The Golden Age of Gas

- What Will it Take to Get There?

Infrastructure and Gas Monetisation:

How does gas get from source to the market?

Royal Institution: 19th September, 2013

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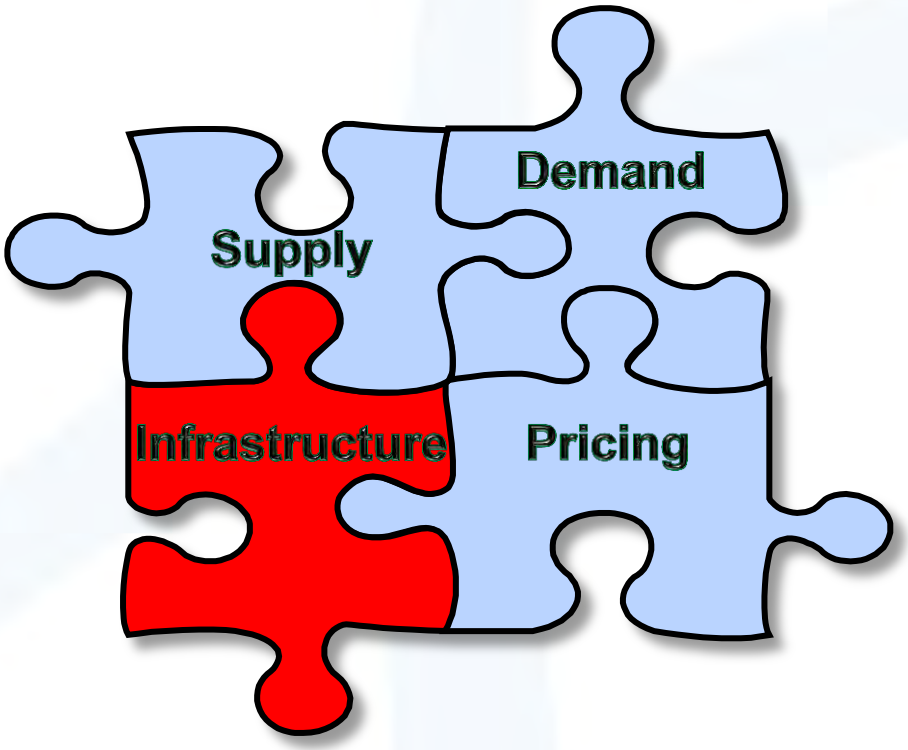
Infrastructure and Gas Monetisation



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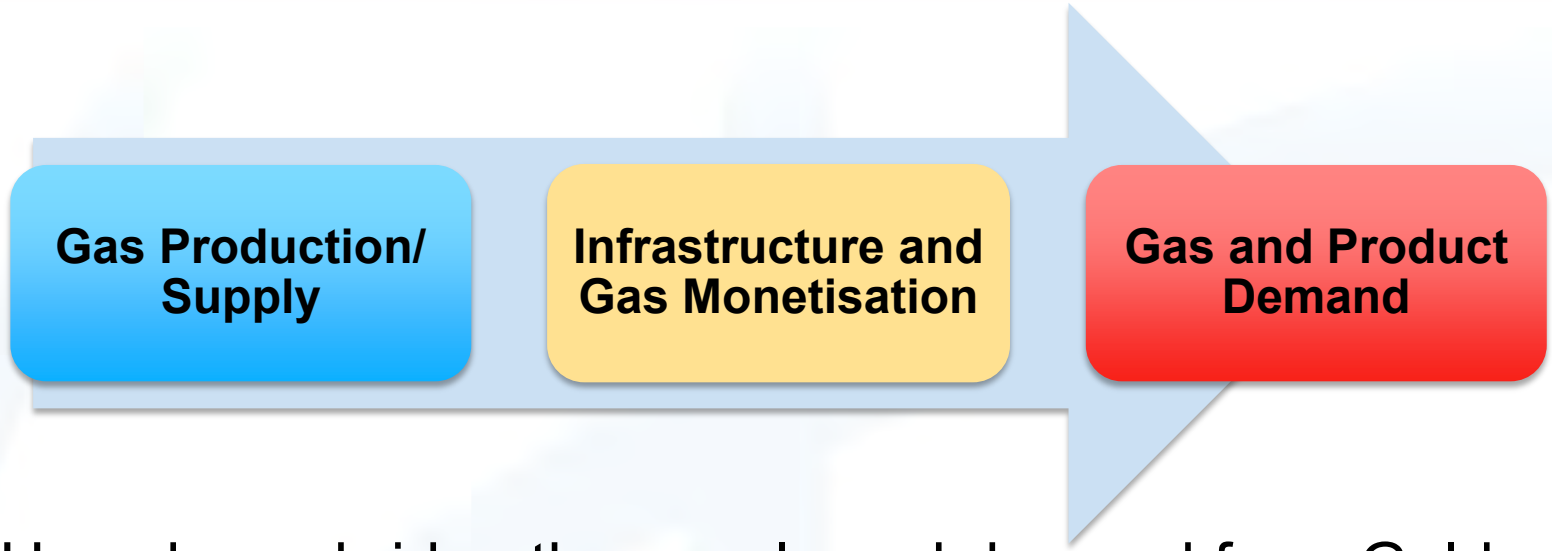

- How do we bridge the supply and demand for a Golden Age of Gas?
- What infrastructure is required to commercialise gas resources?
- What gas monetisation technologies are available for local and export solutions?

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The Golden Age of Gas Requires Infrastructure

- Lack of infrastructure can impede gas commercialisation
  - Villagers in the Shandong Province of China have a solution!.....if you are willing to fill a bag full with natural gas and carry it home, at the risk of, well, exploding?

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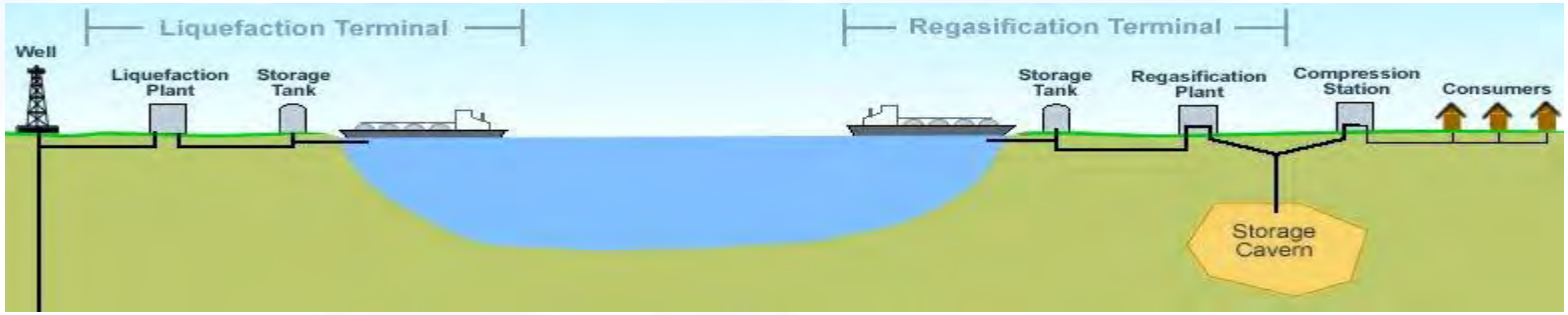
Infrastructure is Required to Move Gas to Demand Centres

- **Gas & LNG exports account for 30% of global gas consumption**
  - Gas export pipelines usage increased by 4.8% AAGR over last 10 years
  - LNG exports growing at faster rate, by 7.5% AAGR over last 10 years
  - LNG Liquefaction capacity is approx. 281 MMTp.a. in 2012 (floating LNG is nil)
  - LNG shipping fleet currently has 362 vessels, a combined capacity of 54 Bcm



- **Gas & LNG imports opening up to new countries**
  - LNG import (land and floating regas) capacity is 642 MMTp.a. in 2012 and expanding- new facilities planned in UAE, Ukraine and Canary islands (Spain)
  - Gas import pipelines & distribution networks (political or commercial investment decision)
- **If LNG is going to be a major contributor to the Golden Age of Gas then huge investments are required to meet forecast demand growth**

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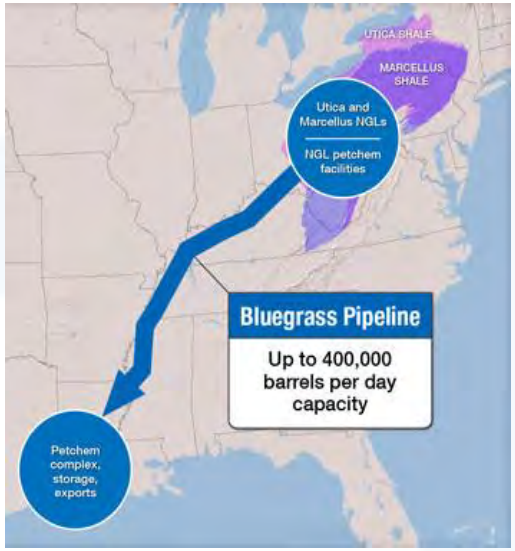
Major Investment in New Gas Export Pipelines

- 80+% of global new gas pipelines will be required in North America - in order of US$15-60 Billion in next 10 years
- Existing infrastructure is near capacity or not located near new shale gas (liquids rich) plays
  - Marcellus forecast to increase by 10 Bcf/d in next 5 years
  - Gas pipelines need to handle additional gas for 100+ MMTp.a. LNG exports
- NGL infrastructure is required, e.g. Williams is forecasting 1.2 MMbpd of NGLs from Marcellus/ Utica by 2020 alone!



- Globally, there are many proposed new/expanded gas pipelines
  - Turkmenistan-Afghanistan-Pakistan-India (TAPI) pipeline, an Iran-Pakistan pipeline, East Russian exports and the Caspian
- Russia-China line is likely given Russia's strategic gas marketing shift eastward
- Plus at least one new line into southern/central Europe is likely to come to fruition
  - Nabucco or South Stream pipelines into southern/central Europe?

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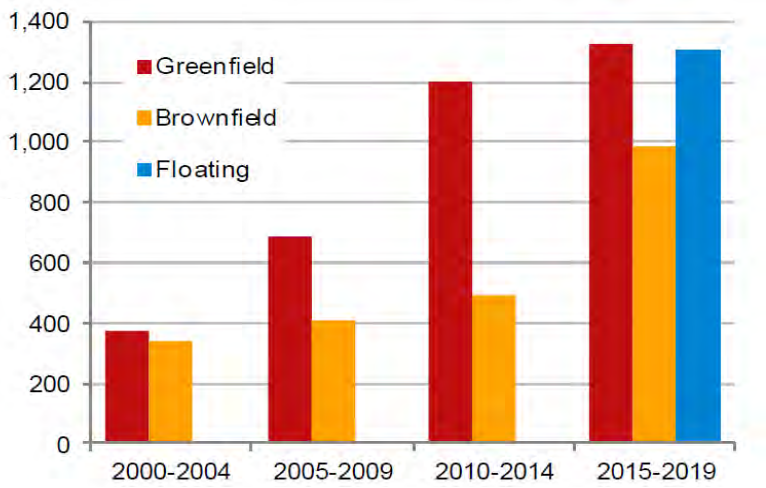
New LNG Liquefaction Export Facilities

- Large scale, land-based LNG technologies still dominate any situation where large reserves can be monetised
- 350 MMTp.a. of new LNG projects are planned or in construction by 2025
  - Not all may find approval or financing, which is typically secured through long term LNG supply agreements
- Huge capital investment is required, approx. US$230 Bn in 2013-17 alone!
- LNG plant costs vary widely (+/- 50%) due to location, level of pre-treatment, marine facilities, utilities and offsites
- US brownfield LNG projects have the lowest cost (estimated US$650-550MM/T)
  - substantially lower than typical greenfield projects averaging US$1,200/T
- **East African, and particularly North American LNG projects are well positioned to compete against the greenfield Australian LNG projects to supply Asia**

Average Liquefaction Unit Costs in US$/T (real)



Source: IGU 2013

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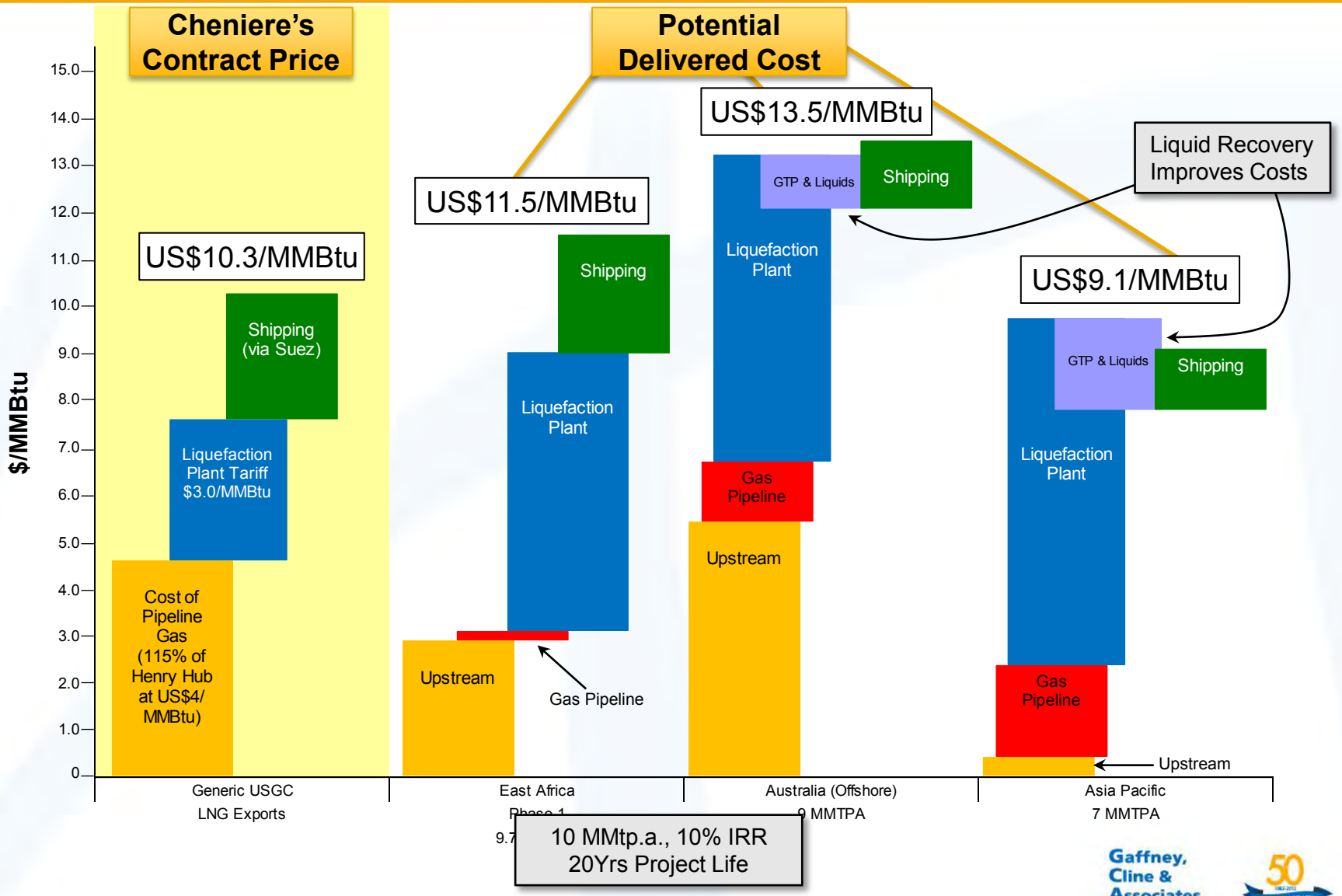
Variability of New LNG Delivered Costs to Tokyo (DES)



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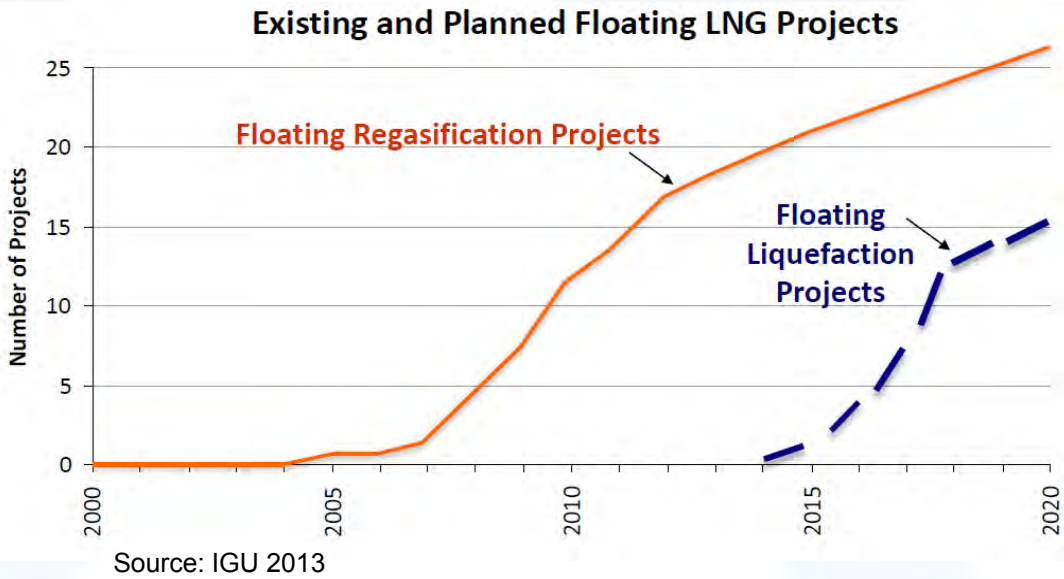
Can Floating LNG Liquefaction Lead the Way?

- Floating LNG production projects could finally open up the market – there are a raft of potential small and large stranded gas projects
- Petronas is in pole position to become the first to commercialise FLNG
  - Petronas' FLNG No.1 facility (2015-6): 1.2 MMTp.a. (FLNG No.2 project FID late in 2013?)
  - Shell's Prelude FLNG (2016): 3.6 MMTp.a. and costs US$12 Bn
    (this will be six times heavier than the world's biggest aircraft carrier!)
  - Santos' Bonaparte FLNG (FID 4Q2014) 2-3 MMTp.a. and costs US$ 8-10 Bn
- FLNG can avoid the nimbies and reduce costs compared to land based solutions, but is capitally intensive and still commercially unproven



Source: IGU 2013

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Additional LNG Import Terminals will be Required

- Traditional LNG import terminals are large land-based facilities benefiting from
  - High regasification rates at 6 Bm^3p.a. (4.3 MMTp.a.)
  - Large LNG storage providing security of supply
- Land-based LNG terminal are costly (US$0.8-1.2Bn) and have long construction schedules (40-46 months)

- Floating LNG storage and regasification units (FRSU) provide a flexible and short term solution
  - Currently there are FRSUs operating in 8 countries
- Advantage of FRSUs is the ability to deliver gas onshore where required
  - It bypasses some onshore nimby limitations
  - It can be moored offshore or at a fixed jetty – but needs fairly benign waters
- FSRU are lower capex, higher opex options that can be delivered in less than 1 year
  - Vessels can be leased or new from US$280-320MM plus mooring facility and pipeline to shore

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What are the Monetisation Options for the Delivered Gas?

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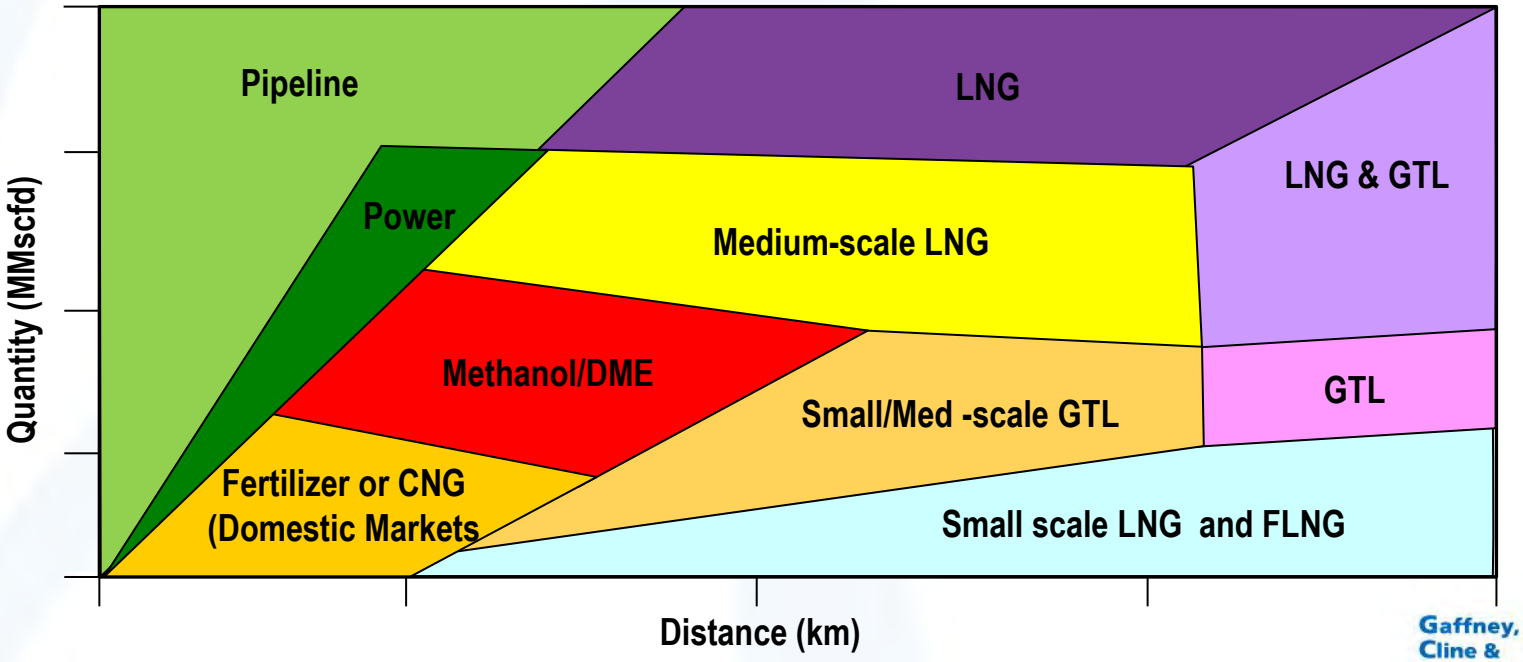
A Golden Age of Gas Requires Monetisation Solutions

- Criteria for determining the appropriate gas monetisation option is based on many factors, some key development options being:
  - Size and quality of the gas resource
  - Location of the resource relative to key markets - local and export
  - Competitiveness of end products

Illustrative Overview of Monetisation Options



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Gas Utilization Options

- Various monetization options are technically feasible but not all are economically viable, or practical long term solutions
- Competitiveness of technologies varies widely depending upon specific project details and regional markets

End Use	Typical Unit Size	MMscfd	Tcf
CNG	10,000 vehicles	4	0.03
Cement Plant	Small plant ~1 MMTp.a.	10	0.07
Fertilizer (Urea)	Average size 1,150 T/day	15	0.15
City gas	1 million domestic users	15-30	0.1- 0.2
Power	200 MW	50	0.5
Methanol	World scale 5,000 T/day	150	1.2
GTL	Medium scale 16,000 bpd	150	1.2
LNG (Land or floating)	Small scale 3,000 T/day	150	1.2
LNG	10 MMTp.a. (2 Large trains)	1360	10

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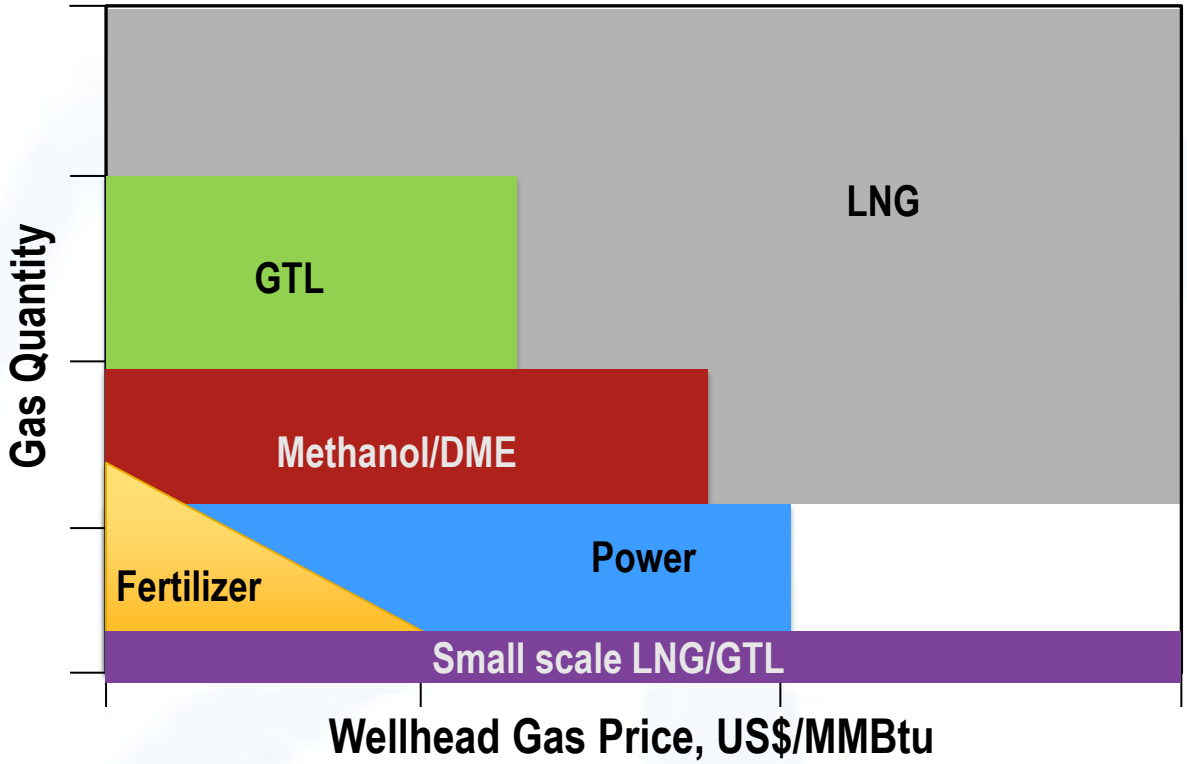
Illustration of Typical Development Options



- Diagram is an illustration only – there are always exceptions!
- Viable developments are project specific

Associated gas

Conventional, onshore

Tight gas, remote

Offshore (incl remote)

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Other Criteria for Determining the Appropriate Gas Monetisation Route

Practical limitations or geo-political restrictions :

- Logistics for project construction and O&M
  - Access to a deep water marine facility,
  - Terrain impediments and roads
- Permission for cross-border pipelines
- Technology availability and reliability
- Manpower/skills availability
- Requirement for strategic partners or agreements from foreign governments
- Project financing
- Environmental approval

Woodside LNG Train V Expansion Project
Module (18,000 tons module weight)

Where netback gas price and ROR ultimately influence the project – however ignoring other factors can lead to cost over runs and delays

Over 70% of oil & gas mega projects developed since 2000 have exhibited poor cost and/or schedule performance

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GTL Technologies Provide Link to Liquid Markets

- Potential new era for GTL - gas conversion options to syncrude, paraffin liquids (middle distillates) and petrochemicals
  - Syncrude injection to crude oil export pipeline
  - Easily transported products
- Prospects have been limited by a perception of high-costs and operational risks
- Potential for good margins especially with wide oil and gas price spread
- Limited number of commercial scale plants, and technology vendors may want a share in the project
- Reactor sizes present logistical challenges for larger units
  - 17 Mbpd train F-T reactors: 2,200 tons, 60m long x 10m nominal diam.

PetroSA GTL Plant, Mossel Bay, South Africa – courtesy of PetroSA

- For small amounts of gas …….you may also consider small scale GTL, i.e. Compact GTL and Velocys

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Other Small Scale Gas Utilisation

- Smaller volumes of gas that can be used for methanol for export, fuel or conversion to more value added products; DME, olefins, gasoline
- Low cost gas is a good option for fertilizer (ammonia to urea) which is easily transported as a solid and good local markets
- Small scale LNG technology is available through numerous vendors providing trains for 0.1 – 2 MMTp.a. train capacity
  - Satisfy local demand for emerging LNG fuel markets or local power generation units (used in remote locations for drilling rigs)
- CNG is more adapted to light duty vehicles/short mileage options
  - Overall CNG (200 bar) requires 3 times the volume of LNG, but with lower capex, albeit higher opex, it is a good local demand option
- **So the question at the pump may well be, "liquid or gas," the one thing that is clear is that NGVs of all sizes are here to stay**

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Quick Look at Two Regions Planning to Export LNG

- North America
  - U.S. set to become a major gas exporter (approvals dependent!)
  - Relocating and starting-up mothballed methanol production
  - Renewed interest in medium scale GTL projects
  - Huge NGL volumes are fuelling new petrochemical boom
- East Africa
  - The reserves are remote from the country's population centres
  - Potential to set up domestic industrial zones to establish added value petroleum liquids and petrochemicals
  - Export pipeline to neighbouring countries is challenging
- What are the prospects for the other monetisation options compared to LNG?

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North America Monetisation Prospects

- Excellent infrastructure means gas resources can be monetised by a number of routes – not as vital to provide one large anchor project

USGC Criteria	Power (200 MW)	Methanol (5,000 T/d)	Urea (1,000 T/d)	LNG (9.0 MMTpa)	GTL (16,000 Bpd)
Gas reserve (20 yr size/ quality)	Small, Sweet (0.5 Tcf)	Moderate, sweet (1.2 Tcf)	Small, sweet (0.2 Tcf)	Large, sweet (8.5 Tcf)	Moderate, sweet (1.2 Tcf)
Market risks	Coal pricing	Possible oversupply	Possible oversupply	Export approval	Large liquid market
Technology constraints /risks	Proven and available technology	Proven and available technology	Proven and available technology	Proven and available technology	Limited experience and few plants
Indicative net-back price	Reasonable ROR can be achieved - but project specific				

- USGC LNG Terminal owners can target exports to Europe and S.E. Asia, via the expanded Panama Canal from 2015, where netback gas prices are more favourable
- West Coast LNG export options (not included) to the Asia-Pacific market also provide robust net-back prices

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Mozambique Prospects

- A larger anchor project is needed to underpin gas developments for smaller consumption options such as power generation and methanol

Criteria	Power (200 MW)	Methanol (5,000 T/d)	Urea (1,000 T/d)	LNG (9.0 MMTpa)	GTL (16,000 Bbl/d)
Gas reserve (20 yr size /quality)	Small, rich (0.5 Tcf)	Moderate, rich (1.2 Tcf)	Small, rich (0.2 Tcf)	Large, rich (8.5Tcf)	Moderate, rich (1.2 Tcf)
Market risks	Hydro competition, Low pricing	Potential market flooding	Market flooding	Strong export market	Large liquid market
Technology constraints /risks	Proven & available technology	Proven & available technology	Proven & available technology	Proven and available technology	Few existing plants and experience
Indicative net-back price	Reasonable ROR can be achieved - but project specific				

- Gas reserves put focus on LNG, GTL and potentially an export pipeline (not shown here)
- LNG is a natural fit – but could GTL find a place in the mix?

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Conclusions

- Huge investments are required for the new wave of LNG and infrastructure projects to facilitate the Golden Age of Gas, but implementation will take time
  - Reasonable ROR are achievable on these projects if the economic drivers remain robust
  - Financing the projects will be a challenge
- Strong growth in new gas monetisation technologies and resurgence in some of the more tradition options
  - New production will challenge traditional market centres
- Competitiveness of the projects are location specific?

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