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Indianapolis

Richard G. Lugar Center for Renewable Energy

Innovations in Low-Carbon On-site Thermal Generation

Energy Self-Sufficiency for Facilities, Factories, Office Buildings, Hospitals, and Warehouses

Presented to: Council of Industrial Boiler Owners
Policies & Technical Issues Conference
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Abstract

PART 1

Lignocellulosic and non-halogen polymers can be converted into energy, chemicals, fuels, and heat using a patented tar-free thermochemical conversion process. The latest innovation produces hydrogen with a very low carbon intensity (0.36 CO_2/H_2 w/w) from low-value feedstock available in warehouses, industrial operations, office buildings and municipal or utility operations. Assuming the cost to gather one MT, net avoided waste haulage, is $30, this “green” bio-hydrogen can be produced for $0.59/kg and used, for example, to generate high-pressure steam in a boiler using modified injectors. With the production credits from the IRA 2022, this carbon-free heat is just $1.38/MMBTU.

PART 2

The subsequent generation of thermal generation uses thorium from the soil, separated by hydrocyclone, plus neutrons from (non-radioactive) deuterium fusion via tabletop linear accelerators, is a 6 MWth small-modular reactor. An early version of this has been proposed to DARPA for operation on the surface of the moon. A commercial unit, fueled by local, earth-abundant materials, will produce byproducts that decay to safe levels in only 80 years, for which existing human technology has viable solutions. These innovations together provide for small- and meso-scale low-carbon thermal generation at operating costs lower than those using natural gas.

Key Take-aways

- Waste-to-Energy
- Spare, Share, Save, Sell
- Minimize Supply Chains
- Act Local, Plan Global
- Always Seek Synergies
- Incremental Improvement With Vision

Meso-scale (non-food) Biomass Reactor

Three units built so far

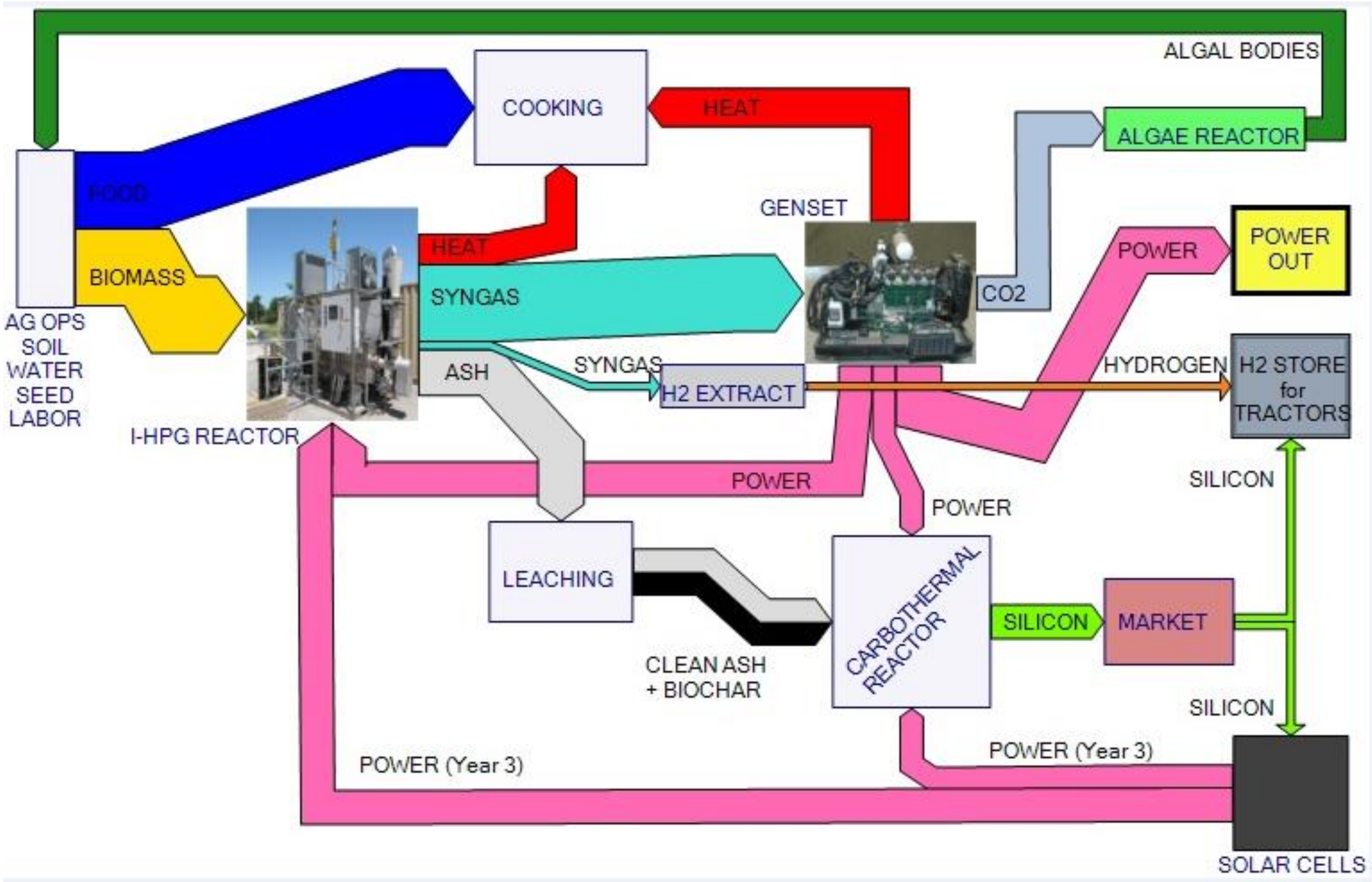
- *USDA*
- *DOE*
- *DoD*

Commercial design

- *On-site electricity*
- *Heat for drying*
- *Biochar for soil*
- *Green Hydrogen*

Outputs are electricity, heat, biochar, hydrogen eventually silicon

Sankey diagram mass & energy flows

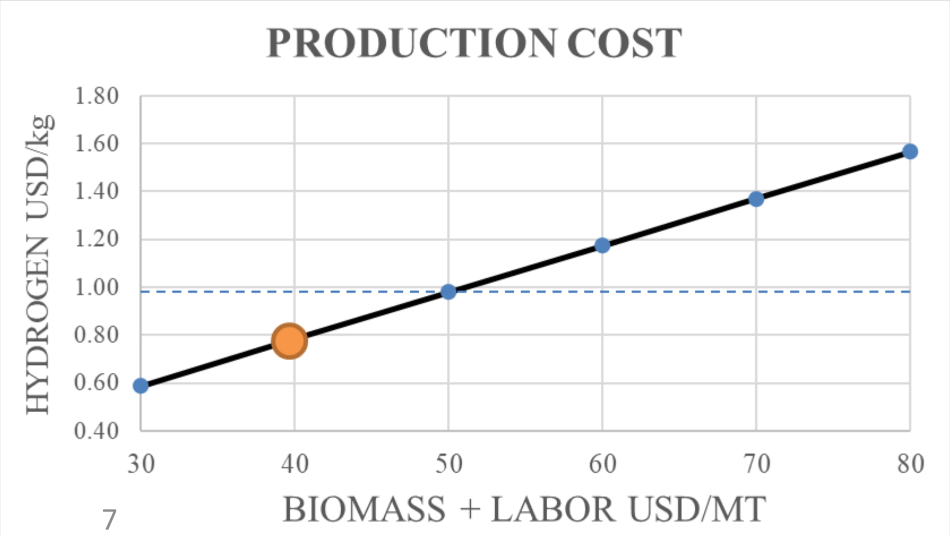


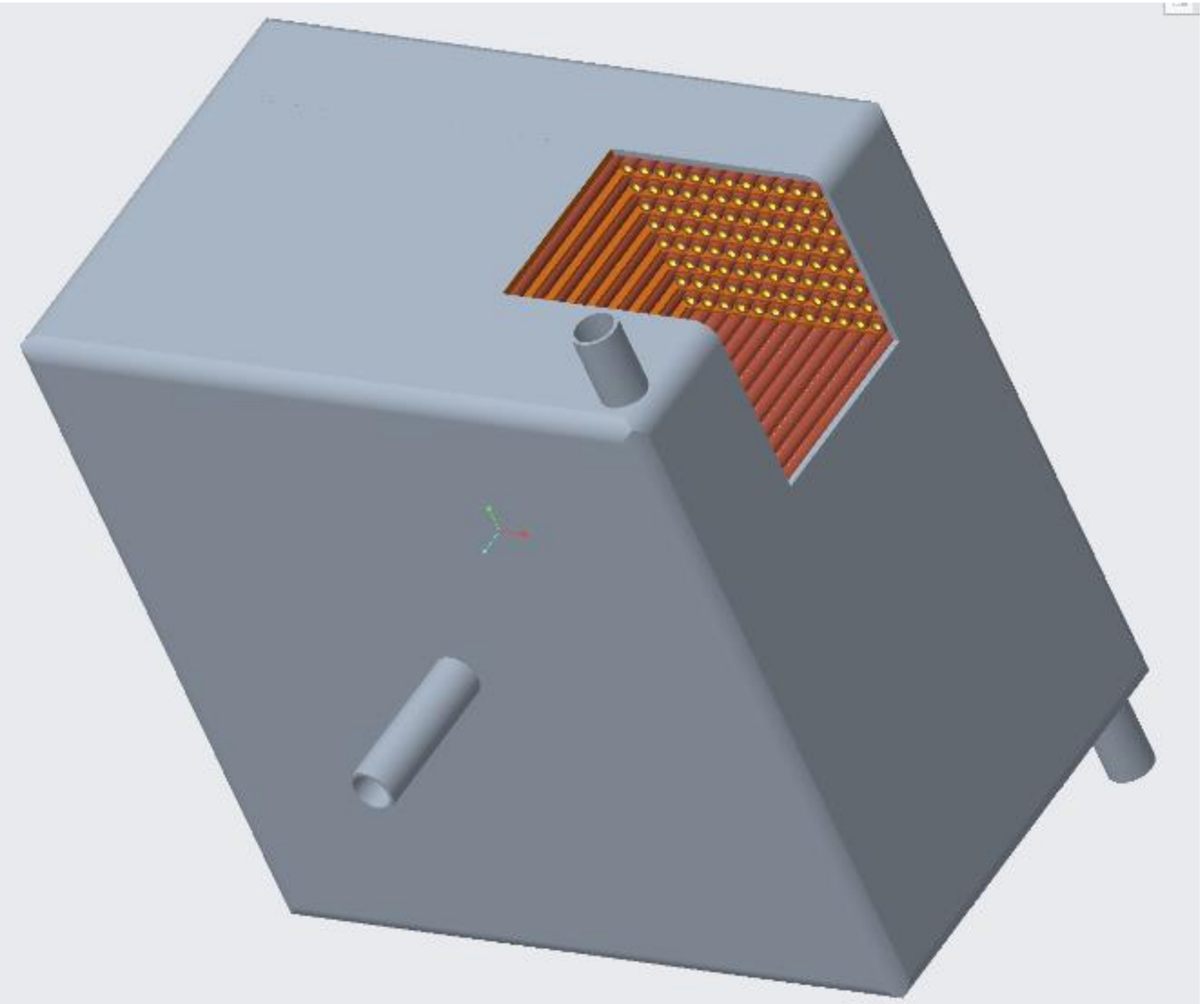
Biomass Combined Heat and Power (CHP) Metrics

- Process 1 to 3 tons/day
- Produce 40 kW 3-phase electric power
- Generate 250,000 BTU/hr
- Passed EPA “stack test” air pollution
- Ash content from 6% to 30%
- Biochar output
  - Reverse desertification
- Pays for itself in 2 years
  - if electric costs are 0.20$/kWh
- Portable
- Accepts any biomass

Hydrogen Extraction

- Membrane Separation Unit
- DOE Phase 2 award $400k
- 2.5 year ROI vs. retail H_2





LAB WORK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DANGER


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Office Buildings

- Empire State Building (esbnyc.com)
  - 2.5 M ft^2 (gross)
  - 84 $kBTU/ft^2$/year energy use (heat and elec.)
- OfficeFinder.com
  - 175 ft^2/person
  - ESB 14,300 people
- Unsustainable Magazine
  - Office waste 2 lbs/person/day
- EPA
  - Office waste 5,000 BTU/lb
    - This may be underestimated

- Office waste at ESB
  - 143 MMBTU/day
  - Efficiency 0.60 (CHP)
  - 86 MMBTU/day (heat + elec)
- Demand at ESB
  - 575 MMBTU/day
- Demand fraction by CHP
  - 15%

Warehouses

- Wastecare.com
  - 1 lb/100 ft^2 per day
  - Assume mostly cardboard, plastic, wood
  - Energy content estimate: 15,000 BTU/lb
- Warespace.com
  - Average size = 17,500 ft^2
- CHP 60%
  - 1.2 kW electrical + thermal
- Meteorspace.com
  - Energy demand 12.2 kW
- Fraction of demand met:
  - 10%

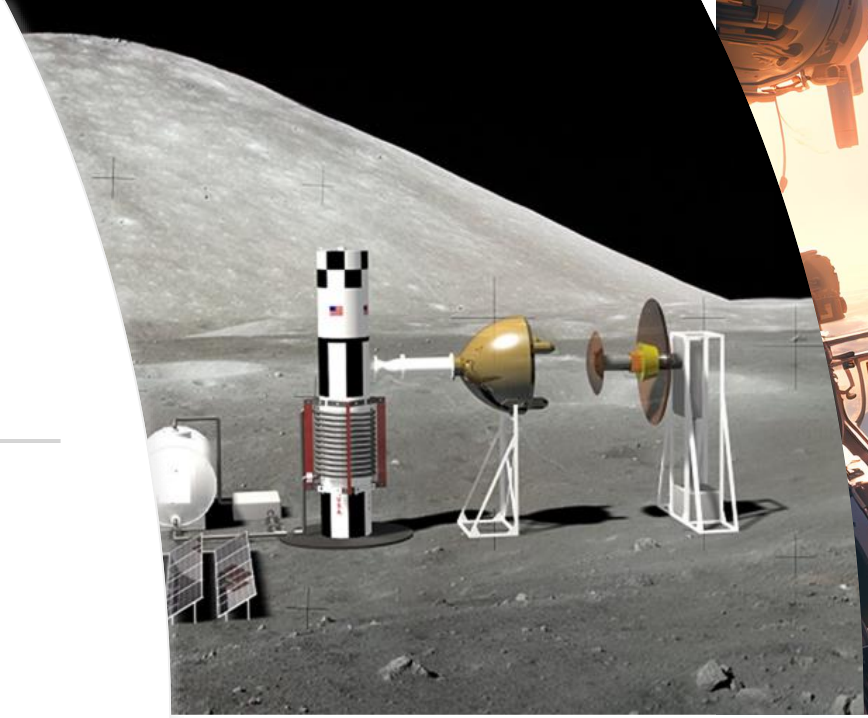
Sewer Sludge (WWTP aka POTW)

- EPA energystar.gov - plant demand
  - 10 kBTU/gal/day energy consumption
- doh.wa.gov wastewater
  - 70 gal/day/person
- Wastewater blog.com - solids generated
  - 0.12 lb/person/day
- US EPA.gov - sewer sludge energy
  - 10,000 BTU/lb
- Electricity at 35% efficiency

- Consumption
  - 0.005 kW/person
- Demand
  - 8.5 kW/person
- Demand fraction
  - *Less than 1%*

Space Solar Power

- Moon is 21% Si
- 4 Patents for Si, Al
- Fab PV on moon
- Deliver to orbit
- Make powersat
- Deliver RF
- Baseload 5 GW
- All metro areas
- All factories
- Make H_2 at night



Fission Thermal Source for the Lunar Surface

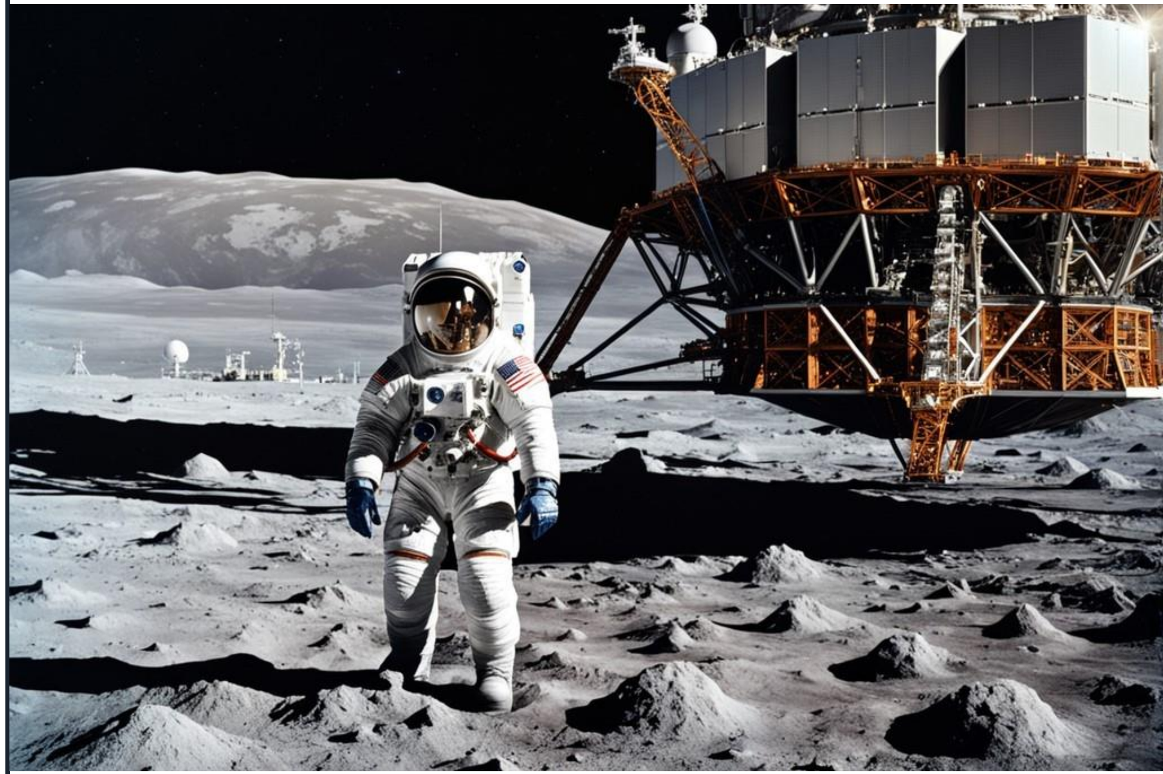
Challenge: **Baseload thermal power needed for continuous lunar surface and subsurface operations**
Build ultra-safe fission reactors using in situ resources for all fissile materials
Nukes on the moon with ZERO radioactive risk to Earth's human population

Technical Description

- Gather thorium ($^{232}_{90}Th$) from regolith, transmute into fissile uranium ($^{233}_{92}U$), initiate nuclear fission reactor.
- Neutrons from fusion of non-radioactive deuterium ($^{2}_{1}H$): Payload has no radioactive materials.
- Provides abundant thermal power resources for baseload operation on the lunar surface.

Technical Advantages

- After the 1st solar-powered instantiation, Gen-2 lunar nuclear reactors become easy and quick.
- Together with ISRU hydrogen storage technology from Green Fortress Engineering, lunar operations can provide both nuclear fuel and reaction mass to nuclear thermal rockets (NTR), which enables fast transport to the platinum riches of the Main Belt asteroids.



Safety

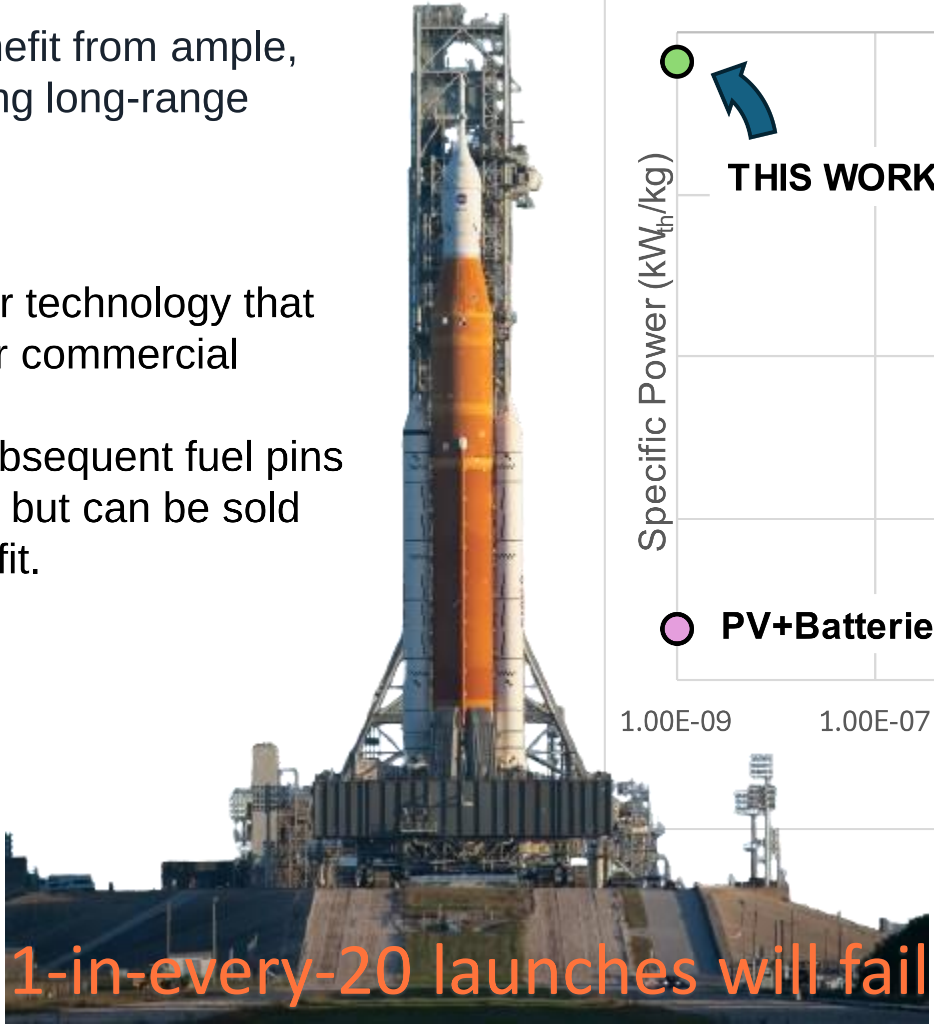
<u>**Anticipated Benefits and Applications**</u>

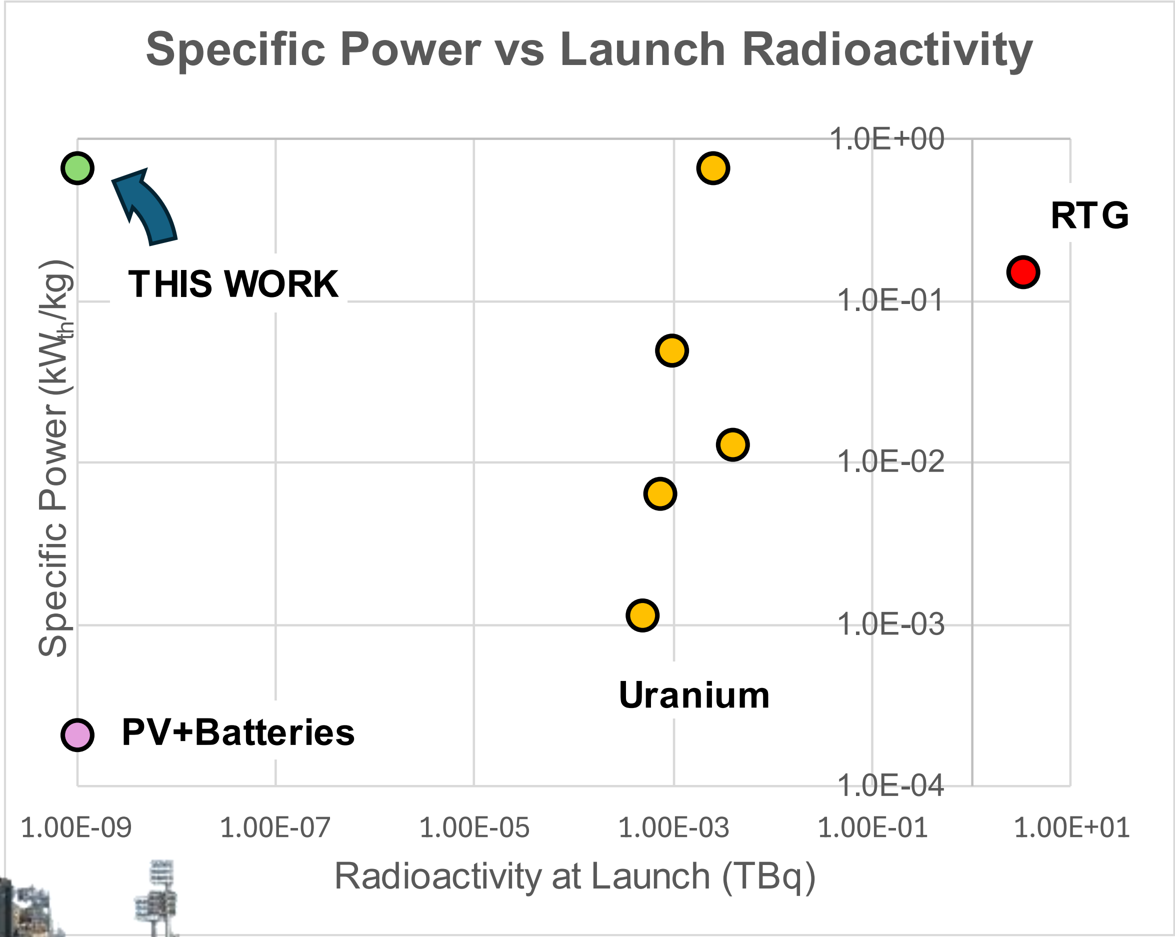
Gov't or DoD:

- ALL space missions benefit from ample, baseload power, including long-range power beaming.

Commercial:

- This is the ONLY nuclear technology that will ever be permitted for commercial operations.
- After the first reactor, subsequent fuel pins become cheap to make, but can be sold strategically for high profit.





The Colossus – 6 MWth

Business Model

- **Baseload electric power** for in situ resource utilization via the patents owned by Green Fortress Engineering
- Nuclear reactors will require special security, so sales are likely to be wired or wireless power, or stored energy in the form of solid-state hydrogen vessels.

Work to Date

- **Conceptual Development** – This technology is the culmination of a breakthrough starting 2019. Now includes a non-hazardous neutron source to enable all-ISRU nuclear fission fuel pins.

- **Proof of Concept** – Hydrocyclone separation by density in simulated lunar gravity. These successful results were published in the *Aeronautics and Aerospace Open Access Journal*, Schubert, et al, 18 May 2021.

Electrical up to 2 MWe

- **Plenty enough for buildings, districts**

Actual placement will be below-grade

Gather Thorium

Hydro-cyclone

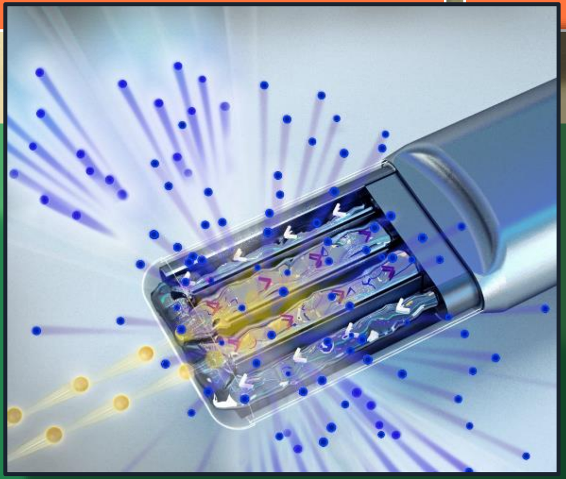
2MT rock yields 16 kg

Benchtop Neutrons

Freeze-separate heavy water, electro-lyze, fuse

Transmutate Th→U

Form pellets, place in SMR



Make-Your-Own

Fueling your own reactor with sand and water

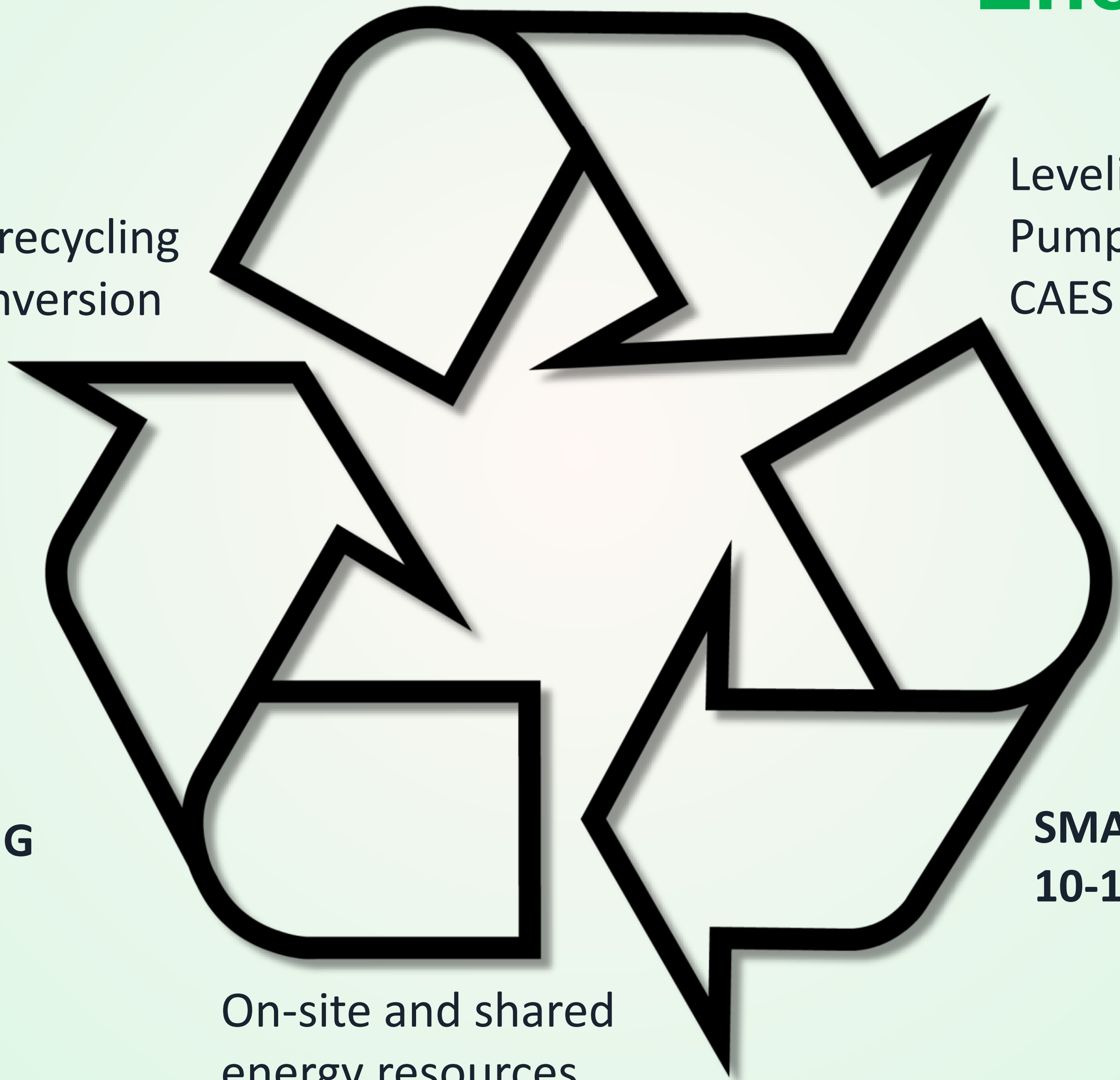
(plus some lye and a transformer)

Closing the Energy Loop

SOLAR, WIND, GEO
TIDAL, WAVE, BIOMASS

Levelize with batteries,
Pumped Storage Hydro,
CAES

Complement recycling
Design for conversion



SMALL MODULAR REACTORS
10-100 MW ELECTRICITY, HEAT

WASTE-TO-ENERGY
ENERGY HARVESTING

On-site and shared
energy resources

SUMMARY

- Thermochemical conversion of carbon-based waste can supply 10-15% of energy demand
- Small-scale nuclear possible with kitchen science technologies
- Energy storage to levelize for baseload power

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Thank you

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