

Final Project Topics: Choose Your Topic

CBE 30235: Introduction to Nuclear Engineering

Spring 2026

Instructions: Choose one of the following topics for your final presentation and paper no later than March 20. Only one group per topic, so lock yours in on the project signup spreadsheet without delay! Your goal is not to write a history report; you must analyze the specific physical, chemical, and thermodynamic constraints of the system. What are the engineering trade-offs?

1. Radioisotope Thermoelectric Generators (RTGs): From Deep Space to Soviet Lighthouses

The Challenge: Evaluate the thermal, material, and safety trade-offs of converting decay heat directly to electricity without moving parts.

The Focus: Compare the engineering constraints of different isotopes (the benign alpha-decay of Pu-238 vs. the heavy biological shielding required for the beta-decay of Sr-90) and their operating environments (deep space vacuum vs. Martian atmospheric convection vs. terrestrial Arctic deployments).

2. Nuclear Desalination: Coupling Reactors to Reverse Osmosis or Thermal Distillation

The Challenge: Analyze the thermodynamic and economic challenges of using a reactor's waste heat or electrical output to produce potable water.

The Focus: Dive into the thermal-hydraulic interface between the secondary cooling loop and the desalination plant. Evaluate the strict engineering barriers and pressure differentials required to ensure absolutely zero radioactive tritium cross-contaminates the public drinking water supply.

3. Aqueous Homogeneous Reactor (AHR) for Medical Applications: HRE-1&2 to SHINE

The Challenge: Contrast the historical failure of the HRE power reactors with the modern success of using subcritical aqueous systems to produce life-saving medical isotopes.

The Focus: Analyze the Chemical Engineering nightmare of water radiolysis and uranium precipitation that destroyed the HRE-2. Then, evaluate how SHINE Technologies uses a subcritical target solution vessel driven by a particle accelerator to safely separate Molybdenum-99.

4. NERVA to DRACO (Nuclear Thermal Propulsion)

The Challenge: Investigate the extreme thermal-hydraulics and materials science required to pump cryogenic liquid hydrogen (~ 20 K) directly through a $2,700^\circ\text{C}$ reactor core.

The Focus: Compare the original 1960s NERVA test reactors (which used highly enriched,

weapons-grade uranium) to the modern DARPA/NASA DRACO designs (which must achieve similar specific impulse using High-Assay Low-Enriched Uranium, or HALEU).

5. Magnetic Confinement Fusion: The Tokamak vs. The Stellarator

The Challenge: Compare the plasma physics, superconducting magnet design, and extreme heat-flux materials required to sustain a star in a bottle.

The Focus: Contrast the symmetric, pulsed nature of the Tokamak (e.g., ITER) with the incredibly complex, continuously operating twisted-coil design of the Stellarator (e.g., Wendelstein 7-X). Pay special attention to the "divertor," the physical exhaust pipe that must survive unimaginable heat loads.

6. Medical Radiopharmaceuticals: Targeted Alpha Therapy and "Hot Cell" Chemistry

The Challenge: Explore the chemical and mechanical engineering required to isolate short-lived, highly radiotoxic isotopes for direct cancer treatment.

The Focus: Analyze the thermal-hydraulics of irradiating targets inside a reactor flux trap or cyclotron. Detail the complex ion-exchange chromatography and solvent extraction required in remote-handled "Hot Cells" to separate isotopes like Actinium-225 without the solvents breaking down from intense radiation.

7. Neutron Activation Analysis (NAA) and Nuclear Forensics

The Challenge: Analyze how research reactors use pneumatic transfer systems to identify trace elements without destroying the physical sample.

The Focus: Detail the mechanical transient fluid dynamics of the "rabbit tube" delivery systems. Then, evaluate the electrical engineering and physics of High-Purity Germanium (HPGe) detectors, pulse-shaping electronics, and the complex gamma-ray spectroscopy required to isolate overlapping isotopic energy peaks.

8. The Liquid-Fueled Molten Salt Reactor (MSR)

The Challenge: Analyze the chemistry and physics of dissolving uranium directly into a molten salt coolant, which eliminates fuel fabrication but turns the primary loop into a radioactive plumbing nightmare.

The Focus: After covering the basic physics, you must choose **one** of the following modern case studies to evaluate how they engineer around the corrosive salt problem:

- **The Replaceable Core Cartridge** (Terrestrial Energy IMSR)
- **The Fast-Spectrum Waste Burner** (TerraPower MCFR)
- **The Two-Fluid Breeder** (Flibe Energy LFTR)
- **The Active Prototype** (China's TMSR-LF1)

9. Pick Your Own Topic: The Wildcard

The Challenge: Identify a distinct nuclear engineering system, historical event, or emerging technology that involves competing physical, chemical, or thermodynamic constraints not covered above.

The Focus: You must define the specific engineering trade-offs (the "Pros" vs. the "Headaches") of your chosen system. **Requirement:** You must submit a 1-paragraph proposal outlining your topic's Challenge and Focus to me by **Friday, March 20** for approval.