.808153836		33	Japan	1.570435159
9	Bahrain	1.78644343		34	South Africa	1.547095236
10	Malaysia	1.786076251		35	Kuwait	1.546454514
11	Saudi Arabia	1.757817934		36	Jordan	1.543542046

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12	Israel	1.739603669		37	Slovak Republic	1.538753223
13	Germany	1.718405973		38	China	1.526857031
14	Belgium	1.703337493		39	Portugal	1.525018044
15	Austria	1.701135726		40	Spain	1.523970929
16	Estonia	1.697145378		41	Hungary	1.506969963
17	Trinidad and Tobago	1.694735429		42	Italy	1.482059592
18	Thailand	1.688272139		43	Turkey	1.475742075
19	Switzerland	1.68354823		44	Morocco	1.472898622
20	Cyprus	1.680891089		45	New Zealand	1.449576484
21	Finland	1.680167827		46	France	1.44535144
22	Chile	1.668499171		47	Lithuania	1.435091543
23	Slovenia	1.654678006		48	Norway	1.421256908
24	Panama	1.647744628		49	Macedonia, FYR	1.41697802
25	United States	1.647545472		50	Costa Rica	1.416278322

Table Three: Country Rankings for Third and Fourth Quartiles

Rank	**Country**	**AHP Score**		**Rank**	**Country**	**AHP Score**
51	Sri Lanka	1.409604915		76	Albania	1.215280724
52	Greece	1.406331117		77	Lebanon	1.20611127
53	Uruguay	1.400430153		78	Colombia	1.199190504
54	Vietnam	1.395948362		79	Bulgaria	1.195502791
55	Tunisia	1.385291279		80	Bosnia, Herzegovina	1.189607502
56	Peru	1.378795854		81	Pakistan	1.182656731
57	Dominican Republic	1.374609304		82	Brazil	1.169498052
58	Latvia	1.370034525		83	Syrian Arab Republic	1.155929626
59	Croatia	1.368205719		84	Bolivia	1.141915042
60	Ghana	1.352799915		85	Nigeria	1.138503495
61	Belarus	1.352458835		86	Serbia	1.136871855
62	India	1.351359255		87	Russian Federation	1.133825446
63	Indonesia	1.333734484		88	Armenia	1.124537245
64	Georgia	1.332721882		89	Romania	1.112661585
65	Kazakhstan	1.323748457		90	Ecuador	1.092704339
66	Mexico	1.307153598		91	Algeria	1.090711893
67	Bangladesh	1.285098981		92	Sudan	1.079883252

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68	Honduras	1.280988076		93	Paraguay	1.078437893
69	Guatemala	1.278294403		94	Ukraine	0.972186101
70	Egypt, Arab Rep.	1.276127937		95	Iraq	0.966842784
71	Turkmenistan	1.254712965		96	Uzbekistan	0.939889469
72	Argentina	1.253410995		97	Venezuela, RB	0.754819582
73	Philippines	1.249527533				
74	Azerbaijan	1.247899425				
75	Kenya	1.215786516				

4.3 Comparative Findings

This study extends the research performed in 2011 by the U.S. Department of Commerce in terms of number of countries evaluated and breadth of the criteria considered.[24] To a large extent, the results of the present study are consistent with those from the DOC study. None of the twenty-seven countries considered by the DOC study were eliminated in this study for failing to meet the necessary conditions specified here. Further, many of the countries ranked highly in the DOC study are also ranked highly here. Much of the difference in the two studies can be attributed to the fact that the present study ranks seventy additional countries that were not included in the DOC study and, rather than scoring countries by their quartile ranking in each criterion, the present study uses a much more quantitative multi-criteria decision analysis.

It is important to note that several factors were considered in this study that were omitted from the DOC study. While economic growth was a factor in that study, GDP and per capita GDP were not considered. Further, several additional conditions pertaining to the existing framework conducive to SMR adoption are considered here. These include criteria measuring electric capacity, infrastructure, and technological readiness. Further, it is important to consider domestic drivers for countries to adopt non-GHG sources of electric generation. In the DOC study, this was addressed by a measure of total CO2 emissions. In the present study, CO2 emissions were also measured but were adjusted and ranked on a per-capita basis. This proved to be important in several cases. The Netherlands, for example, was ranked low for total CO2 emissions by the DOC study yet ranked in the upper quartile in the present study. Motivation to

[24] As discussed earlier, the studies by Solan et al. [22], Kuznetsov [44], and the IAEA [21] projected global demand, but did not address potential markets for SMRs. As a result, they are not addressed further here.

adopt new energy production in the present study was also measured by the percentage of total electric production from oil, gas, and coal sources.

One of the major differences in the two studies is the inclusion of business climate and governmental policy considerations in the present study. By including these considerations, the present study accounts for the potential difficulty in SMR market penetration in countries that express strong interest in SMRs, but in the end may find it difficult to secure financing or conclude deals such as joint ventures due to their business and policy environment. Their inclusion resulted in a relative reduction in ranking for several countries in this study compared to the DOC study. At the same time, some countries ranked highly in the present study but received relatively low rankings in the DOC study. The principal reasons are the inclusion of economic growth, energy imports, and energy consumption, the adjustment for CO2 emissions on a per capita basis.

4.4 Conclusions

The potential for nuclear power to provide an increasing share of future energy growth without increasing greenhouse gas emissions is causing countries to consider the role of nuclear power in meeting future energy needs. For some markets, where demand for electricity is concentrated and where electric grids have sufficient capacity, large energy production facilities, such as large NPPs, may be an attractive option. However, SMRs have distinct advantages in markets where electricity demand is more dispersed, grid capacities are smaller, access to capital is limited, load following to enable renewable energy production is important, and applications in addition to electrical generation are desirable.

SMRs are well positioned to help meet the projected increase in global energy demand over the coming decades, with initial deployment likely to begin within the next decade. The methodology used in this study is suitable for the identification of potential markets for SMR deployment from the perspective of multilateral lending institutions seeking to facilitate the deployment of this technology. As such, the focus is on countries amenable to the deployment and installation of SMRs. There are several countries with ongoing SMR development programs, including Argentina, China, France, India, Japan, the Republic of Korea, the Russian Federation, and the United States, with over twenty reactor designs in development. Although some domestic deployment is likely in these countries, several are well positioned to be exporters of SMRs by being first movers in the development of this technology. The objective criteria in this study are designed to identify likely markets after commercial manufacturing and deployment is underway. As a result, countries more attuned to exporting SMR technology rather than domestic deployment may rank lower than countries with no stated plans or initiatives for SMR development.

The results indicate that developing countries with relatively high-income levels, a robust infrastructure, energy production from high GHG sources, and governmental policies favorable to business are likely markets for SMRs. While several most-developed countries are ranked in the top two quartiles, in large part due to their high scores for both total GDP and per capita GDP, approximately half of the top ranked countries are developing nations. These countries have sufficient levels of income as well as infrastructure, technological readiness, a dispersed population, and a need for domestic sources of energy production. As a result, these developing countries are well poised to adopt SMRs. Several other developing countries with otherwise positive characteristics were either eliminated or downgraded on the basis of income, as measured by GDP and per capita GDP. For these countries, there is a role for international aid and lending institutions to increase capital availability so that economic growth can be fostered without contributing to global climate change. The methodology developed in this research will be useful not only for these multilateral development institutions but also for individual countries assess the role of SMRs in their energy development policies.

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