RAPID Manufacturing Institute

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Our Mandate

- Research, develop and demonstrate high-impact modular chemical process intensification solutions for U.S. Manufacturing.
- Actively build RAPID membership.
- Leverage $70 million of DOE funding with member cost share.
- Benefit a wide range of stakeholders.
- Enable access to process intensification resources, tools, expertise & facilities.
- Establish a technical education and workforce development program.

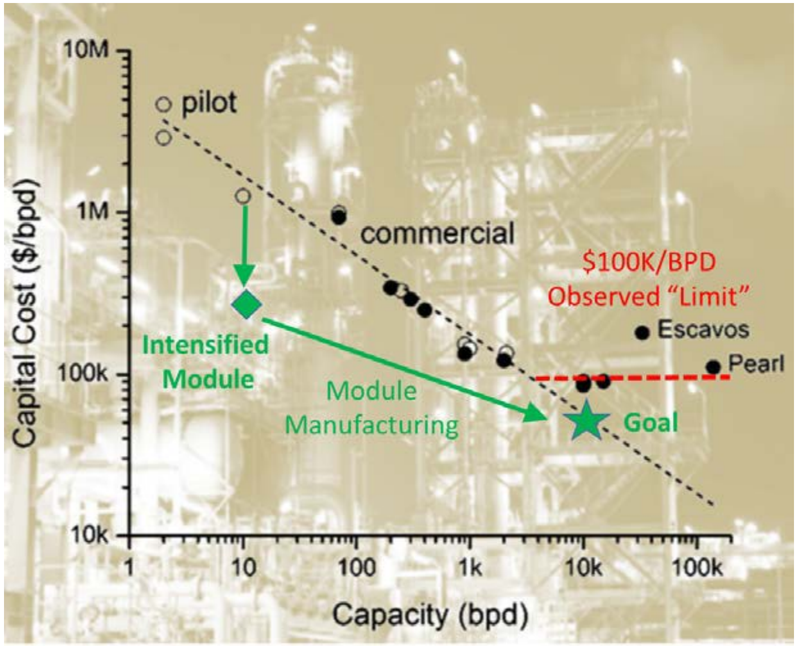
Modular Chemical Process Intensification (MCPI)

1. Combine separate unit operations (such as reaction and separation) into a single piece of equipment. Process performance is optimized via improved molecular level kinetics, thermodynamics, and heat and mass transfer.

2. Modularity of intensified unit process technologies can be scaled through the production of identical modules, rather than a capital-intensive approach that scales up individual unit processes to larger size units

Example of 2/3 scaling law for the capital cost of traditional gas-to-liquids production.

MCPI + mass production of modules can overcome the observed $100K/BPD limit.



MCPI Challenges

Barriers to Adoption:

- High capital costs and risk involved in committing to new processes
- High complexity of an intensified, modular system, without simplifying standardization techniques
- Lack of software and design tools to develop intensified processes
- Minimal workforce knowledgeable in the design and operation of systems

Technical Challenges:

- Modeling, simulation, optimization and control for existing PI processes
- Materials and chemistry intensification for existing processes
- Low-energy separations for existing processes
- Module manufacturing for PI applications
- Modular decentralized scale-out processes

RAPID Technical Focus Areas

Chemical & Commodity Processing

- Develop guidelines for integration of novel reaction and separation modules
- Validate design tools for process intensification

Renewable Bioproducts

- Prototype and scale novel bio-conversion processes
- Improve energy & capital efficiency of existing and emerging processes

Natural Gas Upgrading

- Maximize impact through transfer of technologies and learnings across industries
- Mature and demonstrate transformational and enabling technologies for gas utilization

RAPID Technical Focus Areas

Modeling & Simulation

- Develop methods & tools for design, optimization, and intensification across multiple length and time scales
- Establish methods for intensification of dynamic/ periodic operations

Intensified Process Fundamentals

- Advance inherently energy efficient separation processes & reaction platforms
- Develop fundamentals for multifunctional modules such as hybrid separation/reaction schemes

Module Manufacturing

- Standardize modules and components to drive demand and capital investment within the supply chain
- Lower the cost of PI equipment using advanced manufacturing technology

Initial Partners

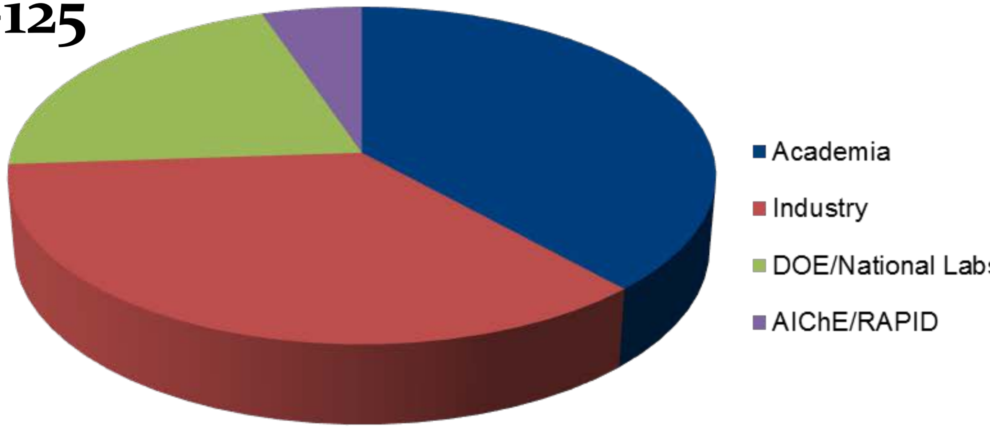
Institute Deployment

DOE selection announced	Dec 9, 2016
Signed Cooperative Agreement	March 24, 2017
CTO hired / staff in place	late March
Roadmapping	May – August
Governing Board	F2F meeting: June
Jump Start projects	Launch in June
Budget Period 1	Through Sept 30

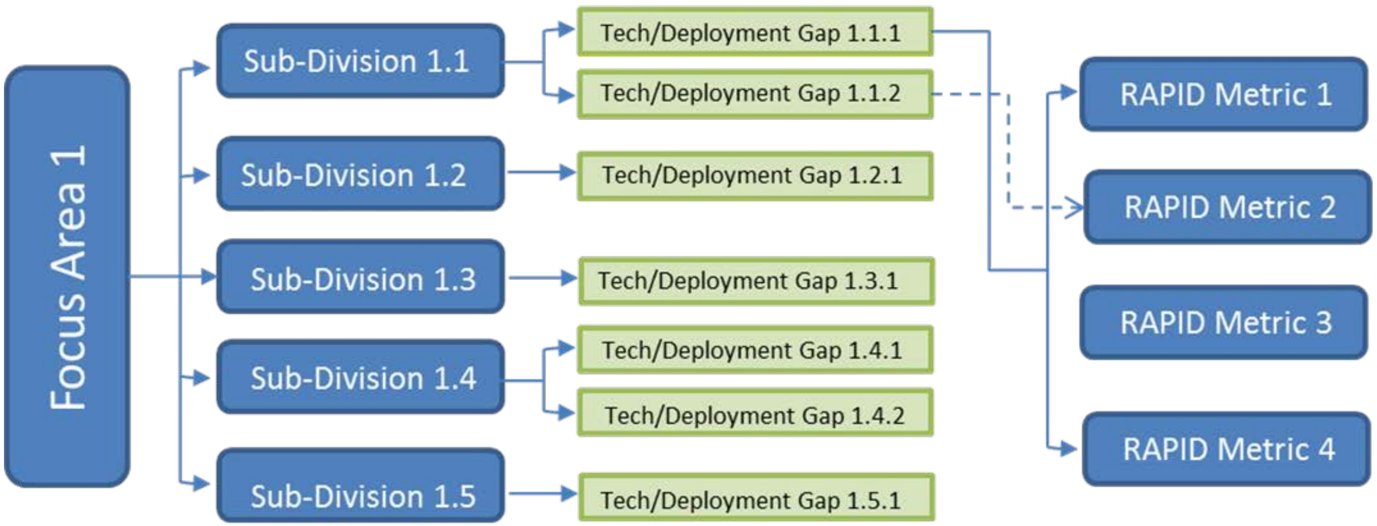
Roadmapping

Roadmapping participants ~125

- 28 companies
- 28 universities
- 12 Federal departments/labs



Roadmapping Process



Measure of Success: Roadmap Targets

- Demonstrate MCPI with >20% energy efficiency
- Develop tools to reduce the cost of deploying MCPI in existing processes by 50%
- Demonstrate 2x energy productivity by a combination of capital and operating cost related to improved feedstock and fuel efficiencies.
- Scale-out module manufacturing that reduce >20% cost/unit, with each doubling in module manufacturing production
- 10x reduced capacity cost, 20% improvement in energy efficiency and 20% lower waste relative to commercial state-of-the-art
- Establish comprehensive Body of Knowledge for MCPI

MCPI = Modular Chemical Process Intensification

Jump Start #1: Chemical and Commodity Processing

Dynamic intensification of the operation of dividing wall columns

Technology Challenge

- Classic paradigm for chemical process control is built on steady state operation - recent theoretical work suggest significant energy savings by considering dynamically controlled process (non-steady state)

Project Outcomes

- Develop theoretical basis for periodic operation of intensified processes & screening criteria to identify candidate technologies
- Experimental proof of concept using dividing wall column (DWC) pilot plant available at UT

Jump Start #2: Natural Gas Upgrading

Adsorptive Nitrogen Rejection from Natural Gas

Technology Challenge

- Nitrogen has been used as an alternative to water in fracturing in unconventional gas – lack of modular gas separation technology leads to >10,000GJ of energy lost to flaring per well

Project Outcomes

- Field demonstration of portable, modular PSA system enabled by breakthrough rate selective adsorbent

Jump Start #3: Renewable Bioproducts

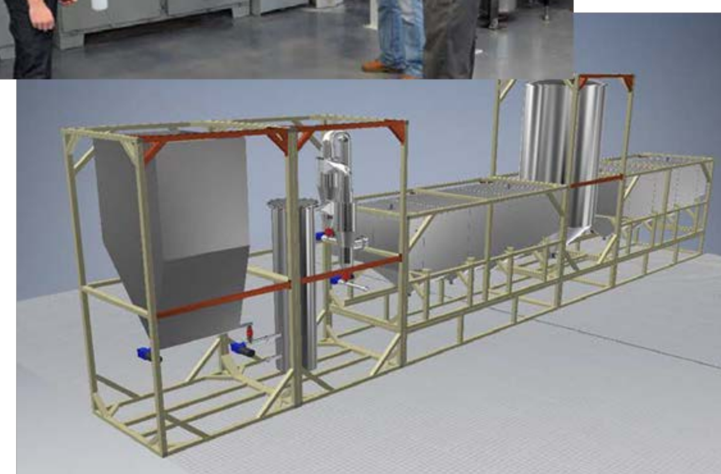
Autothermal pyrolysis of lignocellulose wastes to sugars and other biobased products

Technology Challenge

- Existing technology for conversion of biomass to sugars is carried out at low temperature and long residence time – no ability to use modular technology to address supply chain cost

Project Outcomes

- Demonstrate PI benefits of autothermal pyrolysis to enable modular applications
- Establish Product/co-product yields at pilot scale to feed techno-economic analysis
- Design details provided for commercial scale modular conversion system



Jump Start #4: Modular Manufacturing

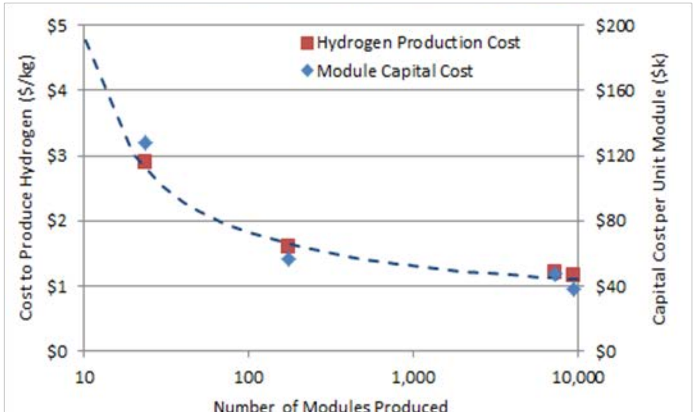
Mfg Supply Chain Development for the Modular Solar-Thermochemical Conversion Platform

Technology Challenge

- Near-term cost savings needed for modularizing and scaling out process chemistries cannot be captured using classical, large-scale methods of manufacturing

Project Outcomes

- Develop novel additive manufacturing techniques and materials that enable modular designs
- Redesign prototype micro- and meso-channel processing technology components to be manufactured using these techniques



Estimated capital and product costs for individual STARS modules as a function of module mass production.

Project Management and Budget

Institute Funding:

Total Project Budget	
DOE Investment	$70 million
Cost Share	>$70 million
Project Total	>$140 million