

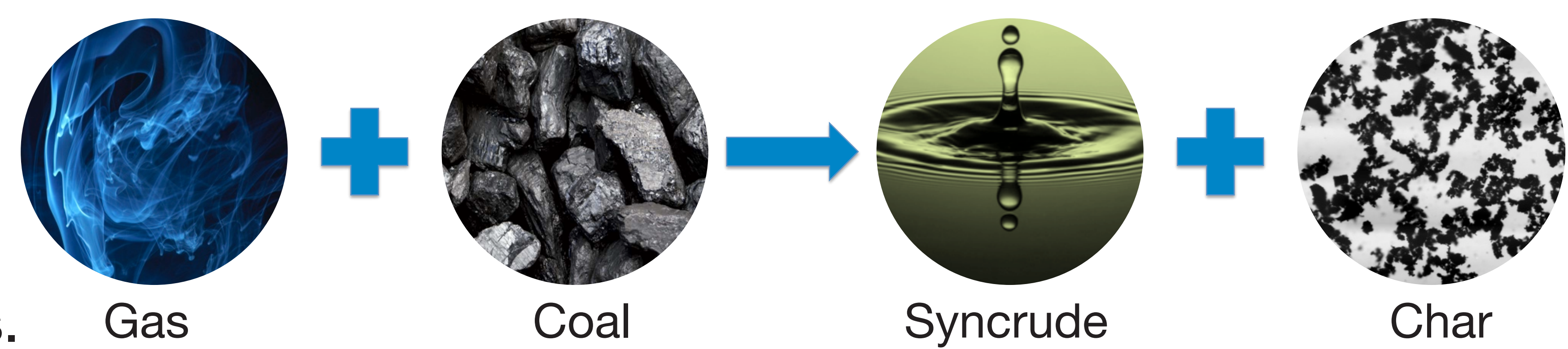


# Wave Liquefaction™: *New Markets for Coal*

A novel REMS approach to manufacturing fuels, chemicals, and materials from coal, natural gas, and other feedstocks.

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Wave Liquefaction™ combines gaseous and solid hydrocarbons to cleanly and efficiently produce liquid fuels, chemicals and advanced materials.



With non-emissive electricity sources, and no CCS, lifecycle CO<sub>2</sub> emissions would be 10% less than for transportation fuels from conventional oil refining.

## ABSTRACT

Wave Liquefaction™ technology is a novel approach to coal liquefaction. With little to no process CO<sub>2</sub> emissions, high thermal efficiency, and low capital and operating costs, Wave Liquefaction™ process enables production of cost-competitive liquid and solid products directly from coal with lower direct and lifecycle greenhouse gas emissions than conventional petroleum refining, without carbon capture. Lifecycle greenhouse gas emissions can be reduced further with use of coal/biomass blends.

Wave Liquefaction™ small-footprint, high-throughput, ambient pressure reactors sharply lower capital costs of coal conversion and eliminate the need for economies of scale. Replication of standard, pre-assembled core reactor units and process trains allows site-specific scaling, reduces technical and financial risks associated with conventional, non-modular scaling, and increases plant availability through process redundancy.

## IMPACT

United States holds more than 27% of the world's coal reserves. Development of truly clean, efficient, and economically viable coal utilization pathways that unlock the true value of coal and overcome economic and environmental challenges of the conventional technologies is of strategic importance.

Advanced coal-to-liquids technologies, such as Wave Liquefaction, can be cost-effectively deployed at a range of scales directly in the communities affected by the downturn in the coal industry targeting established markets and creating new ones. Their development will dramatically improve energy security, reduce coal environmental footprint, and promote job creation and economic development in the regions that need them most.

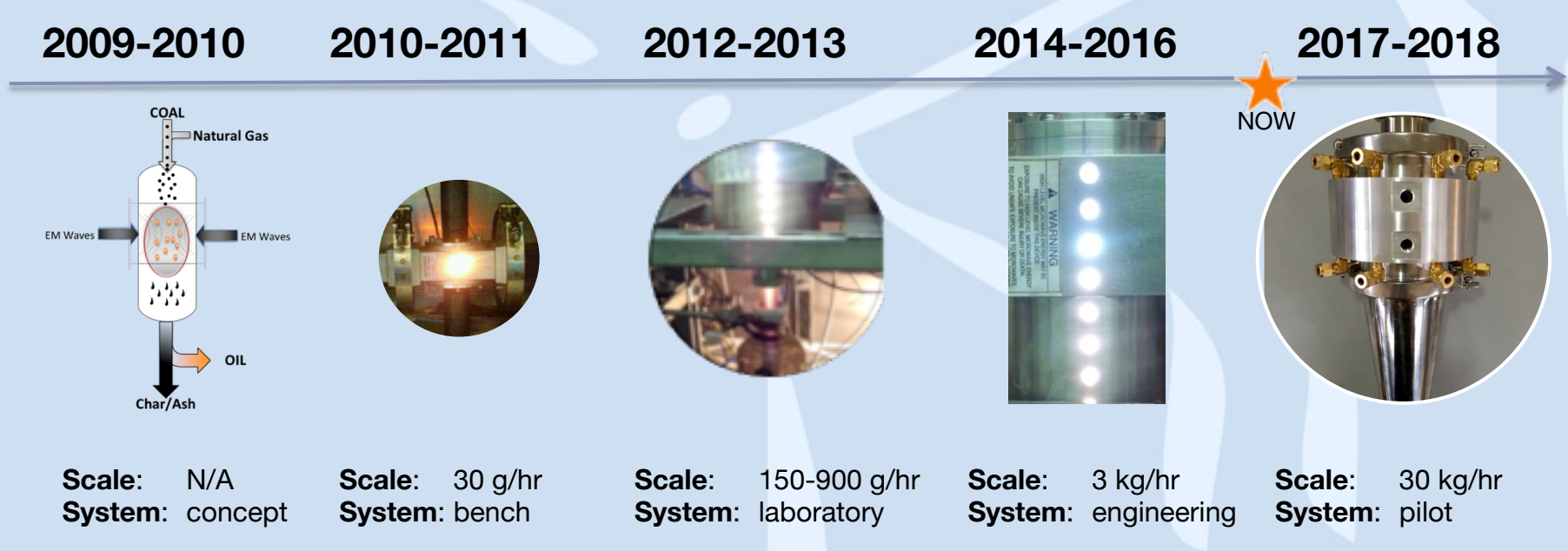
## KEY ADVANTAGES

- modular, small-scale deployment
- rapid, efficient processing
- high feed and product flexibility
- virtually zero CO<sub>2</sub> emissions
- clean (no SMR) hydrogen production

## REPRESENTATIVE COALS

Feedstock Type	Coal Seam	Liquid yield with hydrogen (% wt)	Liquid yield with methane (% wt)
low-volatile bituminous	Pocahontas #3 (VA)	67%	53%
	Pittsburgh #8 (PA)	56%	65%
high-volatile bituminous	H Quest #1 (Russia)	66%	71%
	Blind Canyon (UT)	68%	60%
	Illinois #6 (IL)	72%	61%
subbituminous	Wyodak (WY)	67%	61%
	Wyodak, dry (WY)	57%	43%
lignite	Beulah (ND)	29%	30%
	Victoria Brown (Aus.)	76%	52%
biomass-coal blend	Blind Canyon (UT) / Pine	52%	45%

## DEVELOPMENT TIMELINE



2009-2011 DARPA funding supported construction of a prototype reactor at PNNL.  
 2011-2013 H Quest supported construction of a laboratory-scale system at PNNL.  
 2014-2017 H Quest Vanguard, Inc started commercialization in Pittsburgh, PA.  
 Since 2010, the process has been scaled-up 100x times.  
 Last step to commercialization: 30 kg/hr pilot system.

## PROCESS HIGHLIGHTS

- rapid, targeted heating
- low gas temperatures
- ambient pressure
- high process throughput (30 kg/hr at engineering scale)
- small reactor footprint (1 liter volume at engineering scale)

No need for thick reactor walls or costly exotic alloys and refractory materials.

## WIDE RANGE OF APPLICATIONS

- Coal conversion targeting crude oil and fuels, chemicals, and materials (activated carbon, synthetic graphite, carbon fiber).
- Natural gas conversion to higher-value chemicals and speciality carbon materials.
- Heavy oil upgrading opportunities.

## MODULAR SCALE-UP STRATEGY

