Advanced Catalysts for Low Temperature Heavy Crude Upgrading

AMO EERE L059-1611

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Washington, D.C.
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Overview

Project Title: Advanced Catalysts for Low Temperature Heavy Crude Upgrading

Timeline:

Project Start Date: 10/01/2018

Budget Period End Date: 09/30/2019

Project End Date: 09/30/2021

Barriers and Challenges:

- Oil viscosity (reduction @ low temperature)
- Pipeline diluent reduction (~25-50 %)
- Cost and Performance (catalyst)

AMO MYPP Connection:

- Process Intensification:
  Advanced Catalysis for Industrial Applications

Project Budget and Costs:

Budget	DOE Share	Cost Share	Total	Cost Share %
Overall Budget	$4,350,000	$500,000	$4,850,000	10.3%
FY18 Received	$2,047,757	$250,000*	$2,297,757	10.9%
Total FY19 budget	$1,450,000	$175,000*	$1,625,000	10.8%

*SC state contribution

Project Team and Roles:

Savannah River National Laboratory (Lead)
- Small scale nanocatalyst testing
- Synthesis/functionalization of nanocatalysts
- Modeling thermodynamics and energy distribution

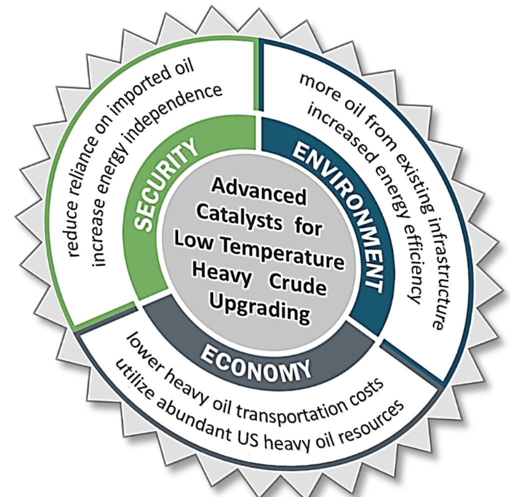
Mainland Solutions, LLC
- Developing flow-through nanocatalyst heating systems
- Low-cost industrially relevant nanocatalysts
- Technoeconomic analysis

Bechtel Corporation
- System engineering designs and process flow diagrams
- Commercial relevance for insertion

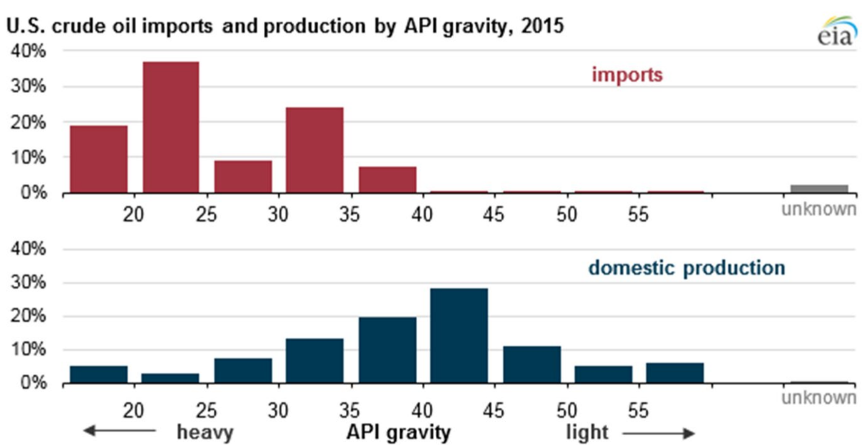
University of South Carolina
- Metal functionalization of nanographitic carbon

Project Objective

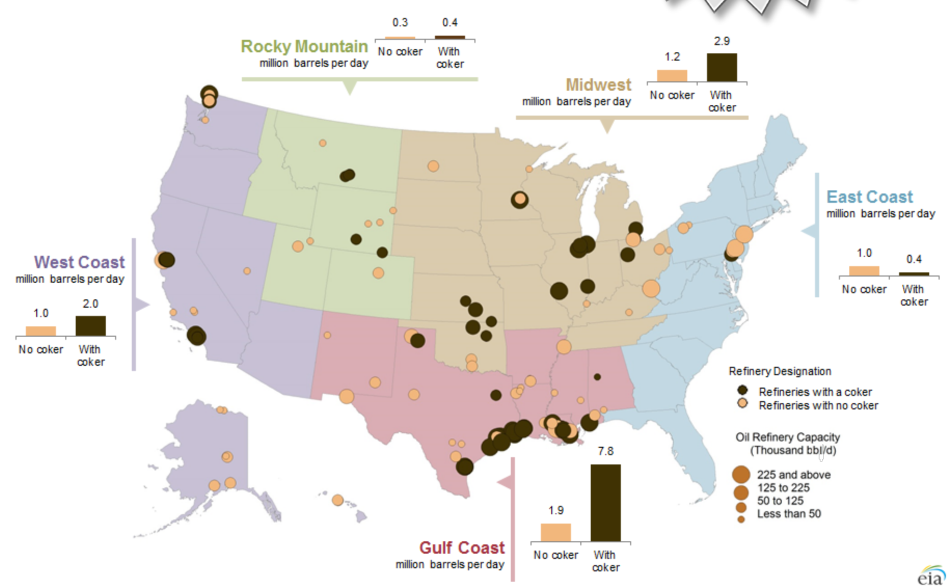
Worldwide conventional oil supply is projected to decline. Unconventional oil (heavy oil and tar sands), with at least twice the abundance, requires new technology to recover/transport. Heavy crude oil is highly-viscous and cannot easily flow through production wells or pipelines.



<u>Objective</u> - Reduce viscosity of heavy crude directly at the production well to facilitate pipeline transportation at reduced costs using selective catalysis.



Source: U.S. Energy Information Administration, EIA-914 and EIA-814

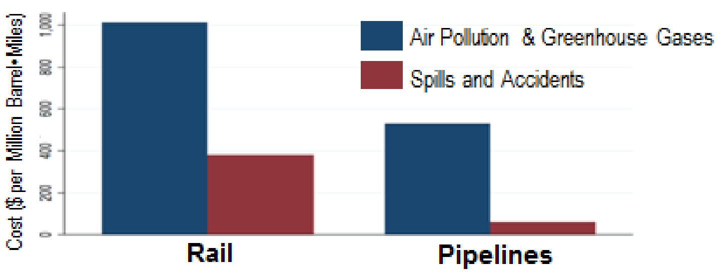


Source: U.S. Energy Information Administration

<u>Alignment with AMO</u> - Process Intensification: modular system at oil well, energy efficient process design, crosscutting within oil and gas production

Technical Innovation

- <u>Current Approach</u>: Heavy crude - transported by truck/train and/or by pipeline with diluent. Upgrading uses catalyst at elevated pressures/temperatures (>350°C).
  - Dilution - Diluent adds significant costs (comprise up to 30% by volume in pipeline).
  - Current partial upgrading - delayed coking, deasphalting, visbreaking (high capital and operating costs, high greenhouse gas emissions).
- <u>Overarching Project Approach</u>: Design an energy-efficient, modular, in-field partial upgrader to reduce viscosity at the production well and reduce diluent requirements.



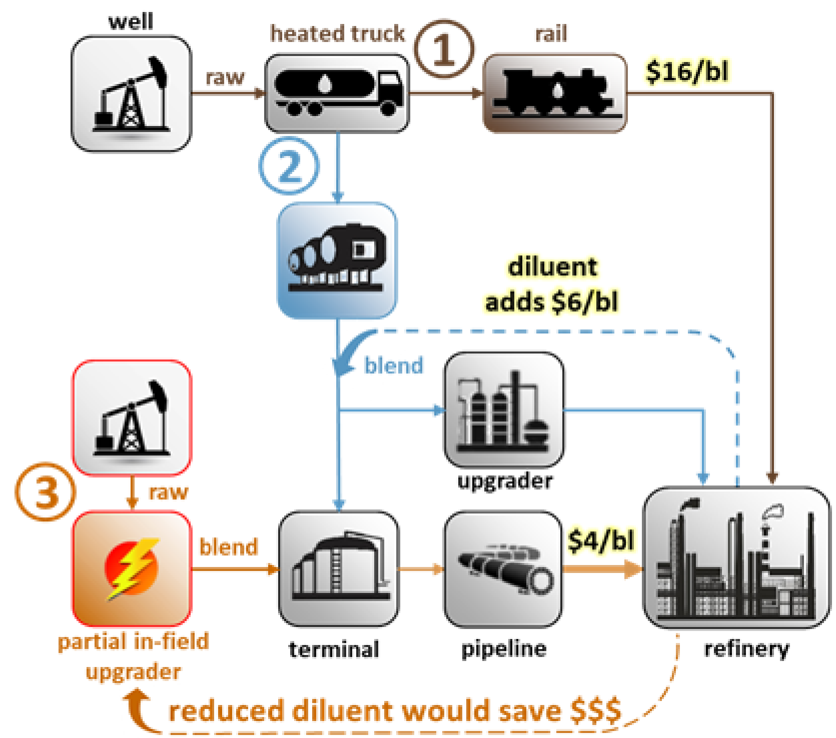
Karen Clay, Akshaya Jha, Nicholas Muller, and Randall Walsh "The External Costs of Transporting Petroleum Products by Pipelines and Rail: Evidence From Shipments of Crude Oil from North Dakota," National Bureau of Economic Research Working Paper, (2017)

	Origin	Destination	Crude	Rate $/bl
Pipeline	Alberta, CAN	Cushing, TX	Light	$3.78
Pipeline	Alberta, CAN	Cushing, TX	Heavy	$4.54
Pipeline	Cushing, OK	Houston, TX	Light	$2.71
Pipeline	Cushing, OK	Houston, TX	Heavy	$3.26
	Origin	Destination	Crude	Rate $/bl
Rail	North Dakota	Houston, TX	Bakken	$10.38
Rail	North Dakota	NY Harbor	Bakken	$10.55
Rail	Alberta, CAN	Houston, TX	Canadian Heavy	$16.73

+$6 for diluent

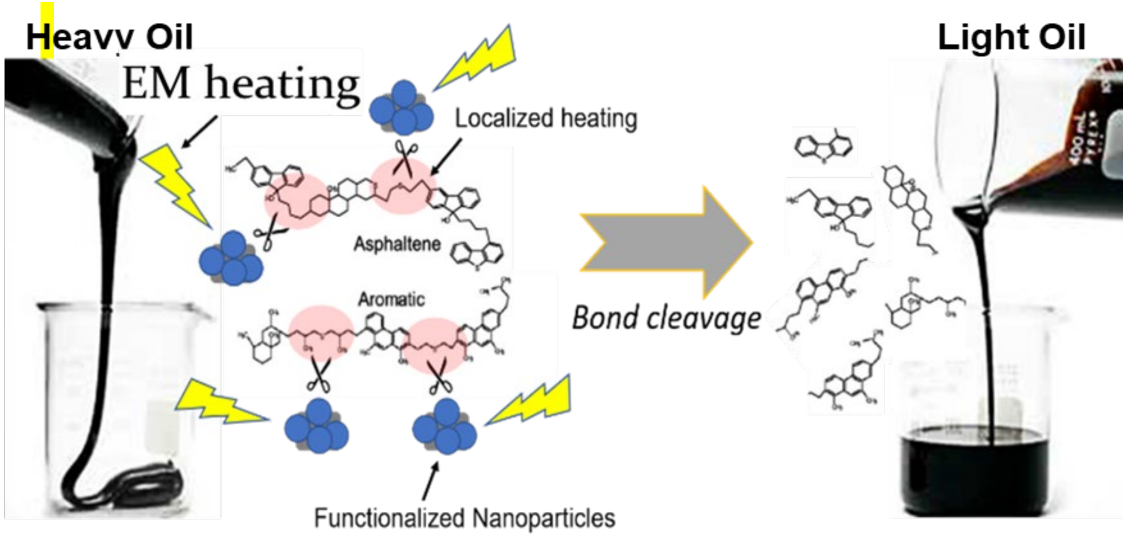
Source: Argus, *Petroleum Transportation North America*, Aug. 22, 2014

Heavy Crude: Well to Refinery

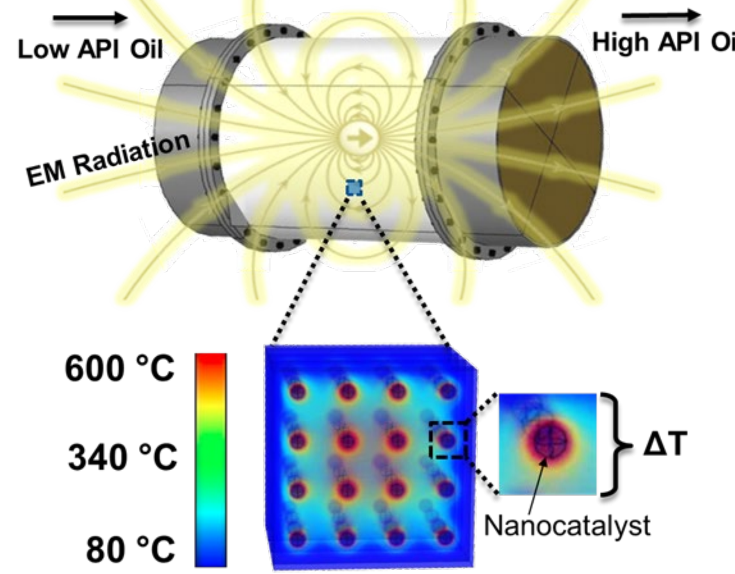


Technical Innovation

- <u>Technical Approach</u>: Utilize advanced nanocatalysts coupled to electromagnetic (EM) energy, resulting in locally heating the catalyst to cleave complex carbon-sulfur or carbon-heteroatom bonds in heavy crude for viscosity reduction at industrially-relevant low bulk oil temperatures.



- Partial upgrading targets asphaltene sulfide/disulfide bonds.
  - Lowers average MW and viscosity
  - Increases API gravity
  - Slightly increases middle distillates
- <u>Potential Risk:</u> Catalyst lifetime and recovery methods need development.

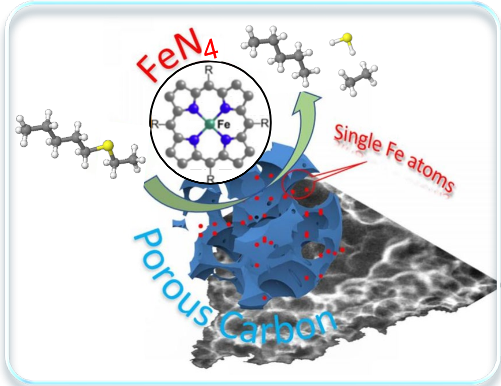


Localized Heating of Catalysts Dispersed in Oil

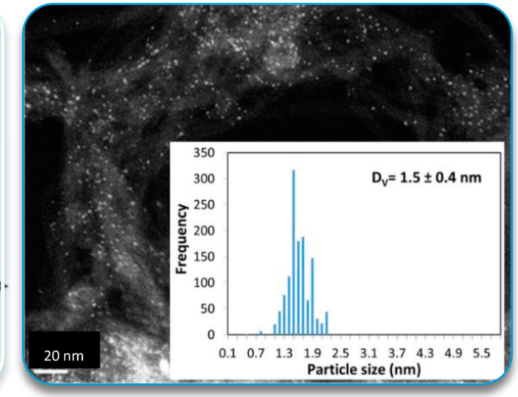
- Heat the catalyst directly – high activity resulting from high local temp.
- Bulk oil – remains at low temperature (< 100 °C), volatile fractions remain liquid.

Technical Approach

- Low temperature, heavy oil upgrading achieved by:
  - Developing state-of-the-art nanocatalysts (right)
  - Targeting low energy sulfide/disulfide bonds within asphaltenes (lower right)
  - Directly heating catalysts (below)



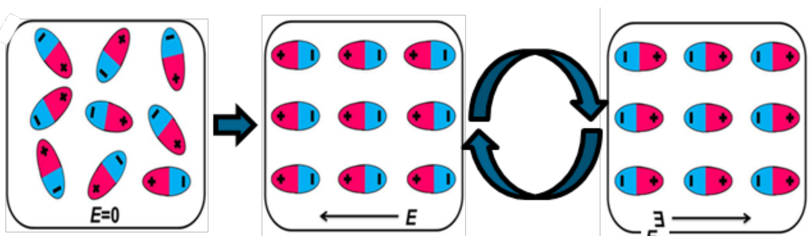
Atomically coordinated Fe



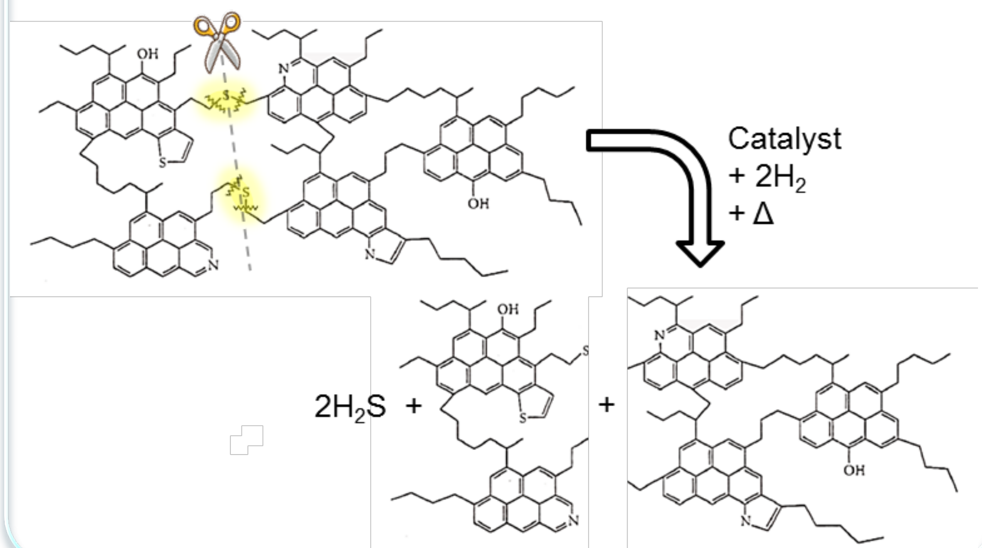
Strong Electrostatic Adsorption
<20nm diameter metal particles well dispersed on support

Microwaves efficiently absorbed by catalysts

- Electric dipoles align with the E-field and are rotated; this reorientation creates heat
- Rapid, energy efficient heating
- Uniform heat distribution throughout sample



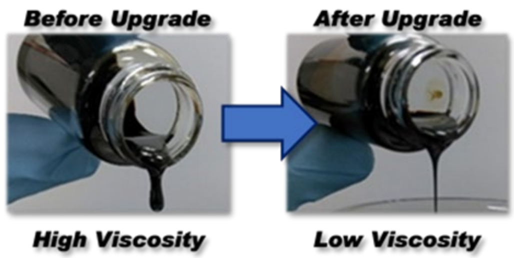
Asphaltene bond scission at R-S-R’



Technical Approach

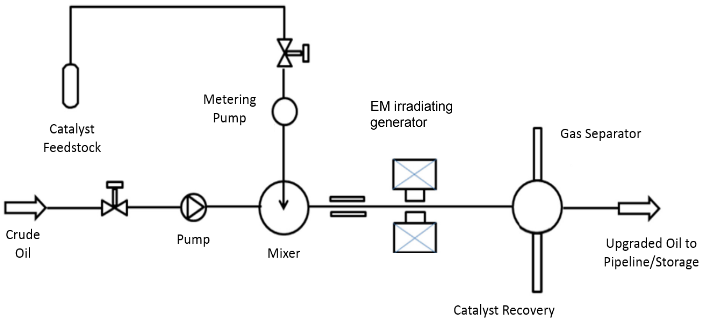
Savannah River National Laboratory

- Development of nanocatalysts and functionalized graphitic particles.
- Small-scale testing of catalysts in electromagnetic heating systems.
- Experimental and modeling work to support economic and technical scalability, and to address potential risks prior to technology development.

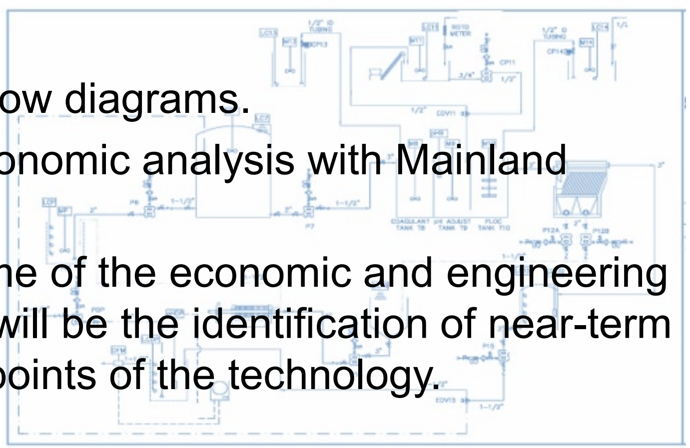


Mainland Solutions, LLC

- Lead construction of direct heating methods systems (e.g., microwave) that are better suited for specific nanocatalysts and *flow-through upgrading*. They are also working with SRNL to characterize heavy crude oils.
- Economic and technoeconomic analysis.



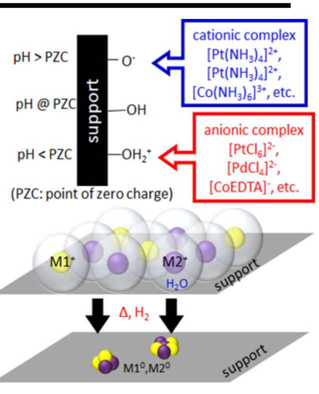
Bechtel



- Process flow diagrams.
- Technoeconomic analysis with Mainland Solutions.
- An outcome of the economic and engineering analyses will be the identification of near-term insertion points of the technology.

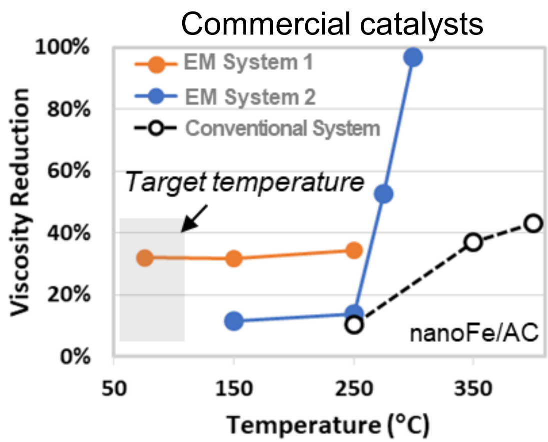
University of South Carolina

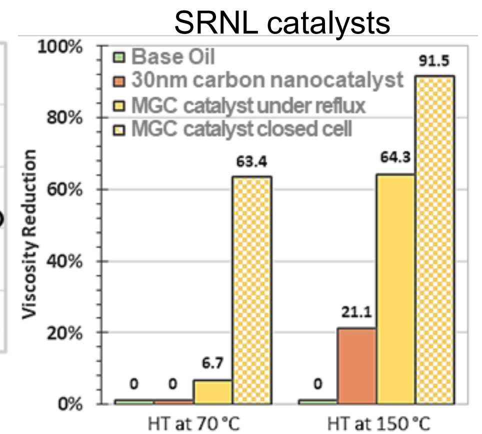
- Scalable state-of-the-art catalysis synthesis.
- SEA <20nm diameter metal particles well dispersed on support.

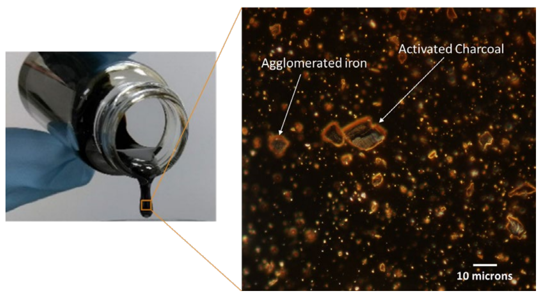


Results and Accomplishments

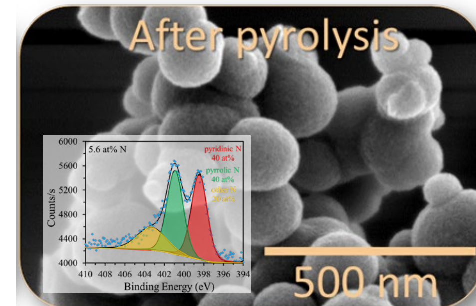
- EM heating of nanocatalysts dispersed in heavy crude (field sampled) show significant viscosity reduction (63 %) at low temperature (70° C). All milestones (Q1 and Q2) achieved up to-date.
- High surface area (1200 m^2/g) meso-graphitic carbon (MGC) were prepared and characterized at SRNL and further modified by the University of South Carolina with well-dispersed <10 nm Fe and Co nanoparticles (Fe-MGC and Co-MGC).
- Computational modeling using COMSOL Multiphysics has been initiated to simulate localized temperature distributions of the catalyst in heavy crude.
- Future work includes: optimize catalyst/EM coupling; develop flow-through system; provide technoeconomic analysis and system designs; reduce need for diluent by 50% at project end; field test technology.



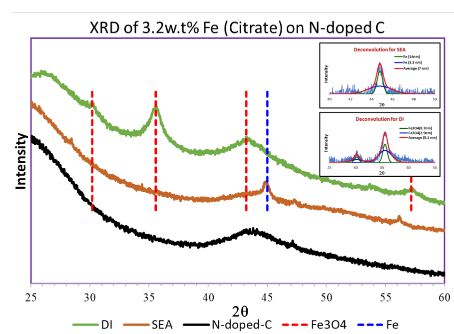




Imaging as-prepared catalyst/oil

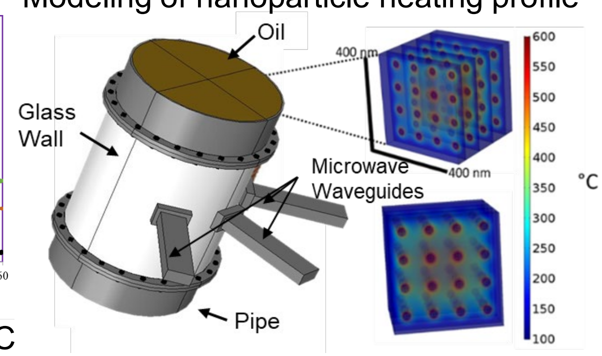


Meso-graphitic Fe/N catalysts

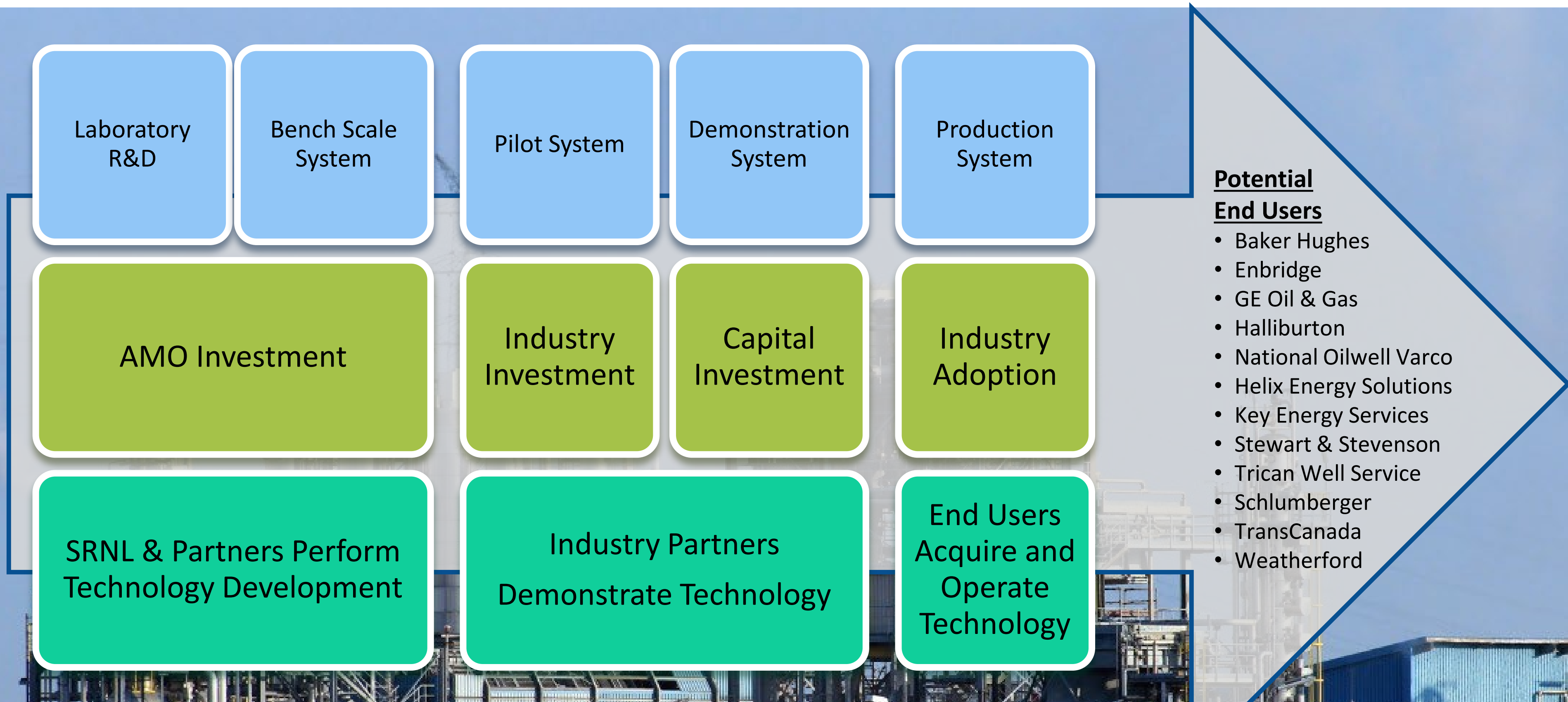


~7nm Fe nanoparticles on MGC

Modeling of nanoparticle heating profile



Transition (beyond DOE assistance)



SRNL Further Technology Development and Eventual Transition

Patenting, licensing, and continued collaboration in technology areas including:

- Nanocatalyst design and synthesis.
- Heavy oil upgrader equipment designs optimized for our nanocatalyst technology.

Patent Disclosure Submitted!

SRNL Current Industrial Partners to Aid in Transition

- ***Mainland Solutions***: A small business technology provider for secondary & tertiary oil service providers.
- ***Bechtel Corporation:*** A large business which provides engineering solutions to major petroleum and energy companies and is guiding designs to improve integration with existing field operations.