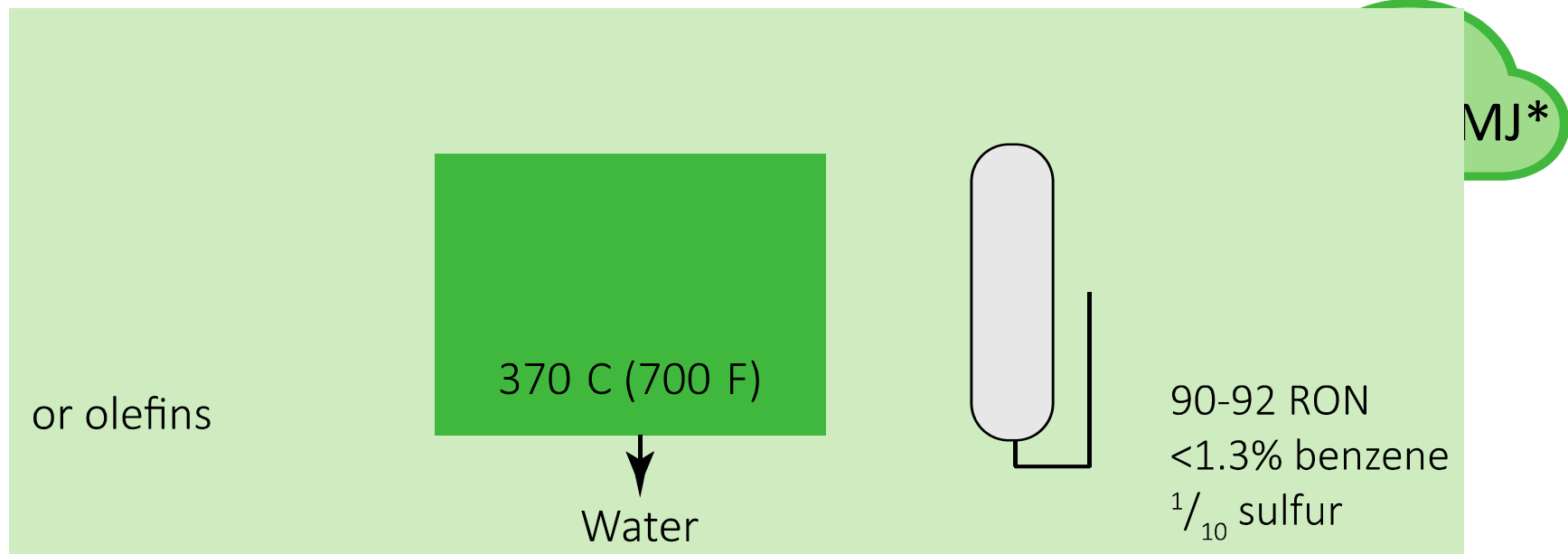


# Methaforming: Profitable “last mile” technology for biofuels

[www.ngt-synthesis.com](http://www.ngt-synthesis.com)

# Methaforming: One Step Conversion of Various Feeds into Gasoline



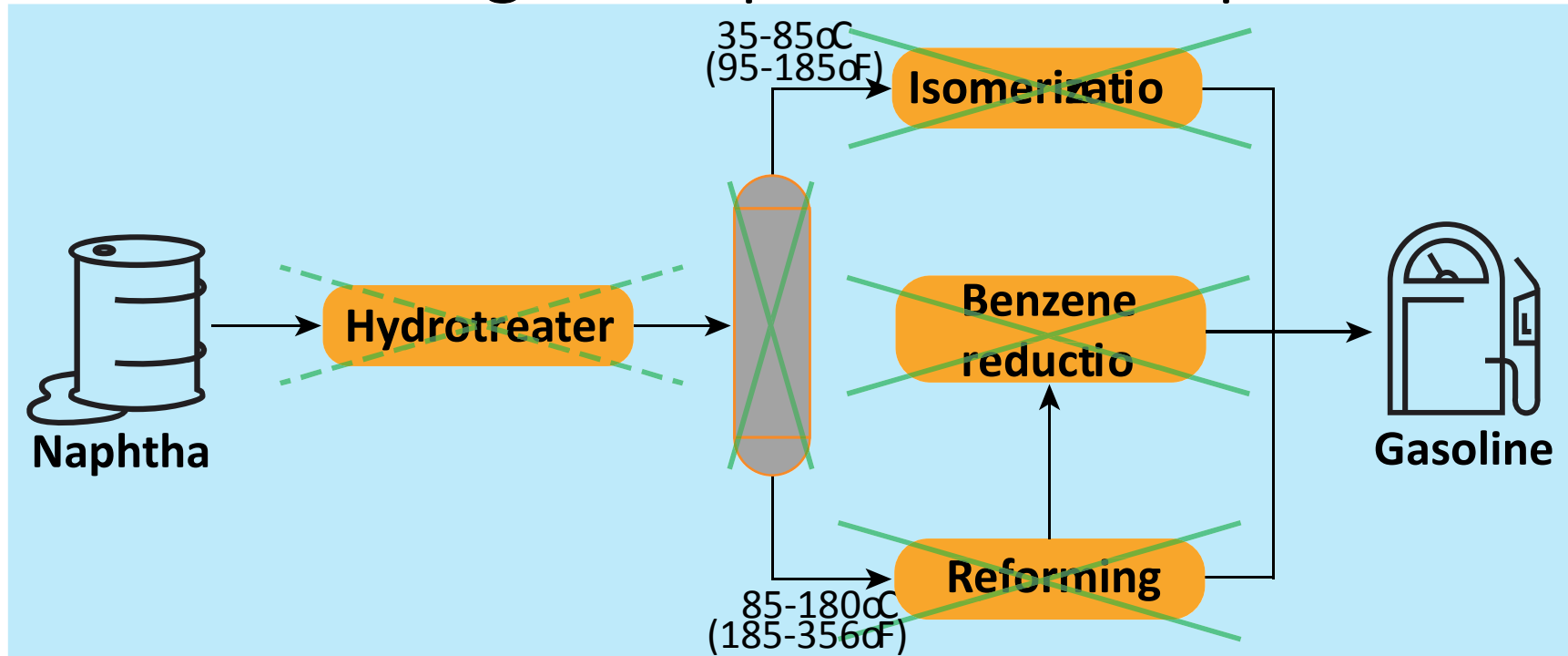
- Wide range of possible feeds
- Simple one step process
- No precious metals in the catalyst
- High yield of gasoline blendstock
- Capital and operating costs like a hydrotreater

\* Compared to 3.2 gCO<sub>2</sub>/MJ for traditional naphtha processing.

## Process Flow and Yields

- Process flow like a hydrotreater except:
  - Alcohol or another co-feed instead of hydrogen,
  - No recycle compressor.
  
- Yields like a reformer except:
  - Most benzene converted to toluene,
  - Part of alcohol becomes water,
  - Regenerate catalyst 1/mo (5 year life).

## Methaforming is Simpler and Cheaper



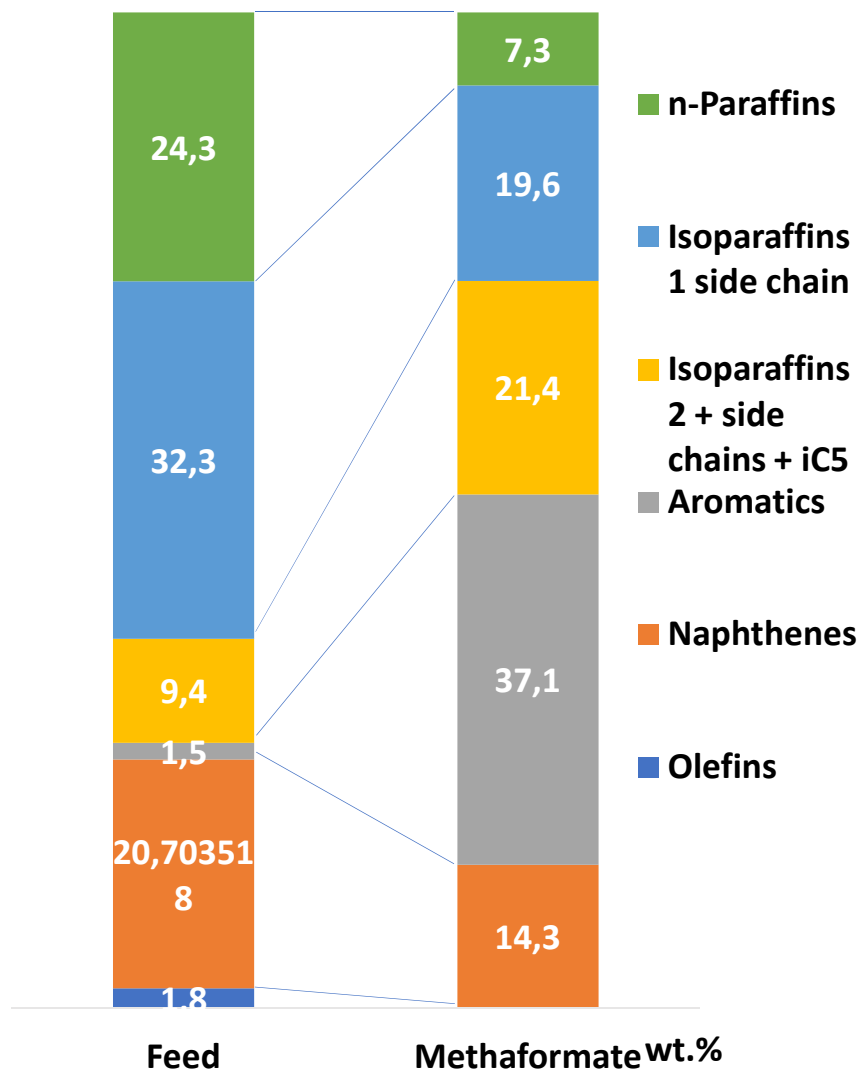
### Catalytic reforming and isomerization

- Most common technology
- Feed hydrotreater required
- Several process units

### methaforming

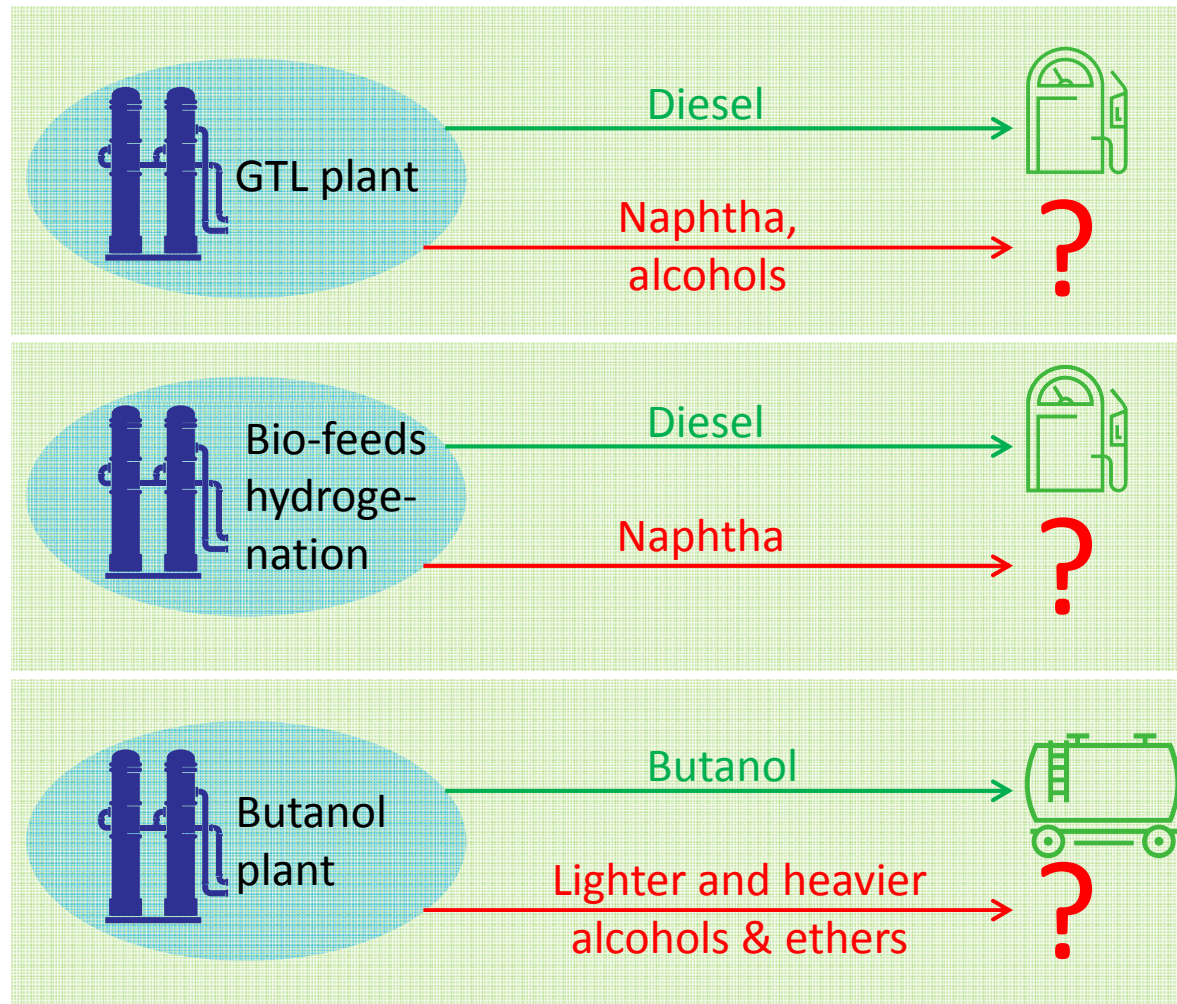
- Reduce costs to 1/3
- Reduce sulfur by 90%
- Simple single process unit

# Methaformer Yield Details



Delta: PROD - FEED		
Product	mt	Change, %
<b>n-Paraffins</b>	<b>(0.185)</b>	<b>(76)</b>
<b>Isoparaffins</b>	<b>(0.098)</b>	<b>(23)</b>
1 side chain	(0.171)	(53)
2+ side chains + iC5	0.073	78
<b>Aromatics</b>	<b>0.274</b>	<b>na</b>
1 ring	0.266	na
2 rings	0.009	na
<b>Naphthenes</b>	<b>(0.196)</b>	<b>(64)</b>
5-C-ring	(0.084)	(49)
6-C-ring	(0.112)	(83)
<b>Olefins</b>	<b>(0.017)</b>	<b>(95)</b>

# Nearly every renewable fuel has low value byproducts



# Feed Flexibility – Key to Profitability

## Acceptable main feeds

- Light naphtha and solvents,
- GTL naphtha,
- Benzene-rich naphtha,
- Narrow fractions of C<sub>6</sub>-C<sub>7</sub> hydrocarbons,
- Gas condensate,
- Virgin naphtha,
- Natural gasoline,
- Pyrolysis gasoline,
- Raffinate from aromatics extraction unit,
- Light FCC naphtha,
- Mixes of these.

## Feed Flexibility – Key to Profitability

### Acceptable co-feeds

- Ethanol,
  - Methanol,
  - Propanol, butanol and heavier alcohols,
  - Ethers,
  - Light olefins,
- Other byproducts of alcohol production,
  - Crude alcohols with up to 50% water,
  - Mixes of these.

# Methaformer vs Traditional Reforming Suite (HDS+semi-regen reformer)

New 860 K tpa unit (20 K BPD )	Methaforming	Alternative	Δ Methaforming - Alternative
Yields*, \$ million/yr	29	24	+ 5
OpEx, \$ million/yr	8	12	- 4
CapEx, \$ million	25	55	- 30
Total NPV, \$ million	120	20	<b>+ 100</b>

**methaforming**

\$ 9 million/yr profit advantage  
\$ 30 million lower CapEx

**Net present value @12% is \$100 million higher**

\* Yields include fuel gas produced/consumed, H2, RON value.

# Convert Semi-regen Reformer

Existing 860 K tpa unit (20 K BPD )	Methaforming	Alternative	$\Delta$ Methaforming - Alternative
Yields, \$million/yr	126	95	+ 31*
OpEx, \$million/yr	13	23	- 10
CapEx, \$million	20	-	+ 20
Total NPV, \$million	750	490	<b>+ 260*</b>

**methaforming**

\$ 41 million/yr profit advantage  
\$ 20 million CapEx to convert

**Net present value of conversion @12% is \$260 million\***

**\*Excluding carbon credits opportunities**

# Methaforming Light Virgin Naphtha with C2= vs. Isomerization with Recycle

New 190 K tpa unit (5 K bpd)	Methaforming	Alternative (isom)	Δ Methaforming- Alternative
Yields, \$million/yr	55	55	0
OpEx, \$million/yr	3	8	- 5
CapEx, \$million	25	43	- 18
Total NPV, \$million	375	320	+ 55

**methaforming**

\$ 5 million/yr profit advantage  
\$ 18 million lower CapEx

**Net present value @12% is \$ 55 million higher**

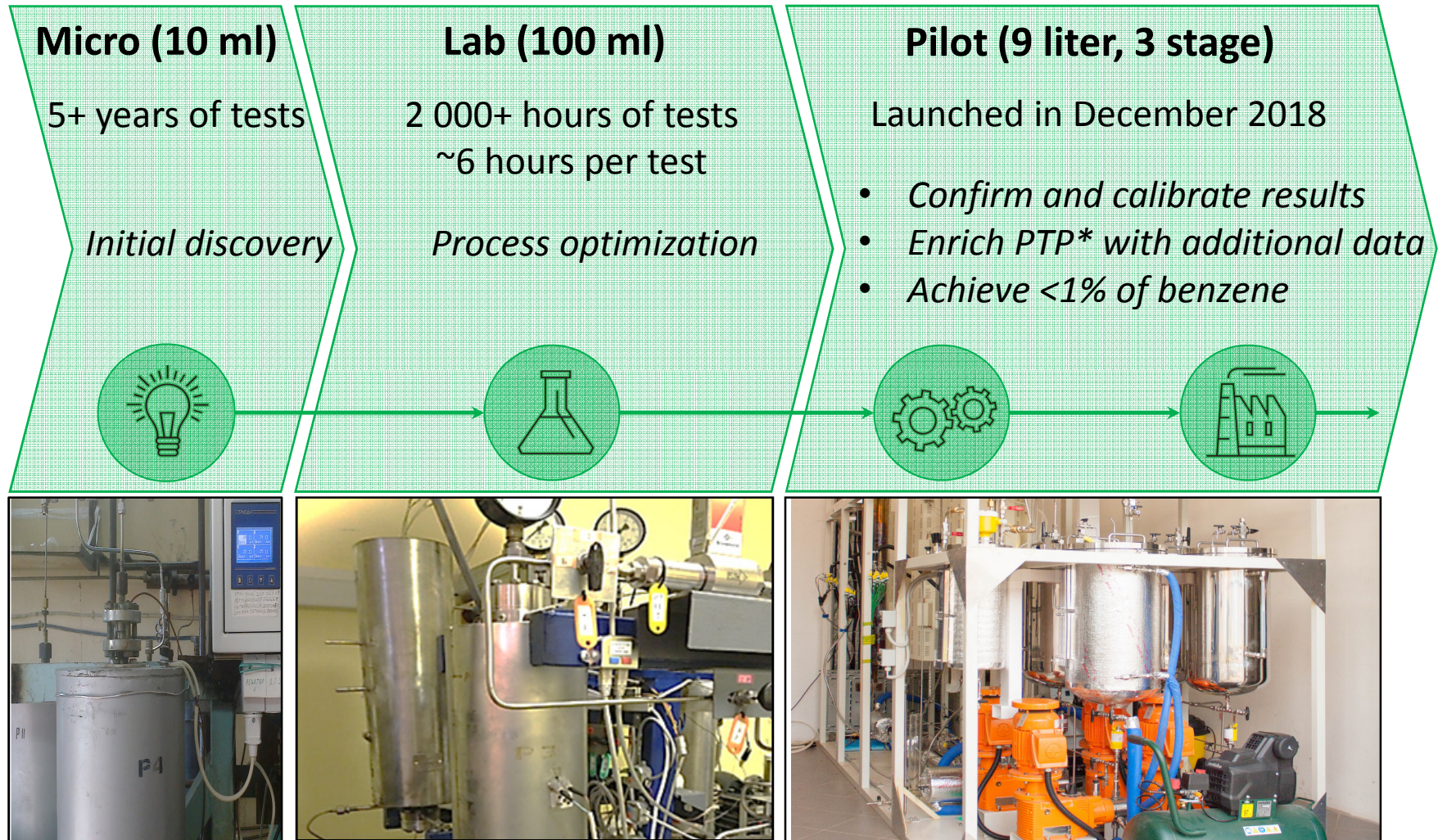
# Grassroots Unit to Process Raffinate and FCC dry gas

New 88 K tpa unit (2 K BPD )	Our Unit	Alternative (direct blending)	Δ Our Unit - Alternative
Yields, \$million/yr	62	41	+21
OpEx, \$million/yr	4	0	+4
CapEx, \$million	14	0	+14
Total NPV, \$million	<b>+100</b>	n/a	<b>+100</b>

**methaforming** \$ 17 million/yr profit advantage

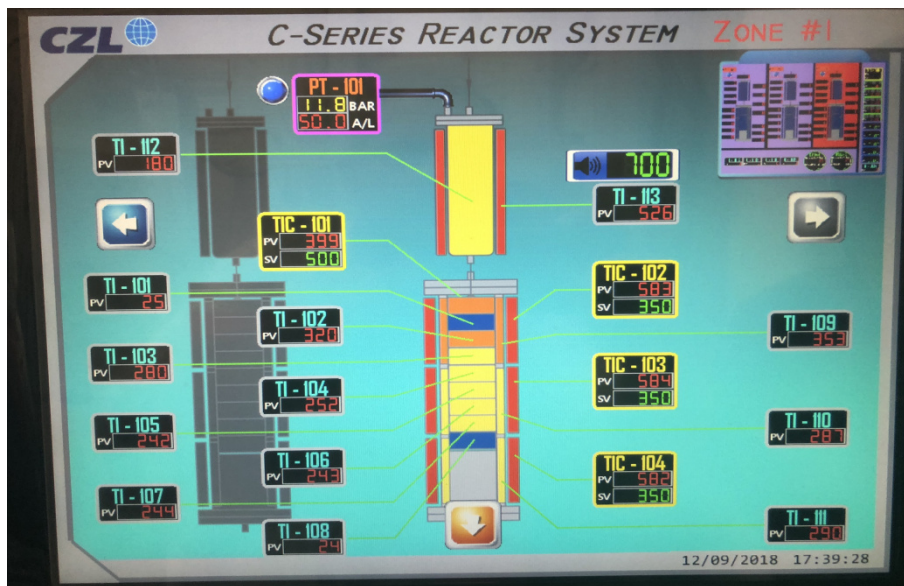
**Net present value @12% is \$100 million**

# Pilot Plants



\* Preliminary technology package – documentation to design a commercial plant.

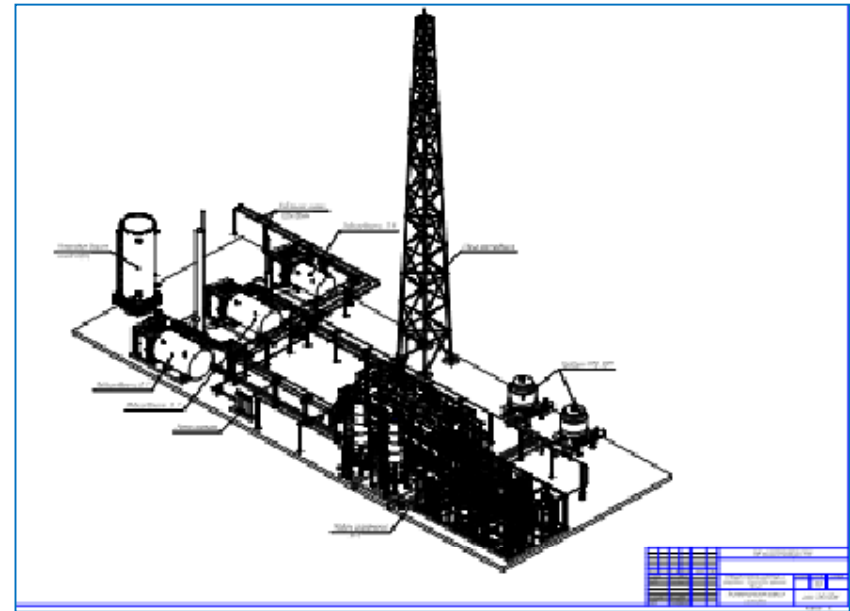
# Methaforming demo plant\*



\*In cooperation with Omsk refinery, Russia

# Skid Mounted Methaformers Ready for Order

- Detailed mechanical design complete.
- Two sizes, prices at FOB Black Sea:
  - 6 k tpa (150 BPD) for \$900 K (6 mo delivery);
  - 21 k tpa (530 BPD) for \$2 million (15 mo delivery).
- Includes all inside battery limits (ISBL).
- OSBL by owner – much may already exist
  - feed and product tankage, MeOH/EtOH receiving;
  - hydrogen-rich gas H<sub>2</sub>S removal, LPG sweetening;
  - utilities: fuel gas, electricity, wastewater treating.



## Technology Acceptance by Refiners

- **Owner of 6k tpa (150 bpd) first commercial plant** now building 12k tpa (300 bpd) Methaformer.
- **Refiner in Uzbekistan:** FEED done for 55k tpa (1300 BPD) Methaformer.
  - Feed: light naphtha, full range naphtha.
- **Major Russian refiner:** pre-engineering in progress for 480k tpa (11k BPD ) unit, launch in 2023.
  - Feed: raffinate, benzene precursor naphtha, FCC dry gas, methanol.
- **Merchant processor in US:** Convert 65 K tpa of low-cost spot purchased naphtha into finished gasoline.

## Summary

- Upgrade low value byproducts of biofuel production to drop-in gasoline and LPG
- Produce gasoline from naphtha, FCC dry gas and methanol at 1/3 the cost with comparable yields
- 5 times carbon footprint reduction compared to traditional naphtha PFD
- Can be profitable even at very low scale



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