Think Smaller: microchannel Fischer-Tropsch enables biomass-to-liquids
Velocys
The company at the forefront of smaller scale GTL and BTL

- **Leader** in smaller scale gas-to-liquids technology
  - 15 years and >$300 million invested in product development
  - Exhaustive global patent protection (>7,600 granted gas-to-liquids patent claims)

- **Commercialization underway**
  - Commercial reference plant under construction
  - Supply chain is delivering

- **Well capitalised with strong resources**
  - £52m fundraise in Sept 2014
  - Commercial center in Houston, Texas; technical centers near Columbus, Ohio and Oxford, UK
  - Permanent pilot plant in operation
The Fischer-Tropsch (FT) process for biomass-to-liquids (BTL)

- **Gasification**: Biomass, waste, coal
  - Output: Syngas (carbon monoxide + hydrogen)

- **Fischer Tropsch**
  - Input: Syngas
  - Output: Syncrude (Synthetic crude oil)

- **Hydro-processing**
  - Input: Syncrude
  - Output: Clean synthetic fuels (diesel, naphtha, jet fuel)

- **Notes**: Velocys microchannel reactor and super-active catalyst
Velocys Fischer-Tropsch fuels
Choose from a range of high value products

• “Drop in” replacement for petroleum derived fuels, lubricants and other products

• Zero (or near zero) sulfur content
  — Can be used as a blend stock for ultra-low sulfur fuels

• High cetane
  — Meets military specification for aviation fuel
  — FT diesel powered every 24 hour Le Mans winner since 2006

• Lower emissions
  — Lower SOx, NOx and particulates compared to petroleum fuels
  — Quieter engine operation
Velocys FT makes top quality, valuable products
Specialty products not just fuels. Attractive at $40 WTI
Think Smaller™
Velocys microchannel Fischer-Tropsch
Enabling technology – process intensification

Nothing wasted

• Smaller scale facilities makes the most of the resources available

Better options

• Smaller, low cost plants need less gas or biomass to be profitable
  — Enabling FT to be used for biomass and MSW projects
Thinking smaller; using microchannel FT...
...plant scaled to match MSW or biomass collection logistics

Conventional Fischer-Tropsch reactor

Velocys Fischer-Tropsch reactor

Note: Reactor capacities differ considerably
Practical considerations
Use of microchannel FT in biomass-to-liquids projects

- **Minimum feedstock volume**
  - A plant of 1,000 barrels per day (bpd) output (~200,000 tons of waste per year) could be economic, depending on local conditions, including tax regimes.

- **Minimum syngas volume**
  - A plant of 1,000 bpd output would need of the order of 28 million scf syngas per day (post clean-up & H₂/CO ratio adjustment).

- **Gasification provider**
  - Selected by client
  - MSW; e.g. AlterNRG
  - Biomass; e.g. TCG Global, TRI, Enerkem

- **Syngas quality**
  - Syngas clean-up is a major system component for BTL projects
  - Soot-free, sulfur-free, ++
  - Selection of syngas upgrading technology depends on gasification technology & feedstock
Microchannel Fischer-Tropsch
Plant scaled to match MSW or biomass collection logistics

Velocys-enabled plant
Plant size matched to MSW collection logistics

Larger scale conventional FT plant
Would require too much feedstock to be satisfied by economic MSW collection and transport
Commercial roll-out
First ENVIA Energy plant being built
Adjacent to WM East Oak landfill in Oklahoma City, USA
ENVIA Energy
Oklahoma City project

- **Landmark for GTL**
- Landfill gas + natural gas as feedstock
- Major companies committing to smaller scale GTL
- Entered into all main contracts
- **Construction underway**
  - Manufacture of FT catalyst and reactors complete
  - Mechanical completion expected H1 2016
- Will be our commercial reference plant – a **major milestone**
  - Demonstrate parallel operation of full-scale Velocys reactors
Site preparation work continuing
By Ventech and its subcontractors in Oklahoma City

Photos taken early 2015
Supply chain delivering: reactor core manufacturing
Shiloh Industries, Ohio
Manufacture of FT reactors and catalyst complete
Supply chain delivering
Module and vessel fabrication underway
At Ventech, Pasadena, Texas

Photos taken early 2015
Red Rock Biofuels
US DoD sponsored BTL

- Velocys selected for 1,100 bpd biomass-to-liquids (BTL) plant
  - Located in Oregon, USA
  - Using forestry waste feedstock
- Supported by US Department of Defense and US Department of Energy
  - Received $4.1m phase 1 grant for engineering in July 2013
  - FEED study complete
  - Received a $70m construction grant in September 2014
- Targeting final investment decision H2 2015
- **Southwest Airlines** & **FedEx** to each offtake 3 million gal/yr of jet fuel from the plant
GreenSky London
Renewable jet fuel in London

• Velocys selected by Solena Fuels as FT supplier for commercial 2,500 bpd waste-biomass-to-liquids plant
• GreenSky London plant in partnership with British Airways
• Competitive selection process after technology evaluation advised by Fluor
• BA to provide off-take for jet fuel
• Pre-Front End Engineering completed
• Site selection announced April 2014
  — Site of former Coryton oil refinery in Thurrock, Essex, UK

Picture courtesy of British Airways
Summary
Smaller scale BTL using FT is now a reality

• Fischer-Tropsch process now **economic at smaller scales**
• Converts low value input into high quality, high value liquid fuels & specialties
• Velocys technology is **ideally suited to BTL applications as well as GTL**
  — Can be built economically at the appropriate scale
  — Meets the technical demands
• Velocys technology **field demonstrated** in a BTL environment
• **Selected for two commercial BTL projects**
  — As well as two commercial GTL projects
• **Construction of commercial reference plant** has begun
• **Supply chain is delivering**
Thank you

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Appendix
High performance reactor architecture
Microchannels intensify chemical processes

Conventional FT reactor

Velocys FT reactor

Shell-and-tube

Microchannel

~ 10-30 mm

Enhanced mass and heat transfer

~ 0.1-10 mm
Velocys microchannel technology
Compact, robust, efficient and economic

- Principles of design and operation
  - Particulate catalyst in small channels
  - High catalyst volume fraction
  - Syngas downflow, products exit bottom
  - Coolant water / steam generation
  - Heat removal by steam generation

- Strengths
  - High per pass conversion (74-75%)
Pilot plant and training facility
Supporting sales and delivery

• Integrated GTL pilot plant at the Velocys Ohio, USA site

• Provides
  — Performance data to support differing client designs
  — Product for client studies
  — Permanent training facility for plant operators

• Platform for
  — Developing our own field support staff
  — Demonstrating future product generations
BTL field demonstration - Güssing accomplishments

• FT technology demonstrated in Güssing, Austria
• Demonstration conducted 2010 - 2011 on gasified wood
• Demonstrated that the high performance FT helps overcome some challenges of BTL

— High conversion of expensive syngas
— Robust to gasifier upsets
  – 193 syngas interrupts, 32 upsets and 36 shutdowns

• Steady performance
  — Excellent temperature control
  — Robust to changes in H₂/CO ratio