Reactor Plant Cost Reduction to Compete with Natural Gas Fired Electrical Generation

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ABSTRACT:

GEH recognizes that new large light water reactors (LWRs) are not competitive in the current U.S. electrical market for three reasons: Capital Intensive, Cost of the Electrical Product, and Complex Operations. The capital cost is too large for private U.S. companies to buy and build. We recognize that on a dollar per kilowatt basis, new large LWRs are not competitive with gas-fired electrical power generation. Operations of existing nuclear power plants includes extensive staffing, testing, and inspection requirements. Thus, the current operating fleet and any new large LWR are in a less competitive economic position.

Recently, there has been significant interest in the development of new small modular reactors (SMRs) in the U.S. Although current LWR SMRs are targeting lower overall capital cost, current and leading SMR designs are still very costly on a per MWh basis and levelized cost of electricity (LCOE). Based on market analysis performed by GEH, it is imperative that the LCOE of new nuclear be able to compete with combined cycle gas generation. Currently, there are no LWR SMR designs currently in development capable of competing with gas.

GEH's objective is to develop a LWR technology that can compete with gas so that utilities will deploy new nuclear technology. This project seeks significant simplification to make a meaningful impact in the three cost areas (Capital Cost, Electrical Cost, and Operations) improving competitiveness in the today's and future markets. To compete with gas, GEH has set a target of $2000/kW to construct an SMR, representing a 40-60% reduction versus leading LWR SMRs currently in development.

From a construction perspective, a significant driver for both direct cost and schedule duration (i.e. indirect cost accumulation) is the material quantities required for a typical LWR plant. These quantities drive material cost, labor cost and schedule duration for the entire project. A major driver of safety related and seismic class 1 structure volume and material quantities is the equipment (structures, systems, and components) necessary to address a postulated Loss of Coolant Accident (LOCA). Through design simplification and piping reduction, the ESBWR reactor vessel LOCA risk was reduced. Through additional design simplification and innovation, LOCA risk could potentially be reduced significantly, supporting elimination of some LOCA mitigation systems, resulting in the safety classification downgrading or full elimination of equipment (e.g. no safety grade diesel generators, smaller pools, less piping, etc.).

Less safety related systems, structures and components lowers expected O&M costs, suggesting that an inherently safe plant may not need large on-site staffing. A centralized, cost efficient, shared resource

pool could be used for planned maintenance activities and technical support, dramatically reducing overall O&M staffing and cost.

On-site staffing and material quantities could be positively affected by embedding the reactor plant below grade. With an embedded plant, and sufficiently robust access control, it may be possible to reduce the on-site security force as the plant would be self-protecting such that an off-site reaction force may be sufficient. With the plant embedded and not exposed to direct impacts from external events, material quantities could be further reduced. If the volume savings contemplated by GEH through system elimination is successful, then it could be possible to place the reactor plant in a vertical orientation below grade. Vertical excavation techniques have been shown in other industries to be cost effective.

To better understand the feasibility of these concepts, they must be reviewed by many experts in plant design, reactor pressure vessel design and fabrication, construction methods and plant operations. GEH, in partnership with Hitachi-GE Nuclear Energy, Bechtel National, Inc., Exelon Generation Company and Massachusetts Institute for Technology (MIT), proposes to address the reactor plant design simplifications with the following objectives:

1. Simplify reactor plant design by limiting the potential for a LOCA and, by extension, the systems required to mitigate this event.
    a. Research designs for reactor coolant pressure boundary breach (leak) elimination
    b. Research designs for venting and depressurization
    c. Elimination of Structures, Systems and Components no longer required for safety
    d. Estimate the cost implications for these design criteria
2. Simplify nuclear plant construction
    a. Research approaches to vertical, below grade reactor plant construction
    b. Determine if high strength concrete would reduce the overall cost of construction
    c. Determine the impact on construction processes, quantities and schedules and the overall cost impact of embedded designs
3. Reduce Operations and Maintenance (O&M) costs by examining:
    a. Application of pooled resources at a centralized location, and optimize maintenance activities
    b. Estimate the operations and maintenance cost implications of an embedded reactor
    c. Reduced site security staffing needs due to an inherently safe and securely embedded plant

GEH deliverables from this DOE funded project are:

1) Overall Plant (Composite) Design Specification
2) RPV, nozzles and steam/feed lines System Design Description (including concept for each penetration)
3) Structures, Systems, and Components Classification List
4) Containment System Design Description
5) Conceptual Nuclear Island General Arrangement Drawings
6) Conceptual Licensing Plan for key regulatory topics
7) Innovative construction methods report, including:
    a. Report on the study for lowest cost containment study: concrete vs steel
    b. Embedment Study Report
    c. Report on the study elimination of engineered backfill
    d. Design-for-seismic-isolation option analysis
    e. Recommendation for skid-mounted equipment