Welcome and Introductions

- The workshop
- The presenters
- You

FLNG Workshop

- Aim: Introduce technology factors surrounding floating liquefied natural gas (FLNG) production.
- Convenors:
  - Jill Stajduhar
    Associate Director
    Energy and Minerals Institute
    UWA
  - Susan Gourvenec
    Professor
    Engineering
    UWA
  - Peter Hartley
    Professor
    Business
    UWA

Presenters:

- Susan Gourvenec
  Professor
  Seabed Engineering
  UWA
- Kevin Mullen
  Subsea Engineer
  INTECSEA
- Zach Aman
  Associate Professor
  Chemical Engineering
  UWA
Professor Susan Gourvenec

- Centre for Offshore Foundation Systems (COFS), Faculty of Engineering, Computing and Mathematics, UWA
- UWA since 2001
- Research area - seabed engineering
- Teaching - offshore geomechanics
- Consultant to industry
- ISO & API committee member for offshore geotechnics

Adjunct Professor Kevin Mullen

- Subsea Engineer working in offshore oil and gas since 1991
- Came to Australia to work on big gas in 1998
- Executive Engineer at INTECSEA
- Teaching at UWA since 1998, at Curtin since 2015
- Has developed specialised subsea courses for PETRONAS in Malaysia and POSTECH University in Korea

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Dr Zach Aman

- Fluid Science and Resources Division, Faculty of Engineering, Computing and Mathematics, UWA
- UWA since 2013
- Research area – gas hydrates and flow assurance
- Teaching – pipeline flow and subsea field design
- Consultant to industry
- AIChE, ACS, IChemE, SPE

Gas Hydrate Under Extreme Growth:
**You**

- Do you have previous professional experience with FLNG?

- Do you have engineering experience?

- Are you an energy economist?

**FLNG pros and cons**

- Spend a few minutes discussing with those at your table pros and cons of floating liquefied natural gas (FLNG) as a new player in the energy market.

- Share comments with the wider group.

**KMPG survey**

- Global survey by KPMG of professionals involved in the O&G industry.

- Data collected December 2014.

- Analysis split between [Americas, Europe, Middle East and Africa] and the Asia Pacific region.


**What are the most important reasons to choose floating LNG?**

- A. Unlock smaller fields

- B. Access remote fields

- C. Avoid onshore "no-go" zones

- D. Reduce environmental footprint

- E. Deliver projects faster and cheaper
What are the greatest risks for floating LNG developers?
A. Containment of capital costs
B. Cyber security issues
C. Technical issues
D. Project management issues
E. Taxation challenges

How should the Asia Pacific countries improve their energy security and in particular their sourcing of gas?
A. Source gas from new locations
B. Build more LNG terminals onshore
C. Build more pipelines connecting countries in the region
D. Build floating LNG facilities
E. Increase regional energy dialogue
KMPG survey

TOTAL RESPONDENTS: 123

AMERICAS
LATAM
EMEA

How would you best describe falling oil prices?
A. Good for the development of gas markets
B. Bad for the development of gas markets
C. Hindering the development of an Asian pricing hub
D. Likely to defer gas projects
E. Reduce the focus by governments on energy security

KMPG survey

TOTAL RESPONDENTS: 178

AMERICAS
LATAM
EMEA

FLNG can meet future LNG demand
A. Strongly agree
B. Agree
C. Disagree
D. Strongly disagree
FLNG workshop outline

- FLNG basics
  - What is FLNG? What is LNG?
  - Technical challenges
- Break
- Outlook
  - FLNG projects under construction and planned around the globe
- Economics of FLNG compared to conventional LNG production
  - CAPEX vs OPEX, costs and capacity, project life, relocation
- Future trends and challenges
  - Upcoming milestones, implications of FLNG
- Closing activity and discussion session

What is FLNG?

- Floating Liquefied Natural Gas
- Extraction, treatment, liquefaction, export of natural gas (methane) all offshore, from a floating facility.
- Conventionally, natural gas is piped from the offshore field to an onshore processing plant for treatment and liquefaction prior to export.

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**O(10^4) Components in Oil**

- Negative ions: 6,118 Components
- Positive ions: 11,127 Components

**Natural Gas Components**

- Hydrocarbons are distributed in nature

<table>
<thead>
<tr>
<th>No of Carbon Atoms</th>
<th>Name</th>
<th>No. of Isomers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Methane</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Ethane</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Propane</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>Butane</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>Pentane</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>Hexane</td>
<td>5</td>
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<tr>
<td>7</td>
<td>Heptane</td>
<td>9</td>
</tr>
<tr>
<td>8</td>
<td>Octane</td>
<td>18</td>
</tr>
<tr>
<td>9</td>
<td>Nonane</td>
<td>35</td>
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<tr>
<td>10</td>
<td>Decane</td>
<td>75</td>
</tr>
<tr>
<td>20</td>
<td>Eicosane</td>
<td>305318</td>
</tr>
<tr>
<td>30</td>
<td>Tricosane</td>
<td>4.11 x 10^2</td>
</tr>
</tbody>
</table>

**Natural Gas Components**

- Diagram showing vapor pressure and critical points

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Range of LNG Components

- Typical composition ranges in LNG (mol%)

<table>
<thead>
<tr>
<th>Component</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>&lt; 1</td>
<td>3</td>
</tr>
<tr>
<td>Methane</td>
<td>87</td>
<td>99</td>
</tr>
<tr>
<td>Ethane</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>Propane</td>
<td>&lt; 1</td>
<td>5</td>
</tr>
<tr>
<td>Butane</td>
<td>&lt; 1</td>
<td>1</td>
</tr>
</tbody>
</table>

- Pipeline transport of “gas” is the most efficient strategy
  - Limited by distance to market and terrain
- Liquefying natural gas components
  - Reduced temperature to ~ -160 °C (atmospheric pressure)
  - Transport from producers (e.g. Australia) to consumers (e.g. Japan)
  - Enables longer-distance transport via sea

Benefits of LNG-Based Transport

- Significant increase in density:
  - 30 °C and 100 bar: NG is “gas” with density 94 kg/m³
  - -150 °C and 200 bar: NG is “liquid” with density 460 kg/m³
- In this example, LNG shipping “volume” 5 times more efficient!

- Natural gas requires “treatment” to remove unwanted components
  - Product must meet pipeline specifications
  - Remove excess nitrogen, hydrogen sulphide, carbon dioxide, mercury
  - Strip away “heavier” components (even in trace amounts!)
  - Removal of WATER
  - System is reaching -165 °C

From Reservoir to Sales

Reservoir Changes with Time

Critical consideration in design phase
- Worst-case scenario: 90+ vol% water in flow
- Affects pressure drop, flow assurance, refining/processing
Removal of Water

- Glycol (MEG/DEG/TEG)
  - Can be regenerated after use
  - After contacting “wet” gas, glycol is “rich” in water
  - Heated in separate process to remove water
  - Glycol re-cooled for use
- Molecular sieve
- Pipeline specification: 32.8 to 117 kg/10^6 std m^3
- May also consider partial dehydration on seafloor (natural cooling)

Basic LNG Process

- Cryogenic heat exchanger, with three engineering challenges:
  1. A process upset occurs;
  2. Feed stream changes over time; and/or
  3. Scrub column’s operation is not adequate

Liquefaction Process

Typical Design Parameters

<table>
<thead>
<tr>
<th>Orientation</th>
<th>Vertical</th>
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<tbody>
<tr>
<td>Tube Length</td>
<td>28.71 m</td>
</tr>
<tr>
<td>Bundle Length</td>
<td>21.45 m</td>
</tr>
<tr>
<td>Number of Tubes</td>
<td>870 -</td>
</tr>
<tr>
<td>Tube Diameter Outside</td>
<td>19.1 mm</td>
</tr>
<tr>
<td>Tube Thickness</td>
<td>~ 1.0 mm</td>
</tr>
<tr>
<td>Overall Heat Transfer Coefficient</td>
<td>900 - 3500 W/(m^2K)</td>
</tr>
<tr>
<td>Tube Side Vapour Velocity</td>
<td>5 to 10 m/s</td>
</tr>
</tbody>
</table>

References:
2. THYSSENKRUPP AEROSPACE. 2015. Aluminium tube [Online].

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Video: Ethane “Rain”

FLNG basics - architecture

<table>
<thead>
<tr>
<th></th>
<th></th>
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<tbody>
<tr>
<td><strong>Facilities</strong></td>
<td>Semi-sub CPF, FPSO</td>
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<tr>
<td></td>
<td>900 km pipeline</td>
</tr>
<tr>
<td><strong>Reserves</strong></td>
<td></td>
</tr>
<tr>
<td>Gas tcf</td>
<td>12</td>
</tr>
<tr>
<td>Condensate mb</td>
<td>500</td>
</tr>
<tr>
<td><strong>Production capacity</strong></td>
<td></td>
</tr>
<tr>
<td>LNG mtpa</td>
<td>8.9</td>
</tr>
<tr>
<td>LPG mtpa</td>
<td>1.6</td>
</tr>
<tr>
<td>Condensate bbl/d</td>
<td>100,000</td>
</tr>
<tr>
<td><strong>Operational life</strong></td>
<td>40</td>
</tr>
<tr>
<td><strong>CAPEX US$Bn</strong></td>
<td>34</td>
</tr>
<tr>
<td><strong>FID</strong></td>
<td>Jan 2012</td>
</tr>
<tr>
<td><strong>First gas</strong></td>
<td>Late 2016</td>
</tr>
<tr>
<td></td>
<td>Undisclosed</td>
</tr>
</tbody>
</table>

Source: Shell

Source: Inpex

Source: Google
Technical Challenges

- Scale
- Novelty
- Operability
- Examples of engineering technical challenges
  - Outside the pipeline
  - Inside the pipeline

Technical Challenges

- Novelty
  - Water intake risers – cold water for cooling during the liquefaction process
  - 50 million litres of cold water per hour
  - 8 steel tubes, 150 m into the water column
  - Depth determined by temperature gradient of seawater.
  - Retrievable for maintenance/redundancy.
  - 25 yr service life. Durable but tolerate vessel movements
  - Small footprint.
  - Avoid collision with moorings and risers.
  - VIV

Technical Challenges

- Operability

Credit: Dr James Holbeach, Wood Group Kenny, for the innovative analogy

The factory of the future will have only two employees, a man and a dog. The man will be there to feed the dog. The dog will be there to keep the man from touching the equipment.

Warren Bennis

www.shell.com.au
Technical Challenges

- Outside the pipeline
  - Seabed – super-sized anchoring ("scale"), short tiebacks ("cow")
  - Wave structure interaction – cyclones and offloading
- In the pipeline
  - Flow assurance

Mooring giant FLNG facilities

- Very large floating facilities required to stay on station in very rough weather conditions need very big anchors to hold them in place.

Mooring giant FLNG facilities

- Large mooring forces due to cyclonic wind and waves
- Variable seaboards
  - hard, soft, layered
- Pushing envelope of chain and anchor capacity
- Chain-anchor interaction:
  - Hard soil bad – chain pulls upward on anchor, which is weak direction
  - Soft soil – low anchor capacity
- UWA has developed novel anchors and new chain simulation methods

Chain-seabed interaction

- UWA has developed novel anchors and new chain simulation methods

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Chain-sea interaction

Vessel motions

- Cyclonic
  - Is the vessel securely moored in position (see previous example)
  - Are the vessel motions acceptable for comfort and safety?

- Day to day
  - Can LNG be offloaded by tanker?
  - Side-by-side FLNG-LNGC is currently technology
  - Sets envelope of FLNG and LNGC relative motions, limited by ‘reach’ of loading arms
  - Annual production limited by number of cargos that can be offloaded and therefore frequency and length ‘windows’ when vessel motions would be excessive
  - Sloshing of LNG within LNGC adds complexity to motion predictions

Vessel motions

FLNG and FPSO motions

Wave-structure-LNG interaction

Short tieback, high operating cycles

- Short pipelines with high number of operating cycles
- Heating and cooling during cycles causes expansion
- Deliberate lateral buckles are used to relieve loads – but high cycles create more onerous fatigue
- Constraint offered by seabed is critical
- UWA has pioneered methods for simulated pipeline-seabed interaction, and incorporating the behaviour in pipeline design

Pipe-seabed interaction modelling
Flow Assurance: Subsea Risk

- Gas hydrates
  - Reaction of water and natural gas components
- Corrosion
  - Water reacting with carbon steel
- Multiphase flow
  - High liquid holdup = high energy penalty to flow

What is a Gas Hydrate?

- Structure II
  - 136 waters per unit cell
  - 8 large cages (5-6)
  - 16 small cages (5-1)
- Full occupancy of both cages
  - 15.0 mol% guest
  - 85.0 mol% water
- Typically assume 6 mol water : 1 mol gas
- Heavier components into large cage
- Full occupancy of both cages
- Formation requires less severe P,T conditions

The Hydrate Equilibrium Curve

Preventing Hydrate: MEG/MeOH

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Hydrates Grow at Cool. Temps.

Important points:
1) Entrance (5 km)
2) Max. subcooling (15 km)
3) Exit (22 km)

Process Control for Hydrate Mgmt.

Outlook

- FLNG projects under construction and planned across the globe

Economics of FLNG

- Economics of FLNG compared to conventional LNG production
  - Current market conditions
  - How FLNG fits in the LNG market
  - How investment costs vary with LNG vs. FLNG
  - Project financing
Australia’s Gas

- Australia’s gas resources and infrastructure

Liquefaction Plant Cost

- Recent trend of high cost Australian projects

Oil and LNG Costs

- Recent trends

Current Oil Production

- Source: Geoscience Australia
- Source: Bloomberg
- Source: https://mehreen.cartodb.com
Current Oil Production

Source: https://mehreen.cartodb.com

OPEC production stands at around 31.5m barrels per day

The size of FLNG

- Australian LNG projects, capital costs and unit costs
  - FLNG is small – single train
  - Typical fields will require several FLNG
  - Prelude: 3.6 MTPA LNG + 1.3 MTPA condensate + 0.4 MTPA of LPG

<table>
<thead>
<tr>
<th>Project</th>
<th>State</th>
<th>Year completed</th>
<th>Capital cost A$B</th>
<th>Capacity MTPA</th>
<th>Unit cost $/t</th>
</tr>
</thead>
<tbody>
<tr>
<td>North West (shelf train)</td>
<td>WA</td>
<td>2014</td>
<td>2.5</td>
<td>4.4</td>
<td>1 688</td>
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<tr>
<td>Gailen LNG</td>
<td>NT</td>
<td>2008</td>
<td>3.3</td>
<td>2.2</td>
<td>1 131</td>
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<tr>
<td>North West (shelf train)</td>
<td>WA</td>
<td>2008</td>
<td>2.6</td>
<td>4.4</td>
<td>661</td>
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<tr>
<td>Pluto LNG</td>
<td>WA</td>
<td>2012</td>
<td>14.8</td>
<td>4.3</td>
<td>3 465</td>
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<tr>
<td>Gorgon LNG</td>
<td>WA</td>
<td>2013</td>
<td>42.0</td>
<td>15.0</td>
<td>2 927</td>
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<tr>
<td>Queensland Curtis LNG</td>
<td>QLD</td>
<td>2015</td>
<td>10.4</td>
<td>8.5</td>
<td>3 555</td>
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<td>Gladstone LNG</td>
<td>QLD</td>
<td>2010</td>
<td>15.6</td>
<td>12.0</td>
<td>1 987</td>
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<td>Prelude</td>
<td>NT</td>
<td>2016</td>
<td>2.9</td>
<td>7.4</td>
<td>12.777</td>
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<td>APA LNG</td>
<td>QLD</td>
<td>2019</td>
<td>13.6</td>
<td>2.5</td>
<td>3 032</td>
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<td>Wheatstone</td>
<td>WA</td>
<td>2016–17</td>
<td>29.9</td>
<td>8.2</td>
<td>3 258</td>
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<td>Ichthyus</td>
<td>NT</td>
<td>2016–17</td>
<td>30.3</td>
<td>8.4</td>
<td>3 646</td>
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</tbody>
</table>

Source: BREE

Small is the new black

- Smaller size of FLNG
  - Can turn this constraint of FLNG to advantage
    - Allows phased development of larger fields (3 FLNG for Browse)
    - Reduces financial exposure and initial CAPEX
  - Higher OPEX compared to conventional LNG production

Financing of FLNG megaprojects

- Phased development
  - Improved cashflow
  - Reduces initial CAPEX
  - Reduced risk

Chart: UWA Subsea Technology 2013 Team 1

Woodside Browse FLNG Development Plan

Graphic: courtesy Woodside 2013 Half Year Results Briefing Aug 2013
Financing of FLNG

• The first wave of FLNG projects was self-funded
  – Shell had no partners and no finance for Prelude
  – Since FID, Shell have partnered with INPEX (17.5%), KOGAS (10%) and OPIC (5%) on Prelude.

Image courtesy Shell

FLNG entirely offshore

• FLNG entirely offshore
  – Turning constraints of FLNG to advantage
  – Potentially no requirement for WA Domgas
  – Western Australia’s Domgas reservation policy requires LNG Producers to make available Domgas equivalent to 15% of LNG production
  – LNG price delivered to Japan typically $14.5/MMBTU (~A$14/GJ), with cost of liquefaction $3.50/MMBTU and shipping costs A$3.50/MMBTU
  – Domestic gas price typically $4-6/MMBTU

Revenue Component

- Export Gas: 8%
- DomGas: 18%
- Condensate: 74%

Pie Chart: based on data from UWA Subsea Technology 2013 Team 3

* September 2014: The Future of Australian LNG Exports, Oxford Institute for Energy Studies

Future trends and challenges

• What are the upcoming developments in FLNG?
• What trends are developing?
• What are the opportunities for cost reductions through further learning?
• What will FLNG developments look like in the future?
• Will FLNG developments have implications for costs of conventional LNG or floating regasification terminals?

Image courtesy Shell
Current Developments

- “Conventional”, mini and micro FLNG
- The constraint is LNG tankers
  - Up to 266,000 m³, the majority are 120,000-140,000 m³

<table>
<thead>
<tr>
<th>FLNG Facility</th>
<th>Capacity</th>
<th>Length</th>
<th>Storage</th>
<th>Storage</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shell Prelude</td>
<td>3.6 MTPA</td>
<td>488 m</td>
<td>220,000 m³</td>
<td>10 days</td>
<td>600,000 tonnes</td>
</tr>
<tr>
<td>Petronas Kanowit</td>
<td>1.0 MTPA</td>
<td>365 m</td>
<td>177,000 m³</td>
<td>29 days</td>
<td>125,000 tonnes</td>
</tr>
<tr>
<td>Exmar Pacific Rubiales</td>
<td>0.5 MTPA</td>
<td>144 m</td>
<td>16,000 m³</td>
<td>5 days</td>
<td></td>
</tr>
</tbody>
</table>

*Exmar Pacific Rubiales FLNG has 144,000 m³ FSU alongside

Subsea Aspects

- What about subsea?

The subsea side of Prelude

- Having FLNG close to wells is an enabler
  - Allows pipeline heating
  - Reduces dependence on chemicals (MEG)
- Shorter distance to wells
  - Slugs and liquid hold-up in flowlines is less of a problem
  - No need for compression or boosting
  - Less failure-prone equipment on the seabed

Existing LNG developments

- A suitable candidate for FLNG?

Gorgon
- 3 drill centres
- 8 wells
- 250 metre depth
- 70 km tie-back to plant
- 34" carbon steel pipeline
- High CO2 content (15%)

Jansz
- 2 drill centres
- 10 wells
- 1350 metre depth
- 147 km tie-back to plant
- 30/34" CS pipeline

Image courtesy gcaptain.com
Image courtesy PETRONAS
Image courtesy Shell

Image: IPTC 14548
Subsea heating

- Heating of flowlines for hydrate prevention
  - Direct electric heating or trace heating or heated water pipes
  - Reduce need for MEG
  - Reduce need for MEG reclamation on FLNG vessel
- Why?
  - Shell Prelude has 800 m³/day MEG regeneration system to provide buffer storage, collection and regeneration of MEG
  - MEG facilities including MEG storage tanks, MEG desalination package, MEG regeneration package, MEG injector and MEG booster pumps

Subsea heating

- Electrical Heat Tracing (EHT)
  - Low voltage, low power (4-30 W/m)
  - Redundant trace heating cables
  - Fibre optic for thermal monitoring

Subsea heating

- Direct Electrical Heating (DEH)
  - AC current to pipe
  - Field Proven: Single phase required
  - High voltage and power required (100-150 W/m)
- Integrated Production Bundle (IPB)
  - Heating cables/hot water tubes between pipe and insulation
  - Use spare heat from compression / power generation
  - Use for risers
- Electrical Heat Tracing (EHT)
  - Heating cables between pipe and insulation
  - Pipe in Pipe (PIP)
  - AC three phase power
  - Low voltage, low power (4-30 W/m)
  - Higher safety, less dielectric ageing
  - Qualified wire traces and subsea connectors
  - Allows redundancy

Heated Flexible Risers

- FLNG Risers: Functional Requirements
  - Internal diameter: 10 to 16 inch
  - High fluid velocity: circa 30 m/s
  - Pressure: 300 to 450+ bar
  - Temperature: -35 to 130°C
  - Water depth: 200m to 1,300m+
  - Design life: 25 to 40 years
  - Heating to prevent hydrate formation
  - Insulation: 0 to 5 W/m²K
  - H₂S and CO₂ resistance
  - Potential sand production
- Design challenges from erosion, high and low temperatures, wear/fatigue and “singing risers”
Subsea heating

- Electrical Heat Tracing (EHT)
  - Low voltage, low power (4-30 W/m)
  - Redundant trace heating cables
  - Fibre optic for thermal monitoring

Power requirements for Islay EHT

<table>
<thead>
<tr>
<th>Power required per metre</th>
<th>Overall power required</th>
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</thead>
<tbody>
<tr>
<td>Minimum temperature above HAT (ca. 20°C)</td>
<td>8 to 10 W/m</td>
</tr>
<tr>
<td>Heat up pipeline from 4 to 20°C in 24 hours</td>
<td>10 to 20 W/m</td>
</tr>
<tr>
<td>Heat up pipeline from 4 to 20°C in 30 hours with 15% of hydrates</td>
<td>30 W/m</td>
</tr>
</tbody>
</table>

Subsea heating

- Reeled installation
  - Faster than S-lay or J-lay
  - Fabrication is performed onshore
  - Controlled environment, off the critical path
  - Weld repairs are performed onshore

FLNG Risks

- FLNG puts all processing equipment in close proximity
  - FLNG vessel exposed to inventory of risers and flowlines
  - Prone to escalation
  - Inherently dangerous, not inherently safe

- An as-yet unproven technology
  - Potentially subject to cost blowouts
  - More dangerous to your bottom line

- FLNG systems will suffer more downtime than onshore LNG
  - No linepack in long pipelines
  - More dependent on high availability subsea systems
  - More risk to your bottom line

FLNG Risks

- Risk is higher with FLNG than FPSOs
  - Risk = Likelihood x Consequence
  - Likelihood is higher with gas than with oil developments
  - Consequence of loss of FLNG = $13 billion
  - Shell Prelude
  - Consequence of loss of FPSO = $1.5 billion
  - UIBC 2012 data

\[
\begin{array}{|c|c|}
\hline
\text{Number of Total FPSOs} & 154 \\
\text{Number of FPSO Projects} & 79 \\
\hline
\end{array}
\]

- Average Floating System Cost (and LTV)
  - Range of Costs: $4.3 billion

- Shell statement in Prelude EIS
  - After comprehensive studies, model testing and in-depth reviews, Shell’s FLNG design safety is considered equal to the latest FPSO or integrated off shore facility.
FLNG Risks

The Real Estate for 3 x FLNG

Problems with Current Layouts

• The compact Prelude layout brings problems
  – Short flowlines – no linepack – high uptime requirement from subsea
  – Single umbilical – single point of failure
  – 9% CO₂ vented up flare stack – 2.3 MTPA released

Future Layouts

• Mature FLNG developments may look very different
  – FLNG vessels located 20-40 km away from wells
  – Linepack improves system availability
  – Well fluids are cooled before reaching risers
  – Vessels can be moored in shallower water
  – Vessels can be located in conditions better suited for LNG transfer
  – Flowline heating is viable

Problems with Current Layouts

• More potential problems
  – Potentially high temperatures in risers
  – Mooring may not be optimal
  – Metocean conditions may be poor for LNG transfer to carriers
Mature FLNG developments

- Technical maturity
  - Taking advantage of new technology
  - Using subsea layout to improve operability and up-time
  - Separating vessel and wells
  - Regulators catching up with the developments
- Bespoke vessels
  - Matched to reservoir composition and metocean conditions
- Financing of FLNG megaprojects
- Reducing risks
  - Political risk, legislative changes, regulatory
  - Security, terrorism, environmental activism
  - Workforce and union issues

Case Study - Browse LNG

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Case Study - Browse LNG

Remoteness of Browse Basin from Existing Infrastructure

Challenging Access

Courtesy: Geoscience Australia 2012 (updated)
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Perspective view of Scott Reef from the west. Vertical scale exaggerated

Courtesy: Scott Reef Rugbjerg, 2009

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**Project Economics Key Figures**

- **CAPEX** - $46.2B Total Project Cost
  - FLNG - $42.9B
  - Subsea - $3.2B
- **OPEX** - $440M per FLNG vessel annually including fuel, staff, transport assistance
- **NPV10** $35.0B
- **IRR** 10.53%

The Drama of Browse LNG

- Revisit pros and cons and survey results
- Panel and group discussion

Recap and discussion
FLNG can meet future LNG demand

A. Strongly agree
B. Agree
C. Disagree
D. Strongly disagree

FLNG pros and cons

• Have your opinions changed during the course of the workshop?

Further reading

Independent FLNG report by UWA and APPEA to be released soon. Watch these spaces: www.emi.uwa.edu.au www.appea.com.au

Future Resources: Natural Hydrate
Wrap up

- Feedback questions
  - anonymous or feel free to put your name
  - please drop in box on way out
- Takeaway information about oil and gas capabilities at UWA.
- Feel free to get in touch with any of us in the future.
- Thank you for attending.