Properties of LNG

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LNG Workshop

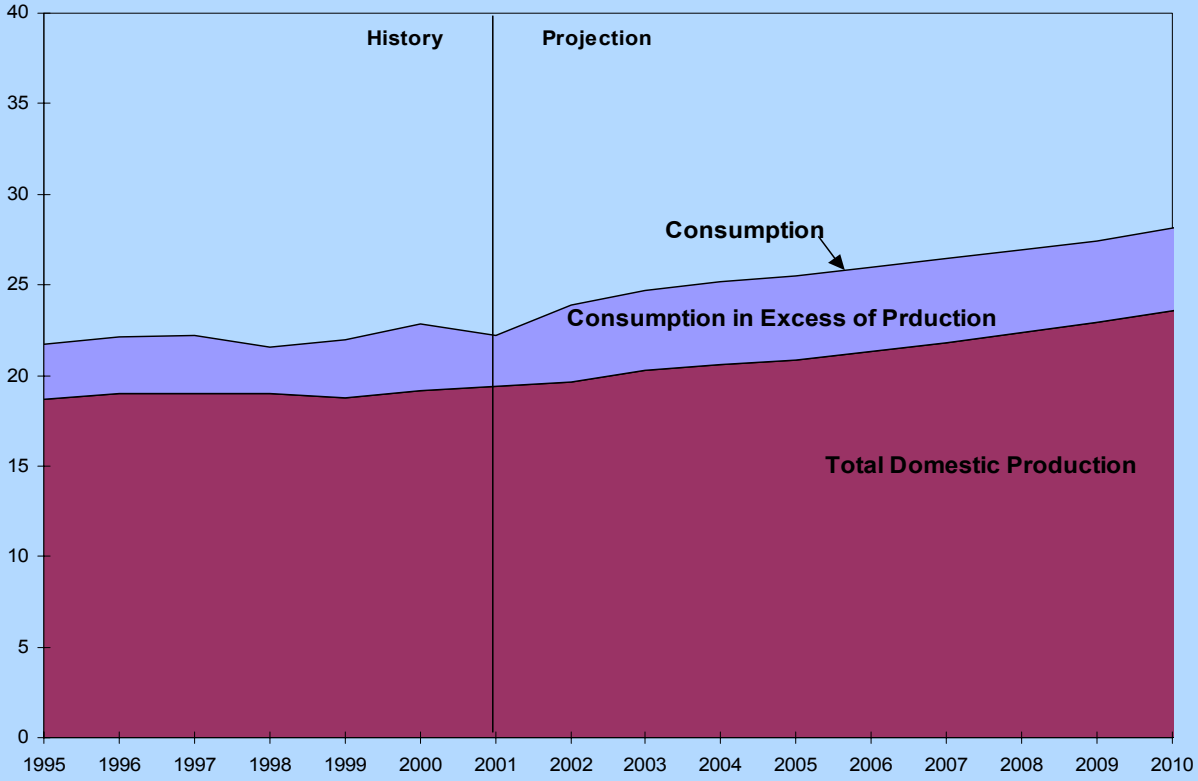
Solomons, MD

Background – LNG in the US

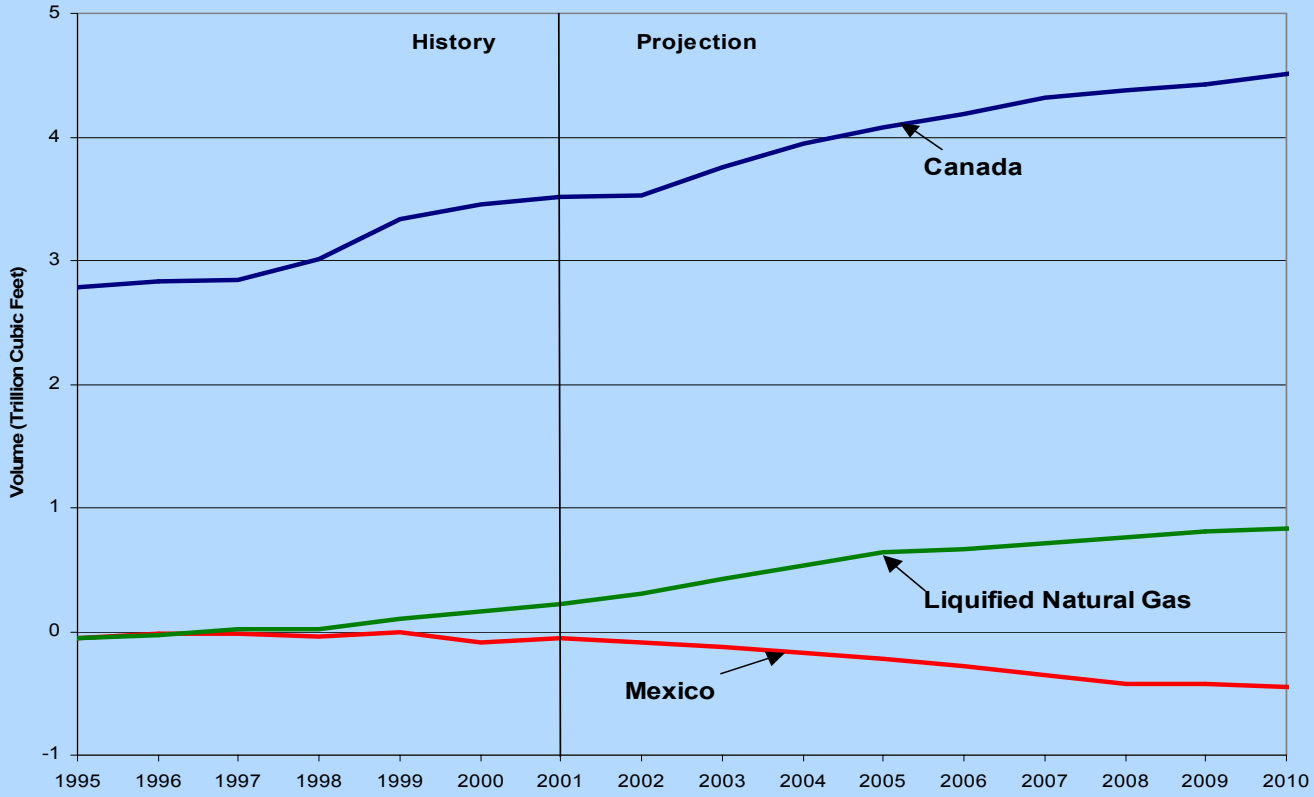
- US Natural Gas imports and Exports
- Projections of Market Growth
- LNG's Role in the US Market

- Focus on LNG marine transport issues
- FERC, DOE - Security and Operations, DOC – NOAA, USCG

Imports Will be an Important Source of Supplies to Satisfy Growing Demand

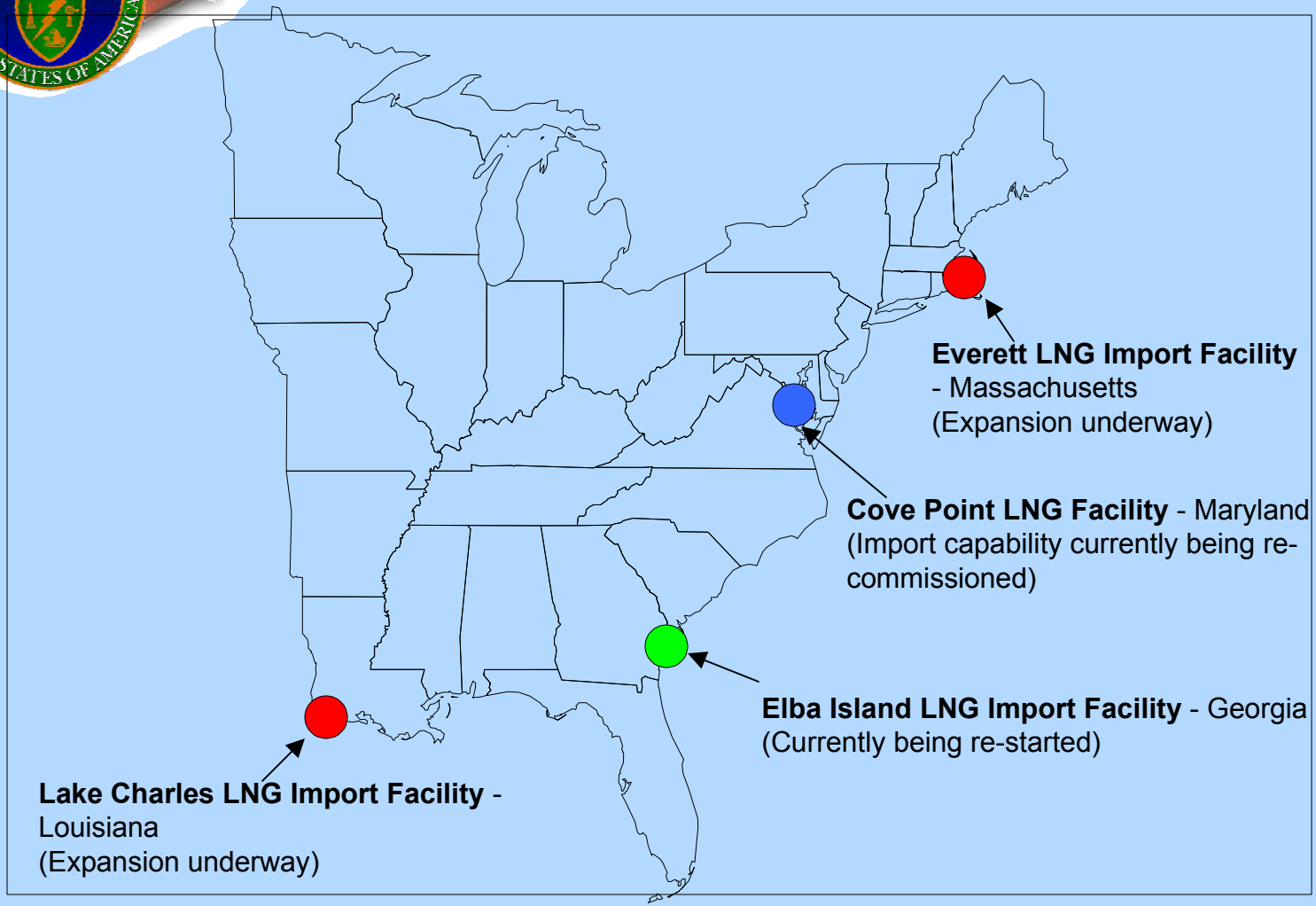


Gas Imports From Canada and LNG Imports Are Projected to Grow As Sources of Supply



U.S. LNG Import Facilities

U.S. Department of Energy



U.S. LNG Import Facilities

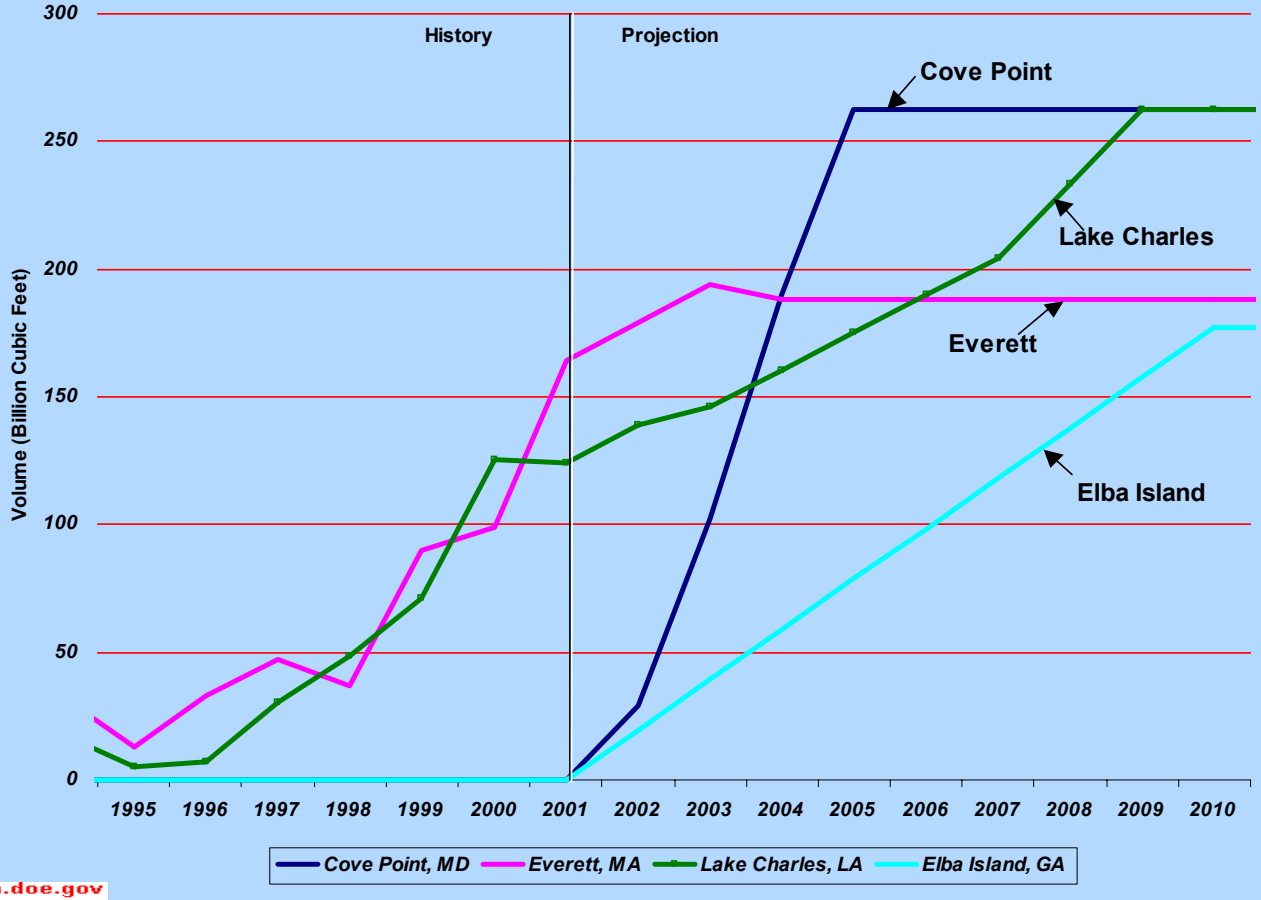
Current Capacity

Location	Status	Sendout (MMcf/Day)	Storage (Bcf)	Possible Capacity Expansion
Everett, MA	Active	450 100 by truck	3.5	165 MMcf/d– sendout
Lake Charles, LA	Active	700	6.3	300 MMcf/d– sendout
Elba Island, GA	Restarting operations	440	4.1	360 MMcf/d– sendout
Cove Point, MD	• Active for Storage • Planned opening for imports 2002	1,000 (nameplate)[1]	5.0	2.8 Bcf – storage

Note: Except where noted, sendout capacity is LNG vaporization which is then shipped via pipeline

[1] This is Cove Point's nameplate capacity. Capacity for reopening has not yet been determined.

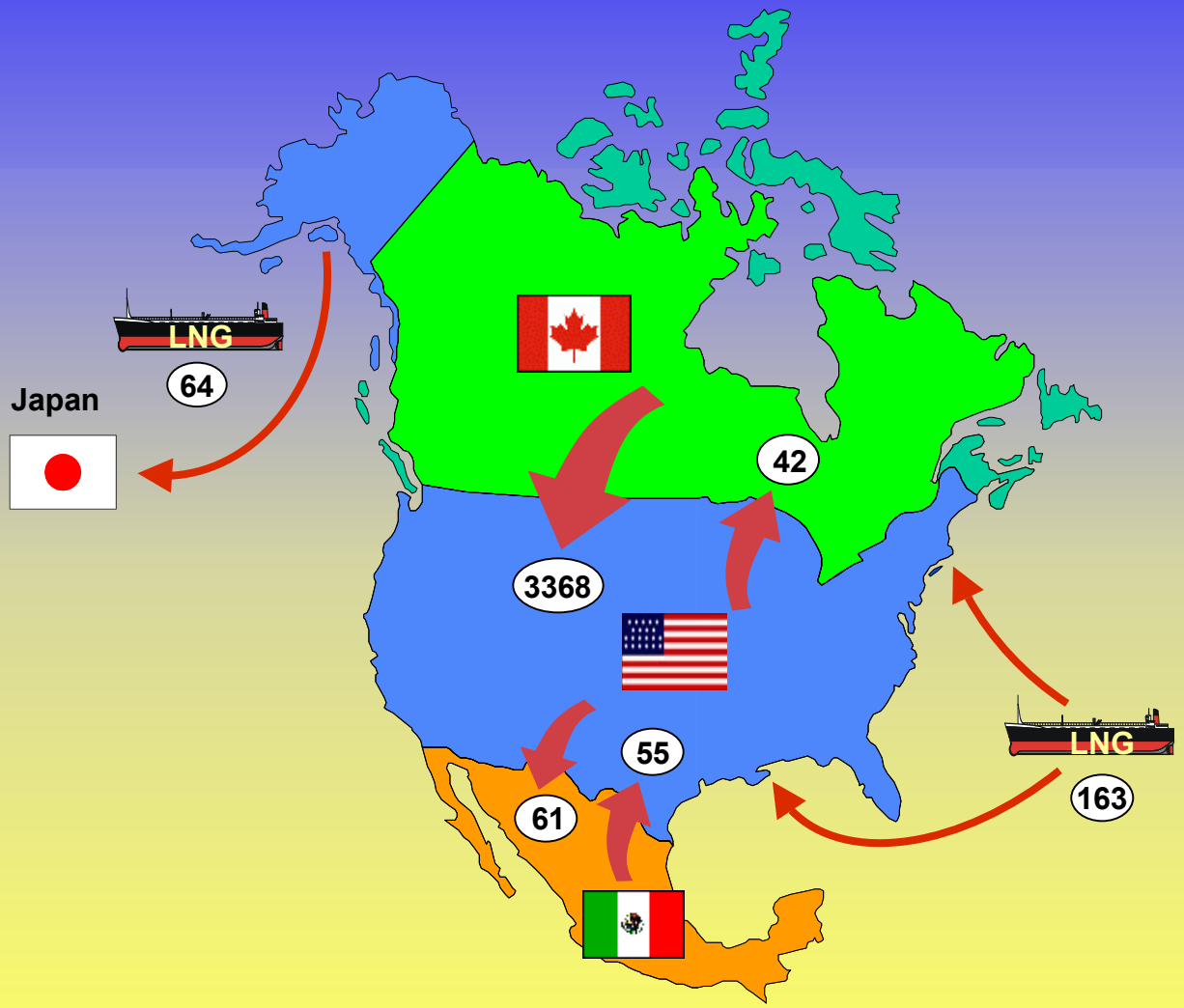
LNG Imports Projections by Receiving Facility



LNG Imports are a Key Element of U.S. Supplies

- LNG Imports have grown by more than 2 and one-half times between 1998 and 2000, from 85 Bcf to 224 Bcf
- LNG imports are expected to grow from 1.3 percent of U.S. consumption to more than 3 percent by 2008
- LNG imports can be quite significant on a regional basis
- New greenfield projects often meet local resistance

Natural Gas Imports & Exports, 1999 (BCF)



Algeria
76

Australia
12

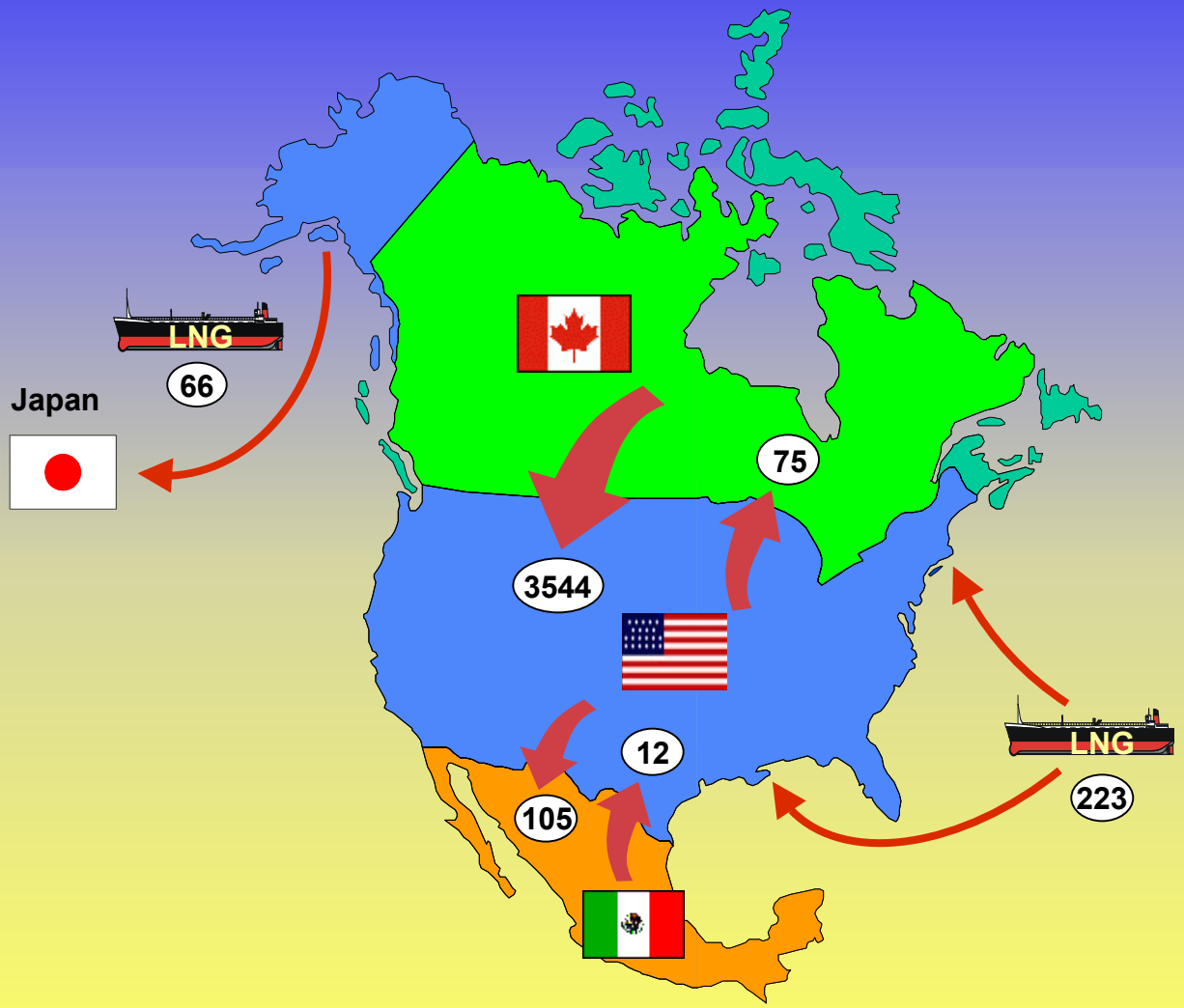
Malaysia
3

Qatar
20

Trinidad and Tobago
51

United Arab Emirates
3

Natural Gas Imports & Exports, 2000



Algeria
44

Australia
6

Indonesia
3

Nigeria
13

Oman
10

Qatar
46

Trinidad and Tobago
99

United Arab Emirates
3

LNG and Natural Gas

- Physical properties and behavior
- Myth and Legend
- Knowledge and Common Sense
- Hazards -

LNG Properties

- **Liquefied Natural gas is a Cryogenic Liquid**
  - LNG Density - 26.5 LB./Cu. Ft.
    - Lighter than water (65 LB/Cu. Ft.)
  - LNG Boiling point - (-259^{o} F)
    - Liquid Nitrogen - (-320^{o} F)
    - Liquid Oxygen - (-297^{o} F)

Natural Gas Properties

- **Natural gas is lighter than air**
  - Natural Gas Density - 0.47
    - (Air - 1.0)
- Natural gas rises under normal atmospheric conditions

Myth and Legend

- "Catastrophic release of LNG creates a BLEVE -- boiling liquid expanding vapor explosion"

NOT TRUE

  - In laboratory and open ocean combustion tests, there have been ***no*** documented cases of LNG BLEVEs

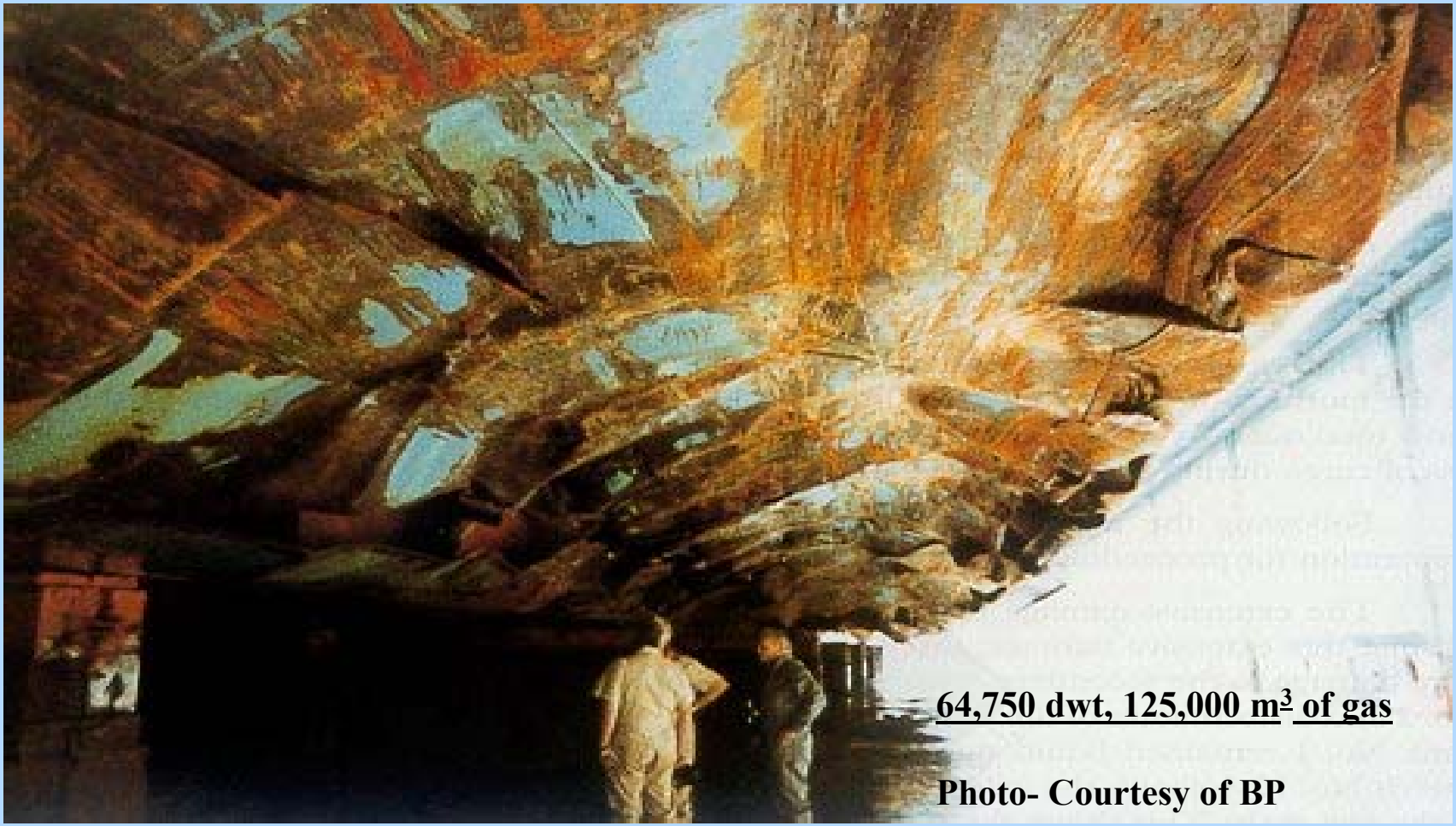
Myth and Legend

- "An LNG Tanker is a floating Bomb"

NOT TRUE

- **Liquefied Natural Gas tankers have been run aground, experienced loss of containment, suffered weather damage, been subjected to low temperature embrittlement from cargo spillage, suffered engine room fires, and been involved in serious collisions with other vessels - NO CARGO EXPLOSIONS REPORTED**

El Paso Paul Kayser – In Dry Dock after grounding in Straits of Gibraltar



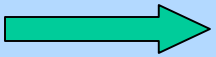
64,750 dwt, 125,000 m^3 of gas

Photo- Courtesy of BP

Common Sense and Knowledge

- Natural gas needs to be in vapor form and mixed with air to burn
- Natural gas is combustible in the range of 5% to 15% volume concentrations in air
- Combustible mixtures in confined space will burn explosively
  - **LNG does not explode or burn**

Common Sense and Knowledge

- LNG is a cryogenic liquid – physical contact or spillage constitute a personnel and equipment hazard
- LNG  Natural Gas
- Natural Gas presents an asphyxiation hazard

LNG Tanker Underway

Photo Courtesy of BP

What happens with a spill on water?

- LNG pool vaporizes rapidly (faster than an equal sized pool on land)
- LNG spill on or within hull can cause brittle fracture (carbon & low alloy steel)
- LNG can undergo “rapid phase transition”, a ***physical*** vapor explosion (not combustion)
- LNG pool formation accompanied by ignition
- Natural gas cloud formation with subsequent burn back

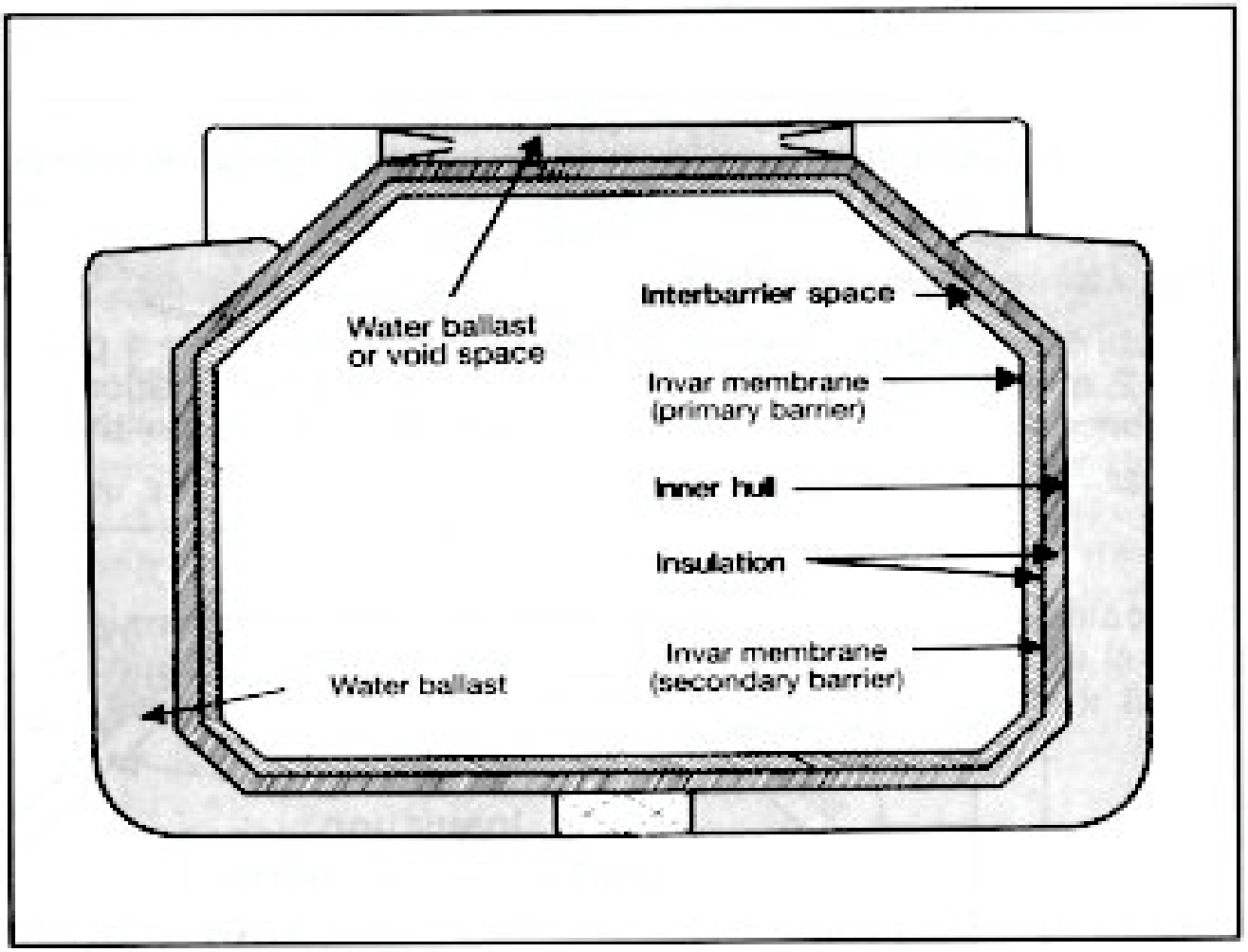
Assessing The Hazard
30 Years of LNG Experience

- LNG history in the US dates back to 1940's
- LNG tanker trade initiated with exports in 1969
- Eight marine incidents have resulted in spillage of LNG - some hull damage due to cold fracture and no cargo fires
- Seven incidents not involving spillage - two from grounding - no significant cargo loss
- LNG carriers are inherently much more robust than typical crude, fuel, and chemical tankers

LNG Tanker at Loading Berth, Kenai, Alaska

Photo: Courtesy of Phillips Petroleum

Cross Section of LNG Tanker



Cutaway Model of LNG Tanker

Assessing The Hazard

- LNG vaporizes and causes condensation of atmospheric moisture – visible cloud
- As LNG vapor cloud warms it lifts
- Water is a superior heat source compared to soil/solids
- Spills on water tend to vaporize rapidly creating a potentially combustible plume that migrates until a) the LNG source is exhausted, and b)dilution by air reduces the concentration below the lower flammability limit (LFL)

Assessing The Hazard

- An ignition source close to the origin of the spill is likely to cause ignition and result in rapid burn off of natural gas vapors
- Absence of an ignition source would result in a plume that could migrate downwind for a considerable distance.
- A remote (downwind) ignition of a plume in the flammable portion of the vapor cloud would result in relatively slow (subsonic) burn back to the spill pool

Assessing The Hazard

- The opinion of experts indicate that a catastrophic failure caused by collision or terrorist act would result in numerous ignition sources close to the vessel and ignition and burn down would occur

Jettisoning Test – Trial to test Equipment

Photo: Courtesy of BP

What Has Changed Since Sept. 11, 2001?

- Everyone is looking at their environment differently
- Potential threat to infrastructure has increased - Responsible parties are reacting
- Assumptions about what constitutes threats are being reassessed

Assessing the risk

- Models
- Analogs
- Other related hydrocarbons/chemicals

Assessing the risk

- Following suspension of LNG tanker dockings at the Distrigas (Tractebel) facility in Boston Harbor DOE, working with FERC, DOT (OPS), local and state public safety officials, commissioned a series of model runs intended to mimic a serious and catastrophic breaching of a single tank of an LNG carrier.

Assessing the risk

Modeling Catastrophic Failure

- One meter (3.3ft.) and five meter (16.4 ft.) hole in one tank of tanker
- Rapid (but not instantaneous) loss of cargo onto water
- Variable atmospheric conditions
- Dispersion, Fire Radiation and Burn Times

Dispersion Model Results

QUEST Consultants

Release From Tanker

Hole Size	Atmospheric Conditions	Pasquill-Gifford* Atmospheric stability	Liquid Impoundment	Distance to Lower Flammability Limit (LFL)
5 meters	1.5m/s	F	No	2.5 miles
5 meters	5 m/s	D	No	0.6 miles
1 meter	1.5m/s	F	No	2.3 miles
1 meter	5 m/s	D	No	0.5 miles

* **Stability D** is characterized by fully overcast or partial cloud cover during both daytime and nighttime. The atmospheric turbulence is not as great during D conditions as during A conditions; thus, the gas will not mix as quickly with the surrounding atmosphere.

Stability F corresponds to the most "stable" atmospheric conditions. Stability F generally occurs during the early morning hours before sunrise (thus, no solar radiation) and under low winds. The combination of low winds and lack of solar heating allows for an atmosphere which appears calm or still and thus restricts the ability to actively mix with the released gas.]

Pool Fire Results

QUEST Consultants

Release from 25000m^3 Tank

Hole Size	Atmospheric Conditions	Liquid Impoundment	Distance to 7000 Btu/hr-ft^3	Distance to 4000 Btu/hr-ft^3	RFL (ft) * to 1500 Btu/hr-ft^3
5 meter	9m/s	No	1020	1260	1770
1 meter	9m/s	No	835	1020	1420

* **Radiant Flux Levels** - measured from center of pool

Estimated Burn Times

QUEST Consultants

Spill Description	Inventory Spilled (cubic meters)	Time to Burn Out (minutes)
5 m. hole in ship	25,000.	37.
1 m. hole in ship	25,000.	64.

Summary of Conclusions from the Lloyd's Report

Report draws from many sources, historical, experimental, and modeling

- Historically for all types of LNG - no loss of life - land based property damage - environmental damage
- LNG carriers inherent strength has prevented loss of containment
- A missile hit or explosion will provide a large number of ignition sources
- If containment loss should occur under specific conditions
  - Holing may not be visible

Summary of Conclusions from the Lloyd's Report

- There is potential for escalating failure due to embrittlement - with subsequent explosion/fire
- Ignition and sustained burn of a vaporized LNG cloud is difficult - multiple ignition sources would probably result in a burn back to the source
- Unconfined LNG vapor cloud detonation has not been demonstrated and unlikely
- External ignition (of vapor cloud) results in slow moving flame
- Rapid Phase Transition will not cause ignition but potentially damaging for ship/equipment

Summary of Conclusions from the Lloyd's Report

In terms of pool spread

- The LFL for methane/air mixtures is ~5% so the LFL boundary is well within the visible cloud
- Modeling of dispersion cloud 3-6 km. Dispersion on that scale unlikely because of local ignition sources
- Exposure at 300 meters (1000ft) from a pool fire would cause pain within 60 seconds
- Warming gas cloud will become lighter than air and rise
- No direct environmental damage or clean up from primary spill
- A fire fed by single (25,000 m^3) cargo tank vented through a 1m^2 hole would last 1hr - burn diameter 25 meters

Summary of Conclusions from the Lloyd's Report

Specific terrorist scenario assessments included in Lloyd's report are omitted from this summary because of concern for providing "template" information

Security Issues

- Security and threat discussions are not contemplated in this presentation - Rely on US Coast Guard to determine treatment
- US DOE if asked is willing to consider access to security and operations personnel and other resources
- Security staff from DOE are present today

Summary

- The US market for natural gas is growing -
- Part of that market demand will be met by LNG
- The experience of the LNG industry suggests that hazards are manageable
- 30+ years of experience with marine transport of LNG - no major failures carriers and cargo inherently safer than other hydrocarbon fuels transported by ship
- Post September 11, 2001- new risk not new hazard

Summary

- Fundamental properties and behavior of LNG and natural gas remain the same
- Risk scenarios do not produce results outside of those contemplated in previous EIS documentation for siting facilities and transportation of LNG

Information Sources

- FERC documents
- DOT documents
- DOE National Laboratories
- US Coast Guard
- Energy Information Administration
- SIGTTO Society of International Gas Tanker and Terminal Operators
- Various consultant reports
- Industry sources
- Other literature