Conceptual Engineering for a Small Modular Reactor (SMR) power plant based on Lead-Bismuth Fast Reactor (LBFR) Technology

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Collaborators: N/A

Program: Advanced Nuclear Technology Development

CBCG is an engineering consulting company based in the TriCities area of eastern Washington State and meets criteria for a small business. CBCG has technical specialty expertise in liquid-metal, fast spectrum reactors. CBCG has been involved in numerous initiatives and DOE sponsored investigations including the reuse of the Hanford Fast Flux Test Facility, DOE's Global Nuclear Energy Partnership Program, and the development of the design concepts for TerraPower's Traveling Wave Reactor project. CBCG's expertise resides in our staff of former Advanced Reactors Programs personnel from EBRII, FFTF, PRISM, and the several Federal efforts for CRBR, the ALMR, and international cooperative efforts.

CBCG is developing a Lead-Bismuth, Fast-Spectrum, Small Modular Reactor (SMR) design concept for application in the U.S. marketplace. CBCG's expertise is liquid-metal fast reactors and selected lead-bismuth for cost and safety advantages. CBCG plans factory production for improvements in costs and quality of the reactor components and a modular plant design to facilitate construction and further reduce costs and improve construction schedule. For the proposed project, CBCG will develop a pre-Conceptual design and preliminary cost estimate based on a configuration developed by the CBCG team. This project provides critical technical and financial data for venture financing and marketplace acceptance.

Since 2010, CBCG has been investigating the small modular reactor (SMR) marketplace with the community economic development organizations in an effort to attract an SMR vendor to locate their operations base in the region. In 2012, CBCG developed an interest in a unique Lead-Bismuth, Fast-Spectrum SMR being developed for international marketing by a Russian Federation firm and initiated teaming discussions, unfortunately, world events made such a teaming unworkable.

CBCG considered the advantages of the lead-bismuth coolant to be compelling for the pursuit of a new design based on the team's experiences and publicly available information regarding the properties of the lead-bismuth eutectic. Upon investigation, CBCG found extensive technical publications by U.S. researchers and the IAEA on this eutectic, as well as ongoing research funded by the USDOE at MIT and Los Alamos. CBCG elected to pursue the development of a lead or lead-bismuth cooled, fast-spectrum SMR as a new design concept based on the team experience and learned knowledge in the US liquid-metals, fast reactors programs developed in Idaho and Washington fast-reactor projects.

The selection of the lead-bismuth liquid metal coolant allows the nuclear systems to operate a near-atmospheric pressure with a coolant boiling point (1670^{o}C) that far exceeds the value of potential fuel damage. The design provides:

- ***Safety Advantage*** – the plant is not subject to depressurization events– the coolant cannot boil-off and expose the core nor is there a motive force to eject materials into the atmosphere,
- ***Cost Advantage*** – the modular design, factory fabrication of nuclear vessels and components, and the elimination of the highly complex safety systems needed to mitigate the potential depressurization accident significantly reduces the front costs for this technology plant.
- ***Affordability Advantage*** – the module power levels allow the owner to incrementally add power as demand progressively increases.
- ***Availability Advantage*** – the technology offers flexibility in mission application as well as fuel cycle management. Depending on operational conditions, the fuel-cycle will be on a seven-year basis, assuming a three-month outage, the plant Capacity Factor exceeds 96%.
- ***High-Level Waste Disposition*** - the technology can recycle over 90% of the plant waste requiring long-term disposal. As the cornerstone of "closed-fuel-cycle" complex, the concept eliminates the need for enrichment facilities.

CBCG's design is for a Small-Modular Reactor plant, in two configurations: a 600MWt/240MWe and a 250 MWt/100MWe standard plants. CBCG has completed several critical investigations under the Gain Program and self-funded initiatives. These efforts validated CBCG's initial assessments that this technology holds no regulatory showstoppers and is licensable under current federal regulations. Based on this prior work, CBCG is submitting this Application to seek assistance funds to take the concept designs to the next level of preparing an integrated plant conceptual design focused primarily on the nuclear reactor, heat transport, and reactor support systems and structures. The balance of plant systems can be supported by "off-the-shelf" vendors offering pre-engineered packaged systems which align with the steam conditions produced by the CBCG design concept.

The Lead-Bismuth SMR concept is an innovative design concept which offers significant improvements in plant safety, simplicity of design and operations, modular approach to construction, and substantial reductions in safety driven design requirements all of which reduces both in overnight, construction, and operational costs. CBCG this technology to be competitive with gas on a cost per kilowatt basis.

In summary, CBCG is proposing an 18 month effort, which will develop a pre-Conceptual Design for the Nuclear Island, including Nuclear Support Systems and Nuclear Plant Structures; prepare a Technology Readiness Level assessment and Test Program Plan to address areas requiring additional R&D. CBCG will select commercially available balance of plant systems and structures to provide for an integrated plant Conceptual Design. CBCG will also prepare the Operations Plan and Fuel Cycle Plans based on the Concept Design and planning requirements. This level of design definition is then used to create the Life-Cycle Cost estimate and financial proforma for investment financing and due diligence reviews to support private sector financing and future federal assistance requests.