Methaforming®
Production of high-octane gasoline from naphtha and methanol at 1/3 the cost
**Methaforming**: One Step Conversion of Hydrocarbons with Methanol into Gasoline

- Simple one step process
- No precious metals in the catalyst
- High yield of high-octane gasoline blendstock
- Capital and operating costs like a hydrotreater
Methaformer: Process Flow and Yields

• Process flow like a hydrotreater except:
  – methanol instead of hydrogen
  – no recycle compressor

• Yields like a CCR reformer except:
  – most benzene converted to toluene
  – half of methanol becomes water
Methaforming vs Reforming: Simpler and Cheaper

Catalytic Reforming & Isomerization

Naphtha → Hydrotreater* → Reforming → Isomerization → High octane gasoline

35 - 85 °C

85 – 180 °C

Benzene reduction

Catalytic reforming and isomerization

• Most common technology
• Feed hydrotreatment required
• Several process units

Methaforming
Reduce costs to 1/3

*If sulfur <500ppm in naphtha
**Competition: Methaforming vs Combined Process**
(desulfurizer + isomerization + reformer)

<table>
<thead>
<tr>
<th>For 20 K BPD unit (860 K tpa)</th>
<th>Methaforming</th>
<th>Combined process</th>
<th>Δ Methaforming-Combined process</th>
</tr>
</thead>
<tbody>
<tr>
<td>yields, $MM/yr</td>
<td>206</td>
<td>202</td>
<td>+4</td>
</tr>
<tr>
<td>opex, $MM/yr</td>
<td>7</td>
<td>21</td>
<td>- 14</td>
</tr>
<tr>
<td>capex, $MM</td>
<td>50</td>
<td>156</td>
<td>- 106</td>
</tr>
<tr>
<td>total NPV, $MM</td>
<td>1300</td>
<td>1080</td>
<td>+220</td>
</tr>
</tbody>
</table>

Methaforming is better than combined process:
- $4 MM/yr better yields
- $14 MM/yr lower opex
- $106 MM lower capex

Net present value @12% is $220 MM better
Competition: Methaforming vs semi-regen reformer

<table>
<thead>
<tr>
<th>Existing 20 K BPD</th>
<th>Methaforming</th>
<th>Reformer</th>
<th>Δ Methaforming-Reformer</th>
</tr>
</thead>
<tbody>
<tr>
<td>yields, $MM/yr</td>
<td>206</td>
<td>149</td>
<td>+57</td>
</tr>
<tr>
<td>opex, $MM/yr</td>
<td>7</td>
<td>14</td>
<td>-7</td>
</tr>
<tr>
<td>capex, $MM</td>
<td>20</td>
<td>-</td>
<td>+20</td>
</tr>
<tr>
<td>total NPV, $MM</td>
<td>1330</td>
<td>920</td>
<td>+410</td>
</tr>
</tbody>
</table>

Methaforming is better than reformer:
- $57 MM/yr better yields
- $7 MM/yr lower opex
- $20 MM capex for conversion

Net present value @12% is $410 MM better
The Market: the World and the US

Replace existing semi-regen reformers for higher yields
- Increase earnings $57 million/yr for 20 k BPD conversion
- Existing 6 million BPD of semi-regen reformers

Replace reforming in new refineries and expansions
- Worldwide gasoline growth 1 % per yr
- Requires 2.5 million BPD of new reforming capacity by 2025 vs current 12

Other applications of the technology as specialty process
- FCC olefins can replace MeOH with large added value
- Convert light naphtha into higher octane, lower volatility blendstock
- Convert pyrolysis gasoline into higher valued aromatics
- Convert LPG into gasoline blendstock

In the US, opportunity to convert condensate into high octane gasoline
- Conversion of 1 K BPD idle hydrotreater will pay back in <1 year
Pilot Plant: Results and Plan

Micro plant
- Reactor volume – 10 ml
- Capacity – 0.014 bpd
- Total test time - 5+ years

Laboratory plant
- Reactor volume – 0.1 L
- Capacity – 0.14 bpd
- Total test hours > 2000
- Typical hours per test – 6

Pilot plant
- Reactor volume – 2 L
- Capacity – 3 bpd
- Start up – Feb 2015
- Confirm yields, catalyst life and scale up
• Based on an idle existing naphtha hydrotreater or reformer
• Start up – 2016
• Status: Looking for idle units in Russia and the US
Core Team: Solid Skills in All Key Areas

Denis Pchelintsev – CEO
Co-founder of several successful technology startups, previously - CEO NIPTIEP Institute. PhD in engineering.

Olga Malova – Head of Catalysis
Co-author of catalyst, experience in catalytic processes, projects with Bayer, Eni; author of 30 patents, PhD physical chem

Joseph Lischiner – Technologist
Co-inventor, author of the first Russian gas-methanol-gasoline and oligomerization plants; author of 25 patents, PhD in chemical engr

Stephen Sims – NGTS North America President
Energy Advisor at Houston Technology Center
President of startup, General Methanol; Career with major oil: Exxon, Citgo, ConocoPhillips

Alexei Beltyukov– Chairman of the Board
Entrepreneur, several profitable exits. Started Brunswick Rail (now >$2bn); managed a portfolio of underperforming assets, IRR >42% over 9 years. Previously at McKinsey.
Demo plant: revamp of existing hydrotreater

• Finalized design of reactor
• Completed preliminary technology package (PTP)
• Preparing PTP for hydrotreater conversion to Methaformer
• Contacting refiners

Intellectual property

• Prepared comprehensive IP strategy
• Received 4 new Russian patents to be followed by PCT
• Completed freedom to operate analysis
• Selected US IP attorney to guide & implement IP strategy
Commercial Demo Plant: Refiner Discussions

Major Russian refiner
Initial application: benzene precursor naphtha, raffinate, light FCC gasoline & dry gas
- Completed 50 pilot plant tests totaling 500 hours
- Evaluating 10 K tpa pilot plant & 600 K tpa commercial unit

Innovative CIS refiner
- Initial application: light naphtha, benzene rich reformate
- Completed 6 additional pilot plant tests
- Evaluating 60 K tpa commercial demonstration unit

Independent US refiner
- Initial application for light naphtha
- Evaluating replacing semi-regen reformers
- Developing pilot plant plan for light naphtha (C5/C6)
Summary

• Methaforming produces high-octane gasoline from low-octane hydrocarbons and methanol at 1/3 the cost with comparable yields

• Low cost conversion of semi-regen reformer improves yields over $50 million/year
Yields: Methaforming vs CCR combined

Methaforming produces:
- 1% less hydrogen
- 1% less gas used
- 8% more LPG
- 10% more gasoline

Combined process gives:
- 7 higher octane

<table>
<thead>
<tr>
<th></th>
<th>wt fraction</th>
<th>Total combined process</th>
<th>Metha</th>
<th>Metha-Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>MeOH</td>
<td></td>
<td></td>
<td>-0.283</td>
<td>-0.283</td>
</tr>
<tr>
<td>Naphtha</td>
<td>-1.000</td>
<td>-1.000</td>
<td>0.000</td>
<td></td>
</tr>
<tr>
<td>H2</td>
<td>0.028</td>
<td>0.017</td>
<td>-0.011</td>
<td></td>
</tr>
<tr>
<td>Fuel Gas, C1/C2</td>
<td>-0.014</td>
<td>-0.006</td>
<td>0.008</td>
<td></td>
</tr>
<tr>
<td>C4</td>
<td>0.000</td>
<td>0.071</td>
<td>0.071</td>
<td></td>
</tr>
<tr>
<td>LPG</td>
<td>0.039</td>
<td>0.046</td>
<td>0.007</td>
<td></td>
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<tr>
<td>gasoline blendstock</td>
<td>0.883</td>
<td>0.981</td>
<td>0.098</td>
<td></td>
</tr>
<tr>
<td>refinery fuel &amp; loss</td>
<td>0.064</td>
<td>0.015</td>
<td>-0.049</td>
<td></td>
</tr>
<tr>
<td>H2O</td>
<td></td>
<td>0.159</td>
<td>0.159</td>
<td></td>
</tr>
<tr>
<td>octane</td>
<td></td>
<td>97</td>
<td>90</td>
<td>-7</td>
</tr>
</tbody>
</table>

Comparable net economics of yields
**Yields: Methaforming vs semi-regen combined**

Methaforming produces:
- Same hydrogen
- 5% less gas used
- 9% more LPG
- 13% more gasoline

Combined process gives:
- 3 higher octane

<table>
<thead>
<tr>
<th>wt fraction including fuel gas used</th>
<th>Total combined process</th>
<th>Metha</th>
<th>Metha - Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>MeOH</td>
<td></td>
<td>-0.283</td>
<td>-0.283</td>
</tr>
<tr>
<td>Naphtha</td>
<td>-1.000</td>
<td>-1.000</td>
<td>0.000</td>
</tr>
<tr>
<td>H2</td>
<td>0.017</td>
<td>0.017</td>
<td>0.000</td>
</tr>
<tr>
<td>Fuel Gas, C1/C2</td>
<td>0.043</td>
<td>-0.006</td>
<td>-0.049</td>
</tr>
<tr>
<td>C4</td>
<td>0.000</td>
<td>0.071</td>
<td>0.071</td>
</tr>
<tr>
<td>LPG</td>
<td>0.029</td>
<td>0.046</td>
<td>0.017</td>
</tr>
<tr>
<td>gasoline blendstock</td>
<td>0.849</td>
<td>0.981</td>
<td>0.132</td>
</tr>
<tr>
<td>refinery fuel &amp; loss</td>
<td>0.064</td>
<td>0.015</td>
<td>-0.049</td>
</tr>
<tr>
<td>H2O</td>
<td></td>
<td>0.159</td>
<td>0.159</td>
</tr>
<tr>
<td>octane</td>
<td>93</td>
<td>90</td>
<td>-3</td>
</tr>
</tbody>
</table>

Methaforming yields $7/Bbl better
Yields: Methaforming makes aromatics

Methaforming

- Converts 83% of n-paraffins
- Retains 89% of isoparaffins
- Increases aromatics by 36% in total
- Dehydrogenates 30% of naphthenes

<table>
<thead>
<tr>
<th></th>
<th>wt %</th>
<th>naphtha</th>
<th>Methaformate</th>
<th>Delta: Metha-naphtha</th>
</tr>
</thead>
<tbody>
<tr>
<td>C5-</td>
<td></td>
<td></td>
<td>7.2</td>
<td>-7.2</td>
</tr>
<tr>
<td>n-paraffinic</td>
<td>30.0</td>
<td>5.2</td>
<td>-24.8</td>
<td></td>
</tr>
<tr>
<td>olefinic</td>
<td>1.4</td>
<td>2.7</td>
<td>1.3</td>
<td></td>
</tr>
<tr>
<td>i-paraffinic</td>
<td>29.0</td>
<td>25.8</td>
<td>-3.2</td>
<td></td>
</tr>
<tr>
<td>naphthenes</td>
<td>31.4</td>
<td>22.1</td>
<td>-9.3</td>
<td></td>
</tr>
<tr>
<td>aromatics</td>
<td>8.2</td>
<td>44.2</td>
<td>36.0</td>
<td></td>
</tr>
<tr>
<td>total</td>
<td>100.0</td>
<td>100.0</td>
<td>0.0</td>
<td></td>
</tr>
</tbody>
</table>
Yields: FCC ethylene can replace MeOH

- MeOH replaced with C2=
- C2= upgraded to:
  - .58 Methaformate
  - .40 LPG/C4
- Same Methaformate yield

<table>
<thead>
<tr>
<th></th>
<th>Prod-Feed with MeOH</th>
<th>Prod-Feed with C2=</th>
<th>C2= minus MeOH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methanol</td>
<td>-0.241</td>
<td>0.000</td>
<td>0.241</td>
</tr>
<tr>
<td>Naphtha</td>
<td>-1.000</td>
<td>-1.000</td>
<td>0.000</td>
</tr>
<tr>
<td>Ethylene</td>
<td>-0.184</td>
<td>-0.184</td>
<td>0.000</td>
</tr>
<tr>
<td>Methaformate</td>
<td>0.723</td>
<td>0.724</td>
<td>0.001</td>
</tr>
<tr>
<td>LPG</td>
<td>0.229</td>
<td>0.265</td>
<td>0.036</td>
</tr>
<tr>
<td>C4</td>
<td>0.133</td>
<td>0.167</td>
<td>0.035</td>
</tr>
<tr>
<td>Fuel gas</td>
<td>0.005</td>
<td>0.013</td>
<td>0.007</td>
</tr>
<tr>
<td>Water</td>
<td>0.135</td>
<td>0.000</td>
<td>-0.135</td>
</tr>
</tbody>
</table>

C2= uplifted 500 $/mt from replacing MeOH