



Rapid Advancement in Process Intensification Deployment (RAPID) – Overview

AMMTO & IEDO JOINT PEER REVIEW

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Washington, D.C

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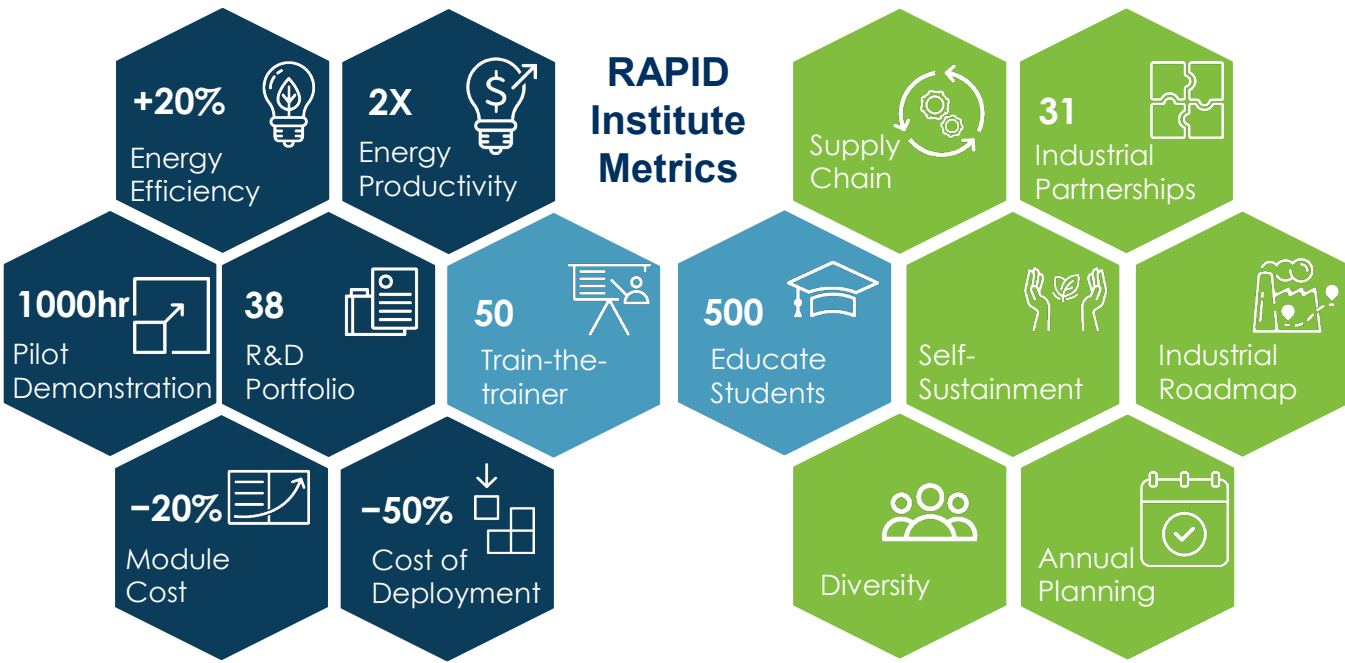
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BP1-5

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Mission

Build a self-sustaining member consortium that convenes public and private organizations to research, develop, and deploy process intensification (PI) and modular process technologies to enable more resilient, lower cost, and reduced energy footprint manufacturing in the process industries.

Barriers



Impact

<p><u>Energy, Emissions, & Environment:</u> Several technologies at >20% energy efficiency & >2X energy productivity</p>	<p><u>Cost & Competitiveness:</u> Several technologies at <20% module cost & <50% deployment cost</p>
<p><u>Technical & Scientific:</u> 247 peer reviewed publications 31 inventions (patents, applications, and disclosures)</p>	<p><u>Other Impacts:</u> 75+ members 3,650 individuals trained 11 eLearning courses to-date</p>

Project Outline

Innovation: A collaborative technology ecosystem (development, scale-up, education) to enable the transformation of the process industries for a decarbonized, energy and capital efficient future

Project Lead: RAPID Manufacturing Institute (dba of American Institute of Chemical Engineers)

Project Partners: 75+ institutions (56% industrial, 31% academic, 13% other R&D)



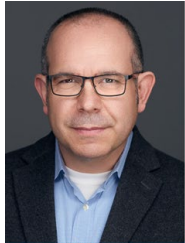
Timeline: January 2017-June 2023 (NCE), 99% complete – Submitted for 5 year renewal (2023)

Budget:

	FY21 Costs	FY22 Costs	FY23 Costs	Total Planned Funding
DOE Funded	\$15,313,683	\$11,495,111	\$2,742,711	\$70,000,000
Project Cost Share	\$20,347,350	\$16,061,835	\$7,238,566	\$94,500,000

End Project Goal: Build and grow a successful member consortium to promote modular chemical process intensification (MCPI) and related process technologies to address the 14 institute metrics, towards self-sustaining operation.

RAPID Team



Ignasi Palou-Rivera,
Executive Director &
CTO



Kevin Chin,
COO



Ashley Smith-Schoettker
Dir. Outreach, Education,
Membership



Keith Joseph,
Sr. Education & WFD
Specialist



Tricia Gillenwater,
Principal Program
Manager



Julia Faeth,
Program Manager



Fadhil Al-Aboosi,
RAPID Fellow



Maithreyi Thukaram,
Project Manager

AIChE

Support for

- Finance
- HR
- IT
- Meetings
- Marketing/Comms

Member Community

Participation in

- Governance
- Tech Advisory
- Focus Area
Leadership
- R&D Projects
- Educational Efforts

Low overhead model with virtual operation and cost-efficient support from AIChE to:

- Build Member Community
- Educate students and professionals
- Drive Thought Leadership
- Fund and manage R&D projects

Background & Strategic Approach Membership



By participating in RAPID, members can...

- ❑ **Accelerate** development and adoption of technologies for resilient and sustainable manufacturing through member connections and capabilities
- ❑ **De-risk** new technology development/deployment
- ❑ **Receive priority access** to software and modeling tools, technology reports, and consulting services
- ❑ **Educate** the current and future workforce with tools to re-think conventional processes Map

Focus Areas

Application Verticals



Chemical Commodity Processes

Cross-Cutting Fundamentals



Intensified Process Fundamentals



Natural Gas Upgrading



Education



Modeling and Simulation



Renewable Bio Products

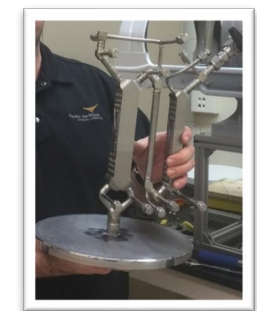


Module Manufacturing

Modular Chemical Process Intensification (MCPI)

Process Intensification

- Rethinking processes to dramatically **improve performance**
- Shift from **unit operations** paradigm to **integrative** paradigm
- Transition from **batch to continuous**



Modular Processing

- Rethinking systems to enable flexible, **distributed manufacturing**
- Shift from **bigger is better** paradigm to **small, modular** paradigm
- Transition from volume scaling to **numbering up**

Results and Achievements

R&D and EWD Projects

BP1-BP5 (CY 2017 - 2022)

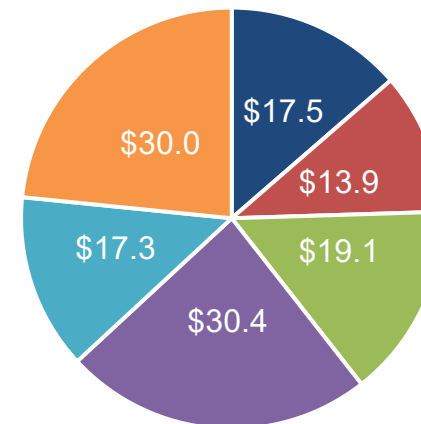
- 37 R&D projects (\$128.2M)
- 1 cross-cutting metrics/modeling project (\$9.2M)
- 4 EWD projects (\$1.5M)
- FFRDC support (\$3.3M)
- All projects finished by end calendar 2022
- \$45.5M federal share, \$84.1M cost share

- Chemical Commodity Processing
- Natural Gas Upgrading
- Renewable Bioproducts
- Intensified Process Fundamentals
- Modeling & Simulation
- Module Manufacturing

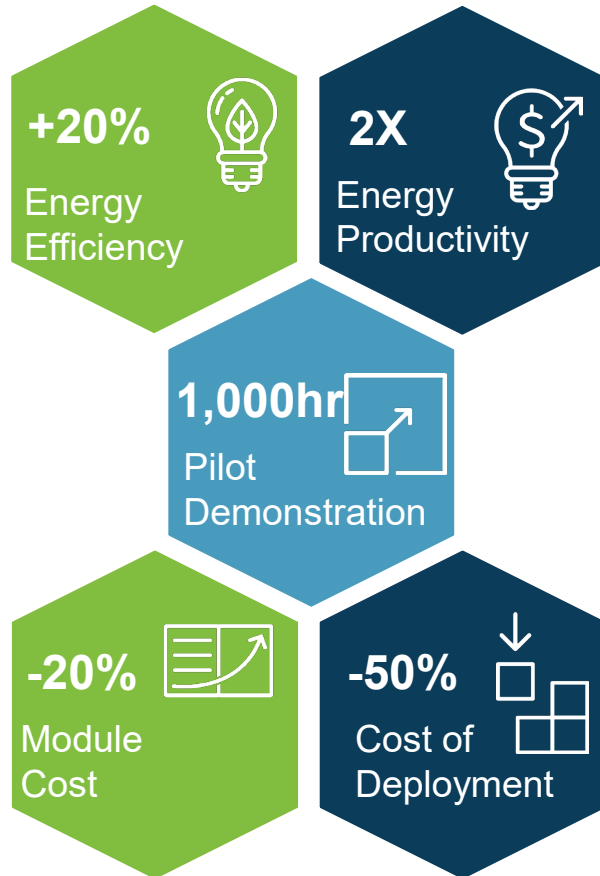
Project Count



Project Spend (\$128.2M)



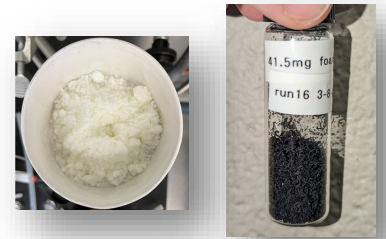
Results and Achievements Technology Metrics



- Metric #1** 20% improvement in **energy efficiency**
- Metric #2** Doubling (2X) in **energy productivity** (\$/kWh)
- Metric #3** 1,000 hr **pilot demonstration** (with 20% improved energy efficiency, 10X reduced capacity cost, and 20% lower emissions/waste)
- Metric #4** **Experience (or learning) curve** with 20% reduction in module cost for each doubling in the number of modules produced
- Metric #5** Module **deployment cost reduction** by 50% compared to current SOTA

As required, at least one developed technology has met each technical metric.

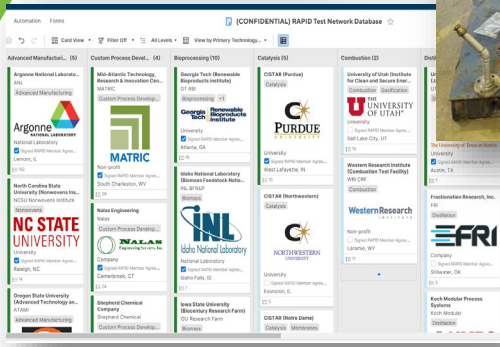
Results and Achievements Implement Sustaining Plan



U.S. DEPARTMENT OF
ENERGY
Office of
ENERGY EFFICIENCY &
RENEWABLE ENERGY

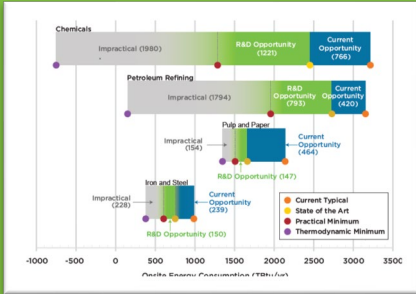


- Accelerated Process Development
- Batch To Continuous
- Data & Modeling for Scale-Up
- Virtual Operator Training
- Technology Overviews



Future Work & Impact

MCPI to Dramatically Increase Energy & Capital Efficiency



Primary Metals	1608 TBTU	
Petroleum Refining	6137 TBTU	
Chemicals	4995 TBTU	
Wood Pulp & Paper	2109 TBTU	
Glass & Cement	716 TBTU	
Food Processing	1162 TBTU	

DOE AMO Energy Bandwidth Studies
<https://www.energy.gov/eere/amo/energy-analysis-data-and-reports>

2017

Original Coop. Agreement



Advanced Process Technologies for Decarbonizing the Process Industries

DOE Industrial Decarbonization Roadmap

Office of Energy Efficiency & Renewable Energy

2023

Renewal Coop. Agreement (under review)

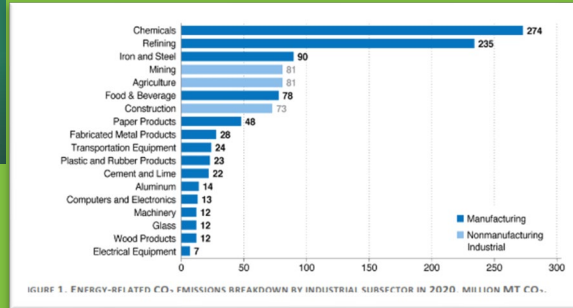


FIGURE 1. ENERGY-RELATED CO₂ EMISSIONS BREAKDOWN BY INDUSTRIAL SUBSECTOR IN 2020. MILLION MT CO₂e.
2022 DOE Industrial Decarbonization Roadmap
<https://www.energy.gov/eere/industrial-decarbonization-roadmap>

Delivering Institute Sustainment

- Strategic membership
- Emphasize value-delivery
- Diversified funding streams, public and private

Promoting DEIA and Energy Justice

- Across **all** institute operations
- Expand reach to key groups:
 - Small/Medium Enterprises
 - Minority Serving Institutions
 - Disadvantaged Communities

Advancing U.S. Mfg Competitiveness

- Technology development & scale-up
- Re-shoring mfg. processes
- (Re-)Training the future workforce

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2023 IEDO Peer Review



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4 Key Priorities



Original DOE Agreement
\$160M Total Funding (\$125M over 38 R&D projects)
Projects funded under DOE AMO cooperative agreement

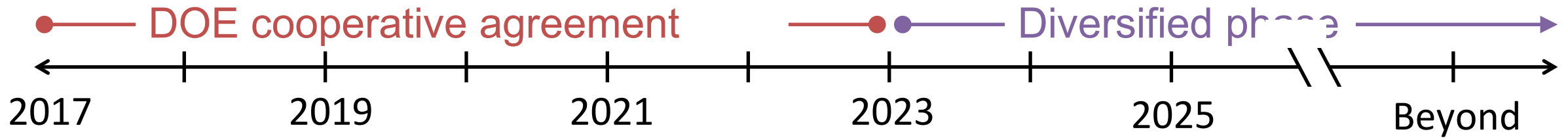
New Potential DOE Agreement
\$60M (Fed+CS)
New DOE award (5 years)

- Other Projects:**
- Over 11 projects (2019-2022)
 - RAPID lead on 4 projects
 - \$14.4M through late 2022
 - Several pending proposals

Other Federal Funding
Projects from DOE (AMO, BETO), DoD (DARPA, ONR), DOC (NIST)
RAPID and members collaborate on different federal funding opportunities

- 2022 Projects** (6 company sponsorships):
- Process Electrification
 - Transition Tech.

Industry-Sponsored Project Funding
Members pool funding for selected projects



Premier



Choice

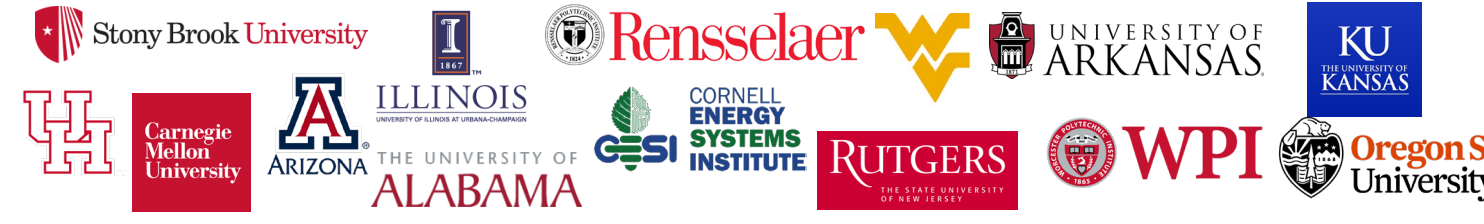


Industrial Enabling



Academic Enabling

Non-Profit & National Lab Enabling



Affiliate & AffiliateU





2023 Member Dues & Benefits

Each tier includes benefits listed + the tiers below it.

Premier (\$55k/\$25k)

4 More Corporate Associates (10 Total) |
Guaranteed seat on Governing Board and TAB |
Industry: IP License for R&D Purposes
Non-Industry: IP License per IP Plan

Choice (\$25k/\$10k)

3 More Corporate Associates (6 Total)
Technical Advisory Board Sub-Committees
Industry: IP License for R&D Purposes
Non-Industry; IP License per IP Plan

Enabling (\$7.5k)

3 Corporate Associate Permissions to Access Exclusive Member Content such as: RAPID Review, RAPID Test Network, and RAPID Software Toolbox | Access to Project Funding as Available and if Awarded | Deeper RAPID Education Discounts to All Employees | IP License per IP Plan

AffiliateU (\$3k) (University-only tier)

Covered under RAPID Member Agreement and NDA Language | Eligible to apply for RAPID project opportunities as available, once granted would be required to upgrade to Enabling

Affiliate (varies, \$1k-\$5.5k; does not sign member agreement)

Access to Virtual Members Directory | Quarterly Members Council Meetings & Networking Opportunities