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Memo

To: **Small Reactor Economics Study participants**

Date: August 4, 2010

From: Ed Kee

Subject: **Initial view - designs and attributes**

This memo is a summary of the reactor designs and attributes to be included in our Small Reactor Economics Study.

This selection of designs and attributes reflects the numerous comments and suggestions we have received. Your additional comments and suggestions are welcome, especially if we get them by the end of August.

Approach

The overall approach is to (a) identify all relevant attributes for the selected designs; (b) analyze/assess each of these attributes; and (c) map the attributes (and the assessment/analysis results) back to each of the selected designs.

An attribute is a design or other feature that that distinguishes a small reactor design from a conventional large light water reactor design.

For some attributes the analysis will result in a dollar value or cost. Other attributes may be assessed in a qualitative manner.

Designs

We include 5 design categories, with several designs in each category. The objective is to include enough designs so that all relevant attributes are represented. We may add some designs if we find that some interesting and relevant attributes are not represented.

1. Light water reactors

The designs in this category include: mPower (B&W and Bechtel, USA); NuScale (NuScale Power, USA); IRIS (Westinghouse, USA); KLT-40S (OKBM Afrikantov, Russia); and CAREM (INVAP, Argentina).

2. High-temperature gas-cooled reactors

The designs in this category are: HTTR, GTHTR (JAERI, Japan); GT-MHR (General Atomics, USA); HTR-10; HTR-PM (INET, China); PBMR (PBMR, South Africa); and Antares (Areva, France).

3. Liquid metal-cooled fast reactors

The designs in this category are: 4S - Super-Safe, Small & Simple (Toshiba, Japan); PRISM (GE- Hitachi, USA); Hyperion Power Module (Hyperion Power, USA); ARC-100 (Advanced Reactor Concepts, USA); and Encapsulated Nuclear Heat-Source (UC Berkeley, USA).

4. Molten salt reactors

The designs in this category are: Liquid Fluoride Thorium Reactor (LFTR); and Fuji MSR (IThEMS, Japan).

5. Other

The designs in this category are: Travelling wave reactor (TerraPower, USA); EM2 (General Atomics, USA); various PHWR designs; and MIPS Aqueous homogeneous reactor (B&W, USA)

Attributes

Attributes are features of the various small and alternate reactor designs that differ from large LWR designs.

1. Cost

Our study will not estimate the costs of various small reactor designs. Rather, we will include qualitative analysis and discussion of scale economies, design features, manufacturing approaches and other issues related to capital cost. As available, we will include and discuss public estimates of costs.

Cost-related attributes include: Project unit capital cost (i.e., $/MWe); total project capital cost; O&M cost; and fuel cost.

2. Size (MWe)

Size-related attributes include: Single unit/shaft contingency; spinning reserves; siting; need for transmission lines; capacity expansion planning; fossil thermal plant re-powering potential; and operational unit commitment.

3. Project Development time

There is an assumption small reactor projects will require a shorter time between project initiation and commercial operation date than a large LWR project.

Project development time attributes include: Resource planning risk; investment risk; interest during construction; and sequential build of modular units.

4. Factory build approach

Many small reactor designs anticipate building major components (or the entire reactor) in an off-site factory.

Attributes related to factory build include: potential for cost reduction; quality assurance; license implications; inventory and queue management; and customer queue trading potential.

5. Fuel and reactor type

Attributes related to fuel and reactor type include: time between refueling; type of fuel; uranium fuel enrichment level; ability to burn used LWR fuel; ability to burn surplus weapons plutonium; ability to burn thorium or U-238; fast fission and breeding approaches; on-site vs. off-site refueling; and approach to spent/used fuel.

6. Proliferation risk

A key selling point for some small and alternate reactor designs is their lower proliferation risk (i.e., a lower risk that the reactor can or will be used to develop a nuclear weapon). Level of proliferation risk represents a single attribute that is derived from a variety of design features, applications, and operating modes.

7. Higher temperature heat energy

Attributes related to high-temperature heat energy include: higher thermal efficiency; air cooling; more efficient water cooling; use of alternate balance of plant approaches (e.g., He Brayton cycle or Super-Critical CO2 cycle instead of conventional Rankine cycle); potential for application to hydrogen cracking and other high-temperature applications; and industrial process heat applications.

8. Operational Performance

Attributes related to operational performance include: ability to follow load; need for operators; number of operators; balance of plant maintenance approaches; multiple modules controlled by single control room; off-grid or remote applications; and other items.

9. Safety paradigm

Some small and alternate reactor designs use a reactor or fuel approach that has a fundamental different set of nuclear safety issues and perhaps a much higher level of nuclear safety, than a conventional large LWR.

Attributes related to safety include: passive safety approaches; pressure of primary coolant; underground construction; loss of coolant vulnerability; and any new safety issues.

10. Site approach

Conventional large LWR projects require a large and relatively remote site and may need to be close to a source of cooling water.

Site-related attributes include: need for cooling water; requirement for security/exclusion zone; ability to repower old thermal power plant sites; modular approach; and other items.

11. Commercial availability

The attributes associated with commercial availability include: commercial backing; level of development; and related items.

12. Design maturity

Attributes related to design maturity include: completeness of design; existence of prototypes; reliance on proven and commercially available components; balance of plant approach; extent of interaction with NRC; and related items.

13. Time to market

This will be an overall assessment of the likely time when the first commercial (i.e., sold to a real customer) unit will be placed into commercial operation (i.e., selling electricity or thermal output for profit).

14. NRC License process

The current US NRC Part 52 licensing process is in place. Some small and alternate reactor designs appear to have a design/business plan that relies on significant changes to the existing NRC licensing approach. Also, there will be issues related to NRC licensing of an exotic reactor design or fuel (e.g., see NUREG-1368)

Attributes will include: the estimated level of difficulty and time needed to obtain a license; the reliance on significant changes to the NRC approach to licensing or reactor safety; the extent to which the NRC has already considered the design; the projected date for a DCD application; and the likely date of an approved DCD.