Testimony of Christina Back, Ph.D.
V.P., Nuclear Technologies and Materials, General Atomics
Before the U.S. Senate Committee on Environment and Public Works, Subcommittee on Clean Air and Nuclear Safety "Enabling Advanced Reactors and a Legislative Hearing on S.2795, The Nuclear Energy Innovation and Modernization Act"
April 21, 2016

Chairman Capito, Chairman Inhofe, and Ranking Members Carper and Boxer, thank you for the invitation to appear before you today. My name is Christina Back and I am the Vice President of Nuclear Technologies and Materials at General Atomics. General Atomics is a privately held company providing high-technology systems with over 60 years of experience in nuclear energy starting with the TRIGA research reactor. I was asked to describe what "advanced reactors" are, and what we believe may be appropriate issues for you to consider when developing public policy for encouraging the development of new reactor concepts.

We believe that it is important for our country to increase its use of nuclear energy because it is critical to maintain a diversity of energy sources and nuclear provides emission-free, baseload electricity. If we could make nuclear energy cost-competitive it would provide thousands of years of safe, clean electricity for our country. In addition, remaining the technology leader in nuclear energy is critically important to minimize foreign dependence and strengthen national security.

Unfortunately, because nuclear energy using existing technology is currently too expensive to be competitive, the U.S. nuclear industry is in decline. To reverse this trend, we believe our country must do what it does best: bring the ingenuity of its people to bear on creating new ways to produce nuclear energy safely, cleanly and at much lower cost. We are very pleased that there seems to be increased interest in this effort as shown by Members of this Committee, attention from the Administration, and efforts from industry.

In order to be helpful to the Committee's effort, I would like to start by noting that thus far, the term "advanced reactors" has been used rather loosely, and can mean different things to different people. Some people consider it to refer to any non-light water reactor, such as a gas-cooled, sodium-cooled, or molten salt-cooled reactor. Others use it to refer to a new light water reactor, such as a Small Modular Reactor (SMR).

To establish the context, let's remember that, fundamentally, nuclear energy involves splitting an atom and using the heat energy released, to turn a generator to produce electricity. At the end of the day, electricity is a commodity, and many consumers do not care whether it is made from nuclear fuels or from burning coal or gas, or from renewables; what matters is its cost.

To provide that commodity in today's world, an "advanced reactor" must improve over existing reactors in the following 4-core attributes. It must:

- produce cost-competitive clean electricity,
- be safer,
- produce significantly less waste, and
- reduce proliferation risk.

These four attributes are consistent with the definition of the seven improvements identified for an advanced reactor in the Nuclear Energy Innovation Modernization Act. Essentially, three of the defined improvements: reliability, thermal efficiency and ability to integrate electric and non-electric applications, are connected with the first attribute, cost-competitive electricity. Fuel utilization is intertwined with the third attribute, less waste. We believe every worthy advanced reactor concept must address these 4-core attributes jointly. It is not sufficient to excel at one with disregard to the others.

Now, I would like to discuss General Atomics' reactor concept, the Energy Multiplier Module or EM^2, as a way to illustrate what "advanced" can really mean. EM^2 was designed, from the beginning, to meet the 4-core attributes I just mentioned.

In the design of EM^2, GA gave serious consideration to risk versus payoff, and we chose to employ innovative design and innovative engineered materials to reach our goals. What makes it compelling to rethink advanced reactors now is that in the last 30 years, scientists have made unprecedented advances in understanding materials. It is now actually possible to engineer and manipulate materials for specific applications. Use of customized materials and technologies is what we chose to do for EM^2. This is what sets GA apart.

Now I will go through each of the attributes. First is cost. The drive to minimize costs led to the design of a much smaller reactor that could produce much higher power output per reactor volume than today's reactors. It also led to a push to higher efficiency, i.e., 50% more electric power from the same amount of heat. We do this by producing the electricity from higher temperature heat.

Second is safety. For a radical improvement in safety, EM^2 uses engineered ceramic materials that are capable of working in higher radiation and higher temperature environments. The fuel is contained in materials that can survive accident temperatures over 2 times higher and would not be subject to failure like those in Fukushima. While challenges remain, our results so far have been promising. If they hold up, we will revolutionize this industry.

Third is waste. Minimizing waste products is linked to better fuel utilization. For EM^2, this is accomplished by the innovation of long-burn core physics and by higher conversion efficiency. Consequently, EM^2 will use only 20%of the fuel and produce only 20% of the waste of a current reactor for the same amount of power.

Finally, fourth is non-proliferation. The innovative design of EM^2 keeps the fuel in the reactor for 30 years, without the need to refuel or reposition fuel rods. Less handling of the fuel, and tight security allowed by offsite core fabrication significantly reduces proliferation concerns and lowers operating costs.

As a guiding principle, we believe that to bring advanced nuclear power into the market, the cost of nuclear must be significantly reduced below the existing levels projected for new light water reactors. This reactor, if it performs as designed, would produce power at perhaps 40% lower cost than today's existing nuclear reactors, and with a capital investment per EM^2 unit in the $1.5 billion range. It would be produced in a factory, reducing proliferation concerns and potentially reducing licensing costs, and shipped to the site and installed within 4 years, again keeping costs down.

As for any new reactor design, this one will require extensive interactions with the NRC. In particular, this radically new material requires intensive development and testing. We think involving the NRC early in this work is imperative. Ideally, interactions would occur early enough to inform the design from the beginning and produce a safer reactor design. Then, when we applied for licensing based on what the market called for, a few years from now, this early effort would pay off many times over.

Radically new concepts that employ new technology require upfront investments involving some risk. Some of these investments may not pay off, and even those that are successful could require at least 10 years to produce any revenue. While General Atomics has already invested $40 million in the EM^2 concept, these commercial realities make it very difficult to justify early costs to engage the NRC.

If this Committee's objective is to stimulate the development of new advanced reactor concepts, we would suggest that it is in this early phase of development that it would be relatively inexpensive to involve the NRC for early consultations with potentially very high impact. Every advanced reactor concept that involves significant long lead development would benefit enormously from being able to work with the NRC at an early stage.

We suggest the Committee consider authorizing the appropriation of $5 million at first, growing to possibly $15 million over 5 years, to provide NRC services to developers of advanced reactor concepts. To trigger funding, a relatively low cost share of perhaps 3%, could be required. In addition, the NRC could engage outside advice from the DOE, universities, and other experts, to ensure the individual reactor concepts were viable.

We very much appreciate your interest in this subject, and this opportunity to appear before you. The NRC is an important and necessary agent in ensuring nuclear power is safe. Therefore, it plays a critical role in nuclear power innovation. I would be pleased to respond to any questions you may have. Thank you.

CHRISTINA BACK, PH.D. TESTIMONY

APPENDIX 1

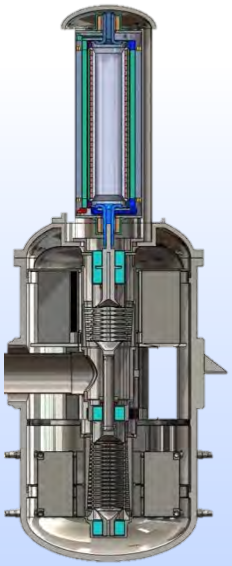
Energy Multiplier Module (EM^2): A Performance-Based Reactor Concept

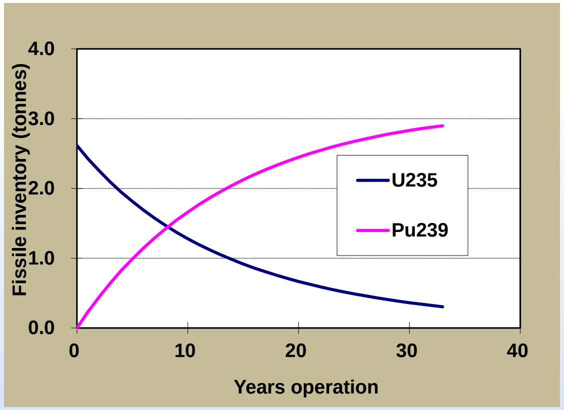
By
Dr. Christina Back
Vice President
Nuclear Technologies and Materials

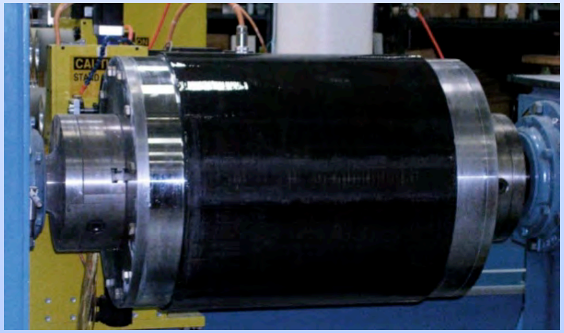
Back Testimony
Appendix 1

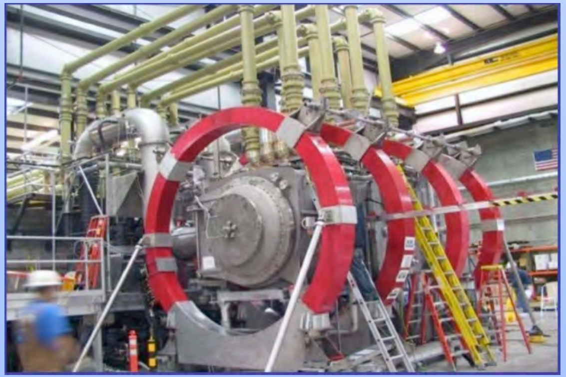
New Technologies Are Key

- Convert-and-burn core physics
- Silicon carbide composite structures
- Advanced fuels
- High temperature systems
- Asynchronous, high-speed compact generators
- Proliferation resistant used fuel recycling









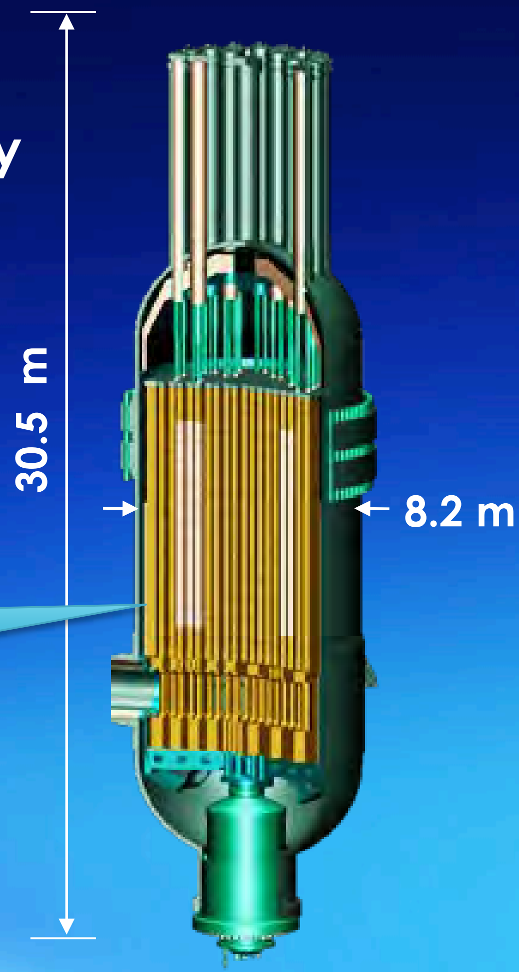
GENERAL ATOMICS

Economics: Higher Efficiency and Higher Power Density

Gas Reactor
286 MWe @ 48% eff.
6.6W/cc power density

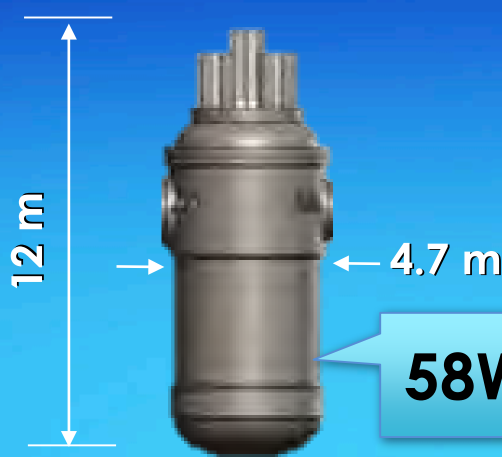
Efficient, large and high power

6.6W/cc



Fast Gas Reactor
265 MWe @ 53% eff.
58W/cc power density

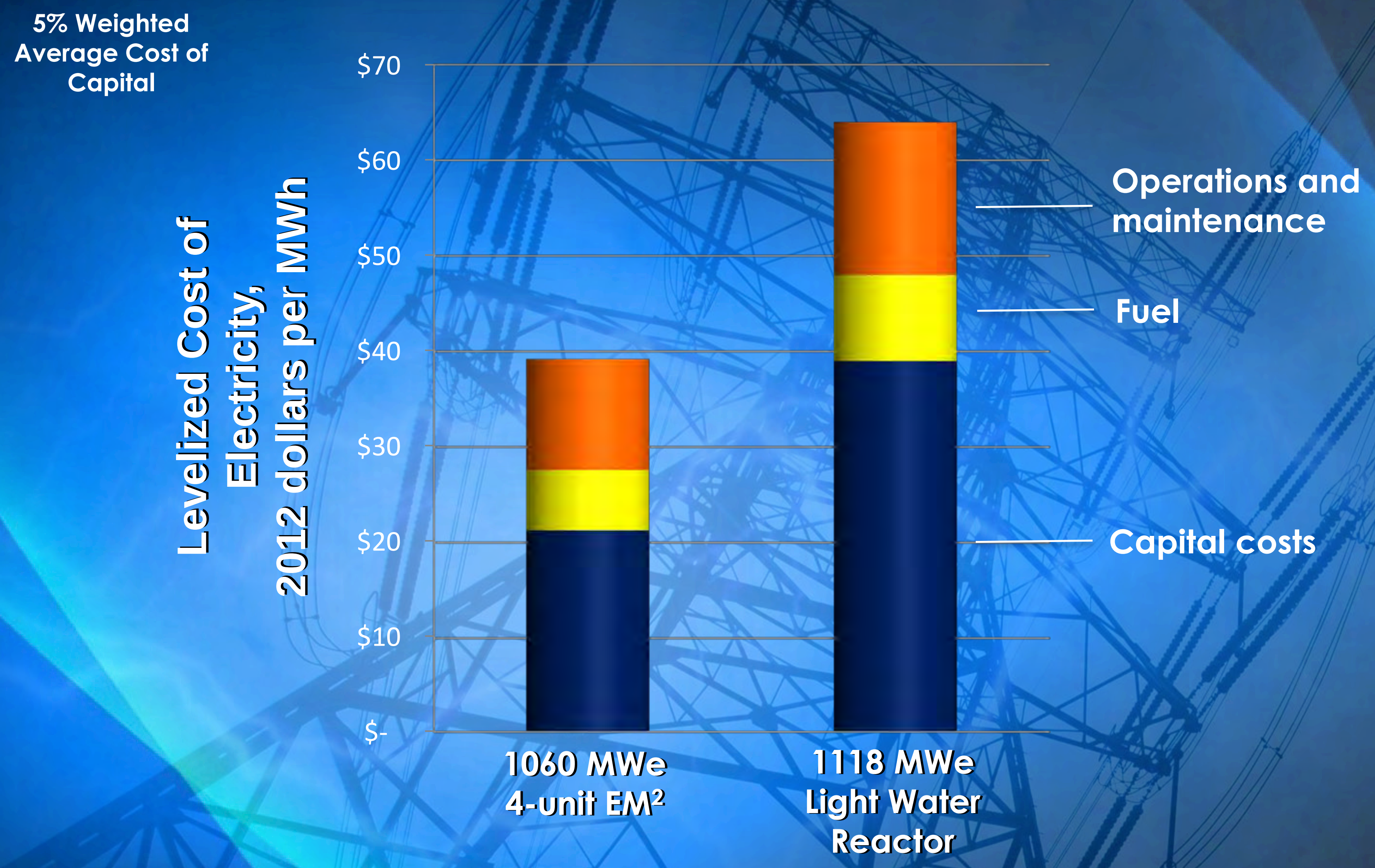
Compact size, highly efficient and high power



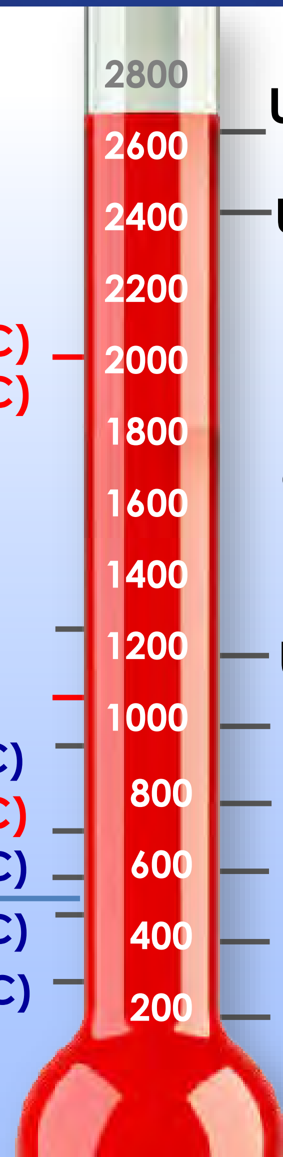
58W/cc

Economics: Performance-Based Comparison

Economics: EM² Cuts Energy Costs by 40%

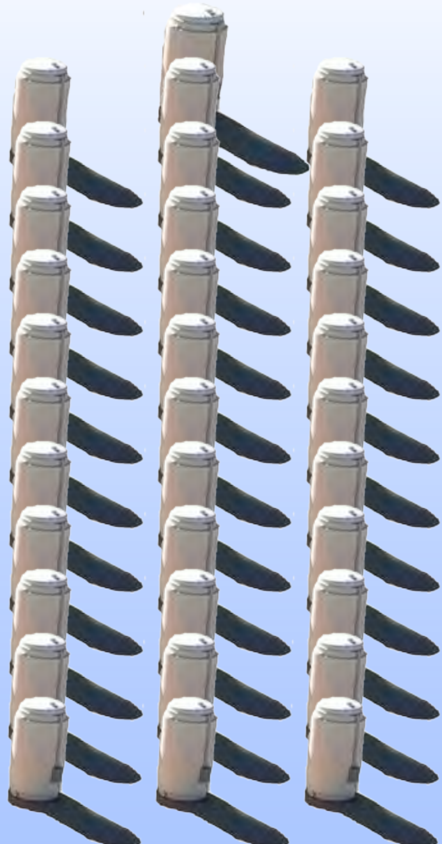


Safety: Requires High Temperature Materials and New Fuels to Achieve Passive Safety



Waste Reduction: Benefits from High Temperature and Radiation Resistant Materials

One LWR produces ~600 tonnes of nuclear waste over 30 years



$$\frac{1}{1.6} \times \frac{1}{3} \simeq \frac{1}{5}$$

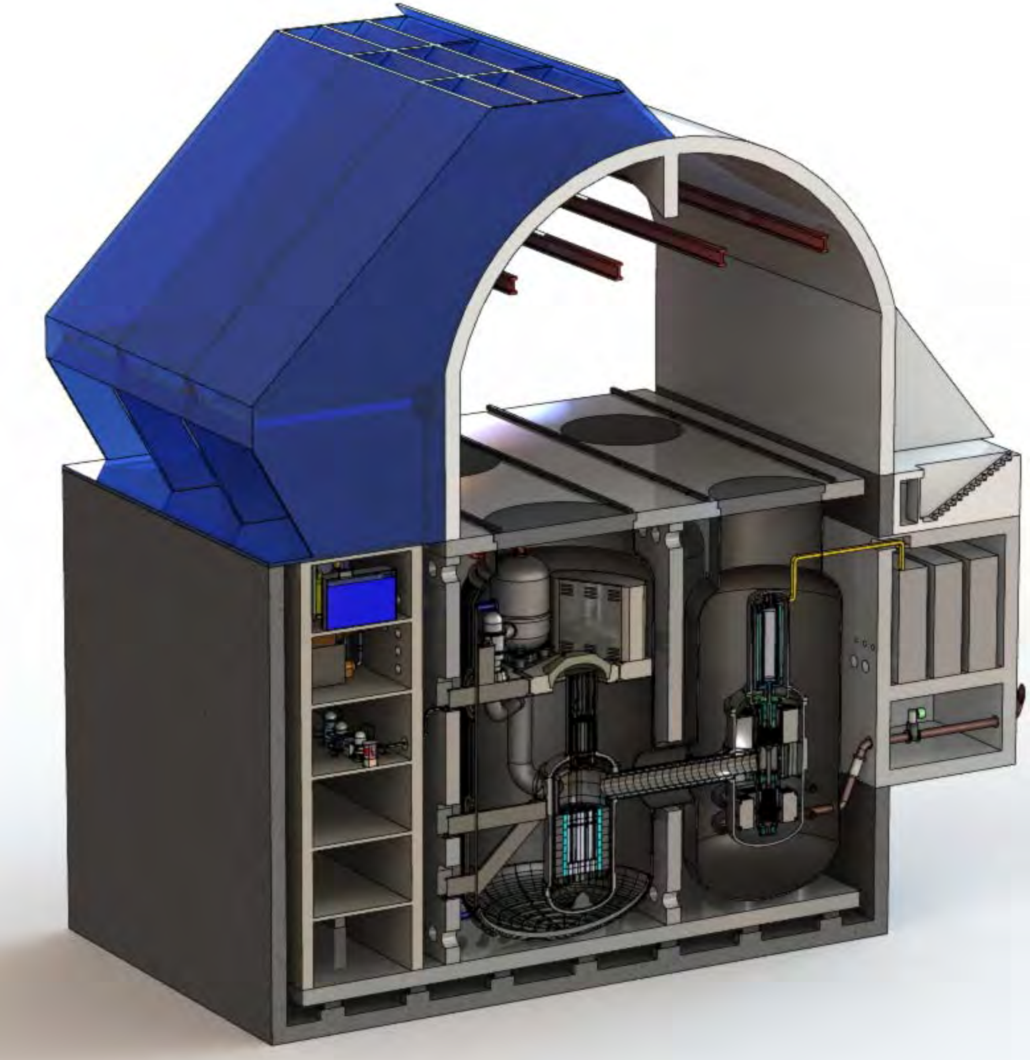
- $\frac{1}{1.6}$: 60% more efficient than LWR
- $\frac{1}{3}$: Higher burnup
- $\frac{1}{5}$: The fuel of LWR

4-unit EM² produces 80% less waste over the same period

For EM² closed cycle, waste is further reduced to 97%

Enhanced Proliferation Resistance: Underground Siting

- **Reduces vulnerability to some surface-based threats**
- **Fuel not accessible**
  - Sealed core
  - Core cannot be reconfigured
  - Fuel handling equipment not on site
- **Fuel highly self-protecting**



Energy Multiplier Module (EM^2) is a Compact Fast Gas Reactor Optimized for the 21st Century Grid

Below-ground construction negates many physical threats and improves security

1060 MWe EM^2 plants fits on 9 hectares

- 30-year fuel life – high burnup
- Multi-fuel capable
- Reduced waste stream
- Cost competitive
- Flexible siting, no need for water cooling
- Rapid load following
- Higher efficiency – 53% net

GENERAL ATOMICS

CHRISTINA BACK, PH.D. TESTIMONY

APPENDIX 2

GENERAL ATOMICS

Christina A. Back, Ph.D.

Vice President,
Nuclear Technologies and Materials

Dr. Christina Back has 27 years of experience leading research in private industry and US Department of Energy (DOE) laboratories, including the DOE weapons complex. She is internationally recognized in both fission and fusion energy research and regularly serves on committees for the National Academy of Sciences, National Nuclear Security Administration, and the DOE. She has over one hundred peer-reviewed publications and is a Fellow of the American Physical Society.

At General Atomics, Dr. Back is responsible for nuclear fission programs, which draw on a diverse portfolio of innovative technologies. Current activities focus on the development of advanced nuclear reactors for electric power, production of isotopes for medical uses, and fabrication of Accident Tolerant Fuel rods for safer nuclear reactors, among other projects.

Dr. Back is a scientist who earned her B.S. in physics from Yale University, and her Ph.D. in plasma physics from the University of Florida. She spent two years as an experimentalist at the Ecole Polytechnique in France. Prior to joining General Atomics, she performed research using high powered lasers at Lawrence Livermore National Laboratory in the Inertial Confinement Fusion and High Energy Density Science programs for 13 years. She has devoted more than two decades to energy research and holds an active DOE-Q and US Department of Defense clearance.

For her contributions, Dr. Back has received numerous awards, including the DOE Technical Excellence Award and Defense Nuclear Sciences Award. In 2013, she was named Woman of the Year in Business by the San Diego East County Chamber of Commerce.