Commercialization Considerations for Gas Conversion Technology Development

Rob Motal, Staff Consultant
Department of Energy –
Advanced Research Projects Agency workshop
Houston, Texas
13 January, 2012

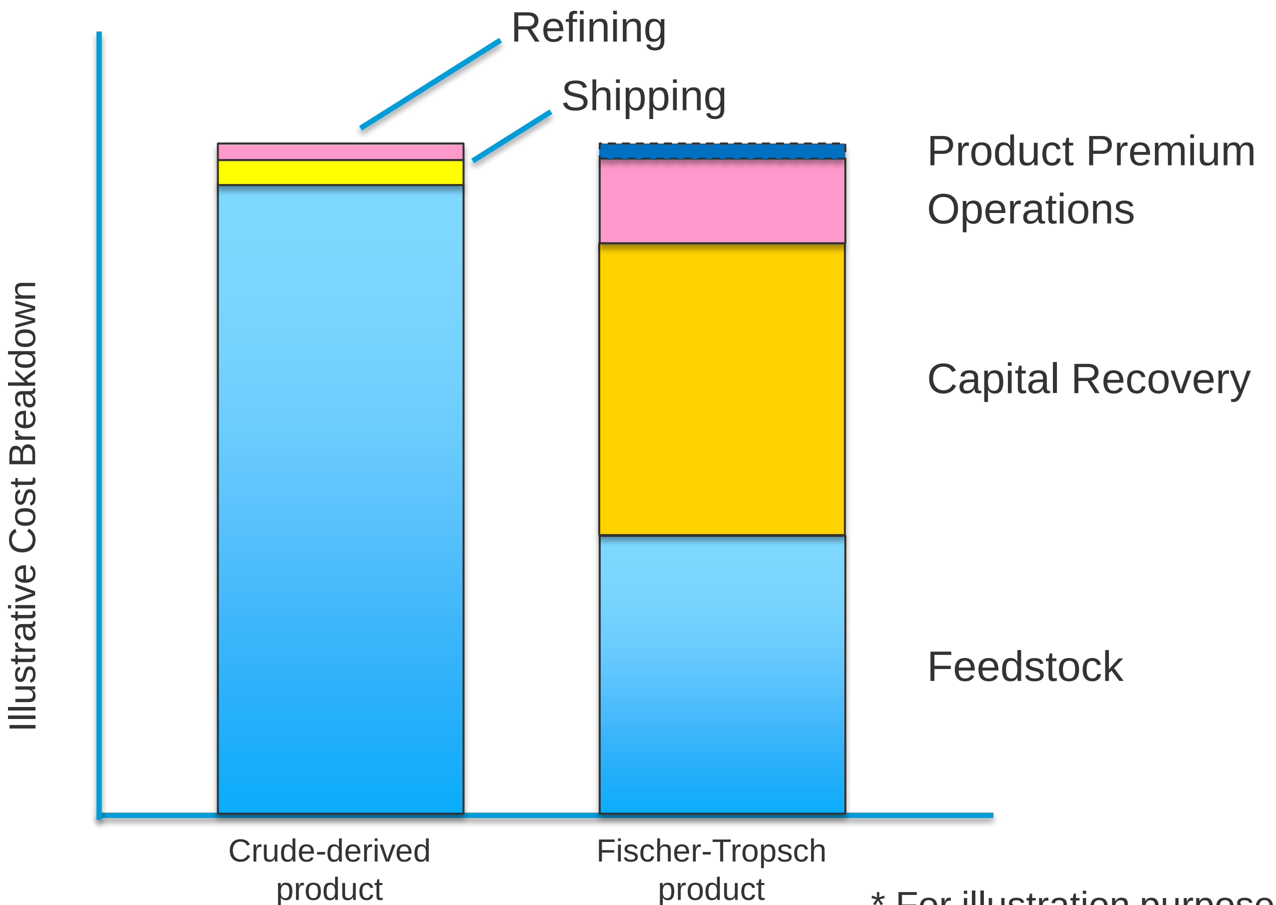
Disclaimer

•This presentation is for discussion purposes only. Neither Chevron Energy Technology Company., nor any of its affiliates (collectively, “Chevron”) makes any representations or warranties (either express or implied) as to the accuracy or completeness of the information, the text, graphics or other items contained herein or with respect to the suitability, feasibility, merchantability, title or condition of any information contained herein. To the extent the presentation contains forward looking statements by Chevron, such statements are made based on Chevron’s current assessment, and future events may change the basis for such statements. To the extent the presentation contains forward looking statements from sources other than Chevron, such statements do not necessarily reflect Chevron’s own views with respect to such information and are not endorsed by Chevron. Recipients’ use of the information contained in this presentation is at their own risk, and Chevron expressly disclaims any liability for any errors or omissions and for the use or interpretation hereof by others. No grant of any IP rights by Chevron, either express or implied, accompanies this presentation.

Content

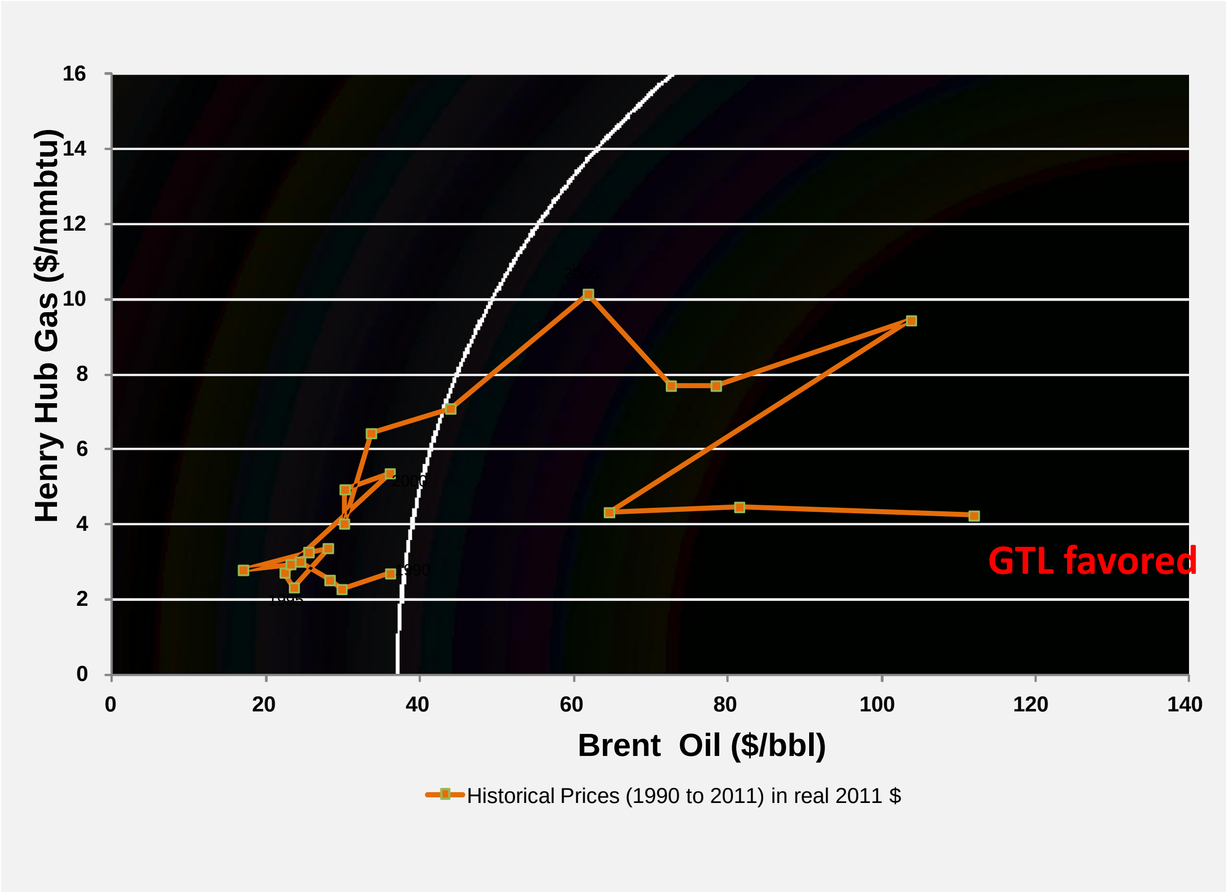
- Background
- Economic Sensitivities
- Associated gas does not drive field economics
- Commercialization will only occur if technology is proven prior to project need
- Market Size
- Sector opportunities for gas technology development

Comparing Crude-derived with Fischer-Tropsch Product Cost Buildup*



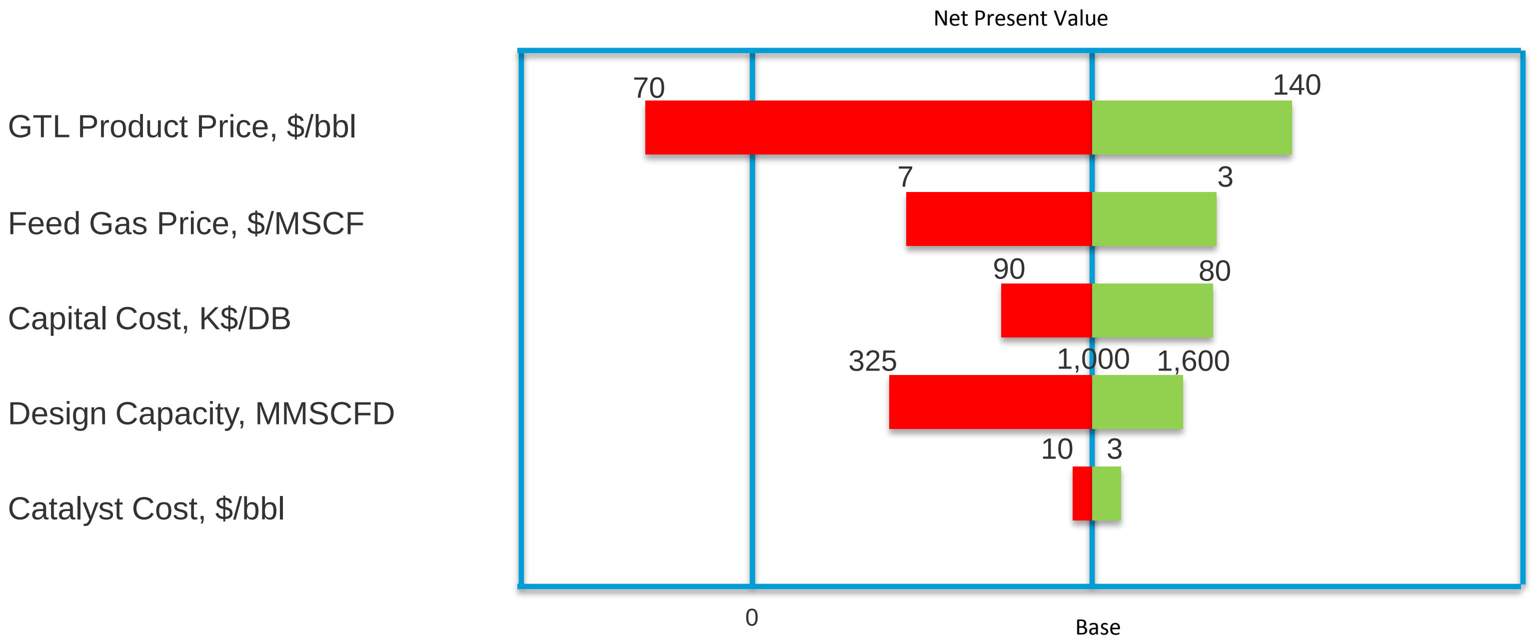
* For illustration purposes only. Not meant to represent Chevron view.

Recent Oil and Gas Price History
Shift in Oil/Gas Ratio is Recent



•Current prices make domestic and remote GTL plants economic using existing technology.

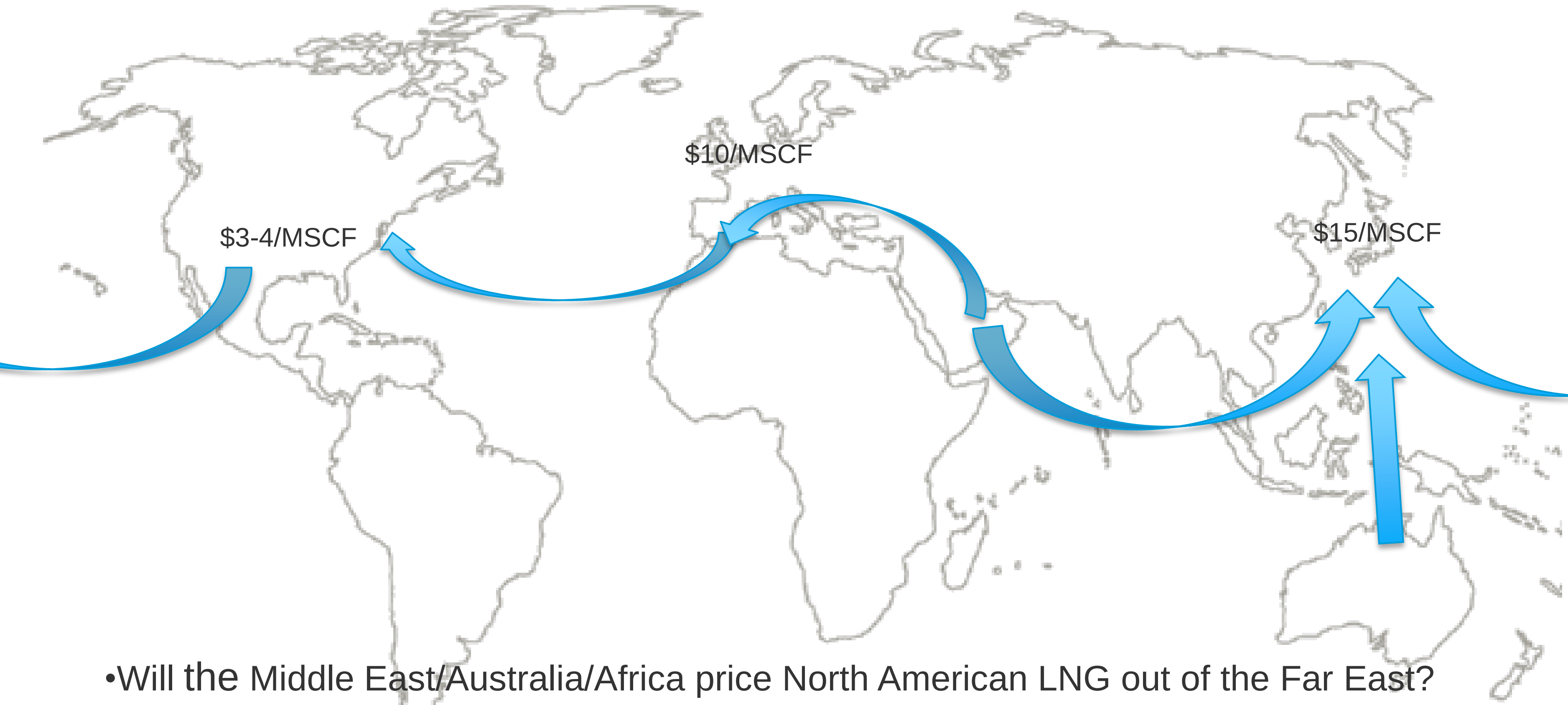
Economic Sensitivity*



- GTL plants have risks beyond control that significantly factor in investment decisions.
- Technology can improve economics through reductions in capital cost, catalyst cost and operating cost.
- Larger plants benefit from economies of scale

* For illustration purposes only. Not meant to represent Chevron view.

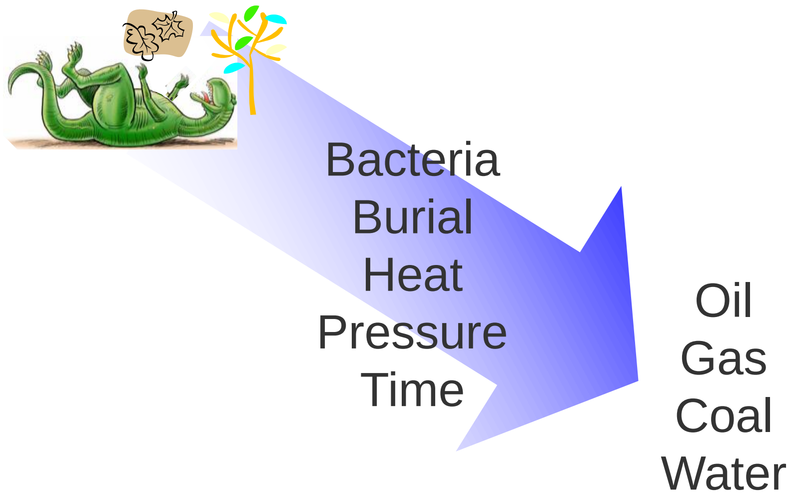
Global Gas Pricing Disequilibria

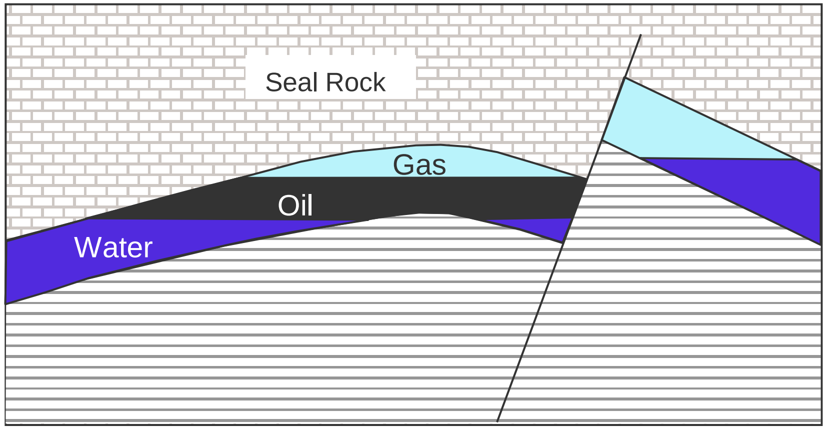


•Will the Middle East/Australia/Africa price North American LNG out of the Far East?
•Will Middle East LNG put a cap on North American gas prices?
•Will Russian gas move beyond Europe?

Gas/Oil Fields

- Industry terms:
  - Proved Gas
  - Gas cap gas
  - Dissolved gas
  - Associated gas
  - Geopressured gas
  - Gas-condensate reservoir
  - Dry gas
  - Rich gas



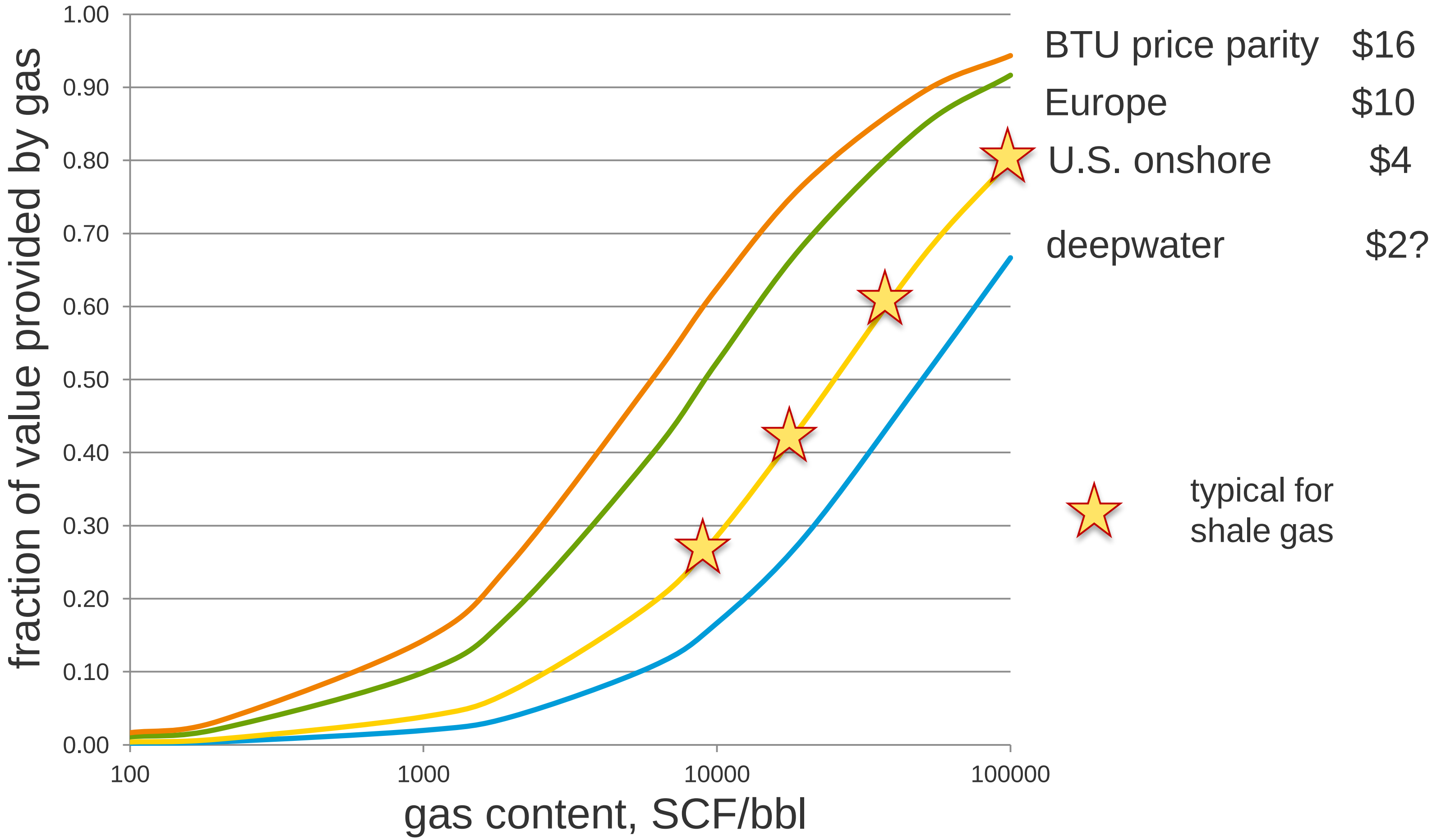


Approximate Gas Content in Hydrocarbon Resources

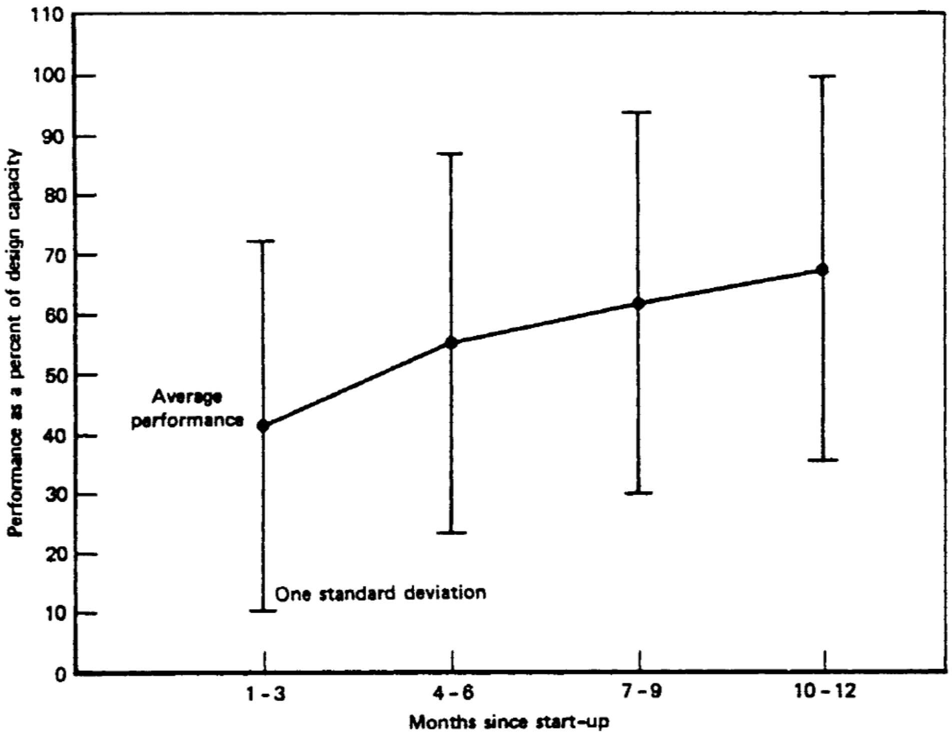
Description	GOR*, SCF/bbl
"Dead Oil"	<200
"Typical" crude oil	500-2,000
"Gassy" Oil	2,000-4,000
Gas Condensate	3,000-5,000
Rich Gas	10,000-30,000
Dry Gas	>100,000

* GOR = gas oil ratio, values shown are for discussion purposes only; they are not meant as definitions

Gas Value Contribution



New Technology Startups



- <u>Understanding Cost Growth and Performance Shortfalls in Pioneer Process Plants</u>, pg 68, 1981, RAND Merrow, Phillips, Myers. Prepared for the Dept. of Energy.

- Delays and extended periods of underperformance are not unexpected.
  - But it <u>still hurts</u> project economics!
- This study was based on detailed information on 44 process plants conceived and built during the Synthetic Fuels era.

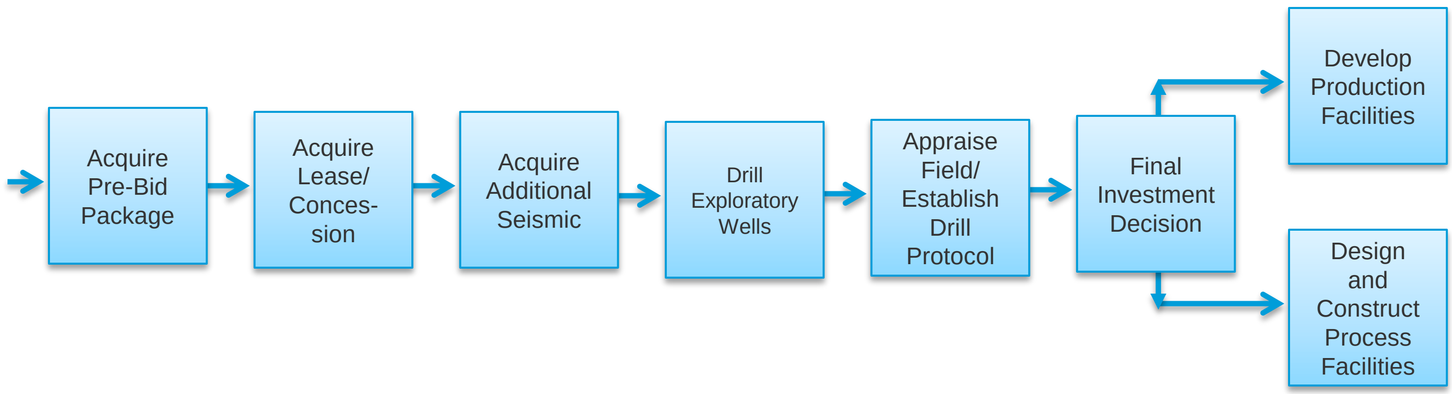
New Technology Startups

RELATIONSHIP BETWEEN PERFORMANCE PROBLEMS AND INNOVATION

Type of Innovation	Always Performed Well? Yes	Always Performed Well? No	Oryx Gas-to-Liquids
First-of-a-kind technology	5	12	√
New materials or methods of construction	0	8	√
Largest project of its type ever	7	16	√

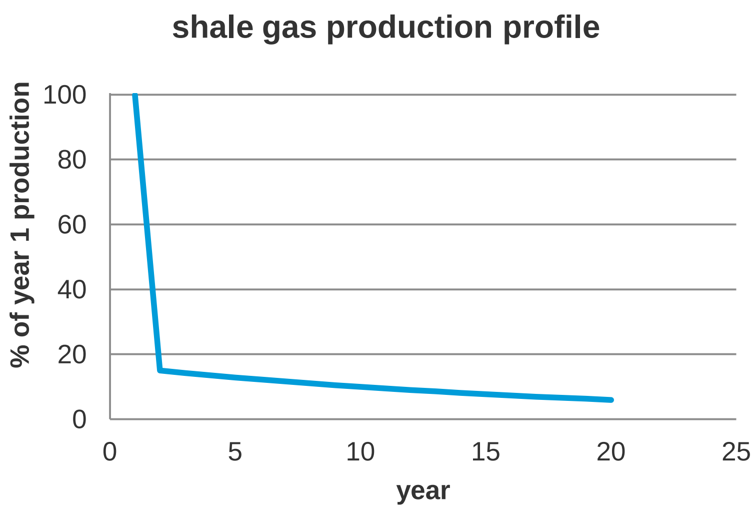
- Understanding the Outcomes of Megaprojects: A Quantitative Analysis of Very Large Civilian Projects, pg 57, 1988, RAND Merrow. Used by permission.

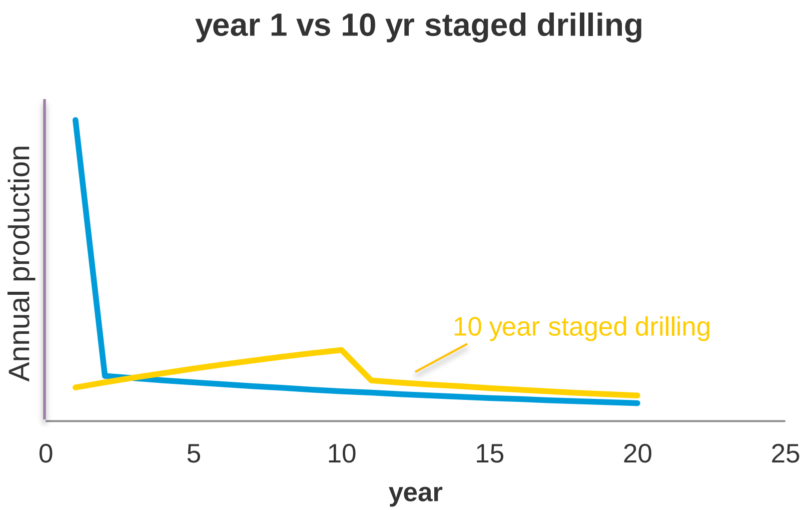
Hypothetical Gas Development



								Total
Cost								
Success Rate		**<100%**	**<100%**	**<100%**	**<100%**		**<100%**	
Risked Cost								

Hypothetical Shale Gas Production Profiles

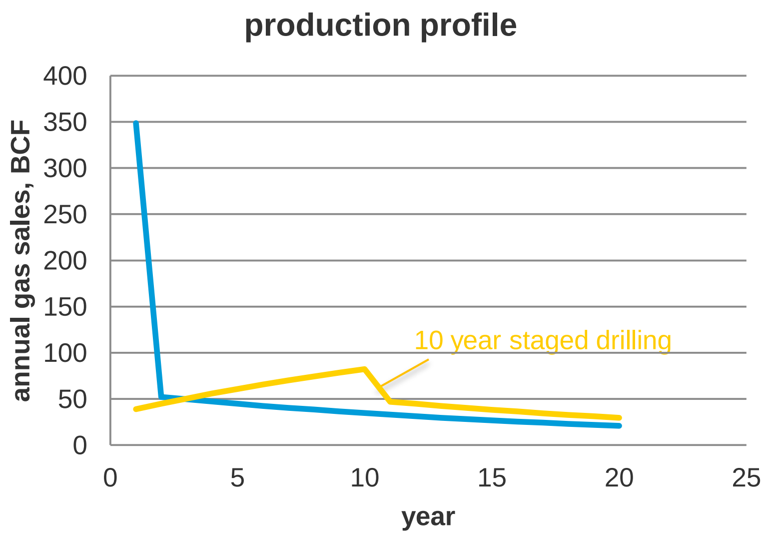




- A typical shale gas well has high production at the start as the gas close to the fractures flows easily to the well
- Once this gas is produced, production drops significantly as the gas further from the fractures must permeate through very low permeability rock.
- Process facilities designed to meet peak production will be limited to <15% utilization for the rest of the time.

- A staged drilling program is often used for shale gas to level out peaks reducing the size of the processing plant.
- A "drill all immediately" campaign requires a process plant sized to handle 35% of total field recoverable reserves per year.
  - Drilling at a constant rate for 10 years reduces the peak to less than 10% of recoverable reserves/year. Utilization increases to 65%.

Impact of Technology Delays/Failure



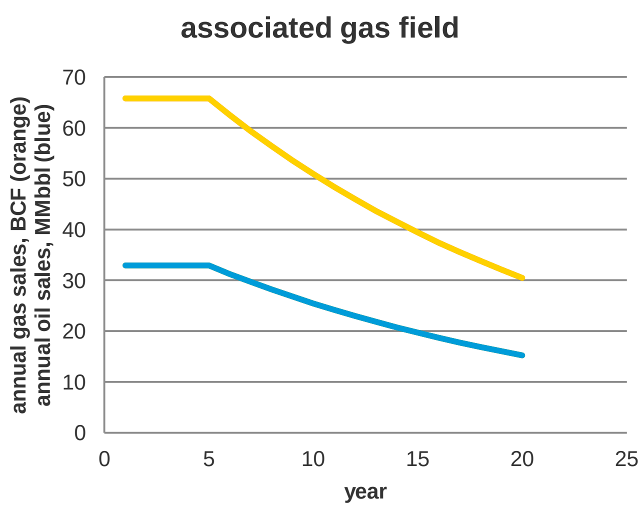
Discounted Revenue

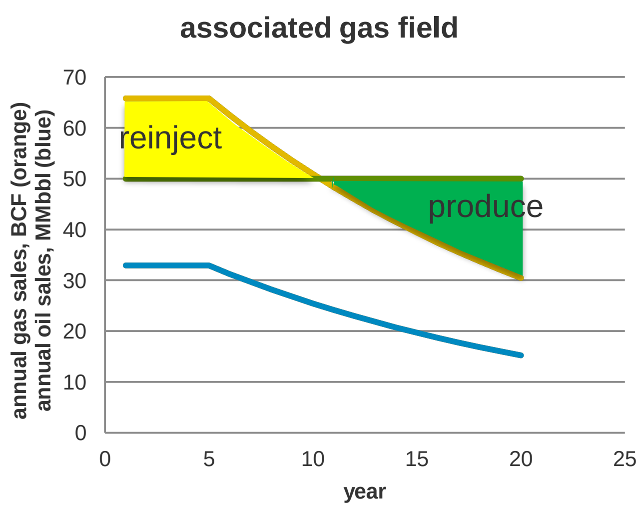
	10 yr rampup	5 yr rampup	Maximum at startup
Performs as Designed	85% of base	~base	base
FOAK * rampup, 5 yr to design	70% of base	~80% of base	80% of base
Failure	0	0	0

*FOAK = first of a kind

- Accelerating production development increases discounted revenues but at higher capital cost to handle higher peak production.
- Failure or delays of the process plant to perform at design negatively impacts project viability.

Associated Gas Production

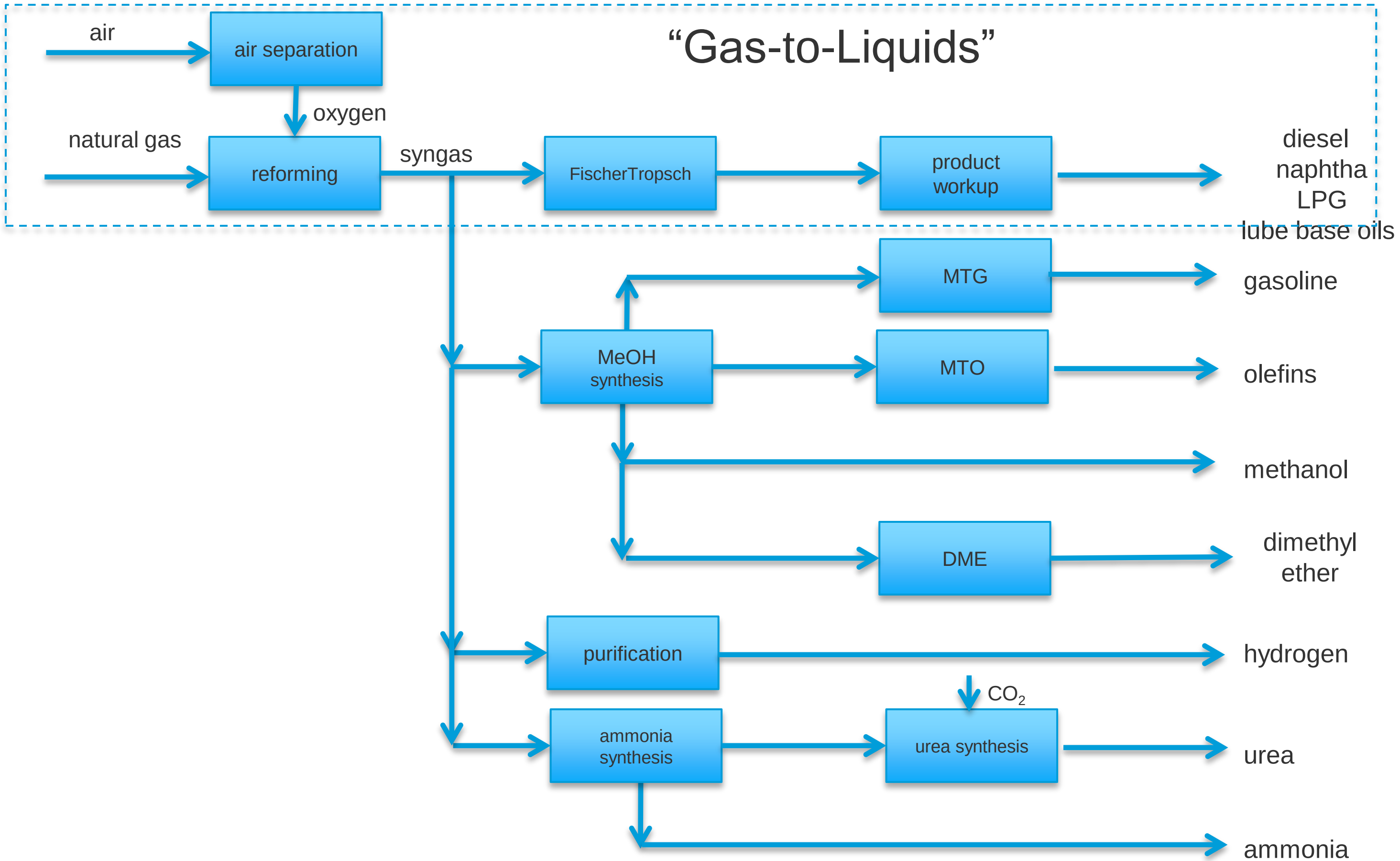




- Associated gas (solution gas) is dissolved in the oil and separates out from the oil at the surface.
  - Often these fields are developed with a flat production plateau for a number of years before decline sets in.
  - This limits the size of the topside production facilities and results in a higher utilization rate.

- The gas conversion facilities can be further downsized by reinjecting a portion of the produced gas in the early years and then use the injected gas to supplement the declining associated gas production.

Non-Fuel Products/Byproducts



Global Market Size

Product	2010 Demand	Forecast Demand Growth, 2020-2021	Feed Gas Needed for Demand Growth, 2020-2021
Gasoline	7.5bn bbl	182 MM bbl	5.5 BCFD/yr
Diesel	8.9 bn bbl	217 MM bbl	
Naphtha	2.1 bn bbl	52 MM bbl	
LPG	2.7 bn bbl	66 MM bbl	
Ammonia	130 MM tonnes	3.2 MM tonnes	0.3 BCFD/yr
Methanol	48 MM tonnes	1.2 MM tonnes	0.1 BCFD/yr
DME	~3 MM tonnes	~0.2 MM tonnes	<<0.1 BCFD/yr

8.1 BCFD/yr

* Assuming 2%/yr annual growth; 5%/yr for DME. These are FOR ILLUSTRATION ONLY; they are not meant to represent Chevron forecasts

** Assuming all growth met with gas-fed conversion units

Sector Gas Conversion Technology Challenges

- Evolutionary/Revolutionary (Conventional Shore-Based Fischer-Tropsch GTL)
- Non-Constant Feed (Shale Gas)
- Low Temperature/Lack of Infrastructure (Arctic)
- Safety/Motion Sensitivity/Footprint (Offshore)
- Once-Through, Confined Space (Downhole)

Technology Challenges – Conventional Fischer-Tropsch

Revolutionary

- Non syngas approaches
- Direct Conversion
- Biological analogues

Evolutionary

- Catalytic membranes
- Small channel reactors
- Water removal membranes in FT reactors
- Process optimization
- Power coproduction, gas turbine-based processes
- Catalyst Improvements (materials, manufacture, molecular understanding)
- Reforming burner improvements
- Computer-aided hydrodynamic reaction modeling

Technology Challenges
Non-constant production

- Transportable modular mass-produced components
- Minimizing byproducts
- Minimizing offsite utility requirements
- Reducing visibility/environmental impact
- Carbon dioxide in feed gas

Technology Challenges
Arctic

- Permafrost
- Arctic temperatures (carbon steel fracture, liquid solidification)
- Startup and restart difficulties
- Lack of infrastructure
- Mobility
- Human Issues
- Product transport

Technology Challenges
Safety/Motion/Footprint

- Safety
  - High pressure hydrogen
  - Equipment placement
  - Adequate ventilation
  - Limited egress
- Motion
  - Medium-duration wave effects
  - Longer-duration tilting
  - Motion magnification at height
  - Extreme motion operability
  - Motion-induced fatigue/wear
- Footprint
  - Expensive real estate
  - Center-of-gravity issues

Technology Challenges Downhole

- Diameter limitations (5-10”)
- Once-through
- 200-400°F
- 50-15,000 psi
- Varying pressure/feedrate
- Contaminants (H_2S, CO_2, mercury, salty water, sand, production fluids, diamondoids, higher hydrocarbons)