# Carbon-Neutral Energy Portfolio and Nuclear SMR Design

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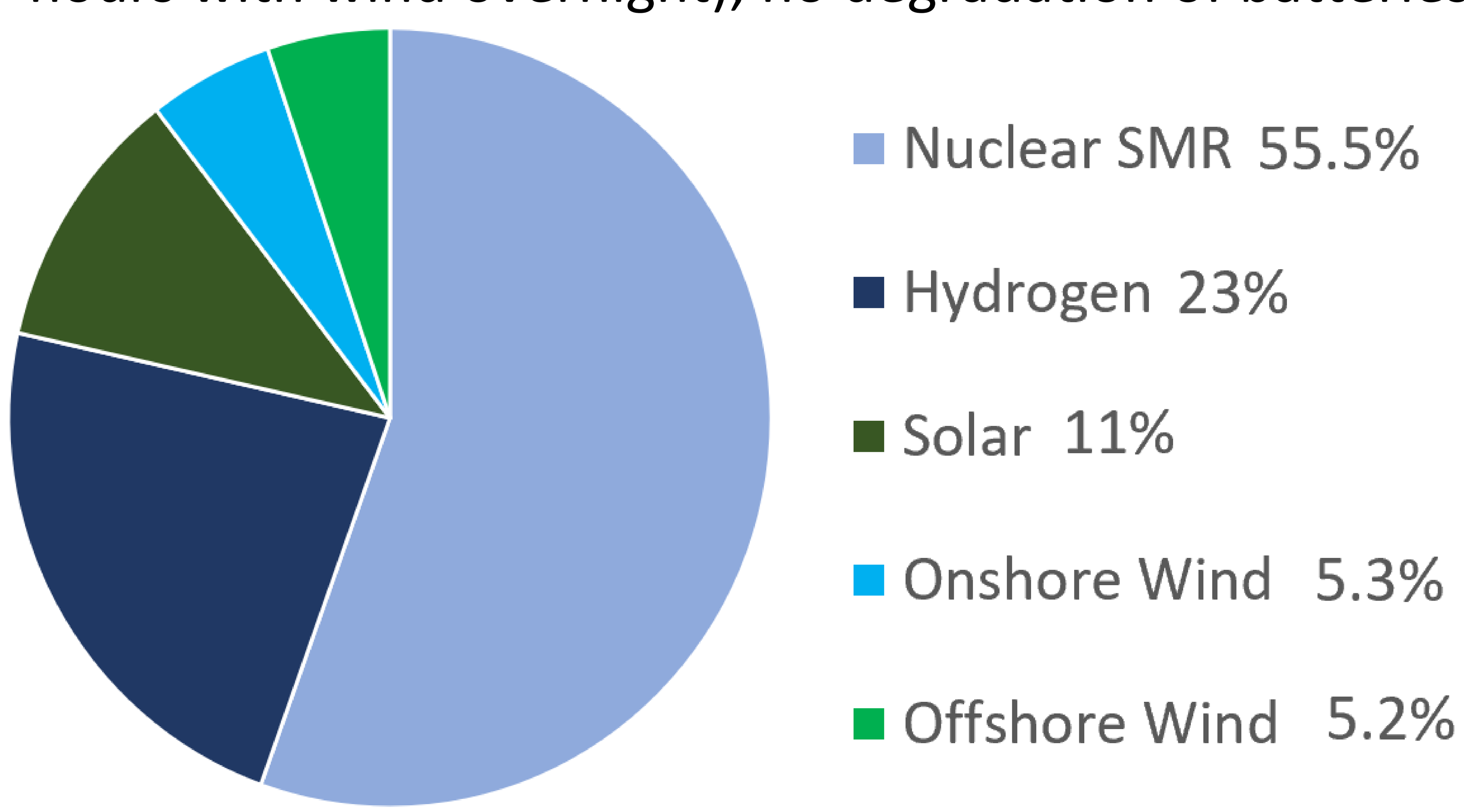
## Background and Goals (1)

Continued use of carbon-emitting fuels has led to nearly irreversible damage to the environment, along with many negative effects on human health. To move towards a cleaner energy future, the goals of this project are:

1. To design a 25GW carbon-neutral energy portfolio that can realistically be implemented by 2030.
2. Design a nuclear small modular reactor (SMR) power plant to be implemented into the grid that is safe, reliable, and cost-effective.

## Energy Portfolio & Economics (2)

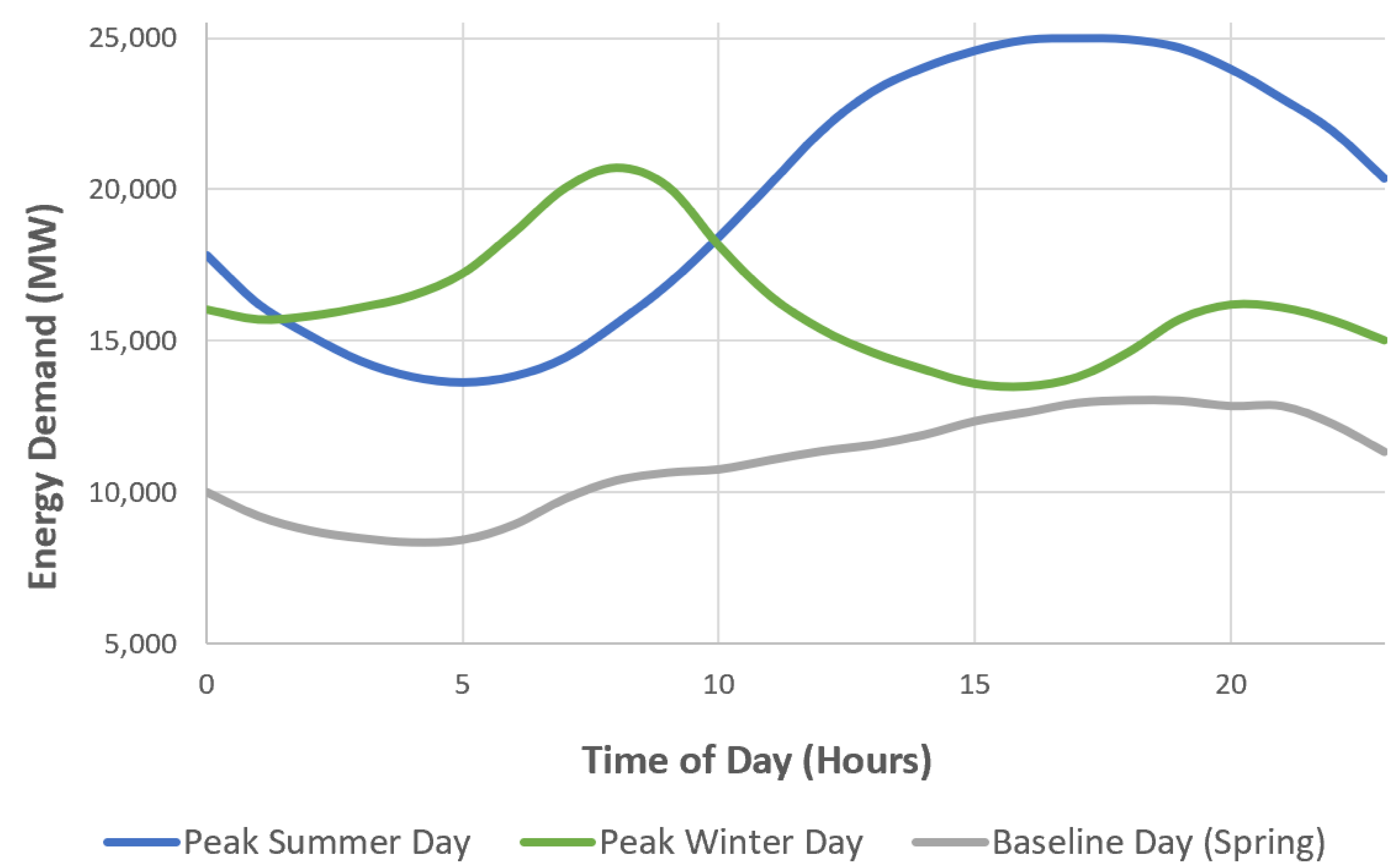
**Key Assumptions:** 5% energy loss (26.25GW produced), optimal weather conditions every day (4-5 peak sun hours with wind overnight), no degradation of batteries.




| Power Source | LCOE ($/MWh) |
|---|---|
| Onshore wind | $65 |
| Offshore wind | $120 |
| Solar + Battery | $65 |
| Solar | $40 |
| Nuclear SMR | $90 |
| Hydrogen | $140 |
| Battery | $120 |

- Portfolio optimized to have lowest total cost
- Capital, land, and energy costs considered
- Solar has largest land cost, SMR largest capital cost, and hydrogen largest energy cost.
- **Total = $15.3B project**
- Costs will be made back as energy is produced.
- LCOE determines dispatch order.

## Tiered Dispatch (3)

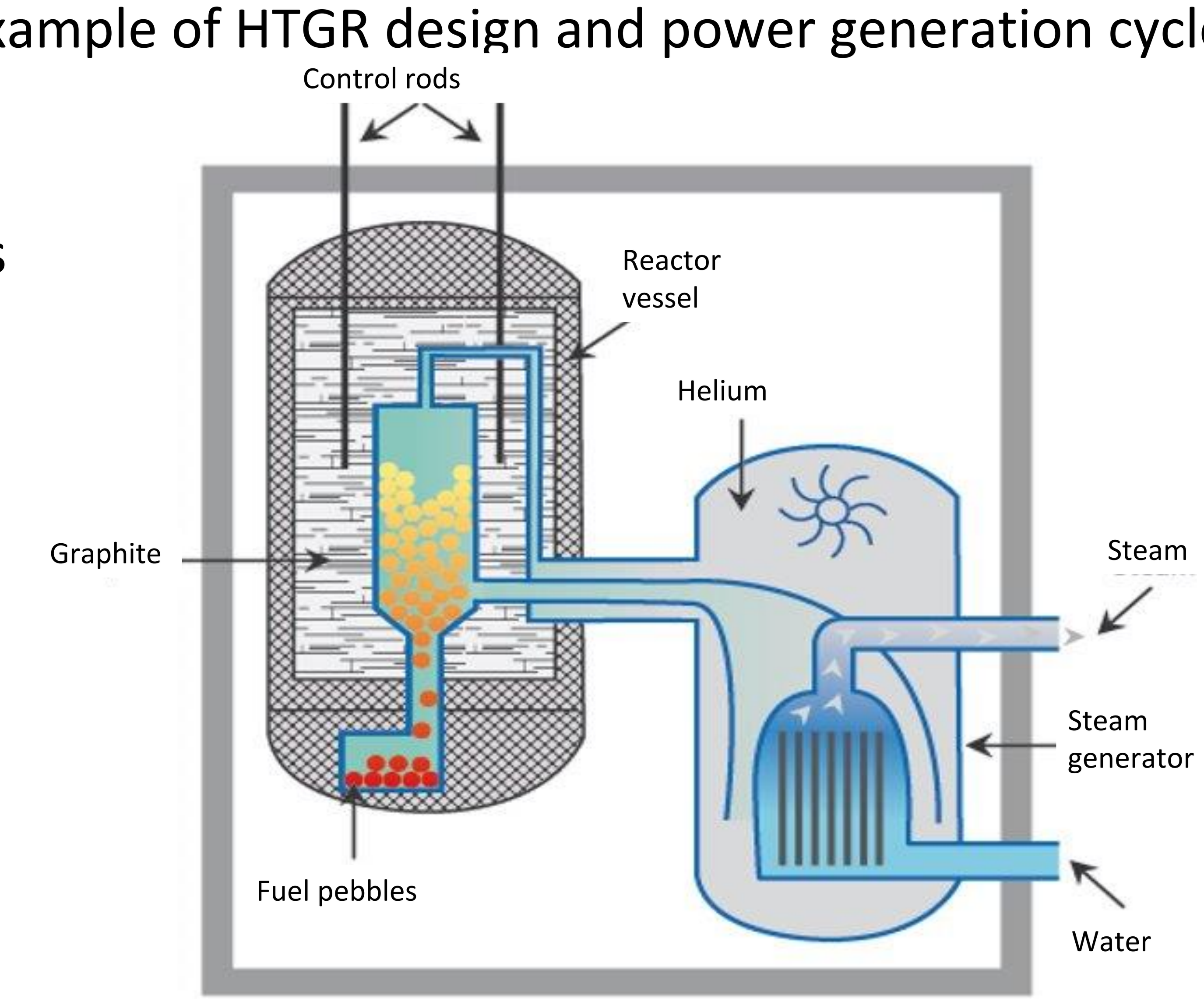



| Season | Maximum Demand | Sources Utilized |
|---|---|---|
| Baseload | 8350 MW | SMR |
| Fall/Spring Peaks | 13,050 MW | SMR, solar, wind |
| Winter Peaks | 20,100 MW | All sources + batteries |
| Summer Peaks | 25,000 MW | All sources + batteries |

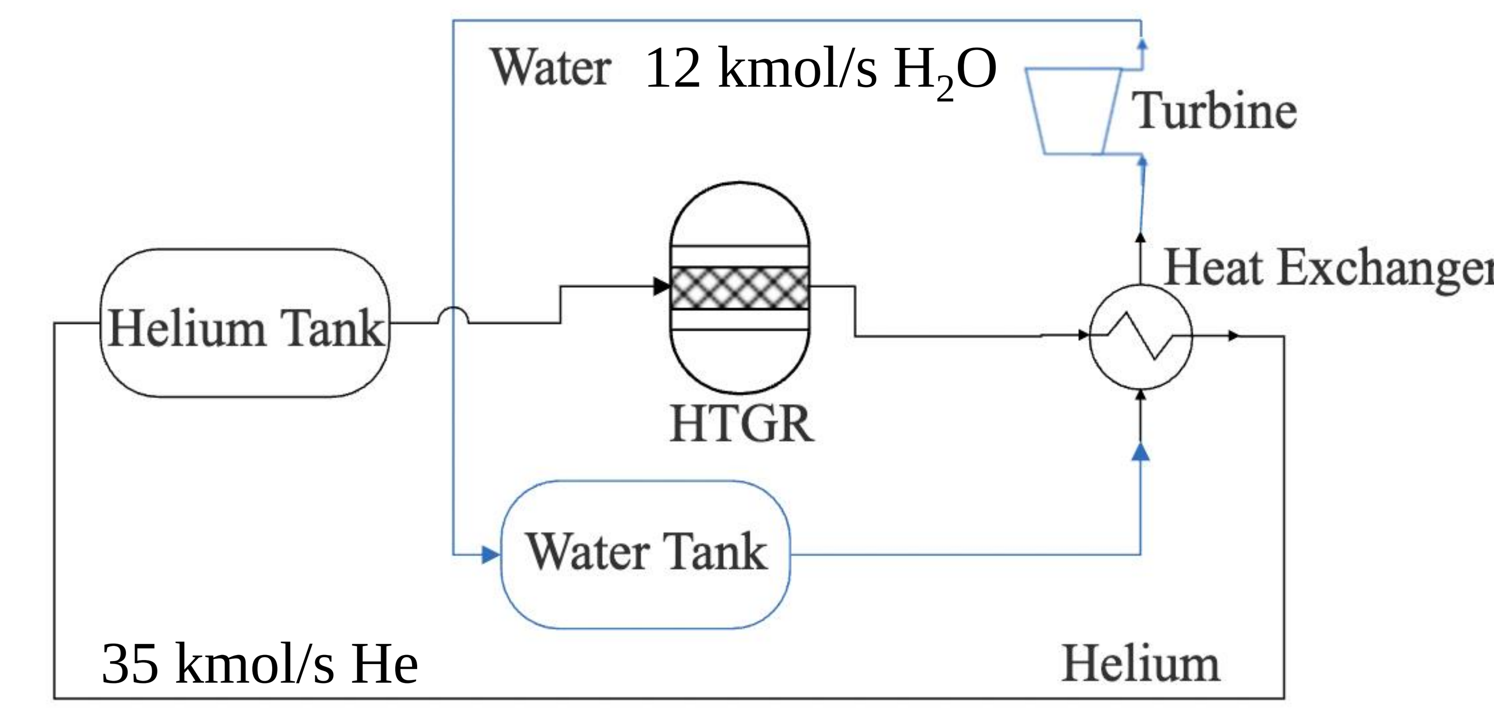
- 90 Li-ion batteries, capacity 50MW/400MWh over 8hr
- Demand most difficult to meet during summer peaks. More flexibility to vary sources in fall and spring.

## Nuclear SMR Power Plant (4)

Example of HTGR design and power generation cycle:




## Block Flow Diagram (5)




- **Thermal Efficiency ~44.5%** • **Power Output= 300MW**
- **Power Generation Cycle:** Helium is fed through a packed bed of fuel spheres in the HTGR, then transfers heat to water in the heat exchanger. This creates steam that generates electricity in a turbine.
- **Reactor Core**: cylindrical, 14.9m height, 5m diameter, exterior made of graphite to moderate reaction.

## SMR Safety & Economics (6)

- Graphite is stable up to ~3000ºC
- Pyrolytic carbon and silicon carbide, which will coat fuel kernels, contain fission products up to ~1600ºC
- Helium is stable and nonreactive at all temperatures

| Capital Costs of Process | Annual Operating Costs | Annual Revenue |
|---|---|---|
| ~$137M | ~$15.4M | ~$370M |

- Most of the costs are buying and enriching uranium
- It is assumed that electricity can be sold at $0.14/kWh

## Conclusions (7)

If the power portfolio were to be implemented, constraints would need to be re-evaluated. The SMR design is safe, efficient, and profitable, so we recommend its commercialization.

## Acknowledgements (8)

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