GAS TECHNOLOGY INSTITUTE

Effective Deployment of Biomass Energy Technologies – Process Demonstration and Process Intensification

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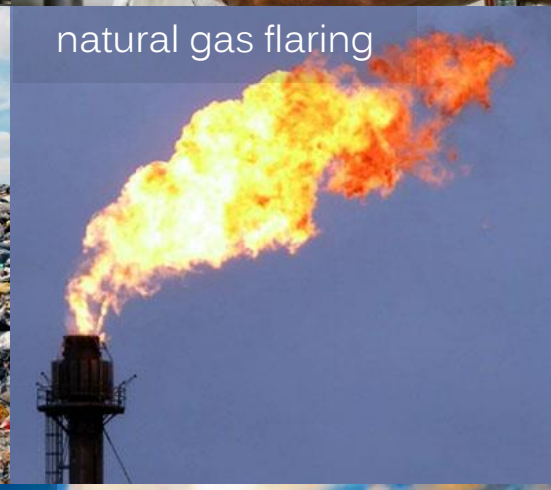
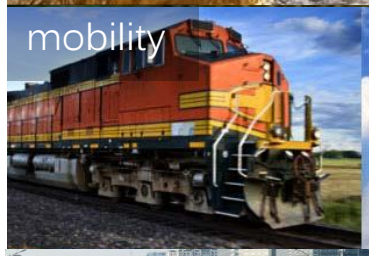
In the last decade:

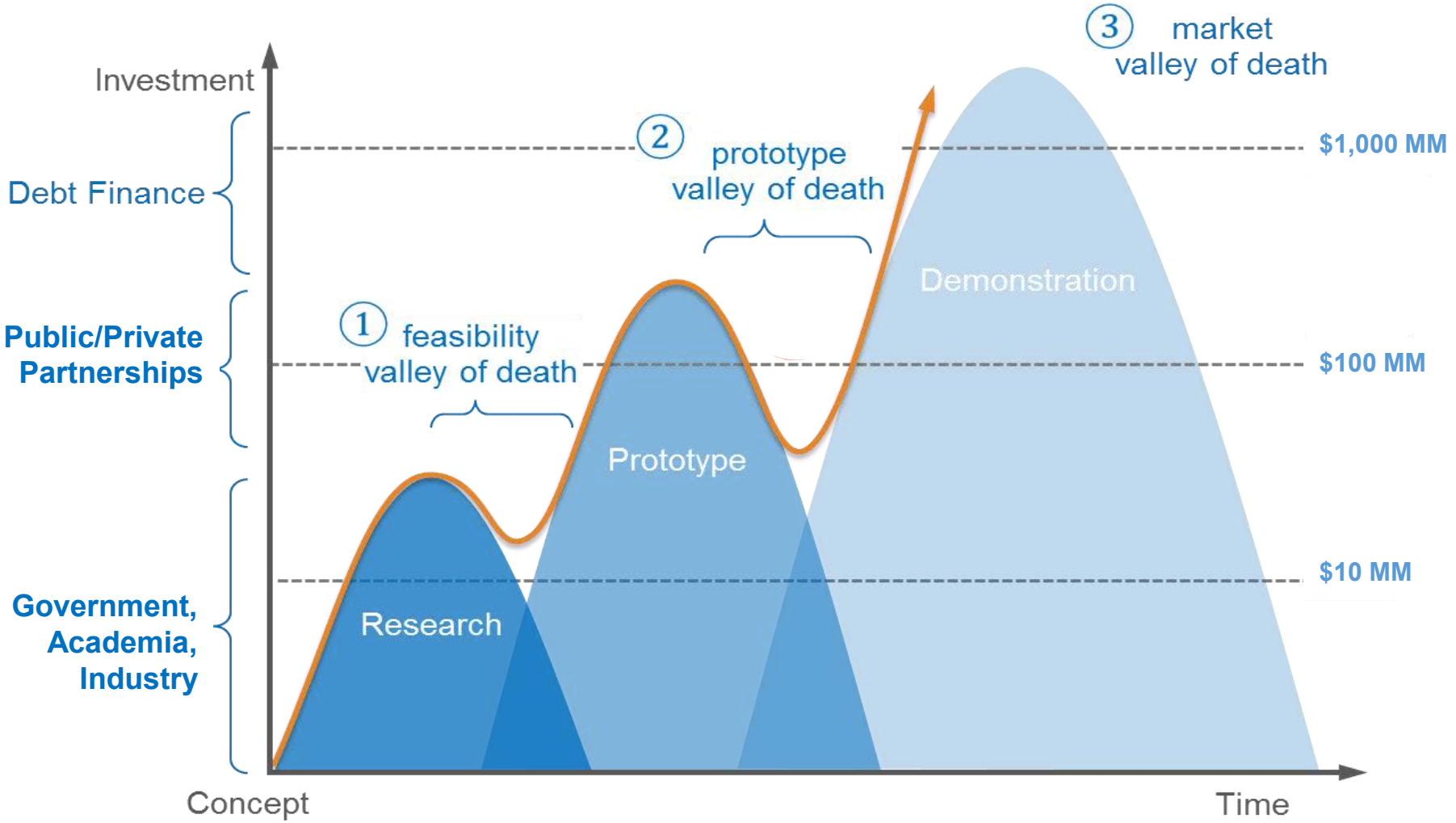
- The energy landscape has dramatically changed.
- The economic landscape has dramatically changed.
- The policy landscape has dramatically changed.

How do we translate research investments into solutions to **today's** energy problems at a pace that keeps them relevant and ultimately profitable?





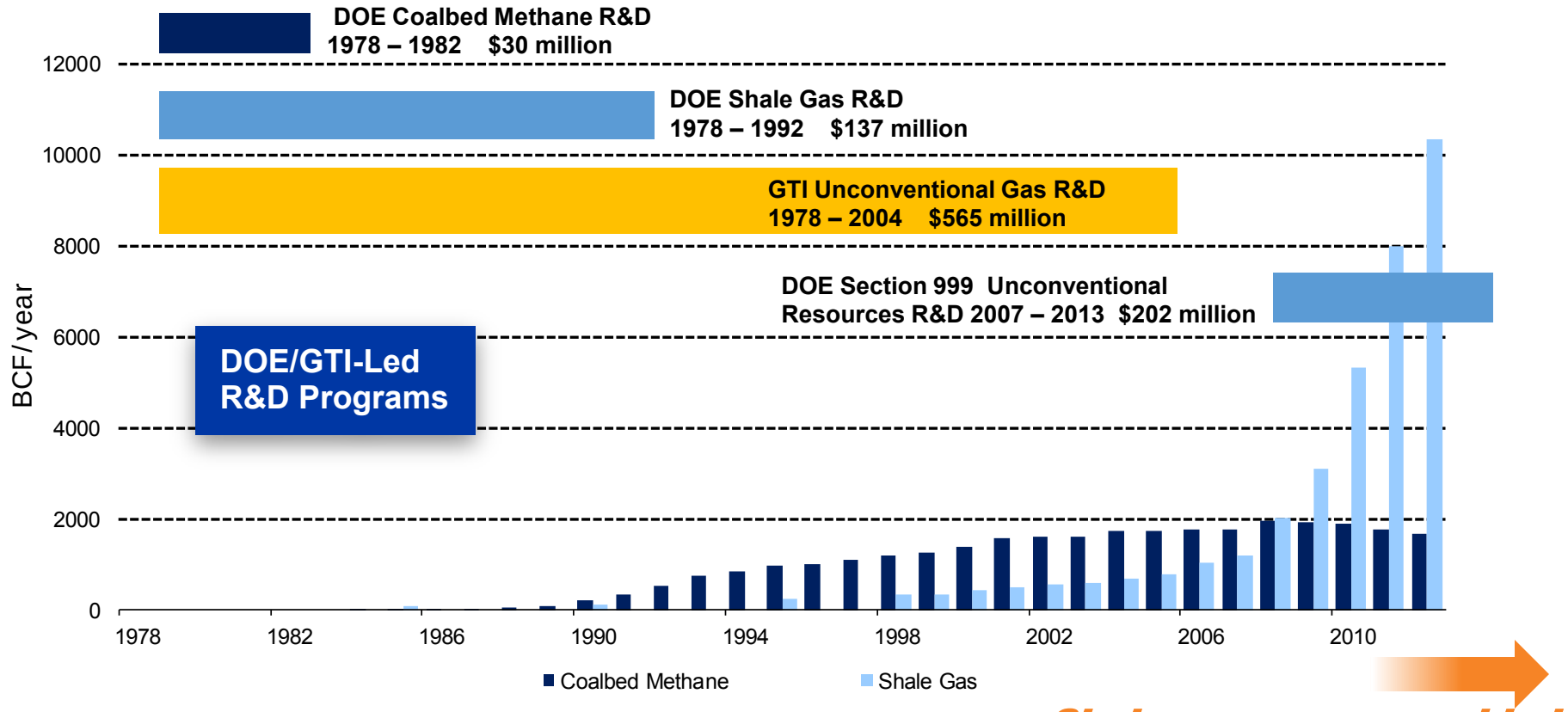
Technical Innovation Is Not Enough



Some very good technical concepts never get developed.

Some developed technologies never get to market.

Sustained Research Investments Led to "Shale Gas Revolution"



Shale resources provided 56% of U.S. gas production in 2105

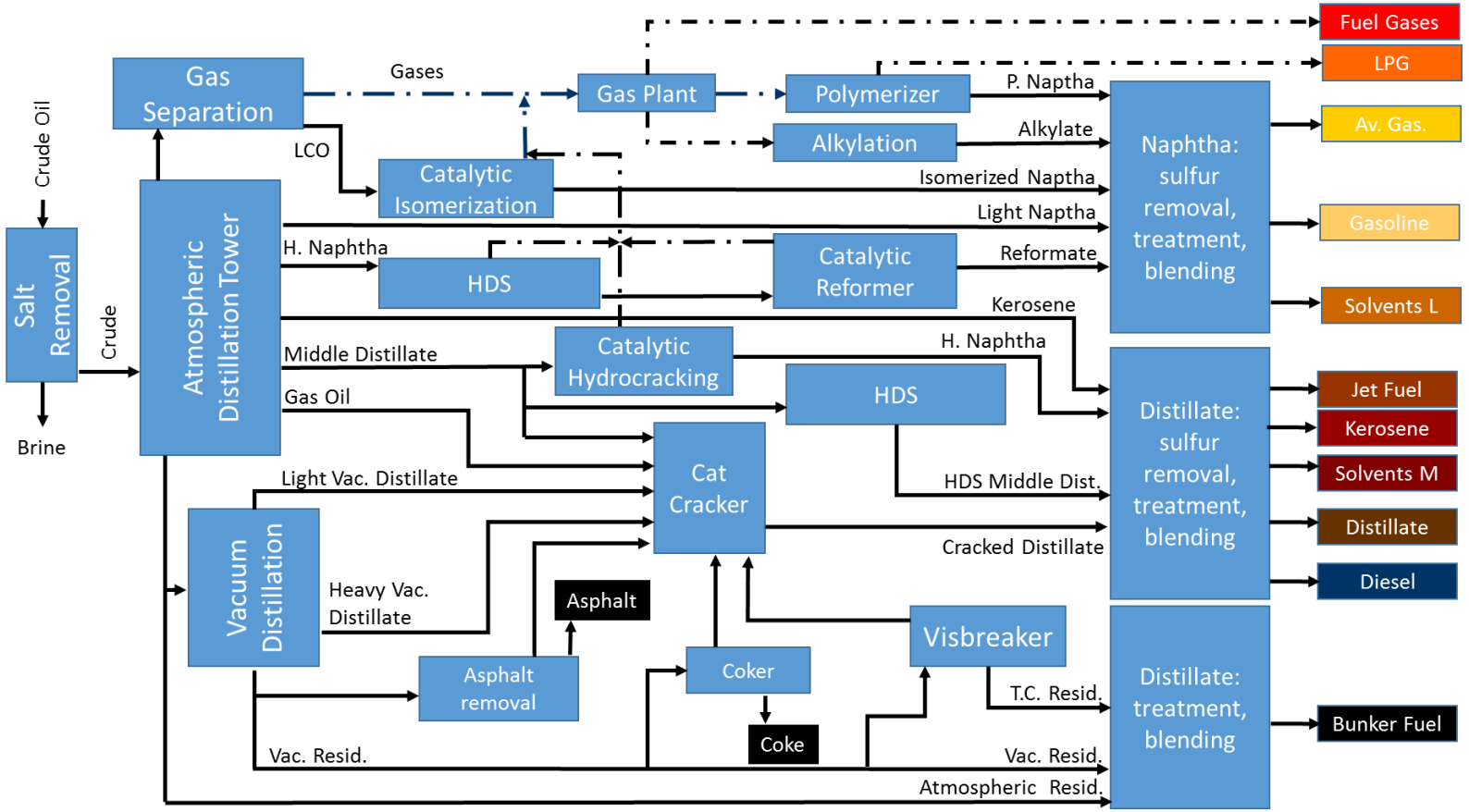
Sources: GTI, EIA, DOE, RPSEA

Advanced Biofuels – A Worthy Challenge

- Produce “drop-in” transportation fuels—gasoline, diesel, and jet-fuel
- Produce for a fuel price under $3.00 per gasoline gallon equivalent
- Be feedstock flexible, making the process attractive across geographies

Can we produce a solution for this energy challenge at a pace that is relevant and ultimately

Traditional Refining – Expensive Paradigm

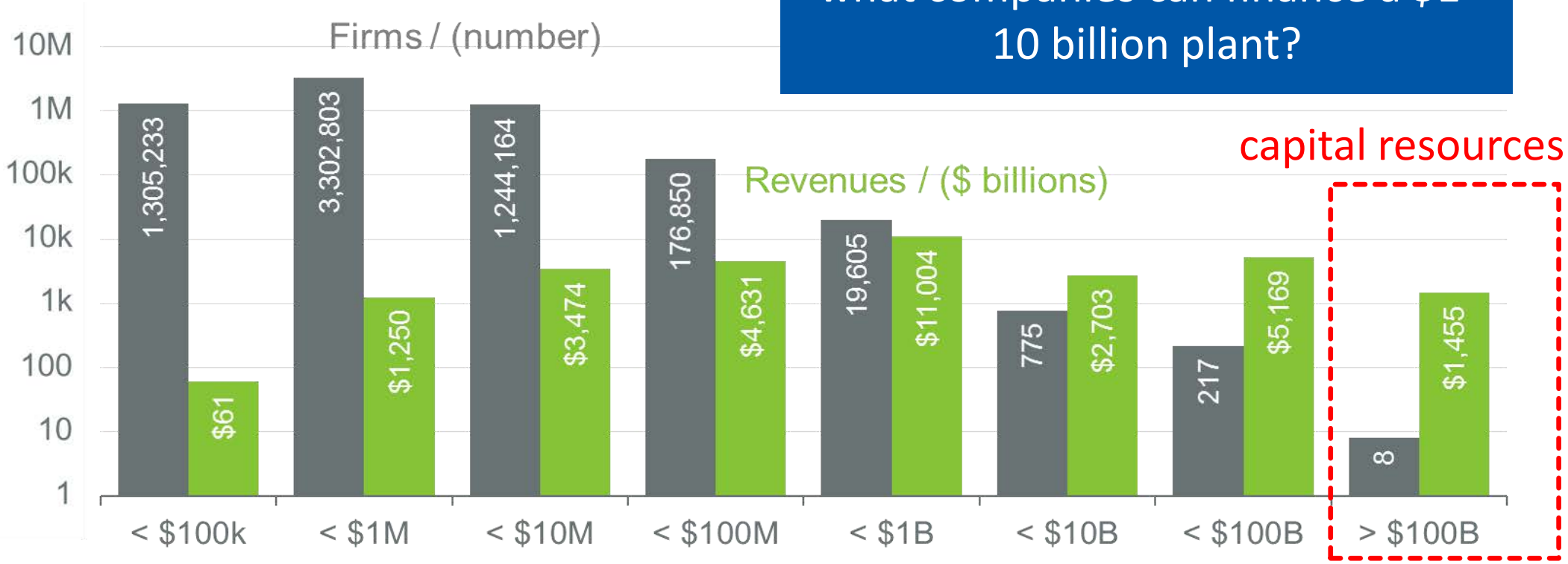


- An oil refinery is actually extremely complex – fuel is affordable only if the refineries are gigantic
- Biomass is a distributed resource: < 2000 dry tons/day scale – this would be about 1% of a 350K BPD refinery
- Biomass conversion must be simple: fewer pots and pans – more processing steps in each piece of hardware

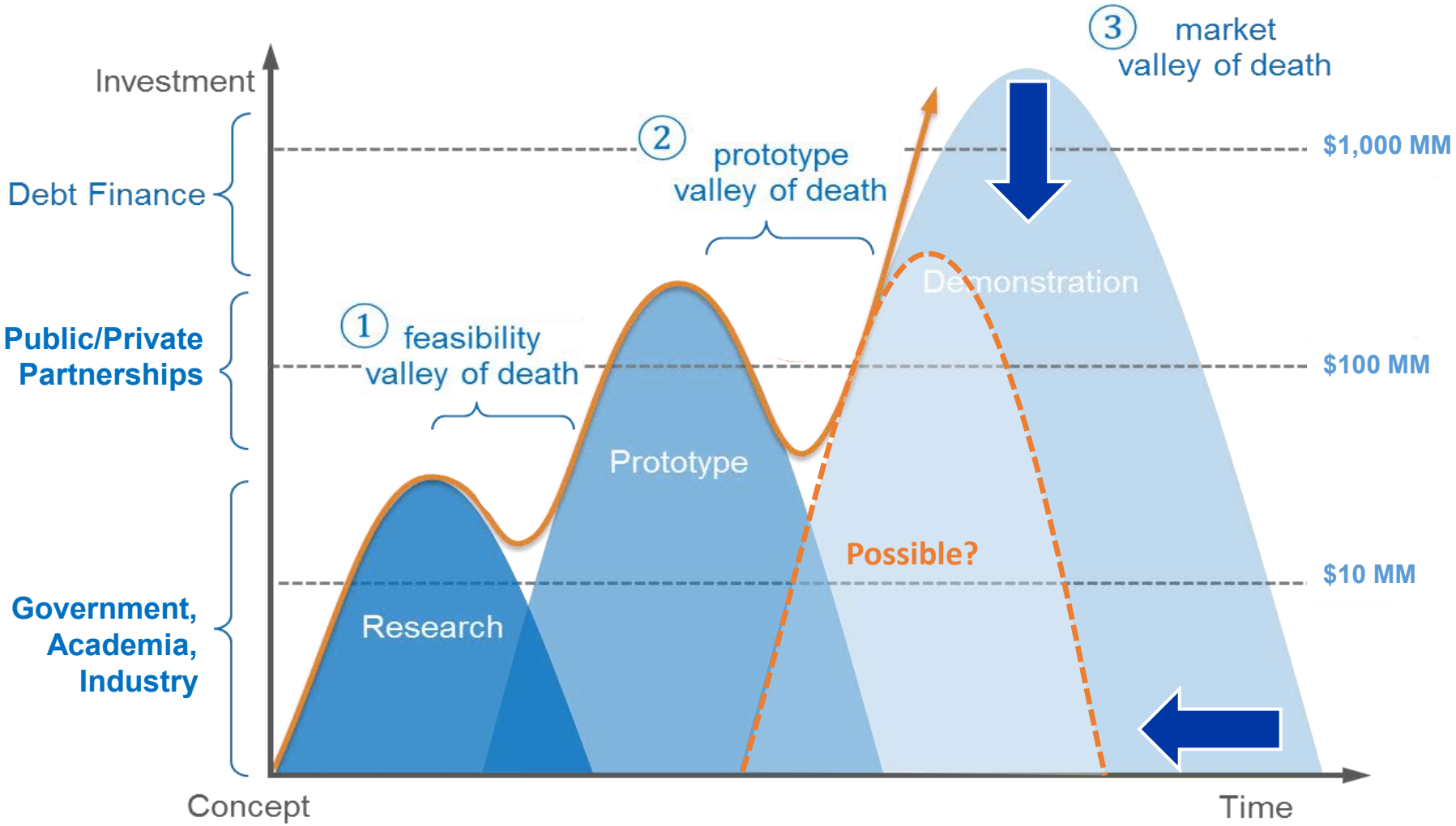
Capital Resources

U.S. COMPANIES BY REVENUE, 2007

what companies can finance a $1-10 billion plant?

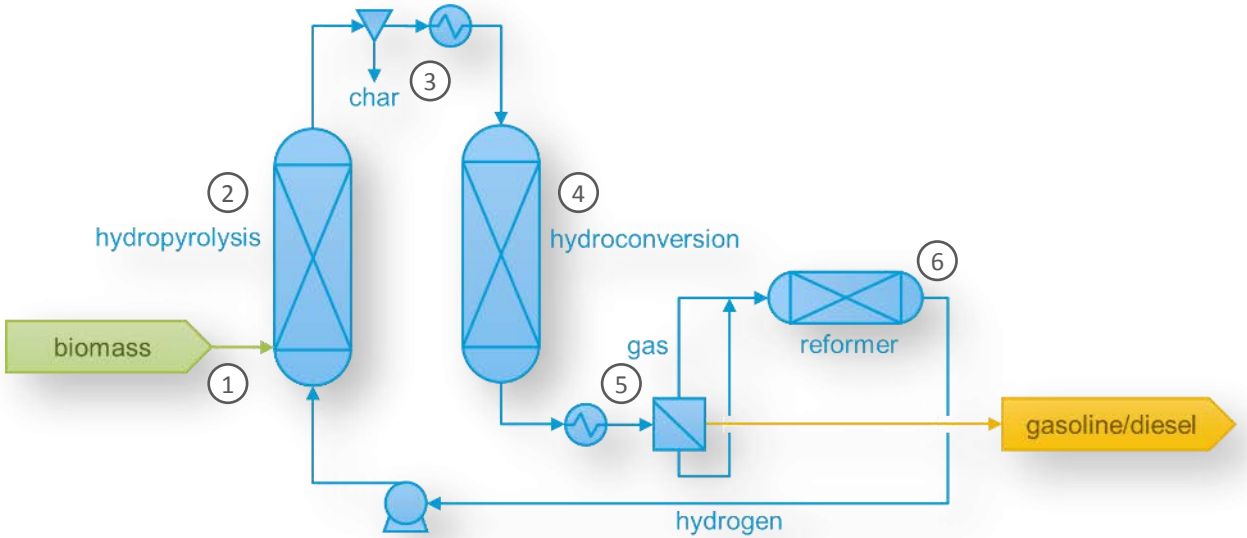


Incorporate Process Intensification Goals



Attack CAPEX and OPEX through compact, smaller-scale, process-intensified solutions.

IH²® Process for Drop-in Advanced Biofuels



Process intensification: Multiple process steps occur simultaneously in the hydropyrolysis reactor – endothermic devolatilization/exothermic deoxygenation

Process is relatively simple: small number of steps – building off competencies in key technical areas.

Easily deployed at 500-2000 dry tons/day scales; feedstock flexibility demonstrated with wood, agricultural residues, algae, and sorted waste.

Result: Produces “drop-in” fuels from biomass at $1.50 to $3.50 per gallon depending on feedstock and scale.

IH²® Process Steps to Market

RESEARCH & DEVELOPMENT

0.02 L/day

2009

1 L/week

2011

22 L/day

Component Testing

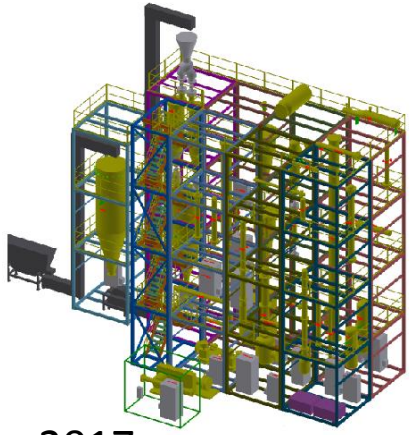
Process Design

Performance Mapping

Systems Engineering

PROTOTYPE

2000 L/day



2017

First Facility at Industrial Scale

COMMERCIAL

220,000 L/day

TBD

GTI Energy Development Center

(1951-1996)

Large pilot systems up to 18 MW_{th} scale and 70 bar pressure for conversion of coal and biomass to chemicals, syngas, methane, and hydrogen.

IH²® process development benefits from established GTI

- Fluidized Bed Reactor Systems
- Pressurized Solids Feeding
- Hydropyrolysis
- Biomass Gasification
- Char Separation and Recovery
- Project Management and

Importance of Long-Term Support for Shared Test Facilities

5 MW_{th} fully integrated and instrumented test bed for gasification, gas processing, and syngas synthesis technologies.

- Accelerates and economizes development programs.
- Gives component providers a place to prove their equipment.
- Enables technology developers to focus on their part of an integrated process.
- Allows standardized performance validation in an industrial setting.
- Integrates scientists, engineers, operators, and technicians.

A Team Effort

Many relationships, agreements, contracts, and resources must be put in place and coordinated to meet technical and pre-commercial objectives

Extensive demonstration-scale activity is essential in order for commercial-

Summary

All process development involves significant technical and financial risks – the energy sector is particularly challenging.

Long-term support for pilot and demonstration-scale facilities helps accelerate technology development and reduces technical risk.

Biomass is a geographically distributed resource, so biomass conversion must be profitable at small scale and on a distributed basis.

Process intensification lowers the economic risk and accelerates deployment.