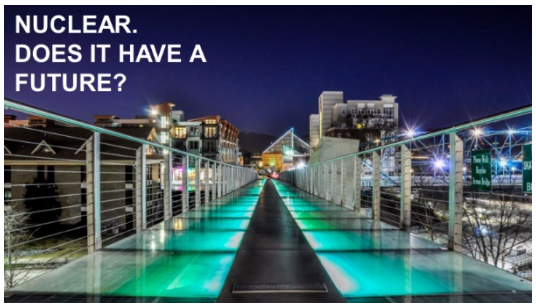
# Nuclear. Does it Have a Future?

Steven P. Kraft*

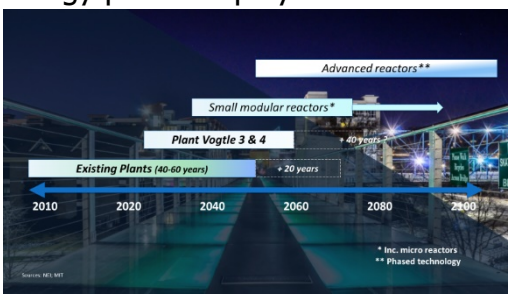
- Nuclear energy will have a brilliant future in the U.S. if a nuclear industry/federal partnership addresses a critical set of complex, interrelated issues.
- Strong, consistent political leadership at all levels with on-going communication with the public is needed.
- Actions must be taken to both assure that the current fleet of nuclear plants thrive, and future plants will be available and desired.




The short answer is 'yes!' While there is a growing interest worldwide, for nuclear energy to have a future in the U.S. a set of complex, interrelated moving parts must come together. Technical, demand, revenue, financing, and politics all loom large.

While nuclear energy provides unparalleled benefits[1] it must also be a successful business. Much has been accomplished, but more needs to be done to assure this success.

***Current Timelines** provide hope.* Following completion of Georgia Power's Plant Vogtle Units 3 & 4 (2243 MWe central generating station) in 2021 and 2022, respectively,[2] small modular and/or micro-reactors will most likely be the next nuclear energy plants deployed.




*Current Timelines*

Optimistic timelines for future development demonstrate the potential for success. However, they are – at best – notional and can mislead if not viewed in context with the potential for inevitable technical setbacks and what resources and actions are needed to bring about desired outcomes. While the timeline for advanced reactors (non-aqueous coolants) is less certain than small modular and micro-reactors, their continued development is vital for both future and present energy needs.

Continuing to develop advanced reactors now assures that the technology will be available when needed later in the 21st Century offering benefits that current and near- and mid-term technologies simply cannot. Just as importantly, continuing to develop advanced technologies provides a critical impetus to keep the current fleet in operation,

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completing those units under construction and deploying near- and mid-term technologies.

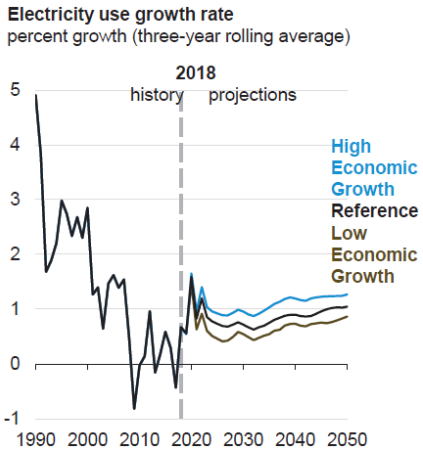

***Technical** issues are the least of the challenges.* Much improvement has been made across the broad waterfront of operations, maintenance, engineering, licensing, cost reduction, technical bases and advances, regulation, licensing, etc. In each of these areas, utilities, suppliers, advanced reactor development organizations,[3] industry organizations,[4] utilities, US Nuclear Regulatory Commission (NRC), US Department of Energy (DOE), etc. have been working with a purpose on technical issues.

There have been many recent positive developments that tell this part of the story. Current nuclear electricity fleet average total generating cost has been reduced 32% below the 2012 average, the highest cost year since 2002[5] and fleet average capacity factor is at 93%.[6] NRC has become more efficient in its operations and decision-making.[7]

NRC and Canadian Nuclear Safety Commission signed an "historic Memorandum of Cooperation" to collaborate on "technical reviews of advanced reactor and small modular reactor technologies."[8] BWXT announced that it will restart its existing TRISO[9] nuclear fuel production line with plans to expand.[10] (TRISO will fuel micro-reactors, space reactors, and advanced reactors.) DOE and NRC signed a Memorandum of Understanding to share technical expertise and computing resources to speed up the deployment of advanced nuclear technologies.[11] DOE is conducting an advanced reactor demonstration program[12] as directed by Congress in FY2020 appropriations.[13]

Development of all future nuclear technologies and related regulations is well in hand. Despite these critical advances, far more is needed to meet the challenges to nuclear energy's future.

***Demand** growth is required.* Absent an unpredicted major upsurge in electric vehicle market penetration,[14] electricity demand growth will remain virtually flat at least until 2050.[15,16] New generating facilities will be built only to replace plants removed from service. Inexpensive natural gas (due to fracking), renewables (wind and solar) assisted by policy decisions and electricity market rules[17] have successfully pushed a number baseload nuclear plants into load following operation (reducing capacity factor) or premature retirement.[18] Unless public policies, market protocols, and tax rules that recognize the benefits of nuclear



energy are widely adopted, additional plants will be at risk of early closure[19] and there will be negative effects on any future plants.

*Revenue must support current and future generation.* Nuclear energy is a business and, despite the vast benefits it provides, unless revenues are enough to, at least, support current operations, it cannot last. This is not unique for any business. Only five states (NY, IL, CT, NJ and OH) have provided by law, regulation, or policy a correction to the market allowing nuclear plants to continue operating for the benefits they provide saving 14 units from premature closure. No others appear on the horizon and the federal government seems not inclined to act.[20]

Insufficient revenue (for most cases), state policy issues or technical reasons have, since 2013, forced nine units into early closing and, if nothing is done, eight more units will face the same fate. This does not bode well for the future of nuclear energy in the U.S.

*Financing is of great importance.* Organizations that purchase and operate nuclear generating units and those that provide the large amounts of money to do so are, understandably, extremely risk adverse. Utilities, whether subject to electricity market rules or cost-based rate regulation, have very strong incentives to keep the cost of generation as low as they can. Higher generation costs compromise either the company's ability to bid into future electricity markets or keep within rates set by public utility commissions or other governance.[21] In either case, persistent higher nuclear generation costs compared with other technologies has led to the premature closure of nuclear units.

New nuclear plants currently appear to have financial support sufficient for their status afforded by interested individuals, organizations, or governance. Plant Vogtle Units 3 & 4 construction are funded by traditional utility methods (equity, debt, and rates) backed by federal loan guarantees. Small modular reactors (SMRs) that are slated for demonstration, spurred on by the stated interest by several western states and a utility, have industrial and federal involvement and funding.[22] Advanced reactors, with their greater research and development needs and longer timelines, have the backing of individuals, venture financing companies and federal money. However, commercial construction of SMRs and advanced reactors will require traditional utility financing.

*RISK drives everything finance.* For utilities to be willing to build, and attract acceptable financing for, any new generation facility – let alone advanced nuclear technology – requires concrete knowledge that the risk of doing so is, at a minimum, manageable. Future electricity demand, cost to develop and put in commercial operation, success of the technology, ability to license, and political and public support are some of the major risk factors.

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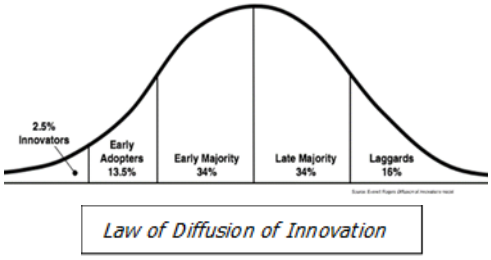
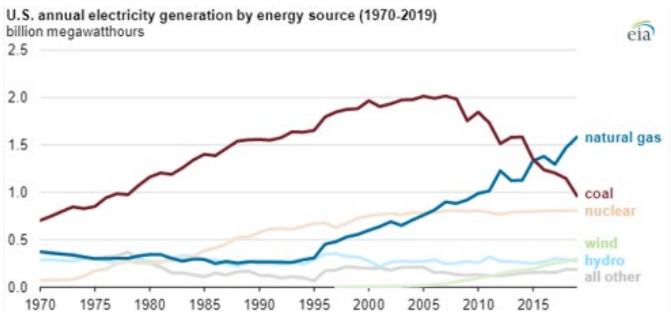
Technology development is a continuum as the well-known progression of space flight, smart phones, and nuclear energy show. Advanced technology developers learn from successes and failures along the way. *The Law of Diffusion of Innovation*[23] teaches that there is always someone wanting to adopt the 'the next big thing;' recall the lengthy and early forming lines to purchase the first *iPhone®*[24] in 2007. Most technology users and their investors, however, need to witness successful experience with the technology, level of acceptance by others and market behavior to assess the risks of taking the plunge. Which is not to say that utilities are unwilling to fund and engage in development of advanced nuclear technology.[25,26] Just not willing to place a lot of resources at risk to do so. Utilities and their investors are at the mean, if not to the right of the mean, of the diffusion of innovation bell curve.

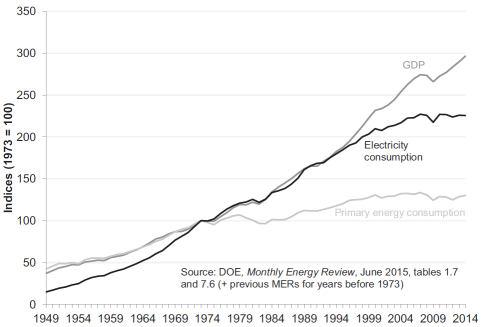


Law of Diffusion of Innovation

A notable exception might be development and deployment of micro-reactors (~1-10 MWe compact containerized fast reactor that can operate independent of a power grid) of interest to the U.S. Department of Defense.[27] Micro-reactors will also provide important development information for larger advanced reactors. If successfully demonstrated and licensed, micro-reactors could be of interest to remote communities.

***Politics*** *drives everything* and strong political leadership is crucial. Nuclear energy will have a future in the U.S. only if its advocates can master technical, finance and political issues simultaneously, which is further complicated by the flat growth in electricity demand. Without growing electricity demand that would require additional baseload power stations on the U.S. grid along with the lower costs at the meter, it becomes a challenge to make the political case for new nuclear to remain in the future energy mix, despite its benefits, as a replacement for plants removed from service. To-date, that replacement has be natural gas.[28]



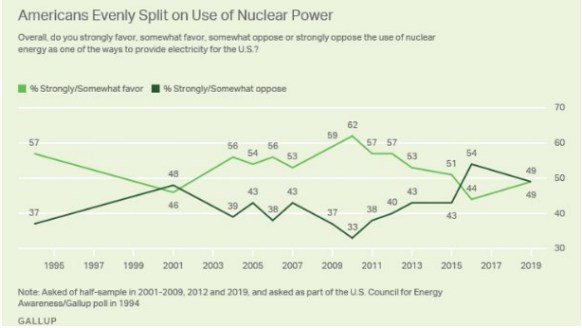




From the early 1970s through the early 1990s, growth in U.S. electricity use and Gross Domestic Product ran hand-in-hand[29] and 1973 saw the single year record for ordering new nuclear power plants – 41.[30] After shocks to the U.S. economy (oil embargoes (1970s)[31,32] and the unprecedented period of "stagflation"[33] (second half of the 1970s)), the enactment federal energy efficiency legislation,[34] and the drive for lower energy costs

throughout the U.S. economy disconnected electricity and GDP growth. While U.S. GDP continued to grow (including rebounding from the 2008-09 Great Recession[35]), electricity growth dropped and by 2000 flattened.

Political leaders respond to public opinion – one way or another. With the public's interest in both reliable electricity and clean air,[36] it is not surprising that Congress and the Administration have been driving advanced reactor development, demonstration and deployment enacting new federal laws[37] with more pending[38] and providing appropriations.[39] Whether this support will translate into concrete action to assist the current fleet economically remains to be seen.

How the public responds to opinion surveys[40] is very much dependent on context and knowledge about the subject.[41] Regarding nuclear energy, the idea of yet to be developed plants providing desired benefits is a far cry from the simple question 'Do you favor the use of nuclear energy?' The answers are more favorable when the public is concerned about energy supplies or rising prices.[42] While folks living near nuclear plants have had noticeably more favorable views consistently over the years, the same cannot not be said about the public in general.[43]




***Yes*** *- nuclear energy can have a brilliant future!* The U.S. nuclear energy industry and federal government need to come together in a true partnership with a common purpose that transcends the political cycle to work on a set of complex, interrelated elements.

Assuring the current fleet can thrive by continuing to lower the cost of current nuclear generation while maintaining the high levels of safe operations and working with federal, state, and regional bodies to correct the electricity markets to compensate nuclear electricity for its true value. Assuring future nuclear energy facilities will be available and desired by continuing programs to develop and demonstrate small modular and advanced reactors, so investment and operational risks are manageable.

By spurring significant market penetration of electric vehicles, future electricity demand will increase responsibly creating a natural market for nuclear generation facilities beyond just replacing plants removed from service.

But, at the end of the day, the single most important action is strong, consistent national and local political leadership based on a continuing stream of information to the public.

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