29th Annual Spring Symposium—SPE

Flare Gas Monetization: Plan, Measure, Act

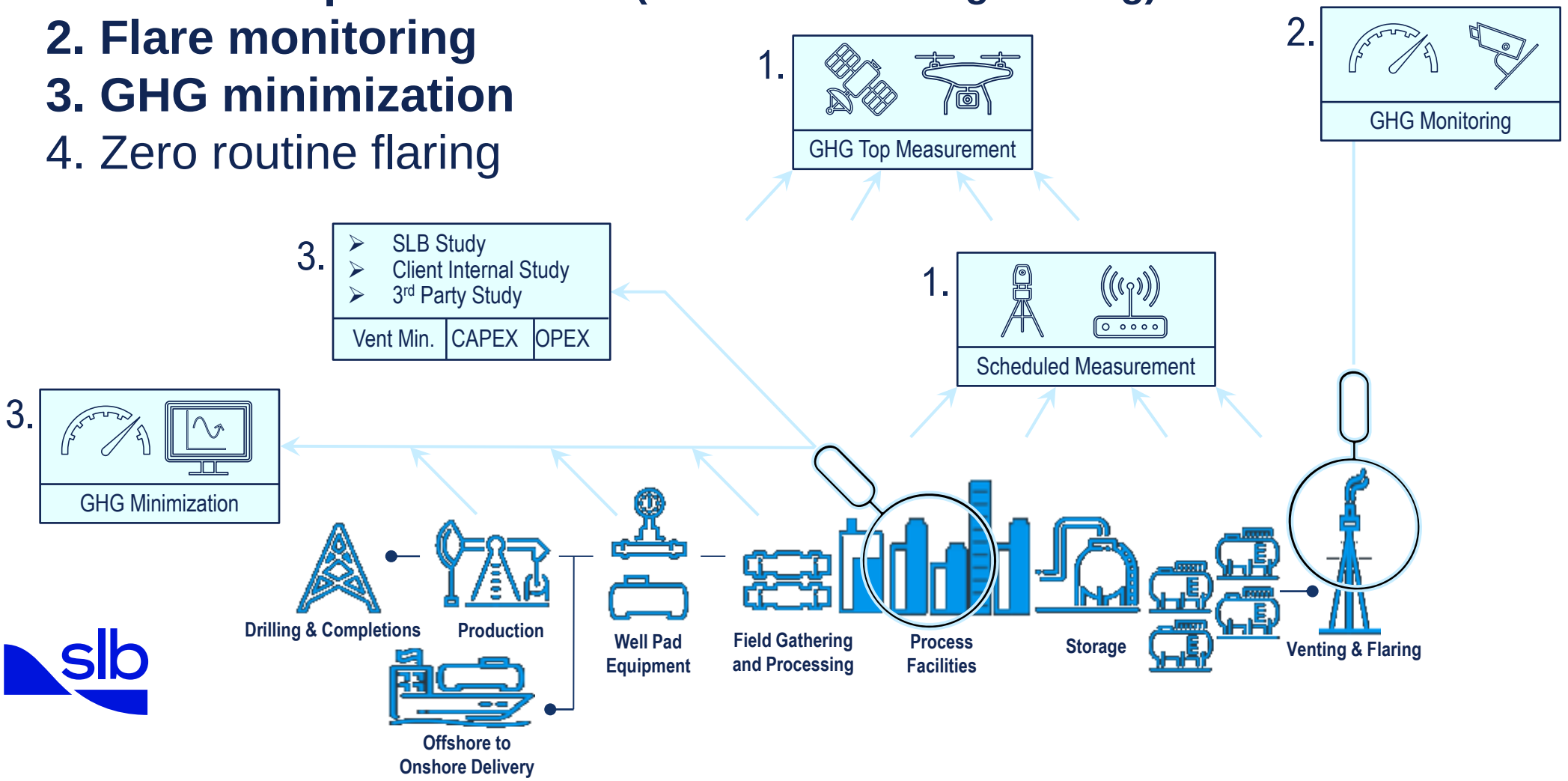
Glen Hay, SLB End-to-end Emission Solutions (SEES)

April 2024

Emissions reduction—Planning towards zero emissions

Steps

1. Methane quantification (measurement/engineering)
2. Flare monitoring
3. GHG minimization
4. Zero routine flaring



Measuring and tracking GHG emissions

How do we handle measuring and estimating different emissions?

Measurements

Detailed Validation


Sealed Chamber


Wind Tunnel


Outdoor Testing

Mobile Measurement

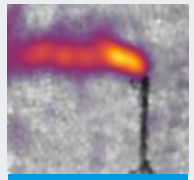

Satellite


Airplane


Drone

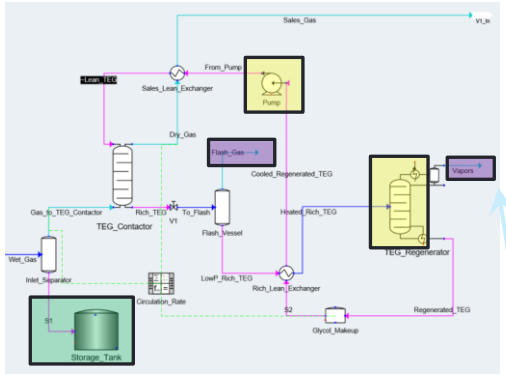
Continuous Monitoring


Point Sensor


Lidar Camera

COMBINED

TEG Dehydration Plant Simulated Example



Engineering

Inventory:

- Storage Emissions
- Venting & Flaring Emissions
- Utility Related Emissions

Emissions reduction—Planning towards zero emissions

Steps

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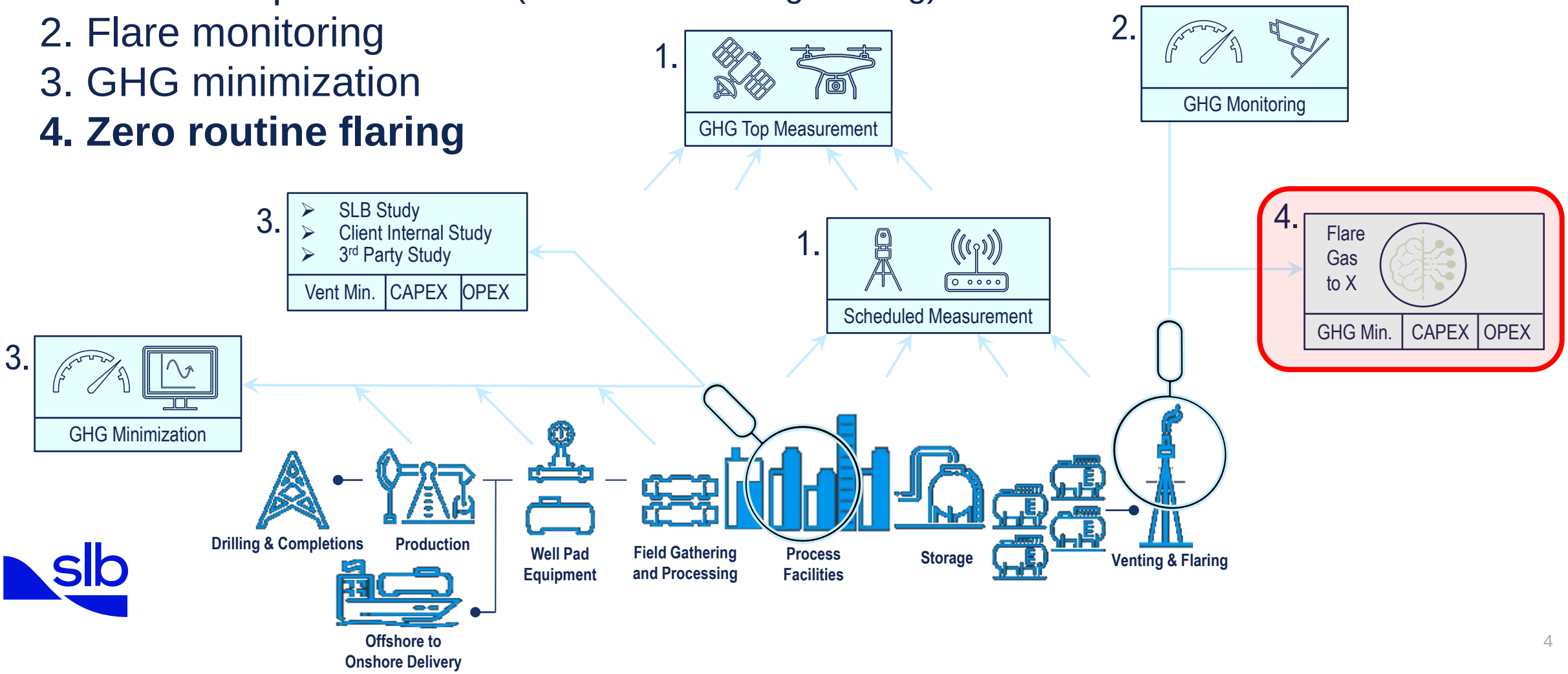
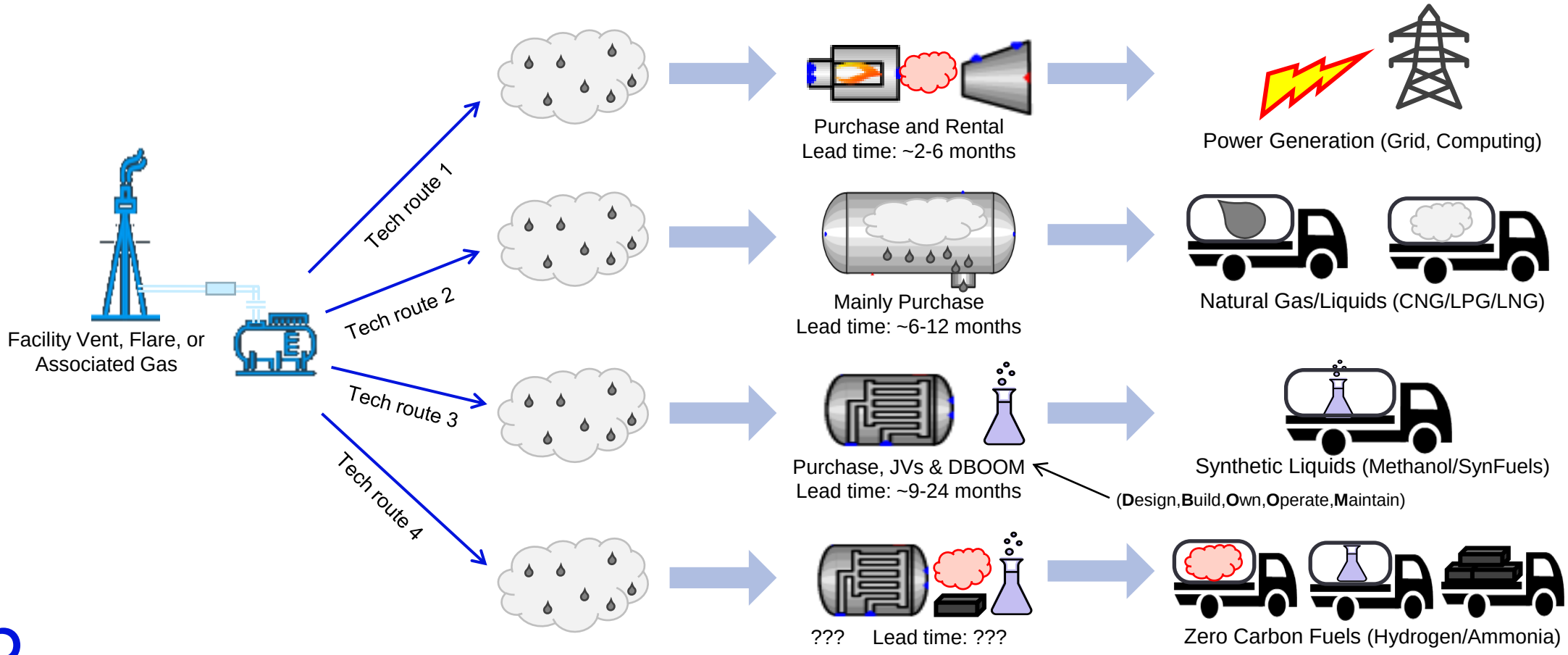
4. **Zero routine flaring**



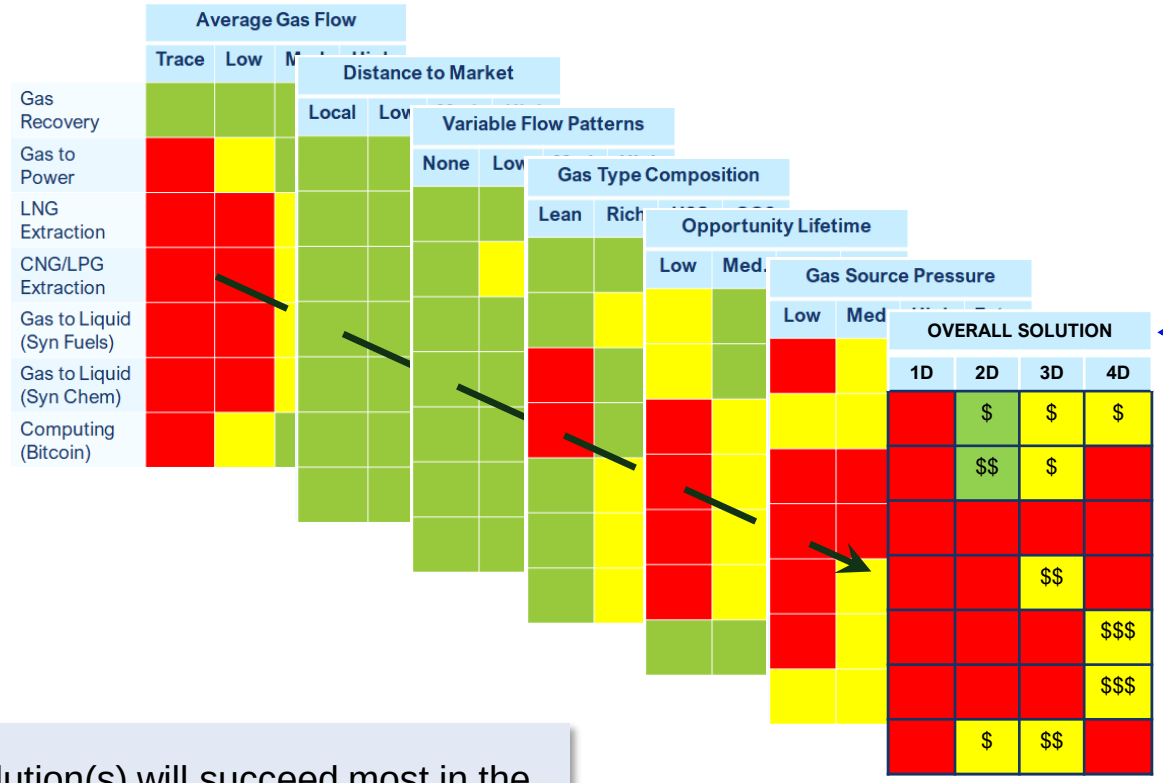
Flare gas monetization—Major technology options

Flare elimination solutions for power, natural gas/liquids, synthetic liquids, and zero carbon fuels

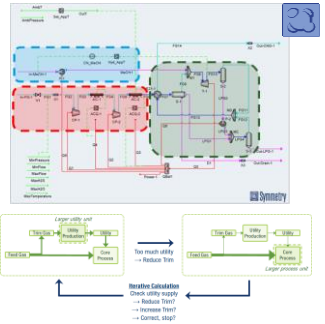


Flare gas monetization—Overall “best” solution considerations

Economically optimized zero routine flaring

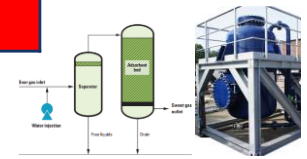


Micro Solution
CAPEX/OPEX



Rigorously Balanced Utilities

↳ Water, Power, etc.



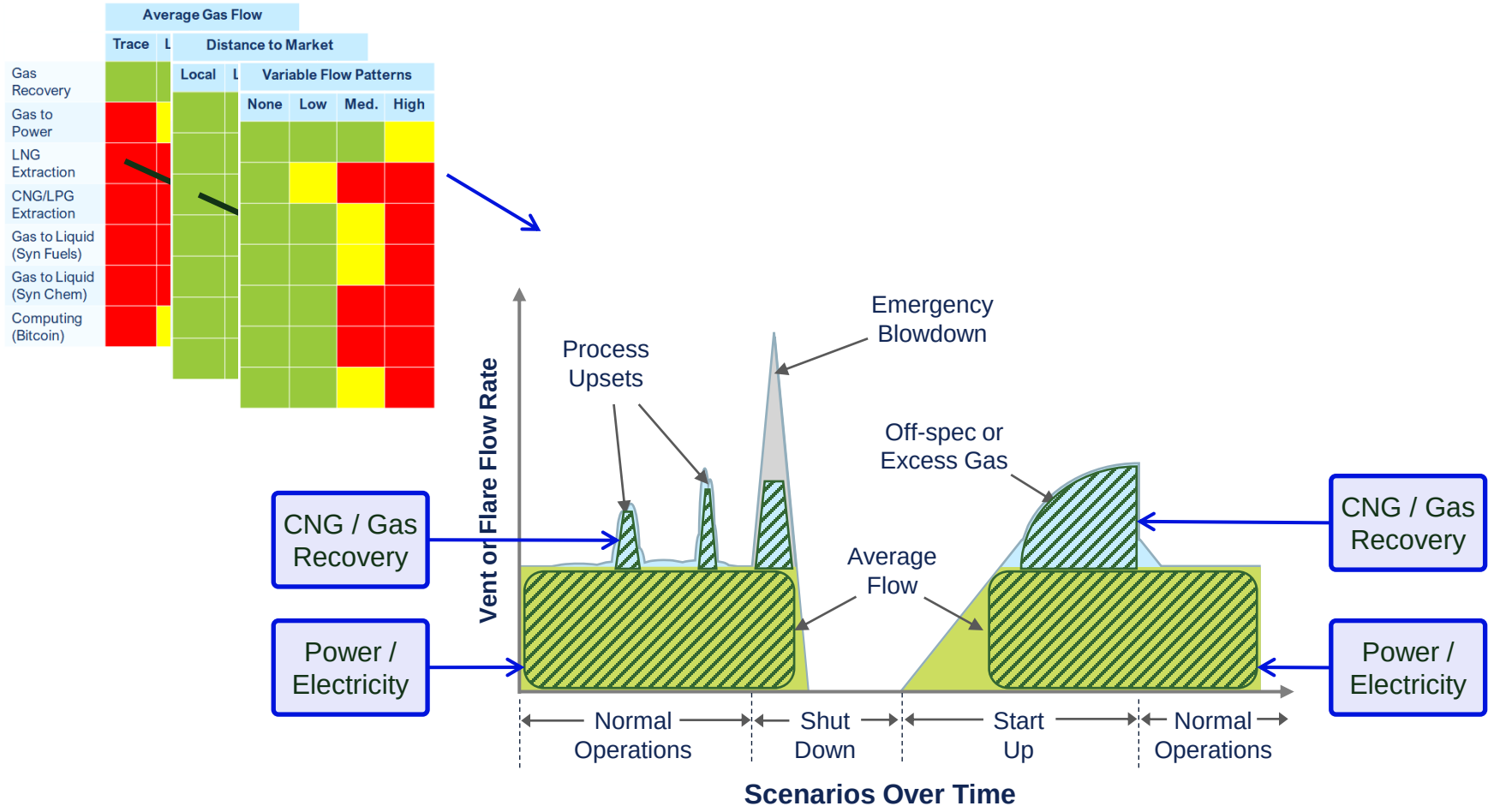
Integrated Overall Solutions

↳ Pre-treatment and Post-treatment

What solution(s) will succeed most in the short and long term?

Flare gas monetization—Overall “best” solution(s) considerations

Economically optimized might be combined solutions



Reference: Flaring and venting guidance, Oil & Gas Authority (2021)

Flare gas monetization—Power generation (grid, computing) and natural gas/liquids (CNG/LPG/LNG) overview

Power generation to local utilization (rigs, injection, ESPs), grid, or computing power

Engine = Low feed H_2S, ~98% destruction efficiency

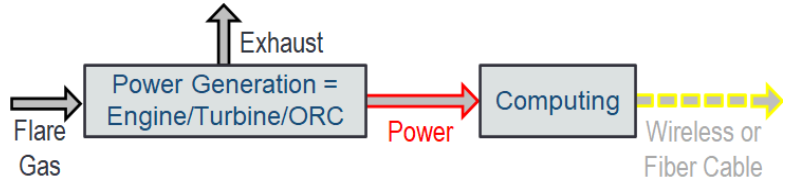
Many units required for larger MW scale

Turbine = Lower OPEX, higher CAPEX, high feed pressure, more scale

Aeroderivative Turbine even more CAPEX, less OPEX

Organic Rankine Cycle
= Lower efficiency, flexible feed gas

Computing = Alternative market value generation



Very mature tech, but small grid power connection a hard sell

Solutions started with Bitcoin… now in AI, CFD, Bio-Computations, etc. (high bandwidth locations)

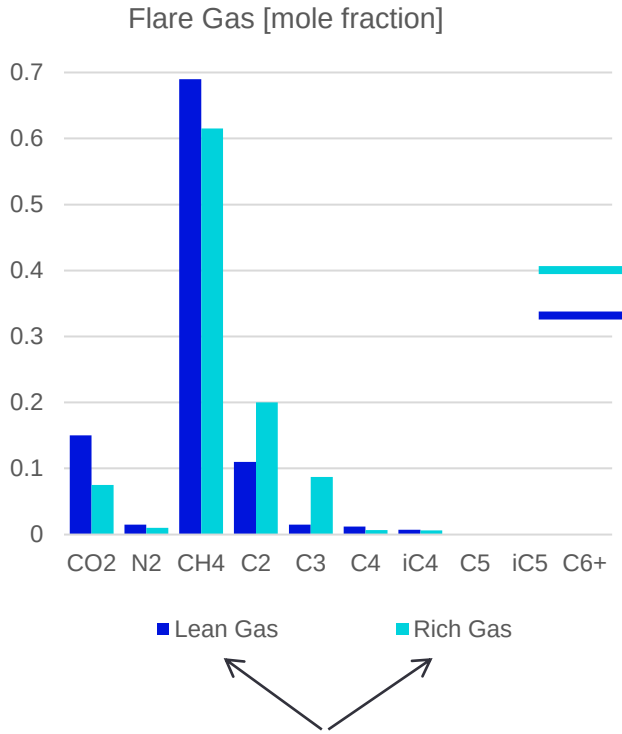
CNG/LPG Extraction (Chiller Loop or Expansion) = High feed pressure, water removal (or hydrate inhibition with methanol)

Solvent extraction more complex and high CAPEX and OPEX for smaller scale units <5 MMSCFD

LNG Cryogenic (Chiller Loop or Expansion) = High feed pressure, water/CO_2 flow assurance

Flare gas monetization—Natural gas/liquids (CNG/LPG) **logistics**

Without conversion, feed gas composition dictates profits



LPG/CNG Extraction

Product	Price
Offgas	---
CNG	$ [redacted] m^3
LPG	$ [redacted] kg

$ [redacted] / MMSCFD
$ [redacted] / MMSCFD
$ [redacted] / MMSCFD
$ [redacted] / MMSCFD

$ [redacted] / MMSCFD
$ [redacted] / MMSCFD
$ [redacted] / MMSCFD
$ [redacted] / MMSCFD

Depending on CAPEX and OPEX of the facility and markets the Initial Rate of Return (IRR) can shift from 25% to 50%

~4-year payback

~2-year payback

FG = Flare Gas (sometimes more or less valued heavy components) *(can contain H_2O, CO_2, N_2, H_2S, etc)*

Std Liq Volume	[m3/h]
METHANE	8.456
ETHANE	2.231
PROPANE	2.110
n-BUTANE	0.986
ISOBUTANE	0.479
n-PENTANE	0.317
ISOPENTANE	0.408
n-HEXANE	0.417
n-HEPTANE	0.000

CNG = $ Compressed Natural Gas
LNG = $ Liquified Natural Gas

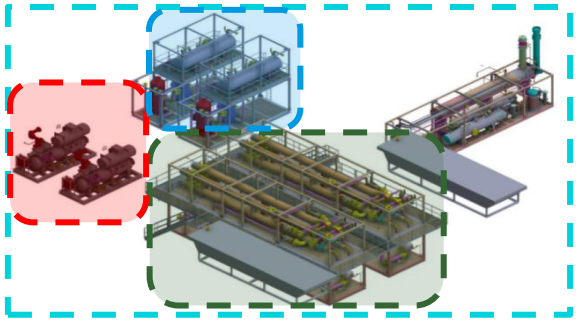
LPG = $$ Liquified Petroleum Gas

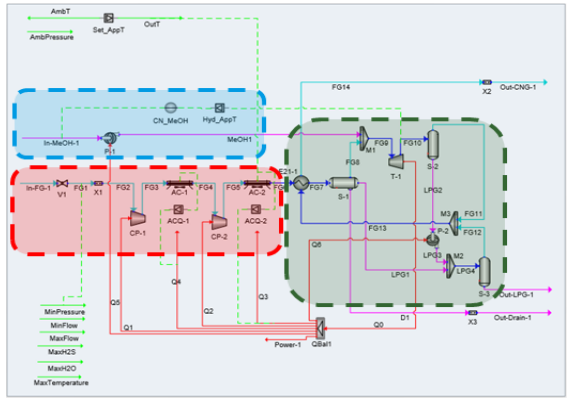
Condensate = $$$ Liquid Fuels

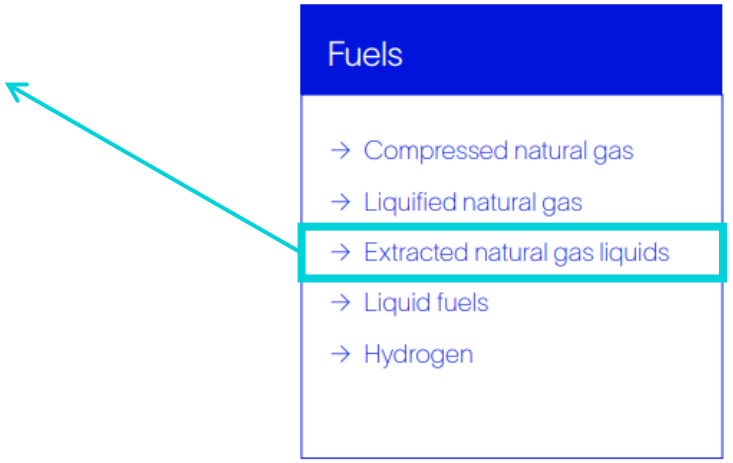
Flare gas monetization—Rigorous thermodynamic validation

Internally developed process simulation software used to rigorously and accurately analyze each opportunity

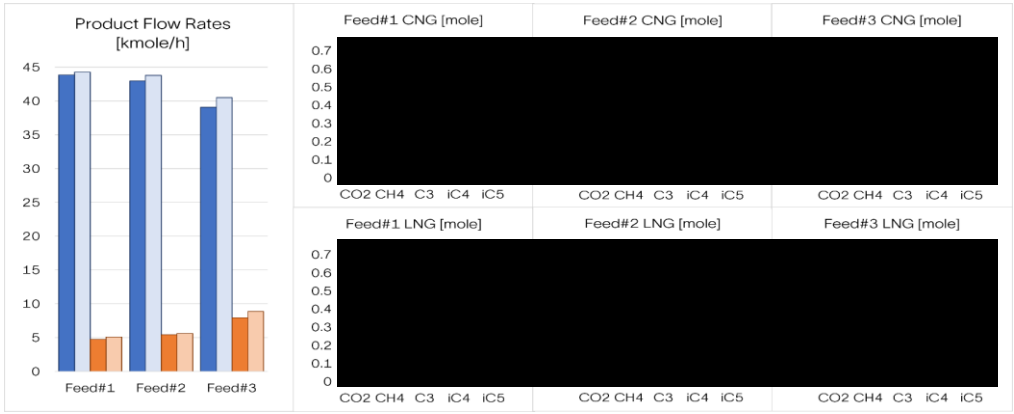
Extract Solution







Product Flow Match



CNG Composition Match

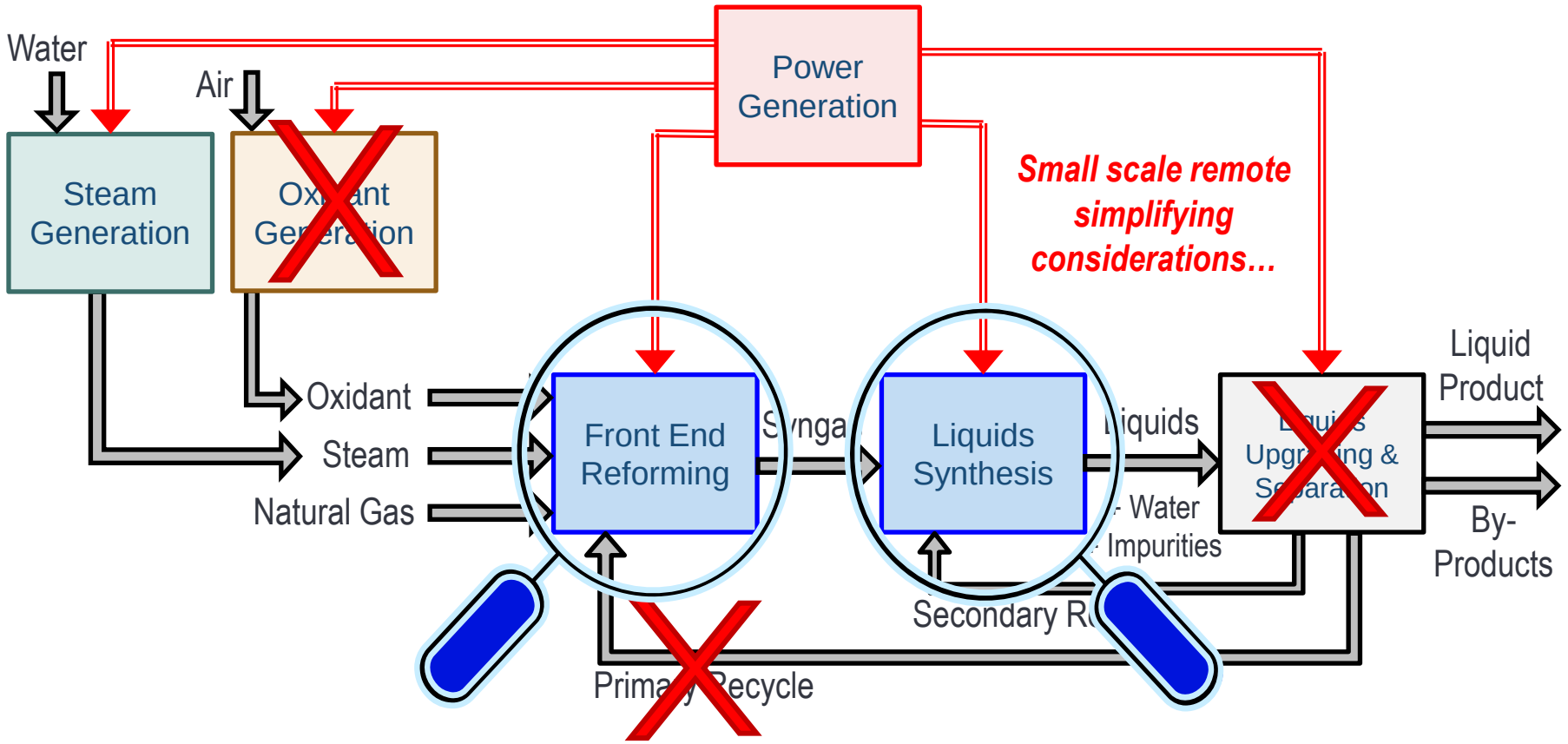
Plant Simulation

LNG Composition Match

Plant Simulation

Gas to liquids—Synthetic liquids (methanol, synfuels) overview

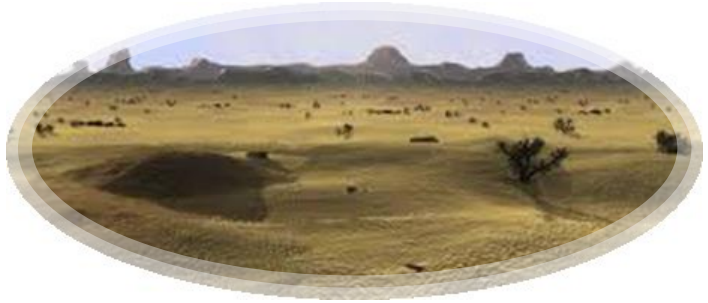
Multiple considerations are required for the overall synthetic liquids production facilities



Gas to liquids—Synthetic liquids front-end reforming

How to pick the front-end reforming design?

Utilities available at stranded gas?
Water, oxidant, power, etc.

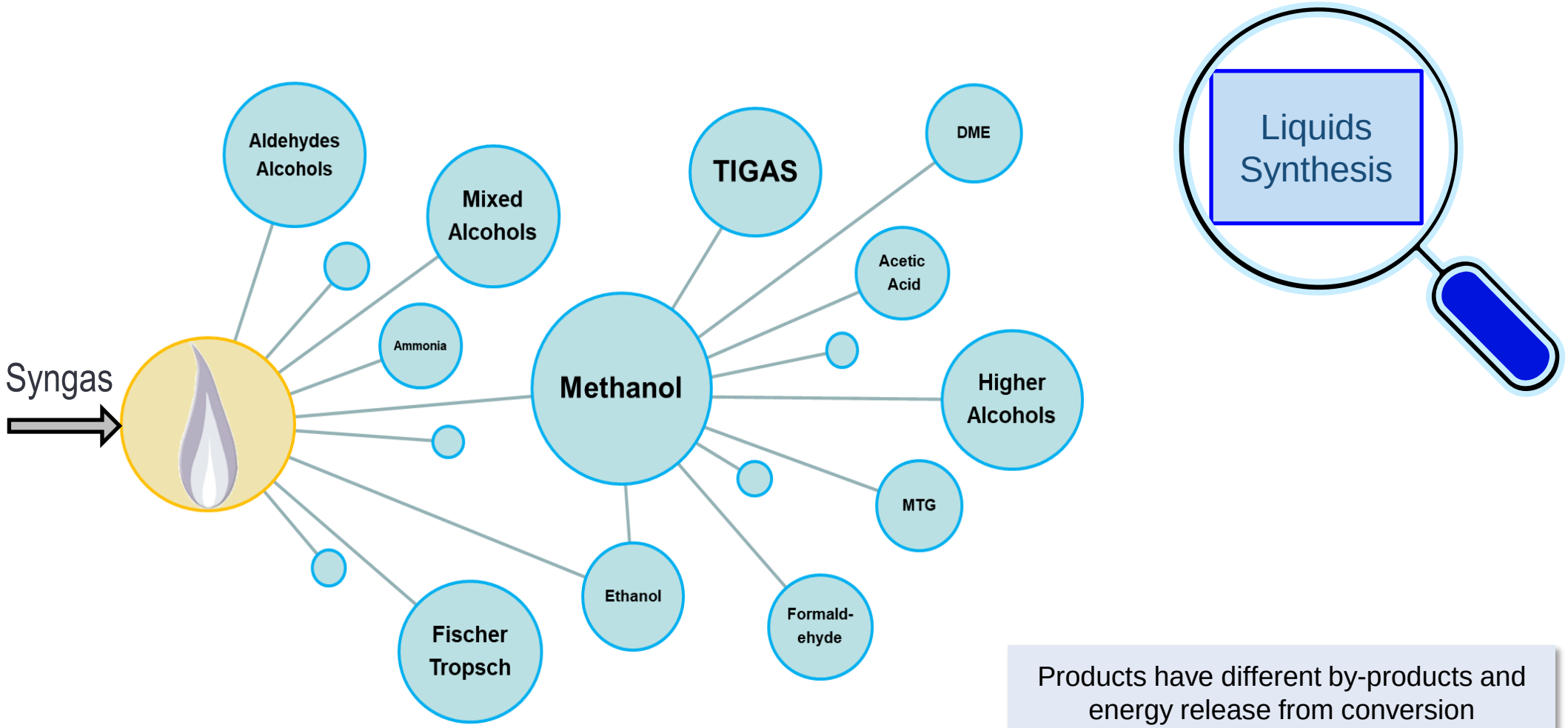


Either furnace or electrified →

	Water	Oxidant	Syngas Impurity	Feed Pressure
SMR	High	None	Low	Medium
ATR	Small/None	High	High	High
POx	Small/None	Medium	Medium	Low
Plasma	None	None	Low	Medium

SMR = Steam methane reforming
ATR = Autothermal reforming
POx = Partial oxidization

Gas to liquids—Synthetic liquids (methanol, synfuels) overview



Products have different by-products and energy release from conversion (and phase change)

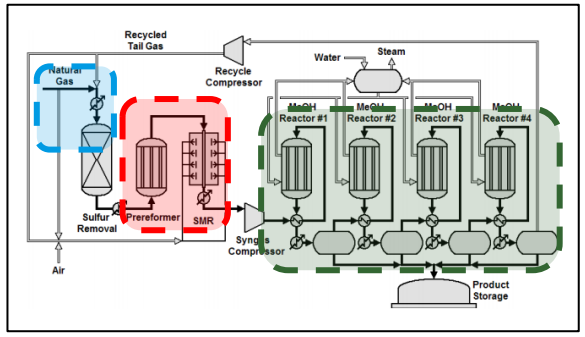
Flare gas monetization—Rigorous thermodynamic validation

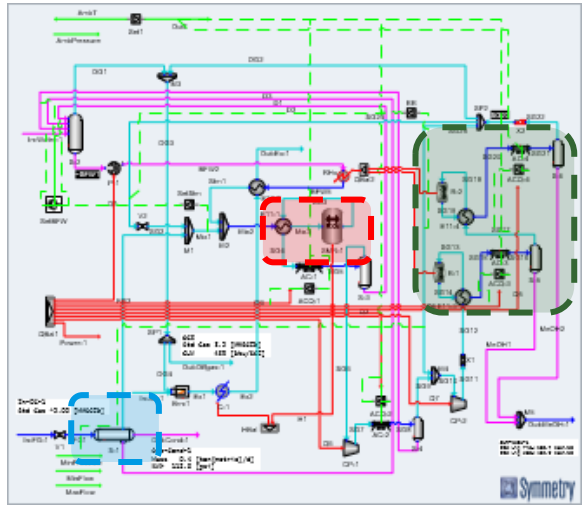
Synfuel Solution

Internally developed process simulation software used to rigorously and accurately analyze each opportunity

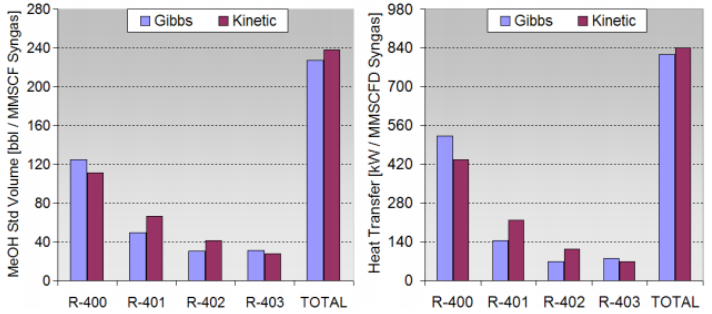
Fuels

- → Compressed natural gas
- → Liquified natural gas
- → Extracted natural gas liquids
- → Liquid fuels
- → Hydrogen





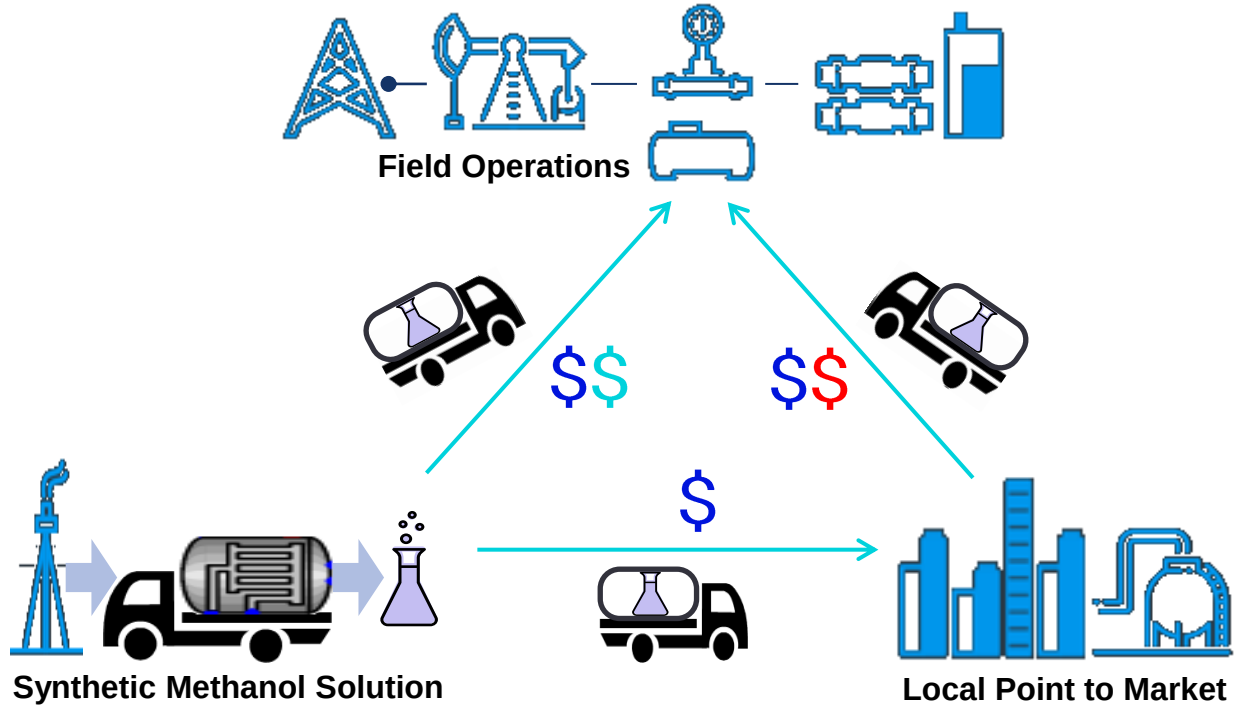
Product Flow Match



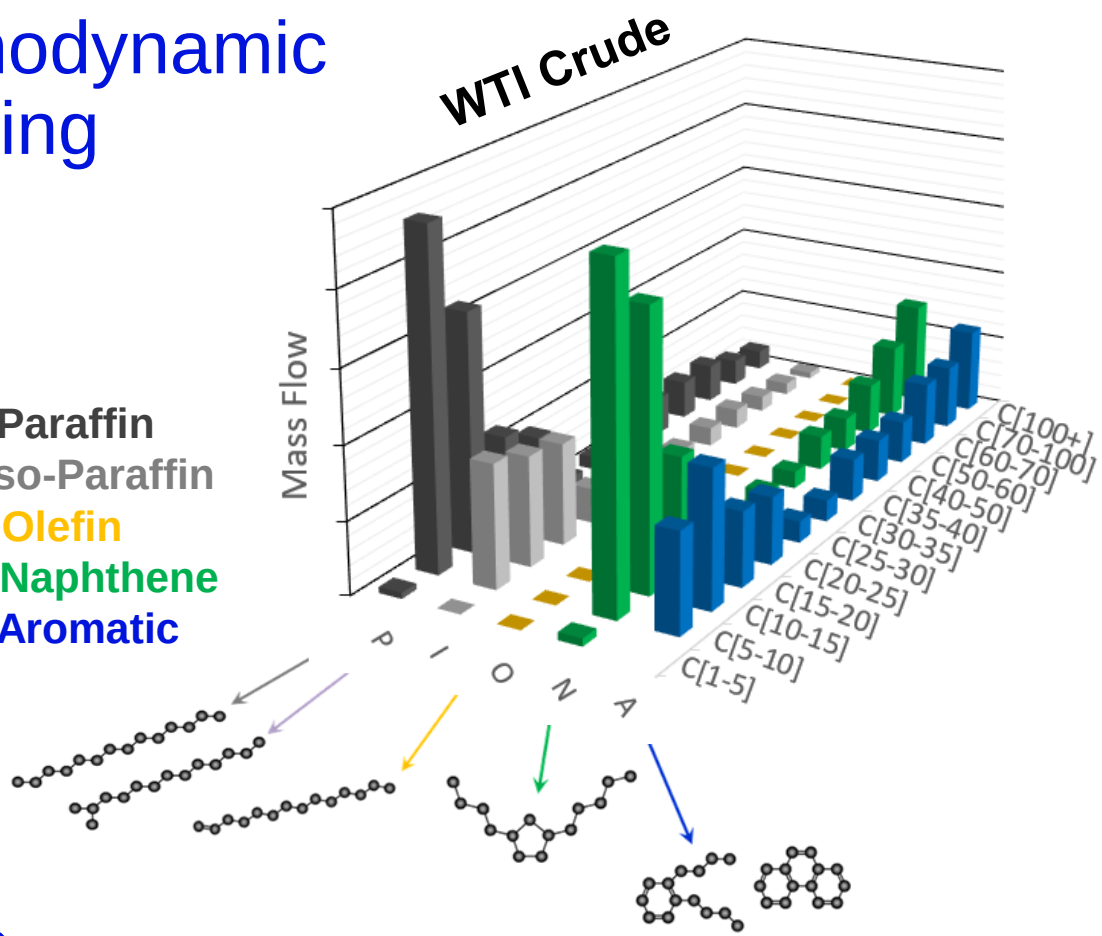
Hay et al, Chemical Product & Process Modeling(2011)

Flare gas monetization—Specialty chemical with inventory and upgrading cost abatement

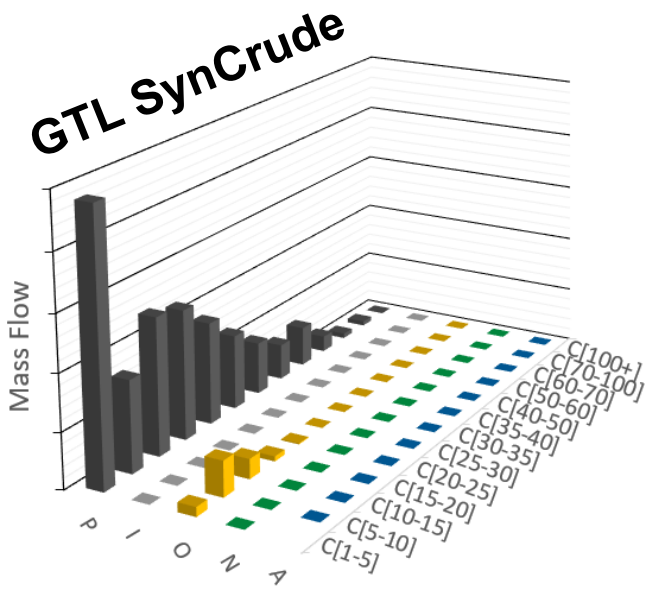
Market point price sometimes does not accurately represent the actual operational cost that could potentially be eliminated locally



Flare gas monetization—Rigorous thermodynamic blending



P = Paraffin
I = Iso-Paraffin
O = Olefin
N = Naphthene
A = Aromatic



Pour Point Temperature

Cut Range, NBP [F]	WTI Crude	Syn Crude
Diesel [500- 650]	~ 15 F	[redacted] F
Kerosene [350- 500]	~ -50 F	[redacted] F

Kinematic Viscosity @ 100F

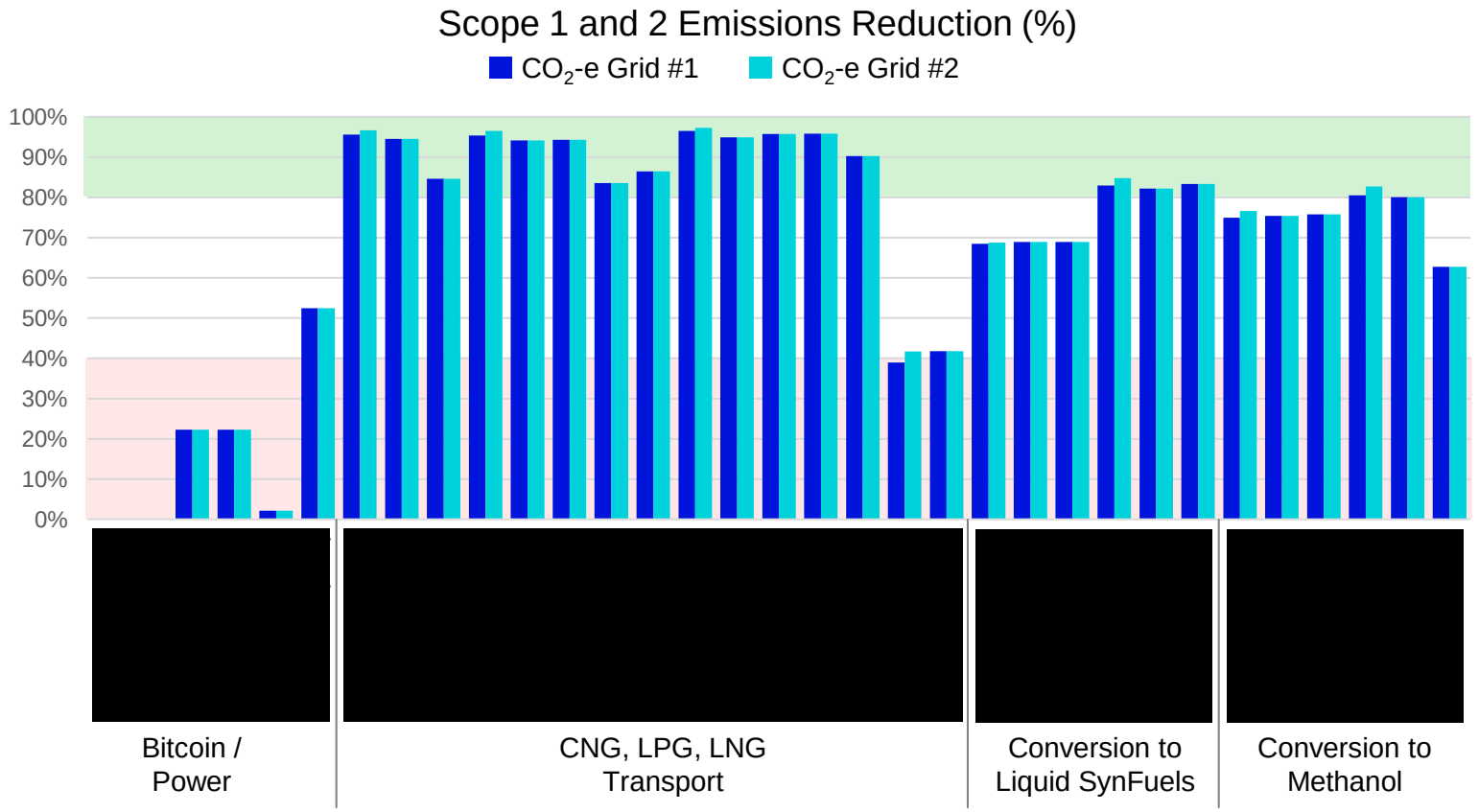
Cut Range, NBP [F]	WTI Crude	Syn Crude
Diesel [500- 650]	~ 9.0 cSt	[redacted] cSt
Kerosene [350- 500]	~ 3.0 cSt	[redacted] cSt

More paraffins in fluid →

Simple index blending rules do not apply unless they account for molecular structure

Flare gas monetization—Scenario scope 1 and 2 emissions reduction

CO_2 equivalent emission reduction based on 98% flare destruction efficiency
(Methane GWP x25)

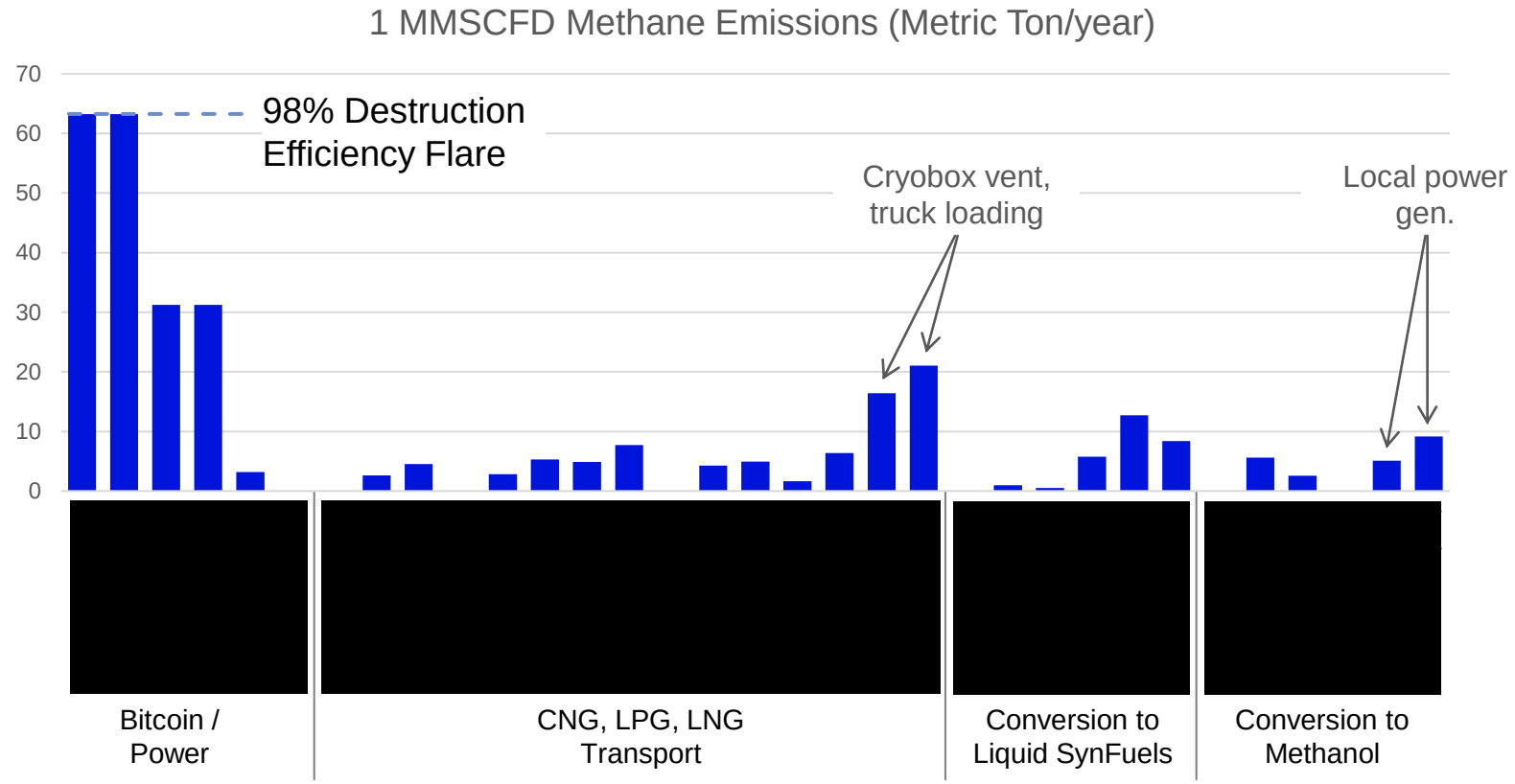


No CCS scenarios (cost prohibitive)

Solutions have varied resulting emission reductions

Flare gas monetization—Scenario **planned** methane emissions

Fugitive methane can also be significant and minimized by monitoring programs, but some planned methane is process related due to venting, combustion, etc.



Solutions have varied reduction of resulting methane emissions

Takeaways

- → Plan-Measure-Act = Gas monetization with reduced emissions
- → Complexities require developed methodologies and understanding to expediate the advisory for optimal returns
- → Business strategy must keep up with emerging technology
- → Local understanding needed to determine best solutions

Thank you, open Q&A discussions