FROM ITS BIRTHPLACE:
A Symposium on the Future of Nuclear Power

March 27 and 28, 2012

Presented by the University of Pittsburgh
Dick Thornburgh Forum for Law and Public Policy
and the Swanson School of Engineering

On March 28, 1979 the world's first nuclear accident occurred at the Three Mile Island power plant in Pennsylvania. For the next several decades[1] no new nuclear power plants were built in the United States. Propelled by energy demand, climate change concerns, and the safe operating record of U.S. nuclear power plants, attitudes in the U.S. in favor of increased use of nuclear power strengthened and mirrored the global "nuclear renaissance." Approvals were given for the construction of new power plants in the southeastern U.S. However, falling natural gas prices in the U.S. in recent years has reduced the economic competitiveness of nuclear power. And a year ago, in March 2011, an unimagined pair of natural disasters triggered the Fukushima-Daiichi accident, giving the world cause, once again, to re-evaluate nuclear power. It is at this decision point that the present symposium was held to consider the future of nuclear power in the United States from a wide range of viewpoints.

We are indebted and express our appreciation to
the **Richard King Mellon Foundation** and the **Hillman Foundation**
for their support which helped to make this symposium possible.

[1] In 1977 the River Bend nuclear power plant had entered construction, and no nuclear power plant was started again in the U.S. until February 2012, when the NRS issued a combined license (COL) to the Southern Nuclear Operating Company for Vogtle Units 3 and 4. Nevertheless, 49 new commercial reactors whose construction had begun prior to the TMI accident came into service in existing power plants during the 1980's and 1990's.

Foreword

This symposium stands distinctly apart from others because of the attention that Pittsburgh commands as the birthplace of nuclear power and hub of energy industries, and the seminal posture of Pennsylvania's Three Mile Island accident to this day as a case study in nuclear crisis management.

The experience at Three Mile Island was thrust to the forefront again in March 2011 by the Fukushima Daiichi disaster. Indeed, March 2012 marked both the first anniversary of Fukushima Daiichi and the thirty-third anniversary of Three Mile Island.

The symposium featured a broad span of distinguished guest speakers from leadership in nuclear industry, specialists in fossil fuel and passive energy sources, academic and scientific constituencies, executives from federal, state, and local agencies within the United States, and representatives from overseas.

Dick Thornburgh, whose Forum for Law and Public Policy at the University of Pittsburgh initiated this symposium, was Governor of Pennsylvania at the time of the accident at Three Mile Island in 1979. Videos and more information about Three Mile Island are available at the Forum archive website: www.library.pitt.edu/thornburgh/index.html

The main topics of the four symposium sessions were:

Nuclear Power and Energy Alternatives

America's Nuclear Future

Three Mile Island, Chernobyl, and Fukushima Daiichi

Political, Legal, and Financial Aspects of Nuclear Power

All the presentations were videotaped and can be viewed on the symposium website, Thornburghforum.pitt.edu which also provides biographies of the symposium participants. In light of the significance of the topic to national interests, this report has been prepared as well to summarize each presentation, the ensuing discussions, and the conclusions. [2] Readers are directed to the excellent videotape on the website for details of any part of this report that interests them.

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[2] These summaries of the presentations, discussions, and conclusions were prepared by Dr. Marsha Torr (www.YourScienceEditors.com).

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Opening Remarks

Introduction of Governor Thornburgh

Mark A. Nordenberg, Chancellor, University of Pittsburgh[3]
March 27, 2012

Any university makes many of its most important contributions through the accomplishments of its graduates. In this respect, few compare with the record of impact and achievement of Dick Thornburgh. As a graduate of the University of Pittsburgh School of Law, he has served as:

- The United States Attorney for the Western District of Pennsylvania
- Assistant U.S. Attorney General in charge of the Criminal Division
- The highly respected two-term Governor of Pennsylvania
- The Attorney General of the United States
- A distinguished attorney in private practice, always with the firm now known as K&L Gates, where he crafted a particular reputation in areas broadly related to ethics—in the private sector and in public life
- A respected author and commentator
- A member of the University of Pittsburgh Board of Trustees

What sets Dick apart is not that he served in all these important roles, but that he accomplished so much good in all of them. And no matter how elevated the positions, his feet always remained firmly planted on the ground. Approachable and available, he has always been an exemplar of all the positive traits that we seek in a leader.

This symposium is being presented by the Dick Thornburgh Forum for Law and Public Policy housed in the University Honors College, and is co-sponsored by the Swanson School of Engineering. The University of Pittsburgh is also home to the Thornburgh Archives. Embedded in the Archives are materials that would support many case studies in leadership from the Governor's long and distinguished career. But perhaps no stronger case can be made for the quality of that leadership than the Governor's response to the accident at the Three Mile Island nuclear facility.

Tomorrow marks the 33rd anniversary of that event, which occurred in the early days of the Governor's first term. He had no road map and limited resources in dealing with the world's first nuclear power plant emergency. With the assistance of able colleagues, such as Harold Denton, of the Nuclear Regulatory Commission (NRC) —whose calm competence conveyed through regular television appearances became a source of reassurance for the entire country—the Governor dealt with what could have been a catastrophe swiftly and successfully. His actions are viewed by many as a model for crisis response.

[3] Mark A. Nordenberg is the 17th Chancellor of the University of Pittsburgh. He joined the School of Law in 1977; served as Dean of the School of Law from 1985-1993; and became Chancellor of the University in 1995. His legal specialization is civil litigation.

But it is not just the timing of that anniversary that makes the University of Pittsburgh and Pittsburgh the ideal setting for this program. As the symposium's title indicates, this region became the birthplace of nuclear power when the Atomic Energy Commission signed a 1948 contract with the Westinghouse Electric Corporation to build and operate a laboratory to develop a nuclear power system for naval applications. A year later the Bettis Atomic Power Laboratory opened in West Mifflin.

In a matter of years, the Bettis Lab developed not only the technologies for the first nuclear-powered submarine—the USS Nautilus, which was launched in 1955—but also the technologies that continue to define nuclear power. The Bettis Lab was responsible for the design and construction of Shippingport Atomic Power Station—"the world's first full-scale atomic electric power plant devoted exclusively to peacetime uses." When Shippingport went online in 1957, Pittsburgh became the first city to have shops and homes using electricity supplied by nuclear power. And we are all proud that Westinghouse remains such a positive force, both in the field of nuclear energy and in this community.

Of course, this region's roots in energy are even broader and extend much further back in time. The era of modern oil production, to give one key example, was launched when the world's first oil well was drilled in Titusville in 1859. And this region has always been one of the world's leading producers of coal. Today the potential of the Marcellus Shale often dominates discussions of both national energy security and regional economic growth. This is also a region with developed strengths in renewables, in energy transmission, and in environmental and green building technologies. Looking at our regional portfolio, it is easy to see why Pittsburgh lays claim to being the "New Center of American Energy."

This region is also the "New Center of Energy Innovation." In addition to research conducted within sector companies themselves, we are home to the National Energy Technology Laboratory, which is so ably and ambitiously led by Dr. Anthony Cugini. Within the Department of Energy, NETL has principal responsibility for natural gas, coal and oil technologies and supports a program of research that will both advance current initiatives and benefit generations to come. Two years ago, on NETL's 100th birthday, we formed an expanded university alliance to serve as NETL's principal academic partner. The University Energy Partnership also includes Carnegie Mellon, Penn State, Virginia Tech and West Virginia Universities.

Within the University of Pittsburgh itself, the high priority that we have assigned to education and research in the energy area is reflected in the creation of our Center for Energy, which consists of more than 70 world class faculty members and their research teams. A few weeks ago, the Center received a three-year $22 million grant from the Richard King Mellon Foundation as an investment in the University and the region, since "energy will be the major driver of our regional economy for years to come." The understandings to be developed through this symposium will be central to that future.

The Goals of the Symposium

Governor Dick Thornburgh[4]
March 27, 2012

Governor Thornburgh, speaking for the Dick Thornburgh Forum for Law and Public Policy, thanked the contributors to the event and all of those who provided major support in enabling it, including Chancellor Mark Nordenberg, John Swanson and the Swanson School of Engineering, Dean Gerry Holder of the Swanson School, John Metzger, Director of the Nuclear Engineering Program, Ed McCord, Director of the Thornburgh Forum, and Kimberly Carson, Administrator of the Thornburgh Forum. Governor Thornburgh then outlined the goals of the symposium as follows:

From the birthplace! There could be no more appropriate title, timeframe or venue for this event than we have here. The Pittsburgh region has been a national center of coal, oil, nuclear energy, and now shale gas technology and production. On a less happy note, thirty-three years ago tomorrow, the world's first nuclear accident at a nuclear plant occurred in the Commonwealth of Pennsylvania at Three Mile Island. It was near the State's capital of Harrisburg where I had just finished my first ten weeks as Pennsylvania's Governor. Thirty-three years ago, my morning breakfast meeting on budget matters with a group of opposition legislators was interrupted by a phone call from our emergency management director notifying me of the accident at Three Mile Island nuclear power plant. This began a 10-day media event before calm was restored, much thanks to the real hero of Three Mile Island, the NRC's Harold Denton, who joins us here today. And a year ago we had the accident, much more serious in its nature, at Japan's Fukushima-Daiichi nuclear facility. All of this and more we will discuss in the next two days in this gathering of experts from a wide variety of vantage points.

The four panels that we have assembled will each spend half a day on discrete subjects and, with the aid of able moderators, will develop a perspective of useful information to further inform us and the world at large on current issues, problems and opportunities in the field of nuclear power. Recent headlines and news reports have suggested a few of the areas that will no doubt shape this exercise. Safety and other concerns were highlighted by the Fukushima-Daiichi accident, and we will examine the lessons learned from the earlier Three Mile Island and Chernobyl accidents. The German Government recently stated its intention to shut down all its nuclear capabilities. Four new nuclear reactors have been approved for construction in the southeastern United States and will be the first new nuclear facilities in this country since the Three Mile Island accident.

There has been a change in attitude recently by some environmentalists towards nuclear power that is colored by carbon reduction and other climate change challenges. Recurring concerns about spent nuclear fuel remain unresolved. We find that our future in nuclear energy depends on developments in tapping other energy resources, most notably fossil

[4] Dick Thornburgh has served as Governor of Pennsylvania through two terms, Attorney General of the United States, and Under-Secretary-General of the United Nations. He is an emeritus member of the Board of Trustees of the University of Pittsburgh.

fuels. Inevitably, there are political, financial, and legal concerns about nuclear power that must be on the agenda. Before we wrap up at the end of tomorrow's activities, you will hear from many people who are eminently qualified to help us evaluate and respond to these matters.

It is not our intention to provide definitive answers to all of the questions that will be raised in these days. Nor do we intend to support or oppose any particular position. Instead, the views expressed in this symposium will help energy policy decision makers, as well as public and private sector leaders and the public at large, consider these issues for themselves and make better judgments about our nuclear energy future.

Many thanks to all who have gathered with us to join in this dialogue.

Session A: Nuclear Power and Energy Alternatives

Moderator: David Shribman, Executive Editor, Pittsburgh Post-Gazette

March 27, 2012

The Future of the Nuclear Option for the United States

Jim Ferland[5]

For many years Westinghouse was one of the central companies in Pittsburgh. In its earlier years Westinghouse was highly diversified, but today, as a $5 billion company, it is almost solely focused on nuclear energy. Its expertise extends from nuclear services and digital operation for power plants, to nuclear fuel, to building nuclear power plants around the world. Westinghouse does not believe that nuclear energy is the sole answer, but understands that we need a diversified energy portfolio. Diversification of energy supplies at the state, national and global level is a good thing. Today nuclear energy provides about 13% of the world's electrical energy supply, and just under 20% of electrical energy in the United States. Nuclear energy should be part of any future energy landscape for many reasons, including its response to the increasing demand for energy, climate challenges, security of the supply, economics, and insurance against future price exposure.

There are significant economic benefits to nuclear energy:

- It has a very flat cost profile that does not change over the years. By contrast, electricity from coal and natural gas depend very directly on changing fuel costs. Today, for example, natural gas is priced at $2.09 MBtu, and so it is presently cheaper than nuclear energy. The question is—what will it look like in 20 years?
- A single U.S. nuclear plant generates up to 700 highly trained permanent jobs with an average pay of more than 30% above salaries in the local area, and 3500 construction jobs.

Safety is the start of any discussion at Westinghouse and nuclear plants in the U.S. are among the safest industries. The U.S. has very strong regulators at the Nuclear Regulatory Commission who scrutinize every aspect of the operation. While often painful, it is the right thing to do and a must for the industry.

The Fukushima experience was a result of a series of unprecedented natural disasters including the largest recorded earthquake in Japan followed by a beyond-baseline tsunami. The impact on the site was severe, with secondary effects driven primarily by loss of power. The analysis of what happened at Fukushima will affect how we operate in this industry and how reactors are built. The lesson from Fukushima is that we need to move towards passive safety systems. The ability to achieve a safe shutdown condition within the first 72-hours without the need for AC or DC power or operator action will do much to maintain safety and let personnel step back. Such a passive design is incorporated into Westinghouse's AP1000. In the case of an outside event, no electricity or human action is required to turn off the plant. Instead, safety relies on gravity, circulation, and evaporation.

[5] Jim Ferland served as President of the Americas Division at Westinghouse Electric Company. He is presently President and Chief Executive Officer of the Babcock & Wilcox Company. He has had responsibility for the development of new markets and projects with PNM Resources, Duke Engineering and Services, and Carolina Power and Light.

If an AP1000 had been built at the Fukushima site, the plant would be back in operation producing electricity.

The nuclear renaissance is not what it was a few months ago. The events at Fukushima have probably pushed nuclear energy back by 6-12 months. However, the biggest present drag on nuclear energy is the price of natural gas combined with the worldwide slowdown in the economy. Unlike oil that sells at the same price per barrel around the world, natural gas prices vary from region to region. In the U.S. natural gas prices are at about $2 MBtu. In Europe they are twice that and in Asia they are 4 to 5 times that. At present the countries pursuing or augmenting nuclear energy programs are: Canada, the United States, Brazil, Argentina, the United Kingdom, the Czech Republic, Poland, the Middle East countries, India, China, Russia, South Korea, and Vietnam.

For the first time in 34 years we have started construction of nuclear power plants in the United States. Two units of the AP1000 reactor design are currently under construction in Georgia. Approval for an additional two units is expected this week. Four more AP1000 plants are under construction in China, and the first is expected to come on line in less than two years. The AP1000 is a reality.

The concepts behind the eight AP1000's being built today and the engineering design of those units were developed 15 years ago. Westinghouse is investing today in Small Modular Reactors (SMR) that will be built in the years to come, probably in the 2020's.

Why the Unites States Should Continue to Develop the Nuclear Energy Option

Dr. Patrick Moore[6]

From its early days much of the environmental movement put nuclear power into the same category as nuclear weapons, and still does. That mistake has led to a number of negative consequences, the most important of which is the construction of a lot more coal plants and a lot fewer nuclear plants, particularly in the United States. Today one third of Pennsylvania's electricity is from nuclear energy—95% of the clean energy in the state. For the U.S. as a whole, 75% of the clean energy is nuclear, and hydroelectric power provides an additional 20%.

Environmental groups need to support nuclear energy and hydroelectric power. Together these constitute over 30% of the power generated worldwide. By contrast, wind and solar power is a drop in the bucket. Until the environmental movement does lend its support, its constituencies will remain a primary obstacle to nuclear energy and to reduction in our dependence on fossil fuels.

Nuclear waste is not "waste" but an important source of nuclear fuel, since 95-99% of the energy remains in that "spent" fuel. The U.S. has 2000-5000 years of fuel supply in its existing used fuel and depleted uranium. Somewhere between 50 to 400 years from now, fossil fuel will be depleted, but enough spent fuel and new uranium and thorium already exists to meet the U.S. electricity needs for thousands of years.

On the health risks: No one died from radiation after the Fukushima accident, and the radiation experts in Hiroshima at the Radiation Effects Research Foundation believe that no one will. Following Hiroshima, a study of over 100,000 people on-site and 20,000 people not on-site on that day found cancer occurrence to be relatively low. People living around Chernobyl were not evacuated after the accident, they were not warned to avoid milk and vegetables, and they were not given iodine, yet the World Health Organization has found no evidence of an increase in cancers. It attributed 56 deaths to radiation exposure, 34 of whom were the firefighters. Among the 350,000 people exposed near Chernobyl that were evacuated to the city of Kiev, there is no effect attributed to radiation, according to the UN.

At present, there are 61 nuclear reactors being constructed around the world. Forty countries are planning to build new reactors. Only Germany has made the decision to get out of nuclear energy. Germany also made this decision on an earlier occasion (2002), and since that time they have built 13,000MW of new fossil fuel plants, many of which are now nearing completion and about to go online. In addition to these, Germany is planning to build a further 10,000MW of fossil fuel plants, yet it is giving the impression of replacing nuclear energy with renewable energy in the form of wind and solar. Germany's transition to renewable energy is financially and technically impossible, and instead, they are actually replacing nuclear energy with fossil fuel.

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[6] Dr. Patrick Moore, Ph.D., is Co-Chair of the Clean and Safe Energy Coalition (CASE). He served as President of Greenpeace Canada for nine years and as Director of Greenpeace International for seven years. He has been a leader in international environmental efforts for 40 years.

Germany has the second highest energy cost in Europe. It has some solar (0.3% at a cost of 100B Euros), 7% wind, and the rest is fossil and nuclear, until they shut the latter down. Yet Germany and Denmark are held up by the green movement as shining examples for the world to follow. Denmark is 85% fossil energy and 15% renewable wind and solar energy, and because of this 15% clean power, Denmark has the highest energy costs in Europe. By contrast Sweden, France, and Switzerland have virtually no fossil fuel; their energy is supplied by nuclear and hydro at a lower price than in Denmark and Germany. Yet these three countries are never used as models by the environmental movement. Countries like Canada, Russia, China and Brazil can consider adding solar and wind, since they have large existing hydro sources. The U.S., at 6% hydro already, and the second largest hydro electricity in the world, has no more hydro resources to tap. For the U.S., the choice is between nuclear energy and fossil fuel.

The Future of Nuclear Power in the United States: A Journalist's Perspective

Matthew Wald[7]

Consider public perceptions of nuclear power and how nuclear power is portrayed in the media. Going back to 1958, there were high expectations for nuclear power, with the possibilities including a nuclear-powered car. Recently, the Russian nuclear industry photographed beauty pageant winners against the backdrop of a nuclear power plant. This was the industry's attempt to de-demonize itself.

The economic advantages of nuclear power have been offset by the recent falling prices of natural gas. Three years ago the price of natural gas was over $13MBtu and now is at just over $2MBtu. This price fluctuation results in a change in fuel cost from 9c/KWh to 2c/KWh.

Public perception of nuclear waste is a problem for the industry. A large nuclear plant near Chicago stores about 30 years of nuclear waste in a facility the size of a basketball court. Nuclear waste is very dense, and the comparative volume of nuclear waste vs. coal waste is not generally recognized. Further, concerns about nuclear power vs. coal power have tended to focus on coal's SO_2/CO_2 emissions. However, radioactivity from coal may be even higher than from nuclear plants.

An approach to clean energy is large-scale wind power. Yet the public does not appreciate the scale of production that wind power requires. Wind power does not match well with peak energy demand, so wind power requires substantial backup. There must be natural gas reserves on standby to meet this balancing need, and that is expensive. A single 20MW wind farm in a single location might have a capacity value of 1MW; it can be counted on for 1MW, or 5% of the rated maximum. The capacity value of ten 20MW wind farms in 10 different locations might be 20MW, or 10% of the rated capacity. Wind power distributed across a state or across the whole country begins to approach reasonable numbers, but it requires a national electric grid, which would be extensive and intrusive (200 feet tall pylons). Earlier plans for such a coordinated grid were blocked, not by public reaction, but by local utility companies. By contrast, nuclear power offers both energy and capacity and is compact.

The small footprint of nuclear power cannot be approached by other sources. For example, Indian Point nuclear plant in New York produces 2200MW of power on 240 acres, most of which acreage is an unused buffer area. In the case of wind power, a 1MW turbine requires 24 acres, so 2200MW of wind power would take about 550 acres. But in fact, the nuclear plant operates at 90% efficiency, while the wind turbine operates at 30% efficiency, and so three times this number of wind turbines and operating area is actually needed to provide the same electricity output as nuclear energy. Six times that operating area is needed to produce solar energy, and the corresponding area required would be 2.6 square miles, compared to 240 acres for the Indian Point Nuclear Power Plant.

[7] Matthew Wald has written on environmental topics and civilian nuclear power for *The New York Times* since the Three Mile Island accident thirty-three years ago. His current focus is on energy and the environment.

It must be kept in mind that all of the U.S. reactors are essentially historical artifacts, in that they are a decades old technology. Energy markets are driven by returns. The unregulated northeast looks to quick returns, and so it is easier to build for gas, whereas the costs in the southeast are spread over many ratepayers, allowing longer-range thinking, and that is where the new investment in nuclear plants is seen.

In the matter of safety, the fossil fuel industry experiences a significant number of deaths each year from a variety of causes including coal-mining accidents. By contrast, even the Fukushima accident has led to zero deaths due to radiation.

An important issue for nuclear power is trust, and there is public trust and policy maker trust. Trust in these senses depends on what the policy makers and the members of the public know and understand.

Key Events in the Directions of Nuclear Policy

Dr. Peter Lyons[8]

What are the key directions today in nuclear policy in the U.S.? Certainly these directions are influenced by a number of events—the Fukushima accident, the findings of the President's Blue Ribbon Commission on America's Nuclear Future (BRC) reported in January 2012, and the certification of the AP1000. Following the Fukushima accident, President Obama asked that the NRC conduct a comprehensive review, and Secretary Chu expressed resolve that the U.S. understand and learn from the Fukushima experience. This also was the primary outcome of the Three Mile Island accident—learning from the experience and ensuring that such an event did not happen again. The nuclear industry learned a great deal through the Three Mile Island experience, and it stands to learn much from the Fukushima experience. Safety is key to all U.S. programs, and that is true for this industry as well. Dr. Marvin Fertel, President and CEO of the Nuclear Energy Institute, stated that the industry's highest focus is the safe operation of its 104 nuclear reactors located in 31 states.

Fukushima highlighted the need to reduce dependence on operators (who were truly overwhelmed in that case) and to move to passive controls. Passive controls use naturally occurring systems, such as circulation of air, water and steam, gravity, and pressure to drive the flow of cooling water with no safety-related pumps required. The passive systems are incorporated into the AP1000 and the concepts of the future Small Module Reactors. The advanced Light Water Reactor fuels have enhanced accident tolerance.

Among the eight recommendations proposed in the BRC report, it is noted that three deal with nuclear waste. The President and the Secretary for Energy have made the decision that Yucca Mountain is not an acceptable solution for a nuclear waste repository in this country and conclude:

1. There must be consent-based siting for nuclear waste, which was not the case in Nevada.
2. A new organization is needed to deal with nuclear waste management.
3. The industry must have access to the nuclear waste fund paid by ratepayers.

Following the release of the BRC's report and recommendations on January 26, 2012, the Congress gave the Department of Energy six months to produce the Administration's response. It will be released in July 2012.

The Department of Energy is highly interested in Small Modular Reactors (SMRs). They represent a paradigm shift from the way nuclear power plants have been built up to now, in which the trend has been to build larger and larger plants around the world. These smaller units can be constructed in a dedicated facility and transported to the site. They have significant benefits:

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[8] Dr. Peter Lyons serves as Assistant Secretary for Nuclear Energy in the U.S. Department of Energy and is responsible for all programs and activities of the Office of Nuclear Energy. Previously, he was a Commissioner of the Nuclear Regulatory Commission, where his focus was the safety of operating reactors and the lessons learned for transitioning to improved existing and new reactors.

- Safety benefits—they use passive decay heat removal and are sited below grade.
- Economic benefits—because of the modular aspect, their design has reduced financial risk.

The DOE is already into a licensing technical support program for SMRs, with the goal of moving towards certification of the SMR design and licensing two SMRs. The Department will invest $450 million in this initiative. DOE currently has a $1.4 billion program to overcome obstacles in the development of SMR technology.

There is renewed interest in nuclear energy in the U.S., and even greater interest in nuclear energy around the world. Four AP1000 plants are being built in China and four in the U.S., with strong support from the DOE.

Fossil Fuel and the United States Energy Needs—The Technical Pros and Cons

Dr. Anthony Cugini[9]

The National Energy Technology Laboratory (NETL) is the DOE's national laboratory for fossil fuels. It is distributed over several sites and employs 1,700 people. Analysis of a National Academy of Sciences study by the Management Information Services has recently reported that the return on investment from the Clean Coal Technology Program realized $13 for every $1 in taxpayer funds invested. This is primarily because the technologies developed were deployed by the large market. Today, fossil fuel is much cleaner than in earlier times, and the technologies developed by DOE research are expected to generate over 1.2 million jobs.

The NETL has been and continues to be very much engaged in the development of shale natural gas. Because of a DOE/NETL investment of $194M in the 70's and 80's, the horizontal drilling and hydraulic fracturing needed to access shale gas is largely considered a developed technology. The U.S. is now tapping unconventional sources of natural gas. Shale is providing 14% of today's natural gas consumption, and coal bed methane is providing 8%.

The energy portfolio for the year 2035 will look much like that of today, mostly driven by fossil fuels. In 2009, 83% of U.S. energy consumption was from fossil fuels (95QBtu), and in 2035 the proportion from fossil fuels is anticipated to be 77% (108QBtu). Fossil energy is a growth industry around the world and appears to have a future for at least the next 20-30 years. This means that technologies to reduce emissions are needed.

Tapping shale natural gas represents a potential paradigm shift in how natural gas is accessed. Instead of drilling in the hopes of finding gas, companies now go into an area underlain by extensive shale formations and "access" known natural gas supplies. The deposits are so large that the projections are for fairly stable production of natural gas for some time to come. Rather than buyers feeling urgency to buy before prices go up or supplies run out, they are tending to wait for prices to go down further. Natural gas prices have fallen and are expected to remain low for the next several years. New technology is opening the door, but the environmental concerns must be addressed. Also, there is now the prospect of the U.S. becoming an exporter.

When natural gas sources are depleted, methane hydrates will potentially represent a widespread source of energy, but new technology is required to harvest this source. Issues concerning the global climate system raise the need for technological options to reduce carbon dioxide emissions from fossil fuels. The first option is to push toward higher efficiency fossil plants. It is possible to reduce CO_2 emissions by 40% from improved efficiency alone. But this is not enough, and technologies for carbon capture and storage are needed to reduce the amount of CO_2 emitted to the atmosphere. The present CO_2 capture approaches are expensive, currently yielding 20-30% less power output and an

[9] Dr. Anthony Cugini, is Director of the National Energy Technology Laboratory (NETL) of the U.S. Department of Energy, and has responsibility for science and technology development programs to meet the nation's energy needs. These include development programs for coal-fueled power and its environmental controls, carbon sequestration, and more efficient and greener domestic oil and natural gas production.

80% cost increase, and so they are not yet commercially viable. Another issue is that it typically takes 25-30 years to deploy a technology, whereas a means for economical CO_2 capture could be used in the marketplace now.

Over the next 50-100 years, trillions of dollars will be spent in modernizing the U.S. energy infrastructure. Cheap access energy has been very much a part of our society and our way of life, and NETL is committed to ensuring cheap plentiful energy with less environmental impact long into the future.

Germany's Decision to Move from Nuclear Energy to Renewable Energy

Matthias Kurth[10]

The decision by Germany to close down its nuclear power plants and to move to renewable energy is akin to President Kennedy's decision to place a man on the moon. Like that decision, this one is expected not only to achieve its primary objective but also to spin off many technical advances with far-ranging impact. It is an ambitious decision and one with substantial consequences, but it is a position that is backed by 75-80% of the German population. The decision has been declared by critics to be everything from "crazy" to "if anyone can make it happen, it will be the Germans."

Germany is taking this step at a time when the economy is quite good and unemployment is relatively low. It must be remembered by those who believe this is just a move to substitute fossil fuel sources, that Germany signed the Kyoto protocol and that everything in Europe is monitored. Consequently, the German efforts in this regard will be evident to all. Germany has no interest in being an energy missionary or in trying to convert others to emulate its approach, but it is committed on its own to making the effort to attempt this energy transformation. It is a decision made by Germans for Germany.

While Germany does not have the most nuclear plants in the world, it does have a substantial nuclear power capability. On March 15, 2011, following the Fukushima disaster, Germany made the decision to shut down immediately 8 of its 17 nuclear reactors. The remaining 9 reactors will run for the next 10 years. It will be necessary to substitute other sources for those shut down.

Germany has set a 50-year goal. In 2008, German's energy consumption was 20% nuclear, 60% fossil, and 10% renewable. By 2058, the goal is consumption at 20% fossil and 80% renewable. By that time it is reasonable to assume that the 20% remaining as fossil fuel will be from fossil technology that is much more environmentally friendly than what is available today.

Is it possible to reach the 80% renewable goal? The renewable energy will come from wind farms, mainly in the northeast, with offshore wind farms in the North Sea and in the Baltic Sea. The substitution for nuclear is required in the southern part of the country where the grid will be enhanced dramatically. An early test of Germany's resolve might be whether the population is willing to accept new high-voltage power lines. The production will need to be integrated with neighboring countries to be successful.

Over the next ten years, offshore wind will add 12GW of capacity, and onshore wind will add 20GW. An offshore turbine runs over 4,000 hours a year and thus has higher energy production than an onshore turbine. Gas fired plants will be increased by 7GW, and solar capacity will be increased by 36GW. All of this will be very expensive: Consumers will pay the 30–50B euros needed for the grid expansion.

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[10] Matthias Kurth served as president of the German Federal Network Agency for Electricity, Gas, Telecommunications, Post, and Railway (BNetzA) from 2001 to 2012. He has held leading positions in the government of the State of Hesse, Germany.

Over the next ten years the plan is to replace old coal plants with high-efficiency coal plants with no net increase in production, and the use of natural gas will climb to provide backup for the renewables until storage technology is available.

Some critics have claimed that Germany will buy its electricity from France, with its 75% proportion of nuclear energy. However, France's domestic needs (all its heating is electrical) are such that it cannot export energy. Discussions are underway concerning the import/export of energy between European countries, and the integration of energy markets between France and Germany and between Germany and Norway. All of this will lead to price convergence.

Several major issues must be resolved. The generation of wind and solar power is somewhat predictable, but storage of this power is needed. It must be smart storage that allows the adjustment of usage to availability. Also, power system security is a concern, since single events can trigger the shutdown of the grid. So distribution must be much smarter. Two other important needs are smart consumption and smart markets.

Germany has high energy prices, and people are motivated to be efficient in their use of energy and supportive of Germany being the frontrunner in the difficult task of transitioning away from nuclear power. With this transition, energy innovations may become the new German export, and smart energy technologies the BMWs of the future.

Discussion of Session A

David Shribman directed discussion to the debate on Germany's position, and he asked Patrick Moore to respond to the presentation by Matthias Kurth. Moore answered that Kurth's data seem to be reliable. Moore said that without significant hydroelectric resources it will not be possible to achieve 80% of the needed power from wind and solar by 2050. To reach 80% from renewable without large hydro resources means that the remaining 20% must be backup for uneven supply. Moore believes that Germany is building new fossil fuel plants. While CO_2 can be captured, it must be stored underground, and all available underground storage will be used for natural gas imported from Russia.

Matthias Kurth responded that the decision to build the 10GW of new (efficient) coal plants was made prior to the Fukushima accident and that these will be ready in 2-3 years. These coal plants are needed to provide backup to the renewable power over the 10-20 year transition to renewable power. Backup is needed while the storage technology is developed, and some storage may be in Norway. The plan for storage is to use excess wind capacity to split water and to store the hydrogen. The hydrogen can be reconverted to electricity later or used as hydrogen in cars. By 2050, it is anticipated that the battery technology will exist. The view was expressed by a panel member that if any country could achieve this ambitious plan, Germany could do it.

Shribman asked the panel to address the future of nuclear energy in relation to natural gas. Jim Ferland explained that utilities make decisions based on the market in which they operate. The northeastern U.S. market is unregulated, and its utilities make short-term decisions. As long as natural gas is $2-$6/million BTU, those markets will not have an incentive to adopt nuclear energy. The Southeastern U.S. is regulated, and therefore it can look further into the future and think of diversification.

A member of the audience asked why we suffer from radiation phobia? Patrick Moore said that he believes it is because radioactivity is invisible and unsensed, and for that reason is perceived as scary. Nevertheless, we understand quite well the radiation levels to which people can be exposed without harm, and those levels are orders of magnitude above the typical background levels. Some people reside in places in the world where they are exposed to >100X the radioactivity that the average American experiences, and live quite well. It is therefore a matter of educating the public. Many of the environmental concerns that are raised concern narratives that cannot be corroborated. Matthew Wald commented that a few years ago, 50,000 people were killed each year on U.S. highways. Now that figure is down to 30,000 with a much larger U.S. population, and we feel that even this is too high, because we all have an expectation of living forever.

Governor Thornburgh noted Matthias Kurth's comment that the high price of energy in Germany is a significant motivation for the population to embark on renewable energy, and he compared this with the comment by Secretary Chu that we need to find ways to increase the price of gasoline so that renewable becomes more attractive.

A question was asked about the future of Gen IV nuclear reactor technology. Ferland replied that these reactors offer a number of advantages and include fast reactors and high temperature reactors, but that all are well into the future. Moore commented on the potential of fast neutron reactors that run off waste nuclear fuel. The U.S. maintained a fast reactor that worked well for a number of years. The program was cut by President Clinton for budgetary reasons. Russia has had a 600MW fast reactor running for 20 years and is commissioning an 800MW fast reactor this year. They have also sold two of these to China. These reactors are the future of nuclear reactors. Another important advance will be the high temperature reactors. This is because the conversion of coal to liquid fuel will enable conventional transportation after oil runs out. Rather than the process that Sasol Ltd. used in South Africa, in which 2/3 of the coal is used to liquefy 1/3 of it, a high temperature reactor would be able to convert 100% of the coal to liquid fuel with lower greenhouse gas emissions. Peter Lyons commented that the DOE is keeping its options open on the technologies, because the decision on whether nuclear waste is waste or fuel will be made in the future.

A question was asked about the new seismic criteria that the NRC will soon release and what the impact might be. Wald replied that the problem is that the current reactors were built long ago, before modern computer design, and there is no database that allows a precise structural analysis. As a result, while we know the seismic resistance for which the reactors were certified, we do not really know what their actual seismic resistance is. We do know that it is not the large structures that are vulnerable, but the smaller items like piping and switch boxes. While the Virginia plant was shut down by the 2011 earthquake in that region, considerable thought is needed on what the real vulnerabilities might be. Ferland agreed, but added that if we have new seismic data, that certainly must be incorporated into the analyses of the reactors that exist, and if necessary some changes must be made. In the case of Fukushima, the bulk of the problems were due to the tsunami and not the earthquake.

A question was directed to Matthias Kurth asking why Germany chose to cut off its entire nuclear capability. Kurth explained that the decision was not based solely on the Fukushima event. The decision to phase out the use of nuclear energy had been made earlier by the previous government and backed by political mandate. The German people are not willing to accept the risk. That risk in Germany is not earthquakes or tsunamis, but it might be terrorist actions, and this together with proliferation and unresolved waste disposal concerns have been discussed for 30 years.

Dr. Evelyn Talbott, an epidemiologist at the University of Pittsburgh School of Public Health, added a point of clarification to the earlier comments by Patrick Moore on the human effects of radiation. A 2001 paper in the International Journal of Epidemiology reported on a 10-year study of children residing in the Chernobyl area, and this study found a significant (3X) increase in leukemia in children exposed to that event over children elsewhere. There was also found to be an increase in thyroid cancer. Her own study found no increase in cancer mortality.

Ferland, replying to a question about the DOE funding of new technologies, said that without the earlier government seed money that Westinghouse received to speed the development of the AP1000, they would not be building those units today. In the case of programs like this that have a long-term development, such funds accelerate innovation. Westinghouse will be applying for similar funds for advance work on the Small Modular Reactor (SMR). It is anticipated that such funding will quicken the time to market by 10-15 years. Westinghouse anticipates having the SMR ready to market in 2020. Lyons added that we have the opportunity to jumpstart the SMR industry in the U.S. or face buying these from China, Russia, South Korea, or Argentina—countries where the technology is owned by the governments. At present, we are unable to manufacture domestically much of a nuclear reactor, but that could change with the SMR.

Session B: America's Nuclear Future

Moderator: Doug Heuck, Publisher, *Pittsburgh Quarterly*
and Program Director, Pittsburgh TODAY

March 27, 2012

An Overview of the Blue Ribbon Commission's Assessment of the Future of Nuclear Power in the United States

The Honorable Vicky A. Bailey[11]

The first meeting of the President's Blue Ribbon Commission on America's Nuclear Future was held in March 2010. The members took seriously the statement by Secretary Chu: The future does not have to be cast in concrete. Quite simply, one can't tell what technology will be available to us 50, 100 or even 150 years from today. We need to step back and ask what strategy should be put in place, knowing that the world will be different in 25 years, and that it is different now than it was 25 years ago.

The Commission was chaired by former Congressman Lee Hamilton and former National Security Advisor Brent Scowcroft. There were 15 commissioners, and all of them signed off on the final report. The recommendations can be seen on the Commission's website at www.brc.gov.

Several points from the Commission's report were selected for discussion at this symposium:

1. Importance was placed on public hearings and public comments. A listening tour formed the basis for the recommendations, which came from hundreds of witnesses and involved sifting through thousands of public comments. The process needed to be—and was—open, accessible, and transparent.
2. The Commission grappled with the issue of defining the role of government in managing nuclear waste. The overall record of DOE and government as a whole on this issue has not inspired confidence in our ability to manage nuclear waste. A frequently heard theme was the lack of trust in government and the call for new institutional leadership. Of DOE's $26B budget, only 2% was ever allocated to waste management. The Commission concluded that new institutional leadership is needed, backed by rigorous financial, technical, and regulatory oversight by Congress and by the appropriate federal agency.
3. The Commission recommended prompt efforts to develop a single nuclear disposal facility and a single nuclear storage facility. Deep geologic disposal is the solution that has been reached by every expert panel that has looked at this issue and by every other country that has pursued the waste management problem. Consolidated storage would allow an orderly transfer of spent fuel from reactor sites to safe and secure central sites. The Commission recommends that the fuel from the shutdown plants should be first in line for transfer so that those temporary sites can be decommissioned and returned to their communities for development.

[11] The Honorable Vicky Bailey's governmental career has included appointments by President George W. Bush to be Assistant Secretary for Policy and International Affairs (2001-2004) in the U.S. Department of Energy, and by President William J. Clinton to be Commissioner (1993-2000) on the U.S. Federal Energy Regulatory Commission (FERC). She has served as president and board member of PSI Energy, Inc., Indiana's largest electric utility, and on the Blue Ribbon Commission on America's Nuclear Future.

4. The Commission recommended that foreclosing technology options be avoided, and it endorsed a multi-faceted approach to energy policy wherever possible. The environmental and security aspects of nuclear power production justify support for public and private sector technology advancement.
5. The Commission recommended greater federal support for research and workforce development. This would produce the expertise needed by the industry through expanded science, mathematics, engineering, and technology programs at universities.
6. The Commission met with social scientists to explore public opinion and, in particular, how public opinion about nuclear energy differs from public opinion about other energy sources. Opinions can be based on fears, real or not, and where that is the case, it is important to understand the basis of these fears, and for people to be given correct information. For example, millions of industry workers who have been monitored closely for 50 years and who have received an average radiation dose ten times that of the usual person show no increase in cancer. People living in Colorado and Wyoming have twice the radiation exposure of people living in LA and yet have lower cancer incidence. Citizens need to be reassured that decisions are safe and should have access to resources that allow them to make their own decisions.
7. Finally, it was affirmed that the U.S. must maintain and strengthen its energy leadership, not just in commercial power but also in international efforts to address safety, non-proliferation, security and counter-terrorism aspects.

America's Nuclear Future Must Not Mirror its Past

David Lochbaum[12]

Nuclear energy will be a part of the U.S. energy future, and therefore we must study past problems to avoid repeating them. There are 104 nuclear reactors operating in the U.S., and the chance of one of them failing is high. The two new plants coming into operation will also have a higher failure potential during their early phases of operation. The plant at Three Mile Island was one year old when its problem occurred. Browns Ferry was two years old. Fukushima was almost at its 40th birthday. The best way to manage risk is for federal regulators to set the bar at a high level and make sure that people clear it rather than slide underneath.

Consider some of the problems that have occurred. In March 1987, the Peachbottom plant in Pennsylvania had to be shut down for two years to correct management failures that had led to such problems as workers sleeping on the job. On March 2, 2008, this same plant was found to have guards sleeping in the control room. Plant management initially denied the reports until a video was aired.

In March 1975, the worst nuclear accident prior to Three Mile Island occurred at Browns Ferry in Alabama. A worker, using a lit candle to check for air leaks between the cable spreading room and the reactor building, started a 6-hour fire that became serious before it was extinguished. In 1980, legislation was enacted to prevent similar fires from happening again. Fire is a serious threat at nuclear power plants because it can wipe out safety systems. The NRC states that fires represent 80% of the factors that can lead to core damage. Yet today, 47 reactors do not meet the fire protection regulations, including the three reactors at Browns Ferry where the first fire occurred. The situation is that the industry is subjected to regulations and then allowed to operate outside the regulations.

In March 2002 a dangerous situation was found in a Westinghouse plant in Ohio. Rusty boric acid deposits on a vessel flange were clear indications that the metal was eroding to a failure that would occur within about two months. The NRC inspector could see this corrosion but asked no questions. The failure would have led to an accident as bad as that at Three Mile Island, and yet the plant continued operation. This despite the fact that in 1998 corrosion was found in the same plant and the operator was fined $65,000. The plant was operating in violation of five safety criteria and yet not shut down. The plant manager said that he would follow the same practice again, maintaining that they needed absolute proof that a plant is unsafe before shutting it down. Fukushima is an example of such absolute proof. The Ohio reactor in 2002 came closer to a nuclear disaster than at any other time since Three Mile Island, yet the NRC had given it "A" ratings.

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[12] David Lochbaum is the Director of the Nuclear Safety Project for the Union of Concerned Scientists and is one of the nation's top independent experts on nuclear power. At UCS, he monitors safety issues at the nation's nuclear power plants, raises concerns with the Nuclear Regulatory Commission, and writes on matters of public interest. He is a nuclear engineer and worked in nuclear power plants for 17 years.

Still looking back in time, 259 new reactors have been ordered in the U.S., of which 127 were cancelled. Among the 132 reactors that did go into operation, only 91 have avoided shutdown times and corresponding lost electricity production. Typically, difficulties are swept under the rug until the accumulation can no longer be hidden. Then it takes more than a year of shutdown to repair all the problems. In 1997, 10% of the reactors in the U.S. were shut down for an entire year to fix safety problems, which caused a drop in production. This led Congress to ask for the regulations to be scaled back, since the industry could not survive such frequent shutdowns.

There have been 49 reactor shutdowns. Reasons have included damage recovery in 6 cases; equipment replacement in 11 cases; and safety problems in 36 cases. There were original design errors in 7% of the shutdowns.

In June 2011, flooding around a nuclear plant in Nebraska exceeded the plant's design. The previous year, the NRC found that the plant did not have sufficient flooding margins and forced the plant to raise its flood protection. However, the following year the flooding was higher than the changes anticipated, but the plant was better able to withstand the flooding. No U.S. plant has yet implemented the recommended changes following the Fukushima accident. The bar is regularly set high and then plants are allowed to pass below the bar.

If the U.S. regulations were consistently managed to a high level and consistently enforced, then it would be possible to run plants to acceptable levels of risk. However, if the NRC continues to allow violations to slide, the industry will be creating its own demise. This is what has happened in Japan, where the public has lost faith in the nuclear industry and its regulatory body. The difference between Japan and the U.S is not the industry or the NRC, but luck.

The Future of Nuclear Power in a Deregulated Market

Peter P. Sena III[13]

First Energy is a $46B company with 17,000 employees and 6 million customers that is diversified in terms of energy sources: 45% supercritical coal and 20% coal; 18% nuclear; 10% hydro and wind; 6% natural gas; and 2% oil. The company operates four nuclear units, including the two Beaver Valley plants in Shippingport, Pennsylvania. First Energy plants run to high standards.

There is a significant difference between regulated markets and competitive retail electricity markets, and the difference lies in the power generation (transmission and distribution being similar). In a regulated market the customer is not offered a choice, while in a competitive market, the customer can choose between companies.

The key drivers of wholesale electricity prices are the following:

- electricity demand - affected by the slow economic recovery;
- national natural gas price - $2 now vs. $13 in 2008 and 2005;
- coal prices - this due to international demand, mainly from China; and
- environmental regulation.

In a deregulated, competitive market, growth of nuclear power takes three primary forms:

- extension of the operating licenses of the existing plants, so that as the plants have aged, every part is being replaced, one switch at a time—countering concerns about aging;
- implementation of power uprates—maximizing power output through equipment enhancements and operating efficiencies; and
- support of nuclear industry-wide expansion—each company expects the other to run to high standards so nuclear power remains safe and part of the U.S. energy portfolio.

The new frontier is the Small Modular Reactor (SMR). This technology is currently in development, but by 2020 could be a viable option for new nuclear power in deregulated electricity markets.

Less costly than a new advanced baseload nuclear power plant, SMRs have the following economic benefits and advantages that are attractive to power generators in deregulated markets:

- each SMR generates 125-250MW;
- they have passive design;
- they are carbon free;

[13] Peter P. Sena III is president and chief operating officer for FirstEnergy Nuclear Operating Company (FENOC), a subsidiary of FirstEnergy Corp. Prior to joining FENOC, Peter was a resident inspector at the United States Nuclear Regulatory Commission. From 1985 to 1990, he was an officer in the United States Navy, serving aboard the USS Alexander Hamilton nuclear submarine.

- they allow an incremental scale of investment; and
- their technology is already available.

SMRs also have the following strategic benefits:

- they maintain regional reliability;
- they strengthen nuclear diversity; and
- they are a source of domestic jobs.

The steam generator at the Beaver Valley plant is being replaced in 2017. This is a major undertaking, and presently none of the principal components, including the generator, is made in the U.S. By contrast, the SMRs could be made in the U.S., since we do have that manufacturing capability. SMRs offer the potential for a large domestic manufacturing base.

The challenges to SMRs are the following:

- the cost is still an issue—while less costly than an advanced baseload reactor, the cost of an SMR is still high, since there are not yet economies of scale;
- there is regulatory uncertainty; and
- they face the creation of additional and changing emergency planning zones.

For the future, we should focus on the following priorities:

- to maintain the focus on safety at existing nuclear power plants;
- to maintain the efficiency and capacity of existing plants; and
- to develop SMRs.

United States Public Opinion About Nuclear Energy: Past, Present and Future

Dr. Ann Bisconti[14]

There are three main aspects to understanding public attitudes:

- What can we learn from the past?
- What are the public views on nuclear energy now and for the future?
- What do neighbors of nuclear plants think?

From the past: In 1983, a national telephone survey of 1,000 people showed high expectations that nuclear energy would be the primary source of electricity in 25 years. Those surveyed were asked what they expected to see and what they would prefer. Here are the results:

Expected		Preferred	
nuclear energy	40%	solar energy	53%
solar energy	33%	nuclear energy	13%
coal energy	6%	hydro energy	11%
hydro energy	3%	coal energy	8%

If those expectations had come true, nuclear and solar energy would have become our primary sources of electricity by 2008.

People love solar energy, but they have always been ambivalent about nuclear energy. On the one hand, they see nuclear energy as important for the future, but on the other hand, they are concerned about its safety.

How do these perceptions play out when there is a nuclear accident? In the case of Three Mile Island, support for building more plants dropped briefly from 50% to 47% and then rose back up to 52% only a month after the accident. When that accident occurred, the country was in the middle of a serious energy crisis. Support fell to 38% three years after the accident when the energy crisis ended—energy was no longer in the news and nuclear energy was out of sight and out of mind. Need trumped safety concerns until the perceived need vanished.

After the Chernobyl accident, the U.S. public's perceptions of the safety of nuclear power plants actually became more favorable. That was because Chernobyl the accident provided a teachable moment in which the media and others explained why what happened at Chernobyl did not happen at Three Mile Island; thus, safety concerns diminished.

Now and for the future: In recent years, a new factor has been added to the fuel-of-the-future versus safety-concerns tradeoff. That factor is the increased recognition of the benefits that nuclear energy provides, such as reliable and affordable electricity and clean

[14] Dr. Ann Bisconti is President of Bisconti Research, Inc. a public opinion and communications research company. Before establishing Bisconti Research in 1996, Dr. Bisconti was Vice President of Research and Program Evaluation for the Nuclear Energy Institute (NEI), where she initiated and ran a 13-year program of public opinion and communications research on nuclear energy—work now continued at BRI.

air. Thus, although the Fukushima accident had a moderately negative impact on public attitudes, the long-term survey trends are favorable for nuclear energy. A new survey done in February 2012 found that the number of those in favor of nuclear energy was increasing (now at 64%) and the number of those opposed was falling (now at 33%). On the matter of safety, in 1984 those giving high ratings to the safety of nuclear power plants nearly doubled from 35% in 1984 to 67% in September 2011 (following the Fukushima accident). A two-thirds majority would support the building of a new reactor near the local existing one.

Neighbors: Surveys of those living within a 10-mile radius of a U.S. nuclear power plants, and excluding plant employees, found that 86% have a favorable impression of their local plant. Nuclear power plant neighbors believe the plant is well operated; that it helps the local economy; that it protects the environment; and that the design protects against extreme occurrences. They also like the fact that the company is involved in the community.

On perceptions of risks of radiation: Radiation is seen as *unnatural,* and so it is important to convey the natural sources of radiation and that radiation is a part of nature. Radiation is *unfamiliar* to the average person, and therefore it is helpful to point out the many uses of radiation technologies in our everyday lives. Radiation is perceived as *uncontrolled,* and so it is important to talk about the extensive mechanisms that are in place for precise measuring and monitoring and the multiple backup safety systems at the reactors. Radiation is perceived as *deadly*. Therefore, if there should be an accidental release of radiation, it is important to explain how much has been released compared with the amount of release that the federal government has established to be safe.

The U.S. public has historically held high expectations for nuclear energy alongside its ambivalence due to safety concerns. Since attitudes are influenced by perceptions of need, safety, and benefits, support has grown over time as perceptions of safety have improved and awareness of benefits has grown. The support of plant neighbors is important, because most new plants will be built at existing sites. In any case, new nuclear power plants may not be built everywhere; they will be built where they are needed and wanted.

Discussion of Session B

Governor Thornburgh asked why the surveys did not find a strong tie between support for nuclear energy and concern about climate change. Dr. Bisconti answered that this is because Republicans tend to be more favorable towards nuclear energy, and they tend not to be convinced of climate change. At present, Democrats associate nuclear energy with climate change solutions four times more than Republicans.

Doug Heuck asked Peter Sena to respond to the number of disquieting issues raised by David Lochbaum on plant management. Sena replied that the serious case of corrosion in 2008 truly was ignored. However, he believed such a matter would not be ignored today and that the NRC does hold the operators accountable to high standards. The Beaver I and Beaver II plants have perfect safety scores at present (ranked 1 and 2 in the U.S.), although that may raise some concern about becoming complacent.

Vicky Bailey said that good regulation is a matter of finding the right balance. She does not believe that intrusive regulation is needed, but she would err on the side of more regulation, because stronger, deeper regulation helps everyone. Lochbaum explained that what we have is a three-way contract between the plant licensees, the government regulators, and the public. When the regulators want more than the regulations require they hurt the licensees. When the regulators accept less than what is required they hurt the public.

The question was asked whether any license extension has been denied. Lochbaum replied that no extension has been denied, but he explained instead that the extensive re-approval process has been continued in some cases until a plant made the necessary improvements. He pointed out that the NRC requires more today than it did 10 years ago; however, the Commission has not gone back and applied the new higher standards to the older plants. It is important to do so, because there is no justification for allowing old plants to operate at lower standards.

Bisconti said that one outcome of the Three Mile Island accident was that an industry organization, the Institute of Nuclear Power Operations (INPO), was set up to foster excellence in safety and to self-regulate within the industry. All of the plants are held accountable to each other through this organization. However, Lochbaum observed that since INPO was formed in 1980, the NRC has shut down plants 49 times for periods in excess of a year to restore safety standards—costing billions of dollars. INPO claims standards higher than those of the NRC, but if that is the case, why did INPO not catch these plants before the NRC shut them down? Sena responded that his company voluntarily shut down two plants in 1998 to make improvements.

A question was asked about long-term dangers of nuclear waste. Peter Sena pointed out that the waste at his facilities is very compact and well stored. Still, the long-term issue remains unresolved. The EPA required that it be proven that storage of waste at Yucca Mountain would have no long-term consequences. It is all about risk perception. Ann Bisconti said that much of the public pictures nuclear waste as liquid. So it is important to explain to the public what nuclear waste is and how much of it there is. Sena said that for the 150 people in the room attending this symposium and their families, the nuclear waste over their entire lifetimes would fit in a single cup. Compare that to the great quantity of waste from coal in terms of CO_2 and coal ash. Bailey observed that nuclear waste has been very safely stored for decades, but that over the long-term there has to be a comprehensive strategy. We already have 65,000 tons of nuclear waste, and we are producing 2,000 tons a year more.

A question was asked about the molten salt reactor technology that China has claimed to be a good solution for its energy needs. Lochbaum said that this is a 1960s technology that is being looked at again, but it is still at the conceptual level, and so it is premature to attempt to evaluate its safety and other aspects. A good use of government money is to examine new technologies, show what does or does not work, and provide answers on which to base business and policy decisions.

A question was asked about what the NRC could have done to prevent the Fukushima accident—would U.S. regulations have prevented that accident? Sena replied that we have good regulations for natural disasters and that we design with margins. The regulation on sitings is clear and explicit—the siting must take into account worst-case natural disasters. We have the experience of surviving major hurricanes and tornadoes well. But Lochbaum commented that we currently have three reactors in South Carolina that the NRC has concluded would melt down if they were operating at the time of a dam failure upstream from the facilities—a Fukushima example. These three reactors are operating today on luck.

Heuck asked whether the media has changed since Three Mile Island in how it deals with nuclear disasters. Bisconti replied that the media present images, and while poll numbers may not be affected, those images remain in the mind and add to the negative public impressions. The public now has images that confuse the tsunami destruction with the radiation issues. This makes it more important to present the benefits and the quality of the plant operations.

A question was asked about the effects that changing administrations in Washington have on energy policy and the nuclear industry. Bailey replied that each president has put his mark on the energy issue. The result is that we do not have a comprehensive energy policy, and regional, state and national issues further complicate this. There is now a sense of urgency (a confidence and trust issue) to motivate Congress to move forward on this, as has been urged by the BRC.

Session C: Three Mile Island, Chernobyl, and Fukushima Daiichi

Moderator: Kathy Kiely, Managing Editor, Sunlight Foundation Reporting Group and former reporter for *The Pittsburgh Press* who covered the Three Mile Island accident

March 28, 2012

The Three Mile Island Accident

Harold R. Denton[15]

Immediately following the Three Mile Island accident, Present Jimmy Carter appointed Harold Denton, Director of the Office of Nuclear Reactor Regulation of the NRC at the time, to be his on-site representative, telling him that he must be kept fully informed, that he would make all necessary resources available to ensure safe restoration and recovery, and that Denton should work closely with Governor Thornburgh.

Denton arrived two days after the accident with about ten of his aides, and over the next few days the number of NRC employees on site grew to 80. DOE had over 40 employees assigned to the problem and, with the EPA, spent the next several weeks making measurements in the area and doing the dosage analysis and projections. Fifteen years passed before the reactor had the radioactive materials removed and shipped off site.

In the hindsight of a 33-year perspective, the issues of significance were:

- There was extensive core melting in the first hours. It was learned later that some 45% of the core had melted and some 20 tons of core fell into the bottom of the reactor. Despite the very extreme temperatures that would have existed, the reactor vessel did not fail. Sixteen hours into the accident, cooling water was restored to the vessel and it was stabilized.
- The accident showed the absolute importance of sturdy containment vessels and the importance to public safety of containment in mitigating an accident. The philosophy behind the containment vessel was established in 1947 when the Atomic Energy Commission formed a committee to look into the issue, and the containment vessel has been used in every commercial reactor designed since that time.
- During the Three Mile Island accident, the amount of iodine released was about 90 times less than the amount of iodine released during the Chernobyl accident. To put the accident in perspective, the amount of radiation released was roughly 10% of that released by Chernobyl.
- On day 3, the hydrogen bubble scare occurred: a bubble of hydrogen was discovered in the dome of the pressure vessel. It was realized that the hydrogen could explode if oxygen were present, and oxygen was being generated by electrolysis of the water. An explosion could damage the containment. However, as was subsequently confirmed, such an explosion was never physically possible. By April 2, the engineers had come up with a process that stripped the hydrogen using a catalytic converter.
- The accident led to a major improvement in the safety of reactors and significantly reduced the risks of future incidents. After the accident, separate investigations were held by the Congress, the NRC, the State of Pennsylvania, and the nuclear

[15] Harold Denton spent a distinguished 30-year career with the Nuclear Regulatory Commission's nuclear safety regulation program, including ten years as Director of the Office of Nuclear Reactor Regulation. When the Three Mile Island accident occurred, President Jimmy Carter sent Mr. Denton to serve as his personal representative at the site, and Denton was the news media spokesman for the federal government during the crisis.

industry with respect to the 64 different reactors operating in the U.S. at the time. The NRC's Office of Nuclear Reactor Regulation reviewed the findings of these various investigations and incorporated modifications into the regulations that included changes in personnel qualifications, training of personnel, symptom-oriented emergency procedures, managing interfaces, feedback of operating experience, and establishment of home-site inspectors at every plant. In light of the Fukushima accident, the NRC is now looking at the issues of backup power and whether it is possible to filter any release so as to prevent release of radioactive components.

- As a result of the President's Commission to look into the Three Mile Island accident, an industry organization was formed, the Institute of Nuclear Power Operations (INPO), which has since made a significant contribution.
- Something not recognized prior to the accident was the availability of vital information from the control room. There were only two telephones in that room. These were the only way to get information out, and the person on the other end of the line was told not to put the phone down or hang up, as the phone system was overwhelmed and they would not get connected again. Denton was able to get a red phone installed in his trailer by the President and operated through the White House switchboard.
- The accident brought out the need for a rigorous approach to emergency planning and preparation. FEMA was made responsible for developing and managing evacuation and emergency preparedness. Plans must be updated, with simulations run, every two years.
- Another factor not fully appreciated until the accident was the need for public access to timely information. The NRC required each plant to establish a public information center.

The Chernobyl Accident—Lessons Learned

Adolf Birkhofer, Ph.D.[16]

The Chernobyl accident occurred during the Soviet era—on April 26, 1986 in the early morning. The reactor design and the information flow had a number of aspects that exacerbated the problems as they occurred. One of the most striking differences in this particular Soviet design is that when the core is voided, the reactor suddenly increases energy production (the design has a large positive void coefficient). Also, the fuel rods were unusually long (7m) and were made by joining two segments to get the required length. The reactor had no rapid shutdown capability. The SCRAM that was in place took about 20 seconds to shut down. The design had very extensive piping with complex routing. There are eleven other reactors of this type still operating in Russia.

Events Leading to the Accident: The accident occurred during a planned outage for routine maintenance and inspection. A test was to be run during this planned outage to assess whether, in the case of a shutdown of the steam turbines, a coasting steam turbine could provide sufficient power to the coolant pumps to bridge the 75-second gap for power from the backup diesel generators to reach full level. These coolant pumps provided the cooling for the reactor core.

It was at this stage that the accident occurred. The test was classified as an electro-technical test, so no validation of the test was sought from the reactor designer or any nuclear or safety expert and was signed off by the plant manager. Because of an unexpected outage at another plant in the region, the start of the test was delayed by nine hours and was eventually begun just before midnight and the midnight shift change. In the history of nuclear power, many of the most difficult situations have occurred at night and shortly after the midnight shift change.

Nominal power for the reactor was 1,000MW. The reactor had been designed so that the power should never fall below 700MW as this led to changes in the physics of the core. However, while this requirement was known to the designers, those running the test did not know about it. For some reason not well explained, and perhaps a malfunction of the controller, the power fell to 30MW. The control of power in this very large reactor was a difficult task. In an attempt to raise power, the operators removed too many control rods, something that should not have been done for this design, and the number removed went beyond the safety limit. Reinserting the rods, because of the rod design, again led initially to power increase. This resulted in generation of uncontrolled steam and fuel vaporization. Efforts to achieve a manual shutdown failed, as it was too late.

Again, this failure mode was known to the designer, but it had never been explained to the Chernobyl operators, despite the urging of the researchers to do so. It is imperative that the operators understand why they are to perform or not perform some operation. The

[16] Dr. Adolf Birkhofer has served as Managing Director of the Gesellschaft für Anlagen- und Reaktorsicherheit, Germany's principal research organization in the field of nuclear safety. He has also served as Chairman of the International Nuclear Safety Advisory Group to the IAEA. He holds doctorates in electrical engineering and in physics.

reactor power reached 100 times normal and the core exploded, with widespread radioactivity. (In the case of the Fukushima accident, the radioactive material was not spread out through a massive explosion as it was in the case of Chernobyl.)

The Causes: The operators were focused on a test and were ignorant of the consequences of their actions. Operator errors were compounded by inadequacies in the design. The control rods should not have been withdrawn fully in order to avoid a positive reactivity addition (increase in reactor power) if they had to be reinserted. The positive reactivity insertion was possible for the first 20% of control rod length.

Lessons Learned:

- The safe operation of a reactor requires a number of basic conditions: a safety culture; a questioning attitude that goes from the operators to the top levels (something not yet grasped by most of the industry); inspection; training preparations; and procedures in place that are clearly understood. It is essential to strengthen containment.
- It is imperative to enhance the role of the international community, such as the International Atomic Energy Agency (IAEA), to develop safety principles to be followed globally. Chernobyl led to the formation of the World Association of Nuclear Operators (WANO), the worldwide mirror of INPO, but Fukushima has shown us that more efforts are needed.

Dr. Birkhofer regrets that following the Fukushima accident more steps were not taken to strengthen the obligations assigned to all responsible organizations, especially the powers of WANO.

Safe Shutdown of the Onagawa Nuclear Power Station—the Closest Boiling Water Reactors to the 3/11/11 Epicenter

Isao Kato[17]

Tohoku Electric Power Company supplies power to the northern part of Japan's main island, encompassing 20% of the nation's land area and 12,000,000 residents (10% of the population). The word "tohoku" means northeast. Tohoku Electric is one of 10 electric utility companies in Japan, and at the time of the earthquake and tsunami it had a capacity of 19GW—hydro, oil, coal, gas, solar, wind, geothermal and nuclear power stations throughout the area. Prior to the events, 28% of the Japan's electricity was supplied by nuclear energy, and now that percentage is zero. In Japan at this moment, only one of the 54 reactors is operating. On 3/11/11 Tohoku Electric Power Company lost 35% of its capacity, and five million customers were left without power. Several of its power plants were severely damaged. After three days, power was restored to over 80% of customers. The company was fortunate to have power stations on both the east and west coasts of the main island, and those on the west coast were still in operation.

The seismic event of March 11, 2011 at 2:46 pm was an M9.0 earthquake—the largest ever recorded in Japan. Following the 3-minute long earthquake, there were numerous aftershocks and tsunamis.

The closest nuclear reactors to the epicenter of the quake were those in the Town of Onagawa. These are owned and operated by Tohoku Electric, and they are the three reactors of the Onagawa Nuclear Power Station (NPS). The most important feature of the station is the 15m-site grade. No safety-related equipment was located below this 15m-site grade. This feature, together with the actions of the operators and engineers, made it possible for the station to ride out the event.

Units 1 and 3 were operating at 100% power at the time of the earthquake. Unit 2 had been shut down for routine maintenance and had been turned back on just 40 minutes before the earthquake struck. At 2:46pm, all three reactors automatically shut down. Eleven minutes after the earthquake, at 2:57pm, there was a fire alarm in Unit 1. At 3:29pm a series of tsunamis began to hit. The tsunamis induced internal flooding of the Unit 2 auxiliary building and, as a result, two of the three emergency diesel generators tripped on Unit 2. AC power remained available throughout the event at Onagawa NPS with one off-site power line out of five, and six on-site emergency diesel generators out of eight.

There were three general areas of damage: fire, flooding, and the toppling of a fuel oil tank for a non-safety auxiliary boiler. Unit 1 had a fire caused by the shaking of switchgears for non-safety equipment. The cooling systems of the emergency diesel generators in Unit 2 were partially inundated by flooding seawater from underneath. While the tsunami was below the 15m-site grade, the seawater current was forced upward through sea water level

[17] Isao Kato is Deputy General Manager of Nuclear Department, Tohoku Electric Power Company, Inc. Mr. Kato holds a Master of Science degree in Nuclear Engineering from M.I.T. and has expertise in nuclear fuel management and safety analysis.

instrumentation tubes into the pump pit, and then the seawater flowed in through the pipe trenches into the 3rd basement of the reactor auxiliary building, where cooling systems for emergency diesel generators are located. Although the diesel generators themselves are located on the ground floor at 15m above sea level, they depend on the cooling systems in the 3rd basement; when two cooling systems tripped, two out of three emergency diesel generators tripped on Unit 2.

The Onagawa nuclear power station was built in an area affected by tsunamis in the past, and therefore the site grade was set at 15m (48.6ft), to be well above the height of 3m that had been predicted in 1970 when the Unit 1 license application was made. Later, when the tsunami prediction was updated to 9.1m, the grade was reinforced with concrete up to a height of 9.7m. The recorded tsunami of March 11, 2011 was 13m (42.7ft). In contrast to Onagawa, Fukushima Daiichi was built on the earlier maximum tsunami predictions of 5.7m, and it was set at a site grade of 10m. Fukushima Daiichi Units 1 through 5 lost all AC power due to the earthquake and tsunamis.

The earthquake and tsunamis damaged the roads in the surrounding area so that the local population did not have a way to leave. Four hundred people were provided with food and shelter for three months in the gym of the plant.

In recent years, Onagawa NPS has been upgrading its protection against earthquake and tsunami events, including the 15m-site grade, pump pit structure, and site grade reinforcement and seismic reinforcements to the plants. Following the Fukushima accident, a number of upgrades were immediately begun at the Onagawa NPS. There is now alternate AC power from air-cooled diesel generators on a high hill; seals that are watertight; and alternate seawater pumps (underway). An additional seawall is being constructed to a height of 3m above the existing 15m-site grade. Also, there are now additional safety drills. Tohoku Electric Power Company is determined to make its nuclear plants even safer.

Nuclear Power: Yesterday, Today, Tomorrow

Brian Johnson[18]

GE-Hitachi is a 700,000-employee company that offers a variety of power technologies including wind, solar, conventional, and gas turbines, but the company sees nuclear energy as a key element of the nation's future. Nuclear power provides predictability and energy security that are paramount. But now, in the light of Three Mile Island, Chernobyl, and Fukushima Daiichi, the question arises how we should respond.

Consider the major events in nuclear power production in the past 50 years. If we compare the nuclear energy industry from 1957 to now, we see major changes. In 1957, the *Nautilus* had just completed a 60,000-mile journey with nuclear power; Shippingport was brought online; and plants were designed with slide rules and simple models. Today we have a large nuclear power industry with a significant safety record. Reactor designs are created using comprehensive computer simulation modeling, solving fluid dynamic models in 3-D. A plant construction is designed, and computer records track each component around the construction site. The fire at Browns Ferry and the Three Mile Island accident resulted from unanticipated events from which the industry learned. In addition the NRC was transformed, as was operator training and public perception, and the INPO came into being.

At GE, reactor plant design is continually simplified and optimized. This pattern is seen across the evolution of generations of reactor designs from Dresden I, KRB, Oyster Creek, Dresden 2, ABWR, and ESBWR. Fukushima has taught us that it is important to plan for circumstances beyond what we know and to rethink defense in depth. While we have come a long way since Three Mile Island, the reporting on the Fukushima accident by the major news channels showed that we still need to do work to inform the public adequately on the facts in such a situation. So the challenge to the industry is:

- Restore public trust,
- Plan for unknowns, and
- Rethink defense.

The Fukushima accident has presented the need to examine the goals of design of existing plants. Immediately after Fukushima, utility companies across the U.S. began looking at their own vulnerabilities if such an event were to occur here. The NRC task force continues this examination from the regulatory perspective, prioritizing what needs to be done in different levels of urgency. In addition, the DOE is looking at the fundamental technologies that can take us a step beyond the circumstances illuminated by Fukushima.

At GE, the emphasis is on passive systems, and DOE is providing leadership in bringing these technologies forward. Addressing the loss of both AC and DC power results in the lowest risk of core damage, but this alone is not enough. Designs must raise the bar for plant safety, keep the fuel covered, and transfer heat directly out of containment. The new

[18] Brian Johnson is Vice President for U.S. Markets New Plant Business for GE Hitachi Nuclear Energy. He holds an engineering degree from Vanderbilt University.

reactors, such as the Economic Simplified Boiling Water Reactor (ESBWR), are smarter and simpler. This is accomplished by the large pool of water and the natural circulation, phase changes, and flows within the water.

If there were one thing that would have helped everybody at Fukushima, it would have been more time. We learned within a few hours after both Three Mile Island and Fukushima that there had been significant damage. During the first few hours there is such a fog of information that people are denied the time to prioritize activities that need to be taken and resources that need to be obtained. A passive design like the ESBWR can take care of itself for seven days.

So, 30-50 years from now, where do we need to be with nuclear power? The next generation of reactor designs and fuel designs will take us well beyond where we are today. For the future, there is a pressing need for an Advanced Recycling Center to reduce the life of nuclear waste from 10,000 years (by taking out the transuranic elements) to 300 years and produce useful fuel.

Fukushima Daiichi and the Regulatory Climate for Nuclear Power

The Honorable William D. Magwood, IV[19]

The Energy Reorganization Act of 1974 divided the Atomic Energy Commission into two parts with different goals and cultures: one to conduct the promotion of nuclear energy research and development—the Department of Energy—and one to conduct the regulatory aspects—the Nuclear Regulatory Commission, which now employs 4,000 people.

Events in just the past year have taught us that we must prepare for the unexpected. For example, the flooding of the Calhoun plant in Nebraska caused shutdown of that plant; Hurricane Irene led to a review of emergency response; the east coast earthquake led to a plant being shut down for several months; and Fukushima showed the public how dramatically nuclear facilities can be affected by unpredictable natural events.

Before the Fukushima event, Japan imported 70% of its energy and 30% was supplied by nuclear energy, so the country was very dependent on nuclear energy to meet its electricity needs. Japan had planned to increase the nuclear component to 40%. The Fukushima Daiichi plant was very large by U.S. standards, with six boiling water reactors and a capacity of 4700MW. It supplied electricity to Tokyo. Two additional reactors using newer technologies were planned for construction on the same site starting in 2012, to meet a growing need for energy.

The relationship between Japan's counterpart to the NRC, NISA, and the Minister of State and Prime Minister is complex and potentially confusing. After the earthquake, the Fukushima reactors were shut down, and 40 minutes later the series of tsunamis began to strike the site. This was followed by an extended power outage during which the backup batteries became depleted, leading to a loss of reactor cooling and to core damage in Units 1, 2 and 3.

The U.S. government sprang into action immediately following the Fukushima accident, initiating a large, multiagency response. The NRC played a significant role in providing assistance to the Japanese and staffed its emergency operations center around the clock for nine weeks. As soon as it was learned that a nuclear emergency had arisen in Japan, an additional 150 people were sent to the U.S. Embassy there to support the efforts. Also, the NRC launched a series of inspections of U.S. plants, looking closely at their ability to respond to large natural disasters.

The major lessons to be learned from the Fukushima experience are these:

- Understand the risks of each plant;
- Recognize that we cannot predict everything that will happen, so design beyond the expectations;
- Plan for recovery from a disaster, realizing that the Japanese did not have the equipment, the procedures, or the people in place to recover; and

[19] Mr. Magwood serves as a Commissioner of the U.S. Nuclear Regulatory Commission. Prior to that he served as Director of Nuclear Energy with the DOE for seven years, during which time he was the senior nuclear technology policy advisor to the Secretary of Energy.

- Plan for the potential for common cause failure on-site and off-site AC power.

U.S. plants are safe, and we should recognize the following circumstances:

- There is no immediate risk to U.S. nuclear power plants;
- Similar events to Fukushima in the U.S. are unlikely;
- Mitigation measures are already in place to reduce the likelihood of core damage and
- We learned a lot from Three Mile Island and 9/11.

The events at Fukushima have raised the following policy questions:

- Should we further revise our approach to energy planning?
- Do we need a new regulatory regime to address beyond-design-base-events?
- Do we need to look beyond safety and address large social and economic disruptions?

Where do we go from here? The NRC is currently reviewing 10 applications for plant licenses. The Commission has approved new construction and operating licenses in Georgia and South Carolina. To date, the impact of the Fukushima accident on U.S. plants has been minimal. The SMRs offer the advantage that they can be brought online as investment allows, but they still have present critical challenges to be addressed.

As a result of Fukushima:

- The NRC will enhance the regulatory framework;
- Current nuclear plants are safe and will continue to operate;
- New plants have been approved; and
- SMRs will be evaluated.

Discussion of Session C

Kathy Kiely commented on the contrast between what reporters knew about nuclear energy at the time of the Three Mile Island accident versus what they know today. She recounted the extraordinary series of events during the accident. Because Governor Thornburgh was new in office at the time of Three Mile Island, a number of Pennsylvania newspapers had assigned political reporters to keep an eye on what he was doing. On the morning of the accident, she received information that something that might have happened at the plant. When she called an expert in the technology and read him the report that all these political reporters had received in a press briefing, he said: “Oh my God! It sounds like they have had a meltdown.” To which she replied: “What is a meltdown?”

Kiely told of Governor Thornburgh’s frustration at not being able to get information during the Three Mile Island event 33-years ago, and she noted how similar this was to the situation during the recent Fukushima event. She asked Mr. Kato if he would comment. Kato reported that there was a fog of information at the time of the Fukushima accident and that Japanese officials did not get enough information to know the status of events. They were focused on bringing about a safe shutdown of the Onagawa plant amid the earthquake and tsunami. Later interested parties were able to receive more information on Fukushima.

Governor Thornburgh noted Denton’s emphasis on the importance of emergency planning—particularly at the local level. On the first day of the Three Mile Island accident, Thornburgh sent Bob Wilburn, his Budget Secretary, to survey the emergency management plans and capabilities of the counties around Harrisburg. As Governor, he needed to have this information in case it became necessary to order an evacuation. Wilburn returned later that day with disquieting news. The counties had efficient emergency plans and plans for evacuation. However, it emerged from his survey that two counties lying on either side of the Susquehanna River, planned to evacuate their citizens across the Harvey Taylor Bridge, but in opposite directions! This brought home to the Governor the importance of careful governmental coordination.

Kiely asked what advocates might do restore public trust most significantly after a disaster. Governor Thornburgh responded that what is needed is candor, patience, concentrated effort at education, and the ability to respond to criticisms, to reach consensus on the path forward, and to realize that any approach will backfire if something is oversold. It is important for the industry to play it straight with the public; for the regulators to regulate; and for the rest of us to keep informed on any consensus that is reached about the best paths forward.

Denton said that it is essential to take steps to limit release of long-lived radiation into the environment leading to long-term ground contamination. In the case of Fukushima, radiation was operator vented. Some countries are looking at vent filtering.

Birkhofer said that prior to Fukushima, efforts were made in Europe to reinforce the confidence of the population, and this was shown to have been effective. A nuclear accident anywhere is a nuclear accident everywhere, and reinforcing cooperation internationally is an important element in public trust. Kato said that in Japan it will be necessary to convince the public that the industry is more prepared than it was before.

The problem may be that safety has been oversold. Johnson said the public does not understand radiation units. By comparison, if we told someone that the temperature in a room was 750 degrees, they would understand that they should not go in there. We need better ways to explain the risks that nuclear energy presents to people and to the environment, so that the public can weigh the impact. In particular, we need to deal with spent nuclear fuel, since people are uneasy about it. Magwood said that the best confidence builder is safe operation of the plants.

Kiely asked if the single unresolved issue is the disposition of spent fuel. Kato reported that Japan has commissioned a spent fuel reprocessing facility based on the French design, supplemented by the British and Japanese design, to recycle the uranium and plutonium. This recycling operation has been the national policy, but after the Fukushima accident, a review of it is now underway.

Birkhofer observed that even the IAEA has only looked at regional spent fuel centers. France is currently going through an interesting exercise; because spent fuel can only be recycled once, ways to reduce long-term radioactivity are needed. For this, the Fast Breeder Reactors are called for, but designs of these must be developed with negative void coefficients, not positive void coefficients as all previous FBR have had. We need research and development on these. Magwood said that the NRC has high confidence that we can store spent fuel on the plant sites for up to 60 years. The NRC is looking into whether it can be stored even longer. That does not mean it is a good idea to store the waste on plant sites for this long; rather, it means that we have time now to look at the storage issue and make the right decisions.

Thornburgh asked what the objections of the U.S. are to recycling. Magwood explained that U.S. policy makers are concerned about the proliferation characteristics of existing reprocessing technology. The technology used in France and elsewhere is based on 1950's technology that separates the pure plutonium from the spent waste. Some policy makers are concerned that these technologies could fall into the hands of countries that would misuse them. DOE is looking at more advanced technologies that address these issues.

A question was asked about the risks of terrorist attacks and how well prepared we are for such attacks. Denton replied that the Department of Defense was brought in to test for weaknesses, and their recommendations were taken seriously. At this point, the facilities are very well protected. He has wondered whether it would not be best to transfer the spent nuclear fuel to the DOD, which has its own nuclear sites. Magwood said that while the facilities at Savannah River and Idaho are DOD sites, they also fall within states and those states have a say.

In response to a question on the business impacts of liability (cleanup), Johnson explained that liability costs are not making owners defer decisions on new plants. These decisions are driven by markets and relative energy costs. Magwood reported that the industry has formed a pool that would contribute a combined $13B towards cleanup following an accident.

A questioner asked why some of the changes made to U.S. plants following the Three Mile Island event were not implemented at Fukushima. Birkhofer said that, in the case of German plants, some of these changes suggested by Three Mile Island or Fukushima where not applicable or transferrable. Instead the German response was to focus on emergency response—to improve its robustness and its reinforcement. In fact, the system of nuclear plant operations developed by Japan—built around scheduled maintenance and overall excellence—became the model for other countries, including the U.S. Kato said that, even though they learned a lot from earlier events, the problem at Fukushima was the loss of AC and DC power in a natural event beyond all expectations.

It was asked when the Japanese nuclear plants would be turned on again. Kato explained that the Japanese government is concentrating on two plants right now, Ohi Units 3 and 4 of Kansai, and is reviewing their stress test reports. This summer will be difficult in Japan without nuclear reactors.

Session D: Political, Legal and Financial Aspects of Nuclear Power

Moderator: Bill Flanagan, Executive Vice President, Corporate Relations, Allegheny Conference on Community Development and host of *Our Region's Business*, WPXI-TV

March 28, 2012

A United States Senate Perspective

The Honorable Lamar Alexander (video presentation)[20]

Senator Alexander recounted an incident that occurred during the Second World War. President Roosevelt sent for the Chair of the Appropriations Committee, Senator McKellar of Tennessee, and told him that he would like $1B to be hidden in the Senate Appropriations bill for a secret project that would end the war. Senator McKellar replied that would not be a problem, but that he had one question—where in Tennessee would the secret project be located? That was the beginning of a discussion that led to the Oak Ridge, Tennessee, part of the Manhattan Project—the greatest concentration of physical science in the history of the United States. We now have 104 civilian nuclear power plants in the U.S. that provide 20% of our electricity and 70% of our clean electricity.

The U.S. uses 25% of all the electricity in the world, but generating this much energy using windmills is not feasible. A reawakening in nuclear energy is underway. Two of the new AP1000's are now being built. Seven more AP1000's are in the approval cycle. The Secretary of Energy, Dr. Chu, has provided excellent leadership on behalf of nuclear power.

Congress is also taking important steps to help this reawakening along. Last year, $100M was approved to support the research, development, and licensing of small reactors. We are very good at small reactors already because of our nuclear navy and these reactors are a little different but the same idea. Small civilian nuclear reactors will revolutionize public access to nuclear energy. If we do not move ahead with a program in SMRs, we will be left behind. There are about 60 countries seriously pursuing nuclear power, and about half a dozen that are seriously pursuing SMRs.

Congress is also discussing the issue of used nuclear fuel, with a goal to develop legislation on its disposal this year. If the Federal government cannot convince the public that we can safely dispose of nuclear fuel over the long term, we will have a hard time persuading state and local governments to accept nuclear reactors. Senator Alexander expects to see the Congress continue to fund research in new reactors through the Energy and Water Development Subcommittee, which he chairs. Ways are also being studied to extend the life of the existing reactors, since many are approaching the 60-year mark. We have to plan now, not just for the replacement of those reactors, but also for sufficient new reactors to meet our growing electricity demand.

In particular, we need to build 100 new nuclear reactors in the next 20-30 years. To do this, there are two major challenges to be addressed:

- The first challenge is creating the leadership that is needed to develop nuclear energy successfully, realizing that shutting down nuclear power is not the solution. Post Fukushima Japan provides an example of people adapting to little air conditioning, factories running on weekends, and the Emperor using candles in the

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[20] Senator Lamar Alexander chairs the Energy and Water Development Subcommittee of the U.S. Senate Appropriations Committee. He has served as Governor of Tennessee, and he was Secretary of Education under President George H. W. Bush. Senator Alexander also has served as chair of the Republican Conference.

palace at night. It is hard to see how Japan can shut down 30% of its electricity and still be a major power.

- The second challenge is that of competing with natural gas at its current low price. The innovation in shale gas has given us perhaps a 100 years' supply at low cost. Just seven years ago, when natural gas was several times its current price, people could not afford to heat their homes, factories were considering relocating to other countries, and utilities were filing for bankruptcy. Other countries are paying a high price for natural gas, which is why they are moving ahead more rapidly with nuclear energy. Once built, it is hard to run a plant more cleanly, more safely, or more inexpensively than a reactor, even for a long period of time.

There are obstacles to using nuclear fuel, but despite them it is hard to imagine the U.S. moving ahead without nuclear energy. Indeed, we need to plan on 100 nuclear reactors over the next 20-30 years.

A United States House of Representatives Perspective

Bart J. Gordon[21]

The political climate in Washington, D.C., is even worse than we see reported in the media—generating the worst gridlock and meanness in 27-years. There are a several reasons for this decline. Highly partisan redistricting over the last 2 to 3 decades has led both parties to greater extremes of advocacy and left them with little interest in seeking common ground. More recently the Tea Party followers have influenced the situation through the candidates they elected as well as their pressure on moderate Republicans with primary threats. Super PACs are also a growing problem. In earlier years many congressmen had their families living in the D.C. area. Their children went to the same schools and played on the same sports teams; spouses worked together on different projects; and so the families got to know each other. Now that the schedule has contracted to Tuesday through Thursday, this family interaction happens less, because many families remain in the home districts. Also, the leadership of both parties has learned that a way to become the next majority party is to prevent the current majority party from getting anything done. Lack of cooperation has escalated, and the filibuster has been much overused, making it very difficult to get anything done with less than 60 votes. All of this has created an extremely difficult environment in which to conduct the business of the country.

Despite that, even at the height of Fukushima, the President and the Secretary of Energy have maintained that nuclear energy must be part of the energy portfolio. Over the years, most Republicans have been supportive of nuclear energy. This is somewhat mitigated by the fact that the loan guarantee program to support emerging industries is considered by many to violate free market principles. The same may apply to tax credits and the Price-Anderson Act. In any event, unlike Republicans, Democrats over the years have been less supportive of nuclear energy, primarily because of the unresolved issue of nuclear waste. However, climate change is leading to their rethinking this opposition. Gordon reported on achieving some successes in passing legislation in the Science and Technology Committee by bringing a lot of people together and conducting a very transparent process. With this approach, he was able to obtain bipartisan support for a nuclear research energy bill that passed the House, but subsequently failed in the Senate. The way one talks about these matters also changes: At present one must talk about energy independence and energy security, rather than climate change and global warming.

Another challenge is that Washington is a very jurisdictional environment, and different committees handle different aspects of a comprehensive area. For example, the Energy and Commerce Committee deals with regulation and deployment, while the Science and Technology Committee deals with research, development and demonstration, the Ways and Means Committee deals with tax aspects, and the Appropriations Committee with

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[21] Bart Gordon represented the State of Tennessee in the U. S. House of Representatives for 26 years, during which time he chaired the House Committee on Science and Technology for four years. He is currently a partner in the Washington office of the K&L Gates law firm. He has been a leader in advocating for science and technology.

funding issues. All of these parts must be brought together for success in passing major legislation.

There are three approaches to any path forward:

- Convincing the President that the proposed approach is the correct approach, and having it implemented within existing programs without legislative action, is the best way to proceed;
- If that does not succeed, bring people together and find a place to insert the proposed project that will pass; or
- If that does not succeed, go through the legislative process in an open way.

Finally, anything must be done quickly after an election cycle, as the next election cycle starts early and changes the dynamic. During this phase, support for an issue can change.

Legal Issues in the Regulation of Nuclear Power

Barton Cowan[22]

Among the many legal issues facing nuclear energy, the following four were selected as significant for the symposium:

- Fukushima and the issue of reasonable assurance of safety;
- License renewal and Federal preemption;
- High-level nuclear waste—Yucca Mountain; and
- Nuclear liability insurance.

Fukushima and the issue of reasonable assurance of safety: The Fukushima disaster has raised a number of legal questions, and one of the most important concerns licensing of nuclear power plants: In order to be licensed, to what extent is it necessary for plants to be designed and have mitigating strategies to deal with external events that are considered remote, and thus beyond the current design basis? Ever since the Atomic Energy Act of 1954, the legal standard for obtaining a license to operate a nuclear power plant has been whether there is reasonable assurance of adequate protection of public health and safety and the common defense and security. Under this statutory standard, the NRC is not looking for zero risk. Rather, risk considerations are based on an assessment of culpabilities if an accident should occur, and the consequences if an accident does occur. The NRC bases its assessment on real world safety concerns. The Atomic Energy Act requires that a reactor be designed for what are called design-basis events and conduct an evaluation of severe accident mitigation design alternatives (SAMDAs). A determination is made as to whether the safety benefits of a possible severe accident outweigh the cost of incorporating the SAMDA in the plant. Because the current nuclear plants have a low risk profile, generally such evaluations have found that the risk reduction offered by the SAMDAs does not warrant the expenditure.

Since Fukushima, the NRC has reopened the question of what is necessary to provide reasonable assurance, and what additional requirements are needed to increase the capability to mitigate beyond-design-basis events. These impacts may also include social and economic disruptions as part of the license renewal process. However, there is some question as to whether the NRC has the power to do this. On March 12, 2012, the NRC issued three orders, one of which will impose the requirement to increase the safety of nuclear power plants to negate beyond–design-basis external events. Yet the NRC did conclude that the sequence of events at Fukushima is unlikely to occur in the U.S. and that continued plant operations and licensing activities do not pose a threat to public health and safety. The nuclear industry was therefore surprised that the NRC issued this March 12 order imposing additional requirements to increase the current capabilities to mitigate beyond-design-basis events to protect public health and safety. The industry has not challenged the NRC and has issued guidelines for the necessary mitigating strategy process

[22] Barton Cowan is Senior Counsel with the Pittsburgh-based Eckert Seamans Cherin & Mellott Law Firm, and is currently Visiting Professor in the College of Law at West Virginia University.

that have been endorsed by the NRC. The stringent goals of the NRC are to prevent any large releases of radiation, and any releases should be a small fraction of any natural sources. Yet in a speech on March 15, 2012, the NRC Chairman said that releases of radiation are unacceptable, even if posing no risk to human health and no threat of land contamination. Statements such as this raise concern that the stage is being set for further contentious litigation over the question—how safe is safe enough?

Two post-Fukushima decisions by the NRC are being challenged in the U.S. Court of Appeals for the District of Columbia Circuit. The two court decisions appear to vacate the approval of the amended Westinghouse AP1000 design certification and vacate the combined operating license for the global nuclear plants.

License renewal and Federal preemption: The initial license for a nuclear plant authorizes operation for 40 years. This period is established by the Atomic Energy Act of 1954, and is based on economic and antitrust considerations and not on technical or nuclear safety issues. A license can be renewed for an additional 20 years. Currently 71 licenses have been renewed, and 14 more are in the process of being renewed. There has been opposition to some of these—particularly the Vermont Yankee plant (supplying 74% of all electricity to the State of Vermont), which was renewed in March 2011 with a 20-year extension. The State of Vermont has opposed this and claimed that the NRC unlawfully renewed the operating license. Oral argument is set for May 9, 2012. In addition, the Vermont Legislature passed several laws that would have resulted in the plant having to be closed. The utility company sued in Federal court claiming that the Vermont statutes were an attempt to regulate the safety of nuclear power, and argued that these statutes were preempted by the Atomic Energy Act of 1954, which gave the right to regulate nuclear safety solely to the Federal Government. The Federal U.S. District Court has ruled twice in favor of the utility company. There are also safety issues in New York raised by environmental organizations over the Indian Point plant, and hearings are scheduled on them for the spring of 2012. These may lead to the same issues of Federal preemption.

High Level Waste—Yucca Mountain: The Nuclear Waste Policy Act of 1982 established a national policy to solve the problem of disposing of high-level nuclear waste. In 1987, the Congress directed the DOE to study the Yucca Mountain site. This site was eventually selected, and in 2006 the DOE proposed that the site be ready to begin accepting nuclear waste on March 21, 2017. The DOE applied to the NRC for a license and the NRC appointed a licensing board to hear the DOE's case. During the 2008 presidential campaign, President Obama ran for election on a promise to shut down Yucca Mountain and, after the election, he did so by cutting off all funding, except for funds to close the site. The NRC ended the licensing procedure. Suit was filed by several parties in South Carolina and Washington for unlawful delay. The case it set for May 2, 2012. The courts have ruled that the Federal Government 's agreements to accept spent nuclear fuel are contracts and that the government has breached those contracts. There have been 76 cases filed by states against DOE for the costs associated with on-site storage resulting from those breaches. At present, these costs are $16B, and DOE has already paid out over $1.4B.

Nuclear Liability Insurance: The Price-Anderson Act of 1957 is the nuclear liability regime in the U.S. It was designed to ensure that adequate funds would be available for claims by members of the public for personal injuries in a nuclear accident. The Act set up an insurance pool of $12.6B to mitigate damage from a nuclear accident. This pool consists of two tiers of omnibus insurance:

- First Tier: Private insurance of $375M with the premium paid by the owners; and
- Second Tier: Industry insurance of $112M/per plant/per accident with the premium paid by each of the plants.

The primary and secondary tiers combine to provide coverage of $12.6B against a nuclear accident. Since the Price–Anderson Act was passed, claims of about $151M have been paid, with $71M of that amount paid as a result of claims from the accident at Three Mile Island. In addition, the DOE has paid out about $65M in claims. The definition of a nuclear accident is broad and also covers transportation of nuclear materials. Under the Act, there is a limit on the liability to the above coverage. In the case of an extraordinary event, there would be a no-fault liability regime for nuclear insurance.

Nuclear Safety and Nuclear Economics: Fukushima Reignites the Never Ending Debate

Dr. Mark Cooper[23]

The $12.6B in insurance coverage is constitutional, but is it right? The cost of recovery from the Fukushima nuclear disaster is estimated at $250B. The attention of the public and policy makers is riveted on nuclear safety. But the 50-year history of nuclear power has revolved around the tension between safety and economics. Nuclear power at affordable cost and acceptable risk—can we achieve both? Is it possible that nuclear power is not worth the risk at any cost? We need to understand how the decisions to go into nuclear power are made in the first place. Using statistical econometrics analyses based on 250 reactors, including construction costs, which have been studied before, the question arises, "What creates the decision to build/cancel, or repair/retire a reactor?" It is critical to understand how those decisions were made in the past.

Some history: In the 1960's, the nuclear industry told Washington that a nuclear accident like Three Mile Island meant that the technology was untested, and GE and Westinghouse said they would not build new reactors if the federal government did not shield them from liability from accidents. Having secured that liability shield, a massive expansion of nuclear power was proposed to take the industry from a handful of small reactors to 250 reactors, each with a 1GWatt capacity for a total of over 200GWatts—an expansion unprecedented in U.S. history. These 250 reactors were to be placed in proximity to metropolitan areas with over 100M people, even though the reactors had not yet been tested in the real world.

Fearing the worst, the NRC adopted hundreds of regulations to try to ensure that those huge reactors so close to so many people could not create harm. However, the industry objected vigorously that it could not exist with such safety regulation costs. The NRC saw the inexperience and bad track record of operators and the unproven designs as justification for the rules. The problem persists today—poor institutional structure and specific challenges.

The principal fear has been radiation, with debates over things like 50-mile exclusion zones. But Fukushima reminded us that there are also social, psychological, and economic factors. After Fukushima, the Japanese were thinking about evacuating Tokyo! Tokyo Electric Power was instantly put into virtual bankruptcy, and the Japanese economy is damaged. The magnitude of events like Fukushima is hard to grasp or communicate.

Before the Three Mile Island accident, the nuclear industry could not control its costs, and they were escalating rapidly. By 1978, more plants had been cancelled than completed. Although the capacity added in the 1970's and 1980's exceeded the capacity cancelled, the nuclear energy gained was not enough, and it has not been able to replace fossil fuel.

During the nuclear renaissance, highly optimistic cost projections were made. MIT projected $2000/KW of plant capacity and said it might go down to $1000/KW. The

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utilities building the plants are now talking about $5000/KW, and Wall Street analysts are projecting $6000-$8000/KW. Actual costs have always exceeded the costs projected by analysts, the utility companies, and nuclear enthusiasts. For these reasons eighty percent of the reactors planned during the nuclear renaissance have been cancelled. As a result, subsidies are needed, and more are needed today than ever. Subsidies occur in the form of the liability insurance subsidies, ratepayer subsidies, loan guarantees, and deals with public power that can raise its own capital—all because the industry cannot finance a nuclear power plant in the market in the usual way. In addition, there are the challenges of lower cost alternatives.

The Fukushima event reminds us that nuclear accidents fall into a category known as "unknown unknowns." But the whole electricity sector is afflicted by the unknown. How is a supplier to acquire resources in an environment in which they do not know what the outcomes or probabilities may be? We do actually have tools to navigate in regions of the unknown, and these include keeping options open, starting with small units that can be applied quickly, minimizing surprises by staying away from the unknown, getting insurance where possible, and diversifying portfolios. Analysis shows that wind energy is less susceptible to ambiguity as compared with nuclear energy, which is most susceptible. Nuclear reactors are particularly unsuited for uncertain environments, driving energy companies to look to other areas first.

Nuclear power at affordable cost and acceptable risk—can we achieve both? Rephrasing the question—is nuclear energy not worth the risk at any cost? It is a complex question, but one must conclude that nuclear energy is not affordable and that the risk is not acceptable. If the owners had to face the full liability of a nuclear accident or operate without subsidies, no reactors would have been built, or if they had they would quickly be abandoned.

The nuclear energy option should not be taken off the table, however, since it may well be needed in the mid-2030's. The history of the industry supports doubts about it, and human nature makes the concerns more real. Government subsidies preclude rational thought. Hyping the nuclear renaissance is bad policy, since it raises hopes that cannot be realized, and people lose trust. If one gives up the fiction that nuclear energy is viable, then one can move on to a rational approach. If nuclear reactors are to be built in the future, here is a set of conditions under which they could succeed:

- One project should be given to each state (two reactors);
- Each should be built on a brownfield site;
- Each should be a dual-unit, because the second unit is so much less expensive;
- There should be advance cost recovery from the rate payers; and
- There should be a loan guarantee.

These are the conditions of Vogtle, and no other reactor has had these characteristics.

People have asked how the Japanese will compete going forward with the loss of the 30% of their energy that had been provided by nuclear power. The Japanese used half the energy per capita that we do. Given our habits, if we had a source of cheap energy, who knows how much we would use per capita. If we are to be smart going forward, we have to get our consumption in line. If not—how will we compete?

The Story of Vogtle 3 and 4

Stephen Kuczynski[24]

Southern Company, a 100-year old company, believes nuclear energy needs to be part of the mix, and already operates four reactors in Georgia and two in Alabama. Its portfolio is 16% nuclear and includes 21st century coal, natural gas, renewables, and energy efficiency initiatives. The company believes that if it can satisfy the customer by reliably delivering electricity at prices below the national average, it can benefit from the regulated environment and reinvest capital. Southern Company is the only company currently investing in all five technologies.

The Energy Policy Act of 2005 provided incentives for companies to build new reactors. A Southern Company subsidiary, Georgia Power, is currently in negotiations with the Department of Energy to finalize a $3.4 billion loan guarantee for the Vogtle 3 and 4 project. The total amount of the loan guarantee for Georgia Power and the co-owners is $8.3 billion. The loan will be fully repaid, and any savings will flow directly to the customers, which are expected to save approximately $15-$20M in interest costs annually because of the loan guarantee program.

The combined construction and operating license for Vogtle units 3 and 4 was received in February 2012, but the process started back in the 90's. The process has a long horizon and is better suited to a regulated environment, but it is not guaranteed even in that market. Southern Company builds its own facilities and has experience building the earlier units in the 70's and 80's. The company adjusts its mix as new developments, such as shale gas, come along. A few years ago, they were 70% coal; now they are 52% coal and 30% natural gas. Since Three Mile Island, safety, cost and operating records have all continued to improve. Nuclear energy maintains fuel diversity and is the largest emissions-free baseload source.

The two new reactors, Vogtle 3 and 4, are expected to come on line near Augusta, Georgia, in 2016 and 2017. Vogtle 3 and 4 are standard passive design AP1000 reactors, built for 60-year operation. While the new reactors will cost $14B to construct, once built they will be very low cost to operate. The construction of two reactors will provide 4000-5000 jobs over the next five years. Although Vogtle 1 and 2 went through a difficult construction phase, the new reactors are being built at a time that offers a number of improvements over construction done in the 80's: interest rates are lower; inflation is lower; and there is a completely different licensing and modular construction process.

The AP1000 is simple and has enhanced safety, particularly because AC power is not required for the shutdown. As information is learned from Japan and from construction in China, changes are incorporated into the design. Vogtle 3 and 4 are the reference point and lead the industry in the U.S. Another plant should be able to go through the process much more quickly. The schedule and budget targets for the Vogtle 3&4 project are achievable.

[24] Stephen Kuczynski is Chairman, President and Chief Executive Officer of Southern Nuclear Operating Company, a subsidiary of the Southern Company. He is responsible for the Southern Company's six nuclear reactors and is an engineer with 27 years of experience in the nuclear industry.

Nuclear Power: A New Regulatory and Financial Paradigm

Robert F. Powelson[25]

Pennsylvania is the second largest nuclear energy production state in the nation (after Illinois). The industry employs 100,000 workers in Pennsylvania, with annual electricity sales of $40B-$50B. Nuclear plants are the lowest cost producers of electricity on the grid.

The Pennsylvania nuclear energy experience is a success story. Prior to 1997, the generation of electricity in Pennsylvania was in a regulated market—similar to that in Georgia now. That model changed under former Governor Tom Ridge, when Pennsylvania became one of the first five states in the nation to adopt a restructured electricity market. This change took electricity generation and all the costs associated with it off the ratepayer side of the balance sheet and moved it to the shareholder side. Pennsylvania is now part of a 13-state grid, and every electron of electricity produced in those 13 states goes into the grid. The energy mix for the 13 states in 2011 was: 55.7% coal; 33.7% nuclear; 7.5% natural gas; 0.6% hydro; 0.2% wind; and 0.6% other sources. In 2011, 49% of Pennsylvania's electricity production came from coal; 33.8% from nuclear; 14.8% from natural gas; 0.9% from hydro; 0.8% from wind; and 0.9% from other sources. The natural gas portion will increase and, important as these are to the mix, wind and solar will not become major components. Pennsylvania is the 6th largest consumer of coal in the country, but coal plants are closing. The market in which Pennsylvania operates works, but it is very different from that in which Southern Company operates in Georgia.

In the early years prior to the Three Mile Island accident, 70 plants were in operation in the United States. There was no standard design for them; the price market was regulated; the cost of construction drove design towards 200KW plants, since "bigger is better;" high level waste storage was not addressed; and it was said that the cost of electricity produced by nuclear reactors would be "too cheap to meter." Pennsylvania ratepayers have already paid $1.4B to build the Yucca Mountain repository facility, and it is a colossal failure of leadership that that facility is not operational. While on-site waste is safely stored at a cost of millions of dollars to the companies, we need a national strategy to deal with spent fuel.

The tipping point that changed the markets in Pennsylvania from regulated to restructured came about as a result of several factors. These were a combination of the OPEC oil embargo (in 1972 the price of a barrel of oil was $3; in 1979 it had reached $30 a barrel; and now it is $100 a barrel); the low demand for electricity; the fact that natural gas supplies were thought to be almost depleted; the Three Mile Island accident; high interest rates (at over 20%, these made it impossible to capitalize new plant investment); public opposition; and the Chernobyl accident.

Then came a perfect storm, which is the poster for electricity market deregulation. Construction began on a state-of-the-art reactor, the Limerick Generating Station outside Philadelphia. The Limerick Generating Station ran into a number of challenges presented

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to the Public Utility Commission that included high interest rates, and public opposition. What was supposed to have been completed for $2.5B came in at $7B. This cost increase had to be absorbed by taxing the customers. In the mid-90s, Governor Ridge decided that this system was both too inefficient and too expensive, and he moved to an unregulated market.

More recently, developments have supported as well as countered the nuclear renewal:

- The renewal started with the Energy Policy Act of 2008 that allowed utilities the addition of two new reactors to be proposed by 2010. Southern Company was one of the early proposers.
- By January 2009, the NRC had received 18 license applications to build 27 reactors. At the end of the process, there were three viable applications.
- In 2003, MIT estimated the cost of electricity generated by nuclear power to be $0.067/KWhr, versus $0.042/KWhr for the new pulverized coal and natural gas.
- The EPA regime is moving unscrubbed coal plants offline.

We need an all-of-the-above strategy that includes nuclear, shale gas, and coal. Our strategy must get cleaner, and a big commitment from Detroit to new LNG technologies for long-haul vehicles promises new transportation technologies.

A new energy dynamic calls for a variety of recommendations, perspectives, and answers:

- An energy policy is badly needed, and absent a national policy, Pennsylvania is developing its own.
- The Federal nuclear loan guarantee program is important and has already made $18.5B available.
- The Fukushima disaster came as a global wake-up call that must be understood and addressed, and the reaction is ongoing.
- The National Association of Regulatory Commissioners has recommended:
    - A new policy on a central repository;
    - A new organization to implement the nuclear waste management program;
    - Access to the funds that nuclear utility ratepayers are providing for the purpose of nuclear waste management;
    - One or more deep geological disposal facilities (Having built Yucca Mountain, why are we doing this over again?);
    - Prompt efforts to develop one or more consolidating facilities;
    - Prompt efforts to develop the transportation of the nuclear fuel waste to the consolidating site;
    - Support for continued innovation in nuclear energy technology; and
    - Active U.S. leadership in international efforts to address nuclear safety, waste management, non-proliferation, and security.
- Some 70+ nuclear plants are going through the process to be relicensed for a further 20 years, but no one knows what will happen after those 20 years, and this adds to the uncertainty of doing business.

- What will be the impact of cap and trade if realized?
- How long will natural gas prices remain low? We are now at historic lows and prices may not stay this low, but are likely to be stable for a number of years.
- The PPL Bell Bend Project is a potential new unit for Pennsylvania and, similar to Vogtle, would use existing footprints and have 1600MW capacity. The new plant is not in the rate base. The market capitalization of PPL is $13B. The plant would cost $8-12B. Without a loan guarantee, and perhaps even with one, this plant is not likely to go forward in light of the economics.
- In Pennsylvania, existing plants are doing "nuclear upgrades," i.e. incorporating new technologies and improving yield. This is a good least-cost option.
- We need SMRs allowing incremental build of 120-300MW.
- Today most of the components for nuclear reactors are manufactured off-shore, and we need some visionary leadership to bring that technology to the United States.

All of these perspectives mean that a new plant will not be built soon in Pennsylvania.

Discussion of Session D

Bill Flanagan told of an occasion exactly 33 years ago when, as a journalism graduate student at the University of Missouri in Columbia, he was working the morning shift for the university's public radio station. At that time, stories were typed on manual typewriters and came in on teletype or wire machines. The wire machine sat at one side of the newsroom and would be clacking away all day long as it typed out the incoming news stories. If something urgent was coming in, a bell rang. On this particular morning, suddenly the wire machine went insane. It sounded like a machine gun, and the paper was shot out of it. Flanagan walked over and pulled out the copy—which was blank. Then three words were printed: FLASH FLASH FLASH. He had never before seen an actual news flash from the Associated Press. Finally, the headline rolled off: ACCIDENT AT THREE MILE ISLAND PENNSYLVANIA. The University of Missouri, in addition to its own radio and TV station, had a nuclear reactor. So Bill and the staff were able to bring in the nuclear engineers and help to educate the public in central Missouri as to what was going on.

Later Bill came to Pittsburgh to work for the Westinghouse Electric Company at KDKA, which was the world's first radio station. He remembered interviewing Westinghouse engineers who were enthusiastically working on the newest reactor technology, the AP600, and feeling sorry for them, because he was sure that after Three Mile Island they would never get the chance to build their creation.

A question was asked about the viability of an industry that required 10 years to plan for a new reactor and then 10 years to build it. Cooper replied that any industry in a 20-year cycle in a 20-minute environment gets in trouble. If one looks at the assumptions that were made to justify reactors in Florida, and then looks at the situation again two years later, every one of those assumptions had changed radically. So, if the decision had been made two years later, they would have reached the opposite conclusion. The horizon is too long. We still have many things we can do today to meet our needs, and we can look more seriously at nuclear energy in about 10 years time. The test is that if one would not do a project like this with one's own money, then it should not be done with other people's money.

Kuczynski said that with the experience of building the latest two plants behind us, it would be possible to shorten the cycle. Cowan and Kuczynski explained another factor in the current development time: The NRC initially certified the AP1000, a new design, in 2006, but after 9/11 the AP1000 design went through a number of revisions, which meant that the Vogtle license approval had to await re-approval of the AP1000. Another construction process could be shorter.

Cooper explained that the effects of uncertain factors can be calculated. One can ask questions like: What level would gas prices have to reach for nuclear to be a viable option? Or, what level would the construction costs need to be to make nuclear a good decision? Or would it be better to wait? The tools are available.

Powelson said that one could not run a steel plant on wind and solar in Pennsylvania. Cooper countered that one could do so in Kansas, and perhaps on solar in the southwest, so one must understand one's resources. In the 20th century, Pennsylvania had cheap fossil fuel and built a lot of industry around it. Whether fossil fuel is still cheap in the 21st century remains to be seen.

A question was asked about the adequacy of the liability insurance pool. In light of the Fukushima cleanup costs, there appears to be a large underinsurance in the United States. Cowan replied that while the insurance pool will not cover a Fukushima-scale accident, the alternative to Price-Anderson is for each utility separately to attempt to get its own coverage, with no contribution from the others. In that case, the utility would assume the primary coverage and would soon go bankrupt, which would mean there would be less coverage than at present.

Also Price-Anderson has had an interesting effect: Because each utility is responsible financially for major accidents at other plants, each has a particular interest in making sure that every other utility is operating its plants well. Price-Anderson has tied the utility industry together.

Powelson explained that before any claims are paid out, there is peer review. In the last decade one of the operators in Ohio had a crack in the structure and filed a claim, but the claim did not meet required standards and was rejected in the peer review process.

Cooper said that the pool should be raised to, say, $100B-$200B, to make it consistent with something that might actually happen. Cowan explained that the primary pool is set at the maximum amount of insurance that the insurance companies will write. If the secondary pool were raised too high, the nuclear industry would drop out, and each utility would stand on its own, with a smaller coverage.

Kuczynski listed the contributors to the performance of companies in the United States–all the regulations that must be met, all the independent oversight, all the upgrades that have been done following each nuclear learning incident—and concluded that the full picture does not justify what Dr. Cooper had just suggested. Cooper responded that if the industry is that safe, it should be possible for a company to build a new plant with its own money in the market place, and this cannot be done.

Powelson told the story of a former EPA Director who said that if the other industries had organizations like INPO, other crises—such as the BP Deepwater disaster—might have been avoided.

A question was asked about the future availability of uranium. Kuczynski explained that there are currently no challenges to the uranium supply. The sources are diverse, which is why it is cheap.

Governor Thornburgh concluded the symposium and observed that the presentations and discussions in the four sessions refocus in a variety of ways the debate on the future of nuclear energy in the United States, and provide a fuller and more accurate context for decisions to be made in the years ahead. "That is what the Dick Thornburgh Forum on Law and Public Policy was established to do and is a gratifying outcome."

To learn more about the Dick Thornburgh Forum for Law and Public Policy visit:
Thornburghforum.pitt.edu

Closing Remarks

Dr. John D. Metzger[26]

The speakers we have heard over the last two days are making decisions all the time that affect the energy policy of the United States, not just now, but in the future. There is probably not another commodity that is more important to our everyday life than energy. Imagine what our lives would be like if we did not have an abundant supply of energy. Our quality of life, our health, and our basic happiness would be substantially affected.

Fifty-five years ago, at the 1957 Annual Scientific Assembly of the Minnesota State Medical Association, Admiral Rickover, the Father of the Nuclear Navy, gave a presentation entitled "Energy Resources and Our Future." In the talk, he said that the world was living in what might be called The Fossil Fuel Age. At that time 93% of the world's energy was supplied by coal, oil and natural gas. Hydropower was 1%, and human and animal power made up the remaining 6%. Yet, Rickover explained, the rate of consumption of energy was increasing at a phenomenal pace, and further, with 6% of the world's population the United States was consuming 33% of its energy.

A surplus energy supply has always been necessary for the growth of a civilization, and over history civilizations have gone from slave labor, to wood, to coal, and oil. The high fossil energy consumption in the United States had allowed a Golden Age standard-of-living to be built. Given that this standard depends on an abundance of energy, Rickover asked what assurance we had that the needed resources would continue to be available to sustain this Golden Age. Because of the finite nature of Earth's resources, there could be no assurance of an infinite supply. At the time of Rickover's talk, experts were predicting that the fossil fuel supplies would be depleted in 25-100 years from 1957: before 2050. He concluded that wind, water and solar could not meet the U.S. needs and that the answer would lie in nuclear fuel. Rickover went on to point out the extent of human impact on the environment: "Another cause of declining civilization comes with the pressure of population on available land."

What is perhaps so surprising is that Admiral Rickover's observations in 1957 are still valid today, and could well have been written today. Presently, over 80% of our energy consumption is from fossil fuel. If we are to have the energy resources we need to sustain the future, we must plan ahead and not postpone such decisions for a later time, when the decline has already begun. Our energy is always going to come at a financial price and an environmental price, and we want to keep the negative impact as small as possible.

While the press has not been particularly kind to the nuclear industry despite strong and growing public support, let us consider some of the advantages that nuclear energy offers.

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[26] Dr. John Metzger is Director of the Nuclear Engineering Program in the Swanson School of Engineering, University of Pittsburgh. His nuclear engineering experience spans the private sector, national laboratories, and academe, and includes the thermal-hydraulic design of nuclear reactors. His earned his Ph.D. at the University of New Mexico.

In recent years we have recognized the need for alternative, renewable, and sustainable energy sources, but inexplicitly nuclear power has been dismissed from consideration. Yet nuclear energy plainly meets the goal of an alternative, renewable and sustainable energy source. Nuclear power is inherently an alternative energy source: a nuclear power plant does not produce greenhouse gases. It is renewable (reprocessing) and sustainable, with more than adequate long-term uranium supplies. The fossil fuel industry is spending billions of dollars to sequester carbon. The waste at a nuclear power plant is *in situ*, it is sequestered, it is controlled, it is accounted for, and the amount produced is almost negligible. Nuclear power is reliable and leads the industry in the all-important "capacity factor."

A bookmarker published for students and educators by the Bureau of Ocean Energy Management shows that a city of 100,000 people uses an amount of electricity that could be provided by 1/30 of a nuclear power plant on 12 acres; or 724 windmills on 1,615 acres; or 241,000 solar panels on 2,907 acres. Also, the nuclear plant can be built where the energy is needed—something not true of wind and solar power. A flaw in the German plan to go fully renewable may be that the plan involves the need to store backup energy. However, one can only store energy if there is excess capacity, and getting to an excess capacity that allows storage will be a challenge. Use of biomass fuels does not count against the carbon count, since it is claimed to be carbon neutral. This is just rhetoric, as biofuels are not carbon neutral over time any more than any other fossil fuels.

On the issue of safety, when one looks at the combined safety record of the commercial nuclear power industry and Naval Nuclear Propulsion Program, no one in the United States has died from a radiation release. While no one has died in a nuclear accident, the nuclear industry always pushes itself to a high standard and continually improves on the basis of experience.

Dr. Metzger thanked Governor and Mrs. Thornburgh, Provost Emeritus James Maher, and Dean Gerry Holder for providing this public forum for the diverse perspectives of the panels. The caliber of the panels has been remarkable, he said, and the symposium has addressed thoroughly and carefully the complex question of what the future of nuclear power should be. Metzger thanked the panels for the best discussions that many present had likely ever heard on this critically important topic.

Conclusions: The Next Thirty-Three Years

The advantages of nuclear energy are undeniable: no greenhouse gas emissions, reliable and economical operation and maintenance, a compact footprint, an almost unlimited and inexpensive fuel supply, and a small and contained waste volume. Concerns about nuclear energy focus first on safety and second on the cost of plant construction compared with that for other fuels such as natural gas. Any nuclear accident, however rare and whether involving a nuclear plant or used nuclear fuel, arouses public alarm about health as well as social, economic, and security disruption. Yet public support for nuclear energy in the United States today is stable, strong, and growing stronger due to fears of global warming. If nuclear energy can continue to be produced safely at competitive costs, it will be seen as a source of energy second to none by most of the world.

Much of what will shape the use of nuclear energy over the next thirty-three years will depend on government policies, economic circumstances, and the continued safe operation of the current fleet of plants. We have seen a change in the world nuclear community. No longer does the United States drive the decisions made by other countries. On one hand, we see that Germany has decided to abandon nuclear power, while countries such as China and India are aggressively moving to build nuclear power plants. We are also seeing countries that have never had a nuclear power program try to tap into this source of energy. The nuclear community is truly a global community, and what happens in one country will affect decisions in others. Consequently, all members of the nuclear community are depending on each other to maintain a high level of accountability and safety. Each of the four sessions of this symposium produced vigorous debates, and the issues addressed combine to frame in one way or another the direction and leadership that is needed in the future.

Germany has made a decision, widely supported by the German people, that nuclear energy is not worth the risk at any price. While this decision was made prior to the Fukushima accident, it is reinforced by that accident. In the case of Germany, the fears are about security rather than a potential for natural disaster. Germany has resolved to abandon its substantial nuclear fleet and has already shut down half of its reactors. During the next 20+ years Germany is committed to an Apollo-like program to develop renewable technologies that will transform its energy production to a wind/solar base. During this period Germany will close its remaining nuclear plants and will build ten high-efficiency coal plants to provide backup electricity while new technologies are developed. The targeted long-range goal is that the country operate from renewable fuel technologies and that these technologies become a major national export.

Doubts expressed about Germany’s initiative center on whether its goal is feasible for a country with no significant hydro resources, and whether the needed storage technologies will be adequate for such a developed country. Many believe that if Germany is successful, its transition will provide a roadmap for other countries and that, if any country can be successful in weaning itself from fossil fuels and nuclear power, it will be Germany. However, other commentators believe that Germany’s decision will have dire economic effects and that, in the end, Germany will depend upon nuclear-generated electricity from neighboring countries.

Much discussion in this symposium dealt with the safety of nuclear reactors and their inherent risk, if any, to health and the environment. The nuclear industry and the Nuclear Regulatory Commission in the United States have come a long way in the 33 years since the Three Mile Island accident, and improvements continue with progressive experience. Great hopes are vested in the new Westinghouse AP1000, the GE-Hitachi ESBWR, and similar fully passive systems that allow for safe shutdown without power and are able to protect themselves without human intervention for a 7-day period following an incident. Such a system at the Fukushima site would have meant a very different and better outcome there.

Yet the Union of Concern Scientists claims that the ongoing number of plant shutdowns for safety violations and equipment problems is troubling, particularly when some of these shutdowns are for problems that have been known for years. This raises concerns among the public about the efficacy of self-monitoring by the industry and the enforcement of regulations by the NRC, and whether plants are being allowed to continue in operation despite a failure to meet regulations. In their defense, the NRC and the industry claim that the current fleet of plants is properly monitored and safely operated. The nuclear power industry realizes that the safe operation of every single plant is important to the continued operation of all plants in the United States.

The ultimate disposition of used nuclear fuel remains unresolved and is a significant political issue in the United States. This is more a matter for political resolution than one to be addressed by the nuclear industry or by technology. But in the absence of a definite national policy, it is important that the industry maintain used fuel in a safe and secure storage facility.

Until recently, national policy had settled upon deep geological disposal at Yucca Mountain, a facility funded in part by ratepayers. However, the current administration has taken Yucca Mountain "off the table" as a repository for used nuclear fuel and nuclear waste. But we must develop a safe and long-term storage plan for radioactive material containing isotopes with half-lives in excess of 25,000 years. With Yucca Mountain off the table, the used nuclear fuel generated at each plant remains stored on-site at that plant. Both the Blue Ribbon Commission and the industry see the need for prompt resolution of this problem, with at least a central repository established to which the materials can be transported for safe keeping, pending a decision. The NRC believes that the used nuclear fuel can be safely stored on-site at the various plants for 60 years, allowing time for technologies to be developed and a better plan implemented. Because the used fuel still contains over 90% of its energy content, recycling is potentially attractive for the future. But as for now, recycling and reprocessing the used nuclear fuel is not seen as economically viable in the United States.

The production of any commodity must address economic costs and benefits. Nuclear power plants have historically demonstrated that they are reliable (industry-wide high capacity factors) and can generate electricity at costs lower than any other generation source. However, the costly capital investment for a large nuclear plant dissuades many companies from pursuing the construction of a new plant in the United States. Often that capital cost is on par with the market cap of the company undertaking the project. The

United States is the only country in the world in which the government does not take responsibility to build nuclear power plants.

The economic vitality of the United States in energy production depends on a number of market, political, and technological factors: the cost and supply of natural gas, the cost of carbon, and the development and viability of other energy sources, such as wind and solar energy. Economic factors driving decisions by utility companies include the type of market in which the utility company operates, the costs of alternative fuels, and the liability costs. In unregulated markets (such as exist in a number of states in the northeast), nuclear companies are competing with electricity costs from other fuels, and at present natural gas prices in the United States are at historic lows. These unregulated markets lead to short-term decisions and do not favor investment in new nuclear reactor plants. Electrical generation companies in these states believe that Small Modular Reactors (SMRs) rather than traditional large plants will allow them to consider the nuclear option. It is anticipated that the SMRs will not have as high an initial capital cost, will allow modular addition of new capacity, and will still have a shorter lead-time. However, development of SMRs will require the financial support of the Department of Energy up to the point where applications for NRC licensing can be submitted.

Utilities in the southern states, on the other hand, operate in regulated markets, and the four new AP1000 reactors being built in Georgia and South Carolina arise from this situation. The decision to build these initial new reactors is based on federal loan guarantees and the provisions of the Price-Anderson Nuclear Industries Indemnity Act. At present, the timeline from the initial decision to build a reactor to its coming online is 15-20 years. This is a long period for a market in which fuel prices, such as natural gas, vary over much shorter times. Consequently, absent governmental support and limited liability in the event of a nuclear accident, no reactor will be built.

Over the next twenty years, the United States will continue to pursue the nuclear option for energy. Most of the currently operating nuclear plants have obtained 20-year license extensions, and the new reactors being built will be available for use for more than 60 years. Beyond these years the viability of the nuclear option will depend upon a number of circumstances. Foremost among them will be the continued safe and reliable operation of the current fleet of plants, both domestically and internationally. This is almost totally in the hands of the industry itself. Any event not caused by a large natural disaster such as occurred in Japan in March of 2011, is in the control of the plant operators. It is essential that the industry and the NRC continue to maintain a high level of monitoring and oversight.

Finally, it must be said that the future of nuclear power beyond the next twenty years will depend on the research and development undertaken now—R&D to enhance the safe operation of nuclear power plants and R&D to better understand the disposition and utilization of our nuclear fuel resources that includes the reprocessing and recycling of used nuclear fuel, the thorium fuel cycle, and the development of breeder reactors.

Everyone who spoke in this symposium agreed that the nuclear energy option must be kept on the table for the future. However, a broad range of opinions divided the contributors regarding our precise level of dependence on nuclear power for the next twenty years.