U.S. Department
of Transportation

**Pipeline and
Hazardous Materials
Safety Administration**

Safe Transport of Energy Products Session

Risk Assessment of Surface Transport of Liquid Natural Gas

presented to

PHMSA Office of Hazardous Materials Safety

Research and Development Forum May 16, 2018

presented by

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Presentation Outline

- Introduction
- Natural Gas Background
- LNG Outlook and Emerging Markets
- Supply Chain Analysis
- Quantitative Risk Assessment
- Rail LNG Risk Assessment
- Emergency Response
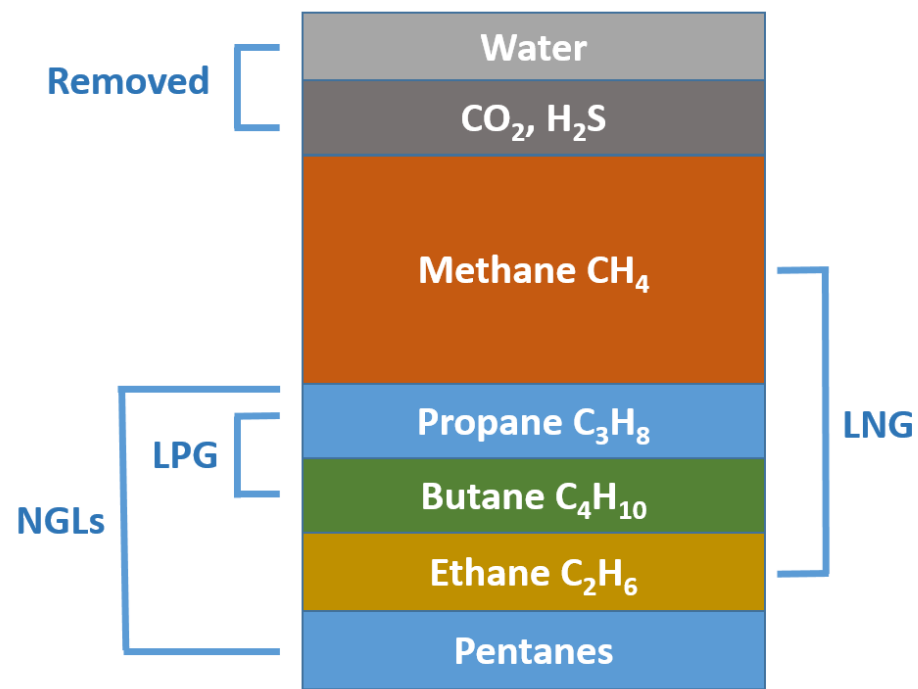- Truck LNG and LPG Risk Factors
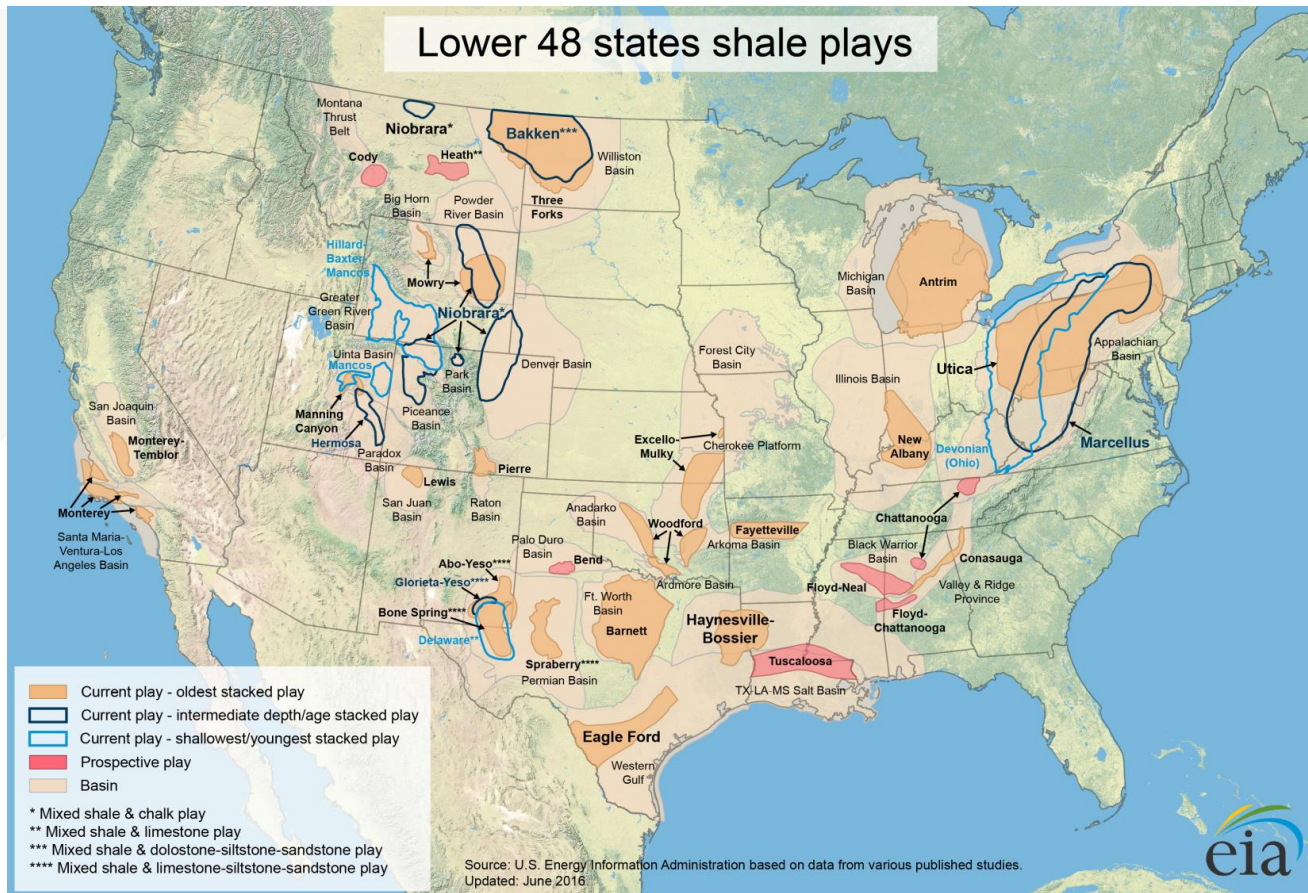- Findings

DistriGas, Everett, MA

Study Purpose

➤ The purpose of the study was to assess the risks of transporting Liquid Natural Gas (LNG) by surface modes with an emphasis on rail. Study products included a Literature Review, Comprehensive Risk Plan, Factors and Parameters required for the LNG Risk Model, and a Final Report.

Natural Gas Properties

Removed

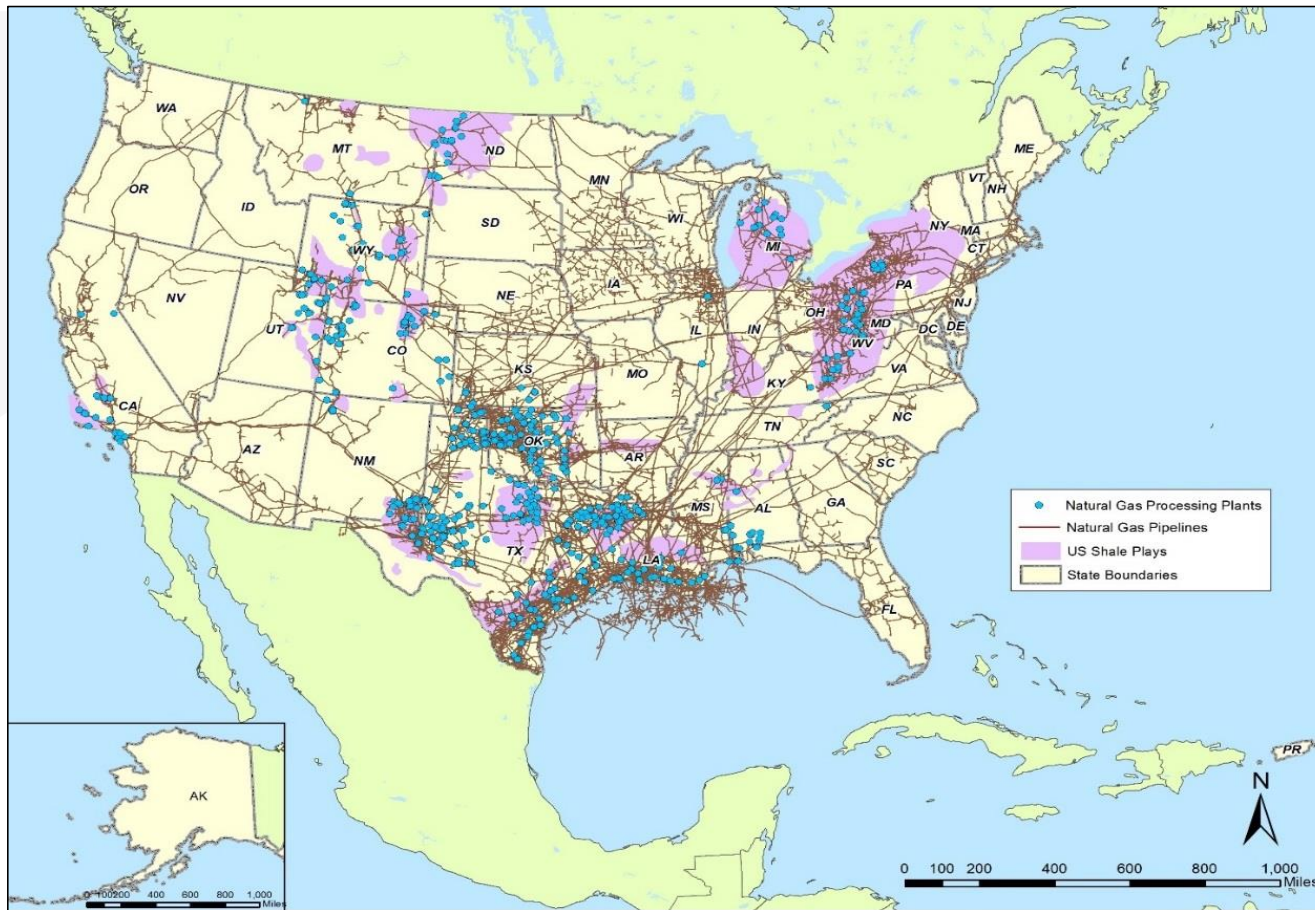| Water |
| --- |
| CO_2, H_2S |
| Methane CH_4 |
| Propane C_3H_8 |
| Butane C_4H_{10} |
| Ethane C_2H_6 |
| Pentanes |

LPG

NGLs

LNG
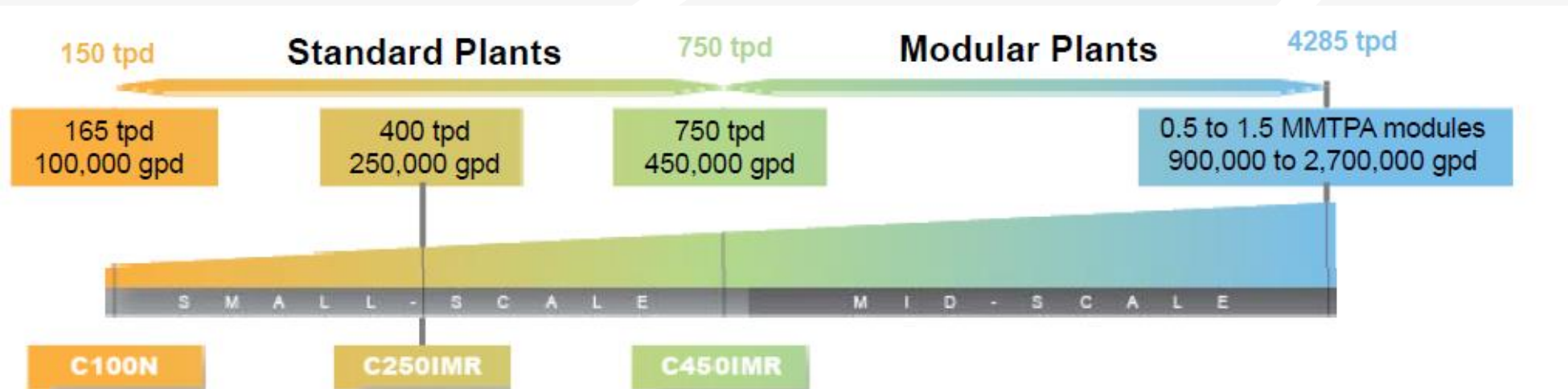
U.S. Shale Gas and Oil Plays

Source: EIA, 2016

Natural Gas Processing Regions & Pipeline Network

Sources: EIA,
Cambridge
Systematics

Liquefaction Facility Capacities

Source: Chart Industries.

New Fortress Energy LNG
Liquefaction Plant, Hialeah, FL

Cheniere LNG
Liquefaction Plant,
Sabine Pass, LA

Sources: Cheniere Energy, New Fortress Energy

LNG Exports and Imports (millions of tons per annum) 2017

Top 5 Countries Exporting LNG	Volume (MTPA)
Qatar	77.2
Australia	44.3
Malaysia	25.0
Nigeria	18.6
Indonesia	16.6

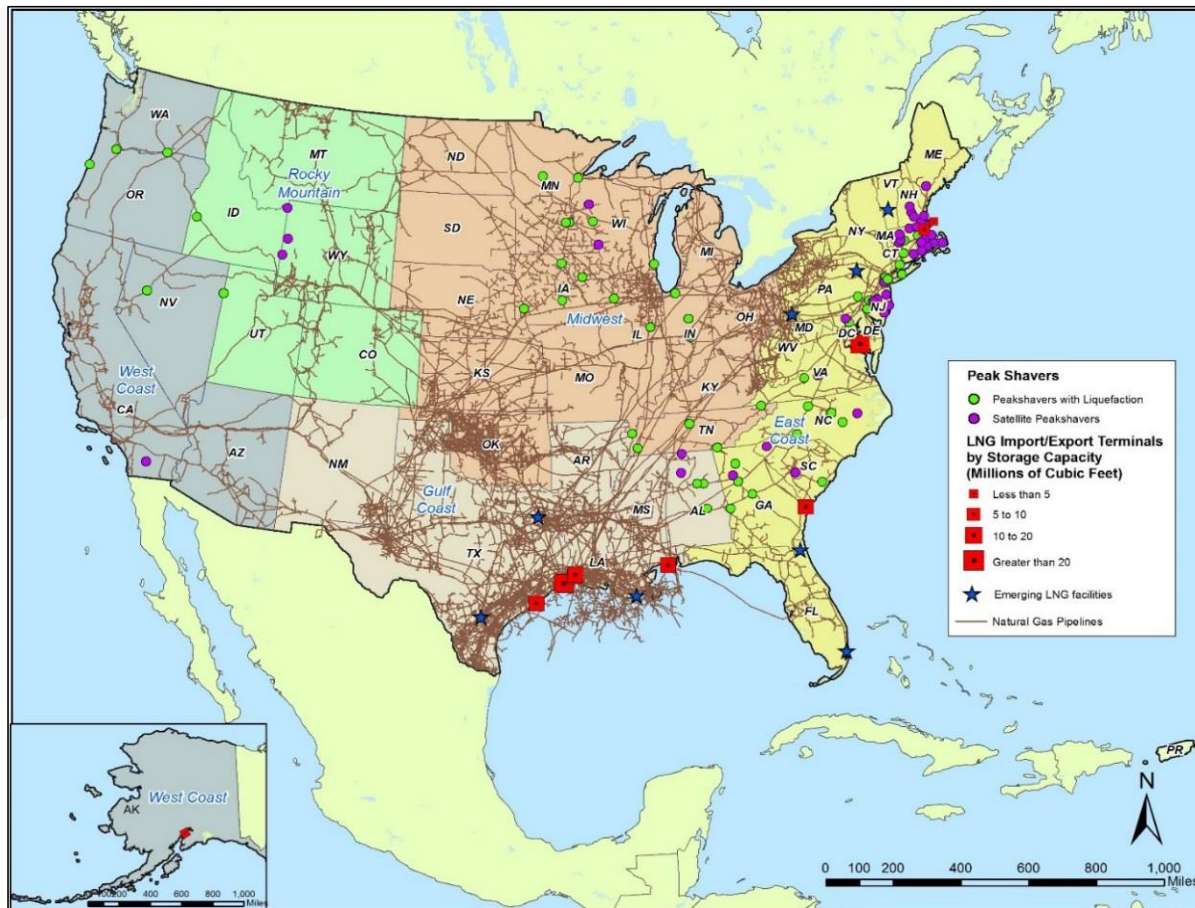| Top 5 Countries Importing LNG	Volume (MTPA)
Japan	83.3
South Korea	33.7
China	26.8
India	19.2
Taiwan	15.0

Source: International Gas Union World LNG Report, 2017 Edition

Emerging Markets: Mining, Maritime, Rail Fuel, Cargo

Sources: Chart Industries, FECR, Tote Marine, CN Railroad

U.S. LNG Facilities

Sources: PHMSA Annual Report 2016, FERC, EIA, Cambridge Systematics

LNG Economics

Supply-Side Factors	Demand-Side Factors
Production amounts	Seasonal variations
Storage levels	Economic growth
Import-Export Volumes	Competing fuel prices
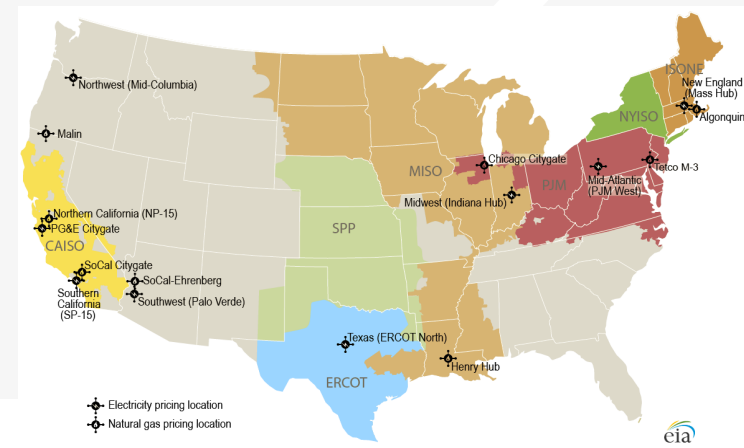
Sources: EIA, Cambridge Systematics

LNG Cryogenic Containers

Rail Tank Car
DOT 113

Cargo Tank Trailer
MC-338

Portable Container
ISO T-75

Source: Chart Industries

U.S. LNG Interstate Movements
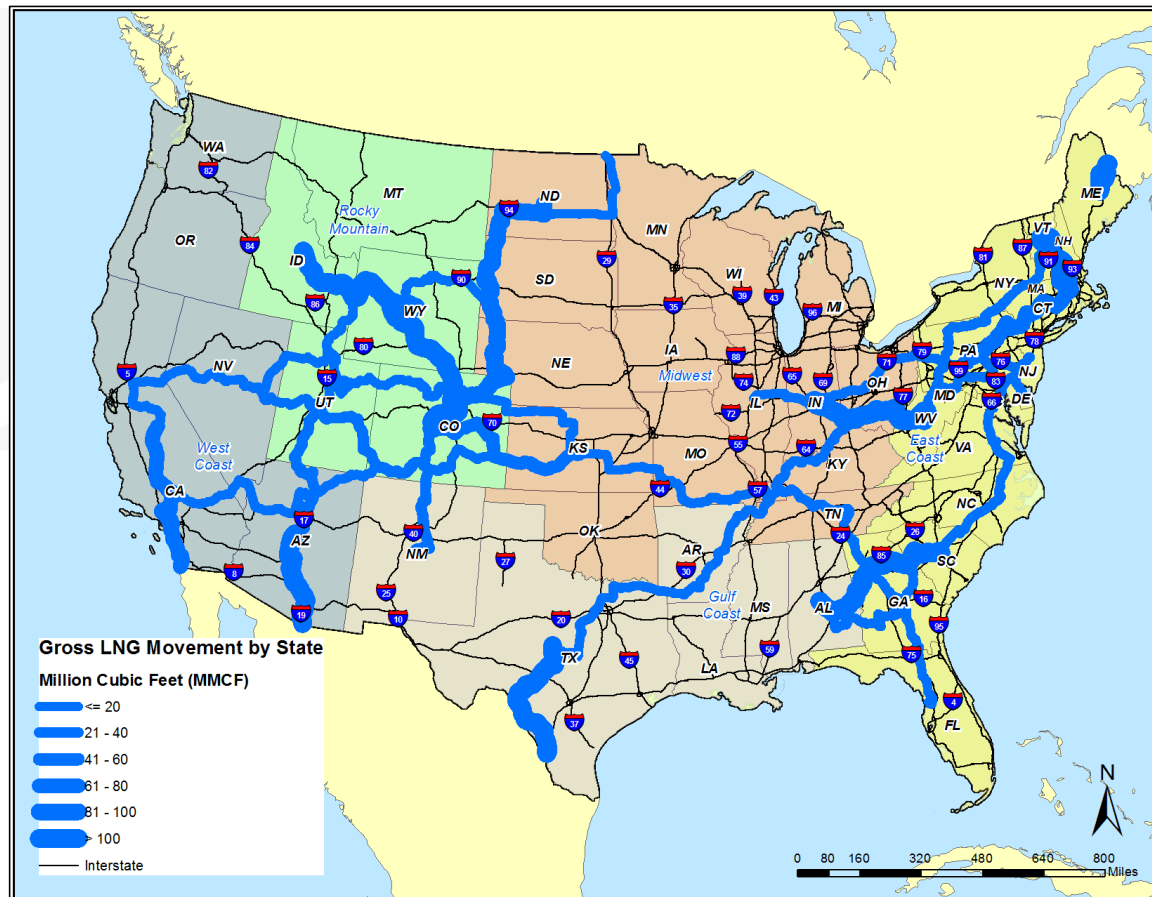
Sources: EIA 2016
Annual Report,
Cambridge Systematics

LNG Transportation Case Study PA to MA

➤ **Rail**: 507 miles

➤ **Truck** 353 miles

➤ 72,041 MCF gas

➤ **80 Trucks**
   12,700 gals (10,943)

➤ **91 ISO Tanks**
   12,200 gals (9,571)

➤ **28 Rail Cars**
   34,500 gals (30,680)

Sources: Cambridge
Systematics, NS

LNG Movement from Harrisburg, PA to Worcester, MA
- Intermodal
- Rail
- Highway
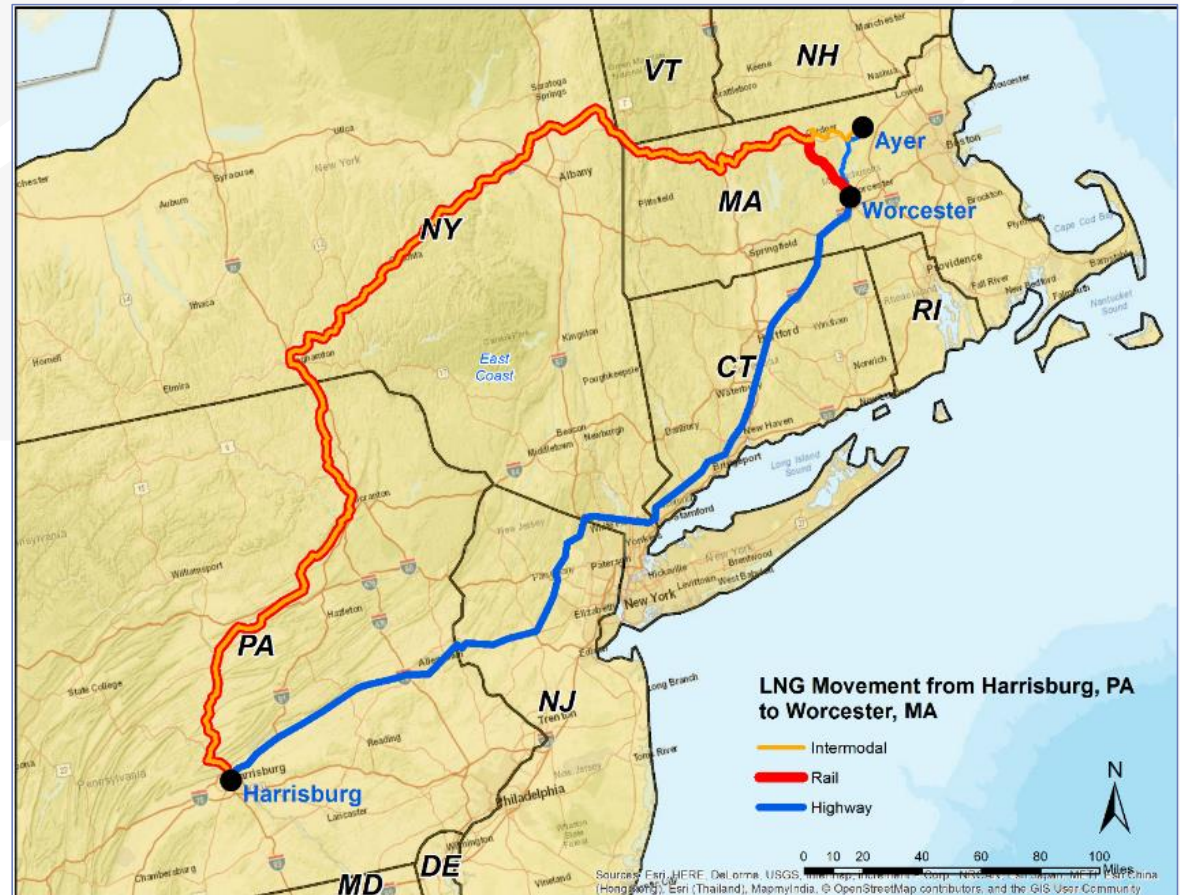
Quantitative Risk Assessment (QRA)

➤ QRA is used to evaluate risk and provide information needed to make decisions about risk exposure

➤ History shows considerable variation in the outcomes of the QRA studies (industry, government)

➤ There are various ways to do a QRA

NFPA Individual and Societal Risk, NFPA 59A

- **Individual Risk:** the frequency at which an individual may be expected to sustain a serious or fatal injury.

- **Societal Risk**: the cumulative risk exposure by all persons sustaining serious or fatal injury from an event in the LNG plant.

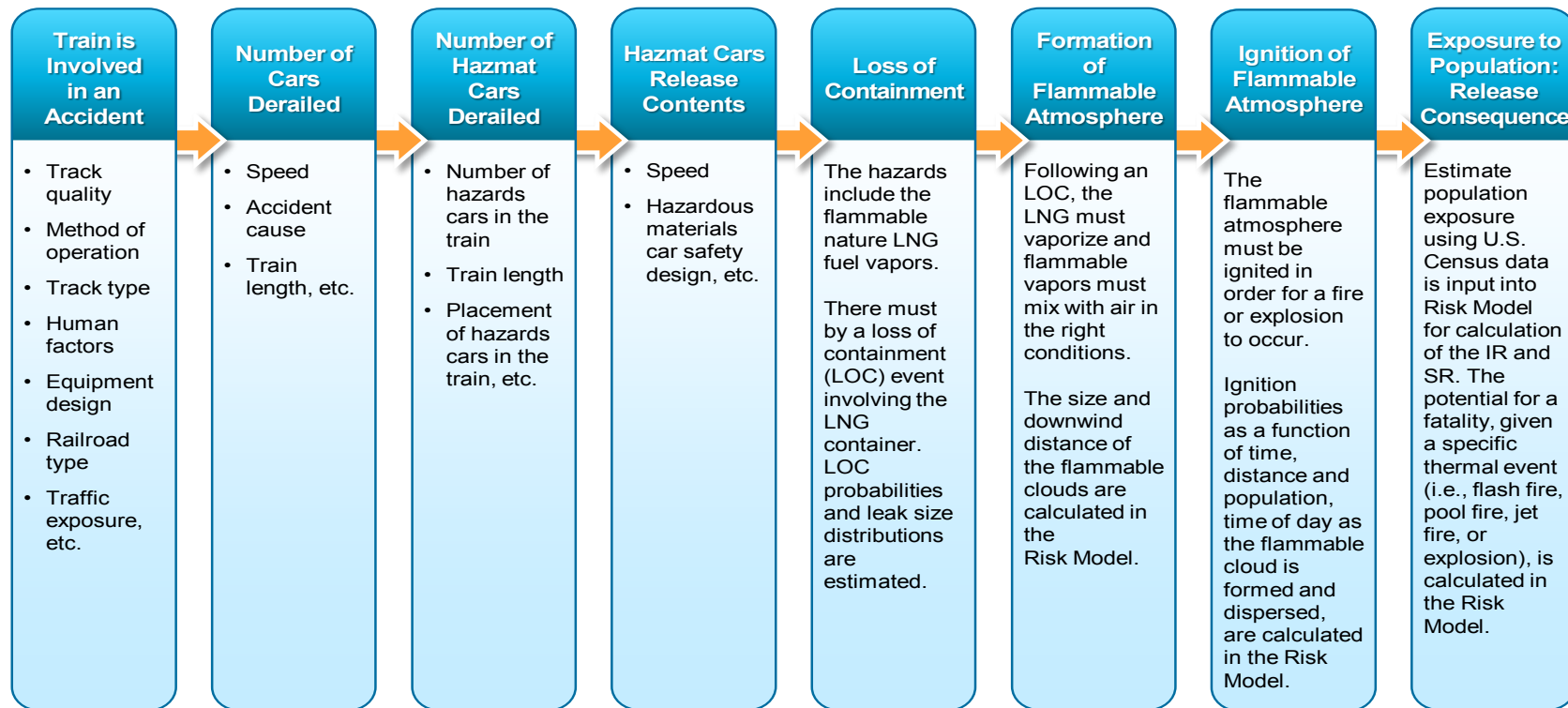Source: NFPA Standard for the Production, Storage, and Handling of LNG, 2016.

Event Chain Diagram for Rail LNG

Train is Involved in an Accident	Number of Cars Derailed	Number of Hazmat Cars Derailed	Hazmat Cars Release Contents	Loss of Containment	Formation of Flammable Atmosphere	Ignition of Flammable Atmosphere	Exposure to Population: Release Consequence
• Track quality • Method of operation • Track type • Human factors • Equipment design • Railroad type • Traffic exposure, etc.	• Speed • Accident cause • Train length, etc.	• Number of hazards cars in the train • Train length • Placement of hazards cars in the train, etc.	• Speed • Hazardous materials car safety design, etc.	The hazards include the flammable nature LNG fuel vapors. There must by a loss of containment (LOC) event involving the LNG container. LOC probabilities and leak size distributions are estimated.	Following an LOC, the LNG must vaporize and flammable vapors must mix with air in the right conditions. The size and downwind distance of the flammable clouds are calculated in the Risk Model.	The flammable atmosphere must be ignited in order for a fire or explosion to occur. Ignition probabilities as a function of time, distance and population, time of day as the flammable cloud is formed and dispersed, are calculated in the Risk Model.	Estimate population exposure using U.S. Census data is input into Risk Model for calculation of the IR and SR. The potential for a fatality, given a specific thermal event (i.e., flash fire, pool fire, jet fire, or explosion), is calculated in the Risk Model.

Sources: Arthur D. Little, Xiang Liu, Exponent, Cambridge Systematics

Factors and Parameters: (partial) Rail Inputs Example
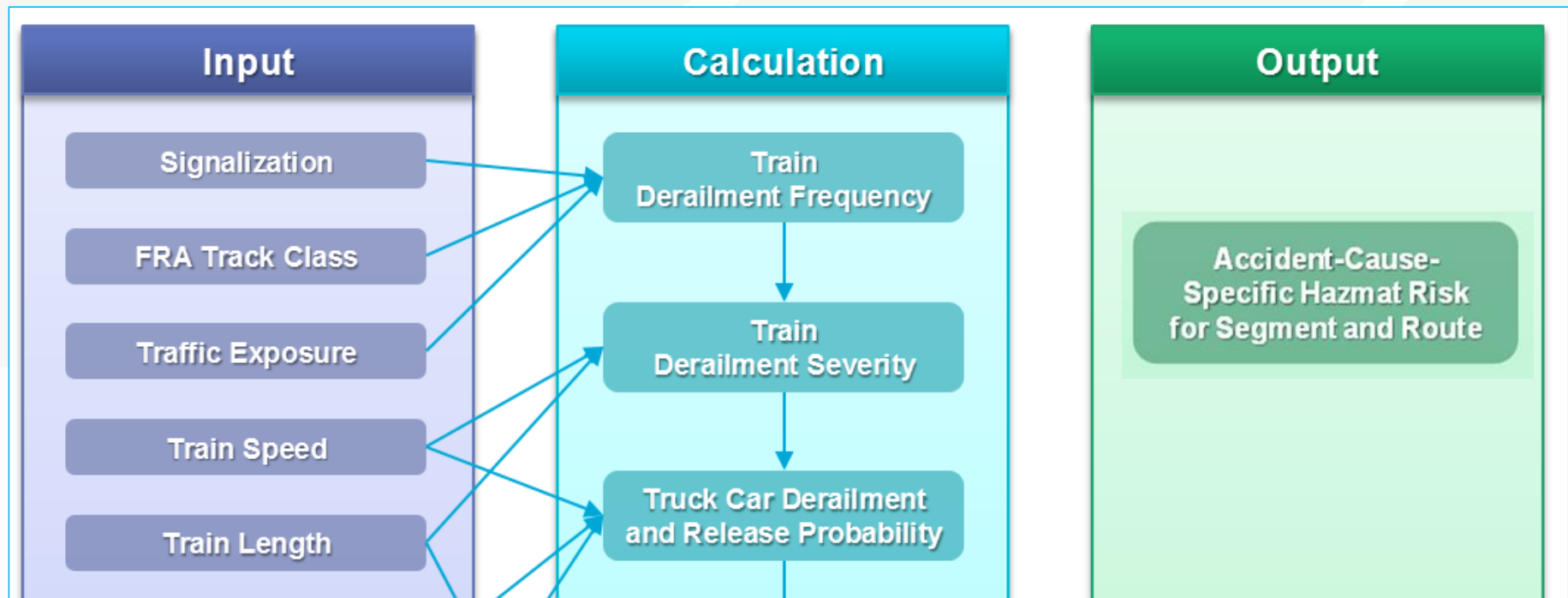
Source: Xiang Liu

LNG Emergency Response

- LNG – the next priority
- High hazard flammable trains (HHFT)
- NGLs associated with liquefaction facilities
- Alaska and Florida LNG Training completed

- ❖ Cannot cap off a leak or interact with container
- ❖ Immediate Evacuation of area and securing of facilities
- ❖ Cannot put water on a cryogenic release
- ❖ LNG must gas off naturally, and ignition sources eliminated

Comparing Truck and Rail Risk Factors

- Trucks transporting LNG have historically very low crash rates

- Truck risk factors include driver behavior, traffic congestion, truck speed, and truck volume

- Rail risk factors include FRA track class, method of operation and traffic density

Photo: Chart Industries

Findings

- Natural gas is capturing a larger share of the energy market

- LNG complements the distribution of natural gas by pipeline, particularly in remote locations

- Demand exists for shipping LNG by rail, which can be both competitive and complementary to the truck and pipeline networks

- LNG Exports will increase through 2022 as import facilities are converted to export facilities

- Emerging LNG markets include maritime, rail and truck fuel operations

Findings

➤ LNG transportation has a good safety record, with minimal maritime, facility, and motor carrier incidents relative to other flammable liquids

➤ Developing a QRA with risk factors and parameters will help to evaluate the derailment and release probability of LNG rail cars

➤ When the probability of LNG tank car derailment is understood, better decisions can be made regarding the crashworthiness, placement, and operation of rail cars

➤ Further study for modeling the probability and consequences of transporting LNG by rail and truck will be beneficial to understanding risks to the public

CAMBRIDGE SYSTEMATICS

Questions, Discussion

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