North America: 
A future LNG superpower?

AIChE South Texas Local Section 
September 6, 2018
Outline

- About ADI Analytics
- North America: A Future LNG Superpower?
ADI Analytics is a boutique consulting firm serving energy and chemical companies with passion, rigor, and expertise.

<table>
<thead>
<tr>
<th>Operating companies</th>
<th>Service providers</th>
<th>Equipment manufacturers</th>
<th>Investors</th>
<th>Traders</th>
<th>Government</th>
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</thead>
<tbody>
<tr>
<td>Oil</td>
<td>Gathering &amp; Processing</td>
<td>Pipelines</td>
<td>Refining</td>
<td>Fuels</td>
<td>Automotive</td>
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<td>Gas</td>
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<td>LNG</td>
<td>Fuel</td>
<td>Lubes</td>
<td>Base chemicals</td>
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<td>NGLs</td>
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<td>Logistics</td>
<td>Syngas</td>
<td>Specialty chemicals</td>
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<td>Power generation</td>
<td>Renewables</td>
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<td>Transmission</td>
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<td>Biomass</td>
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</table>

Markets | Operations | Technology | Finance | Organization | Policy |
Fortune 500 and mid-sized companies, start-ups, investors, and governments have hired us to shape decisions globally.

ExxonMobil  BASF  Sasol  GE  Honeywell  KKR  CelluForce
Shell  Santos  Dow  Lubrizol  Schlumberger  Emerson  Arsenal
Chevron  Thai Oil  DuPont  Veolia  Baker Hughes  A&E Company  Gardner Denver  Elliott
BP  PTT  LyondellBasell  Cabot  Voith  IHI  Lindsay Goldberg
ConocoPhillips  SK  Nova Chemicals  Sabic  Schneider Electric  B&W  Hastings Equity Partners
Marathon Oil  Reliance  Borealis  Solvay  Dover  AECOM  Riverside
Total  Mitsubishi  Air Liquide  Danfoss  ThyssenKrupp
Phillips 66  EMC  Marubeni  Praxair  Accudyne  Harsco  Altira

www.adi-analytics.com
ADI’s acquisition of CMR brings clients expertise, experience, and an integrated view of the hydrocarbon value chain.

ADI is a management consulting firm specializing in oil and gas, power, chemicals, and industrials. It has completed 300+ projects for 100+ clients since 2009.

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ADI acquired key assets of Chemical Market Resources (CMR) in 2017. Since 1990, CMR has provided market research and management consulting services through 500+ projects for 200+ clients in petrochemicals, chemicals, plastics, and polymers.

www.CMRHouTex.com
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- North America: A Future LNG Superpower?
Key messages

1. Thanks to shale, North American has plenty of cheap natural gas

2. North American gas demand growth is slow driving exports

3. Environmental pressures are driving LNG demand globally but the market is oversupplied currently

4. North American LNG projects enjoy many distinctive advantages

5. Small-scale LNG is a promising new frontier but challenged by demand and infrastructure

6. Growing competitiveness of renewables and energy storage are key risks to natural gas and LNG

Key insights from ADI research
Key messages

1. Thanks to shale, North American has plenty of cheap natural gas

Key insights from ADI research
In the long term, global resource and commodity demand is expected to rise led by power and natural gas.

### Natural Gas Demand (MM BOE / Day)

<table>
<thead>
<tr>
<th>Year</th>
<th>2010</th>
<th>2015</th>
<th>2020</th>
<th>2025</th>
</tr>
</thead>
<tbody>
<tr>
<td>57.8</td>
<td>63.5</td>
<td>70.7</td>
<td>77.8</td>
<td></td>
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</tbody>
</table>

**CAGR 2010-25:** 2.0%

### Oil Demand (MM Bbl / Day)

<table>
<thead>
<tr>
<th>Year</th>
<th>2010</th>
<th>2015</th>
<th>2020</th>
<th>2025</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.5</td>
<td>9.4</td>
<td>10.1</td>
<td>10.6</td>
<td></td>
</tr>
</tbody>
</table>

**CAGR 2010-25:** 1.4%

### Coal Demand (MM BOE / Day)

<table>
<thead>
<tr>
<th>Year</th>
<th>2010</th>
<th>2015</th>
<th>2020</th>
<th>2025</th>
</tr>
</thead>
<tbody>
<tr>
<td>72.5</td>
<td>76.2</td>
<td>80.6</td>
<td>82.4</td>
<td></td>
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</tbody>
</table>

**CAGR 2010-25:** 0.9%

### Electricity Generation (Capacity, Terawatts)

<table>
<thead>
<tr>
<th>Region</th>
<th>Year</th>
<th>2010</th>
<th>2015</th>
<th>2020</th>
<th>2025</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S. and Canada</td>
<td>5.0</td>
<td>6.1</td>
<td>6.6</td>
<td>7.0</td>
<td></td>
</tr>
<tr>
<td>Middle East</td>
<td>1.2</td>
<td>1.3</td>
<td>1.3</td>
<td>1.4</td>
<td></td>
</tr>
<tr>
<td>Latin America</td>
<td>0.2</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td></td>
</tr>
<tr>
<td>Europe &amp; Russia</td>
<td>1.3</td>
<td>1.5</td>
<td>1.6</td>
<td>1.6</td>
<td></td>
</tr>
<tr>
<td>Asia Pacific</td>
<td>1.9</td>
<td>2.5</td>
<td>2.9</td>
<td>3.1</td>
<td></td>
</tr>
<tr>
<td>Africa</td>
<td>0.1</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td></td>
</tr>
</tbody>
</table>

**CAGR 2010-25:** 2.3%

**Source:** BP, EIA, IEA
U.S. oil and gas production will continue to rise at a robust pace driven entirely by growth in unconventional wells.
Gas supply has grown significantly with most of the growth coming from Marcellus and that will continue through 2020.
A significant fraction of natural gas production growth is now coming from associated gas and is linked to oil economics.

U.S. Total Gas Production (Billion Cubic Feet Per Day)

Permian will drive growth in associated gas

<table>
<thead>
<tr>
<th>Year</th>
<th>Associated gas</th>
<th>Other gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>8.2</td>
<td>50.2</td>
</tr>
<tr>
<td>2011</td>
<td>10.0</td>
<td>52.7</td>
</tr>
<tr>
<td>2012</td>
<td>11.9</td>
<td>54.0</td>
</tr>
<tr>
<td>2013</td>
<td>14.6</td>
<td>51.7</td>
</tr>
<tr>
<td>2014</td>
<td>17.7</td>
<td>53.2</td>
</tr>
<tr>
<td>2015</td>
<td>19.3</td>
<td>54.9</td>
</tr>
<tr>
<td>2016</td>
<td>19.7</td>
<td>53.3</td>
</tr>
<tr>
<td>2017</td>
<td>20.0</td>
<td>54.2</td>
</tr>
<tr>
<td>2018</td>
<td>22.4</td>
<td>54.8</td>
</tr>
<tr>
<td>2019</td>
<td>24.9</td>
<td>55.4</td>
</tr>
<tr>
<td>2020</td>
<td>27.6</td>
<td>56.0</td>
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</tbody>
</table>

Other gas

Associated gas
Given this background, we anticipate sustained production and ...
... Supply of cheap natural gas at prices below $4 per Mcf through the next several years

U.S. Natural Gas Supply Curve
(USD Per Million Cubic Feet)

Total demand through 2030 and 2040
Key messages

1. Thanks to shale, North American has plenty of cheap natural gas

2. North American gas demand growth is slow driving exports
Natural gas demand has grown primarily in the power sector followed by industrials in comparison to other segments.

**Residential Natural Gas Demand**
(Billion Cubic Feet Per Day)

-2000-2017

-1.6%

**Commercial Natural Gas Demand**
(Billion Cubic Feet Per Day)

-2000-2017

-0.1%

**Industrial Natural Gas Demand**
(Billion Cubic Feet Per Day)

-2000-2017

2.1%

**Natural Gas Demand for Power**
(Billion Cubic Feet Per Day)

-2000-2017

3.3%

Source: EIA
Natural gas exports via pipelines and LNG will after a long time account for the bulk of demand growth until 2025

### U.S. Natural Gas Utilization Growth
(Billion Cubic Feet Per Day, 2017-20)

<table>
<thead>
<tr>
<th>Year</th>
<th>Demand incl Exports</th>
<th>Exports LNG</th>
<th>Exports Pipeline Mexico</th>
<th>Exports Pipeline Canada</th>
<th>Industrial</th>
<th>Power</th>
<th>Res, comm, and transp</th>
<th>2020 Demand incl Exports</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017</td>
<td>74.4</td>
<td></td>
<td></td>
<td></td>
<td>6.5</td>
<td>1.7</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.7</td>
<td>1.6</td>
<td>0.96</td>
<td>89.2</td>
</tr>
</tbody>
</table>
Key messages

1. Thanks to shale, North American has plenty of cheap natural gas

2. North American gas demand growth is slow driving exports

3. Environmental pressures are driving LNG demand globally but the market is oversupplied currently
More countries are importing LNG either as a primary fuel or to complement or switch away from other fuels.

Map of LNG Importing Countries by Primary Use

Source: Shell
Leading LNG buyers have intensified their efforts to reduce costs and risk via diversification across multiple dimensions.

Japanese LNG Importers’ Goals

- **Supply Region**: 2015: 35%, 2020: 25%, Future: 25%
- **Contract Maturities**: 2015: 20%, 2020: 25%, Future: 25%
- **LNG Price Indexation**: 2015: 93%, 2020: 70%, Future: 50%

*Legend for charts:*
- Mideast
- Others
- Australia
- N. America
- Spot
- Long
- Short / Mid
- Oil
- JKM / JLC
- NBP/HH
LNG markets are oversupplied although they may balance sooner than expected in early 2020s

Worldwide LNG Demand and Supply
(Million Tons Per Year)

Oversupplied LNG market

- High case
- Base case
- Supply
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4. North American LNG projects enjoy many distinctive advantages
Natural gas prices will continue to grow moderately as seen recently but will likely stay below or around $4 per Mcf

Henry Hub Spot and Forecast Prices
(USD Per Million Btu)

- Growing demand supports price
- Falling Marcellus costs reduce prices
Abundant, liquid supply of natural gas in the U.S. has enabled new LNG business models based on tolling capabilities …

**LNG Value Chain and Business Models**

- **Upstream**
- **Midstream**
- **Liquefac’n**
- **Shipping**
- **Regasification**
- **Marketing**

### Integrated Model
- Gas producer builds and owns LNG plant …
- … Owns marketing risk and price upside …
- … Ships LNG under SPA contracts, spot cargoes, and FOB sales

### Pure Play
- Developer builds and owns LNG plant …
- … Buys gas from grid to produce LNG …
- … Sells FOB under long-term SPA with some spot

### Toll Model
- Liquefaction owned by third party
- Gas producer leases liquefaction plant to "toll" LNG at a fee …
- … Controls shipping and marketing
North American shale gas-based LNG capacity is disrupting pricing mechanisms and expanding spot pricing

**Henry-Hub Linked Sales Purchase Agreement**
(USD / Million Btu)

<table>
<thead>
<tr>
<th>Source gas</th>
<th>Pipe gas to LNG plant</th>
<th>Liquefaction</th>
<th>Shipping</th>
<th>Delivered ex-ship cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>$3.45</td>
<td>$2.25</td>
<td></td>
<td>$1.10</td>
<td>$6.80</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Henry hub spot</th>
<th>Liquefaction charge</th>
<th>Shipping</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>$3.45</td>
<td>$2.25</td>
<td>$1.10</td>
<td>$6.80</td>
</tr>
</tbody>
</table>

**Henry-Hub linked SPA**
- Buyer pays liquefaction / usage fees regardless of use of the facility and ...
- ... Gas fee that is payable based on the amount of gas liquefied

**Tolling Model**
- Buyer pays reservation / capacity fee regardless of the use of the facility ...
- ... Liquefaction / usage fee based on amount of gas liquefied

**Spot Indexation**
- Emerging pricing mechanism
- Published each business day based on key markets
- Cargoes lifted FOB
... Enabling LNG export projects in the U.S. to supply both Asia and Europe more competitively than Australian projects.

Australian cost inflation has greatly increased their cost of supply and U.S. projects are able to supply LNG at a lower price.

Delivered Ex-Ship (DES) Cost of Supply to Asia
(U.S. Dollar Per Million Btu)

Australia: $15.62
USGC PC: $8.99

Delivered Ex-Ship (DES) Cost of Supply to Europe
(U.S. Dollar Per Million Btu)

Australia: $16.68
USGC: $7.44

Note: PC stands for shipping via Panama Canal.
U.S. LNG capacity is very competitively positioned on the supply curve relative to other projects.

Capital Cost of LNG Capacity

Supply Cost, $/mtpa

Qatar    U.S.    Mozambique    Yamal    Canada    Australia

0  10  20  30  40  50  60  70  80  90  100
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5. Small-scale LNG is a promising new frontier but challenged by demand and infrastructure.

Key insights from ADI research
Small- and mid-scale LNG scale is defined in this study to include plants from 20 to 3,000 tons per day of capacity.

**Large-Scale LNG**

- Conventional LNG plant is made up of trains...
- ... which can be 3 to 7 million tons per annum in capacity
- Example: RasGas LNG, Qatar

**Small- and Mid-Scale LNG**

- A mini plant’s size is 20 to 100 tons per day
- Small plant is 100 to 500 tons per day in capacity and ...
- ... Mid scale is 500 to 3,000 tons per day
Six segments drive demand for LNG from small- and mid-scale facilities and our study models each of them
Infrastructure is critical to enabling the small-scale LNG market and requires investments across the value chain.

**Supply**
- Small-scale LNG production (< 1 mtpa)
- Large-scale LNG production (2 to 8 mtpa)

**LNG Trade Flow**
- Vessels (LNG Carriers)
- Trains
- Trucks
- Floating Terminal
- Onshore Terminal

**Demand**
- Power (export)
- Trucking
- E&P (Rigs & Frac)
- Marine
- Rail
- Industrial (Mining, off grid)
Key messages

North American gas demand growth is slow driving exports

Environmental pressures are driving LNG demand globally but the market is oversupplied currently

Thanks to shale, North American has plenty of cheap natural gas

Growing competitiveness of renewables and energy storage are key risks to natural gas and LNG

Small-scale LNG is a promising new frontier but challenged by demand and infrastructure

North American LNG projects enjoy many distinctive advantages
If fracking was a black swan …
... So was Fukushima in accelerating demand for gas in Asia
The 70% to 90% decline in solar and wind energy costs were unanticipated and another Black Swan
What will the Black Swans of this decade look like?
Key messages

1. Thanks to shale, North American has plenty of cheap natural gas.

2. North American gas demand growth is slow, driving exports.

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