



Microchannel GTL Technology: Demonstration through to Commercialisation

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Agenda

- ◆ Company Introduction
- ◆ Microchannel Technology
 - Overview
 - Steam Reforming
 - Fischer-Tropsch
- ◆ Manufacturing Partnership
- ◆ Field Demonstrations
- ◆ Economic Comparison

Oxford Catalysts Group PLC

Oxford Catalysts Ltd.

- Commercialising >20 yrs' research at university Chemistry Department
- Largest Chemistry Department in Western World
- Company founded by Head of Inorganic Chemistry
- Listed company (LSE: OCG); well capitalised
- Developing and commercialising **catalysts for production of clean fuels**
- Based near Oxford, UK



Velocys, Inc.

- Commercialising 15 yrs research originating in US DoE National Laboratory (PNNL)
- Conducted by Battelle – world's largest independent science & technology organisation (\$4bn R&D p.a. / 20,000 staff / 130 locations)
- Over \$160m invested in technology** to date, primarily by commercial partners
- Global leader** – largest microchannel technology IP portfolio in world
- Acquired by Oxford in Nov-08
- Based near Columbus, Ohio, USA

Board of Directors



Pierre Jungels, PhD, CBE – Chairman

- ◆ **30+ yrs** in **oil industry**: CEO Enterprise Oil; ED PetroFina; MD British Gas
- ◆ NED: Baker Hughes; Woodside Petroleum; Imperial Tobacco

Roy Lipski – Chief Executive Officer

- ◆ Founded, managed, grew and later sold technology business to listed company
- ◆ Previously at **Goldman Sachs**

Susan Robertson, FCA – Chief Financial Officer

- ◆ 17 yrs with **BOC**: CFO and VP of JAG, the £700m Japanese JV with Air Liquide
- ◆ Extensive industry experience in commercial, bus. dev. and finance roles

Andrew Jamieson, PhD, OBE – Non-executive Director

- ◆ 30+ yrs with Shell: Executive VP; member of Gas & Power Executive Committee
- ◆ **Leading GTL figure**: owned \$ multi-billion annual spend, including Shell's **Pearl** plant in Qatar

Jeremy Scudamore – Non-executive Director

- ◆ Former CEO of Zeneca Specialties and Avecia Group
- ◆ Director of **ARM Holdings PLC**

Jan Verloop, PhD – Non-executive Director

- ◆ 30+ yrs with Shell in the Netherlands, UK and Singapore
- ◆ Responsible for **Shell's strategic innovation**; helped create Shell Global Solutions





Microchannel Technology

- Higher productivity
- Lower costs



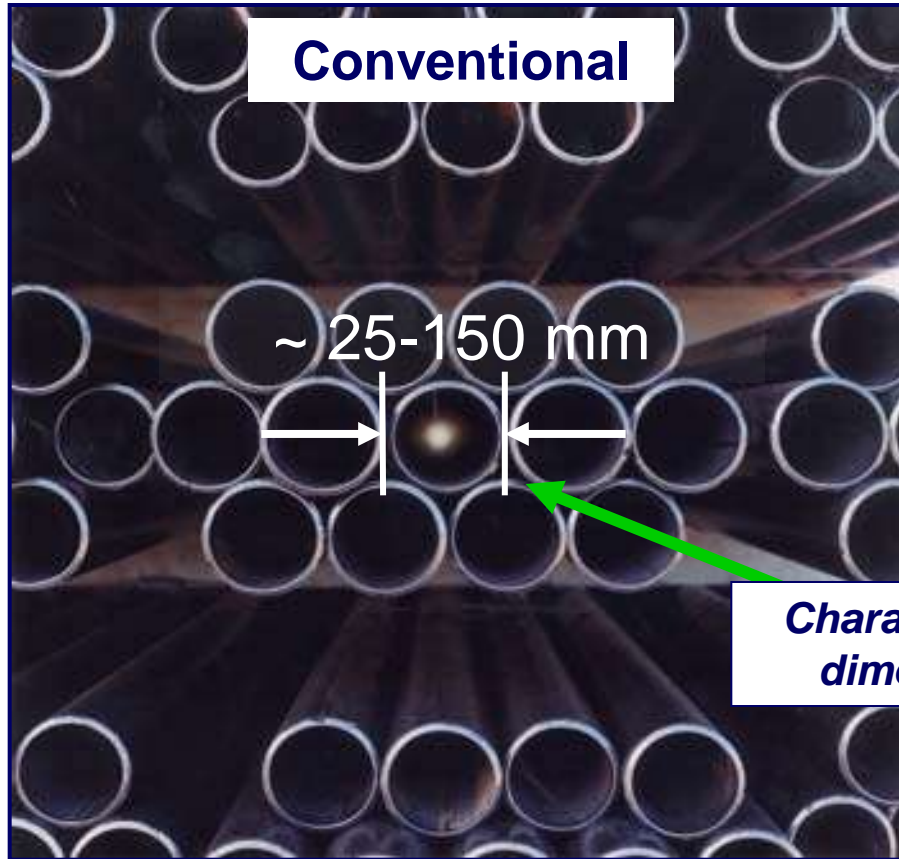
Velocys® SMR Technology Replaces Conventional Reformer



- **Conventional Steam Methane Reformer**
- **Capacity:**
20 million standard cubic feet/day H₂
- **Large Size:**
~30m x ~30m x ~30 m

- **Microchannel Reformer**
- **Same capacity**
- **90% size reduction**

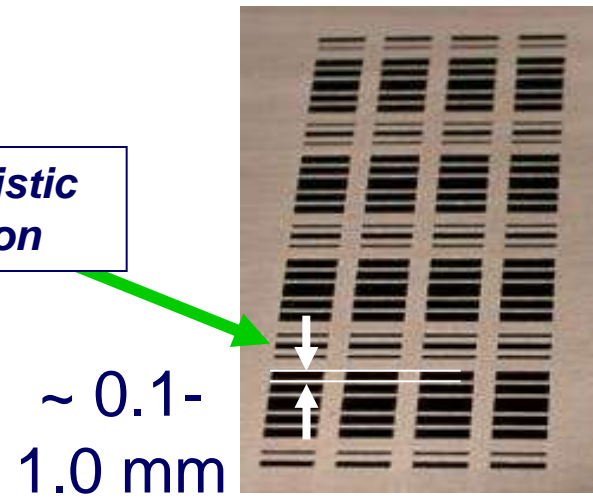
Microchannel Technology Concept



Microchannels exploit fast reactions

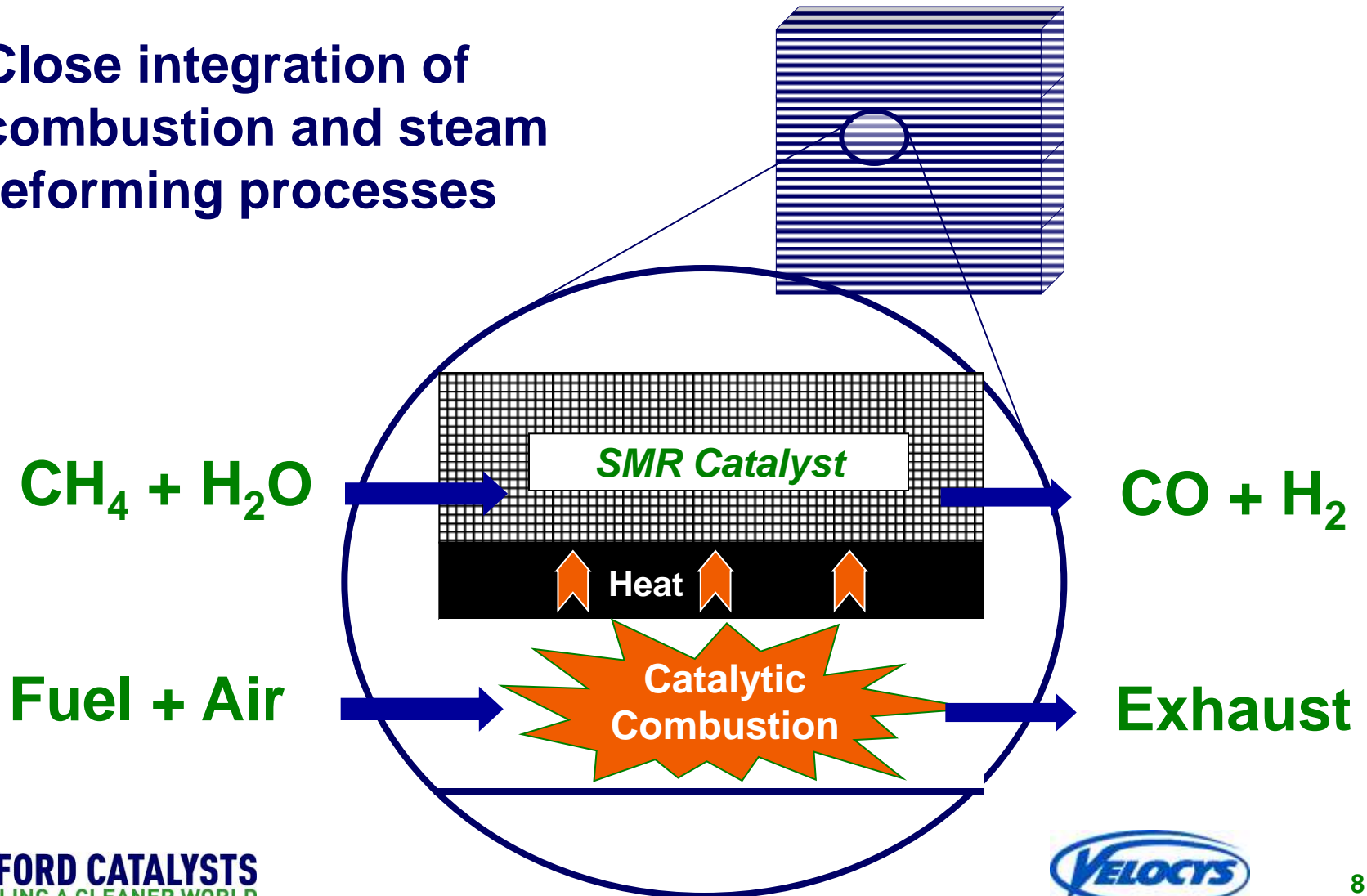
- enhance heat transfer
- enhance mass transfer
- enable intrinsic rates

Microchannel

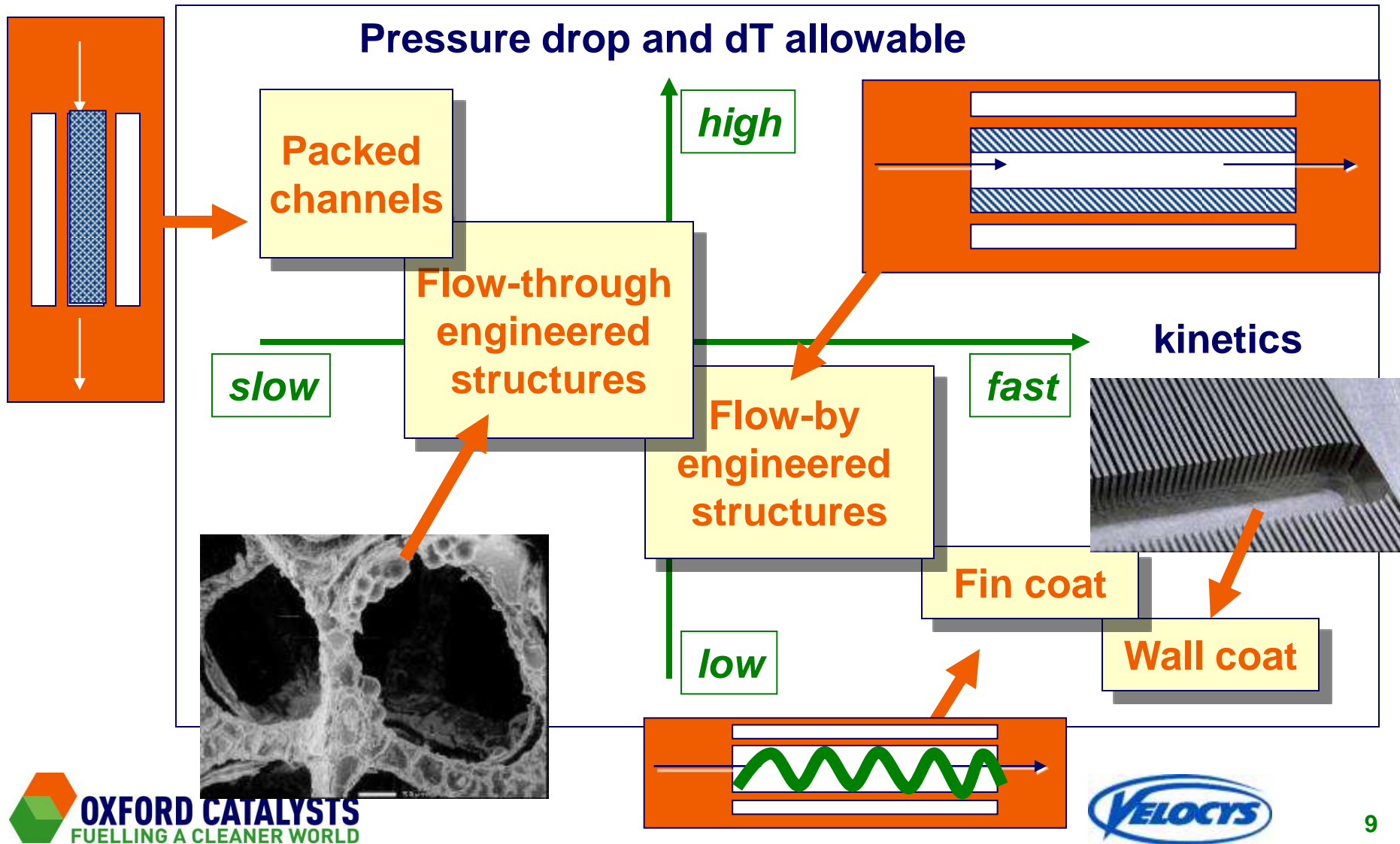


Velocys Microchannel SMR Reactor Concept

Close integration of combustion and steam reforming processes



Velocys Catalyst Selection Strategy for Microchannel Reactors



Impact of Technology

Microchannel technology systems outperform conventional reactors

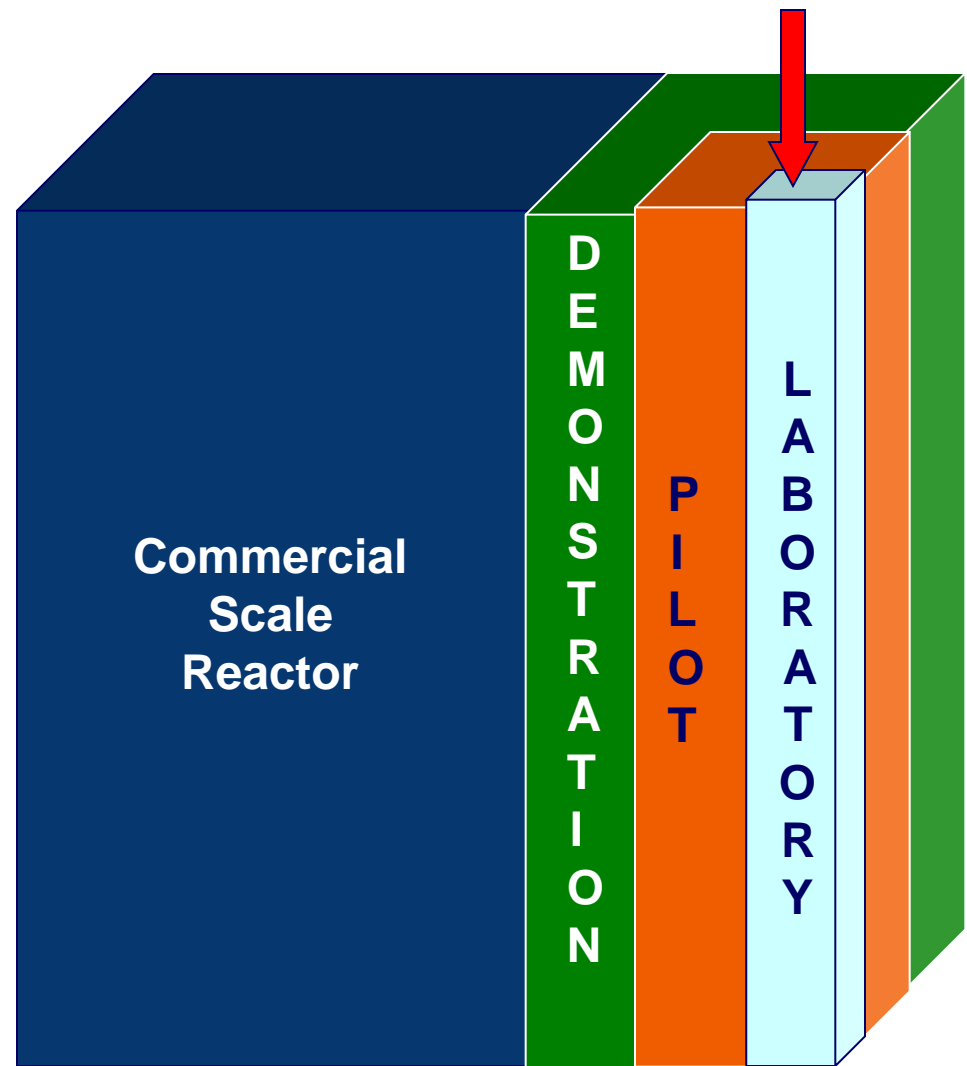
- ✔ Allows use of novel, much more active catalysts
- ✔ Controls reactions at optimal conditions
- ✔ Accelerates processes by 10 – 1,000 fold
- ✔ Enables smaller, more productive reactors



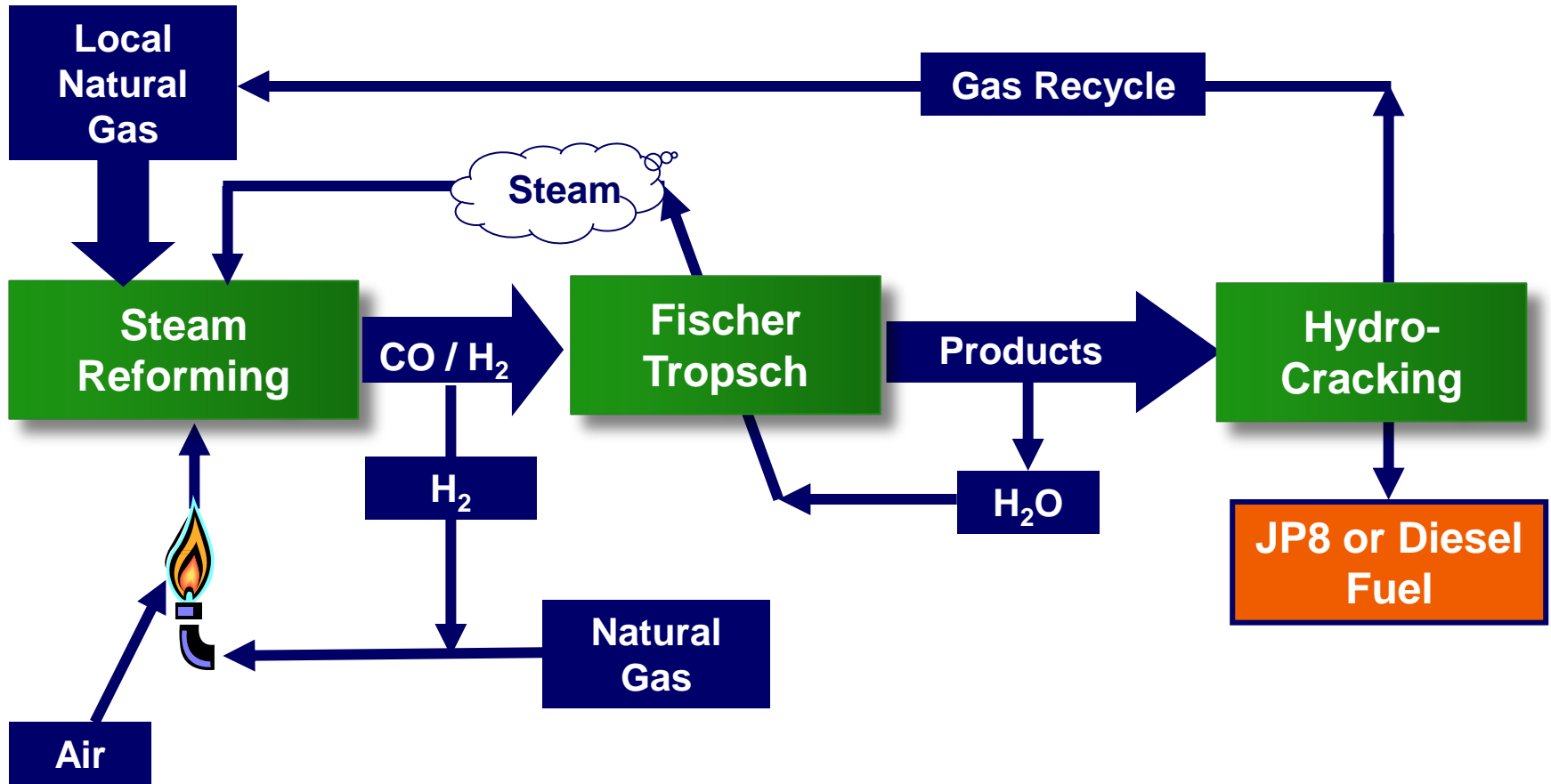
Velocys Scale-up Methodology:

Number of Channels Increases, Size does Not

- Single-Channel Scale
 - Internal channel dimensions same as commercial reactor
- Pilot Scale
 - 10's to 100's of channels
- Demonstration Scale
 - 100's to 1000's of channels
 - Passive internal manifolding
- Commercial Scale
 - > 1000 channels



Velocys GTL Technology Platform



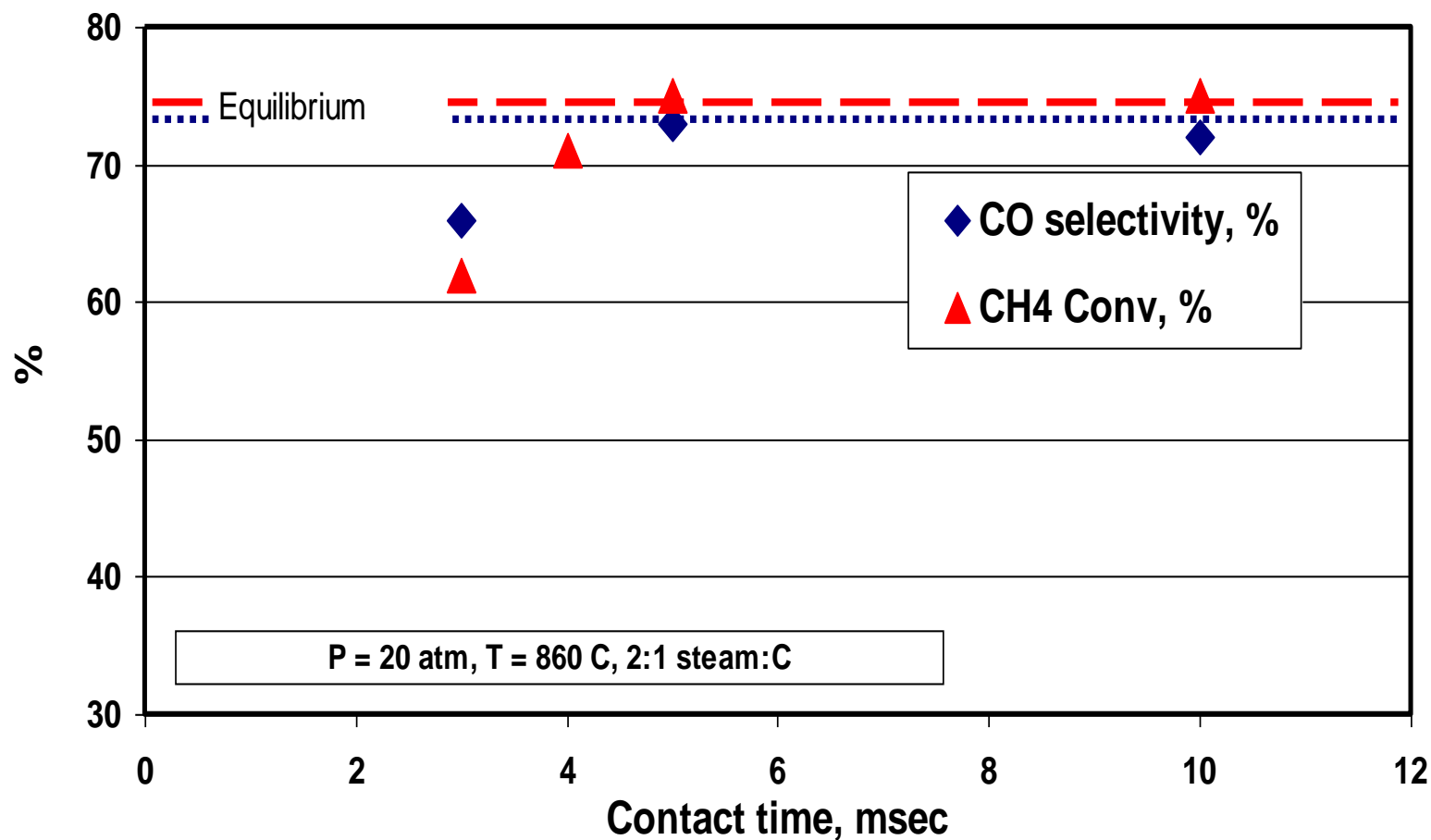
Velocys is actively developing major steps in gas upgrading



Methane Steam Reforming



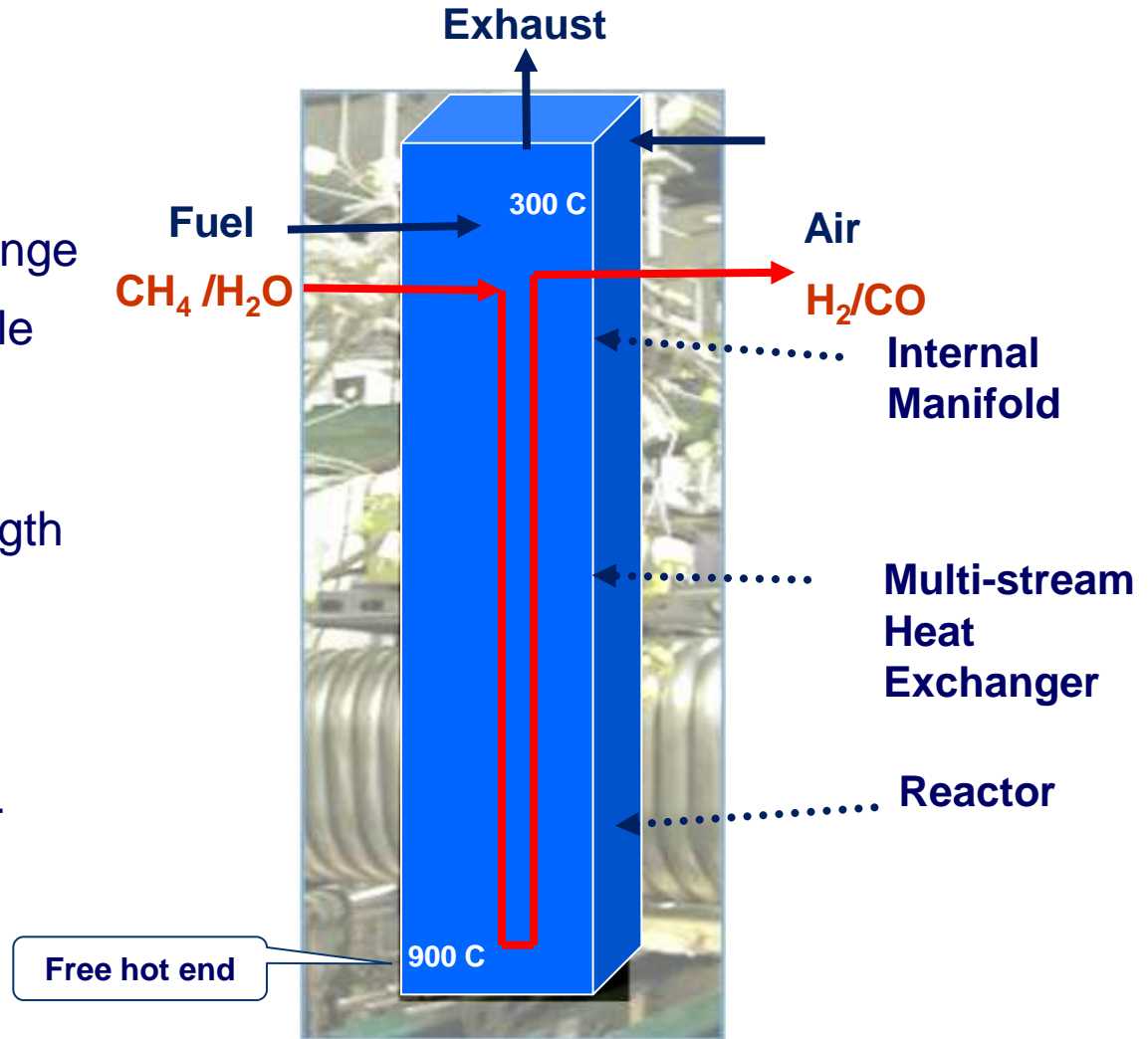
Super Active SMR Catalyst Permits Operation at Very Short Contact Times



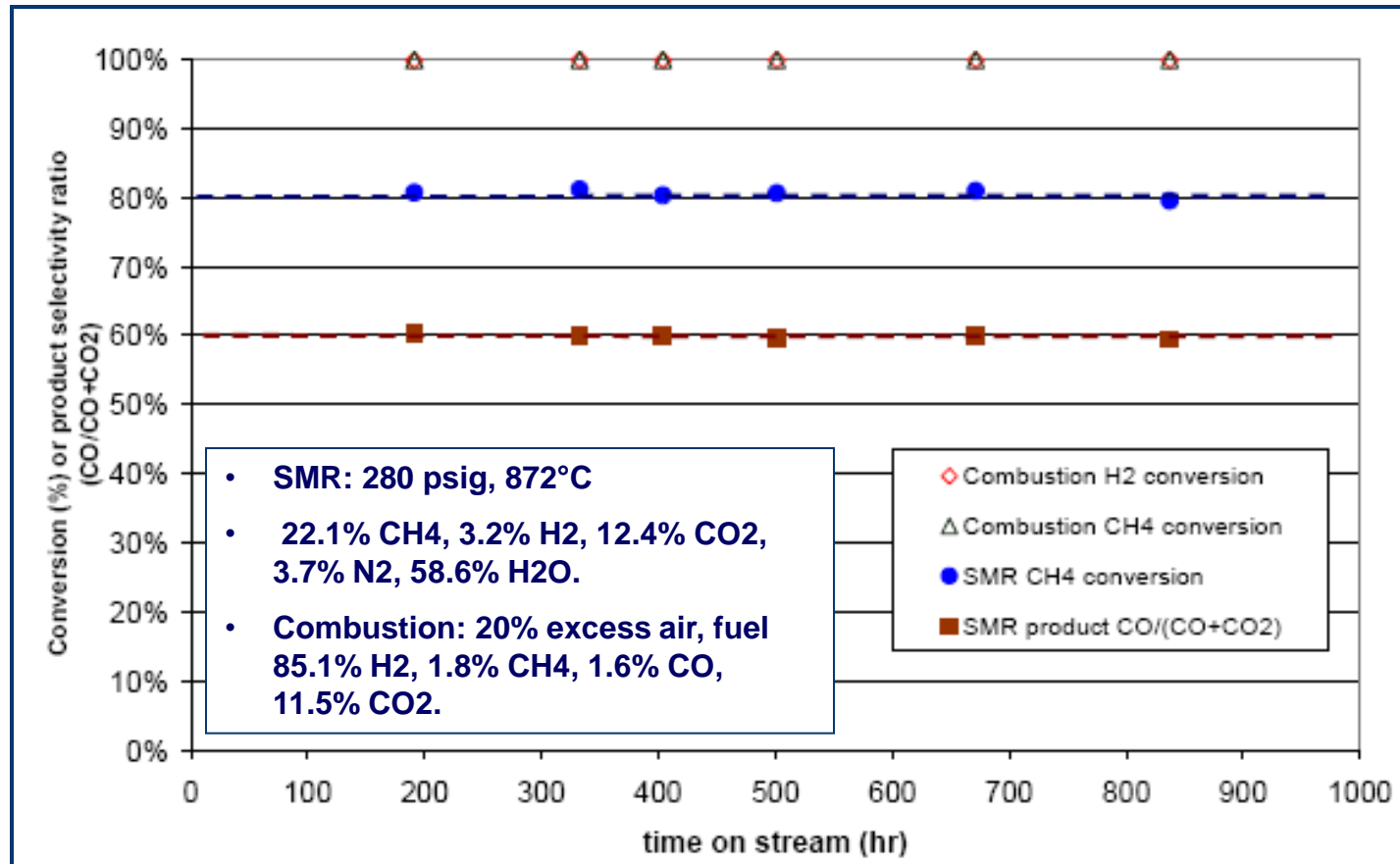
Overcoming mass and heat transfer limitations allows near equilibrium conversion and selectivity at millisecond contact times

Microchannel Steam Reformer Design

- Integrated reforming and combustion
- Recuperative heat exchange
- Integral design with simple manifolding
- Ease of manufacturing
- Robust mechanical strength
- High temperature and pressure operation
- Low dP, Low emissions
- Improved safety - no pre-mixing fuel and air
- Small footprint



SMR Single Channel Performance

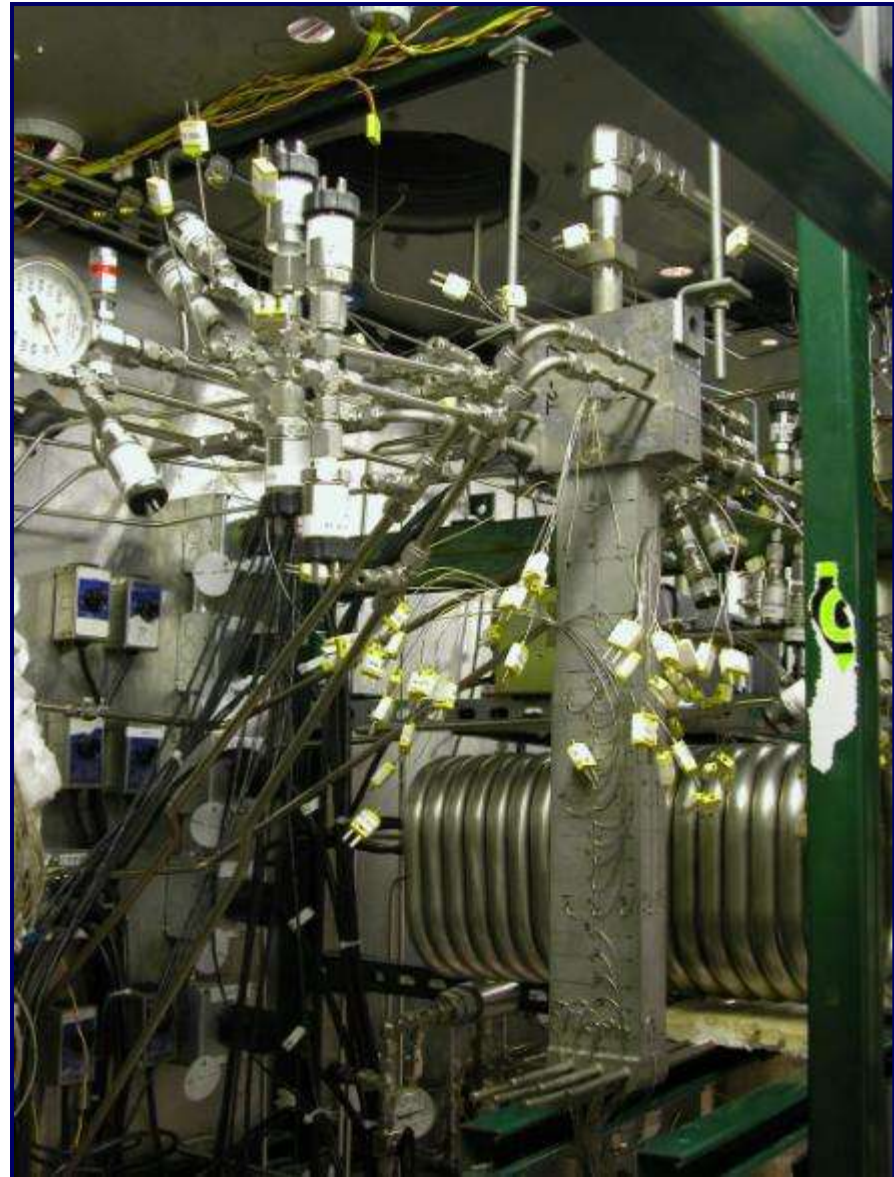


Microchannel reactor combines

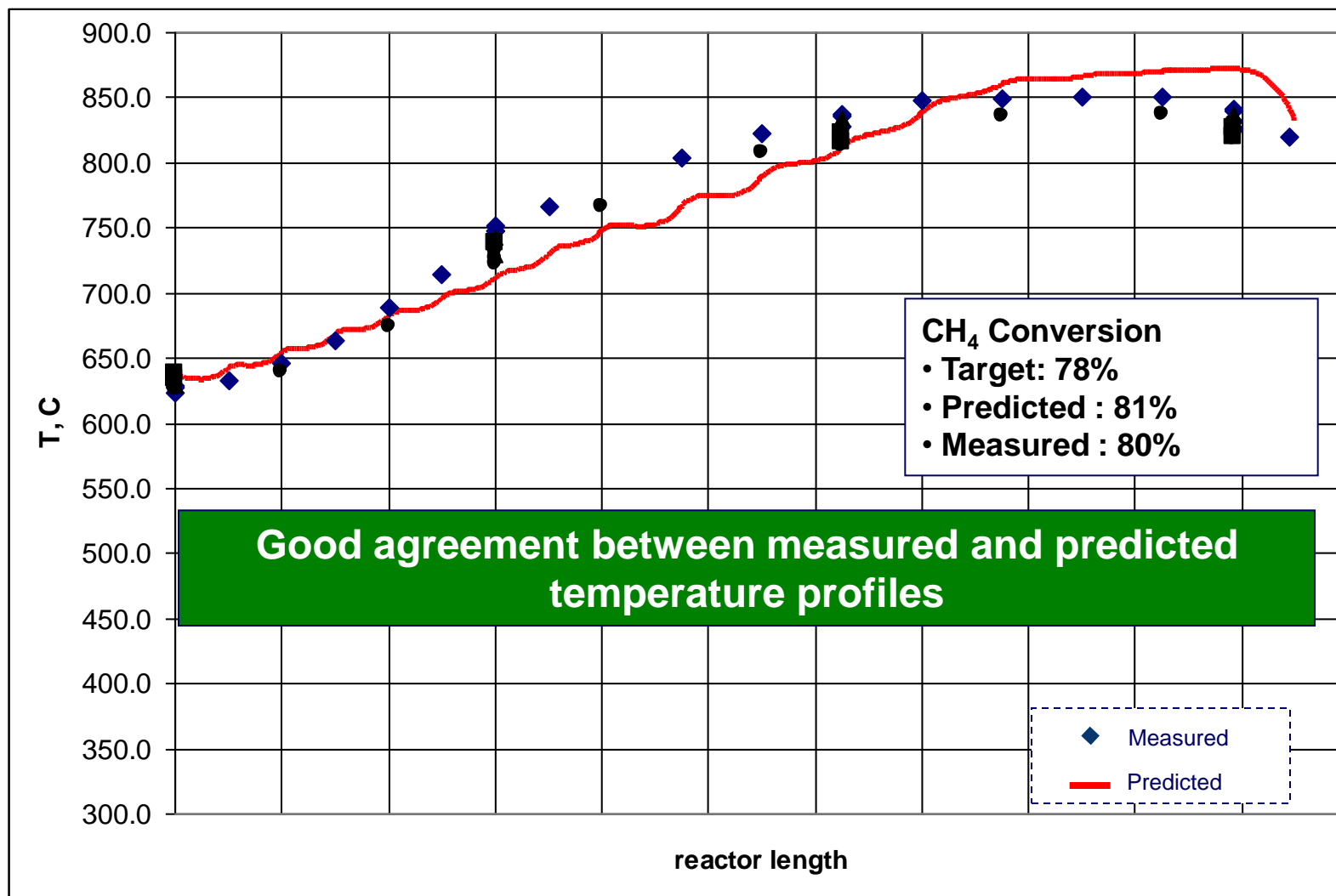
- Excellent thermal integration (low feed and product temperatures)
- Excellent performance (high equilibration temperature)

Pilot Scale Reactor Validation Demonstration

- 48 channel reactor
- ~ 5% full scale capacity
- 500 hour stable SMR operation
- CH₄/H₂ fuel blend
- H₂ production conditions
- Catalyst coated on microchannel walls



Pilot Scale Demonstration Performance vs Prediction



Velocys Demonstration Plant Reactors



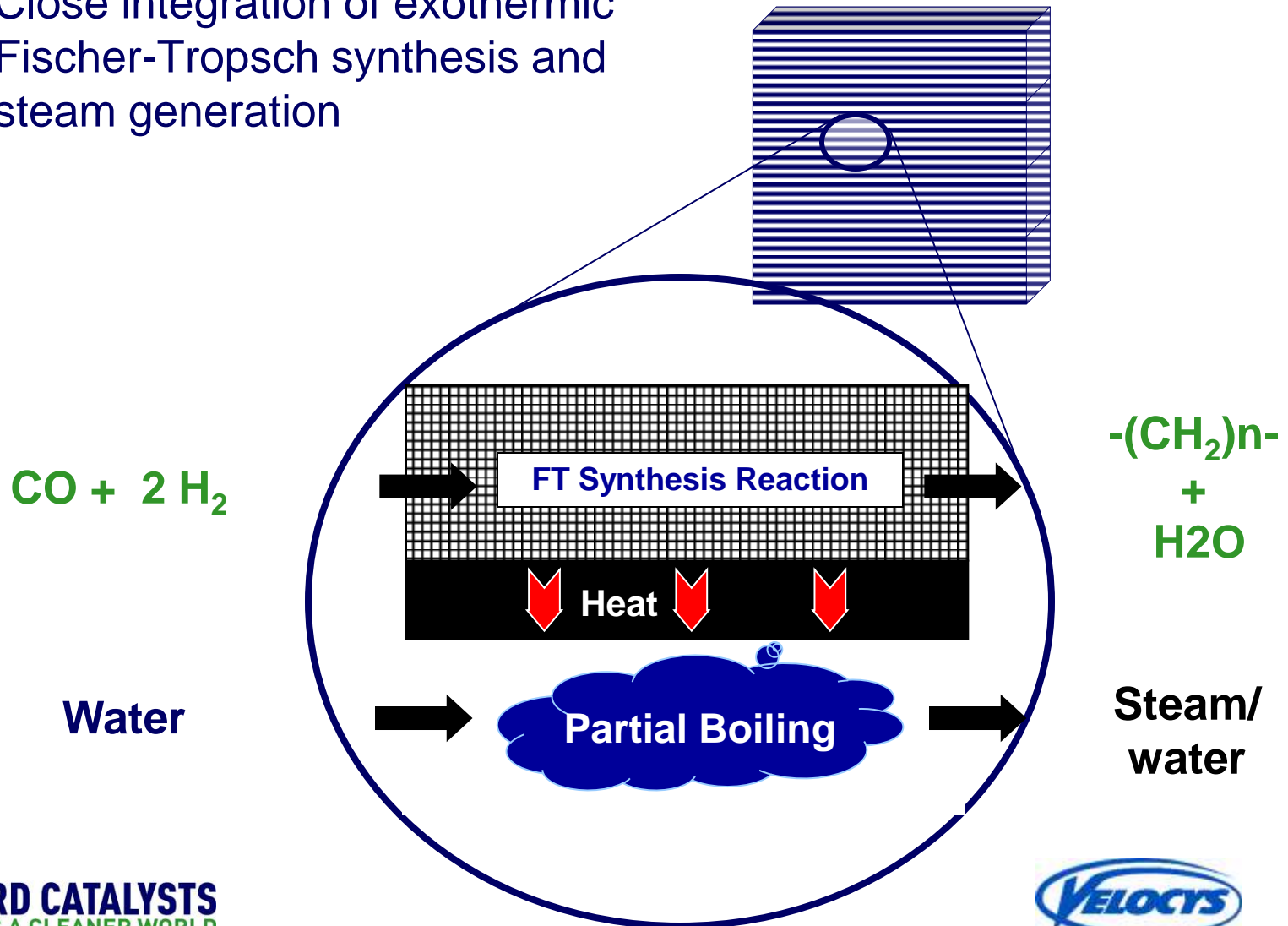


Fischer Tropsch

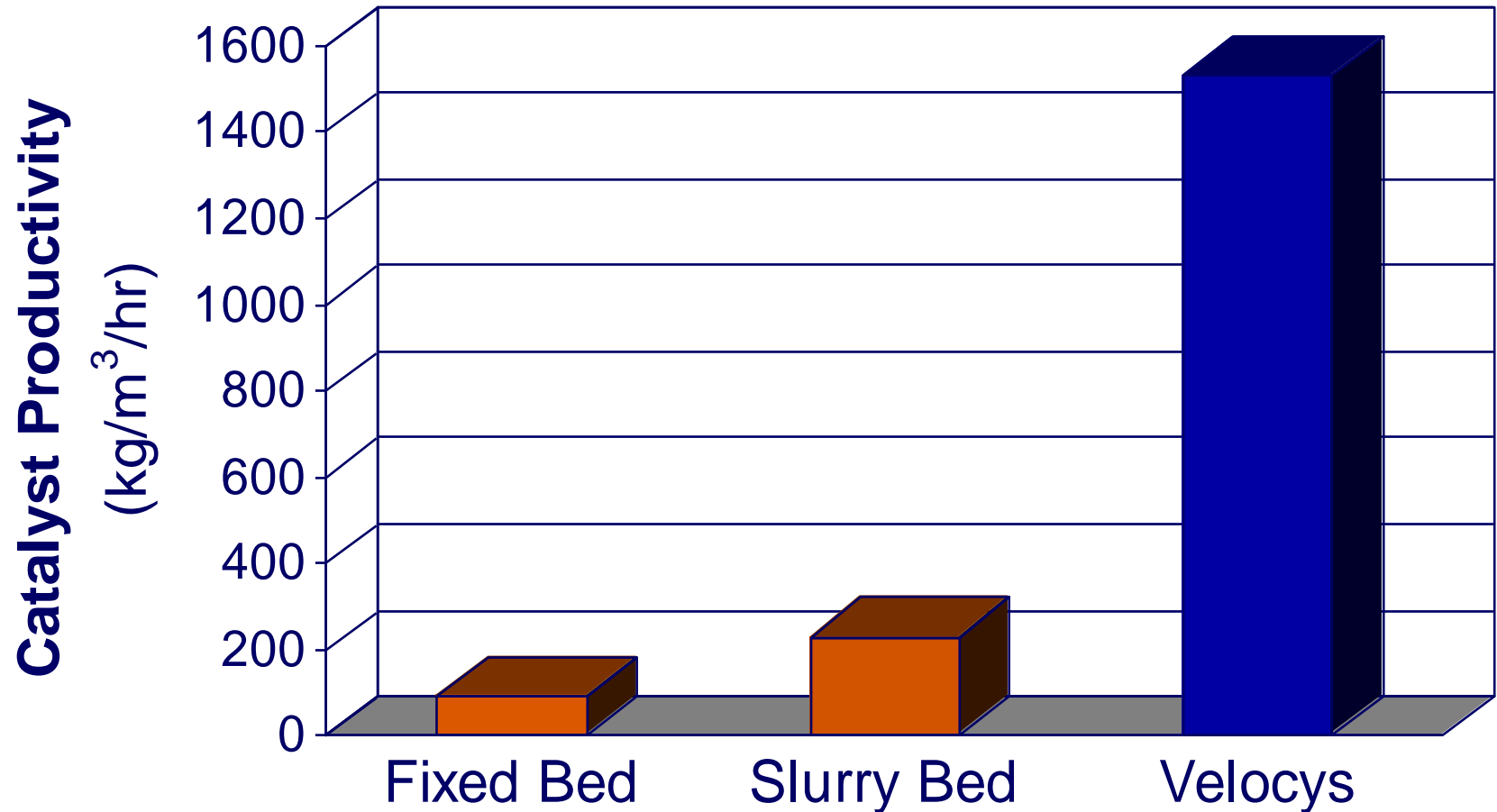


Velocys Fischer-Tropsch Concept

- Close integration of exothermic Fischer-Tropsch synthesis and steam generation

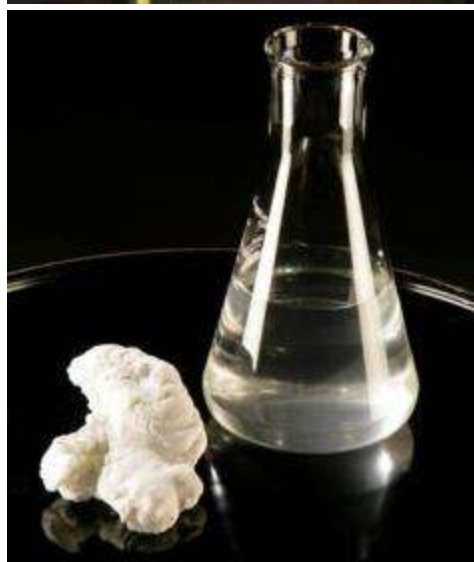
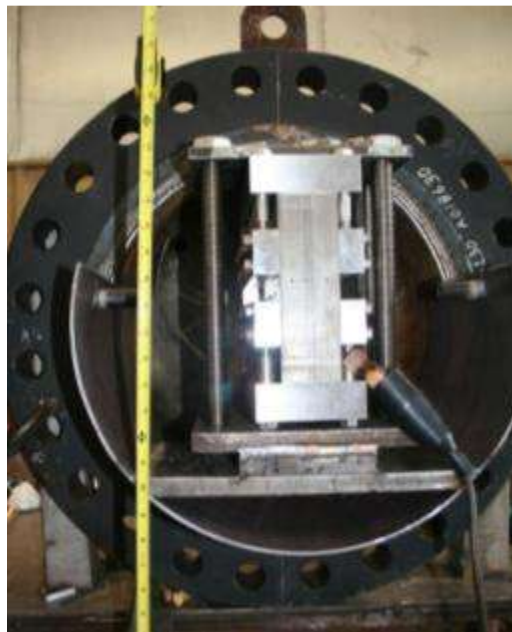


Oxford FT Catalyst Productivity is Unleashed in a Velocys Microchannel Reactor



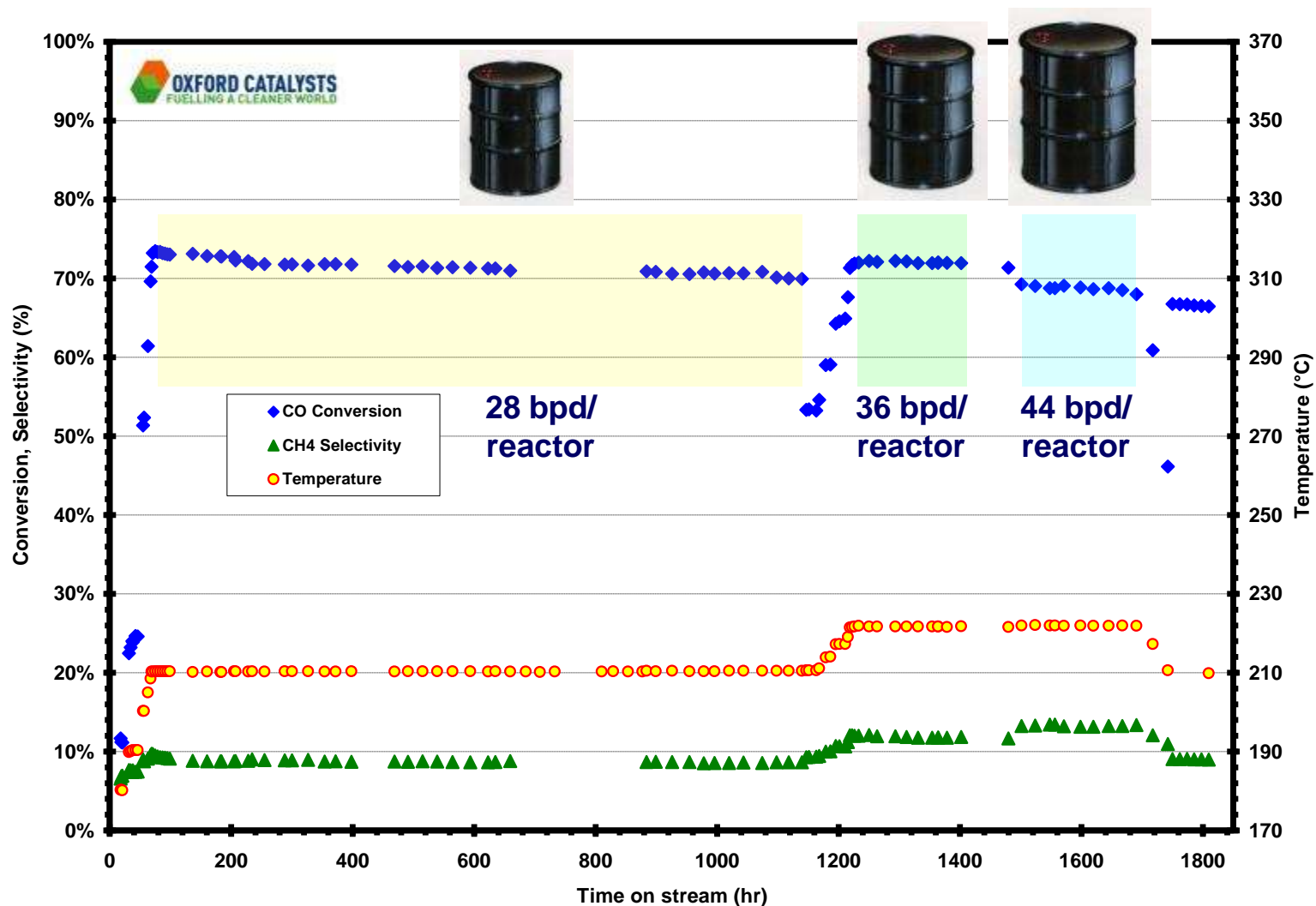
Pilot Scale Reactor Demonstration Summary

- ◆ 4000 hours TOS
- ◆ Robust to process upsets
 - Multiple restarts without performance impact
 - Regeneration cycle demonstrated
- ◆ Performance (2 GPD)
 - Experimental Results
 - $X_{CO} = 72\%$
 - $Sel_{CH_4} = 9\%$
 - Expected Performance
 - $X_{CO} = 73\%$
 - $Sel_{CH_4} = 9\%$



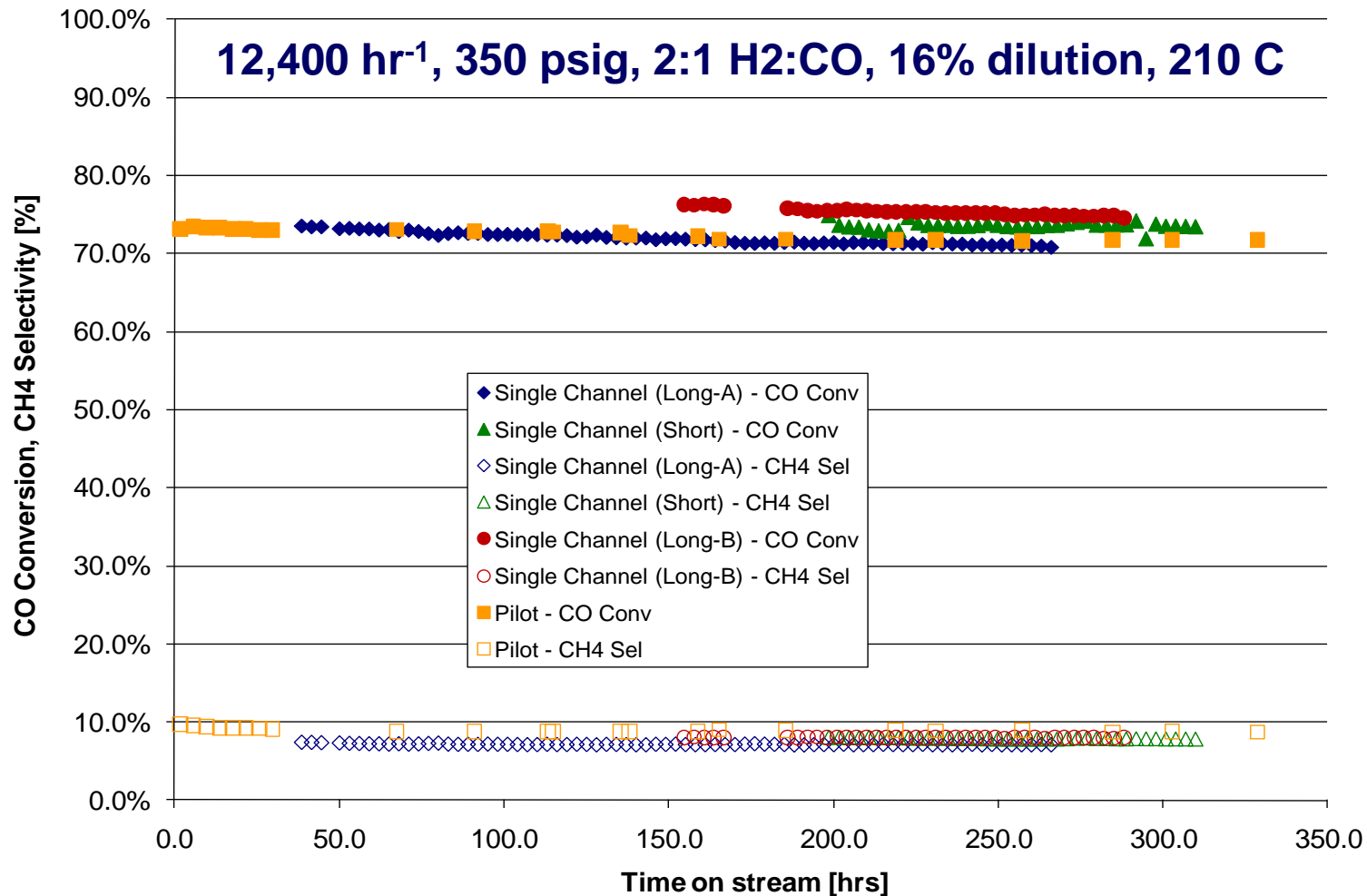
FT Pilot Reactor

Demonstrated Capacity of 40+ BPD/reactor



Demonstrated Ability to Scale-up Technology

One short channel = one long channel = 276 channels

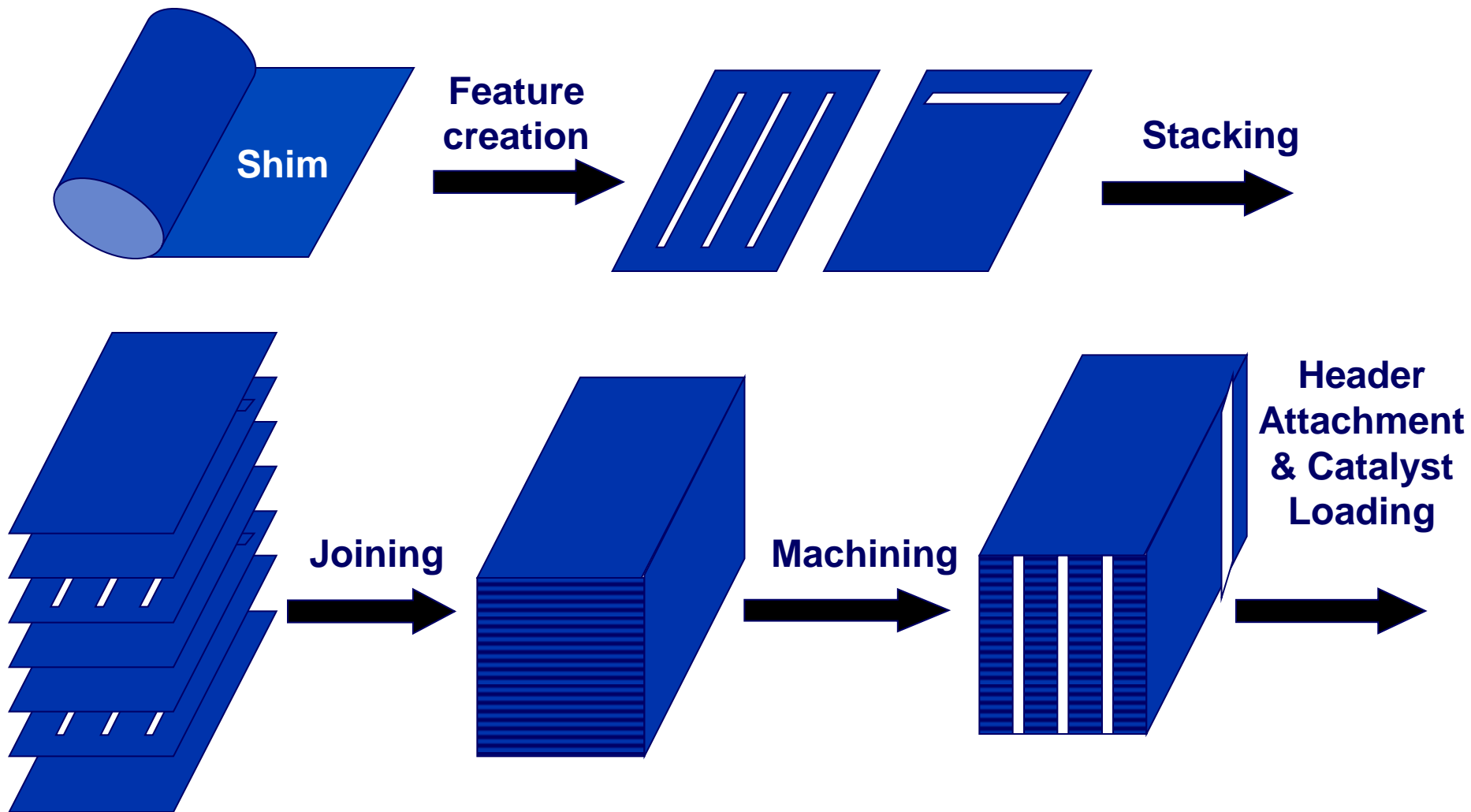




Manufacturing Partnership



Reactor Manufacturing Process



Velocys-Kobe Partnership

Velocys

- ◆ Microchannel technology developer
- ◆ 100+ US Patents
- ◆ Established commercial partnerships
- ◆ Working with MODEC and Toyo Eng. for offshore gas-to-liquids application

Kobe Steel

- ◆ One of Japan's leading steel makers
- ◆ 2,000+ billion Japanese yen of revenue in 2008
- ◆ 31,000+ employees
- ◆ Established supplier for MODEC and Toyo Eng.

Velocys and Kobe Steel have complementary skills required for commercial deployment

Kobe's Manufacturing Capabilities: Takasago Equipment Plant



Making combined use of know-how in high temperature, high pressure low temperature vacuum, analysis and control technologies, we are developing and producing efficient equipments, such as instruments for oil refinery, LNG vaporization and liquefaction equipments, nuclear power instruments.

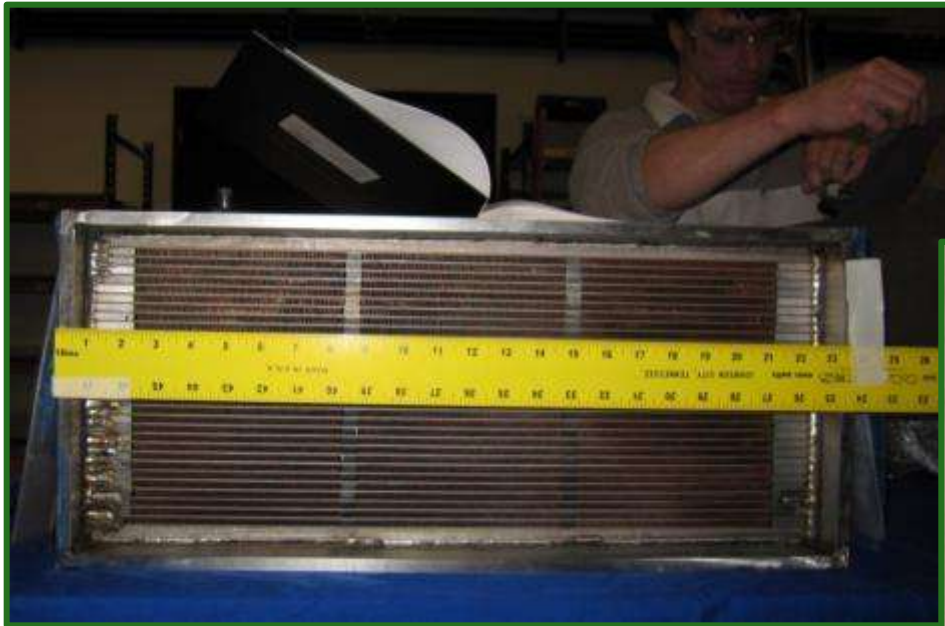
- ◆ Main Product Lines
 - Large scale pressure vessels
 - Liquefied natural gas handling
 - Aluminum brazed heat exchangers
- ◆ Products up to 2,000 tons



Braze aluminum plate-fin heat exchanger

Commercial Manufacturing Scale-up

- ◆ **Kobe Steel** has developed capability to manufacture large scale SMR and FT reactors



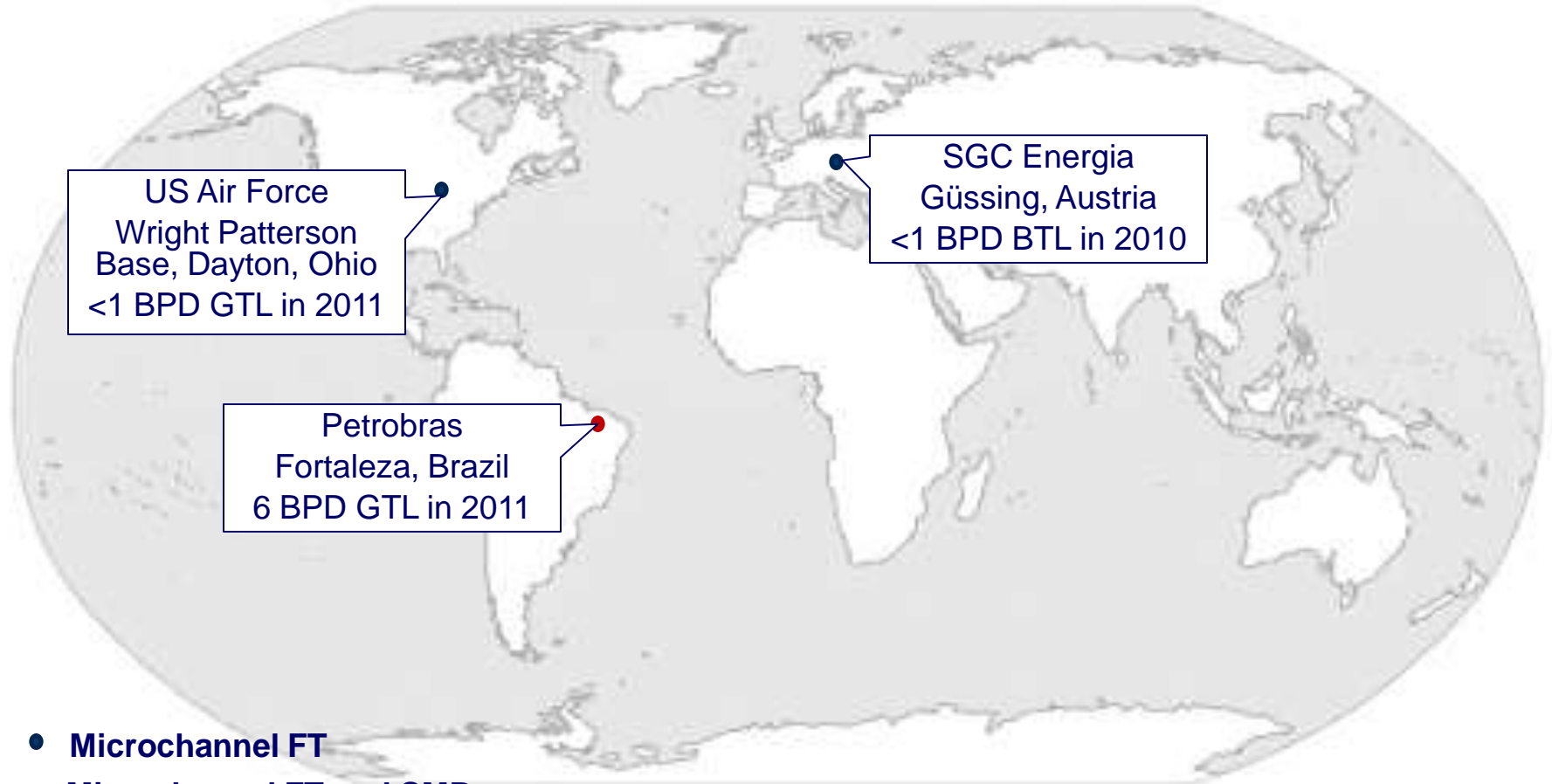


Demonstration Activities

- BTL and Offshore GTL Partners Established
- Field demonstrations beginning in 2010



Velocys Demonstrations



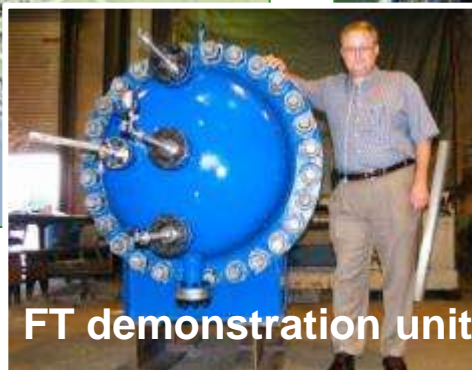
- **Microchannel FT**
- **Microchannel FT and SMR**

Cellulosic Diesel Demonstration

- FT technology to be demonstrated at the **unique showcase** “eco-town” of Güssing, in Austria
- Fully funded by BTL / WTL partner, SGCE: **~\$15 million**
- 6 months demonstration starting **2010** on gasified wood
- Post demonstration, unit to be moved to US Wright-Patterson Air Force Fuel Research Center

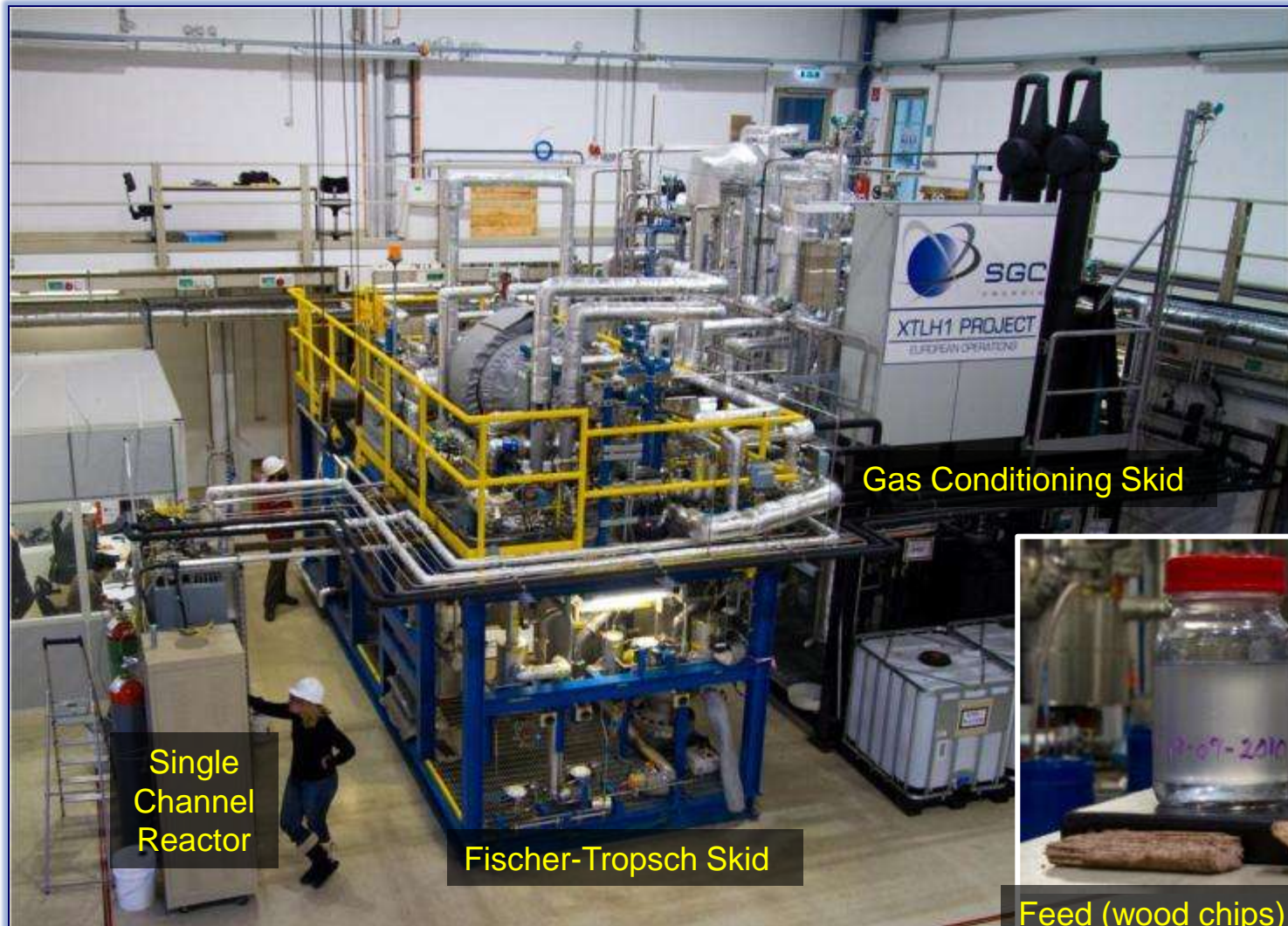


Güssing



FT demonstration unit

XTL FT Skid in Operation in Güssing



Gas Conditioning Skid

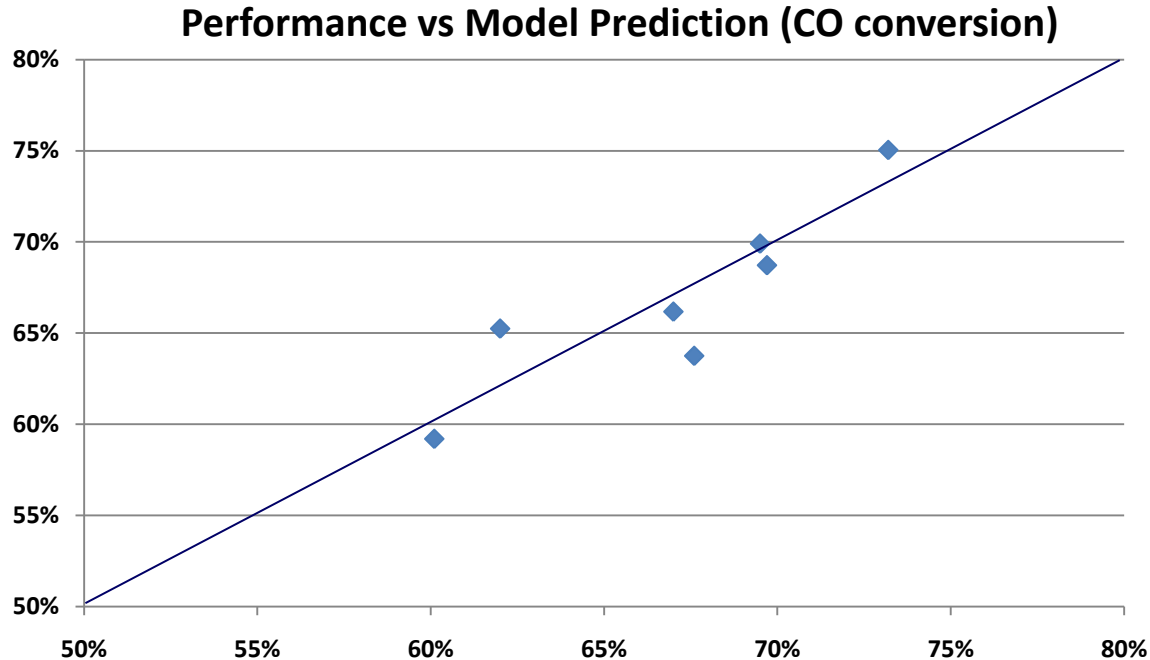
Single Channel Reactor

Fischer-Tropsch Skid



Feed (wood chips) and FT Product

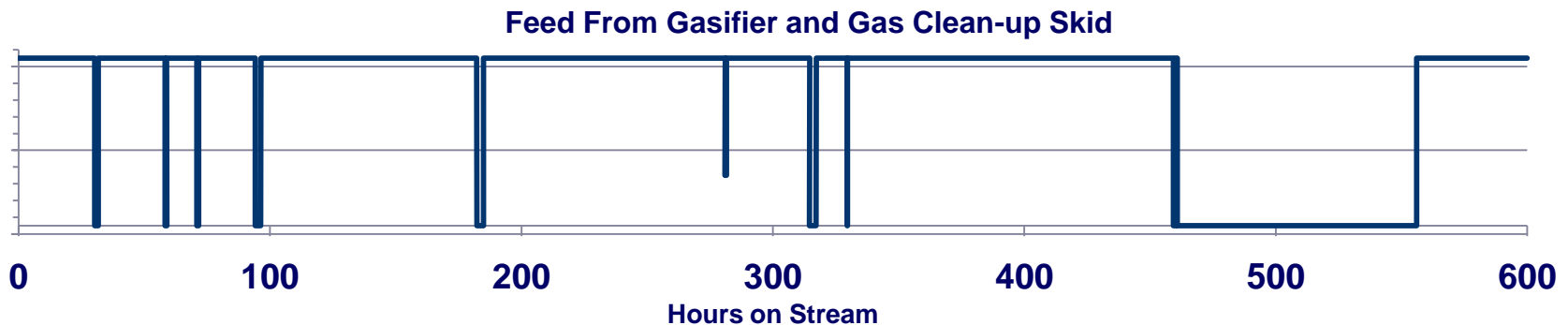
Performance of Single Channel 'Scout' Reactor at Güssing



- Single Channel results at Güssing demonstrate FT catalyst performance on biomass-derived syngas matches lab data

Initial Demo Reactor Performance Summary

- Initial operation 15 July – 3 August
 - 10 feed interruptions
 - Smooth restart demonstrated following each interruption
 - Catalyst activity in single channel ‘scout’ reactor confirms lab data
- Wax production rate meets target
 - ~ 1 ton of Wax produced to date
- Product appearance is very good { $\text{Alpha} = 0.93$ }
- Process-side pressure drop consistent with design basis
- Coolant/steam pressure control strategy validated



Initial Production of FT products



Jet Fuel Demonstration

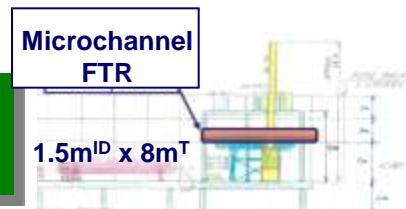
- FT and hydrocracking technologies to be demonstrated at the **Air Force's** demonstration facility on Wright Patterson Base
- 6 months demonstration starting **2011** (natural gas feed)
- Fully integrated demonstration including extensive fuel analyses and testing



Assured Aerospace Fuels Research Facility

GTL Field Demonstration

- Small scale GTL to be demonstrated at Petrobras in Fortaleza, Brazil in **2011**
 - Petrobras: largest contractor of offshore rigs
- Fully funded by partners: over **\$30 million** by Toyo Engineering and MODEC; Petrobras covering installation and operating costs
 - Reactors manufactured and ready



2,000 bpd GTL facility will occupy only ~1/4 of deck space

FT (left) and SMR (right) Demo Reactors Being Installed in Containment Shells (August 2010)

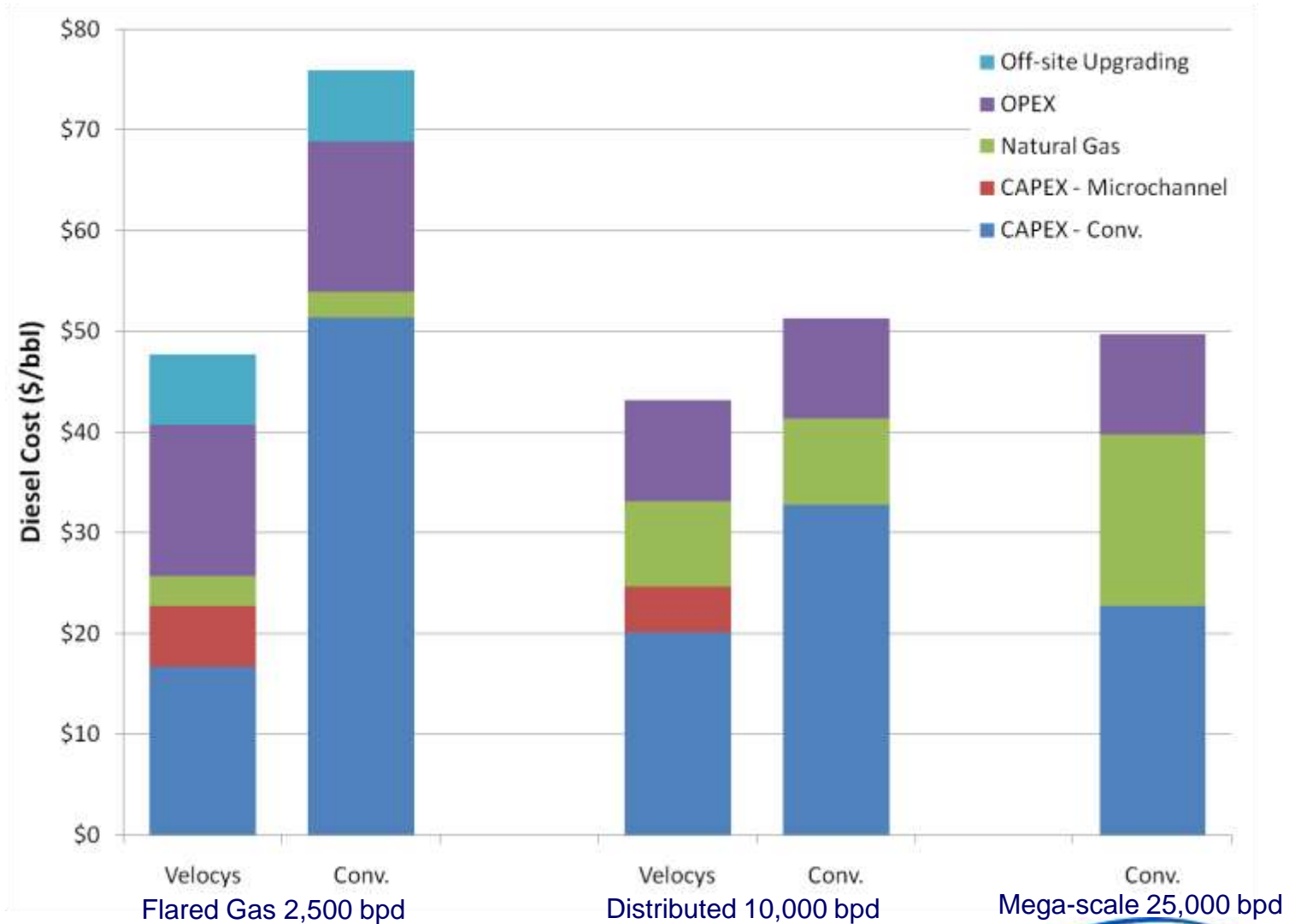




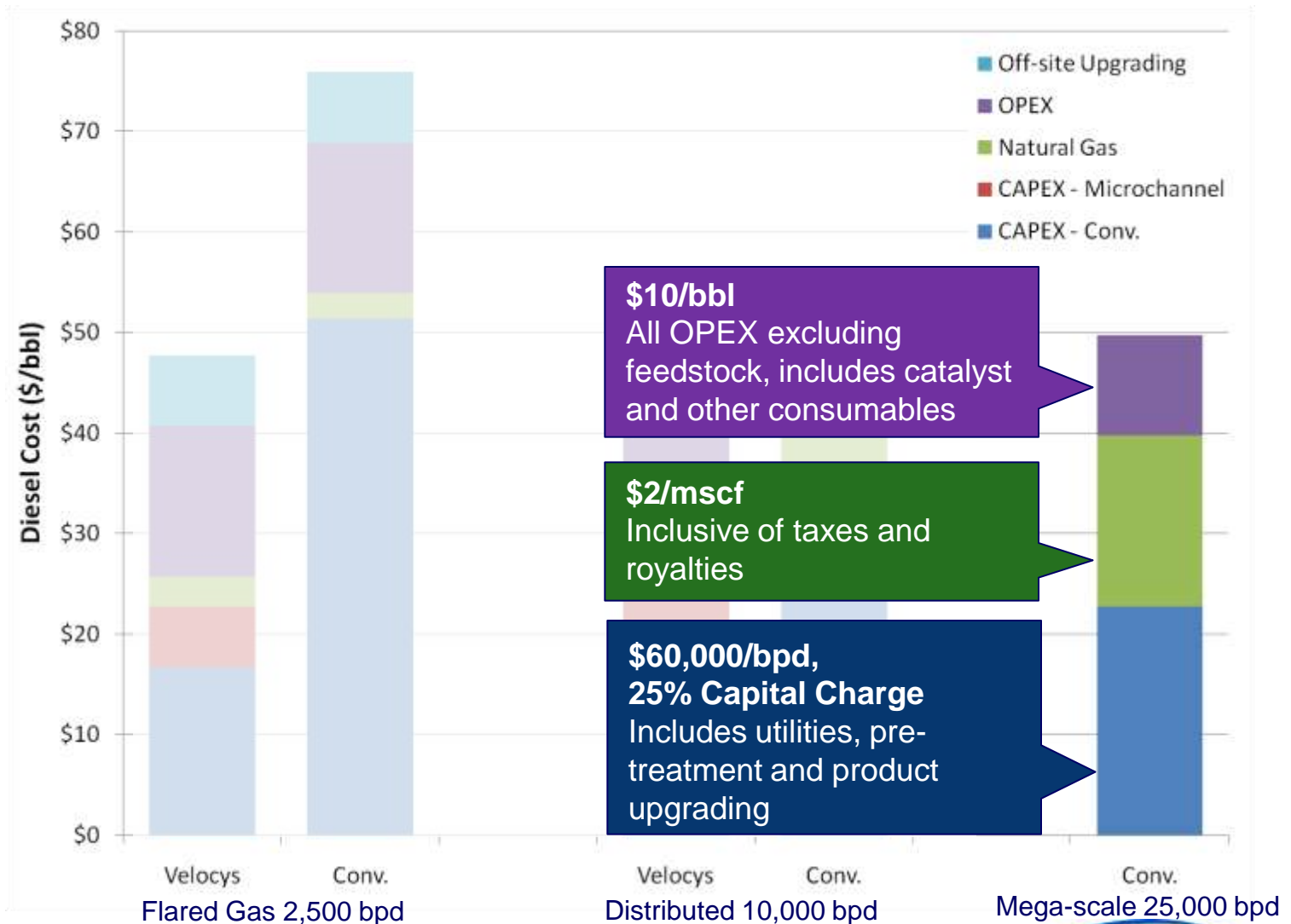
Economic Comparison



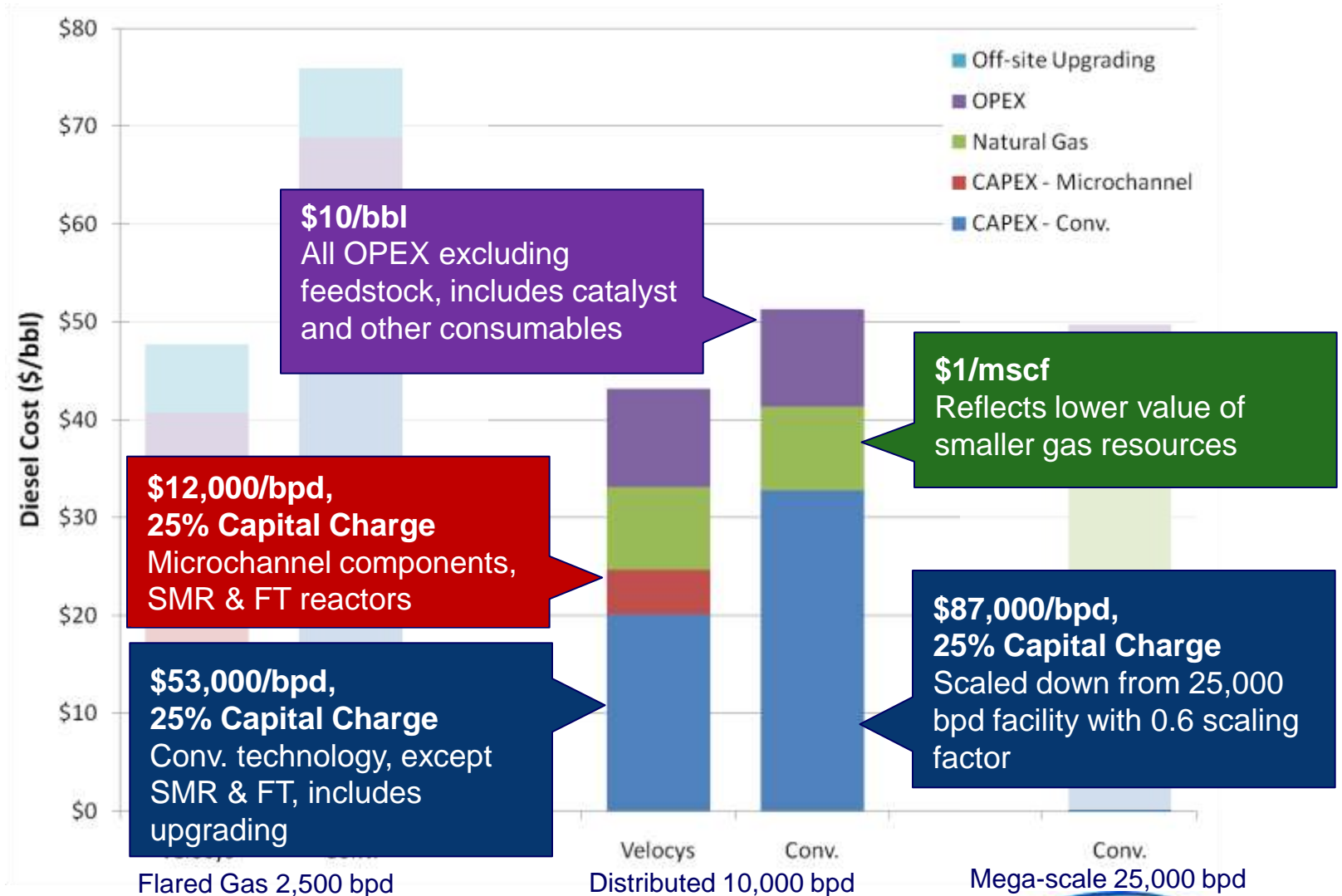
GTL Facility Economics



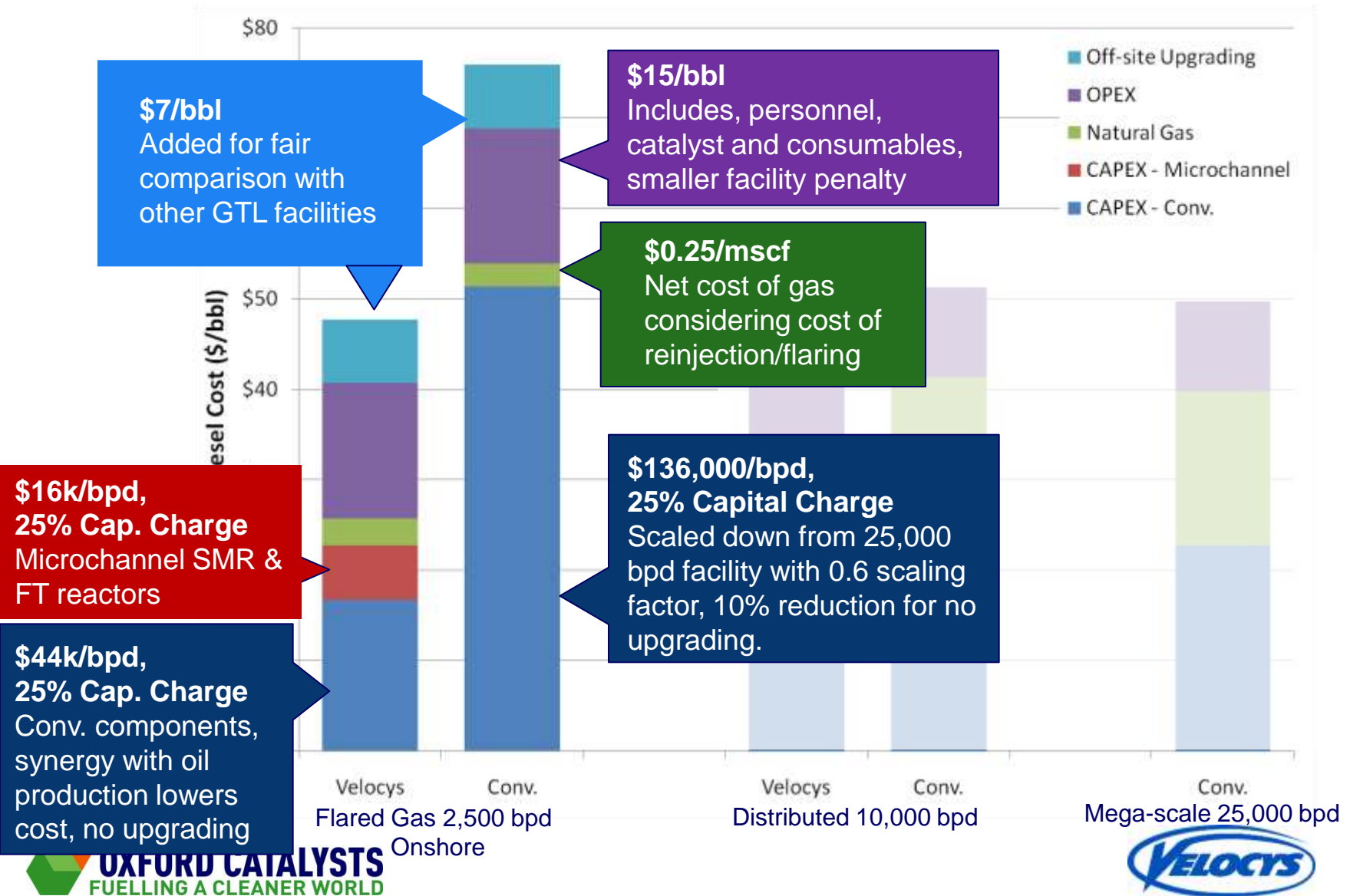
GTL Facility Economics



GTL Facility Economics



GTL Facility Economics



Summary

- ❖ **Microchannel technology can greatly improve reactor performance**
- ❖ **Velocys technologies help unlock small-scale XTL opportunities**