The Next Generation Nuclear Plant
Timing is Critical

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My name is Andrew C. Kadak. I'm a Professor of the Practice at the Massachusetts Institute of Technology, Nuclear Science and Engineering Department. My testimony today focuses on the Next Generation Nuclear Plant. It will identify NGNP's national strategic importance and describe how best to see this project to completion in a manner that will be suited for ultimate deployment in the commercial sector. My background is not a strictly an academic one. Most of my life has been spent in private nuclear utility industry, most recently as President and Chief Executive Officer of Yankee Atomic Electric Company. This company, at one point, operated three nuclear power plants in New England: Yankee Rowe, Vermont Yankee and Maine Yankee. Yankee Atomic also was the owner's engineer for the Seabrook Nuclear Power Station in New Hampshire. Yankee also provided engineering, safety analysis and environmental support services for most of the New England nuclear power stations. Today, I come to you as an academic with industry experience to discuss the Next Generation Nuclear Plant.

The comments and views expressed are my own and do not reflect those of MIT or the Nuclear Science and Engineering Department. In the interest of full disclosure, I have advised the committee staff that I am a member of one of the teams competing for the pre-conceptual design of the NGNP. I can assure the committee that my role on the team, which is to propose a sensible research and development plan for near term implementation, does not affect my testimony since much of what I am about to present are positions and suggestions made to the Department of Energy in the past. My experience with the DOE on high temperature gas reactors began as a technical expert on the high temperature gas reactor group for the Generation IV Technology Roadmap.

As many of you may remember, the Next Generation Nuclear Power Plant was conceived out of the Generation IV initiative of the Department of Energy. The Generation IV initiative was designed to identify promising new technologies that could be deployed in 20 or 30 years. The outcome of that study was that the Department of Energy selected high temperature gas reactors as the technology that they would develop as their top priority since it would coincide with President Bush's hydrogen initiative. This initiative,

which continues, was judged to be important since it is designed to find a clean alternative to replace depleting and expensive fossil fuels for the transportation sector.

The Next Generation Nuclear Plant was accelerated from the 20-30 year time frame to the next 10-15 years largely because of the need to begin development of clean hydrogen production alternatives that would not be dependent upon another valuable fossil fuel, namely natural gas, and to reduce CO_2 emissions that affect global climate change. Originally the Generation IV high temperature gas reactor was called the Very High Temperature Reactor (VHTR) because there was a desire to attain temperatures of 1000 C or higher. Responding to technical community criticism that this extremely high temperature was unrealistic, the Department of Energy convened an International Technical Review Group (ITRG) to assess the realism of the VHTR. Their conclusion, as documented in their report, were that the design objectives of the VHTR were not materially possible. In addition, the proposed carbide fuel would unnecessarily delay deployment since the existing uranium dioxide fuel was already demonstrated and was quite adequate. And most importantly relative to the purpose of this committee hearing, that to gain industry interest and support, it was important to move to an early deployment strategy and not wait 20-30 years.

This early deployment strategy resulted in the Next Generation Nuclear Plant, which was aimed at a 2015-2020 time frame. While the program started off quite well in the sense that the Department of Energy was committed to it, it was set aside because they could not agree on a deployment strategy and the Department of Energy internal plans were judged to be far too expensive. At the time, numerous suggestions were made to the department about an alternate strategy for deployment that would engage private industry. However, the Department of Energy chose to use what is called a "Project Integrator" approach, which was not supported and ultimately resulted in the demise of the program for all practical purposes. Had it not been for the Energy Bill of 2005 and the support of key senators, the Next Generation Nuclear Plant would have remained as a low- if not zero-priority for the Department. The Energy Bill called for having a demonstration plant online and operational no later than 2021. The key word is "operational".

In May of 2005, the DOE published an implementation plan for the NGNP. This plan had an extensive research and development element and a design, engineering, licensing plan and schedule with a cost estimate. Shown on Figure 1 is the cost of the NGNP for a 2017 operational date. This estimate includes a significant research and development effort for the NGNP and the hydrogen plant and design and construction costs for both. Also shown on this graph is the NP 2010 spending profile. The importance of this addition is that many in the utility industry are concerned that their top priority of getting new light water reactors deployed will be affected by the NGNP program. As the funding profile shows, the heavy NGNP expenditures will occur after the NP 2010 program is over in the next two years. This should alleviate the utility industry's concern.

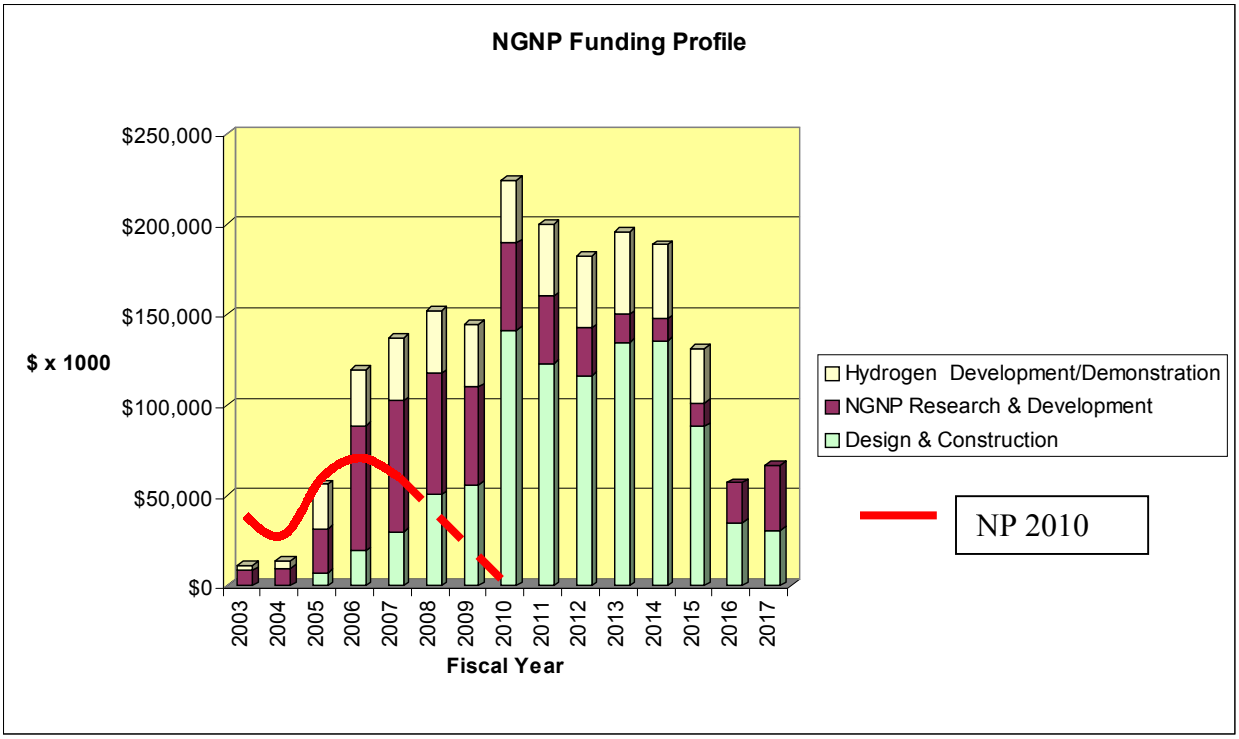


Figure 1: NGNP Cost Estimate

Unfortunately, the Department of Energy has not supported the funding levels required to complete the NGNP on the either schedule. The actual funding requests by DOE are shown below with a comparison to the program needs.

Table 1

Comparison of DOE NGNP Budget Requests vs. Program Plan Needs (including Hydrogen Demonstration)

Fiscal Year	DOE Budget Request	Program Plan Need	Underfunding
2003	2.97	11.23	- 8.26
2004	18.39	13.78	+ 4.61
2005	28.00	56.37	- 8.37
2006	63.75	119.60	- 55.85
2007	42.10	137.40	- 95.30
2008	??	152.36	??

The actual funding level for 2006 for example is less than half of what is needed. Much of the early effort is focused on R&D. This data is somewhat misleading on NGNP progress since a significant percentage of the appropriations were to support the nuclear hydrogen element and not the NGNP design process.

With the pressures of the Global Nuclear Energy Partnership, it is even harder to acquire the resources needed for the Next Generation Nuclear Plant unless DOE renews its commitment to its development. In the past, I have proposed an approach that I and others in the industry believe would bring this project to fruition with a clearly focused plan and schedule at a cost that can be supported within federal budget limitations. I will summarize that briefly for you

A Framework for the Successful Near-Term Demonstration for NGNP

In order for such a project to be successfully undertaken, gain support from the commercial industry, and be completed given the current fiscal constraints of the DOE budget, the project must be structured to strike the appropriate balance between advancing the state of the art of technology, cost and risk sharing between the public and private sectors, and the need to provide a performance-based disciplined approach to project execution. The objective is to build an advanced gas cooled research/demonstration plant in the near term that can be used as a demonstration plant for electricity and hydrogen production to gain commercial acceptance and research platform for developing even more advanced concepts such as the Very High Temperature Reactor. Such a project would have the following characteristics:

1. The project would be contracted and executed in 5 tightly coupled phases: 1) Conceptual Design, 2) Concept Evaluation and Selection, 3) Detailed Design, Component Development and Construction License, 4) Facility Construction and Operating License, and 5) Testing and Operation.

2. Competing teams would be funded by DOE for 1 year during the Conceptual Design Phase to develop a conceptual design and cost estimate. The winning team would be selected during the second phase if their design, schedule, and cost met pre-determined DOE targets. Each succeeding phase would have performance-based contracts between DOE and the successful team to execute the deliverable of the phase. Major capital for construction would only be committed if pre-determined performance and cost targets were achieved in the detailed design phase. The second place team would be available should the primary team not meet desired targets.

3. Clear evaluation criteria would be established prior to the Conceptual Design phase so that the competing teams would understand the important factors to DOE and the industry in subsequent phases. Cost sharing between the winning team and DOE would be an important factor in the evaluation criteria.

4. The down-selection of the chosen team and design would be conducted by an independent international team of experts with expertise in the technology, construction, operations and finance. They will make a recommendation to DOE of the best choice consistent with the design, schedule and funding objectives of the project. This team will act in place of the traditional DOE contractor selection team.

5. There would be no Project Integrator. The prospective contractors for the project would need to bring an integrated team to the project with all of the capabilities needed for its successful execution including fuel design and manufacturing.

6. The objective of this approach is to demonstrate ***to*** the utility industry that the plant can be built at a reasonable cost without the DOE process burden using a commercial procurement strategy. It is hoped that the industry will gain sufficient confidence in the technology upon completion of construction, testing and operation that they would order future plants.

7. The nuclear reactor and interfacing systems would be owned by DOE or a government special purpose entity (SPE). The electricity portions of the plant would be owned by a private SPE. The hydrogen plant(s), since it is very experimental would be owned by DOE (possibly a 50/50 partnership if feasible) since commercial production of hydrogen is not expected. Revenue generated from post-construction electricity and hydrogen generation would be used to first offset private investment and then DOE investment. Revenue generated from use of the reactor and the generation facilities for advanced technology testing by third parties would be apportioned between DOE and the private SPE, thereby reducing the overall cost of the project to the government.

8. The project would be targeted for completion in the 2017 or earlier time frame which ***is achievable*** by leveraging the work currently being done internationally on advanced reactors (Generation IV nations and China) and hydrogen generation.

9. The Idaho National Laboratory's role for this project is one which leverages its expertise and capabilities. As the owner of the reactor and the test facility, it would provide, in conjunction with industry needs, the general specifications that would form the bases for the conceptual design and identify specific areas for research needs. INL would be a key part of the selection process of the supply team in the second phase, particularly in assessing the design's ability to contribute to subsequent advanced high temperature gas reactor and hydrogen generation technology R&D. It would also be a major participant in the R&D activities associated with fuel qualification, materials evaluation and hydrogen technology evaluation as well as the licensing process. It will establish and conduct the R&D for developing the VHTR using the NGNP as a research platform. It is likely also to be the plant operator in a similar capacity as they now operate the Advanced Test Reactor (ATR).

10. This project will also be used to receive an NRC certification for future construction of similar plants. This should attract the commercial industry in this project since with this NRC certification, utilities can proceed expeditiously with deployment much like the NP 2010 program goals. It is envisioned that the nuclear plant could be certified by NRC for both electric and process heat applications in a "license by test" process.

11. A preliminary cost estimate shown on Table 2 based on the previous NGNP estimates is shown below which focuses on the construction of this project as an NGNP not a Generation IV VHTR. The DOE NGNP cost and schedule was reviewed in some detail with particular emphasis on the R&D that could be reduced or eliminated for the NGNP to get the plant built. The research that remains is judged to be needed for NGNP and hydrogen plant deployment. In addition, research and technical development work being done in South Africa and China can be applied to this project to make it more cost effective.

    This estimate has been reviewed by industry people currently involved in detailed design of high temperature gas reactors and hydrogen production plants. What this demonstrates is that this first of a kind plant can be built at about $ 1.2 billion which is about $ 1 billion lower than DOE cost estimates. The cost sharing agreement reflects an appropriate demarcation between industry and government for this advanced research and demonstration project.

    Shown on Figure 2 is the proposed reduction in R&D from the DOE program plan to focus on the lower temperature (900 C versus 1000 C) and build on existing international R&D programs needed to deploy the NGNP early. Shown on Figure 3 is the expected cost to develop and deploy a hydrogen demonstration plant based on industry input compared to the DOE program plan. The intent of these charts is not to predict costs but to point out that with industry leadership and experience that the design, cost and schedule can be improved over DOE long term plans.

12. The cost of the NGNP could be balanced against the cost of Nuclear Power 2010 in terms of OMB scoring. As the NP 2010 costs go down, the costs of the NGNP would scale up. In this way both programs can be executed with minimal budget impact during this period as shown on Figure 1.

NGNP Total Cost Estimate
(Results Based on Independent Review)

Key Assumption - NGNP is not VHTR
VHTR R&D Follows NGNP Development

Summary

NGNP Plant Construction:

Construction	**$ 560**
R&D	**60**
Design	**251**
Licensing	**40**
Total	**$ 911**
Contingency	**84**
Total NGNP	**$ 995**
DOE share:	**$ 868**
Private Share:	**$ 122**

Research and Development:

Fuel	$ 0 Use existing technology - Continue VHTR research
Design Methods	$10 Use existing tools developed elsewhere
Materials	$ 0 Use existing qualified graphite and steels
Power Conversion	$ 50 Intermediate Heat Exchanger

Total DOE contribution $ 60 million

Hydrogen Plant:

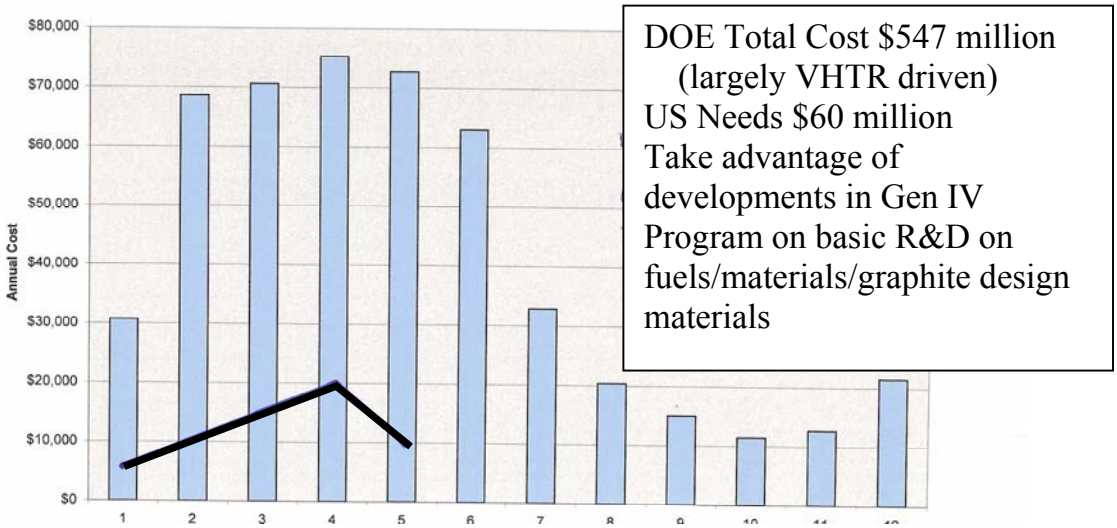
$ 265 million. Based on Westinghouse hybrid sulfur water splitting technology

DOE Contribution: 50/50 or $ 132 million
Private Share **$ 132 million** (if market can be found locally)

TOTAL PROJECT COST: **$ 1,254 MILLION (completion in 2015)**

DOE Share **$ 1,000 million**
Private Share: **$ 254**

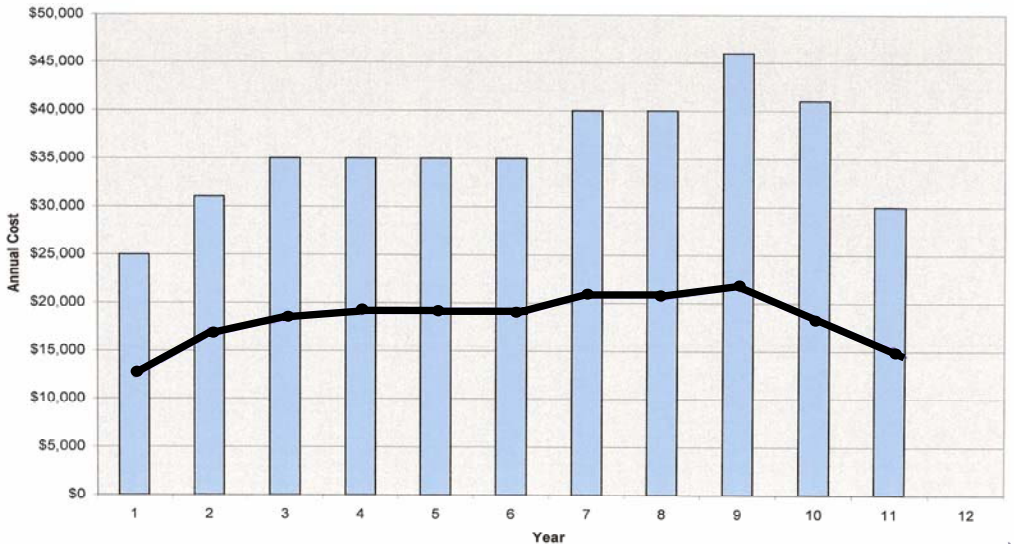
NGNP Research and Development Proposal (DOE)



US Research Needs for NGNP—Design Methods and Intermediate Heat Exchanger

Figure 2

NGNP Hydrogen Demonstration Cost



Industry Estimate for Single Demonstration Plant $265 million (versus $400 million)

Figure 3

What this plan essentially calls for is a funded competition by the department whereby interested developers would be allowed one year to develop a conceptual design, cost and schedule for their version of the Next Generation Nuclear Plant. As you may know, there are two competing concepts for high temperature gas reactors; one is a pebble bed reactor proposed by Westinghouse and the other is a more conventional prismatic reactor proposed by General Atomics and AREVA. Prior to DOE's Project Integrator approach, teams had been organizing to put proposals together for such a conceptual design effort. These teams included developers such as Westinghouse, architect engineers, hydrogen users and producers to be sure that the collective wisdom of the industry was applied to developing a reactor concept that was best suited for meeting the mission requirements of electricity and hydrogen production.

The plan was to have a funded competition whereby these groups would present their design, cost and schedule for this technology, after which an independent review team would evaluate the concepts and down select one for the next phase, which would be detailed design engineering and cost estimation, followed by yet another decision to actually build the plant.

As noted on Table 1, this project was estimated to cost approximately $1 billion spread over five to seven years in terms of actual construction. On an annualized basis this would not be a large amount of money in terms of the overall DOE budget that would end up with a real operational full-scale demonstration plant instead of endless paper studies and analyses.

Chicken or the Egg ?

Much has been said about whether the industry supports NGNP and what role should the government play in its deployment. To answer this question, one needs to identify the "industry". Is it the utilities? The nuclear reactor vendors ? Hydrogen users ? Hydrogen Producers ? Putting the questions this way, one can see whatever industry there is, it is fragmented and not integrated enough to produce a nuclear hydrogen plant. The utilities are generators of electricity. They buy power plants and do not design or develop new reactor technologies.

The nuclear reactor vendors are best described as "nuclear steam suppliers" which is how they sold reactors in the past and that is the business that they know. They do not know high temperature gas reactors. The nuclear reactor vendors of the past, which included Westinghouse, General Electric, Combustion Engineering that were able to invest in new technologies simply don't exist as we knew them anymore. Today most of these companies are service providers to the existing fleet of nuclear power stations and are only now seeking to license advanced light water reactors with resources provided in part by the Department of Energy.

Hydrogen users want only to buy the product. Hydrogen producers are quite comfortable with the use of natural gas in methane steam reforming. Were it not for the cost and supply of natural gas and CO2 emissions, they are quite content with business as usual.

They clearly are not nuclear people who would put forth such a project. It is likely, if asked, they would want to steer quite far from nuclear operations despite its obvious advantage in their business because they are not familiar with it. So which "industry is going to fund the development of a new, potentially economically risky project such as this? How does one show "industry interest" in the absence of a product they can buy or sell and to ask them to invest in project that the DOE says won't be ready until 2021? Whoever thinks this is a metric for moving forward on this type of project does not understand the commercial world.

The question still remains about the level of industry support that should be provided to make this project realizable. To introduce a new technology as called for by the President and the Department of Energy to support a hydrogen mission is simply not possible by the commercial nuclear industry sector. Efforts are being made to create a coalition of reactor vendors, utilities, hydrogen users and producers to provide a focal point for the development of NGNP. It should not be assumed however, that they will be major financial contributors for the building of this demonstration plant since their interests are far too diverse for the construction of a viable business model for each. The plan outlined earlier does form such a basis with the financial apportionment strategy that justifies the investment by each of the interested industry segments.

In the past I have proposed a roughly 80-20 split between government and industry respectively, which would be very roughly apportioned by the degree of research and development needed to provide a demonstration reactor and to provide the confidence to the commercial sector that this technology does work and can be cost effective. The overall proposal calls for building a full-size Next Generation Nuclear Plant to provide the commercial sector with that level of confidence that it could provide cost-effective power and hydrogen.

US Way Behind

Much of the technology development for this project is underway in other nations. South Africa is proposing to build a pebble bed reactor and is now in detailed design and licensing for commercial operation of their demonstration plant by 2011 or 2012. This project is largely supported by their government. In China, a pebble bed reactor is also being designed and licensed using a somewhat different power conversion system for electric generation. They, too, plan on having this plant operational in the same time frame. Thus, two, what we would consider less developed nations, have taken the lead in high temperature gas reactor technology. Japan has had an experimental high temperature gas reactor in operation since approximately 1998, and China has had an experimental small pebble bed reactor producing power in operation since 2000. The United State has nothing currently operating to produce high temperature heat, either for hydrogen, electricity or process heat applications. Thus, the United States is quite far behind in high temperature reactor technology.

One way to jumpstart our effort and catch up to less developed nations is to build this Next Generation Nuclear Plant as a **strategic national project** which is what it was a few

years ago. High temperature gas reactors have been so designated by China and South Africa. Next Generation Nuclear Plant has the potential for putting us back in the lead for high temperature gas reactor technology for hydrogen production. One of the more difficult technical questions is demonstrating and then commercializing thermo chemical production of hydrogen. Hydrogen can also be produced by electrolysis, which is more conventional. We, at MIT, are exploring the process of high temperature steam electrolysis that would allow the high temperature reactor to not only provide the heat but also electricity for this process.

As a researcher who's been exploring high temperature gas reactors since 1998 and one who originally was not convinced that we needed such a technology due to my past light water reactor experience, I've come to believe that the high temperature gas reactor with its higher thermal efficiencies, more efficient utilization of uranium and the possibility of many process heat applications in a generally smaller reactor size, paves the way for the next generation of nuclear power stations. I will not review all the advantages of high temperature gas reactors since they are generally well known. The most significant advantage is that these reactors cannot melt down. There are technical challenges that need to be overcome and the reactor and hydrogen technologies need to be demonstrated for utilities and other energy producers for future purchase.

Recommendations

My recommendation for this committee is to carefully oversee the Department of Energy's plan for the Next Generation Nuclear Plant in terms of funding to allow the demonstration reactor to come online by no later than 2017. Since other nations are already proceeding with operational dates of 2011, we can build on the experience and knowledge gained by these nations to allow for an efficient, cost effective design to be produced to show the industry and the utilities that this is a very viable form of energy production for hydrogen and that it can be quite economical for electricity as well.

Consider adopting the deployment strategy outlined earlier as practical path forward to engage the commercial industry to produce a reactor that will have commercial interest. Without a near term deployment strategy, industry will not be interested and the program may actually die. Unfortunately, I can not find such a comprehensive path forward at DOE for deployment of the NGNP. While a request for proposal was surprisingly issued by DOE in the summer for a pre-conceptual design for the NGNP, it is not clear what will happen after May of 2007 when the pre-conceptual designs are due.

Summary

The payback for this technology could be enormous in the sense that for approximately $1 billion we can develop a clean form of hydrogen production which does not now exist. We cannot continue to dump massive amounts of carbon dioxide into the environment by use of fossil fuels, and we need to start now to prepare for an economy that is not dependent on oil for its transportation needs. Hydrogen, with its potential for fuel cells in power stations, in transportation, and for chemical processing needs, is our transition fuel

until we can find alternatives for transportation. The Next Generation Plant can become the heat source for oil extraction from tar sands, enhanced oil recovery, gasification of coal without the use of fossil fuel emitting greenhouse gases. Thus, the NGNP could become our heat engine that could be an extremely valuable asset in our future energy production options.

The timing is important. We cannot afford to wait until 2021 with a program that does not have the committed support of the Department of Energy to see it through to completion. The best chance for the Next Generation Nuclear Plant is to allow the initiative and ingenuity of the private sector combined with a targeted research plan implemented by our national labs in cooperation with interested Generation IV nations to design and build this plant. This plant would also become the test bed to prove its commercial viability such that the utilities or other energy providers can purchase it with confidence. We need to start to move away from a fossil fuel economy that we are so grossly dependent upon and which is having a demonstratively negative affect on our environment and the economy.

Thank you for your attention.

Andrew C. Kadak