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MONETISING STRANDED GAS RESOURCES ONSHORE AND OFFSHORE

- The Palette Of Enabling Technologies, Their Comparative Merits And Challenges In Commercial Application

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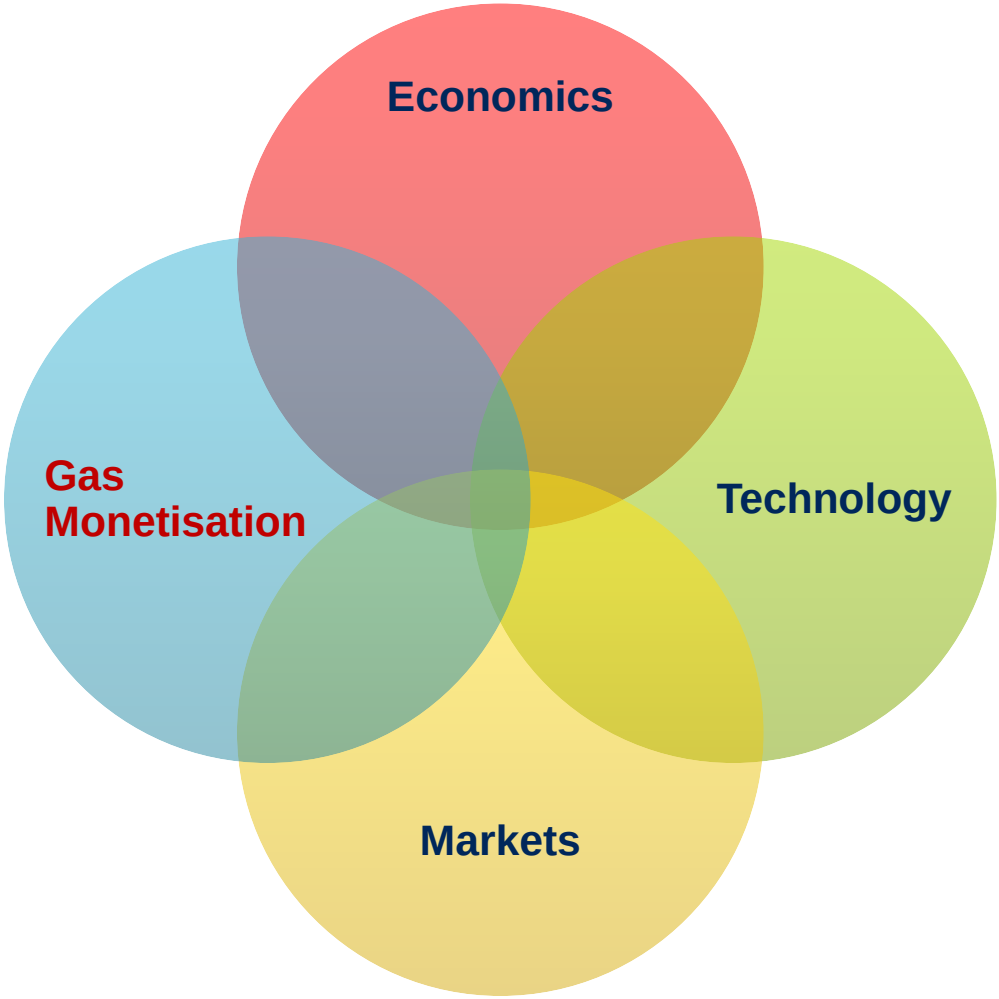
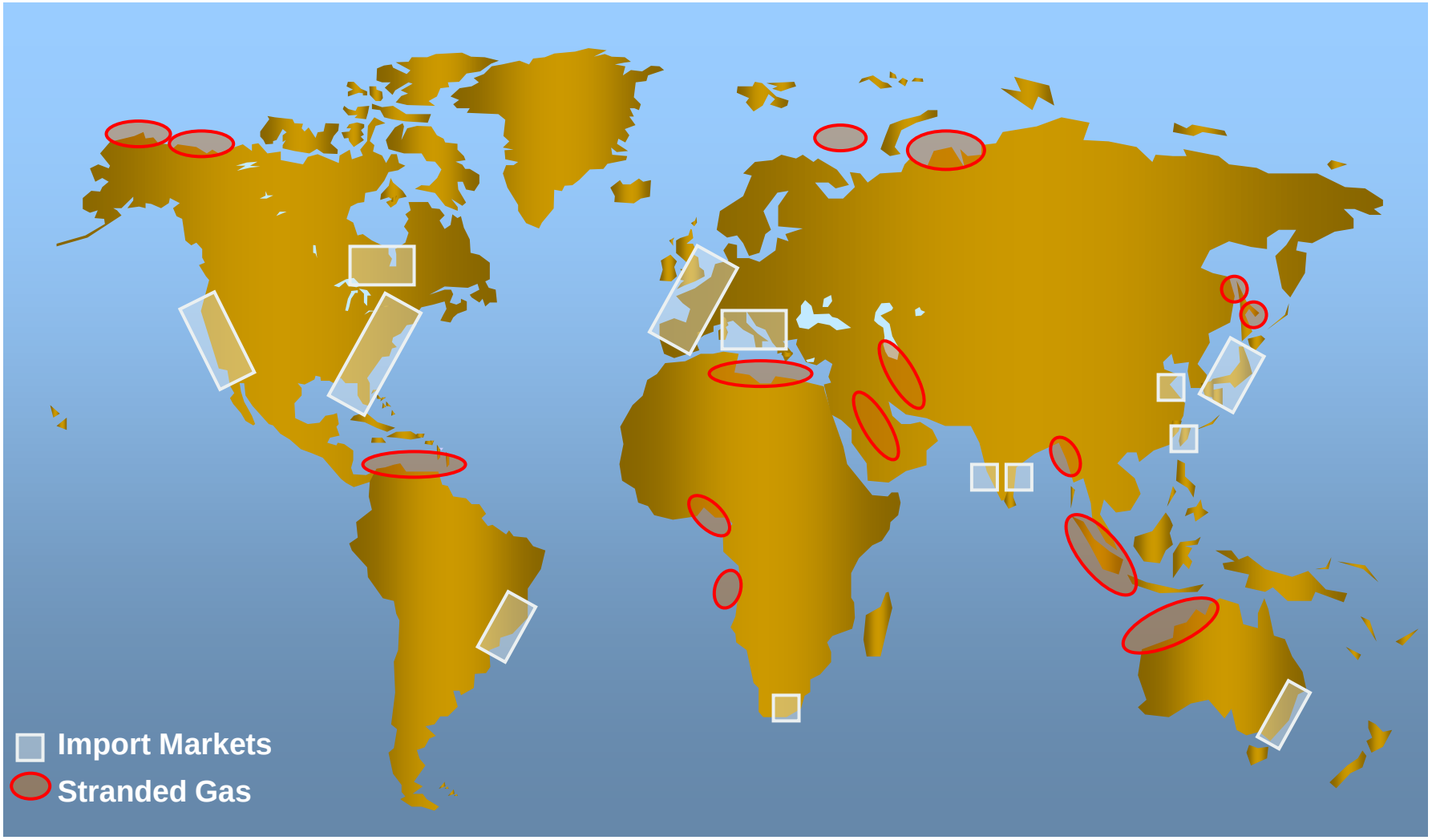
Monetising Stranded Gas Resources Onshore and Offshore

Presentation Overview

- Stranded Gas- Origins and Opportunities
- Candidate Monetisation Technologies
- Drivers for Technology Selection
- Technology Maturity and Technology Risk
- Technical and Commercial Merits
- Case Study and Pathfinding Economics



Stranded Gas and Target Markets



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Stranded Gas

Stranded Gas	**Remote from markets and pipeline infrastructure**
Flared Gas	**Flared from existing crude oil production operations**
Associated Gas	**Captive gas solutions for new oil field development projects**

Drivers for Monetisation

- Oil company focus on environmental management and conservation of hydrocarbons
- Government/State oil company pressure for gas solutions as integral to development plans for petroleum extraction
- Adverse impact on reservoir recovery from long term gas injection strategies
- The remoteness of the associated gas source from conventional gas markets
- Emerging Markets for ‘Clean’ fuels (Legislation Driven)

Stranded Gas Reserves – Barriers to Monetisation

Lack of Pipeline Infra-structure

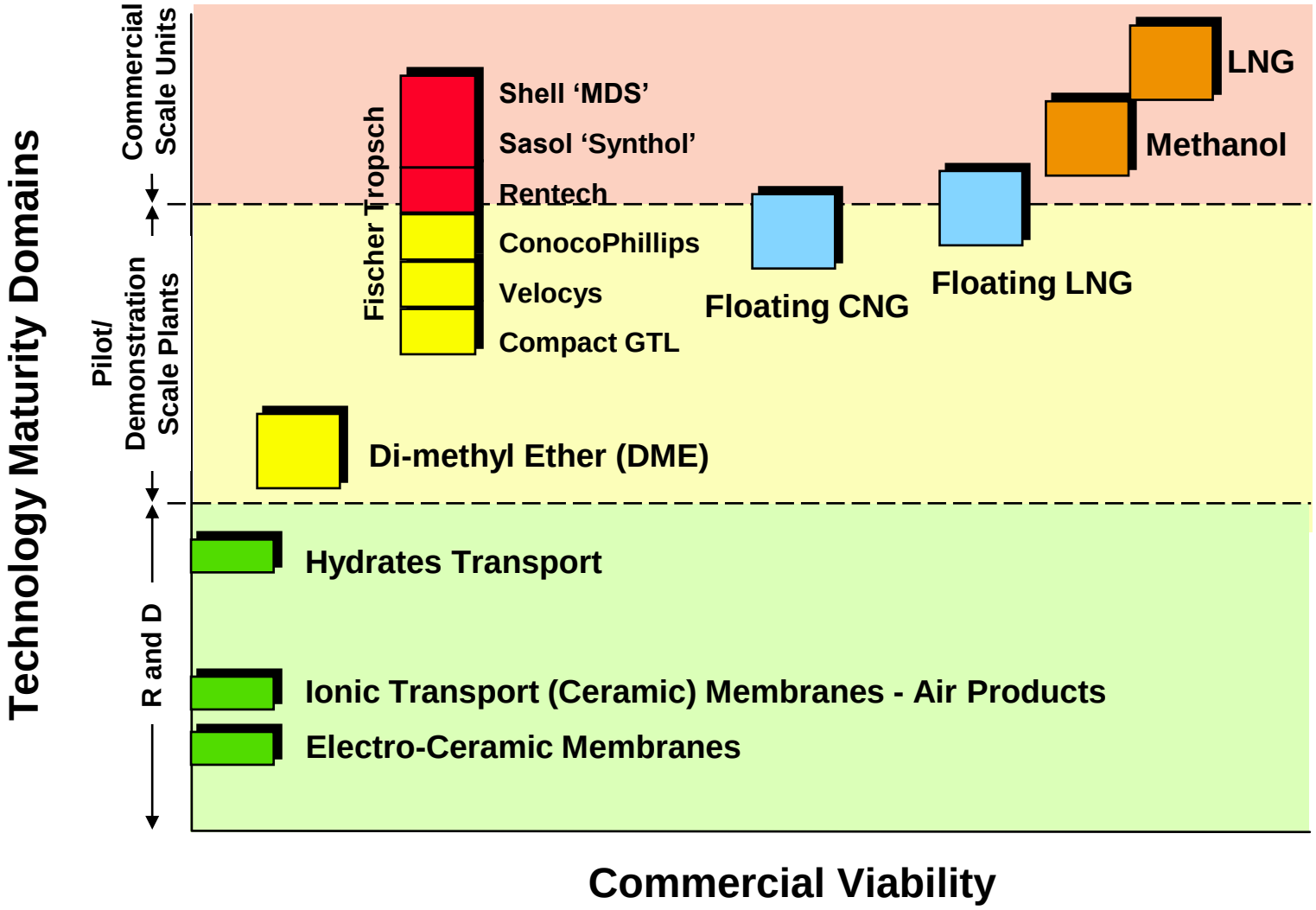
Substantial Contaminants CO_2/H_2S

Stranded Gas Resource

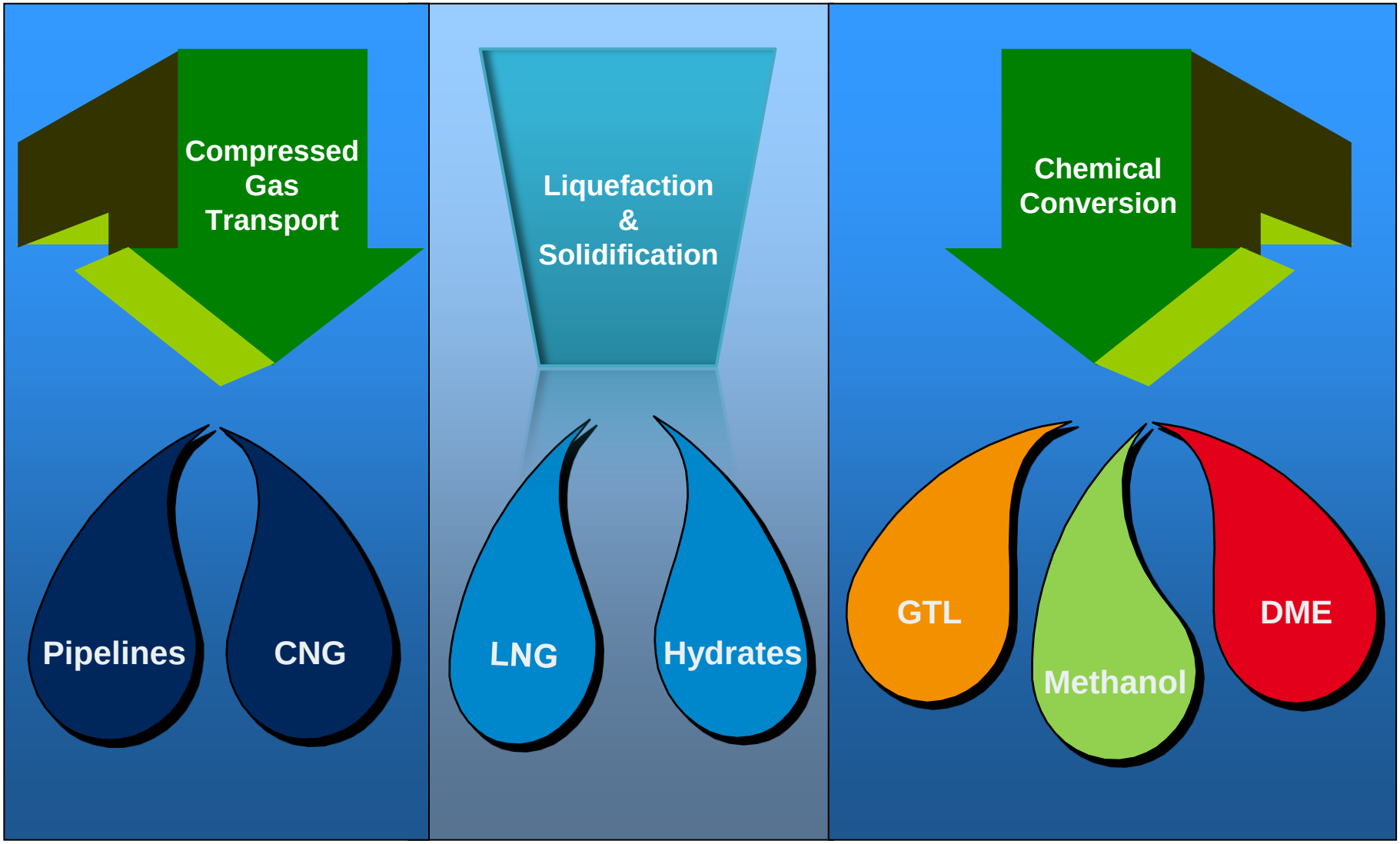
Geographic Constraints

Political Risks to Development

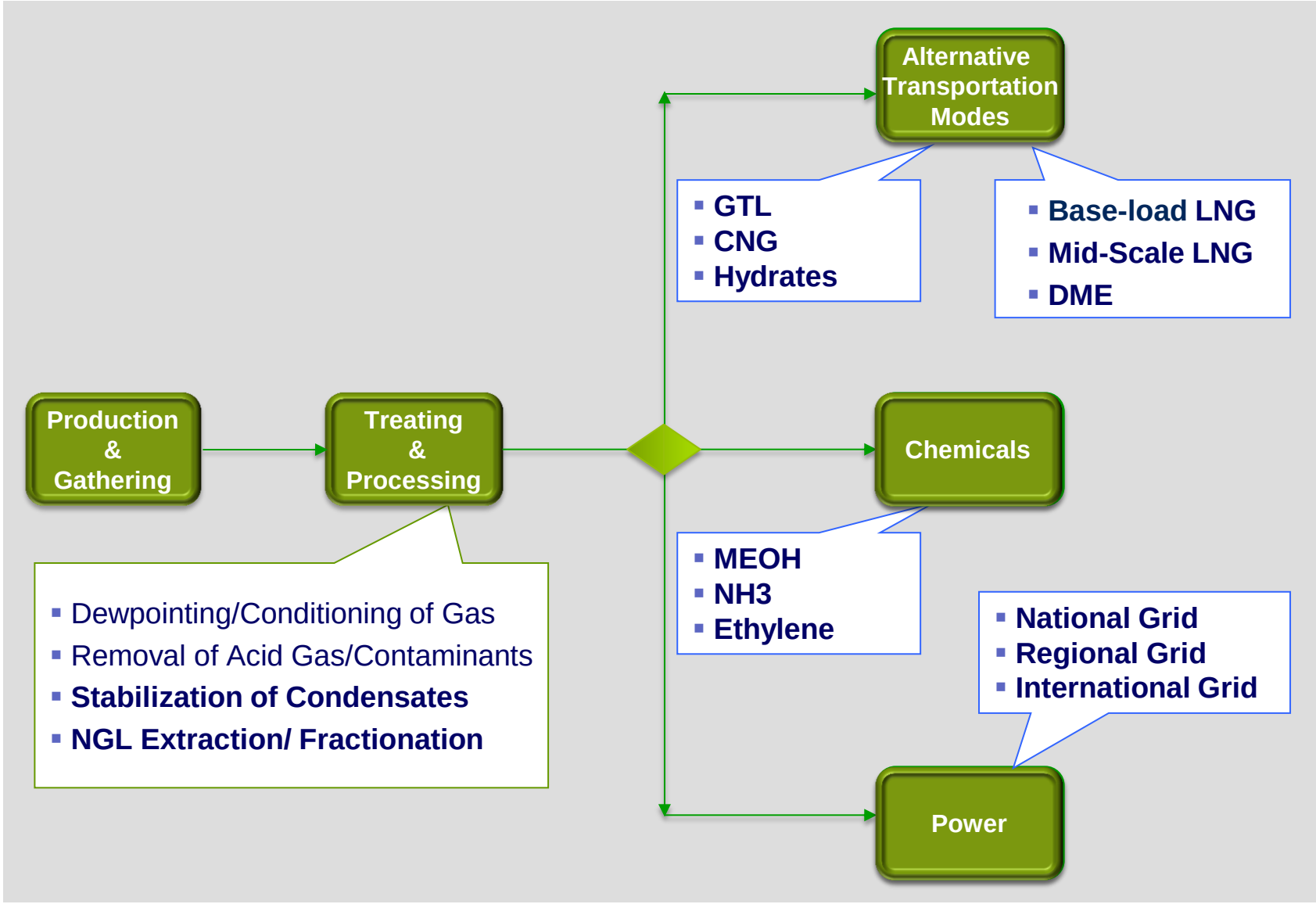
Candidate technologies and Maturity Status



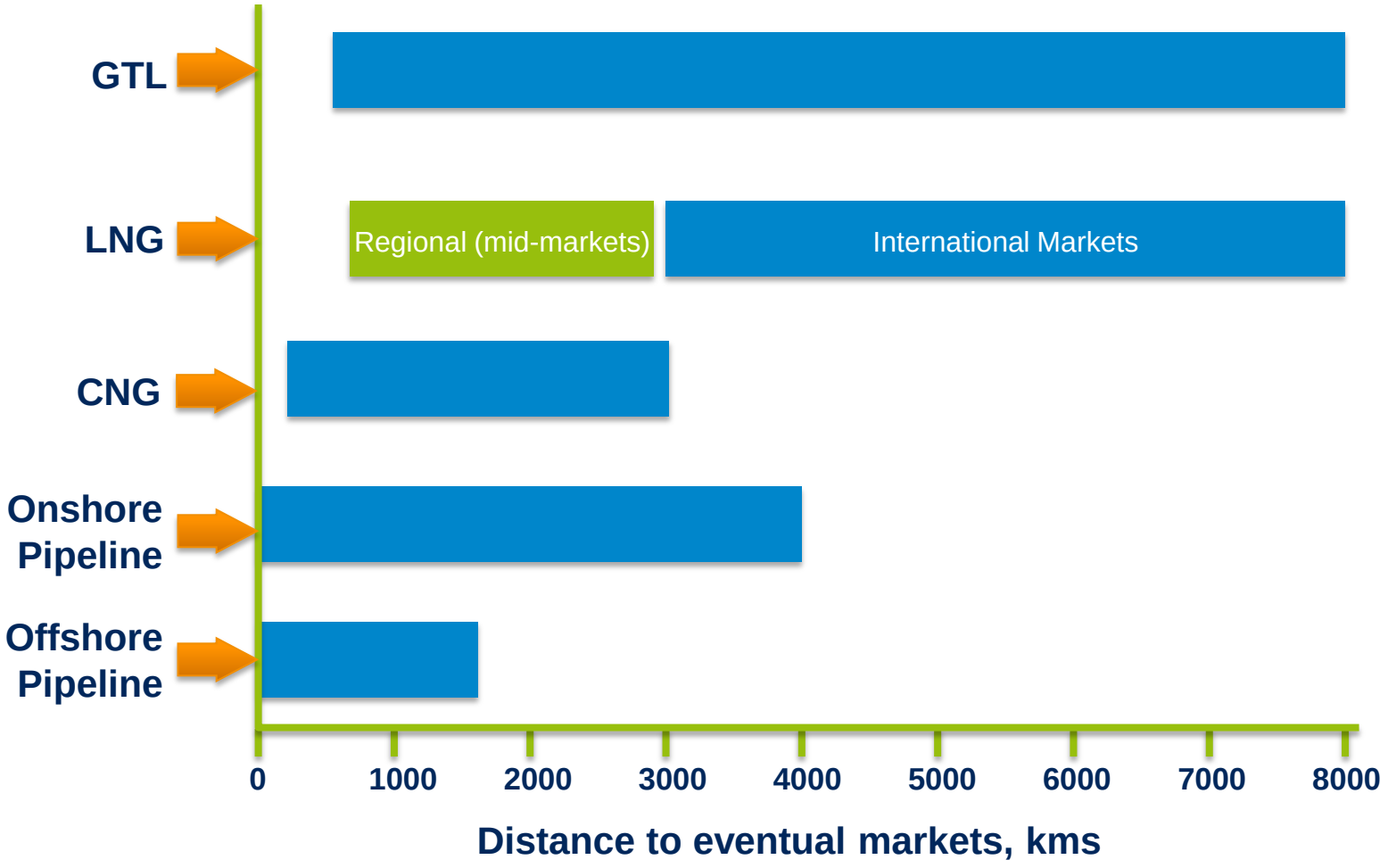
Pathways to Monetisation



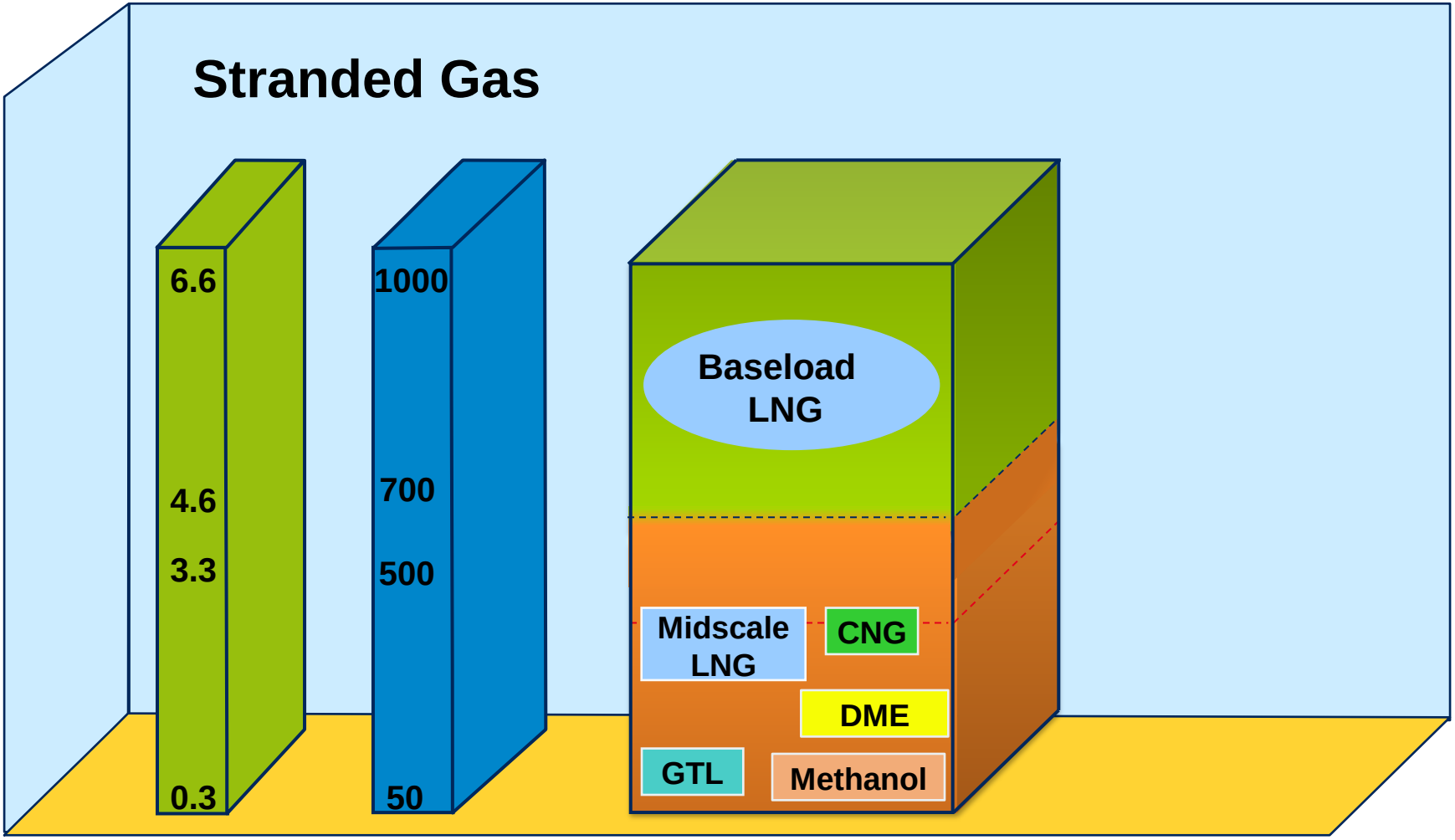
Gas Value Chain



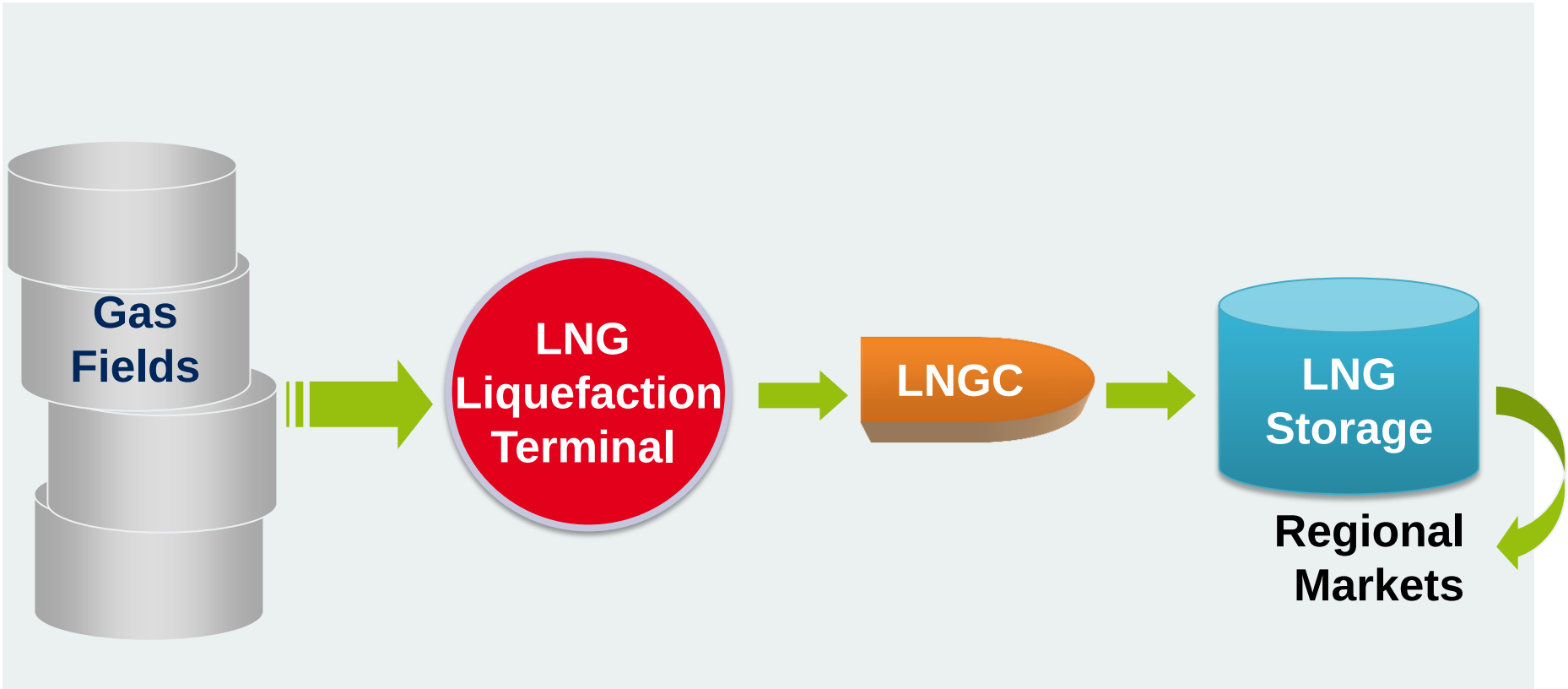
Gas Monetisation – Distance to Markets



Technology Application Bands



The LNG Value Chain

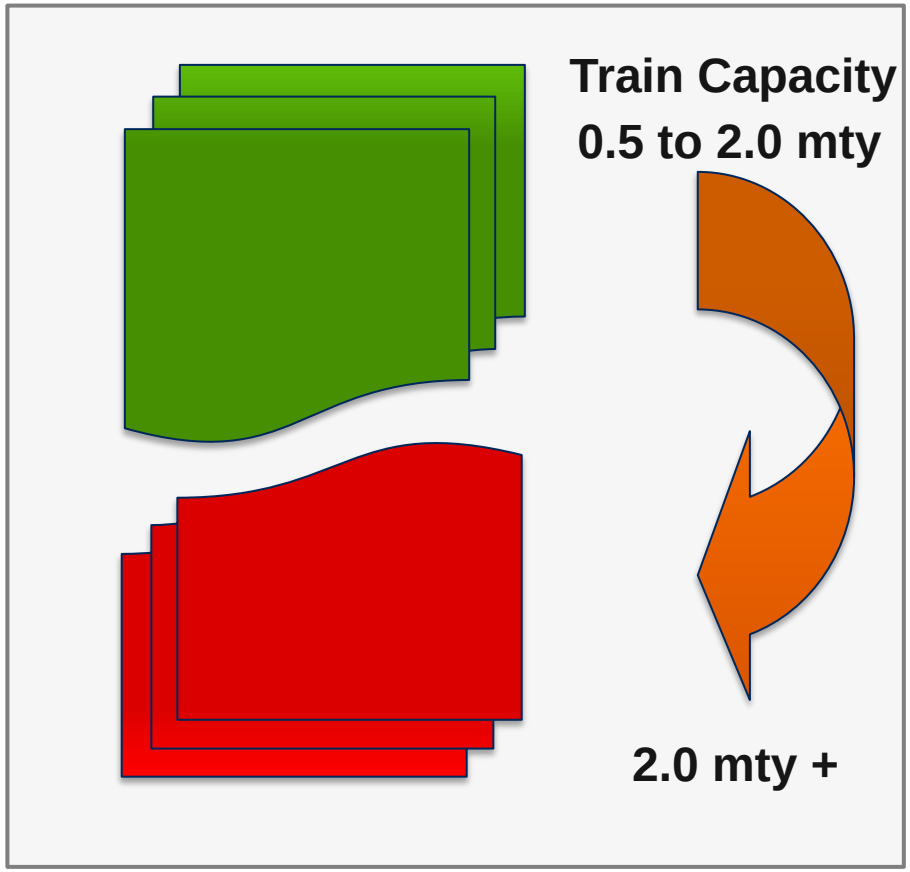


Gas Fields	LNG Liquefaction	LNG Transportation	LNG Receiving & Storage

LNG Liquefaction Technologies

Options Relative to Capacity

- Single Expander Cycle
- NicheLNG (dual expanders, nitrogen + methane)
- Mustang Smart® LNG (open and closed loops)
- Dual Nitrogen Expanders - BHP, Kanfa Aragon
- Single Mixed Refrigerant (SMR) - Linde, APCI
- Optimised Cascade - ConocoPhillips
- Dual Mixed Refrigerant (DMR) - Shell, APCI
- C3/MR - APCI
- Mixed Fluid Cascade - Linde, Liquefin - Axens



Monetisation of Offshore Gas via LNG – West Africa

- Current status of monetisation of gas from shallow and deep water block developments

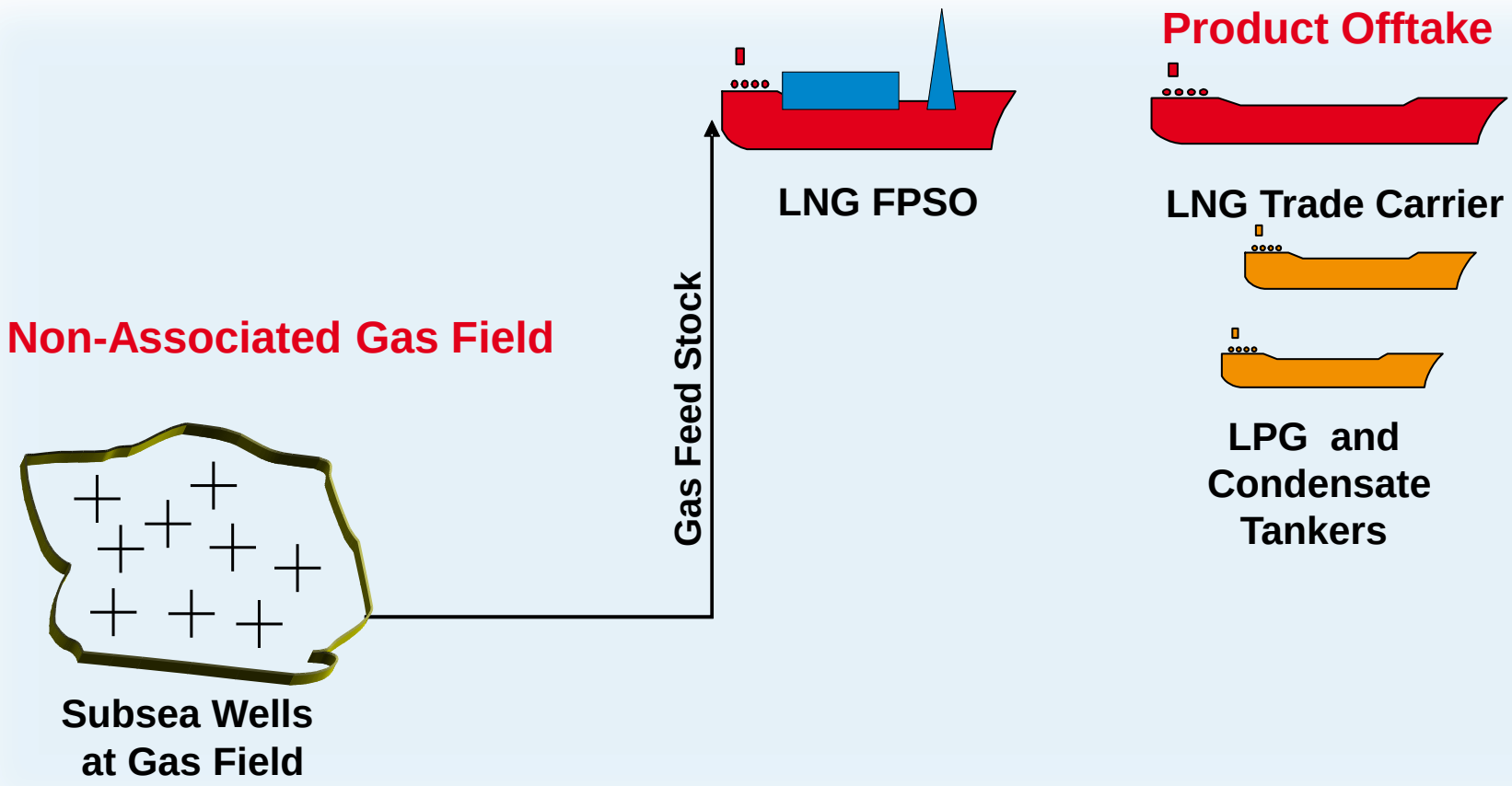
Nigeria:

- NLNG has been the principal vehicle for monetisation of offshore gas.
- Fields served include Bonga, Ofon, Usan, and Egina

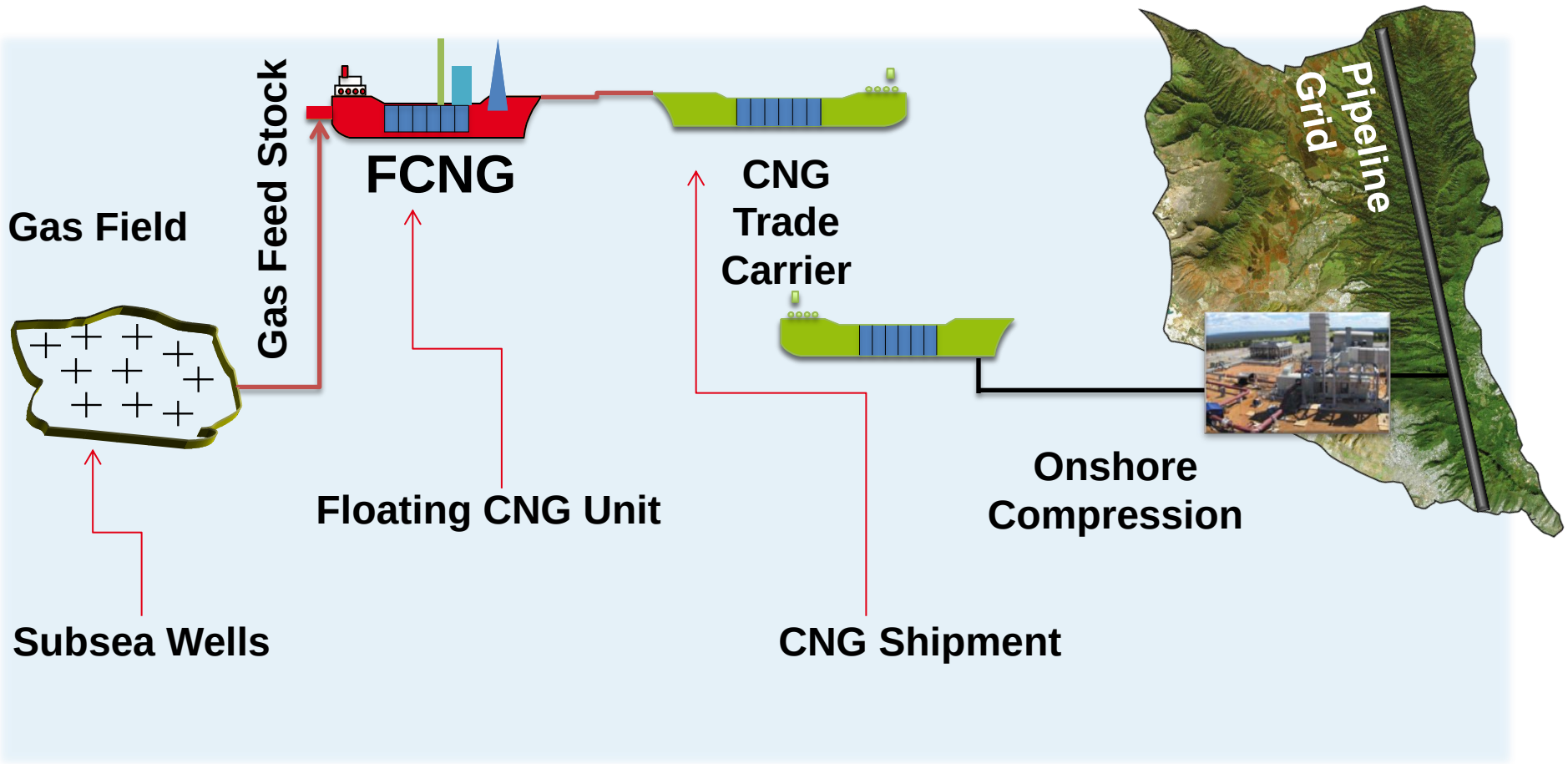
Angola:

- Angola LNG implemented to similarly monetise gas from deep water offshore blocks
- Current start-up issues with this project has deferred monetisation.
- Sonagas actively pursuing parallel options for monetisation of offshore gas

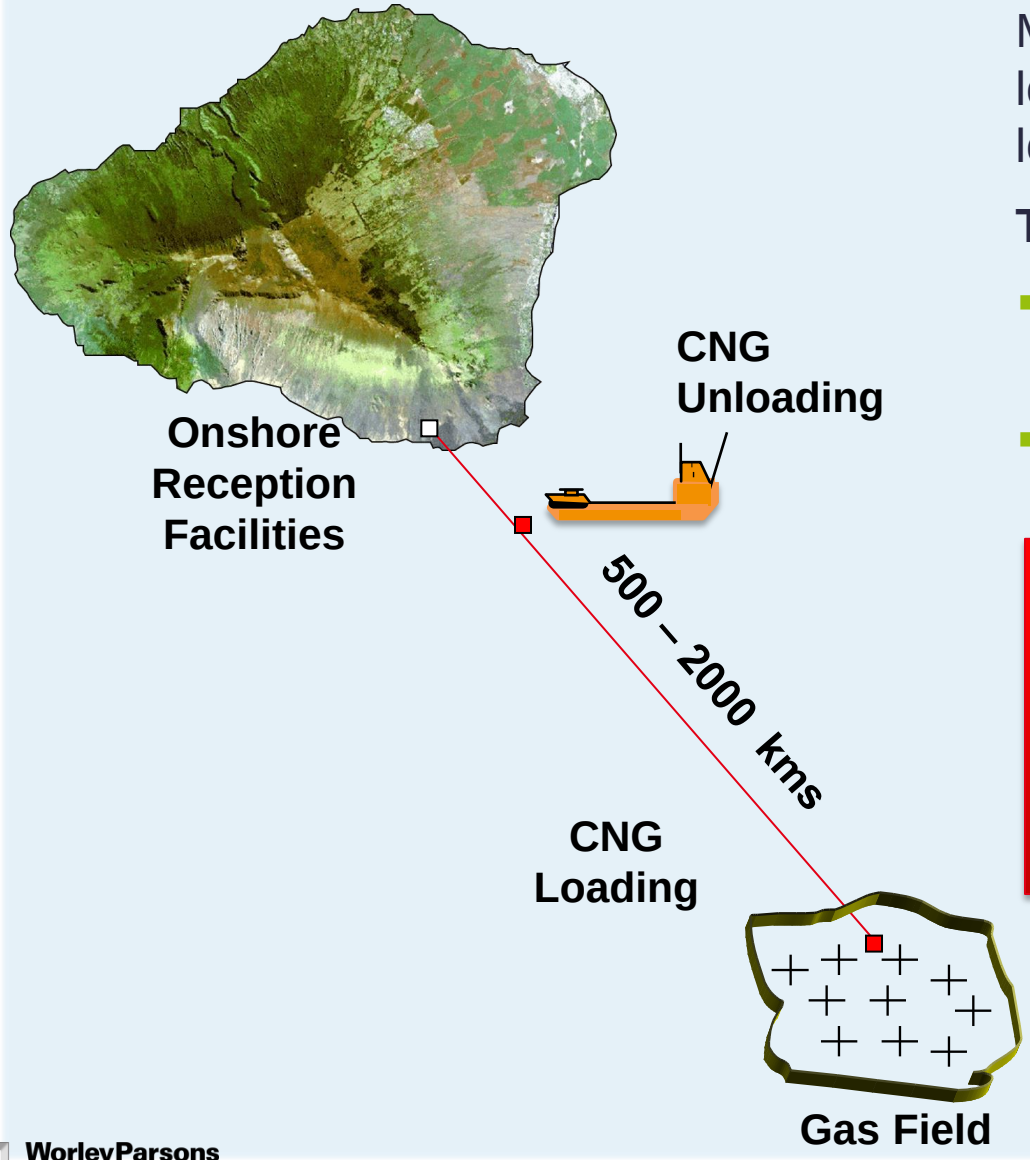
Offshore Gas Monetisation via FLNG



Offshore Gas Monetisation via CNG



Marine Transport of CNG – The Sweet Spot



Modest infrastructure at gas field location and onshore delivery location

Target Market Opportunities:

- Gas Volume Rates of 200 – 500 MMScfd
- Distances of 500 – 2000 kms

CNG Fleet Size & Vessel Capacity function of

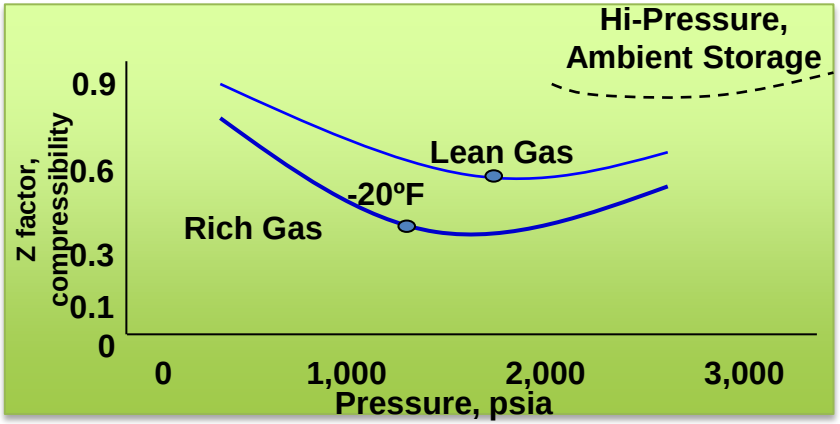
- Gas Rate
- Distance to Market

Offshore CNG Transport – Technology options

LNG proponents have opted for three alternative technology approaches to maximise CNG stored for given weight of containment unit.

- Elevate containment pressure to store more gas
- Chill gas to take advantage of favourable compressibility factor
- Choice of lighter materials (e.g. use of composites)

CNG	Technology Proprietor	Type
Coselle	SeaNG, Calgary	Pressurized, Ambient
Votrans	Enersea Transport, Houston	Pressurized, Chilled
GTM	Transcanada, Calgary	Composite Pressurized Storage

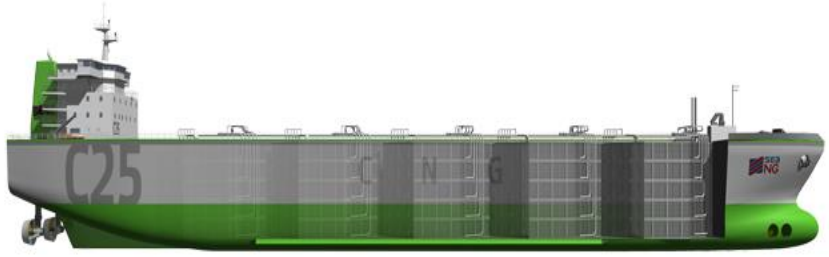


CNG Containment Pressure Range:

- 1500 – 4000 psi

FLNG and FCNG / Opportunities

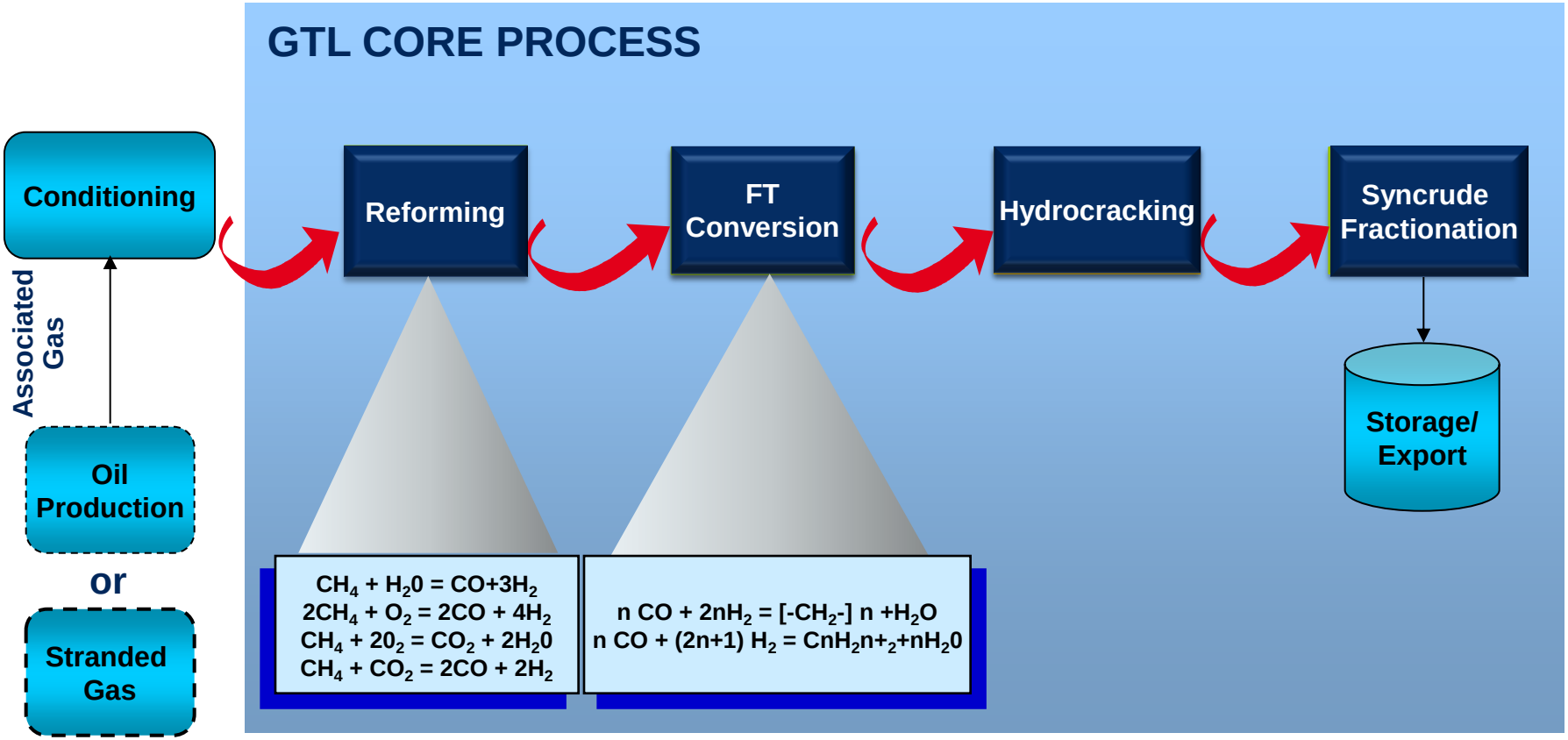
Source: Flex LNG



Source: Sea NG

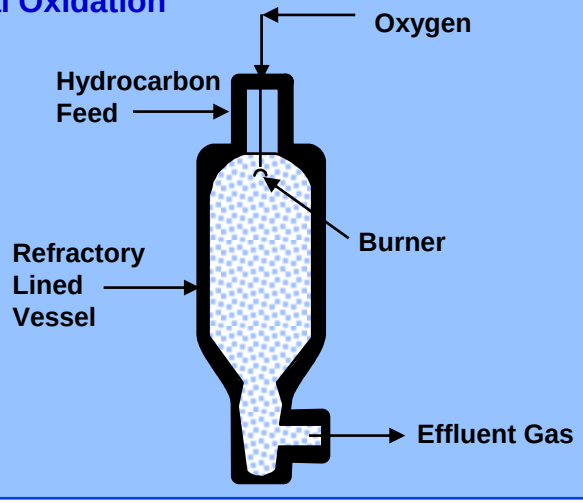
- Design maturation now attained for FLNG concepts for mid-scale production
- Flexible commercial models on offer for FLNG and FCNG (Capex and lease basis)
- FCNG is more economic for monetisation of a lower threshold of gas reserve
- FCNG scalability renders it suitable for gas fields where progressive production build-up envisaged
- Hybrid architecture feasible whereby initial field production commences with FCNG, followed by FLNG deployment

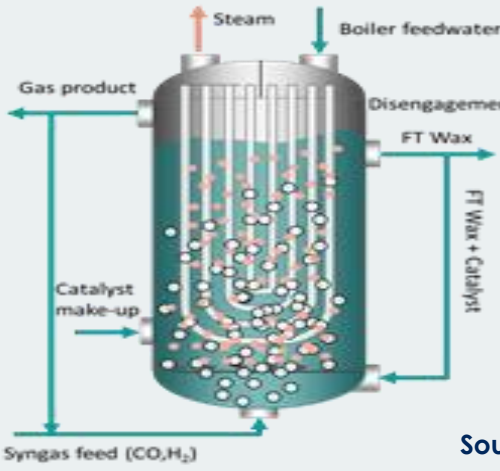
GTL Core Process



Typical Synthesis Gas Generation and Fischer Tropsch

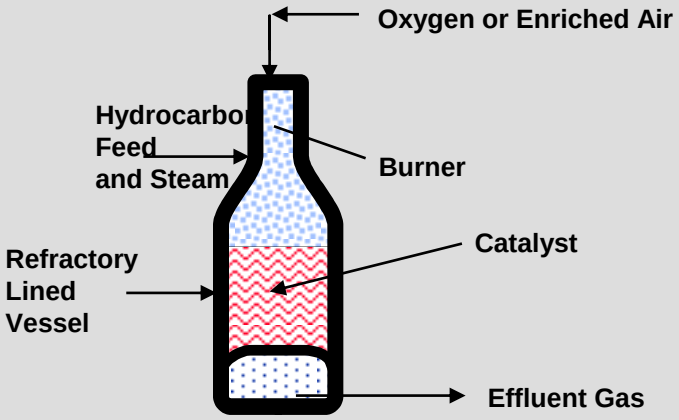
Typical Partial Oxidation



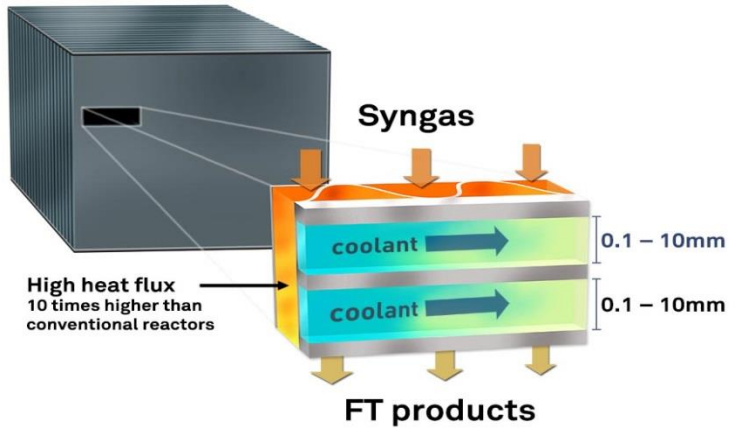


Source: PSE/Total

Typical Autothermal Reforming

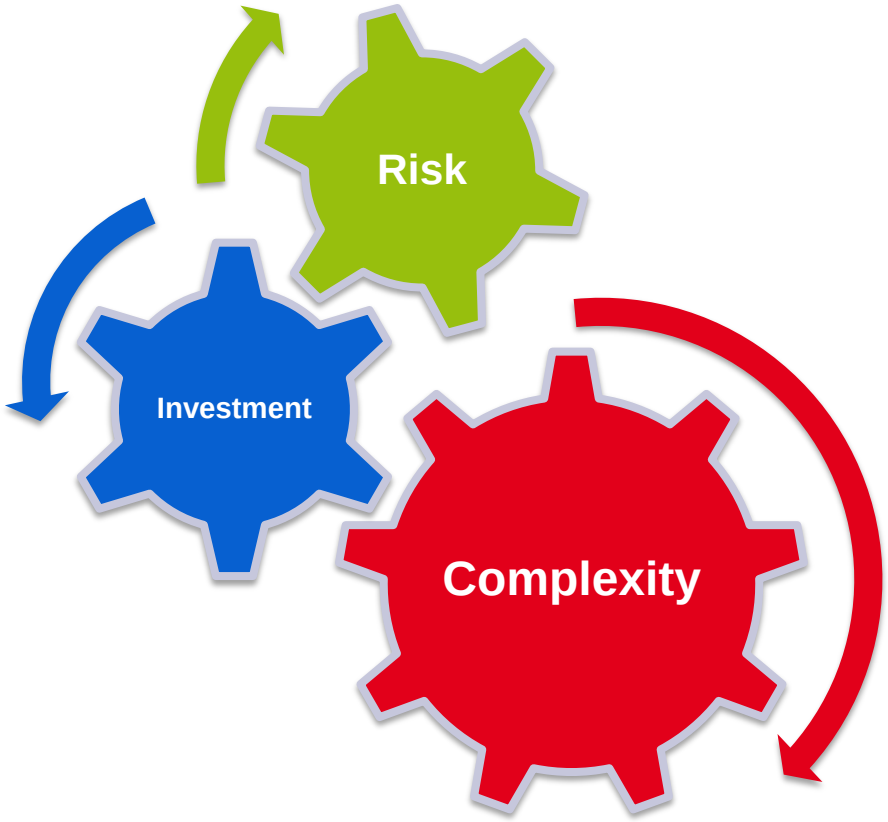


Microchannel Fischer-Tropsch reactor core



Source: Velocys

Barriers to GTL Application -Context of Stranded Gas



Technical Complexity

- Petrochemical type operations
- Multiple integrated operations

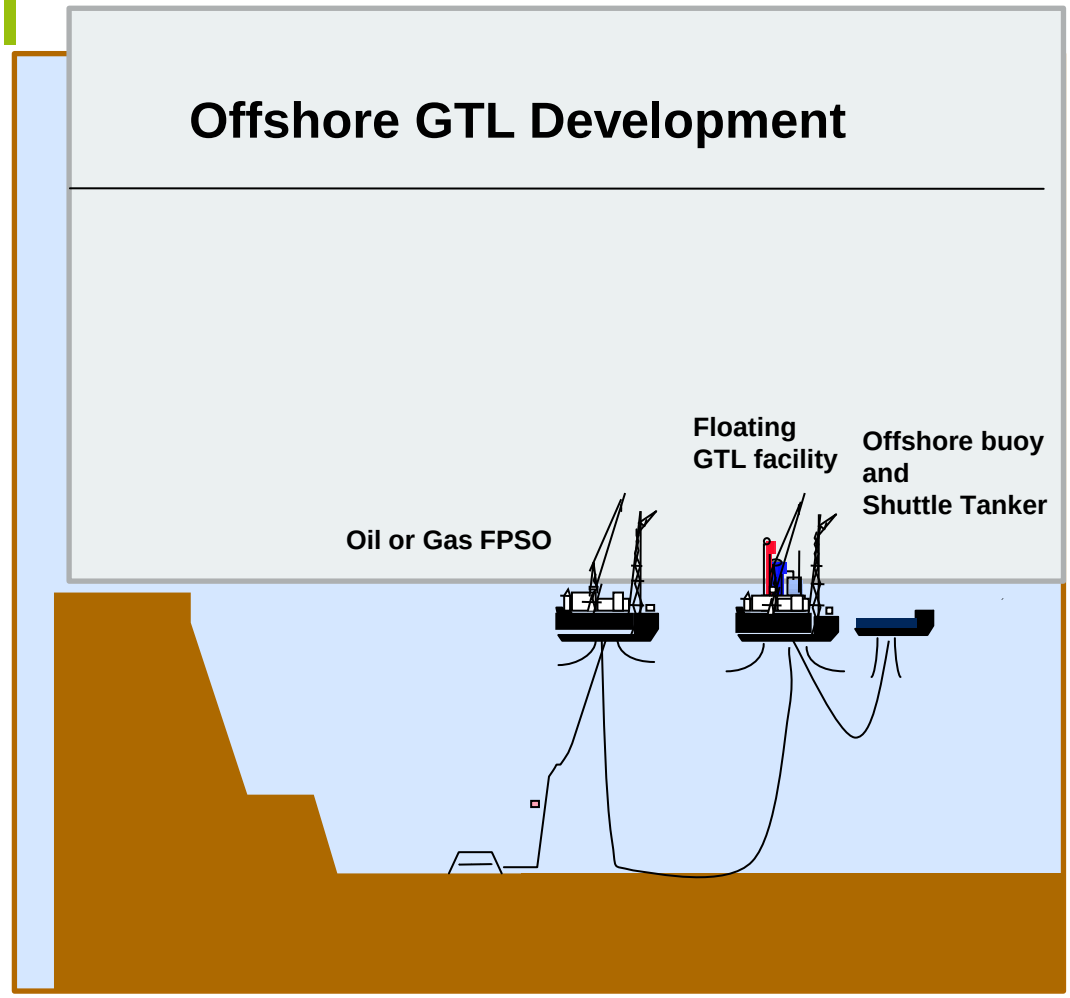
Project Cost

- Wide variation and less predictable
- Currently perceived spread $120,000 to $180,000 per bpsd
- Investment levels challenge economics

Project Risk

- Significant over-runs in reference plants
- Technical Complexity feeds schedule risk

Offshore GTL – Export Options for FT Products



- Exported untreated as syncrude or blended with crude export
- Processed for pour point and exported separately from crude
- Processed for pour point and blended with crude export
- Processed and exported as distillate products (Naphtha, Kerosene, Diesel)

Floater Based GTL Process Schemes

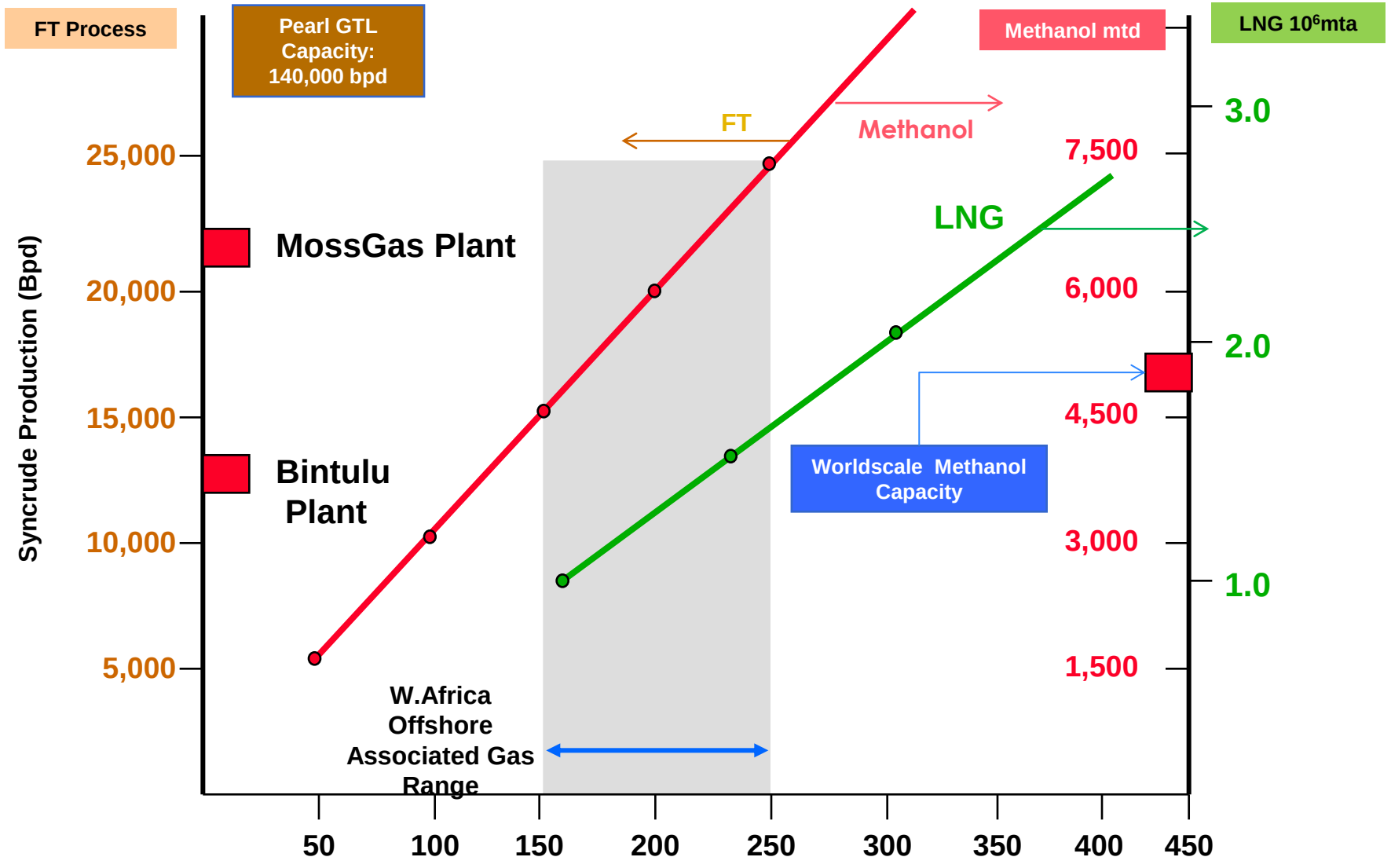
Offshore Design Considerations

Vessel Motion and Impact on Process System Performance

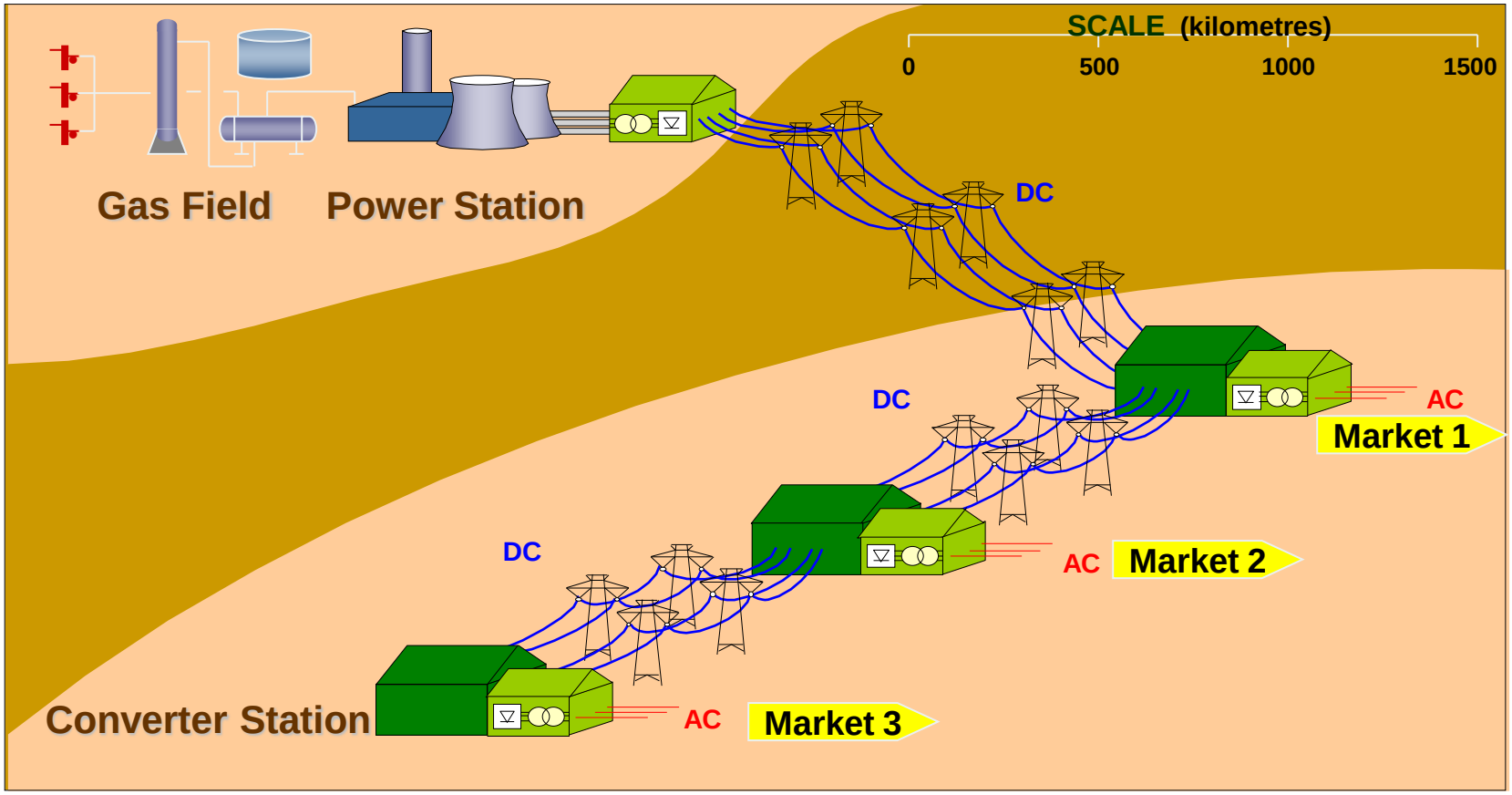
Mechanical Stresses on Process Equipment Mounted on Deck due to:

- Flexing of Vessel Deck and Stresses on Piping Systems
- Large Number and Complexity of Equipment in Intensified Layout
  - Maintainability
  - Separation of Sensitive Air Intake/Vent Sources
- High Equipment Weight, Weight Distribution and Point Loads

Capacity Implications for FT, Methanol and LNG Routes



Gas (Energy) Transportation by HVDC



Gas to Power – Long distance transmission to regional or international markets

Criteria Based Assessment of Technology Options

Onshore Monetisation- Applications

Criteria	Technology Maturity	Capital intensity (▲▲▲= low)	Technology Risk (▲▲▲= low)	Market Opportunity (demand)	Product Price Volatility (▲▲▲= low)	Operability	Intrinsic Safety
NGLs/Stab. Condensate	▲▲▲	▲▲▲	▲▲▲	▲▲▲	▲▲	▲▲▲	▲▲
Mid-scale LNG	▲▲	▲▲	▲▲▲	▲▲▲	▲▲	▲▲▲	▲▲▲
Baseload LNG	▲▲▲	▲▲	▲▲	▲▲▲	▲▲	▲▲	▲▲▲
CNG	▲▲▲	▲▲	▲▲▲	▲▲▲	▲▲	▲▲▲	▲▲
DME	▲	▲	▲	▲	▲	▲▲	▲▲
Methanol	▲▲▲	▲▲	▲▲	▲▲	▲	▲▲	▲▲
GTL	▲▲	▲	▲	▲▲▲	▲▲	▲	▲▲
Ammonia/ Urea	▲▲▲	▲	▲▲	▲▲	▲▲	▲▲	▲▲
Ethylene	▲▲▲	▲▲	▲▲▲	▲▲	▲▲	▲▲▲	▲▲▲
Gas to Power	▲▲▲	▲▲	▲▲▲	▲▲▲	▲▲▲	▲▲▲	▲▲▲

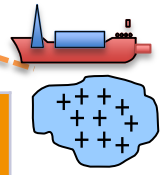
Criteria Based Assessment of Technology Options

Offshore Monetisation – Applications

Criteria	Technology Maturity	Capital intensity (▲▲▲=low)	Technology Risk (▲▲▲=low)	Market Opportunity (demand)	Product Price Volatility (▲▲▲=low)	Operability	Intrinsic Safety
NGLs/Stab. Condensate	▲▲▲	▲▲▲	▲▲▲	▲▲▲	▲▲	▲▲▲	▲▲
Mid-scale FLNG	▲▲	▲	▲▲	▲▲▲	▲▲	▲▲	▲▲▲
Baseload FLNG	▲	▲	▲	▲▲▲	▲▲	▲▲	▲▲
FCNG	▲	▲▲	▲▲	▲▲▲	▲▲	▲▲	▲▲
Hydrates Transportation	▲	▲▲	▲	▲▲	▲▲	▲	▲

Case Study- Monetisation of Offshore Stranded Gas

Component	Mol %
Methane	86.8
Ethane	6.91
Propane	3.87
i-Butane	0.40
n-Butane	0.67
Pentanes+	0.55
CO_2	0.71
N_2	0.08
H_2O	0.01
Total	100



LNG FPSO located at field centre

- **Feed Gas** from subsea wells: Rate : 350 MMscfd
- Feed Gas Prices (cases): Nominally priced at $2, 3 and 5/Mscf at FLNG riser flange.
- LNG FPSO Production Life: 20 years
- Corporation Tax: 38%
- LNG price as delivered to Regasification terminal
- Required IRR: 12%
- Distance to market (cases): 3000 and 5000 km
- No credit taken for revenues generated by NGLs
- FLNG development costs exclude Subsea Capex.
- Nominal LNG production: 2.3 mtpa

Cost of Service

Feed Gas Price	Distance to Market, 3000 km	Distance to Market, 5000 km
USD/Mscf	Delivered LNG Price, $/MMBTU	Delivered LNG Price, $/MMBTU
2	7.29	7.61
3	8.39	8.72
5	10.60	10.94

Concluding Observations

- Technology developments herald unprecedented opportunities for exploitation of stranded gas.
- Geography, size of gas reserves, distance to markets etc will determine the optimum mode of energy delivery
- Base load LNG remains a prime contender for large stranded gas reserves.
- Mid-scale LNG technologies are emerging as interesting options for mid-tier gas reserves.
- Ship transport of CNG has commercial potential for energy delivery to mid-markets & regional markets.

- Conventional Fischer Tropsch GTL offers key opportunities for gas monetisation but scale of investment and project risk are key co-determinants of application.
- Horizon technology such as hydrates transport will further expand an already impressive solutions portfolio.

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