GTI ENERGY

solutions that transform

Electric Reforming of Natural Gas and Other Advanced Process Technologies

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Who we are

GTI Energy is a technology development and training organization, with a trusted team of scientists, engineers, and partners, delivering impactful innovations — from concept to market — for low-emission, low-cost, and resilient energy systems.

Enterprise Employees

500+

TOP WORK PLACES 2019 · 2020 · 2021 · 2022 · 2023 · 2024 — Chicago Tribune

Partners in Active Collaborations

175+

80+ years of experience and leadership in energy production, storage, delivery and use

Research & Development

$1B+

In the past decade

Leading and convening collaborative R&D

Innovation & Commercialization

1,300+ Patents

500 Products

750+ Licensing Agreements

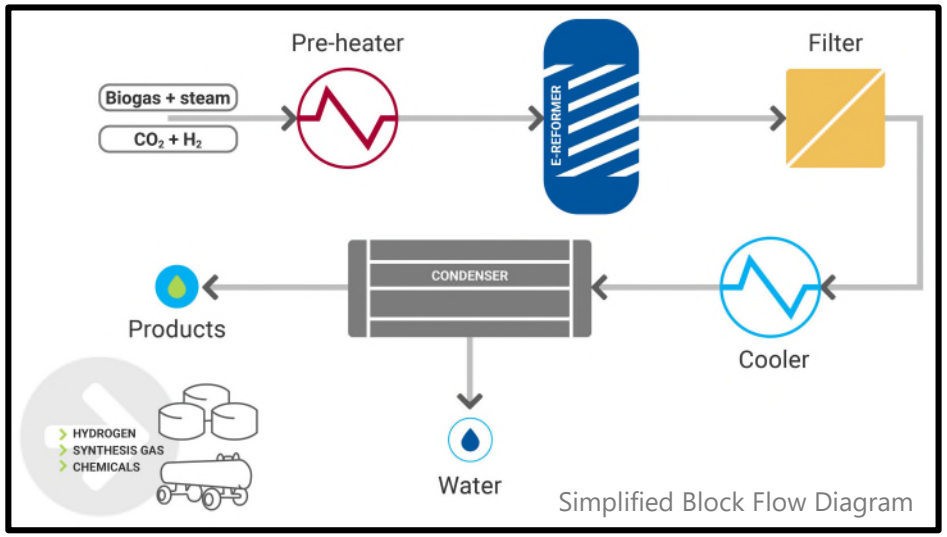
10+ Industry Collaboratives

OTD Operations Technology Development · UTD Utilization Technology Development · GTI Energy Emerging Technology Program (ETP) · LCRI Low-Carbon Resources Initiative · GTI Energy SUSTAIN H_2 · VERITAS GTI Energy's Methane Emissions Measurement + Verification Initiative · carbon [CMIC] management information center powered by GTI Energy · Open Hydrogen Initiative GTI Energy S&P Global Commodity Insights · center for METHANE RESEARCH · GTI Energy HyRes Hydrogen Emissions Research Consortium · GTI Energy RAISE Reliable Affordable Infrastructure for Secure Energy

GTI E-Reformer Technology

Description

- Electric reformer utilizes electric heat to complete reactions (currently evaluating resistive and inductive heating)
- Three reactions occur simultaneously: steam methane reforming, dry reforming, and reverse water gas shift (RWGS)
- Feed gas: Biogas (can be CO_2 rich) + steam, methane + steam, or CO_2 + H_2
- Proprietary catalyst can handle heavier hydrocarbons, CO_2, and CO
- No pre-reformer used as with conventional fired SMR
- E-Reformer technology has many applications:
  - Standalone H_2 generator
  - First stage for liquid fuels production
  - Chemical production (methanol, ethylene, propylene, etc)

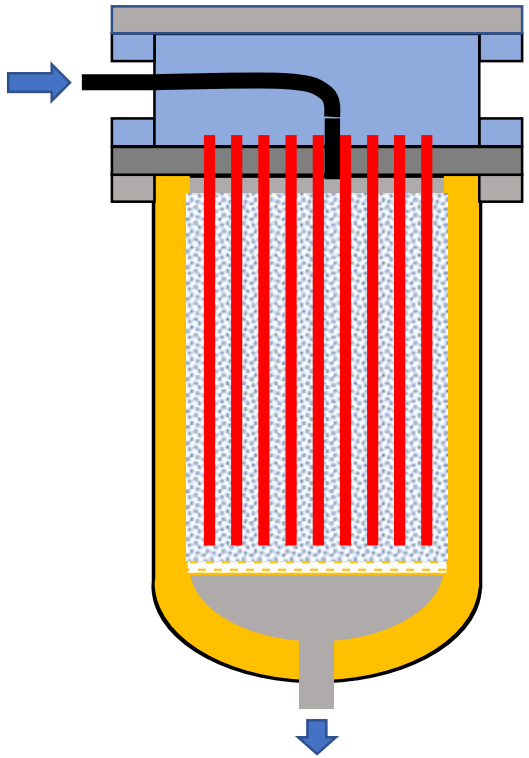


Simplified Block Flow Diagram

Value Proposition

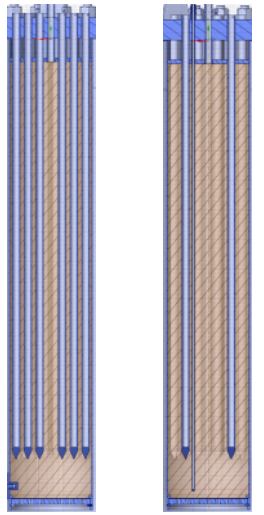
- **Modular** design
- **Smaller footprint, cheaper,** and more **efficient** than current fired reactors
- **40% CAPEX savings** as compared to fired SMR by carrying out conversion of bio-based, CO_2 containing gases, and recycle streams in one step
- **Higher product yields** from the elimination of feed gas combustion
- **Lower CO_2 emissions** due to elimination of furnace for heat

E-Reformer Conceptual to Actual Design

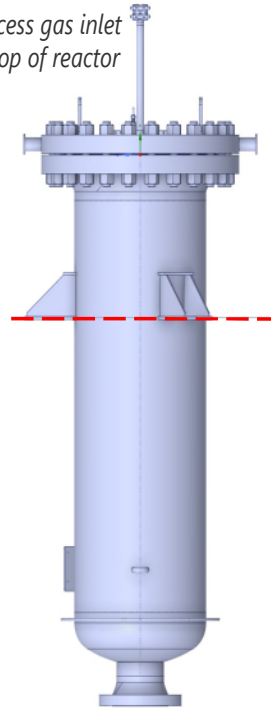


Vessel and Heating Element Cross Sections

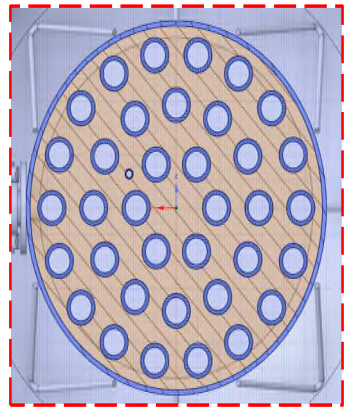
Heating elements installed within sheaths penetrating catalyst bed



Process gas inlet at top of reactor



36 elements arranged in a concentric pattern



Significant Scale-up from Bench Scale to Successful Pilot E-Reformer Test

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3 kW Resistive E-Reformer

160 kW Resistive E-Reformer

GTI Proprietary Catalyst

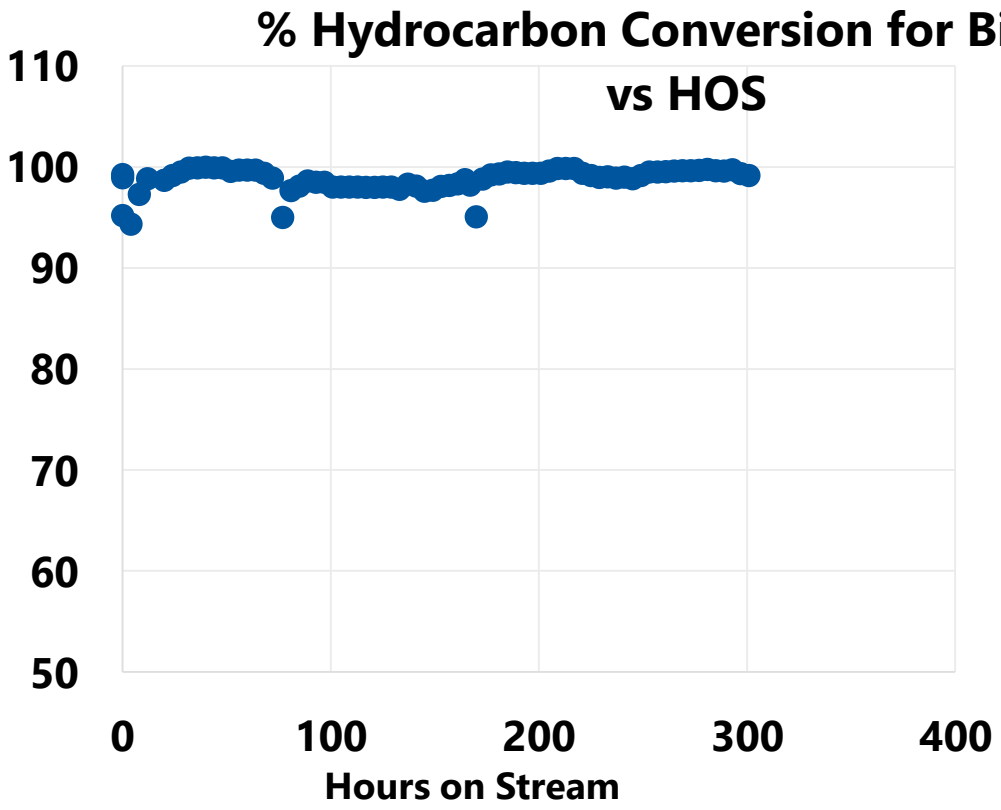
Standard Nickel Based Catalyst

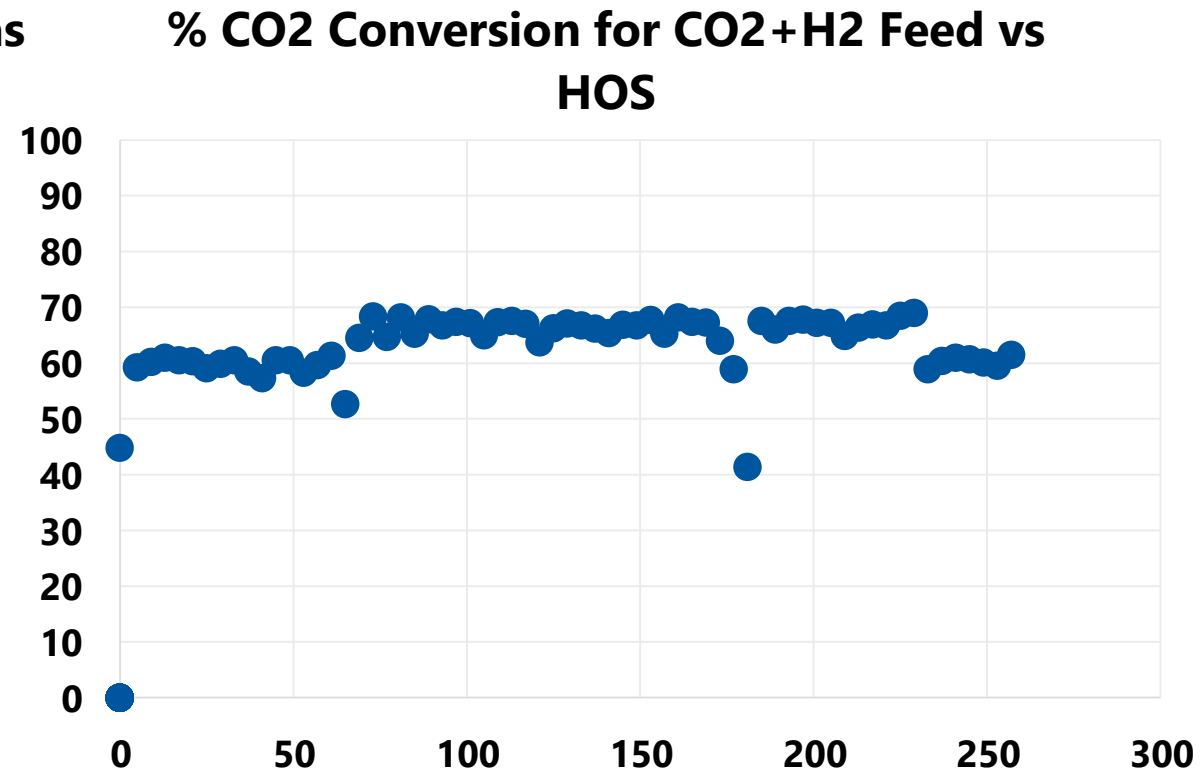
- May require CO and CO_2 removal from feeds to prevent coking
- Requires high steam to Carbon ratio to avoid coking

GTI Proprietary Catalyst

- Converts CO and CO_2 – does bireforming
- Requires lower steam to carbon ratio to prevent coking
- More active – can run at higher space velocity
- More flexible active stable catalyst which can convert CO_2
- New catalyst but manufactured using standard technique by multiple Catalyst Toll Manufacturers

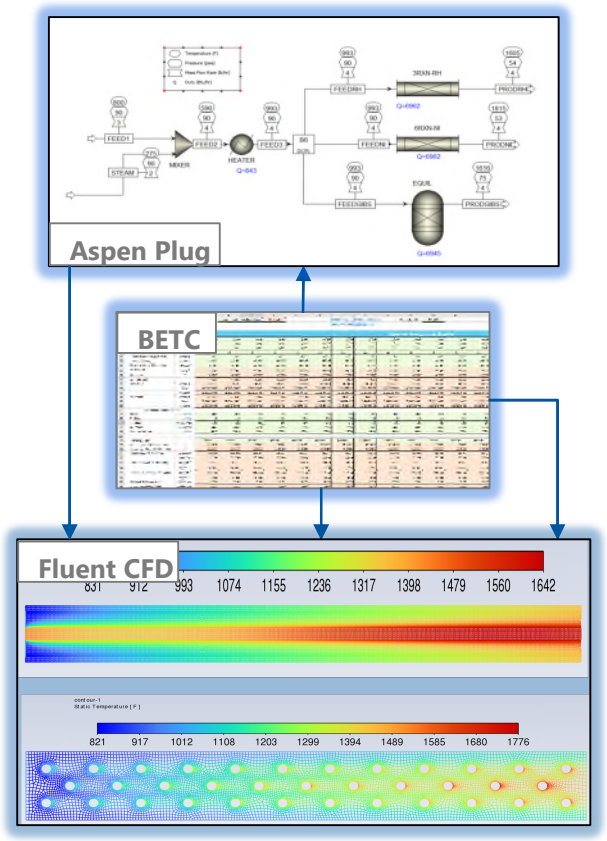
Successful Large-Scale Testing Completed

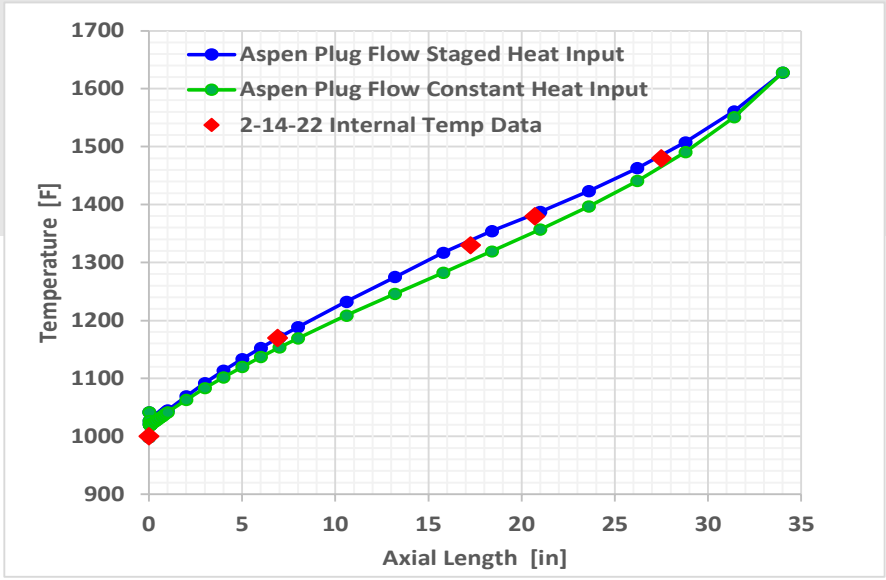


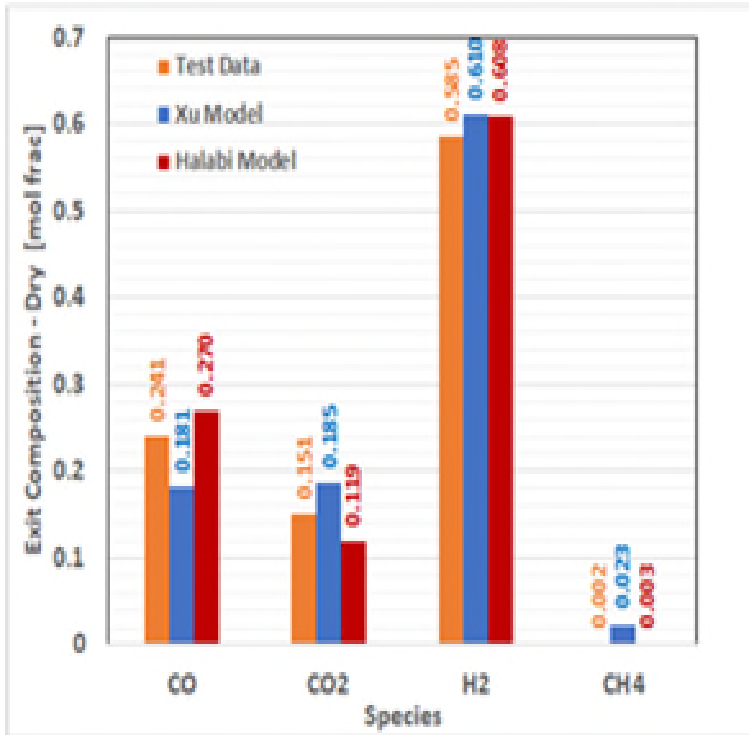


Modeling Reactor Performance

- Particle bed model, AspenPlus plug flow model, and CFD models developed
- Reforming catalytic kinetics included
- Use CFD results to determine spacing of heating elements and size of reactor
- Anchored to lab scale test data







Models anchored for resistive heating, predicting pilot performance well.

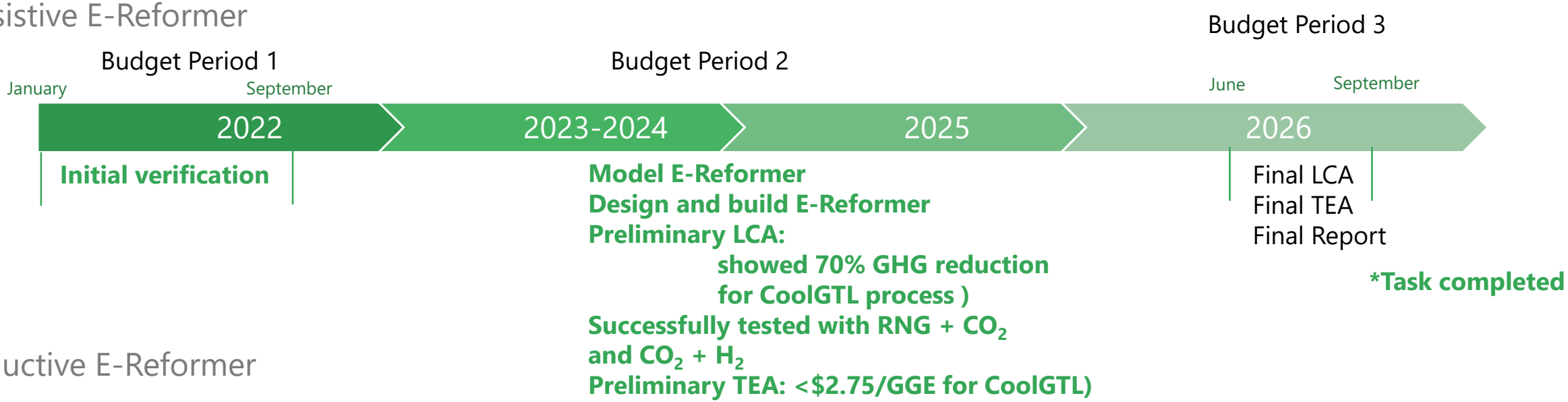
Assessing Scalability of Inductive vs. Resistive Heating

Inductive E-Reformer Development

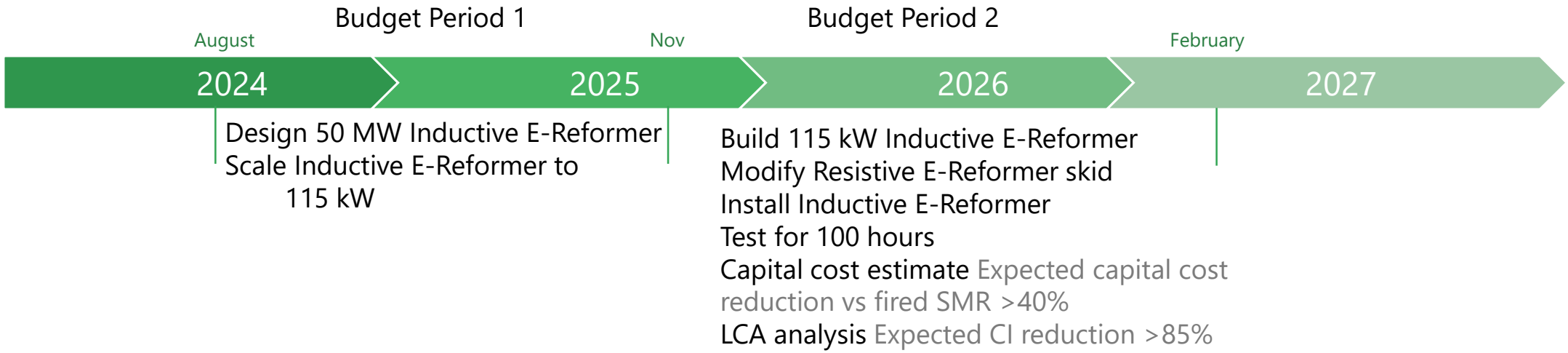
- 1st application in which inductive heaters are used inside a catalytic reactor at 115 kW scale
- Line frequency operation eliminates need for transformers and reduces size of electrical distribution equipment and the number of electrical connections making it economically attractive
- 1st application in which inductive heaters will be transferring heat from the tube internally and externally, removing the need for a pre-heater to heat the feed gas

DOE Project Status

Resistive E-Reformer



Inductive E-Reformer



Additional E-Reactor Testing for Chemicals Production

- Propane to Propylene – Propane dehydrogenation
  - $C_3H_8 \rightarrow C_3H_6 + H_2$
  - Endothermic
  - Catalyst identified
  - Initial small-scale testing promising
- Ethane to Ethylene – Catalytic Ethane dehydrogenation
  - Testing planned
- Other endothermic catalytic reactions for future testing
  - Ammonia decomposition
  - Ethanol to acetaldehyde

Conversion of Challenging Solid Feedstocks to Syngas

WOLVERINE TWIN-SCREW PYROLYSIS AUGER

Wolverine – Waste/MSW/Biomass Conversion

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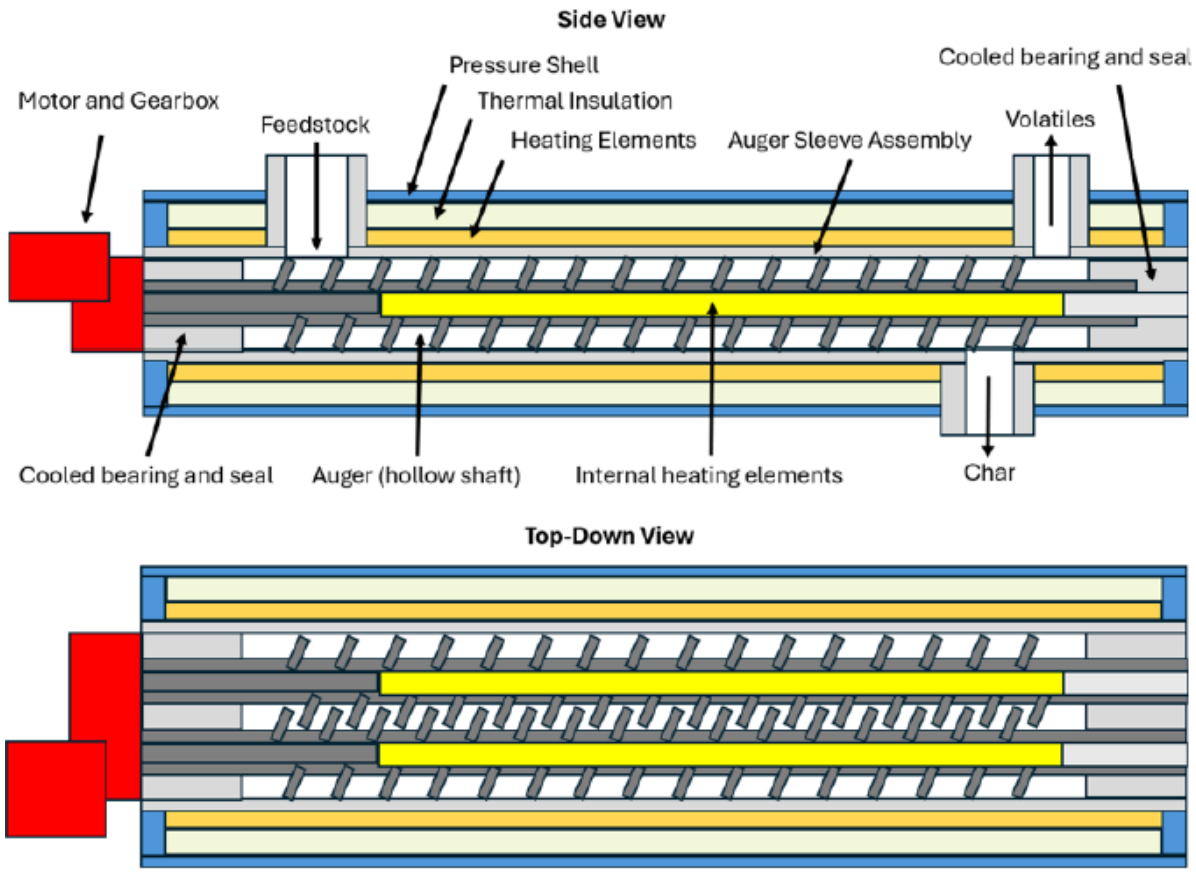
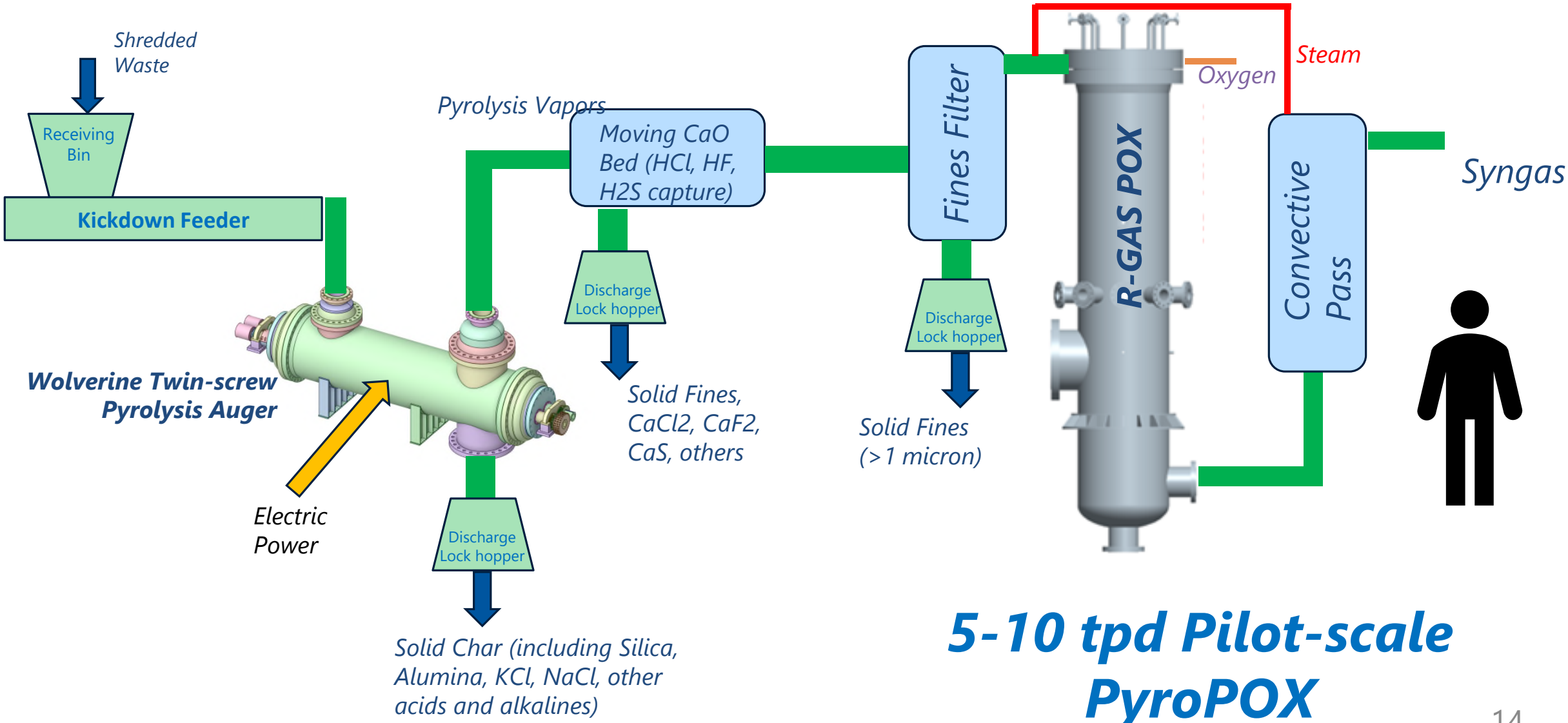
Wolverine Twin-screw Pyrolysis Auger



- **Syngas production from a wide range of possible feedstocks** MSW, tire waste, industrial intermediates, biomass, agricultural wastes, etc.
- **High-Pressure Operation – 20-40 barg** The external pressure shell of the Wolverine operates at near-ambient temperature and is insulated from the high-temperature auger components in the interior
- **Specifically designed to handle challenging solid feedstocks with minimal pre-processing** Electrical heat is supplied to the feedstock both through the exterior wall of the auger AND through internal heating inside the auger shaft – 500-600 ºC
- **Current TRL 3-4** Extensive and detailed thermomechanical design work has been completed - Sizeable R&D funding awarded through ITO office of USDOE (currently still in contracting) – will demonstrate operation at ~5TPD scale using real MSW feedstock (DE-FOA-0003219)
- **Stream of hot volatile gases species (pyrolysis vapors) contains no ash and minimizes acid gas species** Problematic species are largely locked in the char stream and leave the process for safe and appropriate disposal

Wolverine Integration – MSW - with POX Stage



5-10 tpd Pilot-scale PyroPOX

Highly Energy-Efficient and Precise Nanofiltration in Harsh Industrial Conditions

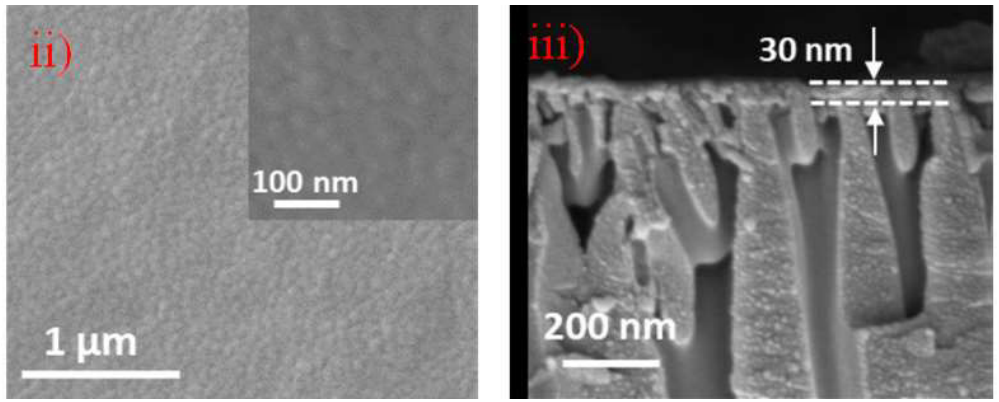
CARBON-DOPED TITANIUM OXIDE (CDTO) MEMBRANES

Breakthrough development of CDTO membranes

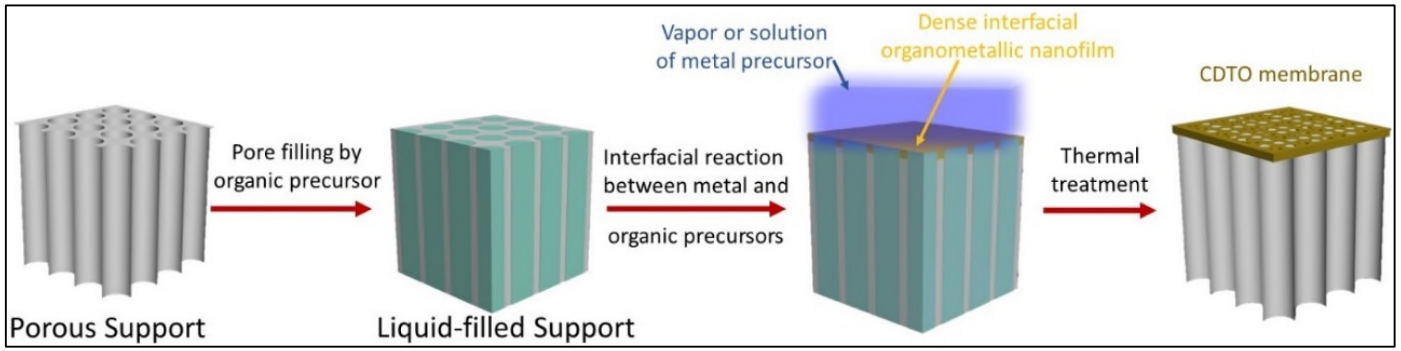
Science

MEMBRANES

Carbon-doped metal oxide interfacial nanofilms for ultrafast and precise separation of molecules



Facile and scalable interfacial process for membrane fabrication



Features/advantages

- Excellent stability and reusability
- Significant energy saving by eliminating phase change for solvent recovery
- Modular layout for the reduction in footprint and simple materials of construction

Application: separation of closely-sized molecules in industrial conditions to decrease energy consumption

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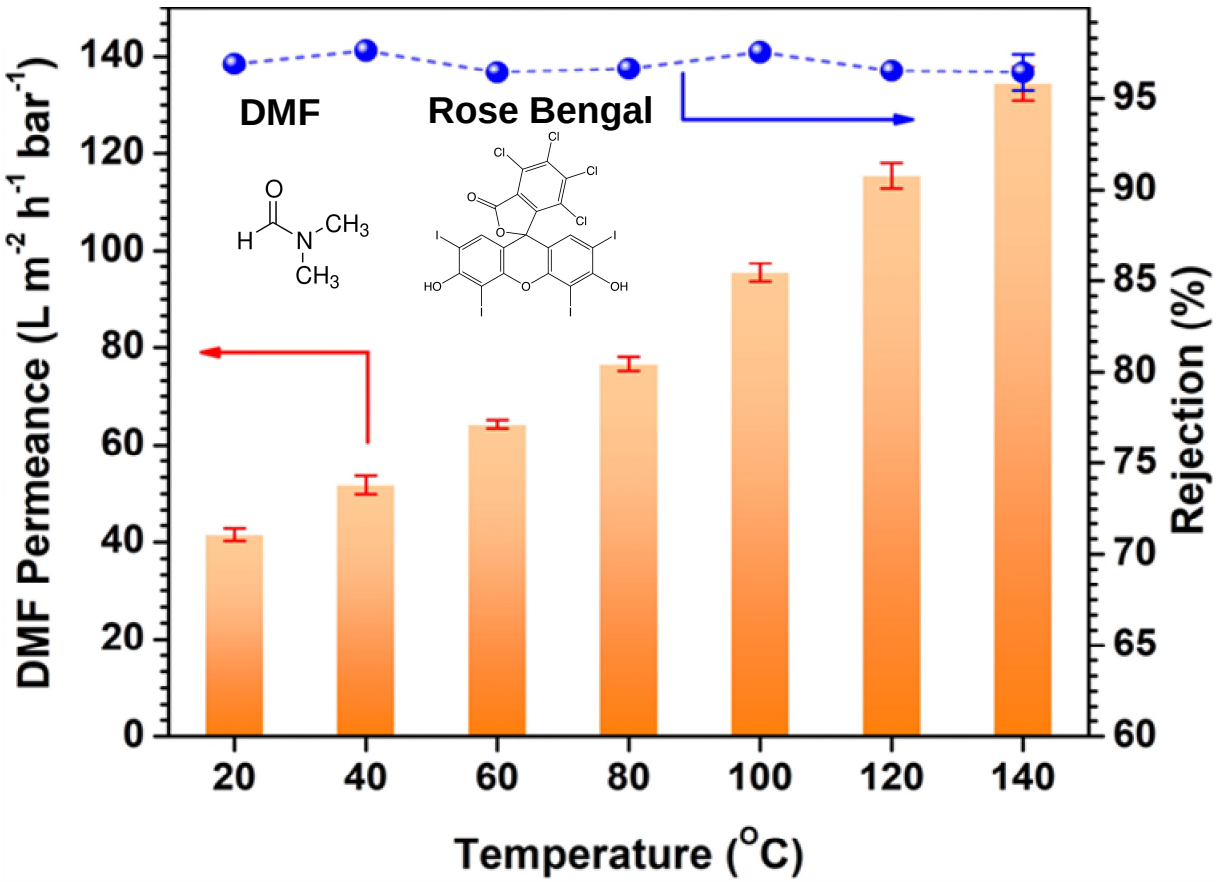
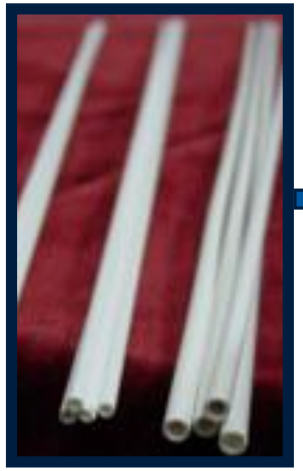
- **Example: dimethylformamide (DMF) / Rose Bengal**

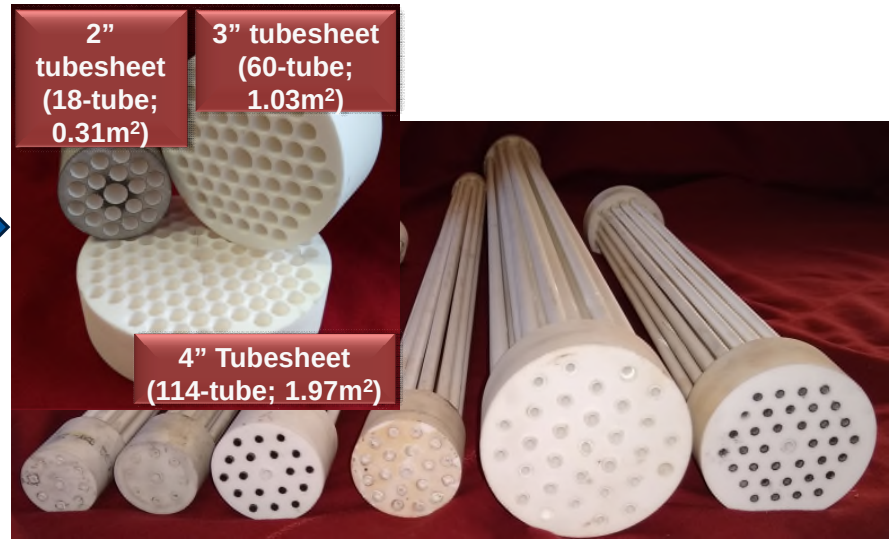


- **Wide application across many industries**
  - **Food industry**: production of vegetable oils
  - **Pharmaceutical industry:** solute separation and solvent recovery
  - **Chemical companies**: separation and cleaning, and recycling of organic solvents
  - **Gas and oil companies**: crude oil separations
- **Partnering with Media and Process Technology Inc. to scale up the CDTO membranes**

Fabricate membrane tubes



Pot membrane tubes to form membrane bundles



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solutions that transform

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GTI Energy develops innovative solutions that transform lives, economies, and the environment

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