International Issues Related to Nuclear Energy

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Introduction

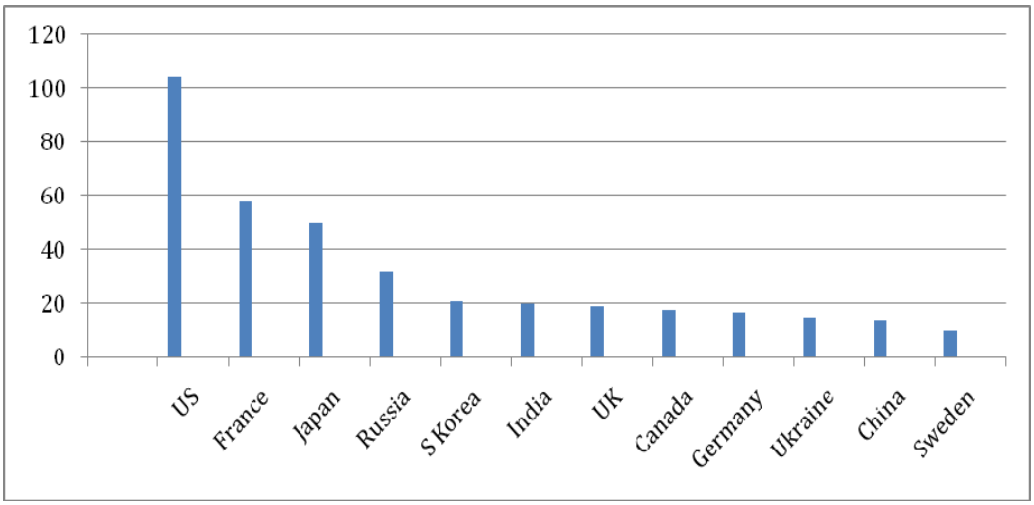
We are entering a new era of increasing demand for electricity, essential for economic growth in the developing world. Nuclear power is on the agenda of many of these nations, but there is a concern that they do not have the necessary legal and regulatory infrastructure to ensure safety and security, and in some cases, also do not have the will to dedicate enough financial and manpower resources to the endeavor. As we have learned once again from Fukushima, a nuclear accident anywhere is an accident that will have implications globally.

In the wake of the Fukushima accident in Japan, serious questions have arisen about the safety of reactor designs, emergency back-up systems, on-site spent fuel storage and the regulatory systems governing nuclear power. These debates are occurring actively across the world, but ironically the greatest impact is likely to be in OECD nations as their publics raise legitimate concerns about nuclear safety and security, while the greatest danger is likely to be in countries that lack a tradition of open discussion.

Worldwide Growth of Energy Demand

Today there are over four hundred and forty nuclear reactors operating in thirty nations.[2] As noted in the chart below, most reactors operating are in technologically advanced and nuclear experienced nations.[3]

Figure 1- *Existing Reactors Worldwide*[4]



But experience does not necessarily assure safety as we have witnessed the most severe nuclear accidents in the US, Ukraine and Japan. These experiences underscore the importance of

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[2] World Association of Nuclear Operators: http://www.wano.info/

[3] Though it is interesting to note the three major nuclear accidents (TMI, Chernobyl and Fukushima) were all in 'technologically advanced' nations.

[4] Source: IAEA http://www.iaea.org/cgi-bin/db.page.pl/pris.oprconst.htm

developing nuclear energy with a "safety first" attitude, especially in nations that are new to nuclear power. If one compares Figures l and 2, it is clear that the growth of nuclear power is likely to be in nations experiencing rapid growth and need for electricity, many of which are not yet as advanced in terms of their governmental institutions.

Nations in Europe with a large and politically strong green agenda have been the ones most affected by the accident at Fukushima. The close proximity of nations that have turned against nuclear power (e.g. Germany) [5] and those that continue to support it (e.g. France) necessitates continued involvement of all European nations, regardless of their stance on nuclear. In the US, nuclear construction will slow due to lower electricity demand and gas prices. The US electricity sector is likely to remain primarily fueled by coal, natural gas and shale gas for some time.

While many industrialized countries pause for reflection, nuclear energy growth in industrializing nations will be rapid. The motivation for nuclear power in these countries arises from economic and political factors, as well as the prestige to have nuclear technology. A major reason for the growth of energy demand in developing countries has been the inspiration of world leaders in the early 1980s to commit to a regime of enhanced international free trade, allowing manufacturing to move to the most efficient and cost effective regions and countries. Thus, the steel industry moved from the US to Japan to South Korea to China and so forth.

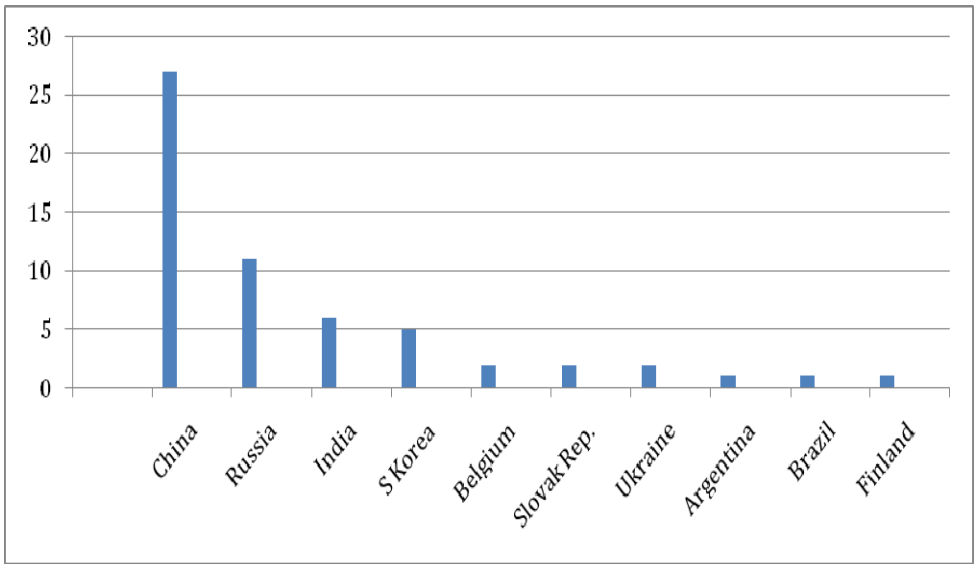
This shift in manufacturing resulted in higher energy/GNP ratios in industrializing countries, while OECD countries moved toward less energy intensive service industries. Thus, it is no surprise that the area of major energy growth of the last twenty years have been in China, India, Southeast Asia and Latin America. Likewise, the world's growth of energy will be in population intensive, low cost manufacturing nations.

Both the end of the Cold War and this economic expansion has lifted much of the world out of poverty and totalitarianism. It has also opened up the wish of economically developing nations to secure the nuclear energy option. Nuclear energy is viewed as advanced technology and as such, carries a certain prestige as well as economic benefit in a world of fluctuating oil and gas prices. And undeniably, it is a cleaner fuel than coal. The projections of the International Energy Agency, however, do show considerable coal growth.[6] In fact, coal may grow twice as fast as nuclear. Nevertheless, the reality is that we are likely to have at least 150 new nuclear plants in developing countries within the next 25 years and even at that pace the share of nuclear power is going to fall as a percentage of total electricity.

The issue is not the overall number of reactors globally, but the location of "new builds" of reactors. The 150 new reactors expected by 2035 will primarily be in nations beginning their nuclear energy programs, many of which are under construction now.

[5] Judy Dempsey and Jack Ewing, "Germany, in Reversal, Will Close Nuclear Plants by 2022." New York Times, May 30, 2011.
[6] International Energy Agency 2010 World Energy Outlook: http://www.iea.org/weo/

Figure 2 - *Nuclear Reactors Under Construction*[7]



Much of the already existing growth (reactors either planned or currently being built) is in China, Russia and India, which have huge projected future domestic power demand increases.[8] There are other nations that are also planning to expand their limited existing programs such as Poland, Lithuania, Argentina, Brazil, the Czech Republic, and South Africa. There are also nations with no nuclear energy programs today that have indicated they wish to enter the field such as Egypt, Ghana, Jordan, Indonesia, Malaysia, Nigeria, Saudi Arabia, the UAE, Vietnam, and possibly others.

The projections we show, therefore, are not wildly optimistic; they are, in fact, likely levels of growth of nuclear power even in the post-Fukushima world. It is true that public reaction in OECD countries has dampened the enthusiasm for nuclear energy expansion, but this is not the case in developing nations, especially those nations in the Middle East and Asia that are autocratically and/or centrally ruled. In these nations, it is the will of the government, not necessarily the will of the people, which will determine nuclear energy deployment.

During the 1970s, an energy economist from MIT's Energy Laboratory, Professor Alan Strout, did some innovative work on consumer purchasing patterns at different levels of per capita income. For example (in 1970 dollars), a consumer would be motivated to buy a small cooker at $l00 per capita, a heater at $250 per capita, a refrigerator at $500 per capita, a car at $1000/per capita, etc.[9] Imagine the purchasing power of a relatively youthful global population as it enters the workforce and begins families. Of course, the key to this is the jobless rate in developing countries and jobs are dependent on economic growth, which is dependent on consumer purchases. At the moment, the system is "stalled" somewhat but once the cycle of economic recovery begins, it is expected that energy growth will expand rapidly. Again, this will not be in the "mature" economies of the OECD countries, but rather the "energy hungry" world of developing nations as the world grows from 7 billion people to over 10 billion by 2100.

The reason this fundamental economic analysis is necessary is to deflate the opinion that

[7] Source: IAEA http://www.iaea.org/cgi-bin/db.page.pl/pris.opercap.htm
[8] Jeremy Carl, Fukushima and the Future of Nuclear Power in China and India, Hoover Institution, Stanford University, 2011.
[9] Alan M. Strout, *The Future of Nuclear Power in the Developing Countries*. (MIT Energy Laboratory: 1977). http://dspace.mit.edu/bitstream/handle/1721.1/31246/MIT-EL-77-006WP-04128995.pdf?sequence=1

industrializing countries are purchasing nuclear power plants solely to gain "nuclear technology." Certainly this is one aspect of the wish to have nuclear reactors, but it is also in many cases wise economics as fossil resources might rise in price.[10] In any event, it is clear that nuclear power will grow, perhaps rapidly, due to energy security and economic reasons and less so because of the concern over climate change.

Let's take China as an example. From a relatively small base, China planned to build up to a capacity of 80 GWe on nuclear electricity in the next 20 years. Even so, nuclear power will meet only 5% of Chinese electricity by 2030.[11] So it is not an issue of "if" nuclear reactors will be built in industrializing countries, it is a matter of how many. And as Figure 2 demonstrates, the building is already underway and the race is on by commercial vendors to supply the nuclear energy option in the Middle East, Southeast Asia, Latin America, and in Eastern Europe. While the current global downtrend will slow this development somewhat, the growth potential is evident.

Criteria for Safe Nuclear Development

Measures to ensure safety, security and non-proliferation are weak, in part due to the fractured nature of the nuclear industry and the patchwork of national and international standards to ensure safe deployment and adequate regulatory oversight. Figure 3 demonstrates the adequacy of the "nuclear infrastructure" in selected regions of the world. This is simplistic, but it shows that there is little consistency in approaches to safety and security. It was surprising that an accident the size of Fukushima could happen in Japan, a nation widely regarded as one of the most technically competent in the nuclear world. While the analysis of Fukushima is not yet complete, it is already clear that a contributing factor was the weakness and lack of independence of the regulators, just as that was a major contributing factor to the Gulf oil blowout in the US. One can only imagine what would have happened in such a situation in a less technically competent country.

Learning the lessons of Fukushima will be important but applying them to existing nuclear energy nations as well as those that are seeking to develop nuclear programs will not be simple. The reality is that the growth of nuclear power will have to be accompanied by an unprecedented effort to ensure high safety standards and adequate independent regulatory authorities. There will also need to be a talent pool to operate nuclear power safely. Some nations, such as those in Eastern Europe, have the operating talent but may lack regulatory talent. Russia, Japan and France may have the needed talent pool, but their regulators are not totally independent. We are fortunate in the United States that we have a rigorous NRC; but that only came after learning the lessons of TMI, lessons that took decades to learn and apply in a modern society with a huge talent pool to draw upon from leading universities and national laboratories.

Another challenge of the nuclear world is the ferocious competition among vendors to sell nuclear reactors and services, often led by governments that are seeking international markets to deploy their nuclear energy reactors and systems. As was the case with the recent reactor sale to the UAE, the most economically competitive price is going to be the strongest inducement to make the purchase.[12] Burdening competitive bids with safety options that add to cost is not likely

[10] The economic feasibility of nuclear power is a disputed topic as cost calculations can vary widely depending on externalities (e.g. waste disposal) incorporated into analysis.
[11] Jeremy Carl, Fukushima and the Future of Nuclear Power in China and India, Hoover Institution, Stanford University, 2011.
[12] As noted by the World Nuclear Association, one of the primary reasons the South Korean company KEPCO won the UAE contract over Areva was cost as well as speed on construction. "The choice was on the basis of cost and reliability of building schedule. An application for US Design Certification is likely about 2012." http://world-nuclear.org/info/inf81.html

to be successful. The world is seeking the VW of reactors, not the Mercedes or Lexus. One possible route for worldwide nuclear power growth is to encourage the vendor to put together an entire package of measures to build, implement, train and operate nuclear plants, including take-back of fuel -- basically a turnkey operation. This if coupled with international standards published by the IAEA, and adopted universally by nations new to nuclear as well as those that already have reactors, as well as an independent regulatory agency, would ensure "safety first."

Another issue is that the nations that have the highest safety and security standards (France, Japan and the United States) also have complicated export control regimes. The purpose, of course, is to ensure adequate safeguards but the result is that potential buyers may seek the less costly reactors that are built to lower standards. From the point of view of the United States, this has the practical implication of driving business to competitors who have less rigorous standards. A key element of international cooperation will be the need to improve the regime of technology transfer to a level comparable to the "COCOM" regime during the Cold War.[13] The US valuably insists bilaterally that a nation commit itself to higher standards; but as the US loses the commercial edge in international deals its political power will be reduced.

An interesting recent debate in the Nuclear Suppliers Group's resulted in a decision to refuse to ship sensitive technology to India despite assurances in the US-India nuclear deal. New NSG guidelines would make transferring such technologies more difficult, but it is interesting to note that France is aggressively pushing ahead regardless, as it sees the Indian commercial nuclear market as a huge opportunity.[14]

Complicating the situation is the debate that is emerging in forums like the IAEA. There is a well known balance that IAEA needs to achieve given its diverse membership. In essence, the grand bargain is that the Group of 77 seeks nuclear technology (not only in reactors/fuel cycle technology, but nuclear medicine and other non-electricity nuclear technologies) as a payout for support for non-proliferation, safety and security policies sought by the United States and other OECD/NEA nations. A recent review of the IAEA (20/20 Report[15]) revealed that this grand bargain is necessary to achieve a safe and secure nuclear future.

The legal reach of the IAEA, however, only extends to safeguards; it does not include safety and security. The IAEA can only advise on these functions. During the recent Fukushima accident, the IAEA had to have its Fukushima reporting approved by the Japanese Government prior to release, which led some to criticize the IAEA for its slow response. Today, the IAEA is a watchdog for non-proliferation, but not for safety, but there is hope that new mechanisms will be forthcoming. In its July 2011 letter to IAEA Director General Amano, the International Nuclear Safety Group outlined some of the steps necessary to strengthen the IAEA in this regard, including: increasing world safety standards; expanding peer review services; updating current conventions; and expanding international emergency response and preparedness.[16]

Key Issues:

[13] COCOM stands for the Coordinating Committee for Multilateral Export Controls, which existed from after WWII to 1994.
[14] Timothy J . Roemer France assures NSG waiver for India not undermined. The Economic Times, July 1, 2011. http://articles.economictimes.indiatimes.com/2011-07-01/news/29726119_1_clean-waiver-nsg-waiver-nsg-decision
[15] International Atomic Energy Agency 2008 20/20 Report: http://www.iaea.org/newscenter/news/pdf/2020report0508.pdf
[16] http://www-ns.iaea.org/committees/files/insag/743/INSAGLetterReport20117-26-11.pdf

- Infrastructure and regulation are the keys to a successful and safe nuclear program[17]. Of special importance is the independence of the regulatory body.[18] The events at Fukushima demonstrated the need for a strong independent regulatory system, even in technologically advanced nations. It must be remembered that the US Nuclear Regulatory Commission (NRC), today considered the 'gold standard,' was strengthened because of the lessons learned TMI.

- A strong knowledge base and human capital infrastructure is also necessary for the long-term sustainability of a nuclear program. This includes university programs, research programs, and a large pool of workers.[19] In many developing and newcomer nations, these do not exist and in developed nuclear nations, years of neglect and underfunding, coupled with an upcoming wave of retirements across all nuclear fields, will exacerbate the situation.

- Safety and security are essential parts of any nuclear program, because as we have learned from Fukushima, an accident anywhere is an accident everywhere for nuclear. Without a strong commitment to safety among all nations, worldwide nuclear power growth will be in jeopardy. Without public faith and confidence, especially in developed nuclear nations, nuclear power cannot advance.

- Nonproliferation concerns must also be considered in future technology-sharing agreements and commercial cooperation efforts. This will factor heavily in any government-to-government deal; and already does, as exporting nations (primarily the United States) are very concerned about the nonproliferation risks in newcomer nations. There is also a danger of increased proliferation risk as commercial competition among vendors and concern for sales (many vendors are either state backed or owned) may trump nonproliferation concerns. The nuclear supply change is global and the United States is only one of many supplier nations.

There are many areas of concern when considering nuclear power, the chart below displays which nations/regions are best positioned on each issue.

Figure 3 – *Where Nations Stand*

	Infrastructure	Regulation	Knowledge Base	Safety/Security	Nonproliferation
OECD					
East Europe					
China					
Russia					
India					
SE Asia					
L. America					
Middle East					

The above table uses the color coding below, from best (blue) to lacking (red).

[17] A detailed analysis of the necessary infrastructure is given in an IAEA report "Milestones in the Development of a National Infrastructure for Nuclear Power, IAEA Nuclear energy Series NG-G-3.1, 2007. It is quite detailed and few of the nations new to nuclear power meet a fraction of it criteria.
[18] Nuclear Regulatory Commission's Japan Task Force Report http://pbadupws.nrc.gov/docs/ML1118/ML111861807.pdf
[19] Nuclear Energy Advisory Committee 2008 Report *Nuclear Energy Policies and Technology for the 21st Century* http://www.ne.doe.gov/neac/neacPDFs/NEAC_Final_Report_Web%20Version.pdf

Priorities for Safety

Safety is the most important aspect for nuclear power in all nations with nuclear reactors. All nations should be evaluating current practices in light of the events at Fukushima. Not only developing nations and newcomers should be increasing safety protocols, as the events of Fukushima have demonstrated. In order to ensure safety in global nuclear operations, certain priorities must be set, including the following.

- Energy Policy Planning and Nuclear Energy: In making future energy policy decisions, nations (especially newcomer nations) must factor in all costs associated with nuclear energy, not just the "cash price" for the actual reactor system from the foreign vendor.[20]

- Independent Regulatory Authority: As we have learned from Fukushima, an independent regulatory authority is a must, not only for newcomer or developing nations but all nations that utilize nuclear power.[21]

- Location, Construction and Grid Connection: When determining locations of new reactors, potential natural disasters (e.g. seismic fault lines), population centers and access to the grid should be incorporated into planning.
- Safe Operation: All nuclear nations, both developed and developing, must strictly adhere to the principles of WANO,[22] as this organization is ideally positioned to be at the forefront of the implementation of new safety measures. However, as of now, WANO has no enforcement mechanisms.

- Emergency Preparedness: As demonstrated by the events at Fukushima, when planning for nuclear emergencies, all contingencies must be accounted for including: backup systems; evacuations; command, control, communication; and the role of military/police/national guard etc.[23]

- Security Measures: Though recent events have shifted the focus of nuclear security to preparing for natural disasters, it cannot be forgotten that a great human threat exists as well. Nuclear facilities will always be a potential target for terrorism and must be prepared accordingly.

- Safe Transport of Nuclear Fuel: As more nations, especially developing ones, embrace nuclear energy, there will be a marked increase in the transport of nuclear fuels worldwide (fuel rods, MOX, spent waste fuel, vitrified waste, etc.). International standards have already been universally adopted here.

- On Site Storage: Spent fuel storage on site is an issue for all nuclear nations, including the United States, which currently does not have a permanent waste disposal center. Standards for dry cask and fuel pool storage must be reviewed to reflect the "lessons learned" from Fukushima.[24]

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[20] IAEA 2007 Report, Considerations to Launch a Nuclear Power Programme: Page 9. http://www.iaea.org/NuclearPower/Downloads/Launch_NPP/07-11471_Launch_NPP.pdf
[21] Nuclear Regulatory Commission's Japan Task Force Report http://pbadupws.nrc.gov/docs/ML1118/ML111861807.pdf
[22] WANO 'Principles' http://www.wano.info/about-us/our-mission/
[23] Nuclear Regulatory Commission's Japan Task Force Report http://pbadupws.nrc.gov/docs/ML1118/ML111861807.pdf
[24] The Blue Ribbon Commission on America's Nuclear Future Draft Report http://brc.gov/sites/default/files/documents/brc_draft_report_29jul2011_0.pdf

- Talent Pool: Building an adequate talent pool (education needed for all aspects of the safe application of nuclear technology) is an essential step in establishing a successful nuclear program. This need also extends to developed nuclear nations, where much of the talent pool is close to retirement age.[25]

- Local Community Consensus: Building local consensus (cooperative agreements with local communities) when locating new reactors and nuclear facilities is important in order to facilitate public trust as well as engender an atmosphere of transparency. This also extends to public education on such issues as radiation standards.

- Liability: An adequate liability and compensation system (who pays in event of nuclear disaster) needs to be firmly established before nuclear operations commence in any nation, whether developed or developing. Essentially, the government must step in as the "payer of last resort" due to the scale of potential liability and compensation in the wake of a nuclear accident. The Convention on Supplementary Compensation for Nuclear Damage was put forth to remedy this situation, though not all nuclear nations (including Japan) have signed it.[26]

- Decommissioning: As reactors mature increased awareness of potential decommissioning problems is required. In this regard, the Japanese may consider making the Fukushima Daiichi plant an international center for studying decommissioning strategy. The experience of the Department of Energy and its national laboratories can make an important contribution in this regard.

- Nonproliferation Safeguards: These must be strengthened including onsite monitoring (primarily by the IAEA), especially as nations in proliferation risk regions employ nuclear power on an ever larger scale.

Key Players and Responsibilities

Now that areas of concerns in regards to safety have been documented in the previous section, it becomes necessary to determine where responsibility for fulfilling these obligations lies. The global nuclear energy game indeed has many players spread out between governments, companies and international organizations but what are their individual responsibilities and concerns?

Figure 4 – *Who is Responsible?*

	Commercial	Research	Nonproliferation	Safety/Security
Governments				
Int Orgs (IAEA, NEA)				
NGOs (Wano, INPO)				
Vendors (Areva, Toshiba)				
Operators				
Quasi Official (NSG)				
US Bilateral				
Educational Establishments				

The above table uses the color coding below, from most responsibility (blue) to least (red).

[25] Nuclear Energy Advisory Committee 2008 Report *Nuclear Energy Policies and Technology for the 21st Century* http://www.ne.doe.gov/neac/neacPDFs/NEAC_Final_Report_Web%20Version.pdf

[26] http://www.iaea.org/Publications/Documents/Infcircs/1998/infcirc567.shtml

- Governments: The most important entity, but as noted, there are variations of regulatory independence, talent pool and legal issues (including liability). There are also concerns about conflicts of interest, as governments are responsible for regulation but also for aiding in the commercial advancement of their respective nuclear industries.

- International Organizations (e.g. IAEA and NEA): International organizations, especially the IAEA, could potentially be the most crucial in enhancing worldwide nuclear safety and security. The IAEA has legitimacy among all parties (developed nuclear nations, developing and newcomers etc.) as an independent body.

- Quasi-official Organizations and NGOs: These include such multilateral groups as the Nuclear Suppliers Group, which is a coalition of national governments with the aim of preventing proliferation. There are also organizations to ensure worldwide commercial and operational nuclear safety, such as the World Association of Nuclear Operators (WANO) and the Institute of Nuclear Power Operators (INPO).[27]

- State Backed Vendors: Nations such as France, Russia and South Korea have large state backed or owned companies that are aggressively competing for a share of the world commercial nuclear power market. This has large safety, security and nonproliferation implications as conflicts of interest can arise. Also, as their influence in commercial nuclear increases, U.S. influence may wane on safety, security and non-proliferation. This is a strategic issue and requires a change in thinking about how U.S. industry and government interact to advance mutual interests.

- Electric Utilities and Plant Operators: The actual electric utilities are large players in whether or not nuclear power expands. The actual nuclear operators are also pivotal in the implementation and execution of new safety and security initiatives and must be included in any planning; in essence, they are the 'front line.'

- Inter-Governmental Agreements: Long established agreements between advanced nuclear powers (such as the US-Japan Nuclear Accord[28] and the US-Euratom Nuclear Accord[29]) have facilitated much scientific cooperation and expertise sharing over the past decades. As new nations push for nuclear power, there are also technology sharing agreements established or in the works between advanced nuclear nations and advancing newcomers (e.g. the US-India Nuclear Accord[30] and the US-UAE Nuclear Accord[31]).

- Educational Establishments: As nuclear power expands worldwide, educational establishments) will need to be enhanced and capabilities boosted, as not only does the talent pool originate from here but so does much of the groundbreaking research. At the university level, it will also be important to educate the future nuclear leaders of the world on the merits and necessity of safety, security and nonproliferation norms. In the United States, operators have benefited from the expanded program of community

[27] http://www.inpo.info/
[28] Text of US-Japan Nuclear Accord available at: http://nnsa.energy.gov/sites/default/files/nnsa/inlinefiles/Japan_123.pdf
[29] Text of US-Eurotom Nuclear Accord available at: http://nnsa.energy.gov/sites/default/files/nnsa/inlinefiles/Euratom_123.pdf
[30] Text of US-India Nuclear Accord available at: http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=109_cong_bills&docid=f:h5682enr.txt.pdf
[31] Text of US-UAE Nuclear Accord available at: http://www.fas.org/man/eprint/uae-nuclear.pdf

colleges for a technical nuclear degree and one can envision a growing market for education and certification online, perhaps coordinated through the IAEA.

Case Examples: Where Nations Stand

Each nation involved with nuclear power has its own regulatory system, responsibilities and priorities for the future, which can make coming up with a 'global standard' difficult. The wide range of national situations is described below.

- United States: The US has a strong and independent regulator (NRC) derived from the 'lessons learned' from TMI (unique role of INPO). It also has a strong talent pool with a high technical ability. It does not engage in reprocessing and has problems with the implementation of permanent waste disposal (e.g. Yucca Mountain).

- France: It has a successful program based on standardization and a partially closed fuel cycle (reprocessing). Its government exercises control over its main operators, AREVA and EDF domestically, and is aggressive in pursuing international sales.

- UK: It has a successful program and has plans to expand with a decently sized pool of talent. It engages in reprocessing (for other nations) as well as limited international commercial endeavors.

- Russia: It has a large and scientifically diverse talent pool, a legacy of the Soviet Union, but serious safety, regulatory and nonproliferation concerns exist as it pushes aggressively into international commercial markets in its current incarnation of the ROSATOM State Nuclear Energy Corporation.[32]

- South Korea: This is a fast growing program (both in size and level of expertise) with a good safety, security and nonproliferation record (though there are some concerns about material diversion) but it wants to engage in domestic reprocessing. It is also a new but powerful player in international commercial deals (e.g. with the UAE). Korea Hydro and Nuclear Power Co. recently announced its intent to develop a reactor with enhanced safety features.[33]

- Japan: A previously strong proponent of nuclear power, Japan has a diverse and large program with the obvious complications arising out of the Fukushima accident. It will need nuclear in the long-run to meet its energy demand but the implications of Fukushima and lessons learned are far from settled.

- China: Asia's largest economy has a program that is fast expanding (both in size and level of technology) as it races to meet electricity demand. Though it is not a large player in international commercial markets yet, there is potential.[34] China is working on indigenous designs and intends to be a global supplier.

[32] http://www.rosatom.ru/en/
[33] http://english.cri.cn/6966/2011/08/31/2743s656094.htm
[34] Jeremy Carl, Fukushima and the Future of Nuclear Power in China and India, Hoover Institution, Stanford University, 2011.

- India: This is a huge potential market but currently the program is quite minimal. There are large nonproliferation concerns on the political side and liability/compensation issues in regards to international vendors successfully beginning projects.[35]

- South Africa: This is a small program but the government is very keen on expanding via international vendors. Also, it is currently in talks with other governments about inter-governmental agreements, including the United States.

Integrated Approaches to Global Safety and Security

With this expansion, especially in 'newcomer' nations, certain questions arise. Primarily, how can a nation without the necessary technological, regulatory and infrastructure development successfully create a safe and secure nuclear program? Nuclear nations would be well advised to follow the guidelines laid out in the 2007 IAEA report *Considerations to Launch a Nuclear Power Programme.*[36]

As demonstrated, many of the nations and regions where the primary growth in nuclear power is projected to occur have serious infrastructure, regulatory, knowledge and safety/security shortcomings. It will be essential to address these areas of concern if these programs are to be safe and secure. In these newcomer nations, will there be fuel-take-back arrangements? Will there be local storage and/or a geologic repository for used fuel? Should newcomer nations be allowed to enrich their own fuel? What are the nonproliferation implications? For this nuclear expansion to be successful, especially among newcomer nations, these issues must be resolved and the fuel cycle has to be closed in one-way or another (either through reprocessing of spent fuel or permanent disposal).

Safety and security, especially among newcomer nations, will be critical to the advancement of nuclear power globally. The natural place for the coordination of safety and security programs is the IAEA, which already has substantial infrastructure and experience in this regard but it must be recognized that though the IAEA has 'watch dog' status for safeguards, but the same is not true for safety in general, an important distinction.

It is one thing to identify the specific measures that need to be implemented. It is another to apply them systematically, fairly and globally. There are, of course, different degrees of balance between national self-interest and governance and international measures that benefit the "law of the commons." Anybody can come up with a checklist of what needs to be done, the key will be implementation and this could be quite complicated in terms of safe nuclear power operation globally.

Three Possible Scenarios

Business as Usual: First, one could consider the current situation as a "business as usual" case. Nuclear power is expanded primarily via commercial operations and priorities with a patchwork of national and international standards that are applied. Safety and security measures are not standardized and are a hit or miss proposition. This is an incremental approach where commercial interests and bidding set the standard in many countries. The advantage of this is

[35] Carl, Ibid.
[36] IAEA 2007 Report, Considerations to Launch a Nuclear Power Programme: http://www.iaea.org/NuclearPower/Downloads/Launch_NPP/07-11471_Launch_NPP.pdf

that nuclear power is primarily in the hands of the host nation. Respectable teams can be assembled internationally to assist in the development and training centers can be enhanced, even put "on-line". In this world we would expect that vendors would play an important role in furnishing turn-key operations. The main consideration of the buyer is likely to be price.

A key issue is maintenance, operation and safety reviews down the road as the task of running the reactor is left to the host nation. Regulatory systems will be established but their independence and effectiveness will vary. The opportunities for corrupt practices in "non transparent situations" may be prevalent, working against the interests of nations such as the US that have strong foreign anti-corruption legislation. The US can use its bilateral diplomatic powers in exchanges with new nuclear energy states to encourage safe nuclear development. A key issue will be the extent to which new nuclear states want to have domestic fuel cycle ability, something that the US has sought to minimize for over four decades.

Strengthened International Conventions: A second approach is to negotiate a stronger international safety and regulatory system with teeth. Clearly the international community is moving in the direction of standardizing safety, but we do not have the legal enforcement frameworks necessary to ensure compliance. International standards with strong legal enforcement by national authorities (the likely mode) or by international organizations (an unlikely mode) can help. Strong penalties may be necessary that can be applied to inadequate construction by vendors or irresponsible operation by operators. This approach would respect the intentions of nations but basically put international nuclear development under international legal guidelines.

We should review the Convention on Nuclear Safety[37] (1994), the Convention on Early Notification of a Nuclear Accident[38] (1986), and the Convention on Assistance in the Case of Nuclear Accident or Radiological Emergency[39] (1986) as they might be strengthened in light of Fukushima accident. The original conventions were established following the Chernobyl accident. Timely review and adjustment in light of Fukushima can strengthen these international standards.

We could also expect under this more aggressive approach that host nations would be encouraged to contract full nuclear services from their vendors. Agreement of vendors to "rules of the road" in the construction and operation of nuclear reactors might benefit the host nation -- and under these circumstances we would see an enhancement of WANO. Key to this system would be agreement among key nuclear suppliers to go beyond nuclear supplier group guidelines to a stronger, more comprehensive system that takes a systemic review of a country's nuclear development, including fuel cycle, reactor development, independent regulatory oversight, safe operation and back-end issues, including waste disposal. This approach is not without political problems. Weapons states have historically not wanted to open up their operations and stockpiles for inspection. Likewise, the US, France Russia, and Japan may not wish to abide by new international treaties.

This might become a serious international problem within the IAEA as the delicate balance between safeguards (wanted by OECD) and technology transfer (wanted by developing countries) is shaken, especially if the process is perceived as lecturing developing countries. It also goes back to the old argument similar to climate change and North-South debates: "You

[37] http://www-ns.iaea.org/conventions/nuclear-safety.asp
[38] http://www.iaea.org/Publications/Documents/Infcircs/Others/infcirc335.shtml
[39] http://www.iaea.org/Publications/Documents/Conventions/cacnare.html

industrialized countries had the opportunity to develop your programs as you wished; now you are telling us how to manage our programs." Indeed this would be the case and there could be issues of pride if outside contractors were given responsibility for "cradle to grave" services. Higher standards would necessarily result in an increase in reactor costs, perhaps adding 5% or more to the cost of a plant. The added cost could be split between the host country and the international community.

A Novel Approach: There might be another option - impractical perhaps but interesting if one continues the multinational approach to an extreme. One could imagine reactors being leased to the purchaser nation with the actual site of the reactor being international ground (like an Embassy). The international community would help subsidize the building of the reactor, buy the land, provide adequate safety features and produce electricity and take responsibility for the backup. The IAEA could have an independent regulatory body (built on United States NRC principles). The host country would be responsible for purchasing electricity with a long-term contract, enabling the international community to "bid out" the construction and operation to vendors. The expectation of this international approach would be that the host nation wants electricity and not necessarily the responsibility for running the plant. The international community is reassured that the "safety first" principle is applied and that the service would offer "cradle to grave" fuel services. The international body governing the construction and operation of the plants can thus begin to systematize and standardize key safety and regulatory concerns and raise the bar for safe operation. The host country would benefit via subsidization from a nuclear energy bank with oversight of the International Atomic Energy Agency.

The downside of this approach -- and it is a major downside -- is that it may reduce the impact of vendors from the United States with greater reliance on large, integrated state vendors - perhaps from Russia, South Korea, France and eventually China. One could argue that a multilateral approach may reduce safety to the least common denominator and work against the interests of the struggling US industry. Others can legitimately argue that the IAEA is not prepared to manage such an enterprise with burdensome governing procedures. Such a plan for international cooperation would need to be crafted with major input and leadership from the United States government and industry to ensure that safety, security and non-proliferation efforts are highly maintained.

These three approaches – and they are not mutually exclusive – illustrate the challenge of balancing national sovereignty and multilateral objectives; economy of electricity production versus the added costs implied by high security, safety and non-proliferation standards; and integrating the many private sector and government interests to provide for a safer global nuclear energy landscape.

The Role of the United States

The US was once the leader in the development of nuclear energy technology. However, in the last few decades we have started many things and finished nothing. Each new administration seems to bring in a change in direction. The United States, once the world leader in the development of nuclear energy, today is not even classified as among those leaders. Westinghouse, whose AP 1000 design is the first of the Generation III+ reactors to be licensed in the US, is a wholly owned subsidiary of Japan's Toshiba, and GE works in collaboration with Hitachi on nuclear reactors. We could have a major influence, but not until we get our own house in order and develop a coherent long range view. An example of a nuclear technology where the United States has 'started but not finished' is small module reactors or SMRs. This

highly promising tech (basically small, transportable, contained and fueled reactors) could become an area where the US can take the lead.

Where we are still the recognized leader is in the regulation and oversight of our fleet of reactors, including not only the government role, but the role of industry itself. The Three Mile Island accident led to a considerable strengthening of the powers of our NRC and to the creation by nuclear reactor operators of the Institute of Nuclear Power Operations (INPO) with a mission "to promote the highest levels of safety and reliability." This includes preparing a workforce for the future, and indeed INPO would be a model for capacity expansion in many countries.

INPO has led to a free exchange of operations information which in turn has enabled the industry to increase reactor "up-time" from about 60% before its creation to over 90% today. Generation of 50% more electricity from the same capital stock is a powerful incentive for cooperation. INPO's example has led to the creation of a similar World Association of Nuclear Operations (WANO), though WANO does not have the authority of INPO.

An encouraging sign of continued interest in some sort of US leadership, though mainly in regard to security and nonproliferation rather than energy, was the gathering of world leaders at the request of President Obama in April 20l0 to address the issue of accounting for and protecting nuclear materials. Not since the founding of the United Nations had so many leaders gathered on American soil. Fifty leaders pledged to a communiqué with 50 action items. This effort will be followed up with a second nuclear summit hosted by South Korea in April 20l2. Most of this summit will focus on securing nuclear materials and that is a wise approach since there are so many conferences on the "lessons of Fukushima" and safety.

At the same time it would be appropriate to introduce the importance of improving the international standards for safety, since all nations will be impacted in this increasingly small and interconnected world. For example, the US emergency response teams that can be deployed internationally as well as domestically could serve as model for a truly international response team, with French, Japanese and American personnel. Also, in regards to clean up efforts, the US DOE has much experience in this area (cleaning up former weapons sites in the US) and could aid in the current Japanese efforts (the 800 square mile zone in Fukushima) as well as teach its methods to an international response group.

Conclusions

In much the way that our energy system and financial systems are international, so is the nuclear world (energy, weapons, medicine and advanced technology). The difference between the financial and energy world is that massive physical damage can result from catastrophic nuclear events whether it be terrorism, lapses in safety or natural disaster. These can be intentional, due to human error or the product of natural events. One recalls the trigger situation of the Cold War where a small misunderstanding could have lead to catastrophic consequences. In a way, we were lucky with the Fukushima accident that it has been largely contained; a remarkable achievement by the Japanese industry and government. But if "it" can happen in Japan, Ukraine and the US, we need to take measures today to reduce the risk, especially as we reduce the broader risk of nuclear weapons and commit ourselves to gradual elimination of all nuclear weapons.

The issues are interconnected and yet the management is fragmented. A systematic approach to these issues needs to be taken. This is not necessarily a technology problem, although nuclear

technologies on the horizon with regards to reactors (SMR, Gen-IV) and fuel cycle technology will greatly assist our efforts. Rather, the challenge is one of collective responsibility in a global world. Nuclear radiation can cross borders as was the case with Chernobyl. The consequences of a safety failure can not necessarily be limited to the place where that failure took place so safety is not a purely national concern and requires strong international control.

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