U.S. DEPARTMENT OF ENERGY
NUCLEAR ENERGY RESEARCH INITIATIVE
ABSTRACT

PI: David C. Wade **Proposal No.: 2000-060**

Institution: Argonne National Laboratory

Collaborators: Texas A&M University, General Electric, ENEA (Italy), Japan Nuclear Cycle Institute

Title: Integrated Nuclear and Hydrogen-Based Energy Supply/Carrier System

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This proposed three year program of R&D aims to develop an economical, proliferation resistant, sustainable nuclear-based energy supply system suitable for deployment in both industrialized and developing economics in the decades following 2020.

It is based on a modular-sized fast reactor, passively safe, and cooled with heavy liquid metal which supplies high temperature heat to an integrated gas turbine power/process heat chemical plant to generate dual energy carriers - electricity and hydrogen (with optional capability for potable water production from brackish or salt water desalinization).

Innovations and benefits include:

- Flexible mix of energy products - The integrated system is to be compatible with state of the art energy conversion systems (gas turbines, fuel cells, etc.) producing a flexible mix of "billable" product including electricity, high level and low level process heat, hydrogen, oxygen, and fresh water supply (via desalinization). The energy carrier can be stored to meet energy peaking needs, and may be used to power fuel cells for emission-free vehicle propulsion.

- Flexible system capacity - The use of standardized modules for the heat source, hydrogen production, and energy conversion functions enables the system capacity to be sized for small service areas using a single set of modules (300 MWt) or for larger and growing service areas using multiple, coupled sets of modules.

- Economic competitiveness - The nuclear and hydrogen-based energy system is aimed at low capital and operating cost through:
  - compactness, and radical simplification
  - modularization and standardization for factory "mass production" and fast site assembly
  - long-life core with cartridge refueling (15-30 year interval) and near 100% capacity factor
  - high fuel energy utilization
  - high energy conversion efficiency (~50% for hydrogen production, >50% for fuel cells)
  - base load operation and storable energy products (synthetic fuel and potable water) semi-autonomous operation

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- Sustainability - The system is designed for sustainability:
  - The nuclear fuel source utilization in a fast reactor is sustainable and lessens competition in the electric power, process heat, and vehicle propulsion sectors for other scarce, irreplaceable energy sources.
  - The integrated, nuclear and hydrogen-based energy supply/carrier system essentially eliminates greenhouse emissions in the electric power, process heat, and fuel cell based transportation sectors which it serves.
  - The integrated system reduces waste streams to low level heat and used nuclear fuel, and enables use of "waste" from one process to be a beneficial input to another process.
  - Integration of desalinization into the process system for recovery of "waste" heat and for sustainable production of fresh water for public works, industrial, and agricultural purposes.
  - The nuclear heat source achieves maximum utilization of the nuclear energy resource whether based on the once-through fuel cycle or, where permitted, fuel recycle.

- Proliferation resistance - The defense-in-depth approaches addressing proliferation concerns include:
  - long-life core with cartridge refueling (15-30 year interval) and no on site
  - fuel handling equipment
  - fuel ownership and (15-30 year interval) cartridge refueling by internationally monitored regional consortium
  - fuel facility and material transportation under international, guarded conditions
  - fuel protected by a high-level radiation "shield" at all stages

- Inherent/Passive reactor safety - The liquid-metal-cooled fast reactor incorporates and extends proven inherent and passive safety features based on decades of development of sodium-cooled systems which are heightened using Pb or Sn heavy liquid metal coolant. The nuclear heat source features:
  - low power density core
  - 100% natural circulation heat transport (eliminating the loss of coolant flow class of accident initiators)
  - reactivity coefficients are such to inherently shut the reactor down in case of power-to-flow mismatch
  - passive decay heat rejection together with passive system shutdown eliminates concern from "loss-of-heat sink" accident initiators
  - high boiling temperature of Pb and Sn together with system passive response eliminates core melt accidents
  - large fuel rod diameter and very large lattice spacing (eliminates core blockages)
  - worth of burnup reactivity control system <$1 (eliminates possibility of prompt excursion)

- low atmospheric pressure system and use of guard vessel eliminate loss of coolant accident initiators
- core compaction is eliminated by integral core design (without subassemblies) and use of spacer grids and recriticality potential is eliminated by fuel which floats in coolant
- seismic isolation is provided in the basic design
- the reactor and heat transport modules are compact, enveloped by a close-fitting containment, and are located in a silo which can be "hardened" to the extent necessary to protect against external threats
- the inexhaustible heat sink is site-specific, including atmospheric air, ground, or ground water
- the coolant and working fluids are separate systems, eliminating possibility of radiological transport to the hydrogen production or energy conversion parts of the plant even in the event of heat exchanger tube rupture (insofar as the working fluid pressure is higher than the reactor system pressure)

This proposal is responsive to the Generation IV/Alternative Power Conversion Cycles element of the NERI call for proposals.