Ethane Transportation with LNG: An Option for Balancing the Global Supply and Demand of Ethane

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Ethane & Global Changes

Most of the ethane based petrochemical projects in the world are located close to the source of rich natural gas

The changes last decade:

• The rapid growth of North American natural gas production & LNG export.
• Ethane surplus in USA is far beyond the requirements of local petrochemical projects.
• Asian economies exhibit high ethylene demand.

These new conditions have driven the petrochemical industry towards new solutions including:

• A revival of new petrochemical projects for exports in the USA close to the new source of ethane
• International trade of ethane using dedicated ethane liquefaction, shipping and receiving infrastructure.
Shortfall of Ethane in Asia, Europe & S. America and Surplus in USA

REASON:
Steady decline of Ethane in several gas fields resulting in unavailability of Ethane in several geographic areas.

SOLUTION:
Ethane can be transported as part of LNG or separately as pure ethane. Recover Ethane at LNG Import / Regas terminals using TechnipFMC's Ethane Extraction from LNG technology.

MARKET:
- LNG regasification terminals can sell the extracted Ethane to nearby petrochemical plants as feedstock for Ethylene production.
Supply Chain

**ETHANE LIQUEFACTION & TRANSPORTATION**

- **Natural Gas**
- **10-12% Ethane**

**Gas Processing** → **Ethane Liquefaction** → **Liq. Ethane** → **Ethane Shipping** → **Petrochemical Plant**

**Natural Gas** → **Natural Gas** → **NG Liquefaction** → **LNG Shipping** → **LNG Import / Regas Terminal**

**LNG SHIPPING WITH ETHANE**

**Natural Gas** → **10-12% Ethane**

**NG Liquefaction** → **LNG Shipping** → **LNG Import / Regas Terminal** → **Ethane Extraction Plant** → **Petrochemical Plant**

**LNG with ~10-12% Ethane** → **Ethane** → **Sales Gas**
Locations with Advantage

LNG Import / Regas terminals near Ethylene Crackers

Locations with Significant Advantage:
• Ethane crackers with supply constraints
• Naphtha crackers under significant cost constraints
• LNG terminals with sufficient capacity to feed nearby crackers

Locations with Moderate Advantage:
• Naphtha crackers under moderate cost constraints
• LNG terminals with limited capacity to feed nearby crackers
## Locations with Significant & Moderate Advantage

<table>
<thead>
<tr>
<th></th>
<th>Locations with Significant Advantage</th>
<th>Moderate Advantage</th>
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<tbody>
<tr>
<td>Crackers nearby LNG import terminals</td>
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## Location Details

<table>
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<tr>
<th>Continent</th>
<th>Ethane Crackers w/in 50 miles of LNG terminal</th>
<th>LPG Crackers w/in 50 miles of LNG terminal</th>
<th>Naphtha Crackers w/in 50 miles of LNG terminal</th>
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TechnipFMC Steam Cracker Technology

Track Record of Success

- Premier licensor of olefins based technologies
- Over 22 million metric tons per annum of ethylene added to the world market between 2015 and 2023 based on TechnipFMC technologies
- World’s largest cracker in operation based on TechnipFMC Technology
- Largest market share compared to other licensors
Locations: S. America

Brazil

- Ethane, mixed feed and Naphtha crackers
- Looking to convert Naphtha cracker to Ethane cracker

Argentina

- Ethane cracker getting Ethane feed from gas fields 600km away
**Locations : Europe**

**France**
- Flexi crackers using LPG & Naphtha, push to shift to Ethane

**Spain & Portugal**
- Naphtha crackers but high Ethane supply potential from nearby LNG terminals

**Netherlands & Italy**
- Flexi/Naphtha crackers using LPG & Naphtha. Possibility to convert to Ethane
Egypt

- Light feed crackers using domestic supply. C2 supply from LNG will be more economical

Kuwait & UAE

- Ethane crackers facing shortage of cheap natural gas

Israel

- LPG/Naphtha cracker looking to upgrade to Ethane feed

Turkey

- Naphtha crackers with moderate cost constraints
Locations: S. East Asia

- **Singapore**
  - Flexi cracker that can use economically attractive Ethane feed

- **Thailand**
  - Flexi and Ethane crackers facing domestic supply constraints.

- **Philippines**
  - Naphtha crackers with moderate cost constraints
Locations: N. East Asia

- **South Korea**
  - Naphtha crackers facing cost constraints with high Ethane supply potential from LNG terminals.

- **Japan**
  - Lots of Naphtha/LPG cracker facing significant cost constraints. Ethane supply potential from LNG terminals low to high.
India

- Ethane crackers can economically benefit from price advantaged Ethane from LNG
- Naphtha crackers with high Ethane supply potential from nearby LNG terminals

China

- Naphtha crackers facing moderate cost constraints with low-high Ethane supply potential from nearby LNG terminals
- More push towards alternate technologies for Ethylene production (coal, Ethanol etc.)
Liquefy Ethane in the LNG Liquefaction Facility for Separated Transportation Solution

Ethane Extraction - CRYOMAX:

- Suit for deep ethane recovery
- Flexible between C2 and C3 recovery modes
- Well handle of feed composition variation

Ethane Liquefaction:

- Stand alone or,
- Multi-product liquefaction

CRYOMAX® Flex-e
(US Patent no. 7,458,232)
Ethane Extraction Technology

LNG Storage → Pump → LNG Vaporizer → Sales Gas

LNG Loading Arm

C2 Extraction Facility

C2 Storage → Vaporizer → C2 To Customer

C3+ Storage → C3+ To Customer

Pumps at various points in the process.
Ethane Recovery from LNG

In LNG Re-gas Terminal

TechnipFMC Ethane+ Recovery from LNG

(US Patent 7,530,236 B2)

Lean LNG

Rich LNG

Flash

Absorber

Demethanizer

Ethane+ Product
Advantages of Dual-column Process

TechnipFMC patented dual-column process will have following advantages compared with all the conventional one-column processes for ethane recovery at LNG receiving terminals.

1. The two columns (absorber and demethanizer) will be operated at different pressures and far away from the critical points, that improves both design reliability and operation flexibilities.
2. The two columns can be stacked into one tower vessel, with no extra plot space required for the second column.
3. The overall dimensions of the stacked dual column (two towers together) can be 20-30% smaller than one conventional demethanizer tower.
4. The dual-column process can be better optimized than conventional one-column processes and reduce the total energy consumption.
Impact on LNG Value Chain for Synergized Solution

Impact on NGL Extraction/Fractionation Unit Design
  • Simplified NGL extraction process – no ‘deep cut’ recovery

Impact on Liquefaction Unit Design
  • Relatively easier to liquefy ‘rich’ gas
  • Lower specific power on total product basis

Impact on Storage and Shipping Tanks
  • Store and ship different density LNG separately to prevent ‘roll over’
  • Avoid stratification by good mixing and proper filling

Impact on Receiving Terminal
  • Ethane extraction unit required
  • Integrate with LNG regas unit to reduce overall cost
Impact on Existing LNG Plant when Modified for Synergized Transportation of Ethane

Impact to NGL Extraction/Fractionation Unit

- By adjusting operating conditions CRYOMAX (or equivalent) process can potentially handle higher ethane content feed gas (than designed for) to a certain degree
- In some cases may require revamp

Impact to liquefaction Unit

- With same refrigeration power, more total production (LNG + Ethane) is expected due to lower specific power
- ‘Net’ LNG production reduction is less than additional ethane production on mass basis
Conclusions and the Cost-effective Approach

- Co-Transportation of Ethane with LNG is a cost effective solution requiring significantly shorter schedule.

- It is of interest under certain favorable conditions – long term contract; good links between the natural gas importer and the petrochemical producer and year round send out rates of regasified methane.

- Long term solution could still be a dedicated & separate ethane liquefaction, storage and solution.
Process Control Hierarchy, MR Loop Schematic
RTPO Workflow, Implementation

- Use historical data to analyse performance, develop empirical models.
- Translate Data Analytics models, insights to improved APC strategy, model setup.
- RTPO: Real Time Production Optimisation
Data Analytics/Machine Learning Techniques

Machine Learning Algorithms Cheat Sheet

Unsupervised Learning: Clustering
- k-means
- k-modes
- Prefer Probability
- Categorical Variables
- Need to Specify k
- Hierarchical
- Gaussian Mixture Model
- DBSCAN

Supervised Learning: Classification
- Linear SVM
- Naive Bayes
- Data Is Too Large
- Explainable
- Speed or Accuracy
- Predicting Numeric
- Naive Bayes
- Decision Tree
- Logistic Regression
- Kernel SVM
- Random Forest
- Neural Network
- Gradient Boosting Tree
- Random Forest
- Neural Network
- Decision Tree

Unsupervised Learning: Dimension Reduction
- Dimension Reduction
- Topic Modeling
- Probabilistic
- Latent Dirichlet Analysis
- Principal Component Analysis
- Singular Value Decomposition

START

Have Responses

Unsupervised Learning: Dimension Reduction
- YES

Unsupervised Learning: Clustering
- NO

Supervised Learning: Classification
- YES

Supervised Learning: Regression
- NO
Data Analysis

MVs (Manipulated Variables)

- F-LMR, F-HMR (flowrates)
- C-N2, C-C1, C-C2, C-C3 (MR comp.)
- T-R (Rundown T)
- V-K (MR compressor IGV pos.)

Additional variables

- T-WB: NG WB temp.
Derived Empirical Models

- Significance analysis, p-tests to identify MV’s
- Modified Least square regression for cross-validation

**LNG throughput**

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Root Mean Squared Error: 103
R-squared: 0.921, Adjusted R-Squared 0.921
F-statistic vs. constant model: 1.1e+04, p-value = 0

**ΔP MCHE**

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Root Mean Squared Error: 7.4
R-squared: 0.85, Adjusted R-Squared 0.85
F-statistic vs. constant model: 4.45e+04 p-value = 0
Maximize LNG production: Utilize MR power

- Utilize all MR power, tune MV’s to stay within plant constraints
Controller Performance: New vs Old

- Mean production shifted to right
- Better control of constraints: MCHE $\Delta P$, T-WB, T-MR
- Additional 1-2 % extra LNG produced.
Conclusions

• Data Analytics successfully applied to develop MR loop models.
• RTPO deployed on LNG train to achieve additional 1-2 % LNG production. Replication to other trains in progress.
• Multidisciplinary technology development: DataScience, Process technology, Process control.
• R&D plans to begin development of an LNG train-wide RTPO.
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