Hybrid Energy System Optimization for Nuclear Energy Sustainable Development

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Project Overview

Background

The impact of greenhouse gas (GHG) emissions is driving international efforts to develop and implement alternative sustainable solutions to minimize or eliminate such emissions. One potential solution is to integrate energy systems. As a leading S&T lab in Canada for carrying out R&D in support of nuclear and other low-carbon technologies, the project aims to develop modelling capabilities and experimental test facilities to investigate nuclear-renewable hybrid energy system in supporting the feasibility of low-carbon energy supply mix.

Objective

- Assess the synergy of a merit-based integrated energy supply mix
- Address technical challenges and advance technical readiness of low-carbon technologies
- Establish micro-grid controller capabilities and management strategies
- Improve and refine Hybrid Energy System Optimization (HESO) tool

Expected Outcome

Development of CNL's capabilities including environmental and technical assessment, technical readiness for energy storage technologies, microgrid controller/codes, and energy system model for heat and power applications.

Federal Stakeholders

AECL, NRCan, ECCC, DND

Partners and Collaborations

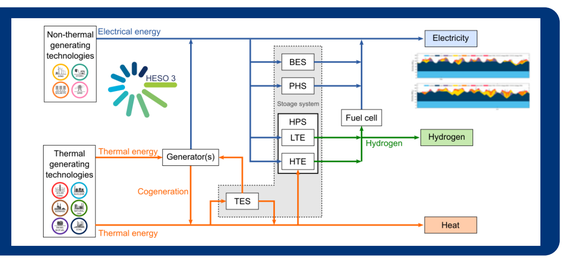
- IAEA coordinated research projects: (1) technical evaluation and optimization, (2) economics of SMR
- Support CEDIR Initiative: Global National Laboratories and University of Waterloo

Modelling and Simulation

HYBRID ENERGY SYSTEM OPTIMIZATION

Aim & Scope
Improve and refine HESO capabilities, examine various components, and perform case studies to benchmark the model and publicise the tool.

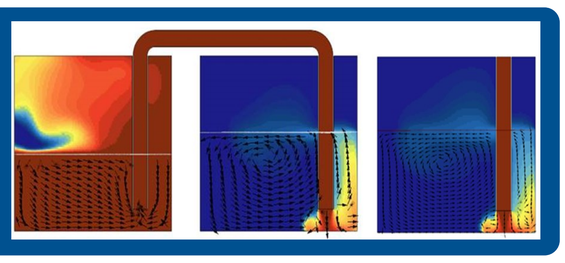
Achievement
Developed HESO with improved and refined components including newly added hourly market prices, hydrogen production with heat, and nuclear technical constraints.



CFD SUPPORTING EXPERIMENT

Aim & Scope
Investigate the influence of scaling on molten salt tank storage system to support lab scale experiment through CFD modelling.

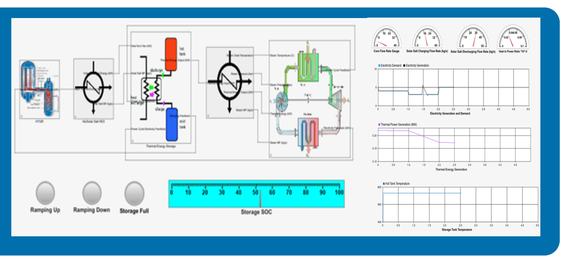
Achievement
Analyzed and documented single- and two-tank systems to study the influence of salt charging flow rates and variation in geometry configuration.



THERMAL SYSTEMS

Aim & Scope
Investigate use of thermal system modelling using calculation modules or thermal system codes for thermal energy flows and efficiencies.

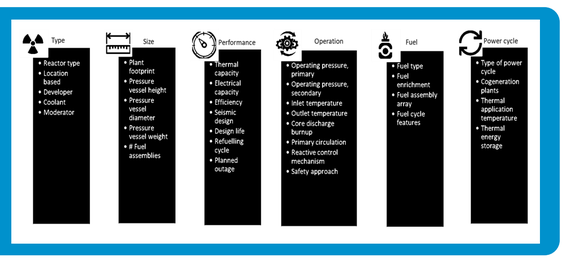
Achievement
Developed thermal and electrical model integration architecture, thermal components, and gas cycle models.



SMR LIBRARY, SMR COST, PARAMETER ASSESSMENT, IAEA CRP

Aim & Scope
Build nuclear input library for HESO, assess knowledge level and importance of parameters, perform sensitivity studies , and participate in IAEA CRP.

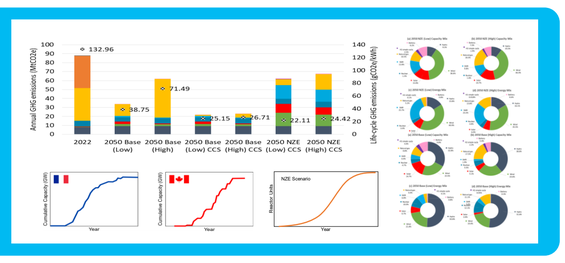
Achievement
Developed SMR cost model and SMR library, classified and performed PIRT, and developed model for IAEA CRP economic appraisal of SMR.



FUTURE ENERGY SYSTEMS

Aim & Scope
Initiate study for Canadian energy system to develop SMR deployment scenarios reaching net-zero carbon emissions in 2050.

Achievement
Determined realistic scenarios for Canada to achieve decarbonization and developed baseline and net-zero scenarios in large-scale electrification for all sectors.



Bench-Scale Experiments

CONCRETE THERMAL BATTERIES OPTIMIZATION

Aim & Scope
Improve understanding of phase change material-enhanced concrete storage temperature ranging between 150-200°C.

Achievement
Development of lab scale concrete thermal storage, consisting of storage medium with U-loop heat exchangers.

MOLTEN SALT THERMAL BATTERIES OPTIMIZATION

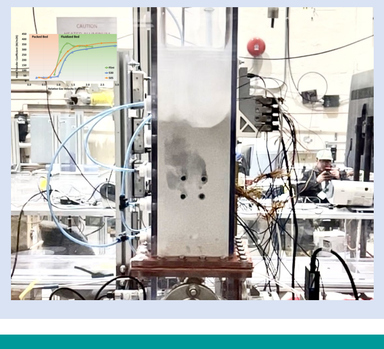
Aim & Scope
Investigate stresses induced by thermal gradients, a common driver for foundation and tank failure in two-tank nitrate molten salt storage systems.

Achievement
Constructed a bench-scale two-tank nitrate molten salt storage system to study flow mixing and formation of hot and cold spots on tank walls.

SAND THERMAL BATTERIES OPTIMIZATION

Aim & Scope
Perform experimental study to assess the benefits of sand thermal energy storage in a nuclear hybrid energy system.

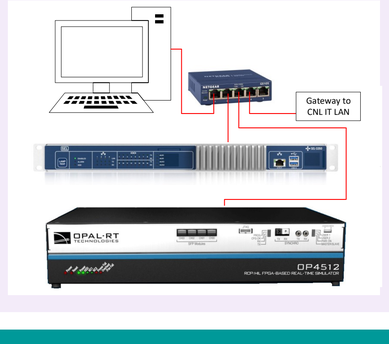
Achievement
Designed, constructed and tested a lab-scale fluidized bed heat exchanger to measure heat transfer coefficient between silica sand and heating tubes.



MICROGRID CONTROLS AND HARDWARE-IN-LOOP

Aim & Scope
Establish capabilities for microgrid controller/codes to examine IES synergetic operation and H-I-L testing.

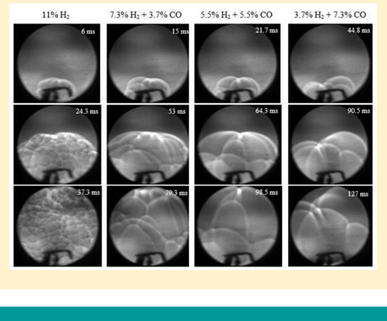
Achievement
Developed electrical hybrid energy system dynamic model with various technologies, a grid connection and battery storage system with static, dynamic, and curtailable loads.



SYNGAS SYSTEMS HAZARDS AND MITIGATION

Aim & Scope
Investigate the challenges and potential mitigation to implement of syngas/ hydrogen energy systems.

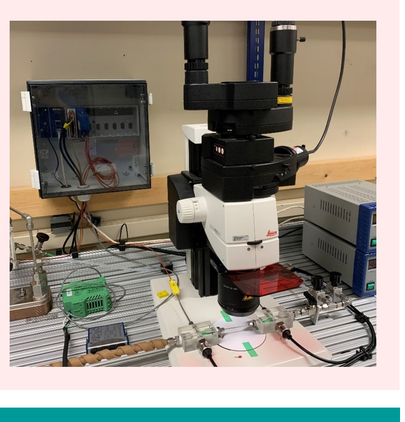
Achievement
Investigated the effects of fuel concentrations, molar ratio of CO/H2, initial gas temperature, steam concentration, and fan-induced turbulence on the flame dynamics.



COMPACT ENERGY SYSTEMS

Aim & Scope
Investigate technological readiness of low-carbon technologies through heat transfer process using miniature features.

Achievement
test loop assembly and installation for microchannel heat transfer and fluid flow and leak tests.



Publications

1. Z. Liang et. al, Experimental Study on Combustion of H2-CO-Air Mixtures in Closed and Vented Vessel, submitted to Int. Journal of Hydrogen Energy
2. P. Sanongboon and T. Pettigrew, "Feasibility and Benefits of Nuclear Reactor Hybrid Energy Systems: A Remote Community Case Study," G4SR4, Toronto, ON, Canada, October 3-6, 2022
3. A.M. Bayomy, P. Sanongboon, and L. Mosscrop, "Business Model for a Nuclear Hybrid Energy System," G4SR4, Toronto, ON, Canada, October 3-6, 2022
4. P. Sanongboon, T. Pettigrew, M. Moore, Techno-Economic Analysis of Small Modular Reactor for Oil Sands Extraction and Upgrading in Canada, to be submitted

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