Direct heating of chemical catalysts for hydrogen and fertilizer production using Microreactors

NEUP Project 21-24152 1

Prof. Hitesh Bindra | Purdue University

DOE-NE Microreactor Program Winter Review Meeting

Direct heating of chemical catalysts for hydrogen and fertilizer production using Microreactors- Update

Hitesh Bindra

Purdue University

TPOC: Piyush Sabharwall

March 9th, 2023

Direct heating of chemical catalysts for hydrogen and fertilizer production using Microreactors

- Team members

Hitesh Bindra (PI), Purdue University

Melanie Derby (Co-PI), KSU

Caleb Brooks (Co-PI), Illinois

Mark Ruth (Co-PI), NREL

- Students

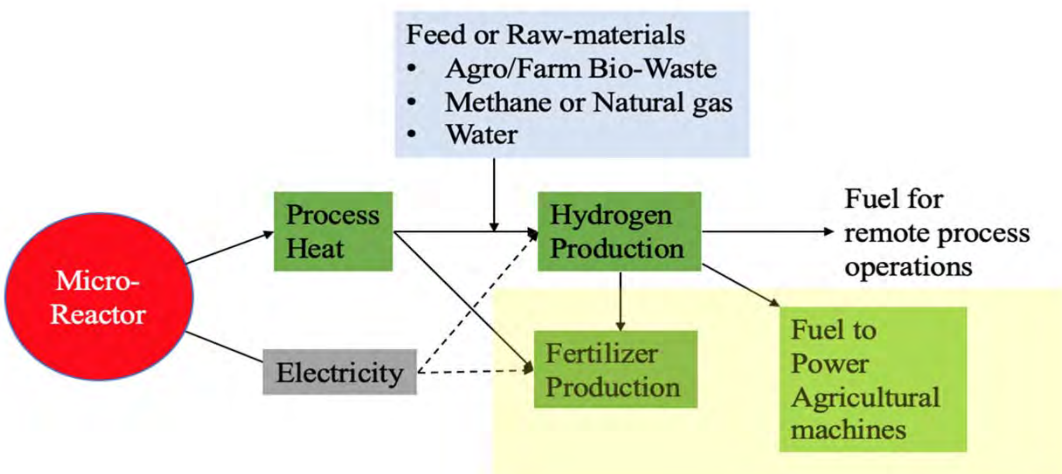
John Matulis(Graduate student, PU)

Broderick Sieh(Graduate student, PU)

Nathan Santhosh Chandra, Jake Marr (undergraduate students, PU)

Bailey Strine (Graduate student, KSU)

Anshuman Chaube (Graduate student, Illinois)

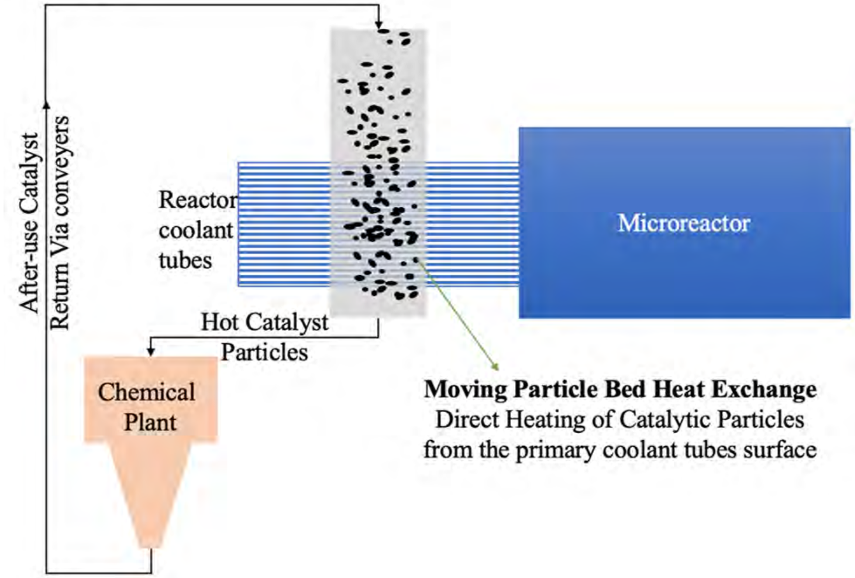


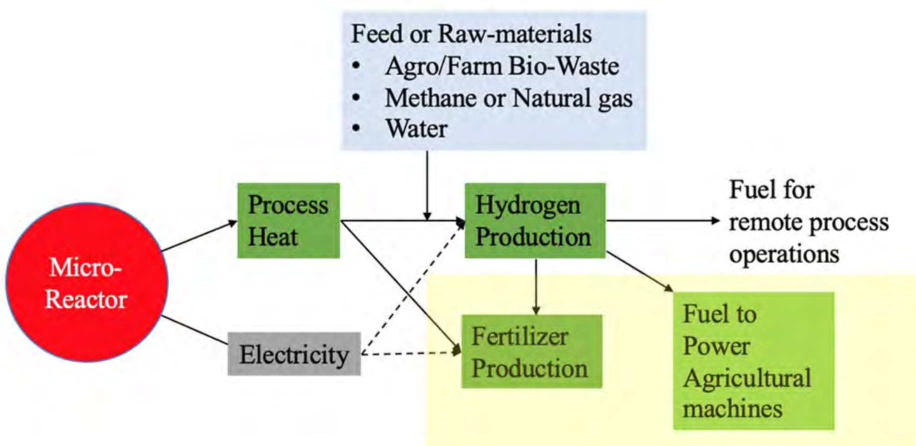
Start Date: Oct. 2021

Direct heating of chemical catalysts for hydrogen and fertilizer production using Microreactors

Project Objectives

1) Design MPBHX and compare other IHX alternatives for microreactor integration.
2) Exergy and techno-economic feasibility of microreactor integration for hydrogen production and ammonia/fertilizer production.
3) Investigate feasibility of microreactors for achieving sustainable agriculture.





- Moving ceramic particles have high volumetric heat density.
- Store heat for later use.
- Catalyst carriers to sustain thermochemical reactions

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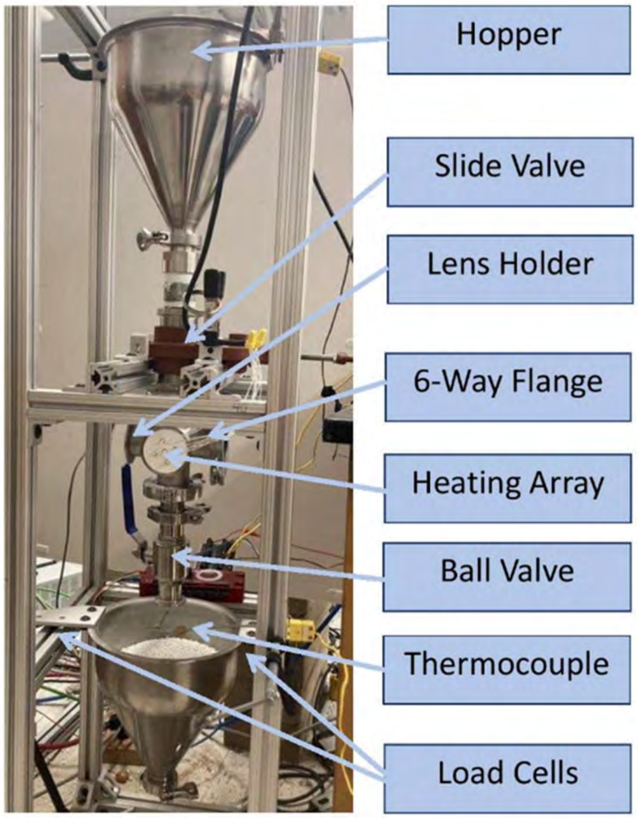
MPBHX concept design with calculations

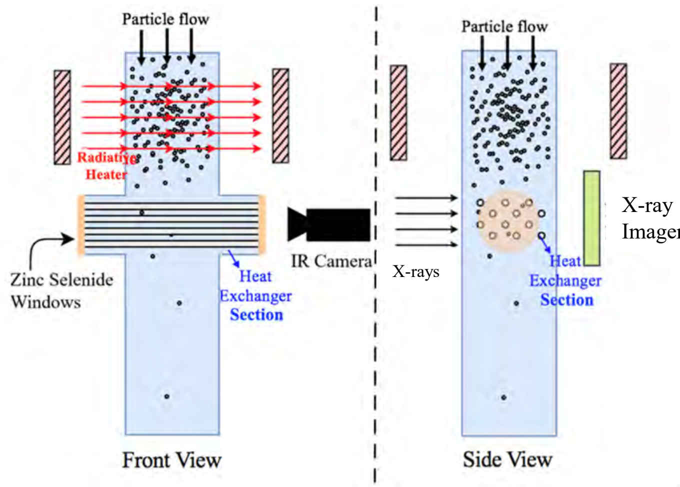
- Performed validation experiments with packed bed heat exchangers to obtain model for the MPBHX design.

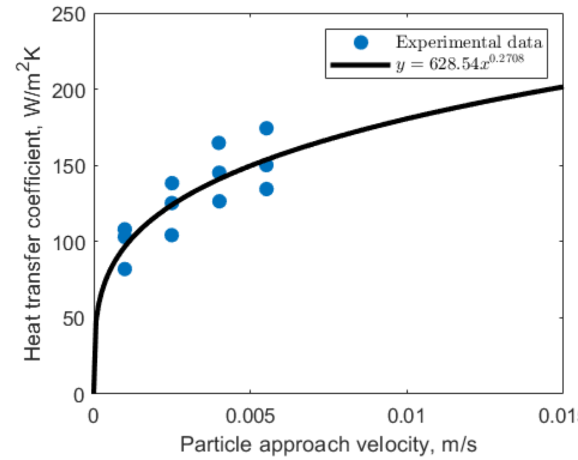
- Design advantages of MPBHX as a function of exergy analysis completed.

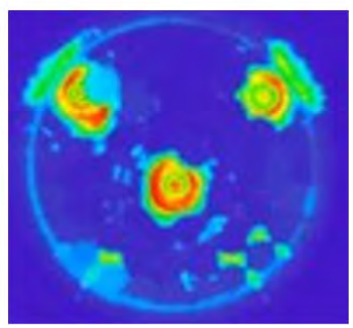
- Evaluated and compared different microreactor IHX integration strategies

Moving Packed Bed Heat Exchanger (Design and Evaluation)

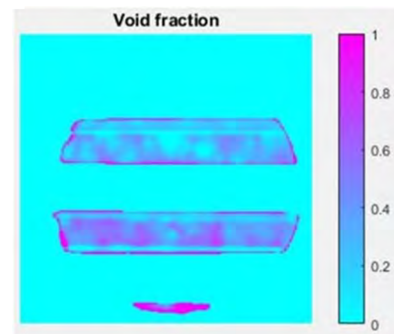








Infra-Red image showing azimuthal Asymmetry in heat transfer wake zone of granular flow



X-ray images showing higher Void in the wake zone below the Heater tubes

1 mm alumina particles

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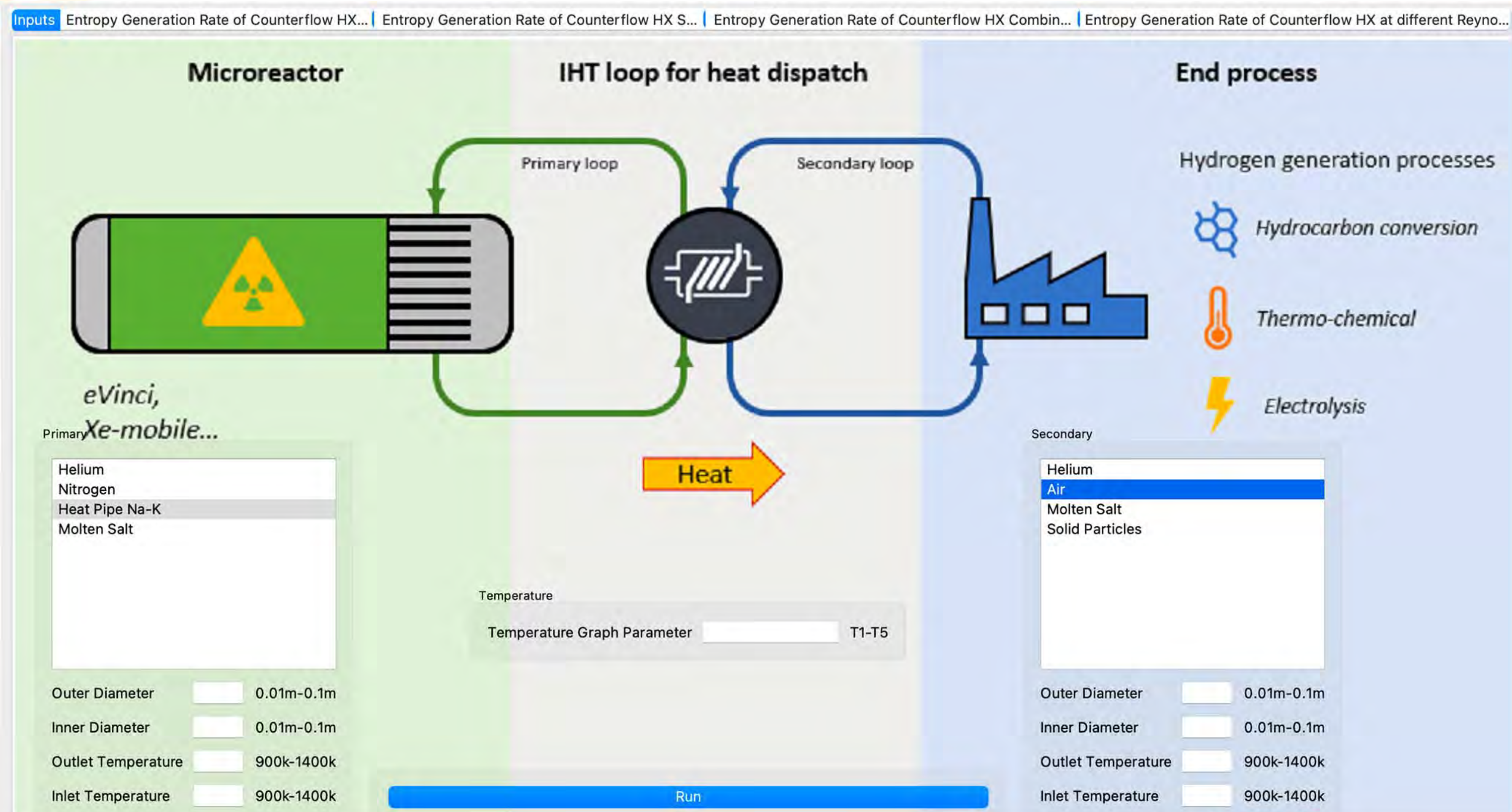
[A] K. J. ALBRECHT and C. K. HO,
Journal of Solar Energy Engineering,141, 3, 031006 (2019).

Exergy based integration assessment tool- Developed



[B] H. BINDRA, P. BUENO, and J. F. MORRIS, Applied thermal engineering, 64, 1-2, 201–208 (2014).
[C] A. BEJAN, G. TSATSARONIS, and M. J. MORAN, Thermal design and optimization, John Wiley & Sons (1995).

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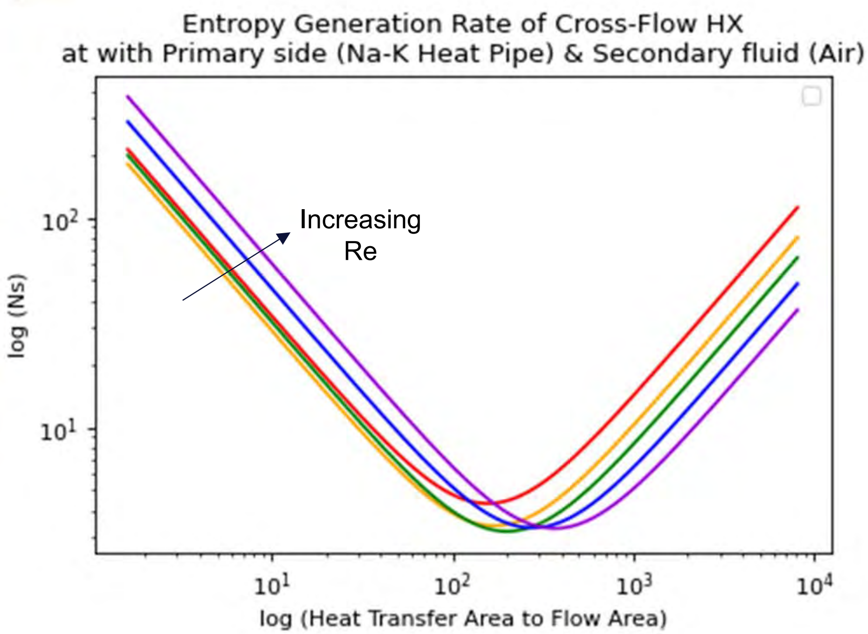
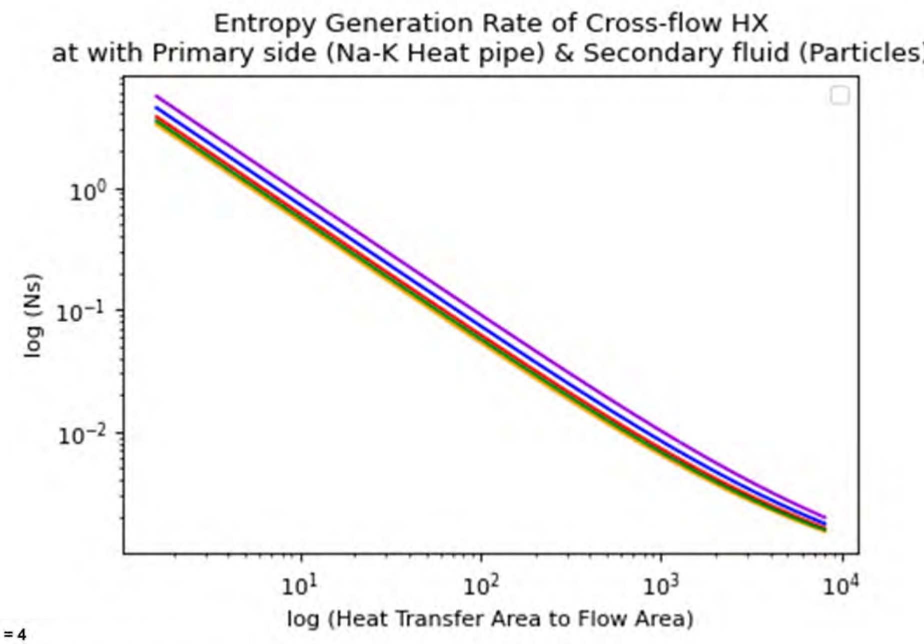
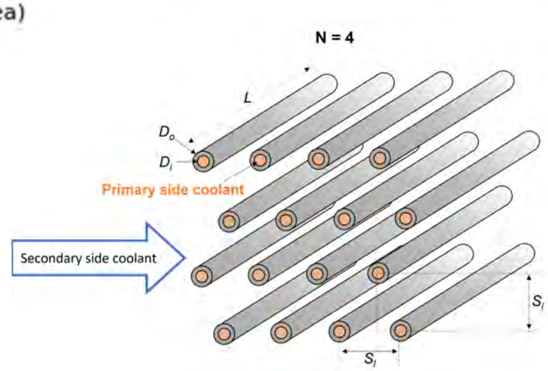
Entropy generation number- Assessment parameter







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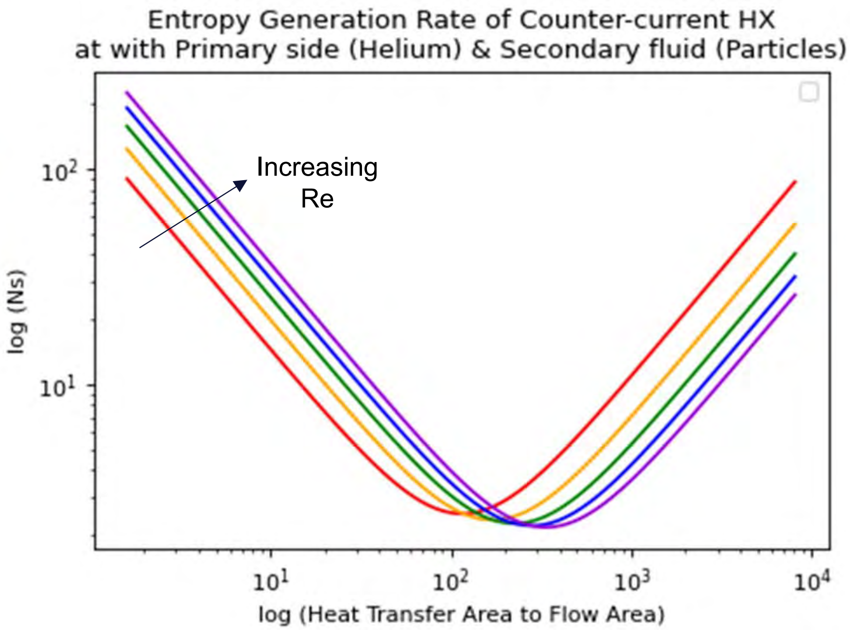

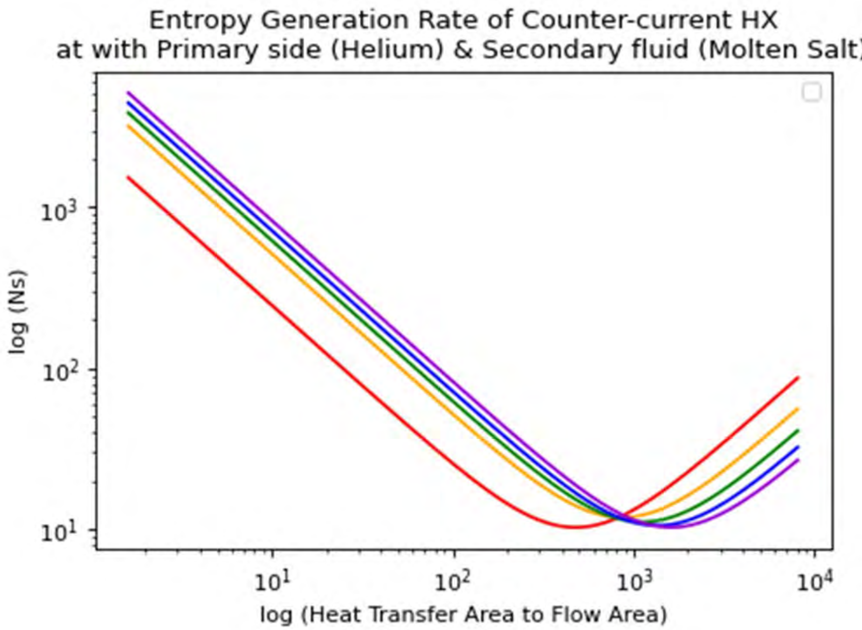

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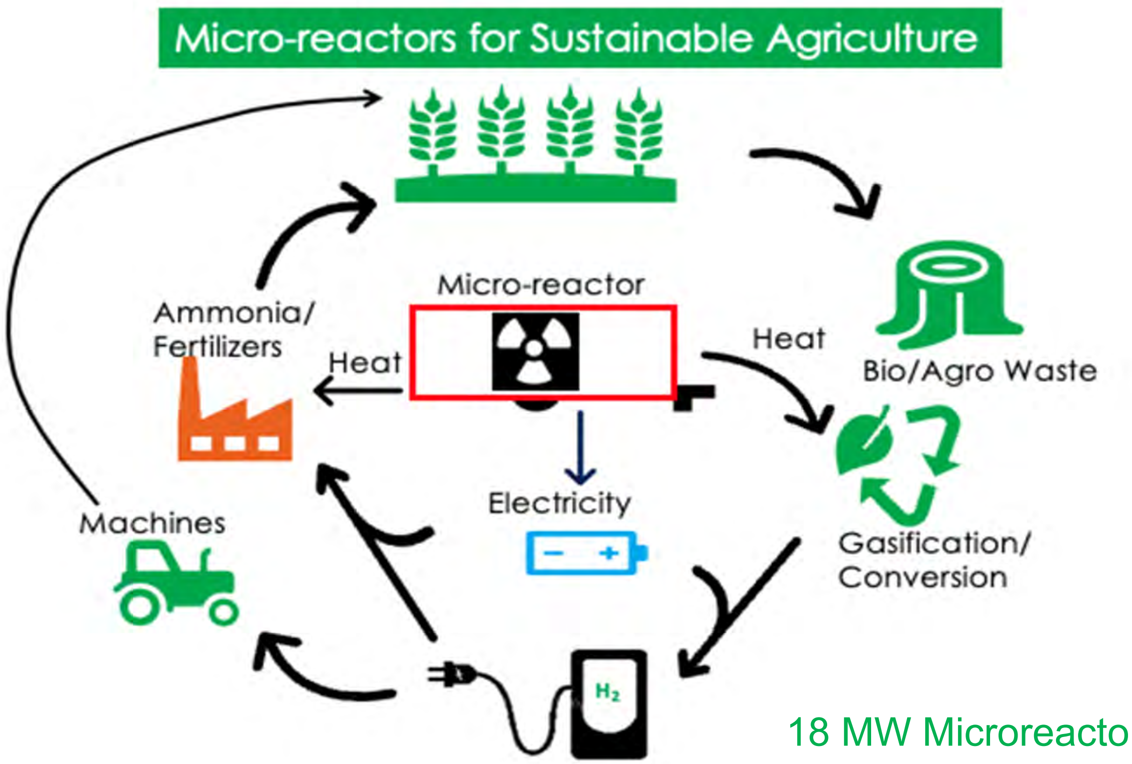
Carbon Neutron Corn farm (30,000 acre farm)



18 MW Microreactor

Produces

1 acre – 170 Bushel (Corn)

1.5 Ton (Residue Corn Stover)

180 kg H_2 gas (Gasification yield)

Needs

1 acre – 150 lbs (Ammonia) ~ 30 kg H_2

48 kWh to produce 1 kg H_2

4320 kWh Total energy

[D] David, W. I. F. "Ammonia: zero-carbon fertiliser, fuel and energy store." Policy Briefing, The Royal Society (2020).
[E] Carpenter, Daniel L., et al. Industrial & Engineering Chemistry Research 49.4 (2010): 1859-1871.
[F] Technologies for hydrogen production

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