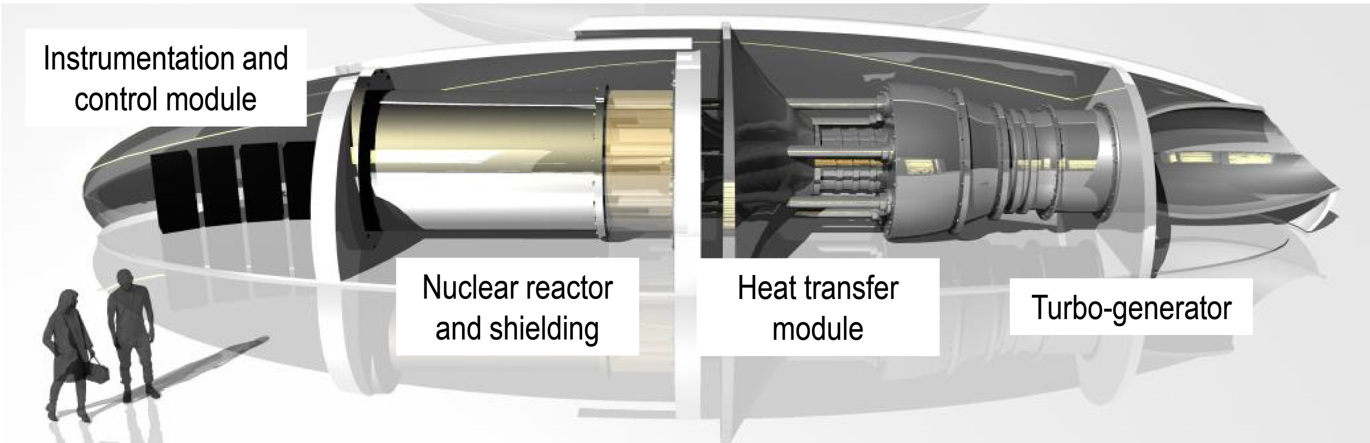


Decarbonizing and Strengthening the Global Energy Infrastructure Using Nuclear Batteries

OVERVIEW

The purpose of this project is to develop a flexible and road-transportable energy system consisting of a nuclear microreactor, hereafter referred to as **Nuclear Battery (NB)**, a turbogenerator, and their interfaces with end-user equipment. NBs have the following salient characteristics:

- Installed in a short time (days to weeks) with plug-and-play connections, exploiting battery-like features
- Autonomous normal operation, with minimal onsite staff for plant monitoring and security
- Factory-fabricated, -assembled, and -fueled
- Capable of supplying heat, electricity, or combined heat and power on demand and continuously for a period of 5–10 years
- Modular energy conversion/transfer, e.g., air Brayton or supercritical CO_2 cycles, Stirling engine, thermoelectric, heat pipes, and advanced heat exchangers
- Transported to the site in one or more shipping containers, requiring minimal site preparation
- Dry cooling—no water supply required
- No handling/storage of radioactive material onsite

The NBs are fueled with low-enriched uranium (<20%) offsite before installation and transport and will be refueled offsite in a centralized facility. In comparison to other low-carbon energy sources, the NB offers compactness, as well as reliable and continuous energy supplies that can be co-located with end users without major geographic constraints, thus greatly reducing the need for expensive and vulnerable energy transmission, energy storage, and fuel distribution infrastructure.

IMPACT

Less than a quarter of global anthropogenic CO_2 emissions are associated with grid-connected electricity generation. Three-quarters of the emissions come from transportation, heat for industrial processes and buildings, agriculture, and fossil fuel production. Many applications within these sectors are hard and/or costly to electrify. Since decarbonization of the global economy is the goal, massive amounts of low-carbon heat, electricity, and fuels will be required. Nuclear is a carbon-free primary energy source with an abundant fuel supply that can support the generation of all these energy products. Over 80% of customer demand is in the form of heat. Nuclear reactors produce heat and thus can have a major impact on reducing greenhouse gas emissions in heat applications.

Small reactor does not mean small power. NBs can be “stacked up” to support sites with any desirable energy output. The capacity of the plant is determined by market demand and the energy requirements of the applications. NBs are about enabling rapid and cost-effective deployment of clean energy systems. They can be either connected to the grid (assuming the economics are sufficiently attractive for that market) or provide energy to co-located off-grid heat and electricity applications, individually or clustered. Examples of such applications include:

- HEAT: generation facilities for hydrogen and synthetic fuels, steam for district heating, chemicals and fertilizers plants, food processing factories, pulp and paper mills, minerals processing facilities
- ELECTRIC POWER: data centers, modular water desalination units, large pumps for flood protection and climate change adaptation for islands and coastal communities, offshore oil/gas rigs operations, portable farms (e.g., Freight Farms), portable biopharma (e.g., KuBio), large portable 3D printers (e.g., AutoDesk), indoor aquaculture (e.g., Dubai salmon farm)
- COMBINED HEAT AND POWER: large college and technology campuses, military bases, mining sites, isolated communities, ports, and airports
- MECHANICAL WORK: propulsion for large ships (e.g., CorePower)

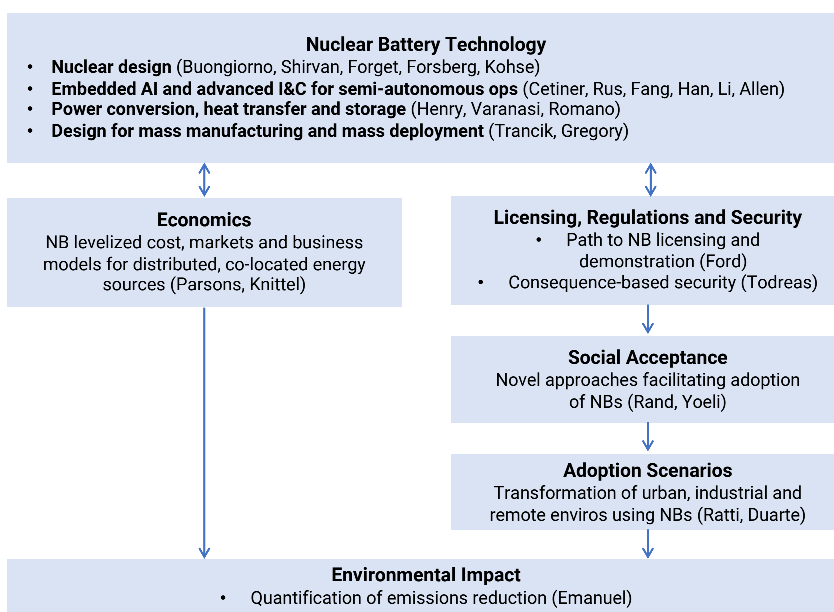
The potential impact of this project should be measured in terms of greenhouse gas emissions reduction with respect to current levels in these various applications, across all sectors of the economy.

TIMEFRAME

The time required for this project is five years. The first phase is estimated to last three years, and the scope of work includes six master tasks with the information conceptually flowing from one task to another as shown synoptically in the figure to the right.

The project will be successful if it delivers the following:

- NB designs that can be economically attractive in many sectors of the economy.
- Models for integration of the NB with end-user facilities, such as the advanced production examples listed above.



- A plan to rapidly scale up NBs from small volume fabrication (in factories available in the U.S. now) to high volume.
- A regulatory path that will ensure timely demonstration of the NB technology in the U.S. by the end of the decade.
- A plan to study and promote social acceptance of the NB technology.

There will be a major Go/No-Go decision point at the end of the first phase. If no technical showstoppers are encountered and the NB economic and environmental potential is confirmed, the project will proceed to the second phase, entailing construction of a demonstration unit suitable for testing at a DOE national lab site and review by the NRC, estimated to be an additional two years. Therefore, the impact of this project will start to be felt by 2030, a key feature of any technology that seeks to address the urgent challenges of climate change.

TEAM

A multi-disciplinary team with faculty and researchers from four MIT schools (Engineering, Science, Sloan, Architecture and Planning), Lincoln Labs and two national labs, led by **Prof. Jacopo Buongiorno** of NSE.
In alphabetical order (with affiliation in parenthesis): **Ross Allen** (Lincoln Labs), **Sacit Cetiner** (Nuclear Reactor Laboratory, Idaho National Lab), **Fabio Duarte** (Urban Studies and Planning), **Kerry Emanuel** (Earth, Atmospheric, and Planetary Sciences), **Nicholas Fang** (Mechanical Engineering), **Michael Ford** (Argonne National Lab), **Benoit Forget** (Nuclear Science and Engineering), **Charles Forsberg** (Nuclear Science and Engineering), **Jeremy Gregory** (Civil and Environmental Engineering), **Ruonan Han** (Electrical Engineering and Computer Science), **Asegun Henry** (Mechanical Engineering), **Chris Knittel** (Sloan), **Gordon Kohse** (Nuclear Reactor Laboratory), **Ju Li** (Nuclear Science and Engineering), **John Parsons** (Sloan), **David Rand** (Sloan), **Carlo Ratti** (Urban Studies and Planning), **Giuseppe Romano** (Institute for Soldier Nanotechnologies), **Daniela Rus** (Computer Science and Artificial Intelligence Laboratory), **Koroush Shirvan** (Nuclear Science and Engineering), **Neil Todreas** (Nuclear Science and Engineering), **Jessika Trancik** (Institute for Data, Systems, and Society), **Kripa Varanasi** (MechE), and **Erez Yoeli** (Sloan).