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Perspectives on Modular Energy Systems

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U.S. DEPARTMENT OF ENERGY

Benefits & Risks to Modular Processing Approach

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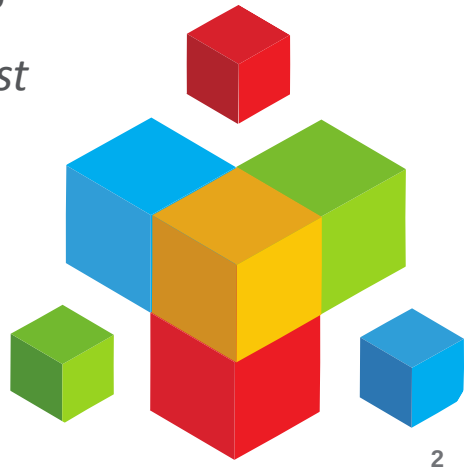
Benefits

- *Reduced upfront capital requirement*
- *Distributed processing, lower cost feedstocks*
- *Lower unit capital costs via centralized construction*
- *Flexibility in modular designs*
- *Faster learning curve (more systems)*
- *Potential plug and play approach*

Risks

- *Likely higher overall capital requirement*
- *Not all technologies scale down*
- *Operating costs a major challenge (sensors & controls critical)*
- *Heat integration/utilization can be more challenging*
- *Potential BOP cost domination*



Several Current Efforts Focused on Modular Processing

Advanced Manufacturing Office

Chemical Modular Process Intensification

Smart Manufacturing

Fossil Energy/ NETL

REMS

Modular CO_2 separations

Modular gasification

National Science Foundation

Modular process intensification

Education

Bioenergy Technologies Office

Distributed processing (biomass & wastes)

Integrated biorefineries

Big Ideas

Energy Everywhere

Opportunity Space for Energy Impacts (AMO)

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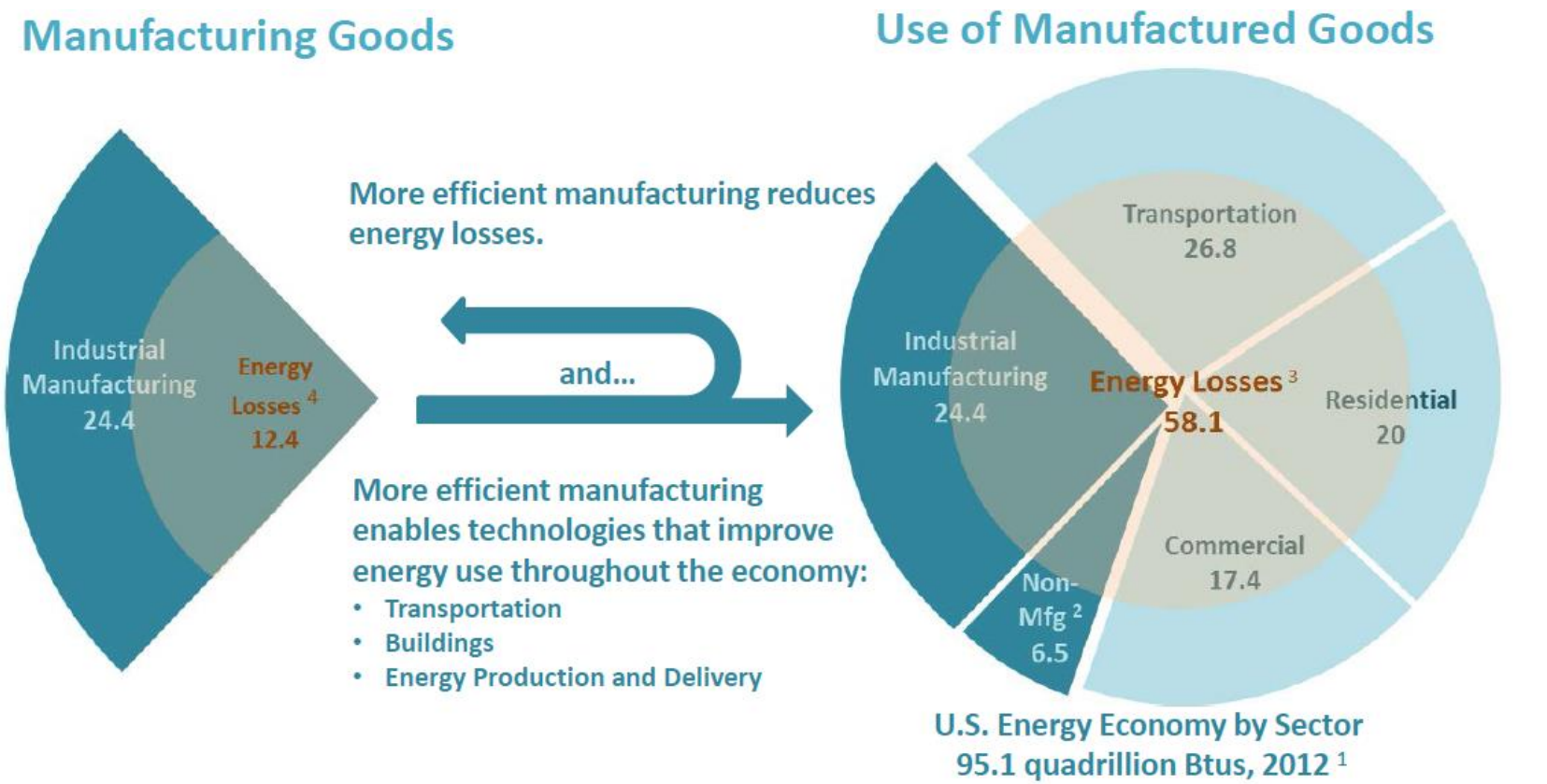

[1] Energy consumption by sector from EIA Monthly Energy Review, 2012
[2] Industrial non-manufacturing includes agriculture, mining, and construction
[3] US economy energy losses determined from LLNL Energy Flow Chart 2012 (Rejected Energy)
[4] Manufacturing energy losses determined from DOE AMO Sankey/Footprint Diagrams (2010 data)

- Improve the productivity and energy efficiency of U.S. manufacturing
- Reduce life cycle energy and resource impacts of manufactured goods

DOE Manufacturing Bandwidth Studies: Energy Savings Potential

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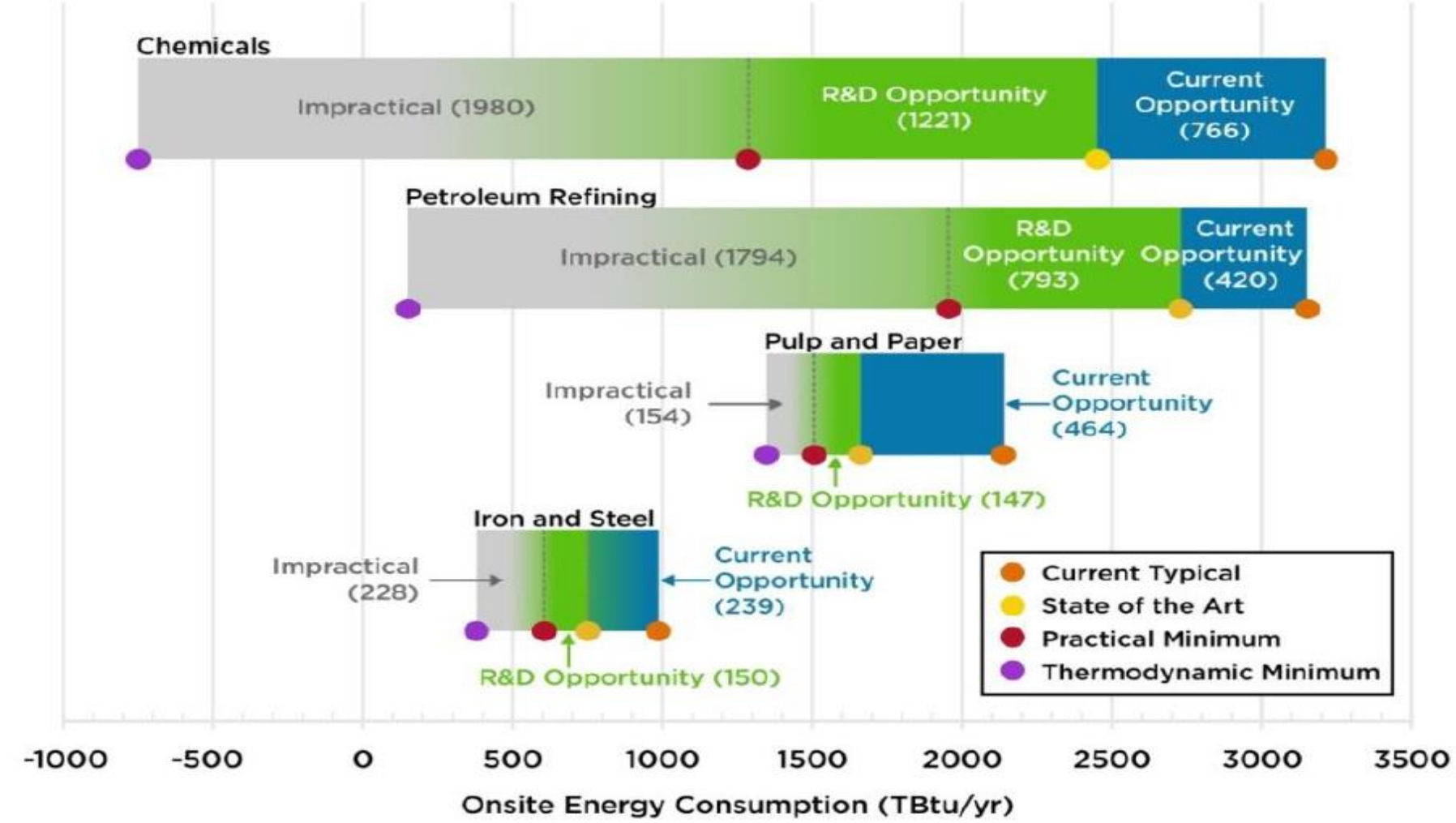

U.S. Energy Bandwidth Study Results Show Energy Savings Potential for Four Manufacturing Industries: Chemicals, Petroleum Refining, Pulp and Paper, and Iron and Steel.

Manufacturing USA Network

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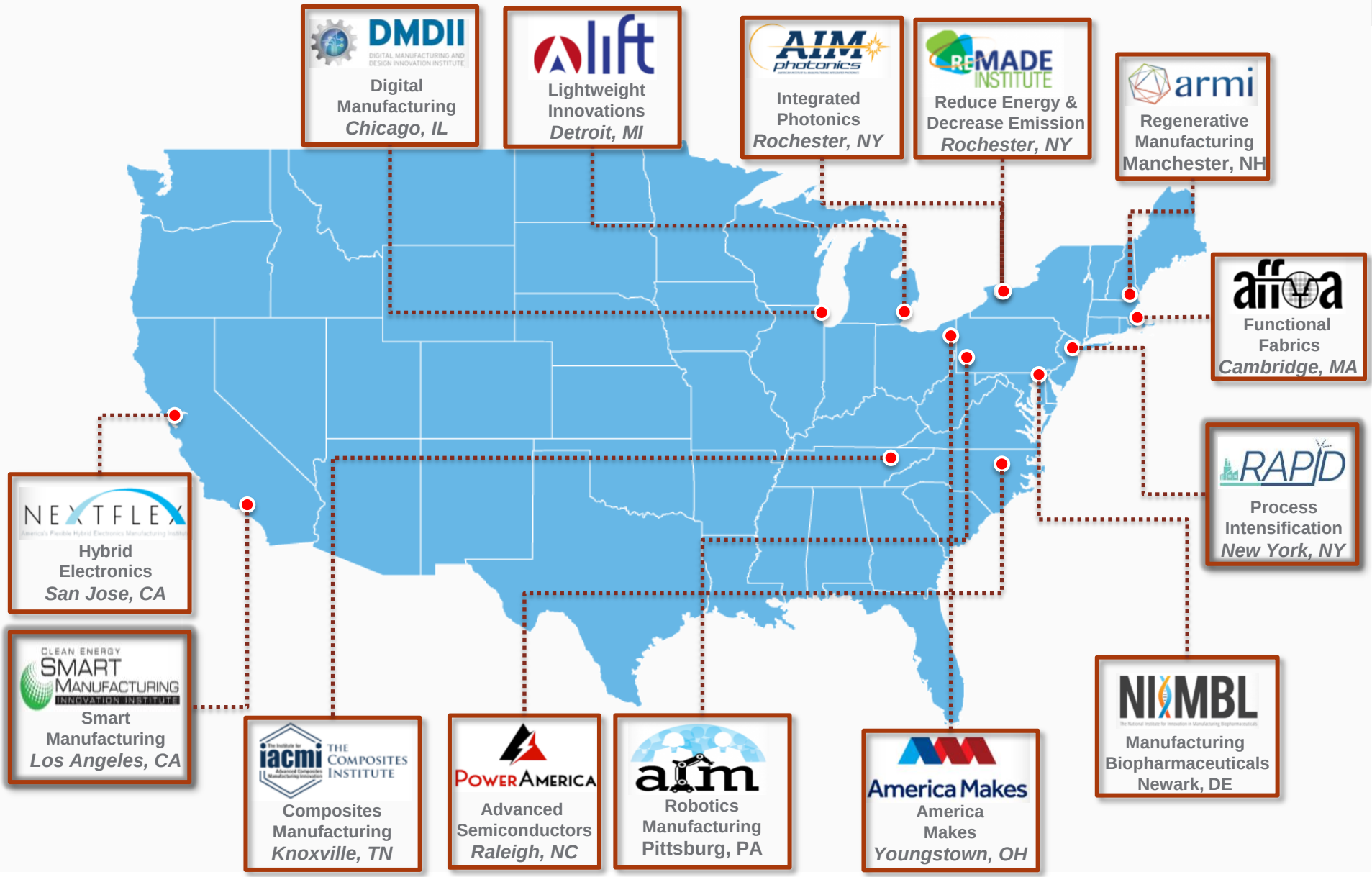

Rapid Advancement in Process Intensification Deployment (RAPID)

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AMO NNMI modular chemical process intensification (Lead org: AIChE)

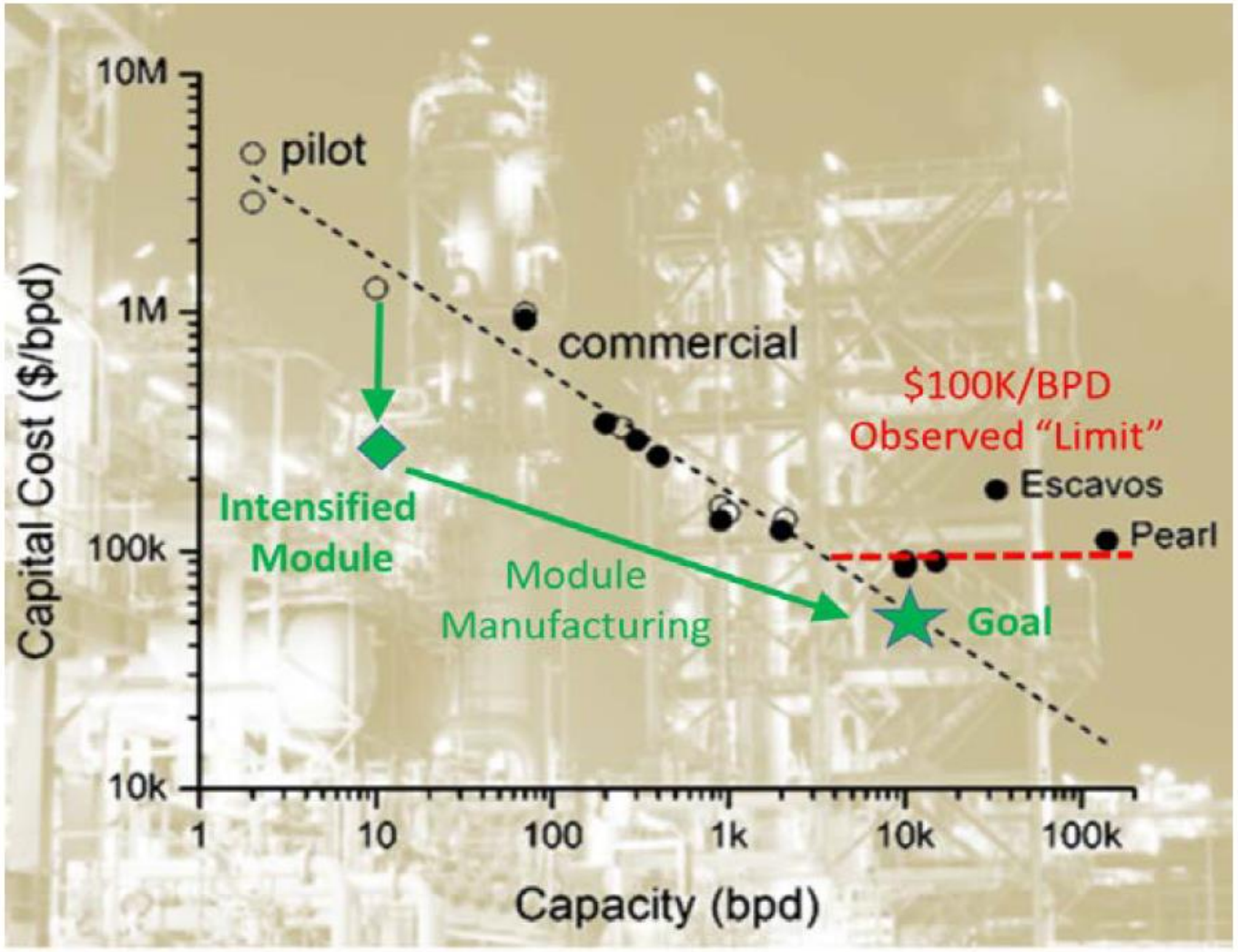
Topic areas:

- MCPI applications for large energy consuming industries *(petroleum, chemicals, pulp and paper, metals)*
- Manufacturing of modules and components
- Process intensification technology development
- Advanced Modeling

Metrics:

- Demonstrate a 20% or greater improvement in energy efficiency in 5 years
- On track to an order-of-magnitude improvement in energy productivity in 10 years
- 20% reduced cost/unit of intensified process modules with each doubling in production.
- 50% reduced deployment costs relative to state of the art within 5 years

RAPID – Economics of Modular Systems



GTL Data – from Modular Chemical Process Intensification FOA

Clean Energy Smart Manufacturing Innovation Institute (CESMII)

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AMO NNMI on advanced sensors & controls for real-time process management (Lead org: SMLC)

CLEAN ENERGY SMART MANUFACTURING INNOVATION INSTITUTE™

Topic areas:

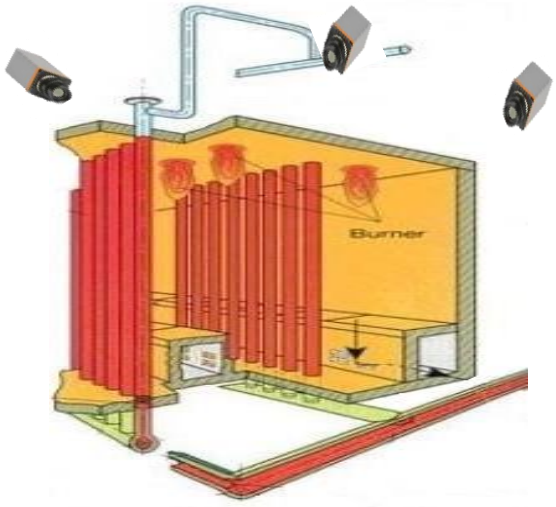
- Open Software and Communication Platforms
- Advanced Sensors
- Real-Time Data Analytics and Control Systems
- Advanced High-Fidelity Modeling
- Testbed demonstrations

Metrics:

- 15% energy efficiency improvement in FOAK industrial test beds in 5 years
- 50% reduction in SM systems deployment costs in 5 years
- US SM workforce capacity increased two-fold by 2020, five-fold by 2030
- 40% increase in SM supply chain participation by 2030

CESMII Example

First Steam Methane Reformer Furnace
Port Arthur, TX



- Already efficient
- Distributed sensing
- Distributed actuation (96 burners)
- High fidelity model & reduced order models

Reduction wasted energy

Simple Model

Reduce Cameras

Halve capital cost

Reduction wasted energy

HPC Model

Burner Controls

Dynamic energy management

Metrics

Extend to 20 U.S. SMRs

Energy Everywhere Big Idea – New Paradigms for Energy Production

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Large plants (> 12GW, 125,000 bpd)

Full heat integration
Optimized use of feed

Distributed production (< 100 MW, 200 bpd)

Heat integration challenging
Not all feed used (e.g., H_2O)

Steady production ⟷ **Strong fluctuations**

Energy Everywhere Big Idea – Waste water treatment example

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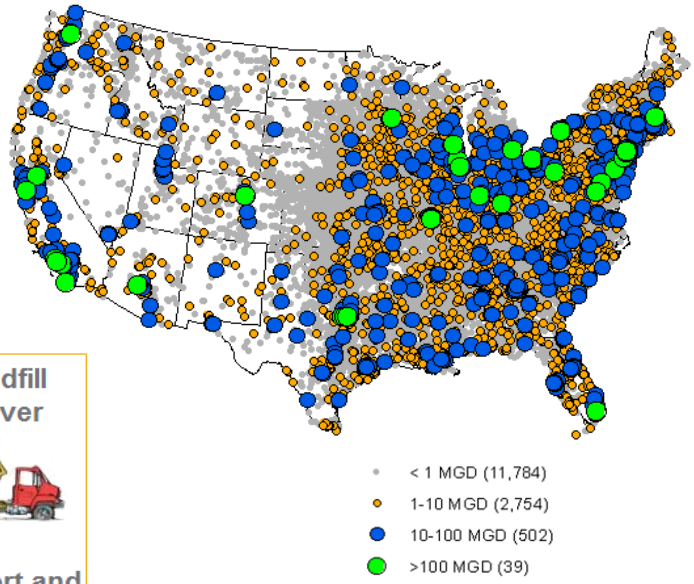
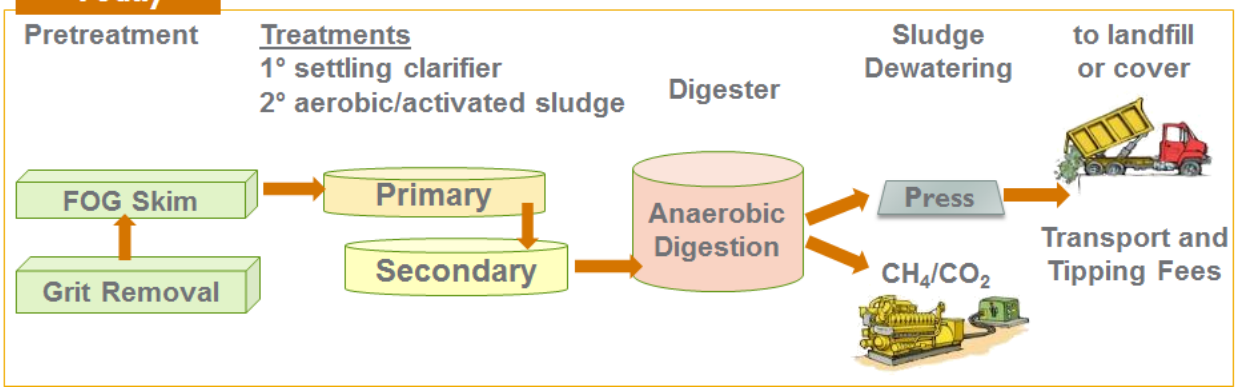
- 16,000 publically owned treatment works in the US
- Treat nearly 32 billion gallons/day of wastewater
- Opportunity for up to 4.6 billion liters of biocrude oil



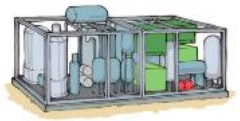
Today



What could be

e.g. Hydrothermal Liquefaction

- Water-assisted pyrolysis
- Subcritical H_2O (no solvent)
- Plug flow (pipes) reactor
- No reactive gas
- 85% carbon conv (potential)



CH_4/CO_2

21 BOE/day

MCPI Example – Solar Thermochemical Processing

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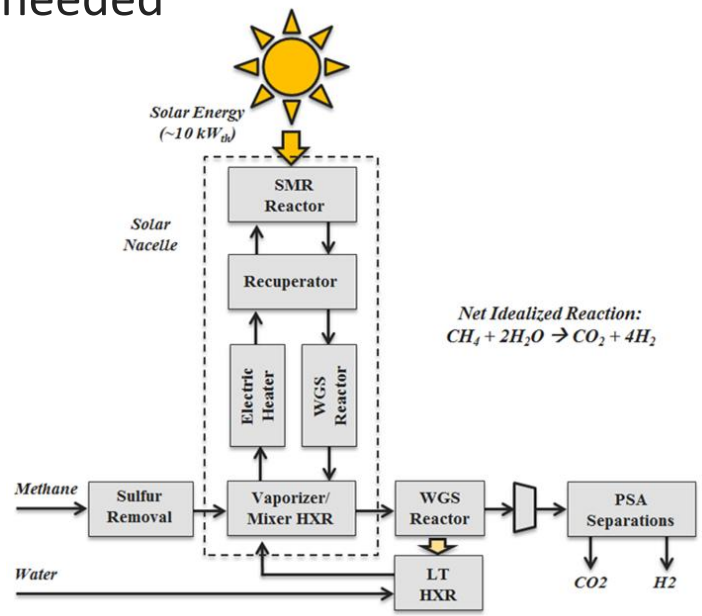
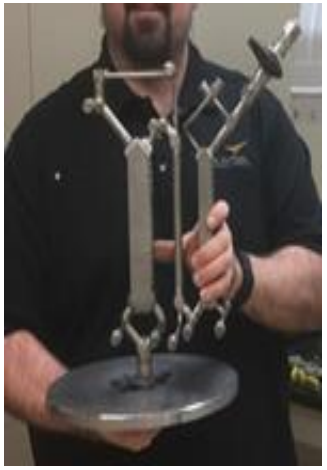
- Based on micro- and meso-channel process intensification
- Concentrated solar used to powered SMR:
  70% solar-to-chemical efficiencies
- Inherently modular
- High-volume module/ component manufacturing supply chain needed





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Questions?

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