Trends of Technology Innovation for the Future of LNG

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Key trends in LNG supply

- LNG supply surplus set to ease earlier than expected
- 120+MTPA supply capacity is vying to take FID in 2019
- Challenge is long term demand uncertainty in Asia
- Supply shifting to short cycle, low cost projects
Renewable energy entered a virtuous cycle of falling costs… LNG shall catch-up

- Crystalline silicon PV module prices have fallen by more than 80% since 2010
- Wind turbine prices have fallen up to 40% since 2009
- Battery storage costs could fall 50% driven by optimization of manufacturing and reduced use of materials
- Renewable electricity is getting competitive with other grid supply options without financial support
The industry needs to be able to reduce development costs of new LNG projects, reversing the growth trend

Current development costs are not compatible with scenarios of prolonged low Brent prices

Development costs need to be reduced

1. Development of most competitive projects
   - Liquefaction development costs vary significantly on the basis of projects scope and geographic location
   - High prices and booming LNG demand during the last years have enabled to develop projects with high development costs
   - In the next period, industry should focus on developing only the most competitive projects

2. Structural cost reduction
   - During last years the industry has been focused on project execution, rather than costs management
   - This has resulted in a context where: (i) one-of-a-kind projects are developed, with limited standardization among projects, (ii) there is limited competition among suppliers, especially in key components (iii) technology improvements are mainly based on scale and thermal efficiency but do not generate significant costs savings (iv) there is limited cooperation among developers, and (v) the focus is on project execution with limited attention to lean approaches
   - The industry needs to implement structural solutions to reduce LNG development costs
## Significant implications for multiple LNG industry participants

<table>
<thead>
<tr>
<th>LNG projects developers</th>
<th>LNG buyers</th>
<th>EPC firms and OEMs</th>
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</thead>
<tbody>
<tr>
<td>• Flat supply curve-new sources of supply highly cost competitive</td>
<td>• Multiple projects requiring contractual commitments on investment to fake FID</td>
<td>• Substantial capacity likely to come to FID in next 4 years</td>
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<td>• Need to take FID despite long term demand uncertainty</td>
<td>• Portfolio buyers and traders taking a greater share with new projects</td>
<td>• Project cyclicality likely to continue</td>
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<td>• North American independent project developers playing a greater role</td>
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<td>• Concentration of projects in US presents specific challenges</td>
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<td><strong>Strategic implications</strong></td>
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<td>• Effective capital project management will be critical</td>
<td>• Strong buying power in the next 1-3 years if able to make long-term commitment</td>
<td>• Prepare for next wave of investment and build out</td>
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<td>• Risk can be mitigated through value chain integration strategies</td>
<td>• Attractive investment opportunities may emerge as projects vie to fake FID</td>
<td>• New approaches to workforce retention and contract management required</td>
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<td>• New opportunities to invest or secure offtake from independent projects</td>
<td>• Supply options are increasing opportunity to diversify supply portfolio or contracting terms</td>
<td>• Specific strategies required to manage 1) tariff impacts and 2) workforce shortages</td>
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Drivers of technical innovation in LNG

Modularization
Cut design, construction and execution time & cost by more than 30%

- Relax specs and industrialize plant design
- Maximize efficiency and reliability around standard design and commoditized equipment
- Execute assembly and testing work in yard located in best-cost country

Optimal train size
Find best trade-off between scale and cost-effectiveness

- What’s the right sizing of the liquefaction unit in terms of CAPEX, OPEX, time to market, production flexibility?
- Could micro and small liquefaction become cost competitive?

Zero Emission
Gain license to operate in the low carbon world

- Plant Hybridization... use renewables and energy storage to replace partly or totally gas-fired turbines at a competitive CAPEX and OPEX
- Tackle methane escapes across the whole supply chain
- Eliminate flaring at start-up and shut down

Debottlenecking
Flexible solutions to capture demand uncertainty

- Hardware and software kit to increase production using the same asset
- Online condition-based maintenance to postpone maintenance outages

Digital Innovation
Drive the next wave of cost reduction

- Additive manufacturing to produce spare parts onsite and reduce working capital and downtime
- Autonomous, low-cost robots able to perform complex tasks and substitute human intervention
- Blockchain to enable safe and easy integration and access of data