Optimal Sizing of a Nuclear Reactor for Embedded Grid Systems

Preliminary Work

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May 28, 2020

Outline

iCAP Goal and Obstacles

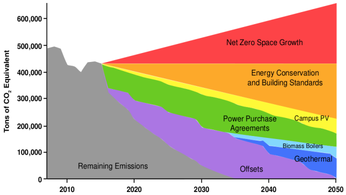


Figure: Shows projected CO_2 emissions for UIUC [7]. Offsets include shutdown of the Blue Waters Supercomputer.

Goal:
Carbon neutrality by 2050 or sooner.

Obstacles:

1. Requires *zero net space growth*.
2. Campus depends on a system of steam tunnels for heating.
3. and more...

The Nuclear Option

Nuclear energy...

1. ...produces almost no carbon emissions [6].
2. ...can produce high-temperature steam.
3. ...requires little physical space*.

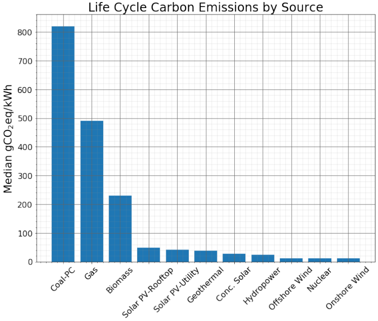


Figure: Lifetime carbon-equivalent emissions by energy source from IPCC findings [6].

*compared to solar and wind.

What is the optimal size for a nuclear reactor on the UIUC grid?

Outline

To answer this question we considered two modeling approaches:

1. `RAVEN` (INL) - Risk Analysis and Virtual Environment [1][5]
2. `TEMOA` (NCSU) - Tools for Energy Model Optimization and Analysis [3][2]

Workflow in RAVEN

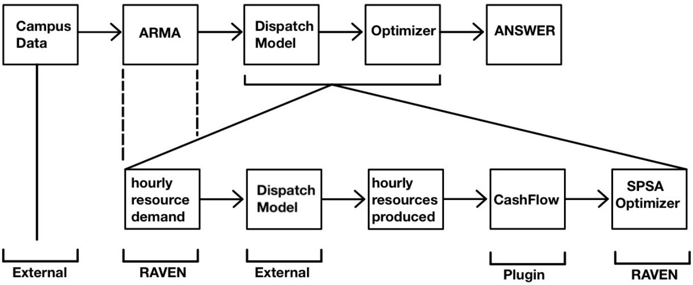


Figure: A general optimization workflow in RAVEN

Outline

Step 1: Generate Synthetic Histories

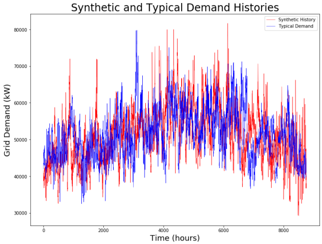


Figure: Shows the synthetic (red) vs typical (blue) hourly electricity demand at UIUC.

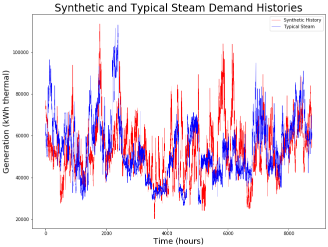


Figure: Shows the synthetic (red) vs typical (blue) hourly steam demand at UIUC.

BAU: Grid Model

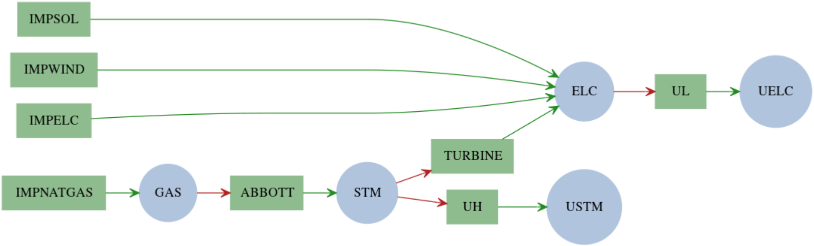


Figure: Graph representation of the UIUC embedded grid.

BAU: Generation

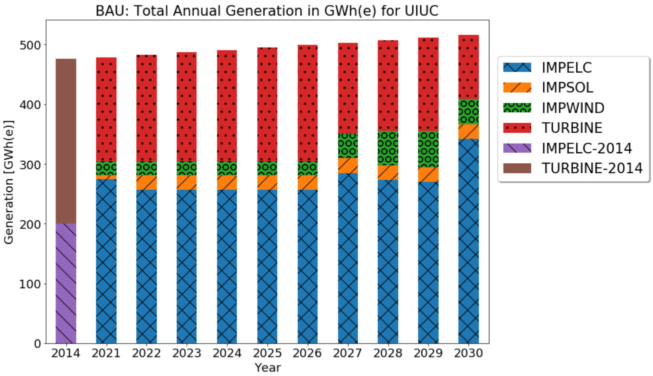
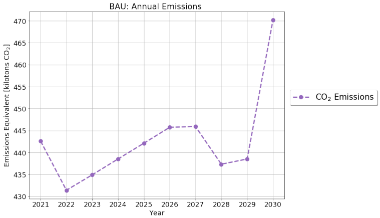


Figure: The change in activity from each energy source from 2020-2030. Assuming 1% demand growth each year

BAU: Emissions



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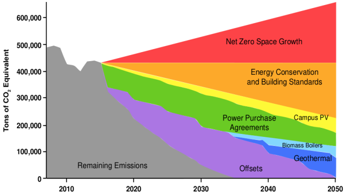

Figure: Predicted growth in emissions from iCAP [7].

Nuclear Scenarios

1. Scenario 1: Zero Capital Costs
2. Scenario 2: No Capacity Limit
3. Scenario 3: Limited to Small Modular Reactor (100MWth)

Table: Summary of Nuclear Scenarios. Costs from EIA and NEI reports [4][8].

Scenario	Operation Costs [$/MWh(th)]	Capital Costs [M$/MWth]	Maximum Capacity [MWth]
1	8.91	-	-
2	8.91	1.982	-
3	8.91	1.982	100

Scenario 1: Generation

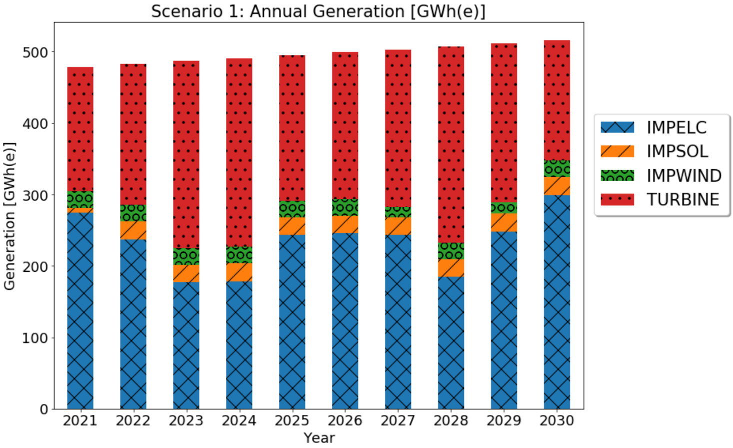

Figure: The electric generation without a cost constraint on nuclear

Scenario 1: Emissions

Figure: The carbon equivalent emissions without a cost constraint on nuclear

Scenario 2: Generation

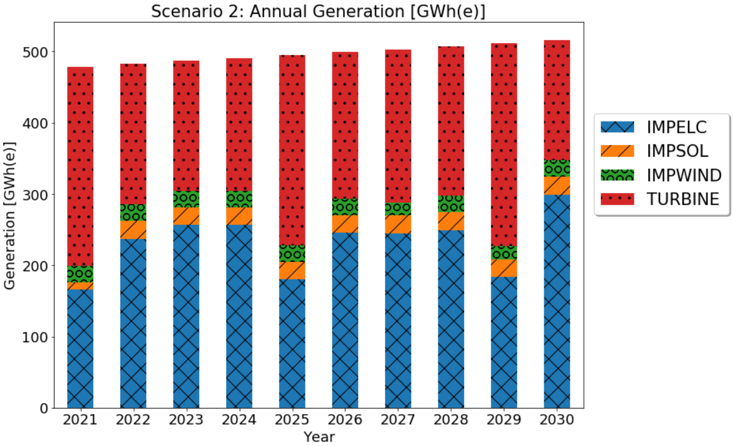

Figure: The electric generation without a size constraint on nuclear

Scenario 2: Emissions

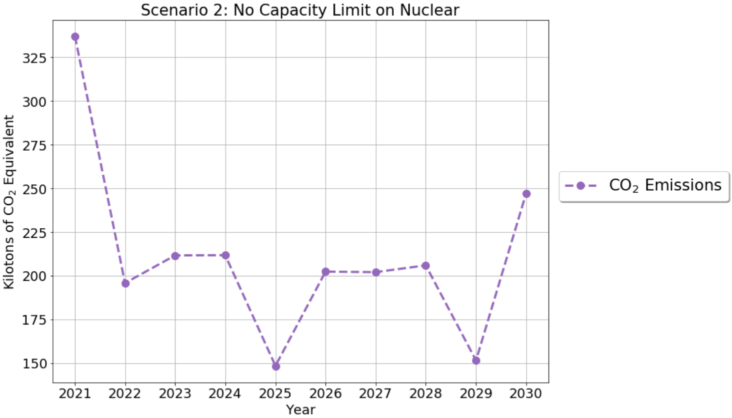

Figure: The carbon equivalent emissions without a size constraint on nuclear

Scenario 3: Generation

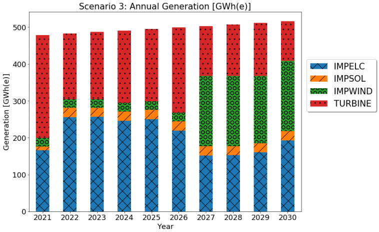

Figure: The electric generation with constrained nuclear.

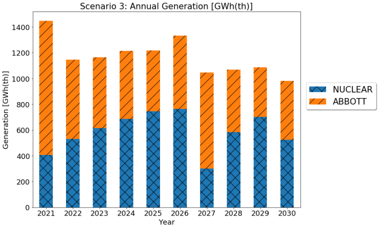

Figure: The steam generation with constrained nuclear

Scenario 3: Emissions

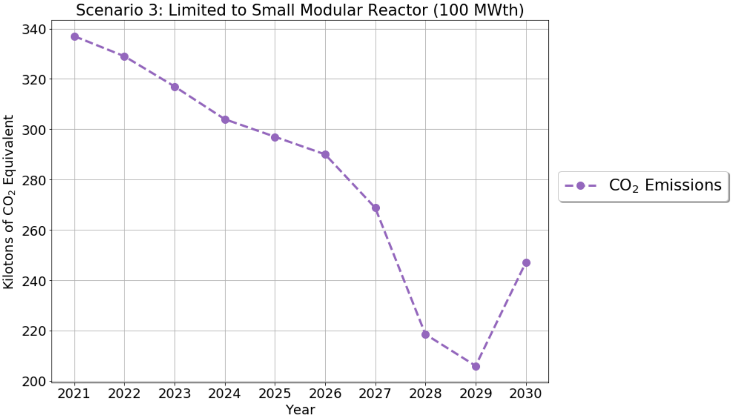

Figure: The carbon equivalent emissions without a cost constraint on nuclear

Outline

Conclusion

Acknowledgement

This work was made possible with data provided by UIUC Facilities and Services, in particular, Morgan White, Mike Marquissee, and Mike Larson.
Additionally, this work is funded by the NRC Fellowship Program.

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