GAS-TO-LIQUID TECHNOLOGY

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Alaska Legislators Delegation

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A HOT TOPIC IN ALASKA

COMPASS: *Other points of view*

Gas to liquids a win/win/win proposition

By SEN. BILL WIELECHOWSKI

From .8 billion cubic feet of natural gas a day, a fraction of what a potential big gas pipeline would deliver to Valdez or Alberta, a GTL plant could produce more than 100,000 barrels of liquid petroleum product.

The question of how to increase throughput in the Trans-Alaska Pipeline System (TAPS) has recently dominated the conversation across the state. I believe we should take a closer look at building a gas to liquids (GTL) plant on the North Slope to help solve this problem.

GTL plants convert natural gas into high-quality refined petrochemicals that sell for a premium, like ultra-clean jet fuel, diesel and propane. This is done through a chemical process developed prior to World War II that is currently being used in places like Qatar, South Africa and Malaysia. From .8 billion cubic feet of natural gas a day, a fraction of what a potential big gas pipeline would deliver to Valdez or Alberta, a GTL plant could produce more than 100,000 barrels of liquid petroleum product.

These premium petroleum products could be shipped down TAPS, either in batches or mixed in with the crude to increase its value and volume. With another 100,000-plus barrels of petrochemicals flowing through the pipeline each day, a GTL plant would lower tariffs and extend the life of TAPS. A GTL plant would also lead to new exploration on the North Slope once oil companies know they will be able to sell the gas, which would likely lead to the discovery of new oil fields.

With low natural gas prices and skyrocketing oil prices projected into the foreseeable future, a GTL plant looks better than ever. According to the state Department of Revenue, even with a very high estimate for construction costs, at today's oil prices the internal rate of return for a GTL plant on the North Slope would be more than 12 percent. With more realistic cost estimates, the return hits 15 percent. With returns like this, a GTL plant on the North Slope merits consideration. And this state report assumes that the GTL plant will only be 60 percent efficient, whereas modern GTL plants can achieve up to 90 percent efficiency. A GTL plant on the North Slope could generate 300 megawatts of energy from the "waste" heat, which would provide a source of low-cost energy, plus millions of gallons of pure water that could be used either for drinking or for building ice roads.

Finished products from GTL plants are highly desirable. The Department of Revenue estimates that consumers will pay 30 percent more for GTL petroleum products than for North Slope crude This is because the products are already refined and virtually free of sulfur and other impurities. GTL plants also separate CO_2 during the conversion process, which can be used to produce more oil and keep greenhouse gases out of the atmosphere through enhanced oil recovery.

Building a GTL plant on the North Slope would not prevent us from pursuing other natural gas projects. Since a GTL plant on the North Slope that produces more than 100,000 barrels of petroleum products a day would only use .8 BCF of natural gas a day, there would still be plenty of gas left for an in-state gas pipeline, or even a larger line to Alberta or Valdez for export.

Sen. Lesil McGuire (R-Anchorage), Sen. Tom Wagoner (R-Kenai) and I introduced Senate Bill 109, which lowers construction costs for companies looking to build a GTL plant on the North Slope. Construction of a GTL plant would create hundreds of new full-time construction and operations jobs on the North Slope and provide billions in revenue to the state and oil companies.

A GTL plant on the North Slope is a win/win/win solution. Oil and gas producers could finally monetize their natural gas reserves, while using the carbon dioxide to help bring even more oil into TAPS. The addition of 100,000-plus barrels per day into TAPS would lower tariffs and extend the life of the pipeline. Most important, Alaskans would have greater fiscal security and stability.

It's time for Alaskans to think big. We have the opportunity to take our destiny into our hands. Gas to liquids could be a key that helps keep oil flowing through TAPS for the next 40 years.

Sen. Bill Wielechowski, D-Anchorage, is vice chair of the Senate Resources Committee.

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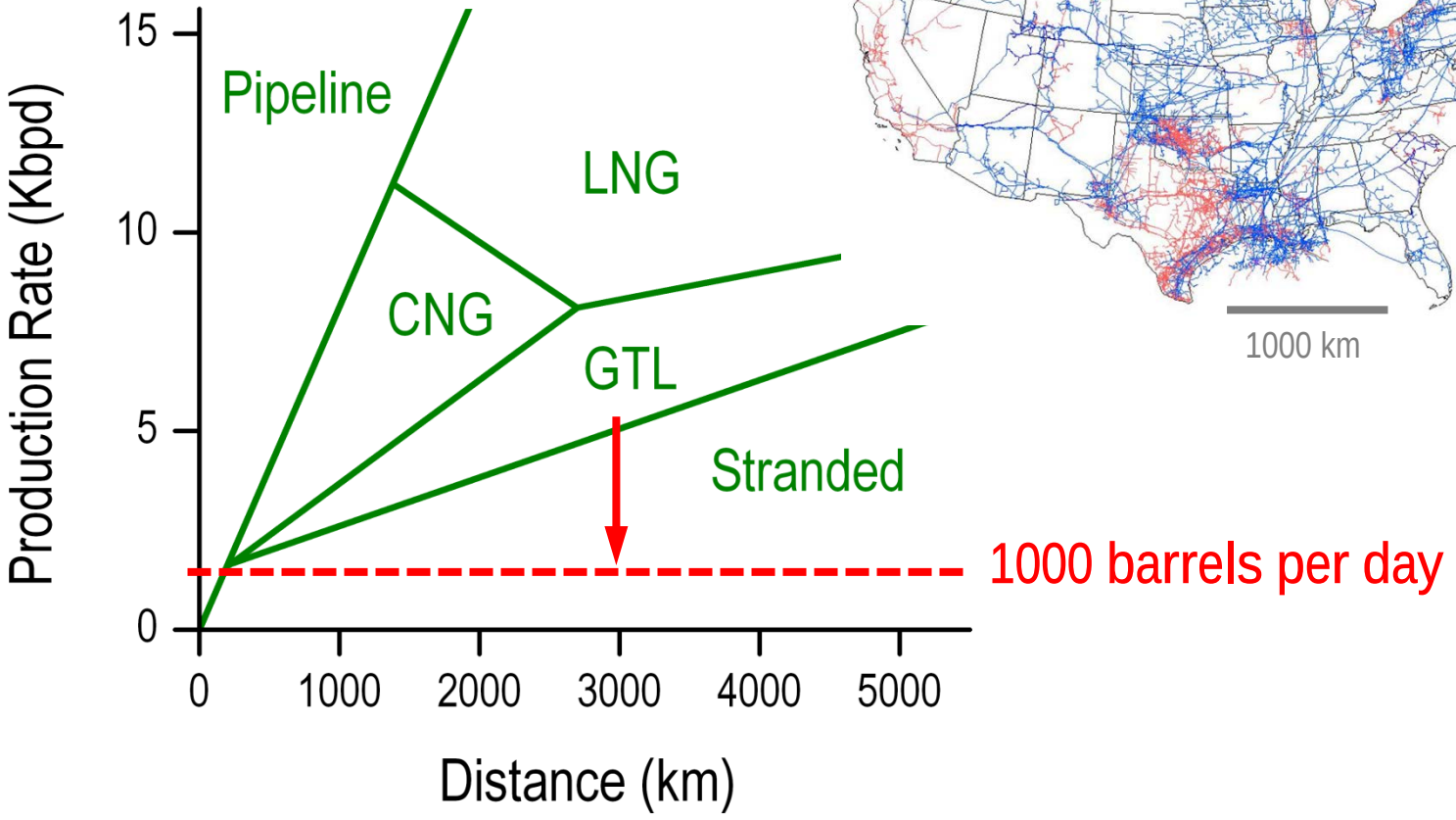
Sen. Bill Wielechowski

Why consider gas-to-liquid technology?

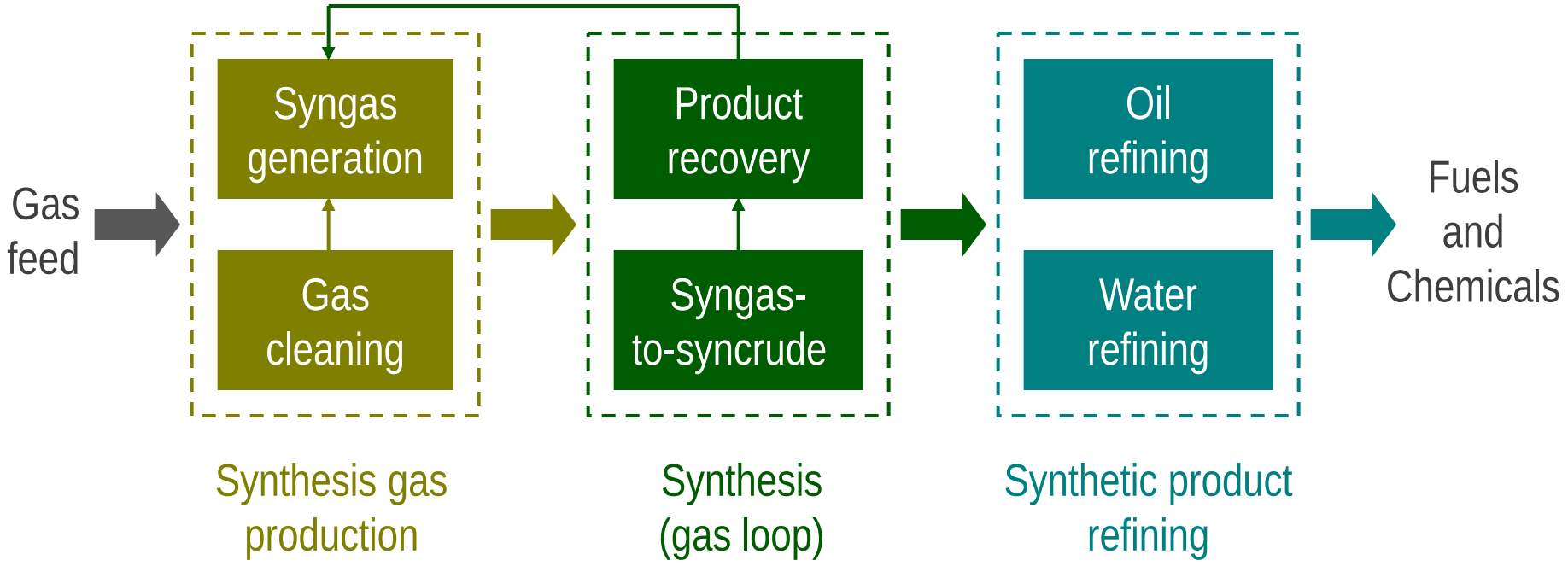
ECONOMICS OF TRANSPORTING NATURAL GAS



[1] D. Hawkins, TransOcean,Global, Gas Flaring Reduction Conference, Paris Dec 13-15, 2006

How is natural gas converted into liquid fuels today?

FISCHER TROPSCH GAS-TO-LIQUIDS



[2] Aron de Klerk, U of Albany, 2011

GAS-TO-LIQUID ECONOMICS

GTL Facility	Company	Capacity	Capital Cost[5]
Pearl	Shell	140,000 bpd[3]	~ $110,000/bpd
Escravos	Sasol-Chevron	33,000 bpd[4]	~ $180,000/bpd
Sasol I expansion	Sasol	---	~ $200,000/bpd

- Payback = $150,000/bpd ÷ $80/boe = 5 years
- FT-GTL is economically attractive at current market prices

bpd = barrels per day
boe = barrels of oil equivalent

[3] A. de Klerk. Gas-to-liquid conversion. ARPA-E natural gas conversion technologies workshop. Houston TX, January 13, 2012.
[4] Pearl GTL - an overview. Shell, 2012. http://www.shell.com/home/content/aboutshell/our_strategy/major_projects_2/pearl/overview/
[5] B. Reddall. Cost of delayed Chevron Nigeria plant now $8.4 bln. Thomson Reuters. 24 Feb 2011.

If the cost of gas-to-liquid technology is not the barrier, what is?

MEGA-PROJECT ECONOMICS

Shell Pearl GTL Facility, Qatar

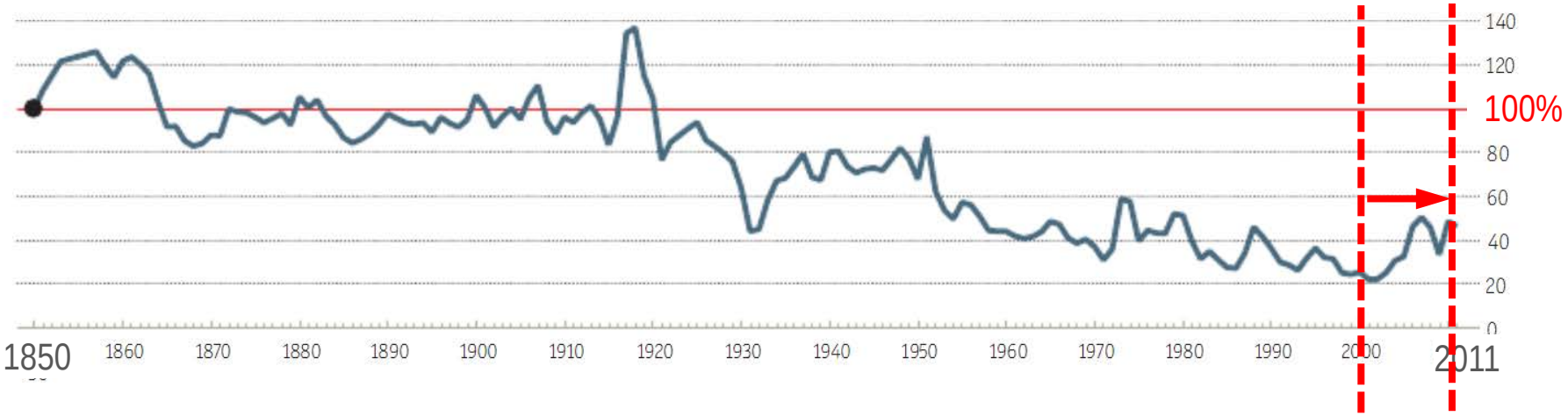
The RAND Corporation Study

- 52 mega-projects
- $0.5B and $10B (1984 dollars)
- Over budget average 90%

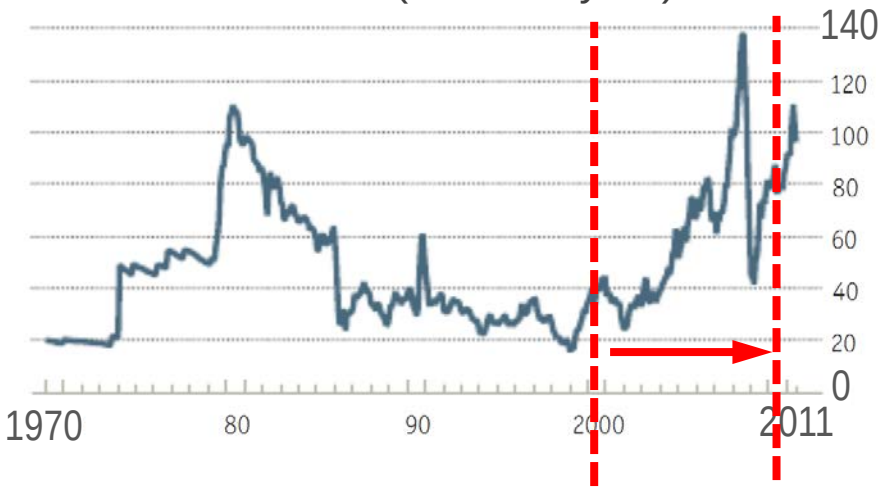
[6] E.W. Merrow. Understanding the outcomes of megaprojects: a quantitative analysis of very large civilian projects, The RAND Corporation, Santa Monica, CA, 1988.

MARKET TIMING RISK

Metal Commodities Price Index (percent vs. year)



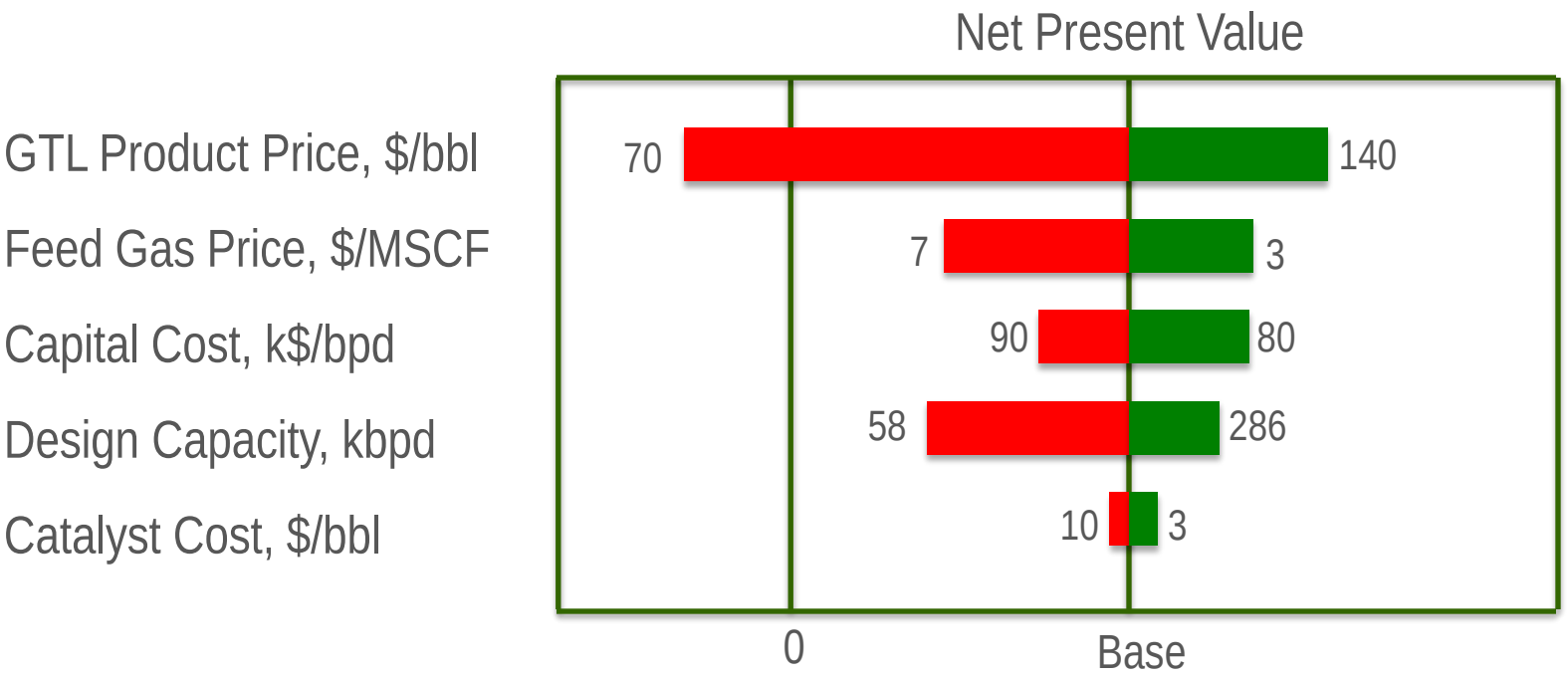
Oil Price ($/bbl vs. year)



project construction

Source: *The Economist*, Thomson Reuters, 2012

ECONOMIC SENSITIVITY



Economics of GTL are most sensitive to the product price

[7] R. Motal. Commercialization Considerations for Gas Conversion Technology Development. *ARPA-E natural gas conversion technologies workshop*. Houston TX, January 13, 2012.

FINANCIAL RISK

financial risk = f (time, size)

- Time
  - Market product prices
  - Material costs
  - Lost operation time
- Size
  - Mega projects 90% over budget
  - Investment risk function of market capitalization
  - Equates to high complexity

The challenge for gas-to-liquid technology is not high cost, it is high risk

ECONOMIES OF SCALE

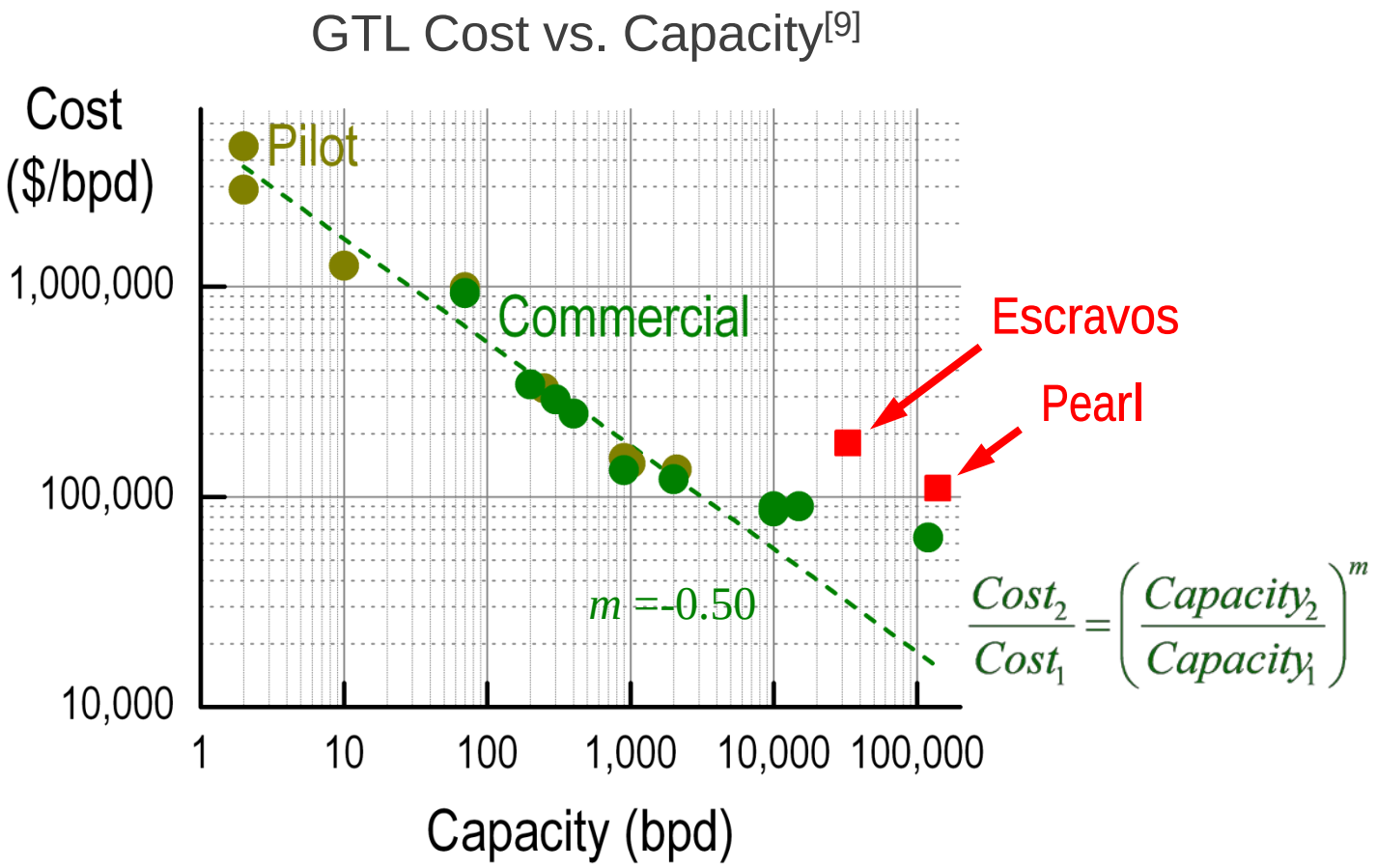
Current paradigm in the chemical process industry

- Economies of scale -- “bigger is better”
- Cost (materials) $\propto$ Area [D^2]
- Revenue (capacity) $\propto$ Volume [D^3]
- Williams equation[8]
- m = 0.38-0.90

$$\frac{Cost_2}{Cost_1} = \left(\frac{Capacity_2}{Capacity_1} \right)^m$$

[8] R. Williams. Standardizing cost data on process equipment. *Chemical Engineering*, 54(6):102, 1947

ECONOMIES OF SCALE



[9] PJA Tijm. *Gas to liquids, Fischer-Tropsch, advanced energy technology, future's pathway*. Feb 2010.

IS BIGGER BETTER?

Sasol-Chevron Fischer-Tropsch Reactor

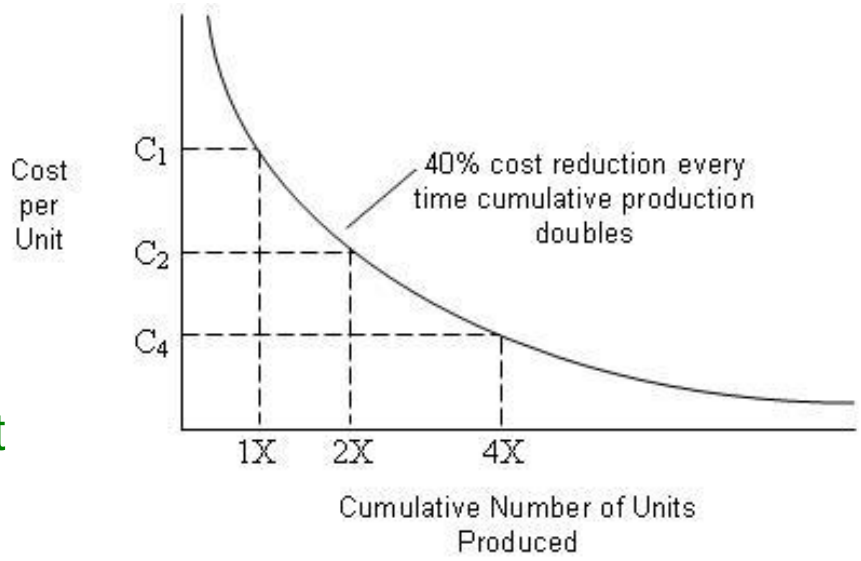
[10] C. Kopp. The US Air Force Synthetic Fuels Program. Technical Report APA-TR-2008-0102. (2008)

How do we get down new cost reduction learning curves for GTL technology?

EXPERIENCE LEARNING CURVES

- 1960s Bruce Henderson of the Boston Consulting Group
- 15% cost reduction every doubling of output – the “85% experience curve”
- Henderson’s Law[11]
  - n: number of units
  - a: elasticity of cost with regard to output

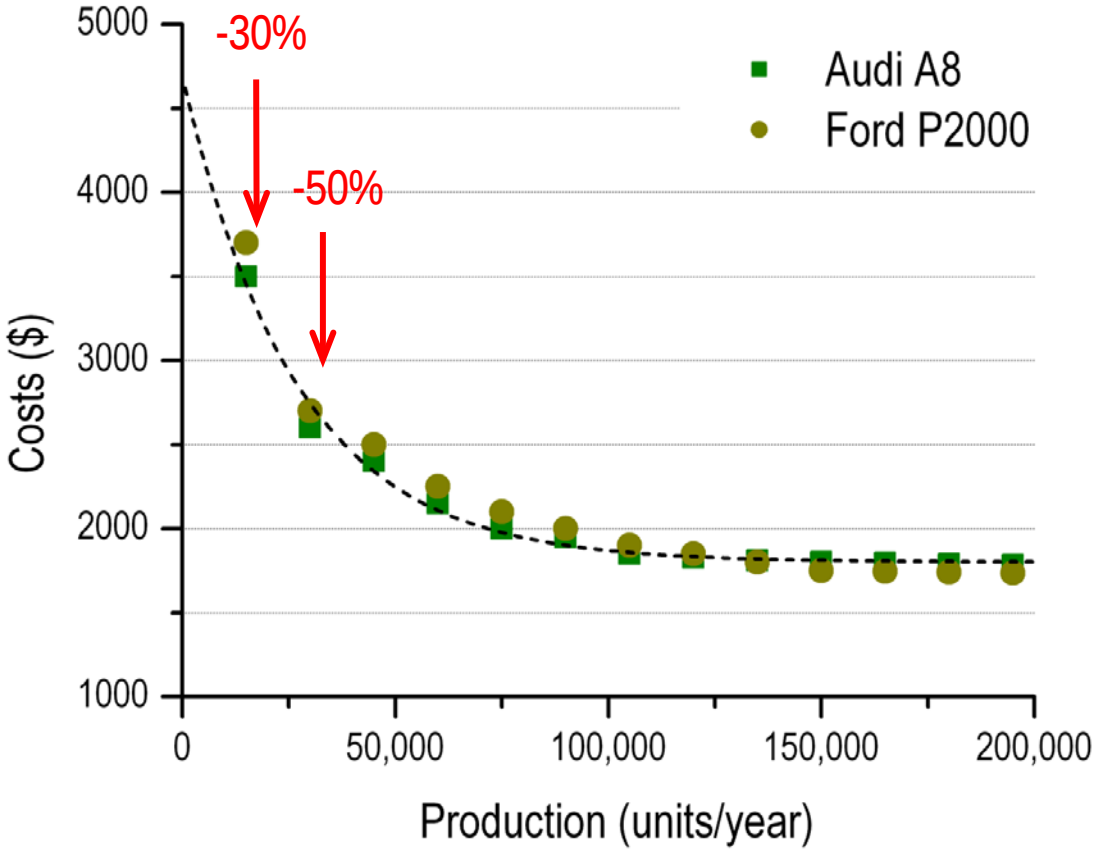
$$Cost_n = Cost_1 n^{-a}$$



[11] A.C. Hax, N.S. Majluf. Competitive cost dynamics: the experience curve. *Interfaces* 12(5):50-56, 1982.

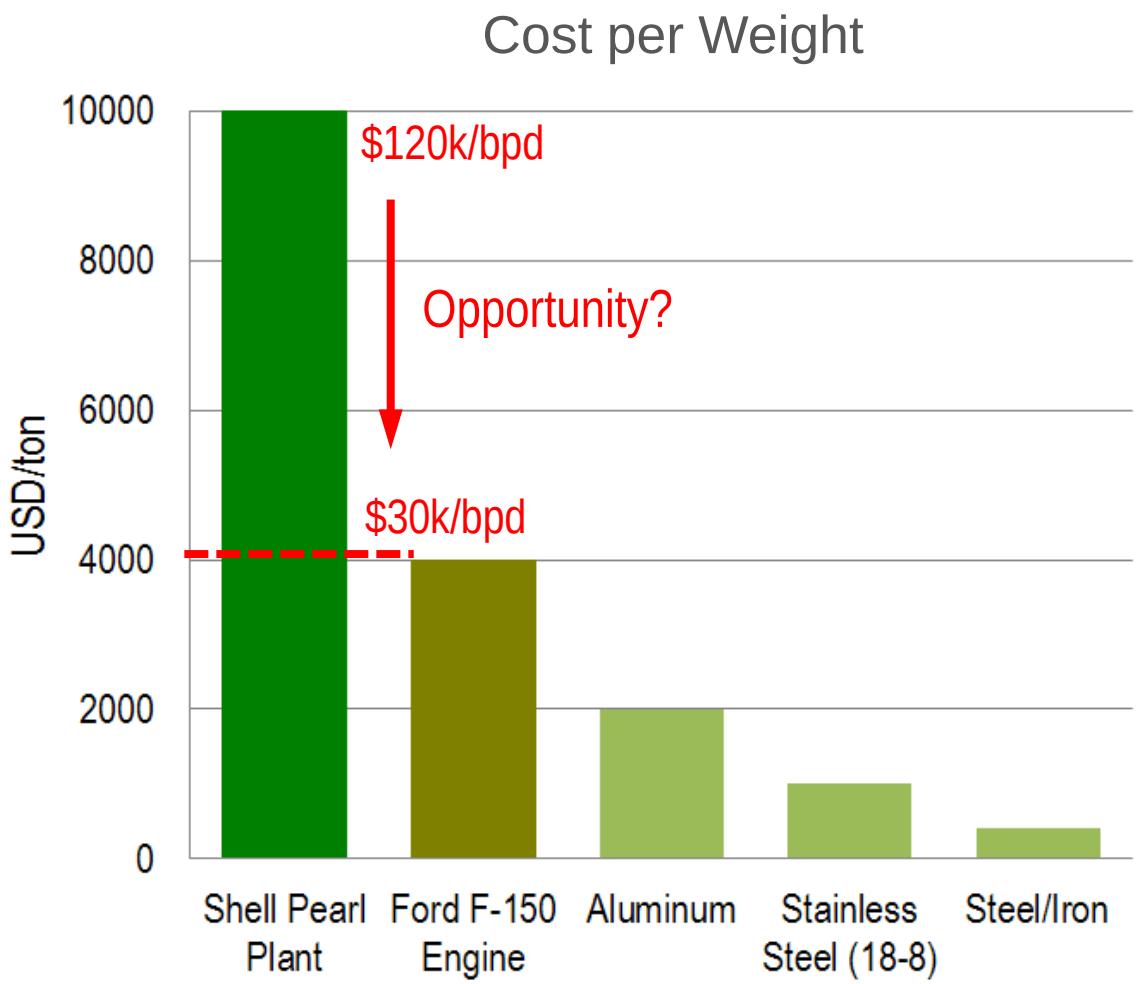
EXPERIENCE LEARNING CURVES

Total Production Costs of Midsize Cars[12]

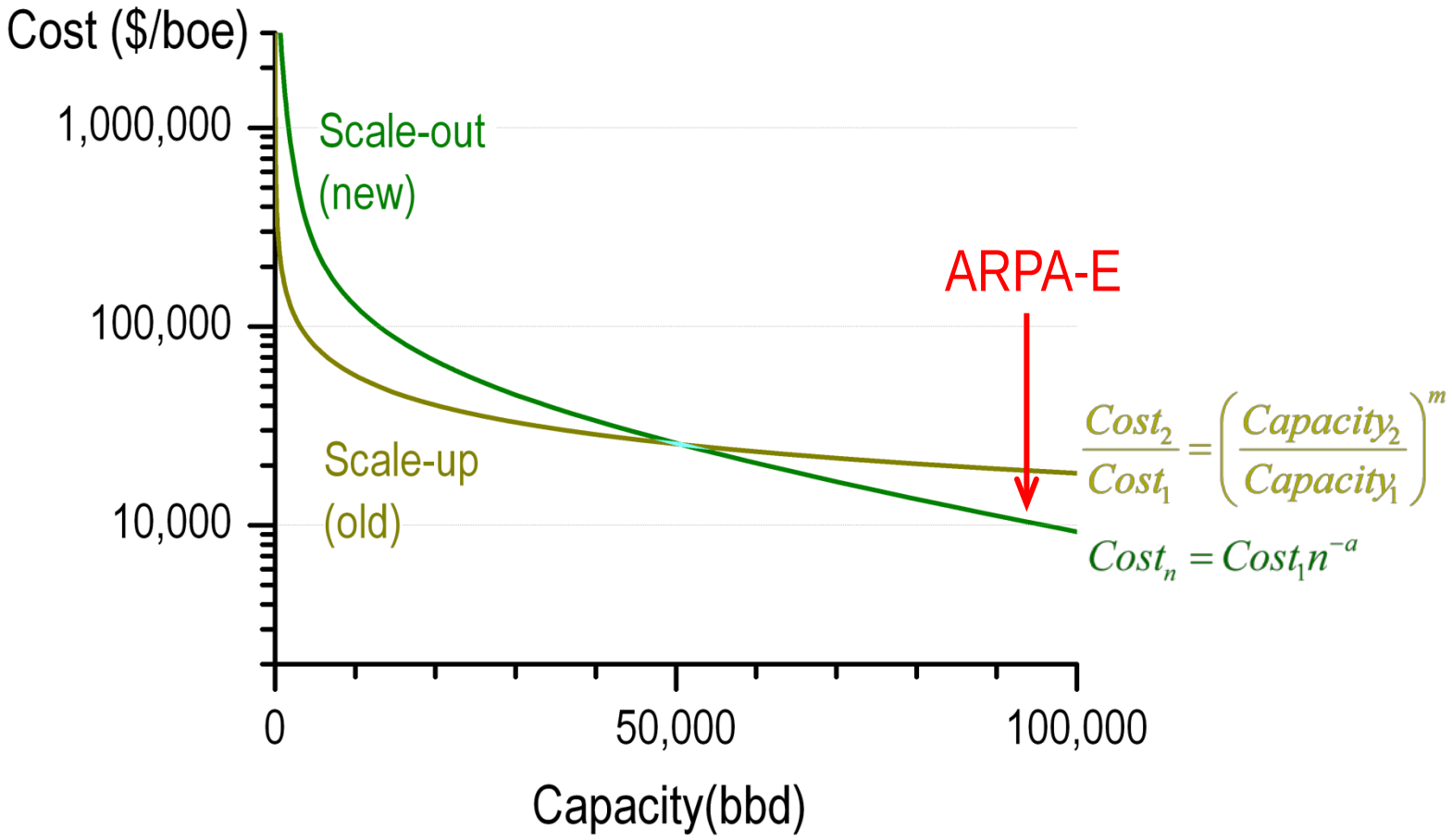


[12] A Kelkar, R Roth, J Clark. Automobile Bodies: Can Aluminum Be an Economical Alternative to Steel? *JOM* 53(8):28-32.2001

COMMODITIES VS. GTL PLANTS



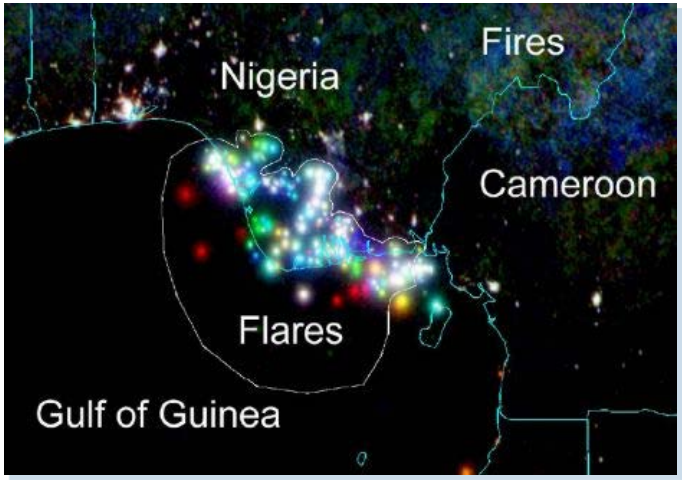
PARADIGM SHIFT



Not “bigger is better”, but “more is better”

BEACH HEAD MARKETS
FLARED AND VENTED GAS

- Global natural gas flaring
  - 5 quadrillion Btu/year
  - 27% US electricity production
  - $13 BN per year market value
- Domestic natural gas flaring
  - 54 trillion Btu/year
- Flared/vented gas wells
  - Negative to zero value gas
  - 50% produce < 1000 bpd
  - 20,000 GTL units at 100 bpd/unit



[13] World Bank, Global Gas Flaring Reduction Partnership, 2012

THE OPPORTUNITY

Small-scale, modular gas-to-liquid reactors

- Less upfront capital
- Quicker response to market changes
- Faster innovation through more players
- Lower complexity, better integration
- Beach head markets
- New learning curves

Minimizes Financial Risk

Success would not only transform GTL technology, but revolutionize the way chemical engineers think about process engineering

SUMMARY

- Main consideration for investing in gas-to-liquids technology
  - Risk assessment
- Future opportunities
  - Development of small-scale, modular GTL technology