Possible Expansion of Nuclear Energy:
An assessment of national capacities and imperatives for nuclear power implementation in non-nuclear countries

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Abstract

Growing concerns over energy security and climate change have lead to an increasing interest in nuclear power development. The International Atomic Energy Agency reports that, as of July 2009, there were 52 countries interested in building their first nuclear power plant. This paper characterizes and evaluates these "Newcomer NP Countries" in terms of their financial, institutional, and technical capacity to develop nuclear power, as well as their imperatives to do so. It does so by reviewing historical data to identify factors which facilitated the development of nuclear energy in countries with existing nuclear power programs and benchmarking the Newcomer NP Countries against these results. The study finds that historically, nuclear energy programs were generally preceded by periods of high growth in electricity consumption. It finds that the capacities of Newcomer NP Countries are, in general much lower than the capacities of Existing NP Countries at the time of development. It identifies 10 Newcomer NP Countries which are the most likely to deploy nuclear energy, 10 Countries where nuclear energy is highly uncertain due to their political instability, 14 Countries where pursuing nuclear energy is possible with joint implementation or strong government support, and 18 countries where development is unlikely.

1. Introduction

Interest in nuclear power has recently reemerged with rising concerns over energy security and climate change. Unlike oil and gas, proven uranium reserves are abundant: even in the face of large nuclear expansion, they are estimated to last at least a century and most likely well beyond (Macfarlane & Miller, 2007; NEA, 2008a). Uranium is also more geographically distributed with a large portion located in OECD or other developed countries (NEA, 2008a). In addition, nuclear energy offers greater protection from commodity price fluctuations. In 2008, the International Atomic Energy Agency (IAEA) reported that a doubling of uranium prices resulted in a 5-10% increase in generating cost while a doubling for coal and gas led to a 35-45% and 70-80% increase respectively (IAEA, 2008a). Nuclear power has also been proposed as one strategy to address climate change (IEA, 2008; Pacala & Socolow, 2004; Sims et al., 2007) since it offers significantly lower GHG emissions than conventional thermal power plants.[1]

The increase in interest in nuclear power has been dubbed a "nuclear renaissance" as many governments have recently expressed interest in reviving or starting their national nuclear power programs (Adamantiades & Kessides, 2009; Nuttall, 2004; Sauga, 2008; Wolfe, 2007).[2] The IAEA reports that 52 countries have contacted it for help in starting a nuclear power program (Rogner, 2009). These countries, referred to as Newcomer NP Countries, vary greatly in economic and social development. As Figure 1 shows, they range from the high-income EU-member states to low-income Sub-Saharan African countries. The capability of some of these countries to deal with significant financial, institutional, and technical challenges associated with a new nuclear energy program is not at all certain.

[1] Life-cycle assessments of nuclear energy indicate that it emits between <1 and 50% of carbon dioxide (CO_2) per kWh when compared to natural gas and <1 and 20% of CO_2 per kWh when compared to coal-fired power plants (Sovacool, 2008). However, there are skeptics to the climate-protection potential of nuclear power particularly when the emissions potential is considered on cost basis (Lovins, Sheikh, & Markevich, 2009).

[2] The "Nuclear Renaissance" also has several skeptics both in terms of the ability of nuclear power to address climate change (Lovins et al., 2009) and the veracity of the so-called "Nuclear Renaissance" (Parenti, 2008; Schneider, 2008).

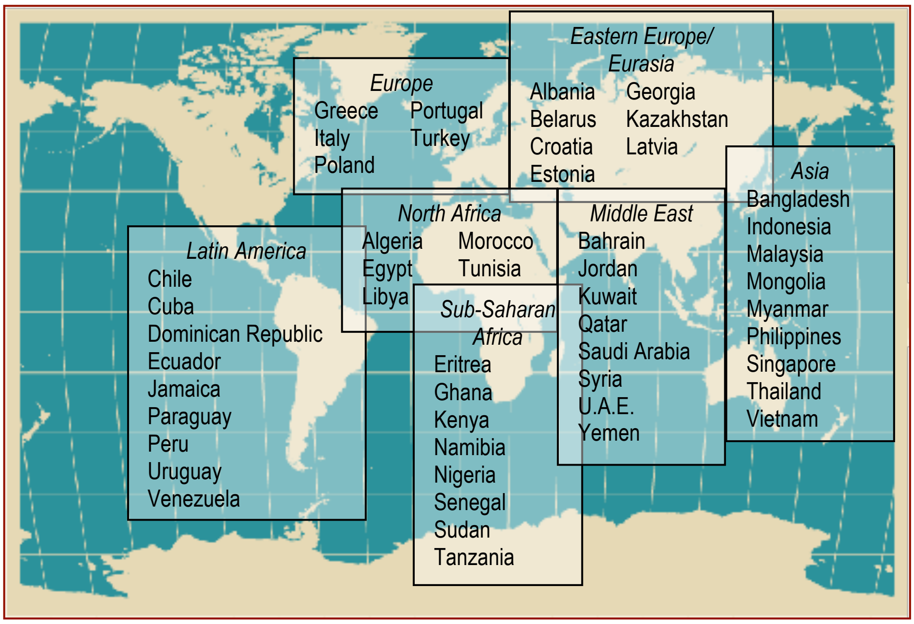

Figure 1 Nuclear Newcomer NP Countries
The countries which have expressed interest in acquiring their first nuclear power plant (Rogner, 2009).

Building even a single Nuclear Power Plant (NPP) requires significant financial, technical and institutional resources. F**inancial** investment required to construct a nuclear power plant (NPP) is approximately USD4,000/kWe (Du & J. E. Parsons, 2009; Harding, 2007). Given that commercial NPPs generally have a capacity of at least 1 GW (IAEA, 2007a), constructing a standard NPP typically costs about USD4 billion.[3] Given that the IAEA does not recommend a single power plant to constitute more than then 5 to 10% of an electricity grid (IAEA, 2007a), the **technical** requirement for nuclear power implementation is an electricity grid bigger than 10 GW or international grid connections allowing for the sale of excess electricity to neighboring countries. Finally, a country must have a sufficient **institutional** capacity to safely manage the nuclear power program, gather international support, and attract, where necessary, private investments.

In spite of the emerging interest in the expansion of nuclear energy and the apprehension about the associated proliferation and safety risks, no study has systematically evaluated the Newcomer NP Countries in terms of their capacities and imperatives (motivations) to develop nuclear power. The barriers and driving forcers for nuclear energy are frequently discussed at the global level (most recently by Adamantiades & Kessides, 2009; Deutch et al., 2009) and a recent series of studies addressed the different driving forces and challenges to instituting nuclear power in different regions (see Toth 2008 for a summary). Additionally, the IAEA has described considerations and milestones related to developing new nuclear power programs (IAEA, 2007a, 2007b, 2008b). Additionally, However, none of these studies systematically combine the global perspective with the national level factors affecting potential new nuclear programs to analyze how nuclear power might develop in different national contexts.

Thus, this study seeks to determine whether safe expansion of nuclear power to some 50 countries is feasible.[4] We approach this question by systematically comparing the capacities and motivation of these "Newcomer NP Countries" to countries with existing nuclear energy programs ("Existing NP

[3] While it is possible to acquire smaller reactors, since smaller models typically have had trouble being economically competitive (IAEA, 2007a), this study limits itself to evaluating the potential for these larger reactors.

[4] This study does not consider Iran or Lithuania in its group of Newcomer NP Countries because they have significant existing capacity specifically related to nuclear energy and thus are not "Newcomers" in the purest sense of the word.

Countries").[5] While this historical analysis does not enable us to predict the future, it does provide insight into if and how nuclear energy can develop in the Newcomer NP Countries.

2. Methodology for Assessing Newcomers

While the dimensions of capacity and drivers for nuclear energy are broadly clear, the threshold at which a country is considered capable and sufficiently motivated to build and manage a NPP is difficult to define. For one, a country's **capacity** requirements are influenced by the national **imperative** to develop nuclear energy. Simply speaking, countries seriously *interested* in building a NPP are more likely to acquire, mobilize, and concentrate the necessary resources than countries lukewarm to the idea. Secondly, while there are indicators which can be used to quantitatively evaluate a country's capacity and imperatives for introducing nuclear energy, except for grid capacity, there is no objective minimum for the different aspects of either dimension.

This paper proposes a systematic approach for setting these thresholds by benchmarking indicators for Newcomer NP Countries' capacities and motivations against historical data for the capacities and motivations of Existing NP countries. It does this by using indicators which characterize a Newcomer NP Country's financial, institutional, and technical capacity as well as its energy demand and energy imperatives. The financial and institutional capacity data as well as the demand imperative are benchmarked against similar data for Existing NP Countries from the time of the start of construction of their first NPP while the technical capacity data are benchmarked against the IAEA guidelines for minimum grid capacity. Since no historical data for energy security in the Existing NP Countries are available, the energy security imperative indicators are benchmarked within the group of the Newcomer NP Countries. The following two sections discuss the indicators used for each component; Table 1 presents a summary of selected indicators; and section three discusses the limitations of this approach.

2.1. Assessing capacity for initiating nuclear power programs

The IAEA (2007b) identified the following key infrastructural considerations for initiating a nuclear power program: technical compatibility, financial capacity, human resources, physical infrastructure for transport of materials and supplies, the legal and regulatory framework, and facilities for processing radioactive waste. The IAEA proposes that these factors be evaluated under the assumption that a country is already stable both socio-economically and politically (IAEA, 2007b). With the exception of grid capacity, the IAEA's evaluation criteria are qualitative and based on a review of a government's activities and documents (IAEA, 2008b). The capacity evaluation in this study takes a different approach by using quantitative capacity indicators; these indicators cover the institutional, financial and technical capacity of a country and aim to evaluate the relative "readiness" or "ability" of a country to implement nuclear power.

The two main technical requirements for implementing nuclear power are a reliable grid which is large enough to accommodate a standard NPP (IAEA, 2007b). A single power plant is not recommended to provide more than 10% of the regional grid capacity; thus, given that standard nuclear reactors are generally 1 GW or larger, this can pose a problem for countries with small power grids (IAEA, 2007a). Since initiating a nuclear power program is expected to take an average of 10 to 15 years (IAEA, 2007a), the year that the grid size is projected to exceed 10 GWe was calculated.[6] If the grid size is not projected to exceed 10 GWe within the next 15 years, the country was evaluated for the strength of international grid connections. using available data for international grid connections as well as IEA electricity trade

[5] Israel and North Korea are specifically excluded from this group because although they have pursued the development of nuclear weapons, they do not have functioning nuclear energy programs.

[6] The projected national generating capacities was calculated by projecting the growth rate in grid size between 1997 and 2007 (EIA, 2008) and assuming compound linear growth.

data (IEA, 2009b; See Appendix A for grid connection data).[7] No technological indicators were used for Existing NP Countries since historically, the competitive size of NPPs was smaller and varied depending on the exact year and national context.

National financial capacity for nuclear power development entails both allocating an initial investment for creating the regulatory, legislative and basic physical infrastructure to support the development of a NPP as well as financing the construction of the first NPP. The initial investment generally comes from public funds while the actual financing of the NPP can come from either private or public sources (IAEA, 2007b).

The two main financial indicators are the country's GDP and its GDP/capita at PPP. The national GDP is used to estimate the availability of financial resources which could be dedicated to the development of nuclear power. We generally use real GDP rather than GDP at PPP because it better reflects the ability to import nuclear technology and expertise from abroad which Newcomer NP Countries need initially (IAEA, 2007a). However, for the Existing NP Countries which are former socialist countries, we use GDP at PPP because they relied almost exclusively on domestic or Soviet technology where the global exchange rate changes were less relevant than domestic economic wealth.[8] In contrast, we use GDP/capita at PPP as a widely used measure to indicate the relative well-being of a country that generally correlates with the level of education, technological development, quality of infrastructure and institutional capacity. The financial capacity indicators are benchmarked against historical values for the Existing NP Countries at the time of the start of construction of their first NPP over 100 MW.[9]

A country's institutional capacity has a large influence on its ability to garner both international support and private investment. In countries with existing nuclear power programs, attracting investments for nuclear power programs is dependant on stable and reliable regulatory procedures (Finon & Roques, 2008; Nuttall & Taylor, 2008). Since the commitment to and reliability of a country's nuclear regimes cannot be evaluated in Newcomer NP Countries, an indicator related to the general institutional capacity was used. The World Bank Government Effectiveness Indicator (WBGEI), measures "perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies" (Kaufmann, Kraay, & Mastruzzi, 2008, p. 7). In other words, it measures the amount of confidence that government policies are effectively and fairly designed, implemented and enforced over-time.[10]

Since the WBGEI indicator measures the perception of the quality of public services and the ability of the government to keep these services separate from politically-motivated actions it is applicable in two main ways. First, nuclear power is inherently dependent on existing infrastructure such as roads and highway

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[7] An attempt was made to evaluate grid reliability by using "value lost due to electrical outages" from the World Development Indicator (2009) database, however it was discarded due to insufficient data and because two Existing NP Countries had high values indicating that low value lost due to electricity outages is not a good measure of grid reliability for the safe operation of a NPP. No other suitable widely-available, national indicator was found for electricity reliability.

[8] Except for an initial relationship between Romania and Canada, the nuclear energy programs in the Former Socialist States were all extensions of Soviet technology and expertise and were under Soviet management (Davey, 1982; Socor, 1985). A sensitivity analysis, the results of which are included in the results section, was run on this decision.

[9] Only NPPs over 100 MW are considered in order to avoid including reactors built for research purposes.

[10] In addition to the Government Effectiveness indicator, the World Bank's Regulatory Quality Indicator, Rule of Law Indicator, and Control of Corruption, as well as the ICRG Bureaucracy Quality Indicator were considered for institutional capacity. The other indicators were ruled out on both theoretical and practical grounds. Theoretically, they either measured a phenomenon very similar to the Government Effectiveness Indicator or a phenomenon less relevant to the development of nuclear power. For example, Regulatory Quality Indicator was rejected because it primarily focuses on regulations which are relevant to small and medium-sized enterprises (SMEs). Practically the other indicators were rejected because they all displayed a high correlation coefficient with the Government Effectiveness Indicator. The other World Bank Indicators all had a correlation coefficient greater than 0.90 for the group of Newcomers and the ICRG Bureaucracy Quality Indicator had a correlation coefficient of 0.80.

systems to transport construction and operation materials. Thus, the capacity of a government to manage public services will have an influence on the ability of a government to provide supportive infrastructure which a NPP requires. Secondly, the perception of the degree of independence of public services will influence the perception of the reliability of commitment to nuclear power.

Since historical institutional capacity data is not available for Existing NP Countries from the time of nuclear power implementation, the WBGEI Indicator is benchmarked against current data for Existing NP Countries and the ownership arrangements within those countries. Logically, for a country to get private investment in its first NPP, the institutional capacity must be *at least as* good as the institutional capacity of those countries with operating nuclear power programs that have private ownership.

Additionally, investor interest in supporting nuclear power may be influenced by the political stability the given country. To evaluate this aspect the World Bank Political Stability ratings of Newcomer NP Countries are benchmarked against the historical occurrence of violent regime changes or internal conflicts of Existing NP Countries. Since this evaluation is pertinent to both a country's capacity and proliferation concerns, a separate section (4) is devoted to describing the methodology and results of this analysis.

2.2. Evaluating the motivation to pursue nuclear power

The main strategic reasons for pursuing nuclear energy include: growing energy demands, a desire to decrease import dependency and increase diversity of energy resources especially under conditions of scarce domestic resources, as well as the mitigation of local and global air pollution (IAEA, 2007a; Toth, 2008). This section discusses the metrics used for both energy demand and security as well as those which were considered for local and global air pollution.

Both the magnitude and proportional growth rate in electricity consumption were considered for the demand imperative. Even though arguments for nuclear power often cite growing "energy" demands, since this study focuses on the use of nuclear power for electricity production, it limits the demand imperative to the electricity sector.[11] Both the proportional and magnitude of electricity growth were used since several of the countries with high proportional growth rates have such small economies that the magnitude of growth is very low. For example, even though Senegal has a growth rate of 8.4% per year, assuming compounded linear growth the actual magnitude of growth indicates that it would only consume the electricity generated by a 1 GW NPP in 22 years. Conversely, many of the larger economies, have low proportional growth rates with a very large magnitude of growth. For example, even though Poland's electricity consumption growth rate is only 2%, the magnitude of growth is equal to about 1/3 of the annual electricity produced from a standard 1 GW NPP.

Two commonly cited reasons for pursuing nuclear energy are related to energy security considerations which translate into the desire to increase both energy independence and supply diversity. Since this study focuses on nuclear energy for electricity production, the **fuel-import dependency of the electricity system** and the **fuel-diversity of the electricity system** are used to measure relative national energy security of Newcomer NP Countries.

The import dependency of the electricity system is determined by calculating the percentage of imported fuel for oil, gas and coal and then proportionally scaling those energy sources to the total amount they contribute to the domestic electricity supply. The percentage of imported coal, crude oil and gas is calculated using 2006 data from the IEA Balance statistics website (IEA, 2009b). The production of a given fuel source in a country is divided by the sum of the production and the imported quantity of that fuel to calculate its respective import dependency. For oil, crude oil is used instead of the petroleum products category because it was assumed to be more representative of a country's indigenous resources

[11] While there is the potential to use nuclear power for desalination and heat production, this study limits itself to nuclear power for electricity production since Newcomers will most likely initially implement proven and tested technologies (IAEA, 2008c).

rather than petroleum products which would be more representative of a country's processing capacity. The representative proportion of the electricity system of each fuel type is computed by dividing the number of GWh produced by a given fuel source in 2006 by the total domestic supply for 2006.

The diversity indicator also covers the fuel-mix for the electricity system due to the reasons discussed above. To calculate the diversity of the electricity system, the Shannon diversity index is used which is commonly used in studies of energy security and diversity (APERC, 2007; Jansen et al., 2004; Stirling, 1994). The formula for the **Shannon diversity index** (Shannon & Weaver, 1963) is as follows:

$$DI = -\sum (p_i \ln p_i)$$

where:
DI = Diversity index
p_i = share of primary energy source "i" in the electricity mix
i = 1….M: primary energy source index (where M is the total number of sources)

In order to calculate the Shannon diversity index this study used 2006 data from the IEA database of electricity data (IEA, 2009a). The IEA reports 13 individual sources of electricity production: coal, oil, gas, biomass, nuclear, hydro, geothermal, solar PV, solar thermal, wind, tidal, and other sources. For simplicity, solar PV and solar thermal were combined into one just solar energy source. Within the 52 Newcomer NP Countries, ten of the twelve energy sources are represented (obviously nuclear is excluded as is tidal energy). Thus, if a country had a perfectly balance fuel portfolio with all ten sources, the maximum value for the Shannon diversity index within the newcomer states is 2.30.

Even though several indicators were reviewed to address the environmental motivations for nuclear energy, none were considered to be suitable. For local air pollution, there is not a national indicator which reflects the average concentration of pollutants from power plants. Sulfur dioxide and nitrous oxide emissions are only available on a per-capita basis and the concentration of particle pollution is influenced by too many natural sources to adequately reflect the local-pollution imperative. Furthermore, while alleviating local air pollution is a convenient benefit of nuclear power, there are more efficient methods available.

For the relationship between GHG emissions concerns and nuclear power, there was no way which was identified to adequately evaluate a country's interest in decreasing their emissions. With the uncertainty of the future climate agreement, there is no way to measure a country's commitment and interest in reducing emissions. Furthermore, even if there were a quantitative measure of commitment, there is no guarantee that reducing GHG emissions would actually correspond to a strong national imperative for nuclear energy. To date, nuclear power is the only technology excluded from the Clean-Development Mechanism for being inconsistent with sustainable development goals (de Coninck, 2008) and there is no indication that this status will change.

Table 1 Summary of Indicators

Type of Capacity or Imperative	Existing NP Countries		Newcomer NP Countries	
	Indicator	Time of Measurement	Indicator	Time of Measurement
Technical Capacity	Not Applicable (see text)		Electricity grid size	Current & 15-year projected
			Strength of international connections	Current or under-construction
Financial Capacity	GDP	Time of Start of Construction of the first NPP >100 MW	GDP	Current (2007)
	GDP/capita PPP		GDP/capita PPP	

Type of Capacity or Imperative	Existing NP Countries		Newcomer NP Countries	
	Indicator	**Time of Measurement**	**Indicator**	**Time of Measurement**
Institutional Capacity	World Bank Government Effectiveness Indicator	Current (2008)	World Bank Government Effectiveness Indicator	Current (2008)
	World Bank Political Stability Indicator	Current (2008)	Evidence of Political Instability from Political Instability Task Force (PITF)	10 years preceding and following the start of construction of the first NPP
Energy Demand Imperative	Proportional Electricity Demand Growth Rate	5 years preceding the start of construction of the first NPP >100 MW	Proportional Electricity Demand Growth Rate	Current (2001-2006)
			Magnitude of Electricity Demand Growth	
Energy Security Imperative	Not available		Diversity of the primary sources of the electricity system	Current (2007)
			Import dependency of the primary sources of the electricity system	

2.3. Limitations of using the historical data on nuclear energy

When comparing Newcomer NP Countries with Existing NP Countries , it is important to keep in mind that the world today is significantly different than the world in which all of the existing nuclear programs developed. Nuclear energy emerged in the late 1950s as a direct offshoot of nuclear weapons programs and aspirations. Subsequently, inspired by the promise of abundant electricity which would be "too cheap to meter" (Laurence, 1955), twenty-five countries initiated nuclear power programs between 1957 and 1976. In contrast, only two nuclear programs were started in the 1980s including one in China in 1985 (data are from IAEA 2009). Since the Chernobyl disaster in 1986, no new country has started a nuclear power program.[12]

Thus, the world in which all the existing nuclear programs were established was divided by the Cold War and as a result, the nuclear energy industry behind the Iron Curtain relied on technology and expertise from the Soviet Union where it was often supported through powerful defence-related programs. Additionally, in Socialist and market-economies alike, the provision of electricity was handled by state-run monopolies so that society as a whole rather than private actors bore most of the financial risk.

Some of the factors, which existed in the 'pre-Chernobyl world' but have disappeared since, made the adoption of nuclear programs easier in the past. For example, politically motivated generous and unconditional support from superpowers is nowadays less likely than under the Cold War. Safety and non-proliferation regimes are more keenly observed after Chernobyl and 9-11. States are less willing to step into the business of power generation, now widely believed to be a domain of markets and private actors. On the other hand, the globalized flows of capital and technology and increasing concerns over climate change, which did not exist prior to 1985, may make it easier to start nuclear programs today. Though these changes in historical circumstances are difficult to interpret we still believe that comparative analysis of the Existing and Newcomer NP countries makes sense as it can shed light on factors and situations that might prompt or hinder the expansion of nuclear power today.

[12] It should also be noted that three of the original countries with nuclear power (the USSR, Czechoslovakia and Yugoslavia) broke apart and two of the original countries (Germany and West Germany) reunited in the 1990s, thus increasing the number of states with nuclear power from 27 to 30.

3. Results

3.1. Historical drivers for nuclear energy

Historically, nuclear power programs are associated with nuclear weapons considerations and high growth in electricity consumption. As shown in Table 2, 24 of the 25 countries for which there are historical electricity data were experiencing growth rates in electricity consumption greater than 5% and 9 of these had growth rates over 9% in the five years prior the construction of their first NPP or the nearest period available. In contrast, the average global growth rate in electricity consumption between 1971 and 2009 was about 3%.[13] Additionally, in general, most of these growth rates were significantly higher than the average national growth rate over the last 30 to 60 years.

Table 2 Historic economic and electricity consumption growth rates for Existing NP Countries at the start of construction of their first NPP. Countries in bold developed nuclear weapons while countries in italics considered the development of nuclear weapons (see text for references).

Country	Year Construction started on first NPP > 100 MWe	5-year average electricity consumption growth rate prior to construction of the first NPP*	Average electricity growth rate from 1960-2006 for OECD countries and 1971-2006 for non-OECD countries
U.K.	**1957**	**7.5%[A]**	**3.8%**
U.S.	**1957**	**6.8%[A]**	**3.8%**
Former Soviet Union	**1958**	**14.4%[C]**	**NA**
Former Czechoslovakia	1958	NA	NA
France	**1958**	**7.8%[A]**	**4.4%**
Canada	1960	6.2%[A]	3.8%
Japan	1961	11.4%[A]	5.3%
Former W. Germany	1962	11.4%[A]	3.8%
Spain	*1964*	*11.8%[A]*	*6.6%*
Switzerland	*1965*	*5.1%*	*3.1%*
Pakistan	**1966**	**7.1%[B]**	**7.9%**
Sweden	*1966*	*6.4%*	*3.5%*
Argentina	*1968*	*6.0%[B]*	*4.7%*
India	**1968**	**6.6%[B]**	**6.9%**
Belgium	1969	7.2%	4.2%
Netherlands	1969	10.1%	4.5%
Former E. Germany	1970	NA	NA
Bulgaria	1970	8.0%[B]	1.7%
Brazil	*1971*	*8.5%[B]*	*6.5%*
Finland	1971	9.1%	5.4%
South Korea	*1972*	*15.9%[B]*	*11.2%*
Hungary	1974	7.5%	3.1%
Former Yugoslavia	*1975*	*9.0%[D]*	*NA*
Mexico	1976	9.5%	6.1%
South Africa	**1976**	**8.9%**	**4.4%**
Romania	*1982*	*4.1%*	*1.5%*
China	1985	6.1%	9.2%

[13] This is a rough estimate calculated from World Bank WDI Data from 1971 to 2006 (World Bank, 2009).

**Where possible, the average electricity consumption growth rate was calculated for the 5 years preceding the construction of the first NPP great than 100 MWe using World Bank data (World Bank, 2009). Where this was not possible due to data limitations, the nearest possible periods were used as coded in the table as follows. A: Growth rate is calculated from 1960 to 1965 with World Bank Data. B: Growth rate is calculated from 1971 to 1976 using World Bank data. C: Growth rate is calculated from 1955 to 1960 using* (Bogomol'nyi, 1976). *D: Growth rate calculated from 1970-1975 from (Socialist Federal Republic of Yugoslavia Federal Institute for Statistics, 1976).*

In addition to a strong demand imperative, there is evidence that military concerns drove much of the interest in nuclear energy (Puig, 2005; Kåberger, 2007; Walker, 1992). Eight of the 27 Existing NP Countries successfully developed nuclear weapons (marked in bold text in Table 2); in addition, another eight considered the development of nuclear weapons as evidenced by active support of development of the bomb or the presence of a combined civilian/military nuclear program (marked in italics in Table 2).[14] Thus, of the 27 countries with nuclear power 16 considered or actively pursued the development of nuclear weapons.

3.2.Imperatives for Newcomer NP Countries

This section characterizes the imperatives for nuclear power implementation in Newcomer NP Countries and considers the energy demand imperative and energy security imperatives for nuclear power. The results for the imperatives are aggregated such that a country's overall imperative for nuclear power is based on the highest imperative rating of the two drivers considered. As an example if a country is rated as having a strong demand imperative and a low energy security imperative, it is classified as having a strong imperative to pursue nuclear power. This aggregation method is used because in order for a country to have a strong enough drive to pursue nuclear power, it does not need to have a strong imperative in all aspects, but rather a strong enough motivation in at least one aspect.

Energy demand imperatives in the Newcomer NP Countries are characterized using two indicators: the annual proportional growth rate of electricity consumption and the the number of years it would take for the electricity consumption to grow (at the current rate) so as to require an additional 1 GW of installed generation capacity (equivalent of a typical NPP).[15] The results of the analysis are summarized in Table 3. Of the 51 Newcomer NP Countries for which there is electricity data, 21 would require an additional 1 GW of generating capacity installed in less than 5 years from now.[16] Most of these countries also have high proportional growth rate in electricity consumption and thus are rated as having a high energy demand imperative. The only two countries within this first group which are rated as having a moderate demand imperative are Italy and Poland which both have low growth rates in electricity consumption of approximately 2% a year.

Another 9 countries may need an additional 1 GW of electricity generating capacity in 5 to 10 years. Three of these countries have moderate proportional growth rates and are thus rated as having a moderate demand imperative and 6 of them have high proportional growth rates and are thus rated as having a high demand imperative. The remaining 20 Newcomer NP countries are rated as having a low demand imperative given that their growth in electricity consumption would take over 10 years to require an additional GW of installed capacity. Even though a handful of these countries have very high proportional growth rates, their existing electricity consumption is so low that the magnitude of annual growth in electricity consumption would not be likely to justify the construction of a standard 1 GW NPP.

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[14] Data are from: (Bunn, 2001; Kåberger, 2007; Kristensen & Godsberg, n.d.; Martin, 1996; Puig, 2005).

[15] The proportional growth rate is the average annual growth from 2001 to 2006. The number of years it would take a country to consume the electricity from a new NPP is calculated with this proportional growth rate and assumes 100% capacity consumption of the NPP and compound linear growth.

[16] There was no electricity data for Uganda.

Table 3 Demand Growth Imperative for Newcomer NP Countries

Number of Years to Consume Electricity Generation from a standard 1 GW NPP	Proportional Growth Rate: <3%		3%-6%		>6%	
	Moderate Demand Imperative		*High Demand Imperative*			
<5	Italy, Poland		Chile, Greece, Kazakhstan, Malaysia	Philippines, Portugal, Saudi Arabia, Venezuela	Bangladesh, Egypt, Indonesia, Kuwait, Libya, Nigeria	Syria, Thailand, Turkey, U.A.E., Vietnam
5-10			Algeria, Croatia, Singapore		Bahrain, D.R., Jordan	Morocco, Peru, Qatar
			Low Demand Imperative			
10-25	Belarus		Ecuador, Estonia	Latvia, Tunisia	Kenya, Myanmar, Namibia	Senegal, Sudan, Yemen
>25	Albania, Cuba, Georgia, Ghana	Jamaica, Paraguay, Tanzania, Uruguay	Mongolia			

**There was no electricity data for Eritrea or Uganda.*

The second imperative is the Security of Supply for Electricity production which is evaluated using the import dependency and a diversity index of fuels for the electricity system (Figure 2). The energy security evaluation is most relevant for countries which do not have a moderate or strong demand imperative; for it is only in these countries that a strong enough energy security imperative would affect the results of this evaluation to switch a country's rating from having a low imperative to a high imperative for nuclear power.

If a country has both very high dependency and very low diversity it can be considered as having very low security of supply for the fuels for electricity production. There are three countries which meet these criteria: Belarus, Eritrea, and Jamaica. Thus, even though they have a weak demand imperative, the extremely low security of supply for electricity production may enable flip highly insecure in terms of its fuels for electricity production may provide sufficient motivation for them to pursue nuclear power.

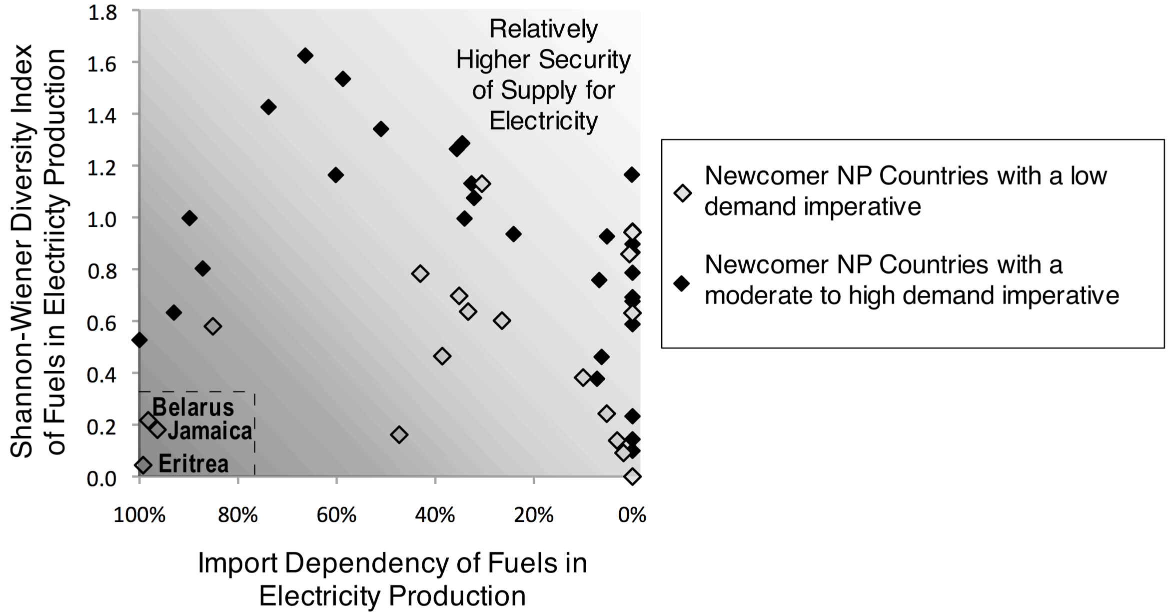


Figure 2 Electricity Fuel Security Indicators for Newcomer NP Countries
Graph is produced from data compiled from (IEA, 2009c, 2009b)

3.3. Newcomer NP Countries' capacity in context

This section discusses the capacity evaluations for Newcomer NP Countries using the data from Existing NP Countries. The section first presents the technical capacity evaluation then proceeds to the financial and institutional results which are both benchmarked against Existing NP Countries.

Of the 52 Newcomer NP Countries: 18 currently have grid capacities which exceed 10 GWe and could accommodate a standard 1 GW NPP and another 8 have grids which will likely exceed 10 GWe within the next 15 years. Of the 26 countries with electricity grids under 10 GWe and low potential for sufficient growth, 10 have strong international grid connections which could be utilized in the event of the construction of a NPP and 16 currently lack strong international connections.

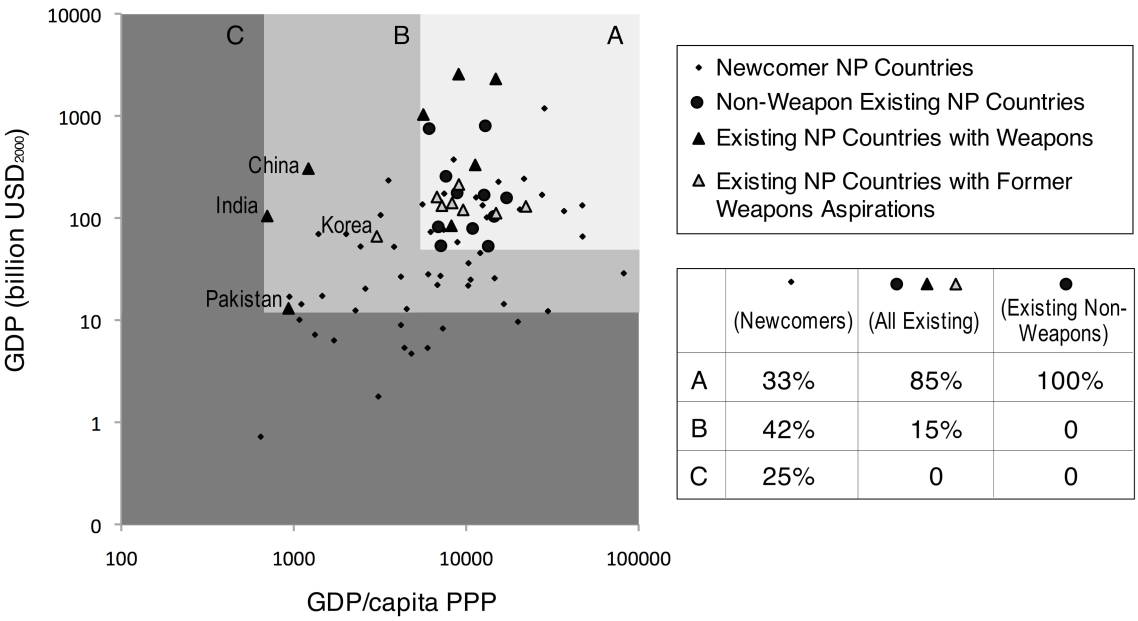
Table 4 Technical capacity results for Newcomers (for grid connection sources see Appendix A)

Technical Capacity							
High				***Medium***		***Low***	
Current grid > 10 GWe		**Prospective Grid > 10 GWe in <15 years**		**Small grid, but strong grid connections**		**Unlikely to have a suitable grid**	
Chile	Portugal	Algeria	Eritrea	Belarus	Latvia	Albania	Nigeria
Egypt	Saudi Arabia	Bahrain	Libya	Croatia	Morocco	Cuba	Paraguay
Greece	Singapore	Bangladesh	Peru	Estonia	Namibia	Ecuador	Senegal
Indonesia	Thailand	Dominican Republic	Syria	Georgia	Qatar	Ghana	Sudan
Italy	Turkey			Jordan	Uruguay	Jamaica	Tanzania
Kazakhstan	U.A.E.					Kenya	Tunisia
Kuwait	Venezuela					Mongolia	Uganda
Malaysia	Vietnam					Myanmar	Yemen
Philippines							
Poland							

GDP and GDP/capita vary significantly in both Newcomer and Existing NP countries. However, the Existing NP Countries *without* nuclear weapons considerations are the most economically homogenous group (Figure 1). The GDP of all Existing NP Countries at the time of construction of their first NPP ranged from 13 billion USD_{2000} to over 2 trillion USD_{2000} and the GDP/capita ranged from $700

PPP/capita to $22,000 PPP/capita (areas A and B). If countries with nuclear weapons or former nuclear weapons aspirations are excluded, the lower boundaries of this range jump from 13 billion USD_{2000} to 53 billion USD_{2000} and from $700 PPP/capita to $6,000 PPP/capita (area A).[17]

In fact Pakistan is the only country with a GDP of less than 50 billion USD_{2000} that has ever built a NPP. China, India, Korea, and Pakistan are the only countries with a GDP/capita PPP less than $5,000. All of these states either have nuclear weapons or pursued the development of nuclear weapons with their nuclear energy programs. This result suggests that when nuclear weapons aspirations or capabilities accompany the pursuit of nuclear energy (or the pursuit of nuclear energy accompanies nuclear weapons aspirations), resources for a nuclear power program can be mobilized even in relatively poor countries.



	◆ (Newcomers)	● ▲ △ (All Existing)	● (Existing Non-Weapons)
A	33%	85%	100%
B	42%	15%	0
C	25%	0	0

Figure 3 Newcomer NP Countries' Financial Capacity benchmarked against Existing NP Countries' Financial Capacity from the time of construction of their first NPP.
GDP/capita PPP data are from (Lindregen, 2009). GDP data are compiled from (CIA, 2008; Maddison, 1995, 2003; World Bank, 2009) *and are all presented in constant* USD_{2000}*.*[18] *GDP values are all real except for the former Eastern-block Countries which are GDP PPP values.*

The spread of financial indicators for the Newcomer NP Countries is much wider than for the Existing NP Countries. Areas A and B in Figure 3 contain all of the Existing NP Countries but only 75% of the Newcomer NP Countries. This means that 25% of Newcomer NP Countries currently have GDPs which are lower than the GDP (at the time of construction of their first NPP) of Pakistan, which itself was anomalously low. The difference between Newcomer NP Country financial capacities and Existing NP Country financial capacities is even starker when only non-weapons Existing NP Countries are considered. Area A in Figure 3 contains all Existing NP Countries with no nuclear weapon considerations. Only one third of Newcomer NP Countries fall into this area.

[17] If the available real GDP values are used for the former socialist states, Hungary and Romania drop below Finland's minimum GDP of 53 billion USD_{2000}. Hungary's real GDP was 31 billion USD_{2000} and Romania's was 43 billion USD_{2000} the year that they began construction on their first NPP. As discussed in Section 2.1, the nuclear programs in the Former Socialist states were extensions of Soviet technology and management. Even with this support it is clear that in spite of the support from a significant cooperation agreement from the USSR(KK, 1974), Hungary struggled financially to complete their NPP which not only affected the Nuclear plant in Hungary but also had a negative impact on other government investment activities (Hudson, 1982).

[18] They are converted using (Sahr, 2009).

Two obvious conclusions follow from this analysis of financial indicators. First, the financial capacity of the Newcomer NP Countries is generally lower than the historical financial capacity of the Existing NP Countries. Secondly, with regard to their financial capacities the many Newcomer NP Countries are closer to the Existing NP Countries with nuclear weapon programs. While it does not mean that some Newcomer NP Countries are necessarily motivated by nuclear weapon considerations, it does indicate the degree of political commitment which will be required to mobilize financial resources for a nuclear energy program in these relatively poor countries.

The range of WBGEI ratings for nuclear Newcomers is significantly wider and generally lower than for Existing NP Countries (Table 5). While 60% of the Existing NP Countries fall in the top quartile of Countries in terms of WBGEI, only 12% of the Newcomer NP Countries do. Furthermore, 21% of the Newcomer NP Countries fall in the **lowest** quartile of WBGEI ratings where not a single Existing NP Country is found. Moreover, 97% of the Existing NP Countries with privately or jointly owned and operated NPPs fall in the top quartile of WBGEI. Thus, it may suggest that only Newcomer NP Countries with similarly high ratings would be able to effectively involve the private sector in the construction of a NPP.

Table 5 Newcomer NP Countries WBGEI Rating Benchmarked against Existing NP Countries Ratings Data are compiled from (Kaufmann et al., 2008). For ownership references see Appendix B.

WBGEI Rating	Newcomer NP Countries	All Existing NP Countries	Existing NP C. with Mixed or Private Ownership
75-100	12%	60%	97%
50-75	40%	27%	3%
25-50	27%	13%	0
0-25	21%	0%	0

Political Stability may also affect the investment attractiveness of Newcomer NP Countries. Since this aspect is also related to proliferation concerns, it is discussed independently of other capacity aspects in Section 4.

4. Political Stability, the risk of conflict and proliferation concerns

The political stability of Newcomer NP Countries is an important consideration in the expansion of nuclear power. From a national perspective, politically less stable countries might find it more difficult to attract investment necessary for constructing an NPP and from a global perspective, such instability may increase the risk of conflict and nuclear proliferation.

The World Bank Political Stability Index (WBPSI) is a measurement of the perception that a government will be overthrown by violent means and reports data for over 212 countries and territories from 1996 (Kaufmann et al., 2008). According to the WBPSI from 2008 (the most recent data available), political stability of the Newcomer NP Countries varies significantly: with the most stable being Singapore (WBPSI=96) and the most unstable being Sudan (WBPSI=2). Nineteen of the Newcomer NP Countries fall within the bottom quartile of the Political Stability Index, i.e they are among the 50 most unstable countries in the world.

Unfortunately, there are no comparable indicators of political stability for the Existing NP Countries at the time of construction of their first NPP. However, there are data available which make it possible to make a tentative comparison of the actual historical incidence of politically destabilizing events in the Existing NP Countries and the risk of violent conflicts in the Newcomer NP Countries by using the WBPSI as an indicator for the former.

The Political Instability Task Force (PITF) details historical periods of "partial or total state failure (i.e. periods of political instability)" in countries between 1955 and 2008 (PITF, 2010). While the incidence of such conflicts among the Existing NP Countries is not very high, 5 of the 27 Existing NP Countries (Argentina, Brazil, Czechoslovakia, India, and Pakistan) had at least politically destabilizing event in the 10 years before or after the start of construction of their first NPP. If we exclude Czechoslovakia with its specific "instability" of the democratic Prague Spring, all of these historically unstable countries pursued nuclear weapons (Bunn, 2001; NTI, 2009b).[19] In contrast, about half of politically stable Existing NP Countries pursued nuclear weapons. Thus, it is appears that historically, support for nuclear power in politically unstable countries was usually followed in connection to a nuclear weapon programs.

According to the PITF (PITF, 2008), 10 Newcomer NP Countries have had politically destabilizing events within the last 10 years (Algeria, Bangladesh, Indonesia, Myanmar, the Philippines, Sudan, Thailand, Turkey, Uganda, and Yemen). These 10 Newcomer NP Countries also have WBPSI-2008 ratings in the bottom quartile. To predict the probability of a conflict within the next 10 years, the WBPSI is used.

In order to compare the historical occurrence of political conflict, with the current risk of political instability, the PITF data for historical instability and the existing WBPSI data are compared. These data show a moderate correlation. In Figure 4, the actual presence of an internal conflict or violent regime change for 175 countries between 1988-2008 is plotted against the WBPSI-1998. The trend line (r^2=0.38) thus represents the probability of an internal conflict occurring within 10 years preceding or following the WBPSI rating. The data show that the drop in WBPSI by 10 percentage points leads to an increase of probability of a violent conflict in 1988-2008 by 10 percentage points. Thus, if we apply the same correlation to the most recent WBPSI rating from 2008, we can derive the probability of violent conflicts for Newcomer NP Countries over the next 10 years.

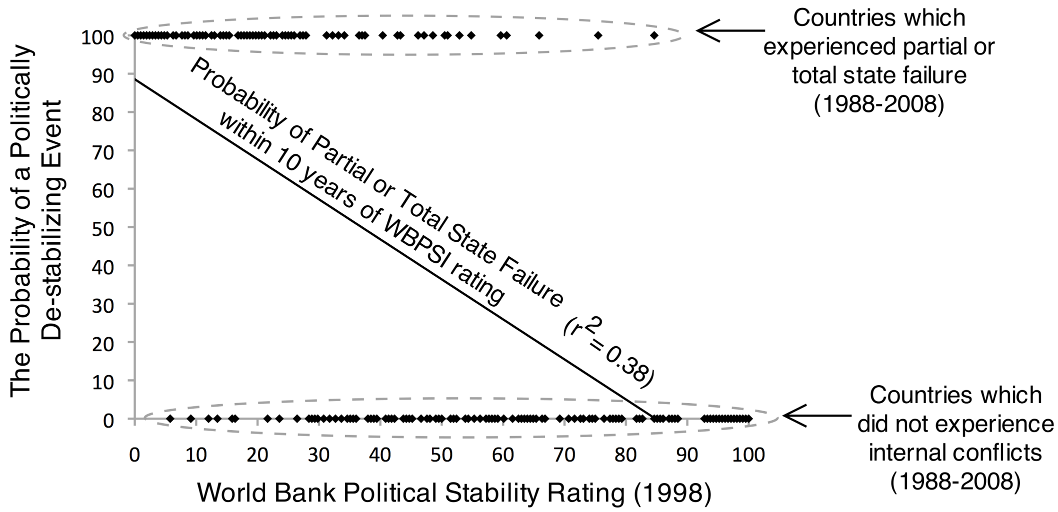


Figure 4 A Comparison between the Historical Data for Regime Crises and the WBPSI (1988-2008)

Based on this correlation, the average political stability rating for Newcomer NP Countries is 41 which translates into a probability of 46% that a Newcomer NP Country will have a conflict within the next 10 years. This probability is significantly higher than the probability for internal conflict in all the Existing NP Countries (19%), and even for conflict in Existing NP Countries with Nuclear Weapons (29%) or

[19] While Pakistan is now a weapons state, several scholars have stated that Pakistan did not begin developing nuclear weapons until 1972 even though it began construction of its first NPP in 1966 (Ahmed, 1999; Nizamani, 2000). However, given their anomalously low financial capacity when compared to the historical data of other Existing NP Countries and their political tensions with India, it is possible that nuclear weapons was a tacit driving force for the development of nuclear energy

Weapons Aspirations (27%). For those 19 Newcomer NP Countries that fall within the bottom quartile of the WBPSI rankings, such a risk is some 65%-85%. In summary it appears that the probability of violent conflicts among all the Newcomer NP Countries is significantly higher not only than the incidence of violent conflicts among all existing NP countries but even among countries which historically pursued nuclear weapons.

Finally, there is a record of nuclear weapons pursuit in some Newcomer NP Countries. Algeria, Egypt, Indonesia, Libya, and Syria have at some point in recent history explored or actively pursued the development of nuclear weapons (Bunn, 2001; Jones, McDonough, & Spector, 1998; NTI, 2008) and Myanmar is thought to be actively pursuing the development of nuclear weapons (NTI, 2009a). Additionally, some argue that the possible emergence of Iran as nuclear weapons state has lead many of its neighbours to pursue nuclear energy as a security hedge (Fitzpatrick, 2008). It is likely that if nuclear energy develops in these countries it will be accompanied by a similar agreement to the one just signed between U.A.E. and the U.S in which the U.A.E. agreed to forfeit the right to enrich and process its own fuel in return for the permission to do business with U.S. nuclear firms (Lakshmanan, 2009).[20]

In conclusion, while the expansion of nuclear energy doesn't necessarily lead to nuclear weapons proliferations, the risk is clearly higher in some countries than in others. While determining the risk factors for nuclear proliferation are beyond the scope of this study (and have been addressed elsewhere (Sagan, 2000; Singh & Way, 2004)), nuclear proliferation linked to the expansion of nuclear energy appears to be of highest concern in politically unstable countries.

5. Clusters of countries and the possible role for nuclear power in these countries

This analysis leads to the emergence of four distinct types of Newcomer NP Countries: 10 countries which have moderate to high imperatives and high capacity and therefore are the most likely to develop nuclear energy, 10 countries which have moderate to high financial capacity, and moderate to high imperatives but which are marked by political instability where nuclear power development is uncertain, 14 countries with small economies and varying degrees of imperatives where the development of nuclear energy would most likely be possible through joint implementation or very strong government support, and 20 countries where the development of nuclear energy is unlikely because the capacities appear to be too low for successful implementation. The following sections will discuss this classification in more detail and reflect on possible pathways for development of nuclear energy in each type of country.

[20] The deal is the first of its kind and was signed recently by Barack Obama who has hailed the agreement as "a model for the world" (Solomon & Coker, 2009).

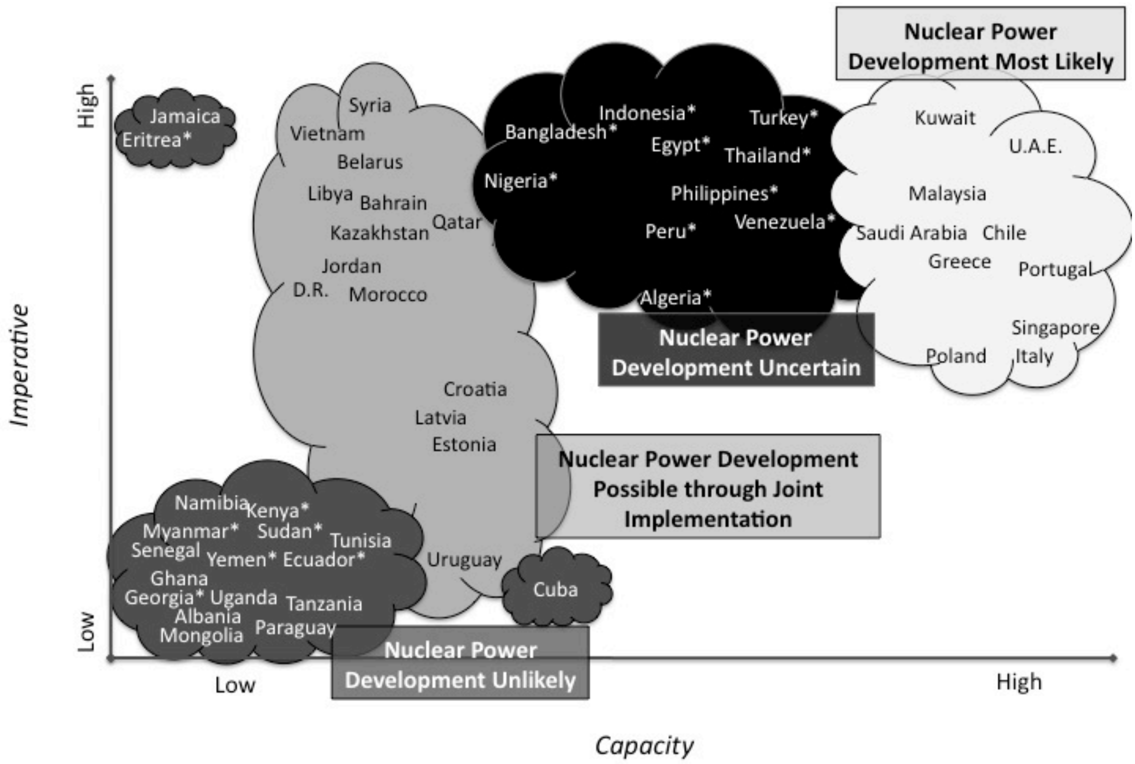


Figure 5 Summary of results from the imperative and capacity frameworks for Newcomer NP Countries
** Indicates countries in the bottom quartile of political stability*

5.1. Nuclear power development most likely

Only 10 countries are rated as having a high enough capacity and imperatives to develop nuclear power in a business-as-usual scenario. This group contains: 3 MENA countries, 5 EU Member countries, 2 Southeast Asian countries, and 1 Latin American country. All of these countries currently have grid capacities which exceed 10 GWe and all except Kuwait have GDPs over 100 billion USD_{2000}.[21] According to the World Bank ratings, they are all either Upper Middle Income or High Income countries. Half of these countries have WBGEI ratings in the top quartile (Chile, Malaysia, Portugal, Singapore, and U.A.E.) and the other half have ratings between 50 and 75% (Greece, Italy, Kuwait, Poland, and Saudi Arabia).

All of these countries have a growth rate in electricity consumption such that within the next 5 years they would require at least the amount of electricity generated by a standard 1 GW NPP. The MENA countries have the highest proportional growth rates of the group ranging from 5.9% to the U.A.E.'s annual growth of 9% while Italy and Poland have the lowest with annual growth rates of 2%.

5.2. Nuclear power development uncertain

In 10 countries nuclear power development is rated as uncertain because while these countries have strong financial capacity and imperatives, they all fall in the lowest quartile in terms of political stability. This group contains 4 Southeast Asian Countries, 2 Latin American Countries, 3 MENA countries, and Nigeria. Their GDPs range from 70 billion to 373 billion USD_{2000}. However, their income levels are generally lower than the previous category. While 4 of them (Peru, Thailand, Turkey, and Venezuela) are Upper Middle Income countries, 5 of them (Algeria, Egypt, Indonesia, Nigeria, and the Philippines) are Lower Middle Income countries, and Bangladesh is a Low Income Country. These countries also have a wider distribution in terms of WBGEI ratings. While 3 of them have WBGEI ratings between 50 and 75% (the Philippines, Thailand, and Turkey), 4 of them have WBGEI ratings between 25 and 50%

[21] Although Kuwait's GDP is only 66 billion, as a high income country with a 2007 GDP/capita PPP over $47,000, it is likely that the country could fund and gather financing for a NPP.

(Algeria, Egypt, Indonesia, and Peru) and 3 of them have WBGEI ratings in the lowest quartile (Bangladesh, Nigeria, and Venezuela).

Six of these countries currently have grids which could accommodate an NPP (Thailand, Turkey, Venezuela, Egypt, Indonesia, and the Philippines) and another 3 have grids which are projected to exceed the requisite 10 GWe within the next 15 years (Algeria, Bangladesh, and Peru). While the technical capacity calculation for Nigeria does not predict that they will exceed 10 GWe within the near future, since this calculation is based on the average growth in the electricity grid over the last 10 years, it is possible that this projection is overly conservative given the extremely high demand growth that the country is experiencing. Furthermore, with their oil revenue, it's quite likely that, if sufficiently motivated, the country would be able to concentrate the necessary financial resources to build a NPP.

In conclusion, given these countries' political instability, generally lower WBGEI ratings and income levels, nuclear power in these countries is likely that investors would be shy to invest in nuclear power in these countries and would need to be implemented with strong government support. However, given the capacities of these countries, they are also the most concerning in terms of nuclear proliferation.

5.3. Nuclear power development possible through joint implementation or very strong government commitment

Another 14 countries are rated as possibly able to implement nuclear power under very strong government motivation or a joint-national or regional implementation effort. These countries are all above the 25th percentile in terms of WBPSI, have sufficient technical capacity, and generally have very low to borderline financial capacities and varying degrees of WBGEI ratings. They include 2 Latin American Countries, 6 MENA Countries, 4 Central-Eastern European Countries, Kazakhstan, and Vietnam. Three of these countries (Libya, Morocco, and Vietnam) have borderline financial capacities with GDPs between 45 and 53 USD_{2000} and a wide variation in income levels from the Low Income of Vietnam to the Upper Middle Income level of Morocco. All the other countries in this category have GDPs between 10 and 36 USD_{2000} and varying income levels. Three of them are High Income (Bahrain, Estonia, and Qatar), 5 of them are Upper Middle Income (Belarus, Croatia, Kazakhstan, Latvia, and Uruguay), and 3 of them are Lower Middle Income (Dominican Republic, Jordan, and Syria).

The institutional and technical capacities of this group vary considerably. The WBGEI ratings range from Estonia's 84%, to 7 countries between 50-75% (Bahrain, Croatia, Jordan, Latvia, Morocco, Qatar, and Uruguay), 3 countries between 25-50% (Dominican Republic, Kazakhstan, and Syria) and 2 countries in the bottom quartile of WBGEI (Belarus and Libya). Vietnam and Kazakhstan currently have grids exceeding 10 GWe; the Dominican Republic, Libya, and Syria are likely to have grids exceeding 10 GWe within the next 15 years; and all the other countries in the group have (or will soon have grid connections which could facilitate NPP implementation.

Due to the limited financial capacity of countries in this group, one potential nuclear development strategy would be joint implementation with neighboring states. Within this group of countries, there are two sets of countries which are geographically close to each other and thus could potentially implement a joint NPP. This would be a possibility for the Middle Eastern countries (Jordan, Qatar and Bahrain) and for Belarus and the two Baltic states (Latvia and Estonia) especially if they join efforts with Lithuania which already has experience of operating an NPP constructed during the Soviet period though shut their NPP down at the end of 2009. In the Gulf States, with the current construction of the Gulf Interconnection grid, which will include Bahrain, U.A.E., Saudi Arabia, Qatar and Kuwait, the possibility for joint implementation also exists.

In addition to varying levels of capacity, the group is characterized by a range of imperative levels. While the MENA countries, Vietnam and Kazakhstan have high demand imperatives, the Baltic States, Croatia, and Uruguay have low demand imperatives. While Belarus has a very low demand imperative, their electricity system is fueled 95% by imported Russian natural gas which could explain their pursuit of nuclear power in spite of a low demand imperative.

5.4. Nuclear power development unlikely

There are a remaining 18 countries where nuclear power development is unlikely. These countries are generally characterized by low financial capacities and small, unconnected grids. Without a sufficient grid, and the small size of these economies, these countries are unlikely to be able to implement nuclear power without the advent of a cost-competitive small reactor. Most of these countries are also characterized by low imperatives for the development of nuclear power. The only two countries with a high imperative for nuclear energy are Eritrea and Jamaica, due to the high dependence and low diversity of their fuel supply for electricity production, however, given the small size of their grids (both <1.2 GWe) and low growth rate it's unlikely that even with a high imperative they would be able to implement nuclear power.

6. Concluding remarks

This study aimed to evaluate Newcomer NP Countries' imperatives and capacities to develop a nuclear power program. In order to evaluate Newcomer NP Countries, it reviewed the primary drivers and barriers to nuclear power development and then set up a framework to evaluate a Newcomer NP Country's imperatives for nuclear energy as well as its capacity to overcome these barriers. The system of indicators includes measures of financial, institutional and technical capacity and was established by comparing the data from indicators for Newcomer NP Countries to current and historical data from Existing NP Countries. By comparing the data for Newcomer NP Countries to both historical and current data for Existing NP Countries, it contributes to the understanding of the driving forces and barriers for nuclear energy and the way these driving forces may play themselves out in Newcomer NP Countries.

While this methodology does offer a contextualized picture of Newcomer NP Countries, it does have three main limitations. For one, it obviously does not include all factors which influence nuclear power development. Due to the lack of suitable indicators, the following capacity considerations were excluded: human resources, ability to garner international support, ability to establish nuclear waste facilities, geographical suitability, popular support for nuclear energy, and indigenous nuclear facilities (such as research reactors). Additionally, this framework excluded imperatives related to local and global pollution as well as indigenous energy sources. The second main limitation is that even though the majority of analysis is based on comparing Newcomer NP Countries to Existing NP Countries, historical data cannot offer an exact parable to today since all existing nuclear power programs were set up in state-controlled monopolies and before Chernobyl and the end of the cold war. The third major limitation is that this study does not consider the potentially game-changing developments in nuclear energy such as the development of commercially-viable small reactors. In spite of these limitations, the past data from nuclear power development in Existing NP Countries offers wisdom and guidance for the future development of nuclear power in Newcomer NP Countries.

Based on the comparison between Existing NP Countries and Newcomer NP Countries, it is clear that several of the Newcomer NP Countries resemble the historical capacity of Existing NP Countries which pursued nuclear weapons, both with respect to financial capacity and political stability. As a result, ten countries are characterized as the most uncertain for nuclear power development. These countries are characterized by sufficient financial capacity and political instability. Combining this result with quantitative characterizations of a country's security concerns could provide guidance to policy-makers about where the pursuit of nuclear energy is safe enough to warrant investment and support. As a multilateral organization, the IAEA maintains that "there are no good and bad countries" in terms of nuclear power (GAO, 2009), however, given the results of this study, it may behoove the international community to develop guidelines of where to support the development of nuclear energy and where to withhold support. While the U.S. Government Accountability Office (2009) recently issued a report with a similar recommendation, this study presents the empirical data to support such a policy as well as a framework to be used to evaluate Newcomer NP Countries.

One issue that would be useful to add to such an evaluation is an assessment of the compatibility and availability of non-nuclear energy sources in order to fully understand the motivation for nuclear power. In the evaluation of Nuclear Newcomers, eighteen countries were identified as having a low imperative and low capacity to develop nuclear power. Thus the question arises as to what the rationale of these countries is for pursuing nuclear energy. For countries with the lack of the demand imperative and minimum technical capacity requirements, why do these countries want to develop nuclear power? For example, for many of the Sub-Saharan African Newcomers, with low electricity demand which is often dispersed in rural areas, it is not clear why there would be interest in nuclear power over distributed generation which would potentially be more compatible with their needs and capacities. Similarly, it is not clear why the North African countries would pursue nuclear power over installing liquid natural gas lines on the Mediterranean or developing a large-scale solar energy farms with connections to Europe. Untangling these alternatives and the preference for nuclear power will be critical to understanding tacit motivations and ensuring the safe and secure development of nuclear power.

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Appendix A

Country	Connection Rating	Notes and References
Albania	Low	Sparse connections with neighbors. (GENI, 2010)
Bahrain	High	Connected with Gulf Grid which is predicted to be ready by May 2010. (Carvalho & Shamseddine, 2009; GCCIA, 2009)
Belarus	High	Connected with the Baltic and Russian grids. From Baltic and Belarusian Maps (GENI, 2010)
Croatia	High	High percentage of electricity is imported. Additional data from the Croatian Electricity Grid Map (GENI, 2010)
Dominican Republic	Low	No electricity imports. The map of the D.R.'s electricity network indicates that there are no international connections (GENI, 2010). No imminent plans for establishing international connection were found.

Eritrea	Low	No connections with neighbors identified (GENI, 2010).
Estonia	High	Connected with Baltic grid. From Baltic Map (GENI, 2010)
Georgia	High	International imports are significant (10% of production quantity).
Ghana	Low	Although Ghana's imported electricity equals 9% of its production capacity, the production is extremely low. There is a plan to institute the West African Power Pool, however several experts indicate that the African power market and energy in general requires huge amounts of investment (Foster, 2008; ICA, 2008).
Jamaica	Low	No international imports. The map of grid connections indicates no international connections either (GENI, 2010).
Kenya	Low	While there are some international connections with Uganda identified in the map of the East African network from African Energy Online (African Energy, 2008a). However, the requisite investment in Africa in energy and electricity is very large (Foster, 2008; ICA, 2008).
Latvia	High	Connected with the Baltic grid (GENI, 2010).
Mongolia	Low	The map of China's electricity network shows limited connections with China (GENI, 2010). Imported electricity is equivalent to 4% of its electricity production in 2006 which was very low. No plans were found for large-scale connection projects.
Morocco	High	Connected with Spain (African Energy, 2008b). Imported electricity equivalent to 9% of the produced electricity.
Myanmar	Low	No international electricity connections (Dhungel, 2008).
Namibia	High	Strong connection with South Africa evidenced by the fact that the country imports as much electricity as it produces.
Nigeria	Low	Some international connections with Benin (African Energy, 2008c). However, the plan for the West African Power pool needs huge investments to be realized (Foster, 2008; ICA, 2008).
Qatar	High	Connected with Gulf Grid which is predicted to be ready by May 2010. (Carvalho & Shamseddine, 2009; GCCIA, 2009).
Senegal	Low	Limited connections with Mali and Mauritania (African Energy, 2008c), however also requires significant investment for connections to be strengthened (Foster, 2008; ICA, 2008).
Sudan	Low	There are possible future connections within Africa (World Bank, 2007), however the project is in a very preliminary stage.
Tanzania	Low	There are possible future connections within Africa (World Bank, 2007), however the project is in a very preliminary stage. The map of the Tanzanian electricity grid indicates limited connections with neighbors (African Energy, 2008a).
Tunisia	Low	There are plans for a possible integration with Italy, however, at this point the project is still being reviewed (Tunisia Online News, 2009).
Uruguay	High	Uruguay is well connected to Argentina (GENI, 2010). Its imported electricity equals 50% of its production.
Yemen	Low	Although there are possible future connections (World Bank, 2007), there are currently no international connections (GENI, 2010).

Appendix B

Country	Ownership and Operation	Owner	Operator	Notes and References
Argentina	State-owned & operated	Nucleoelectrica Argentina S.A.	Nucleoelectrica Argentina S.A.	(NA-SA, 2006)

Country	Ownership and Operation	Owner	Operator	Notes and References
Armenia	State-owned & operated	Ministry of Energy and Natural Resources of Republic of Armenia	Joint Stock Company Armenian Nuclear Power Plant	Financially managed by Russian companies to pay back a debt of fuel supplies; operationally managed by Armenia (NTI, 2003).
Belgium	Mixed	Numerous	Numerous	(NEA, 2007a)
Brazil	State-owned & operated	Eletrobras Termonuclear SA-Electronuclear	Eletrobras Termonuclear SA-Electronuclear	(Eletronuclear, n.d.)
Bulgaria	State-owned & operated	Kosloduy Nuclear Power Plant-plc	Kosloduy Nuclear Power Plant-plc	(Kozloduy, 2008)
Canada	Mixed	Numerous	Numerous	Numerous owners and operators. Two examples: (Bruce Power, 2009; Ontario Power, 2009)
China	Mixed	Numerous	Numerous	(World Nuclear Association, 2009)
Czech Republic	State-owned & operated	ČEZ, a. s.	ČEZ, a. s.	As of March 2008: 67.9% owned by Czech government; 28.5% by companies and corporations and 3.9% owned by individuals (NEA, 2008b)
Finland	Privately-owned & operated	Fortum Power and Heat OY, Teollisuuden Voima OY VOIMA OY	Fortum Power and Heat OY, Teollisuuden Voima OY VOIMA OY	(NEA, 2007b)
France	State-owned & operated	Électricité de France	Électricité de France	85% state-owned (Eléctricté de France, n.d.)
Germany	Privately-owned & operated	Numerous	Numerous	(NEA, 2007c)
Hungary	State-owned & operated	Hungarian Power Companies Ltd.	Paks Nuclear Power Plant Ltd.	(MVM, 2006, 2007)
India	State-owned & operated	Nuclear Power Corporation of Ltd.	Nuclear Power Corporation of Ltd.	Bharatiya Nabhiklya Vidyut Nigam Limited is a government-owned enterprise which is also constructing one. (Bhavini, 2006; Nuclear Power Corporation of Indiat Limited, 2008)
Japan	Privately-owned & operated	Numerous	Numerous	(NEA, 2007d)
Korea	State-owned & operated	Korea Hydro and Nuclear Power Co.	Korea Hydro and Nuclear Power Co.	(EIA, 2007)
Mexico	State-owned & operated	Comision Federal de Electricidád	Comision Federal de Electricidád	(CFE, 2009)
Netherlands	Privately-owned & operated	EPZ	EPZ	(NEA, 2007e)
Pakistan	State-owned & operated	Pakistan Atomic Energy Commission	Pakistan Atomic Energy Commission	(PAEC, 2008)

Country	Ownership and Operation	Owner	Operator	Notes and References
Romania	State-owned & operated	Ministry of Economy and Finance	Societatea Nationala Nuclearelectrica S.A.	The operator is about 90% state-owned ("Nuclearelectrica SA National Comp.," n.d.)
Russia	State-owned & operated	JSC "Concern Energoatom"	JSC "Concern Energoatom"	Currently going through a reorganization but still will be state-owned (Energoatom, 2009)
Slovak Republic	Mixed	Slovenské elektrárne, a.s.	Slovenské elektrárne, a.s.	(NEA, 2007f)
Slovenia	State-owned & operated	GEN Energija, d.o.o.	Nuklerana elektrarna Krško	(NEK, 2009; Radež, 2009)
South Africa	State-owned & operated	Eskom	Eskmo	30% of Eskom is privately owned (EIA, 2008).
Spain	Privately-owned & operated	Numerous	Numerous	(NEA, 2007g)
Sweden	Mixed	Numerous	Numerous	(NEA, 2008c)
Switzerland	Privately-owned & operated	Numerous	Numerous	(NEA, 2006)
Ukraine	State-owned & operated	Energoatom	National nuclear energy generating company	(Energoatom, n.d.)
United Kingdom	Privately-owned & operated	British Energy	British Energy	(EIA, 2006)
United States	Privately-owned & operated	Numerous	Numerous	(EIA, n.d.)