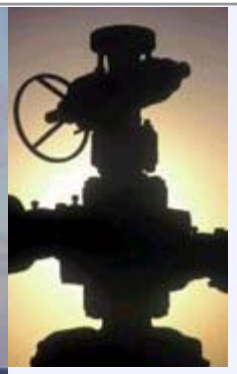

Background, Issues, and Trends in Underground Hydrocarbon Storage

David E. Dismukes

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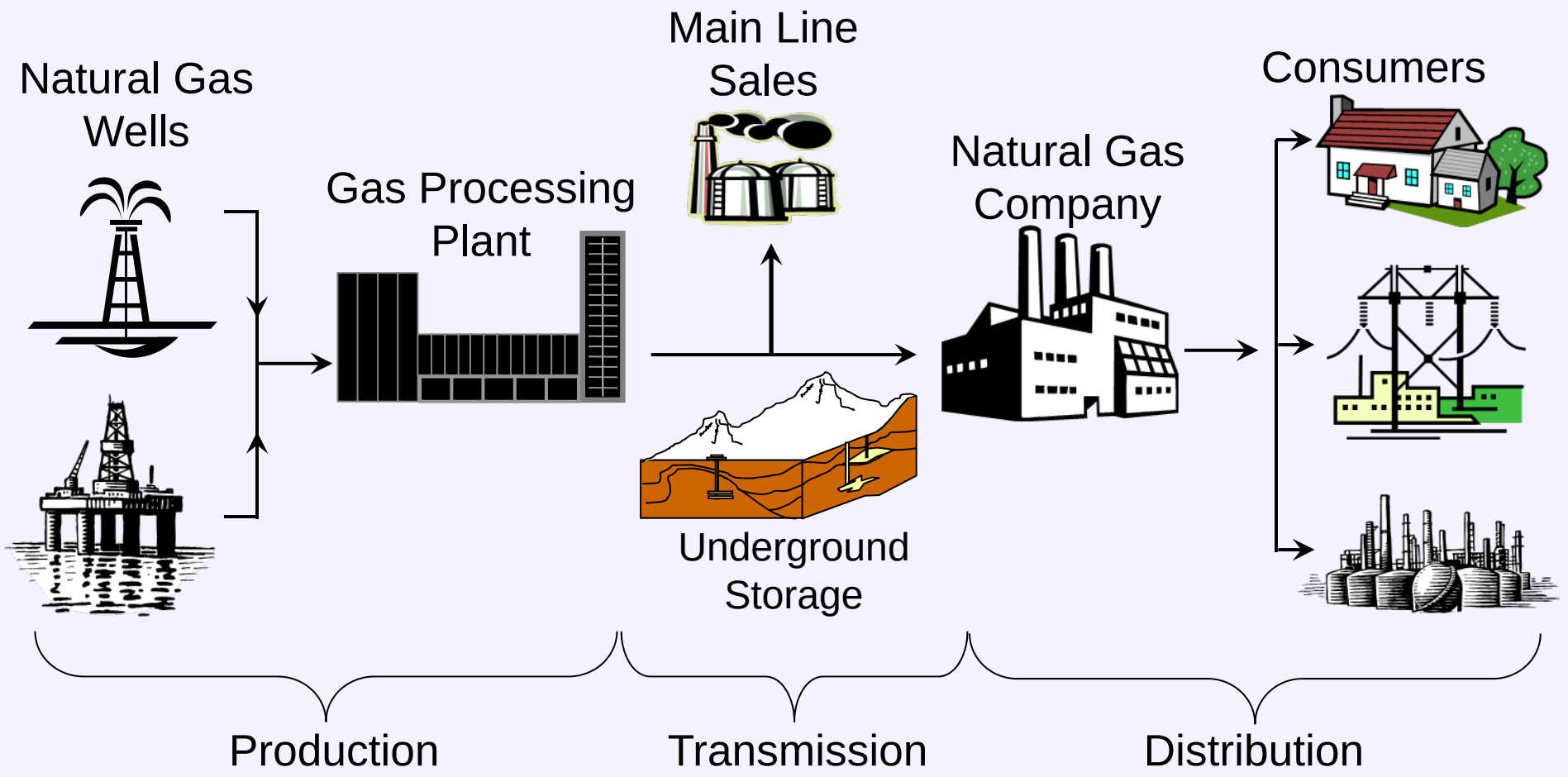
Louisiana State University

Environmental Permitting Class
January 29, 2009

Description of the Natural Gas and Natural Gas Liquids Business

The Natural Gas Industry



Source: Energy Information Administration, Department of Energy

Hydrocarbon Storage Basics

Key Storage Characteristics & Terms

Characteristic	Description
Capacity	Usually though of in terms of base, working and total. (Denominated in Bcf)
Deliverability	Speed of withdraw and injection.
Cycles	Number of complete “turns” a facility can take.

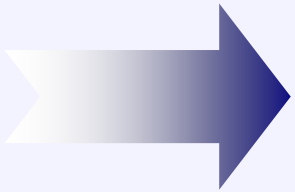
All of these characteristics are a critical components in valuing storage assets.

Why do we store hydrocarbons?

(1) Reliability: hedge on quantity (outages/curtailments).

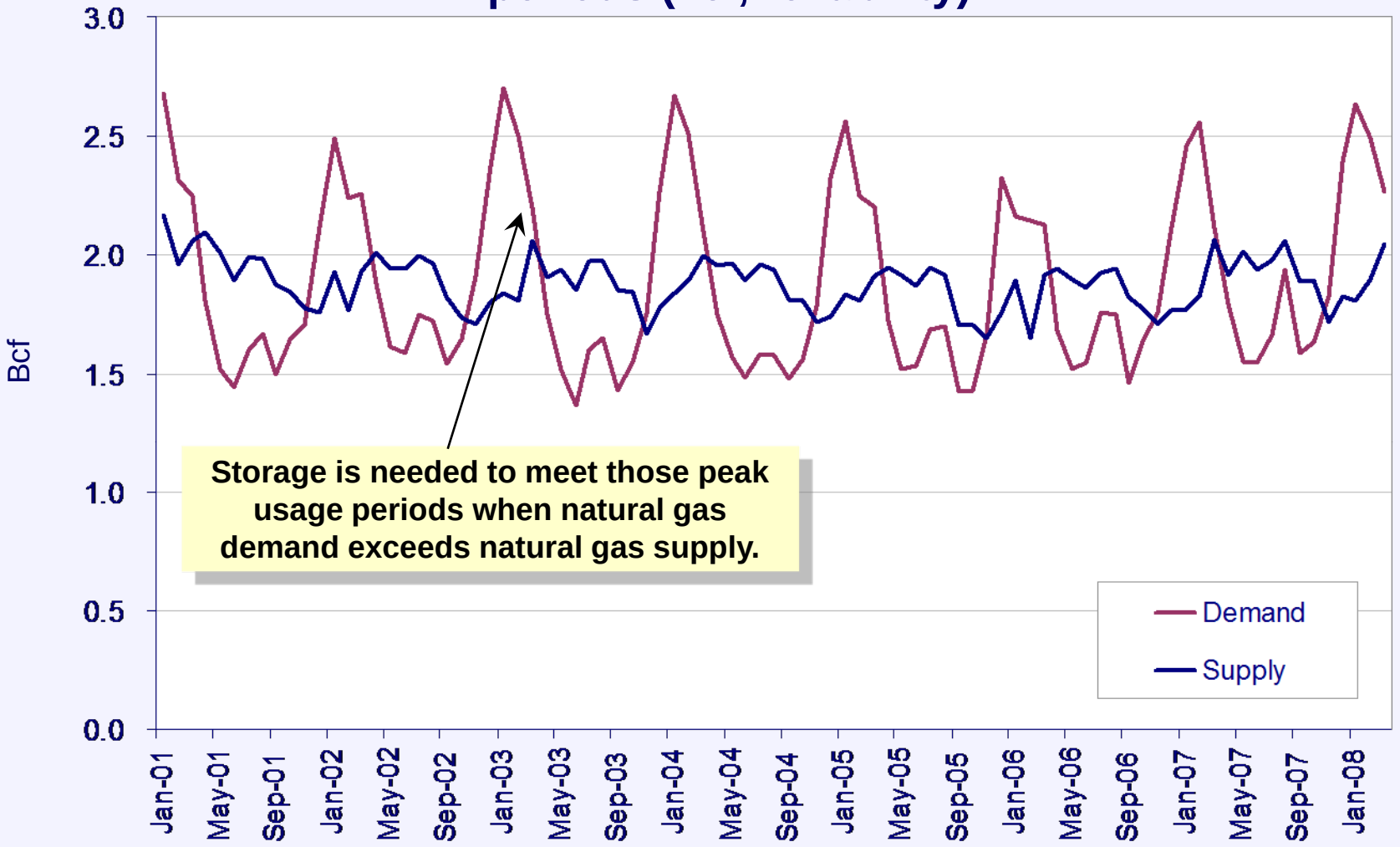
(2) Risk management: hedge on price (volatility).

(3) Profitability: speculation (profits on market changes).



Generally, the more uncertainty and volatility (price) a commodity, the greater the need for storage

Fundamental purpose of storage is to provide gas during peak periods (i.e., reliability).



Source: Energy Information Administration, Department of Energy.

Attractive Storage Physical Characteristics

Storage Characteristics	Function / Nature
Optionality	Location of facility will define the number of potential buyers/sellers given their location and connecting infrastructure
Deliverability	Type of facility tells you how quickly you can move the commodity to take advantage, or hedge, against market uncertainties
Interconnectibility	Location to important infrastructure defines market scope / access

All of these characteristics are a critical part of storage value chain

The Gulf of Mexico region is the most integrated and comprehensive energy economy in the world

The Gulf of Mexico region accounts for:

- **Approximately 30 percent of total U.S. crude oil production;**
- **Roughly 20 percent of total U.S. natural gas production;**
- **Almost 15 percent of total U.S. natural gas liquids production;**
- **60 percent of U.S. crude oil imports;**
- **Over 20 percent of U.S. natural gas (non-pipeline) imports;**
- **50 percent of U.S. natural gas liquids imports; and**
- **43 percent of the Strategic Petroleum Reserve (“SPR”) storage capacity; and**
- **Over 45 percent of total U.S. petroleum refining capacity and 62 percent of the capacity east of the Rockies.**

Storage Quick Facts


Duke Energy Gas Transmission Canada


pse.com

- Natural gas can be stored for an indefinite period of time. The exploration, production, and transportation of natural gas takes time, and the natural gas that reaches its destination is not always needed right away, so it is injected into underground storage facilities.
- There are **57 active underground storage facilities** in the Gulf Coast region, representing 14 percent of the nation's underground storage facilities.
- In 2005, the Gulf Coast region had **1.4 Tcf** of natural gas storage capacity. This represents approximately **17 percent** of the nation's underground storage capacity.

Note: Gulf Coast states include Louisiana, Texas, Mississippi and Alabama
Source: Energy Information Administration, US Department of Energy.

Different types of storage influence different deliverability attributes

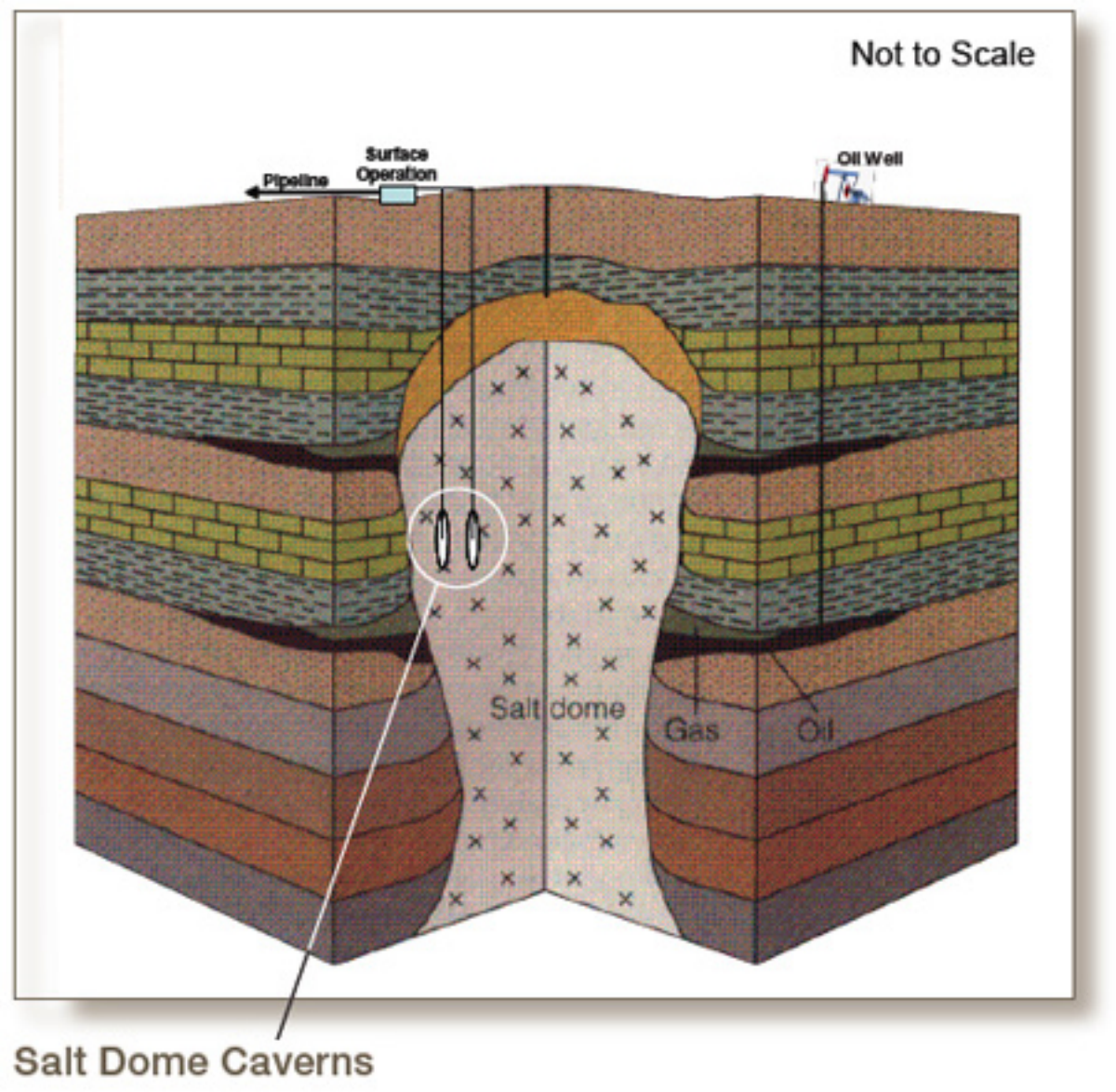
Depleted Reservoirs	• Most common - - has slower injection/withdrawal rates. • Conversion of a field from production to storage duty takes advantage of existing wells, gathering systems, and pipeline connections.
Aquifers	• Usually used only in areas where there are no nearby depleted reservoirs. • Single withdraw period (winter) & used to meet peak load requirements as well. • Least desirable and most expensive type of natural gas storage facility.
Salt Caverns	• Very high withdrawal and injection rates. • Base gas requirements are relatively low. • Most salt caverns/domes in US along GOM. • More expensive, but faster and more flexible.

Storage Types and Statistics

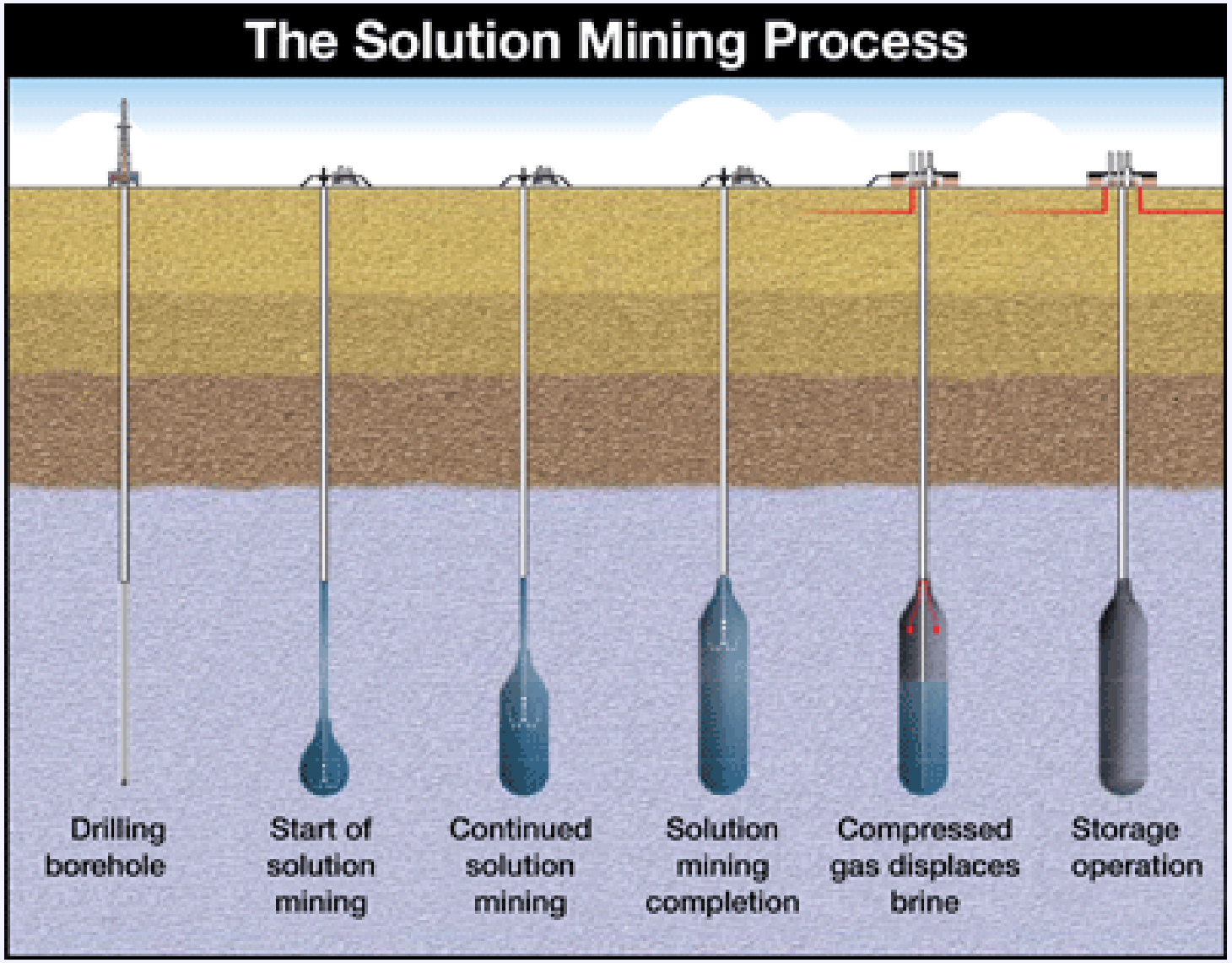
Storage Type	Market Share	Pad Gas Share	Injection Rate (Days)		Withdraw Rate (Days)		Cycles	
			High	Low	High	Low	High	Low
Depleted Reservoir	0.86	50% to 80%	200	250	100	150	1.22	0.91
Aquifer	0.1	50	200	250	100	150	1.22	0.91
Salt Cavern	0.04	20% -30 %	20	40	10	20	12.17	6.08

Salt Cavern Basics

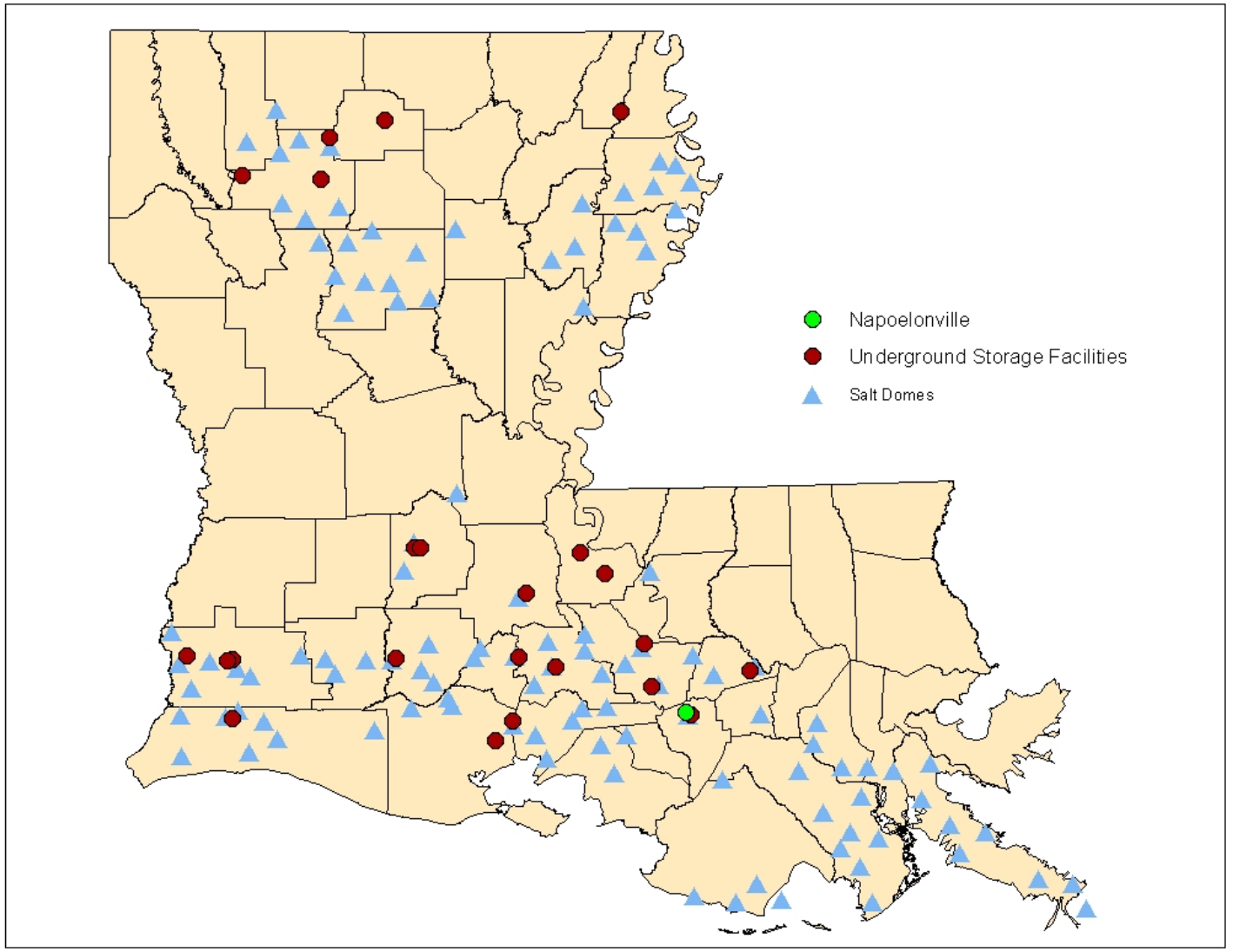
What Does A Salt Dome Look Like?



How is a Salt Dome Mined for Storage?



Deliverability
Existing Salt Domes



Other Types of Louisiana Underground Storage

Company	Facility Name	Type	Product
Egan Hub Partners, LP	Egan Hub	Salt Dome	Natural gas
AGL Resources Inc	Jefferson Island	Salt Dome	Natural gas
Ponchartrain Natural Gas/Acadian	Ponchartrain Grand Bayou	Salt Dome	Natural gas
Bridgeline Storage Co, LLC	Napoleonville Ns-1	Salt Dome	Natural gas
Bridgeline Holdings LP	Sorrento	Salt Dome	Natural gas
Liberty Gas Storage, LLC	Liberty Gas Storage	Salt Dome	Natural gas
Bear Creek Storage Company	Bear Creek	Depleted Gas Field	Natural gas
Gulf South Gas Pipeline Company, LP	Bistineau	Depleted Gas Field	Natural gas
Trunkline Gas Company, LLC	East and South Epps	Depleted Gas Field	Natural gas
CenterPoint Energy - MRT	East Unionville	Depleted Gas Field	Natural gas
CenterPoint Energy - MRT	West Unionville	Depleted Gas Field	Natural gas
CenterPoint Energy Gas Transmission Co.	Ruston	Depleted Gas Field	Natural gas
Transcontinental Gas Pipeline Corp.	Washington	Depleted Gas Field	Natural gas
Ouachita River Gas Storage Company	South Downsville	Depleted Gas Field	Natural gas
Texaco E&P	Anse LaButte	Salt Dome	Natural gas liquids
Williams Energy Services	Anse LaButte	Salt Dome	Natural gas liquids
Shell Oil Co	Ascension	Salt Dome	Natural gas liquids
Dow Chemical - Promix	Assumption	Salt Dome	Natural gas liquids
Dow Hydrocarbons	Assumption	Salt Dome	Natural gas liquids
Enterprise Products Co	Breaux Bridge	Salt Dome	Natural gas liquids
Union Texas Products	Choctaw	Salt Dome	Natural gas liquids
Williams Energy Services	Choctaw	Salt Dome	Natural gas liquids
TransCanada Gas Proc	Napoleonville	Salt Dome	Natural gas liquids
Ucar Pipeline Inc	Napoleonville	Salt Dome	Natural gas liquids
ExxonMobil Co, USA	Sorrento	Salt Dome	Natural gas liquids
Star Enterprise	Sorrento	Salt Dome	Natural gas liquids
Texaco E&P	Sorrento	Salt Dome	Natural gas liquids
Williams Energy Services	Sulfer Mines	Salt Dome	Natural gas liquids
Dynegy Midstream Sevices LP	Venice	Salt Dome	Natural gas liquids
Petrologistics	Sulphur	Salt Dome	Natural gas liquids
Louisiana Offshore Oil Port	Clovelly	Salt Dome	Crude Oil
Strategic Petroleum Reserve	West Hackberry	Salt Dome	Crude Oil
Strategic Petroleum Reserve	Bayou Choctaw	Salt Dome	Crude Oil

Source: Energy Information Administration, U.S. Department of Energy; Federal Energy Regulatory Commission; and PennWell MAPSearch Database.

Pressures Changing Cost and Value for Hydrocarbon Storage

What are the factors increasing costs and value?

(1) Continued natural gas price volatility – seasonal differentials.

(2) Growth in natural gas usage, particularly power generation.

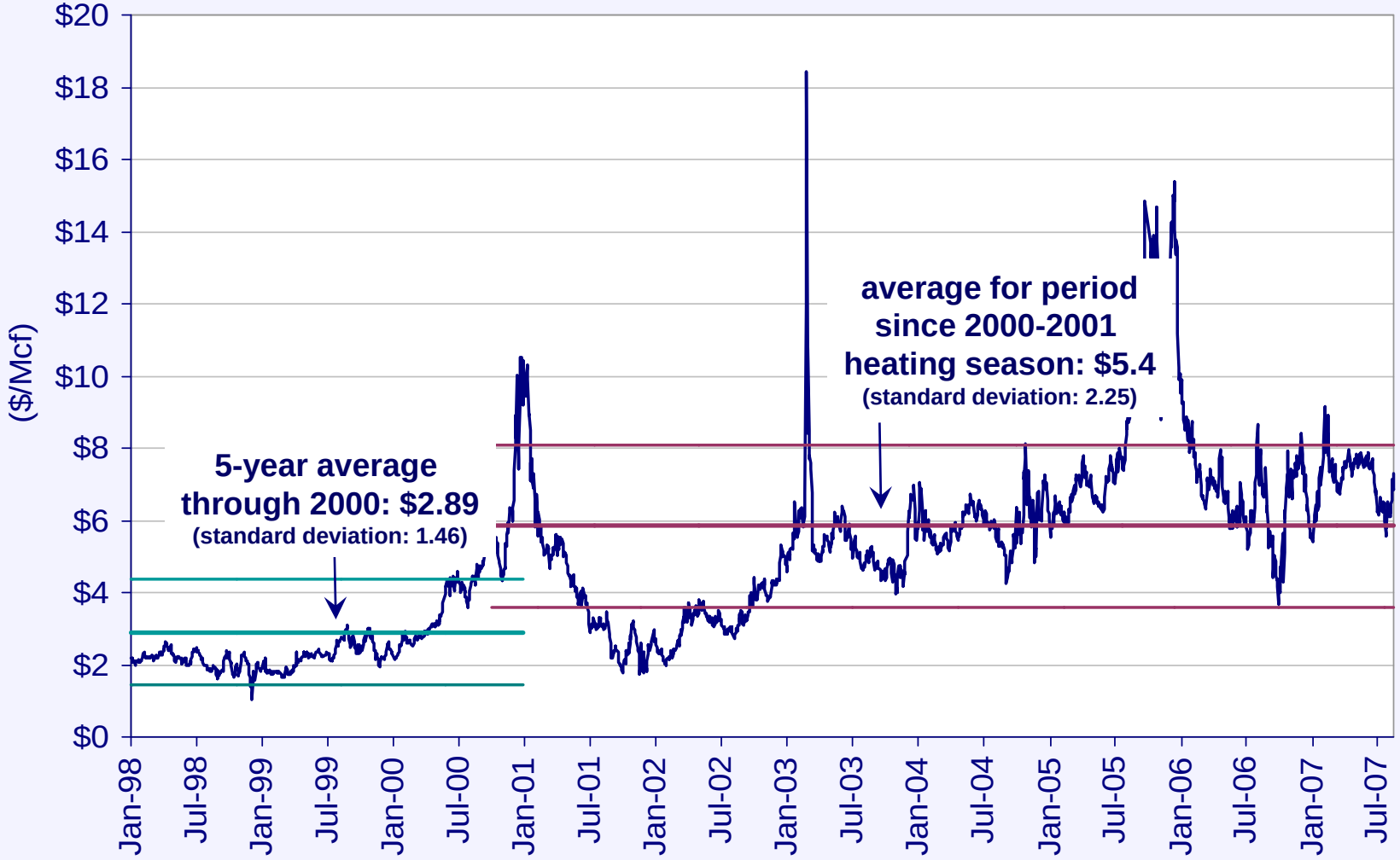
(3) Basis differentials/regional supply corrections (changing pipe and production configurations)

(4) Increasing LNG imports requires capacity development

Pricing Considerations

Daily Henry Hub Prices (1998-Present)

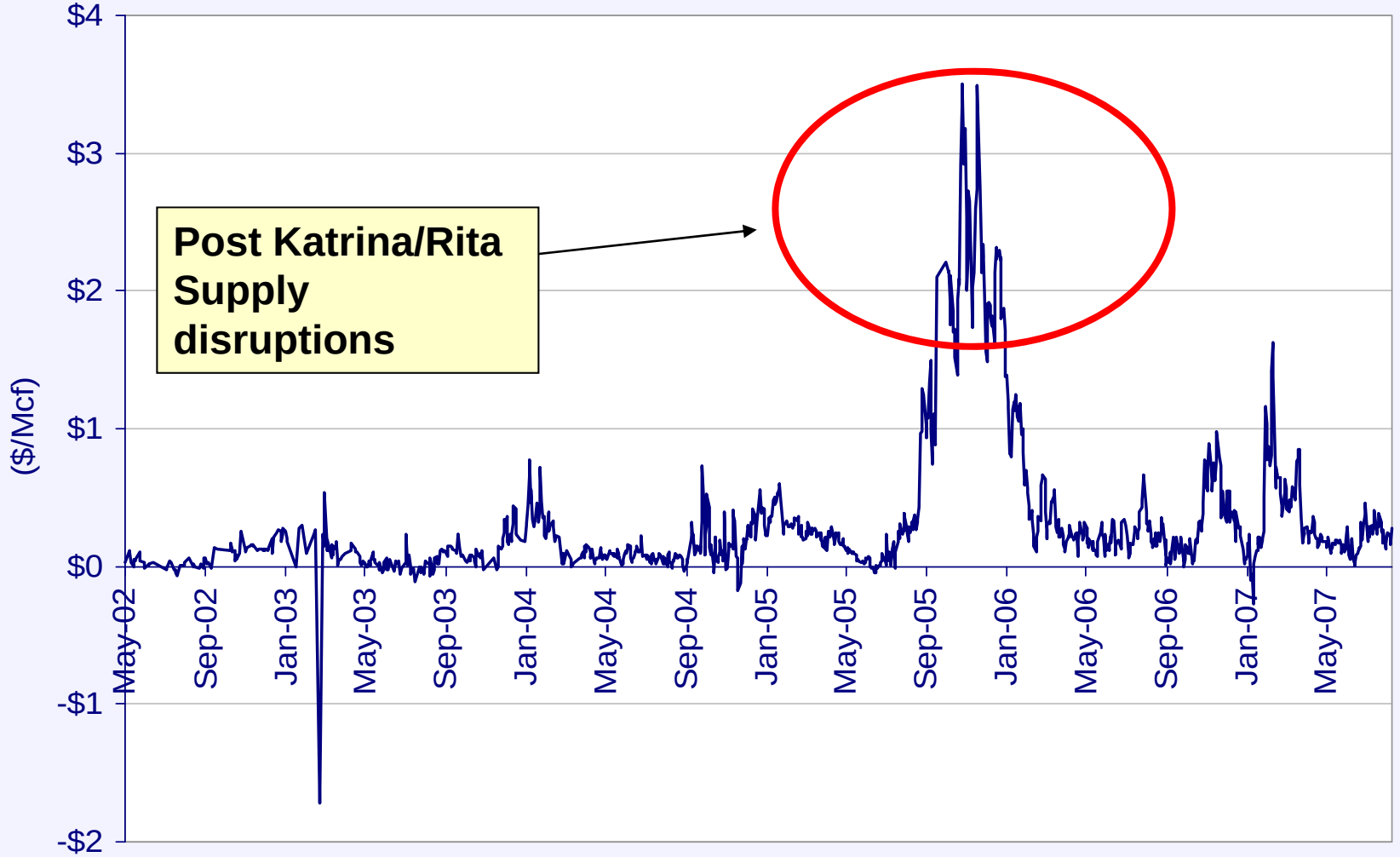
Continued natural gas price volatility for near term.



Source: Intercontinental Exchange

Henry Hub – Houston Ship Channel Spread

Basis differentials can be serious issue during market interruptions.



Intrinsic and Extrinsic Value in Natural Gas Storage

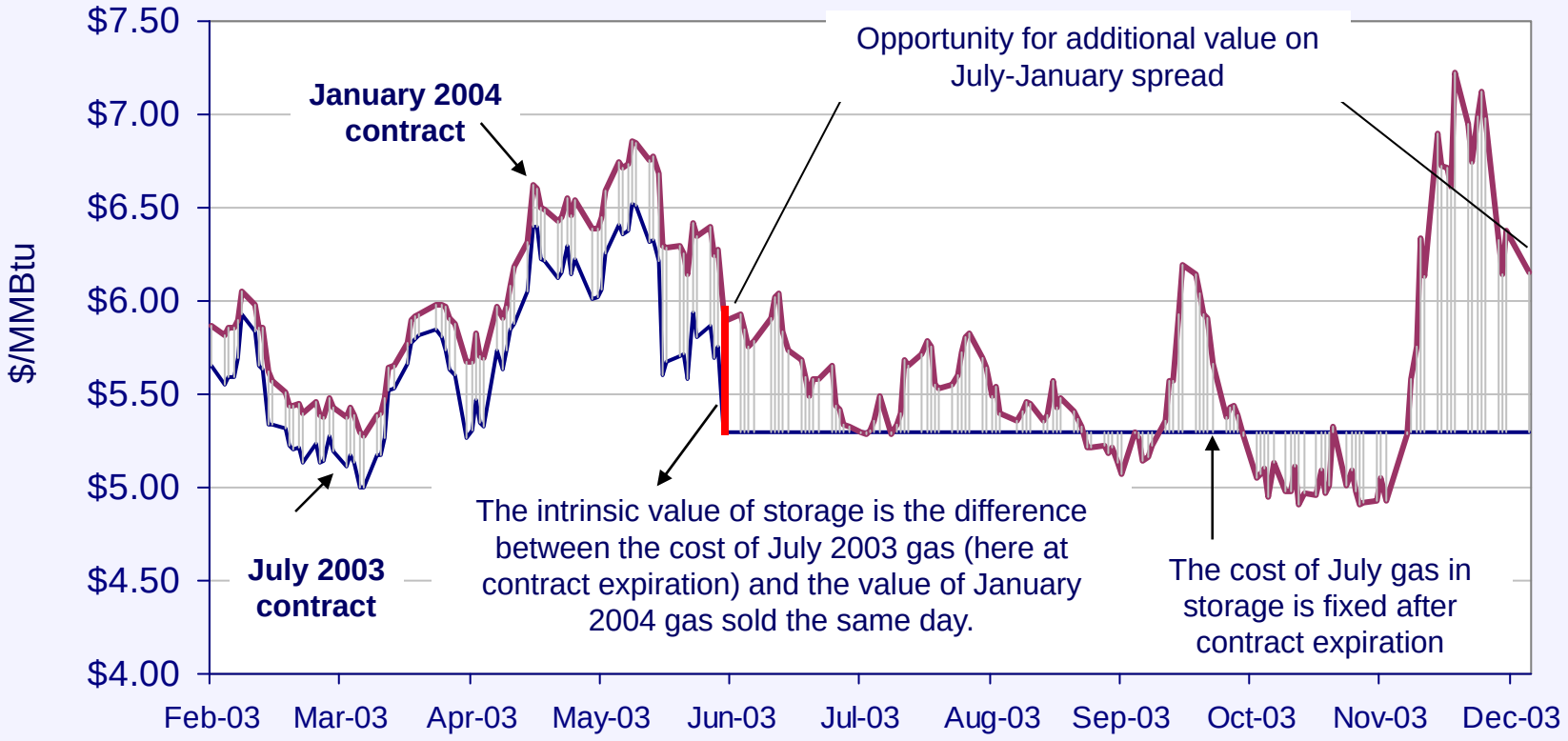
Intrinsic Value:

- The seasonal valuation of storage.
- Evaluated as the difference between the two prices in a pair of forward prices.
- Value secured by locking-in a forward spread, either physically or financially.

Extrinsic Value:

- Determined by the ability to profit by the volatility and uncertainty of prices.

Difference between Intrinsic and Extrinsic Value of Natural Gas Storage

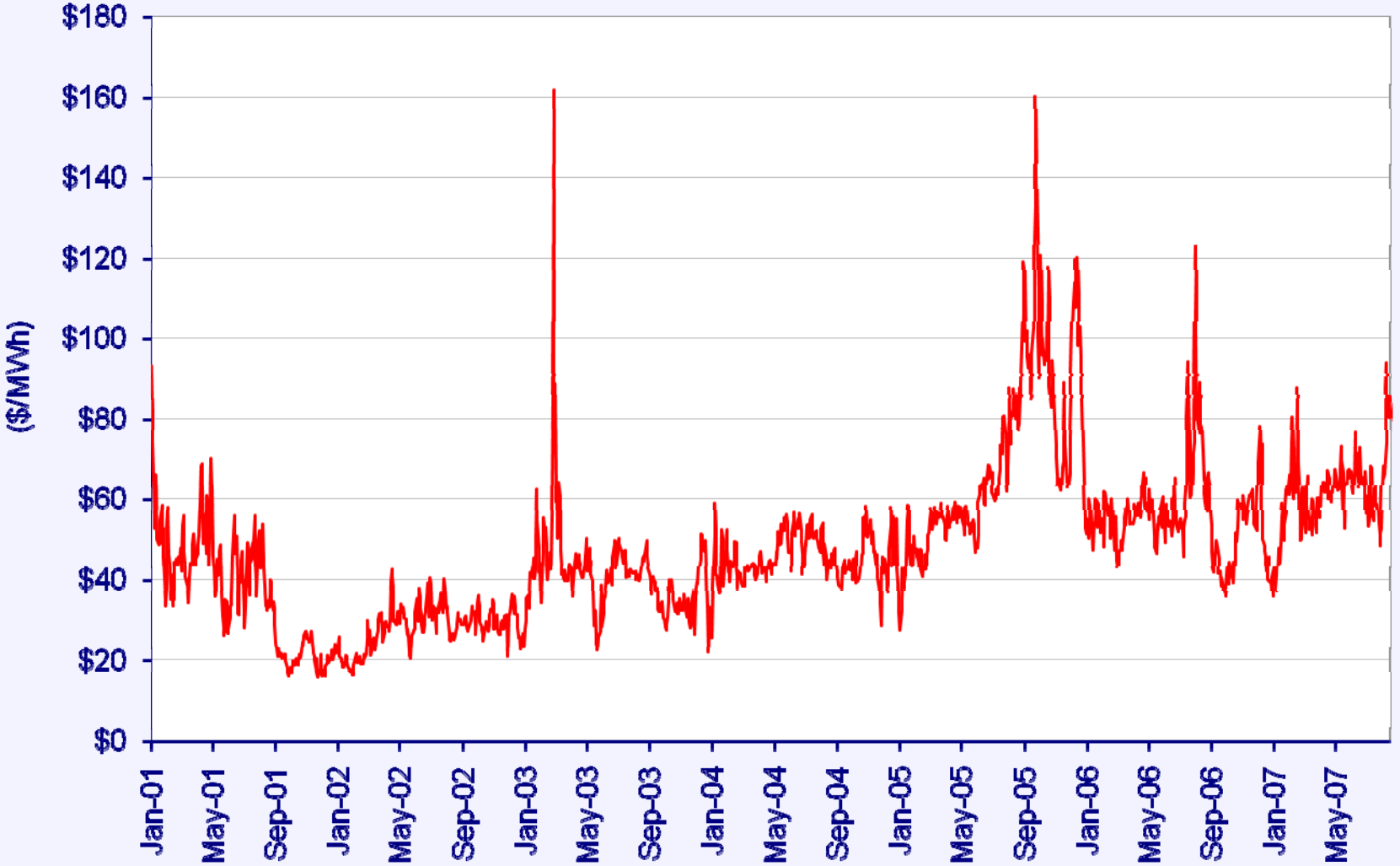


Source: Federal Energy Regulatory Commission and NYMEX.

Power Generation Considerations

Daily Entergy Spot Prices (2001-Present)

Power generation prices volatile – natural gas driven – cyclical load.



Power Generation Impacts

(1) Since the late 1990s, over 225,000 MWs of gas-fired capacity has come on line.

(2) While construction costs have escalated, still relatively attractive to other baseload options.

(3) Gas is important transition (?) fuel for carbon policy.

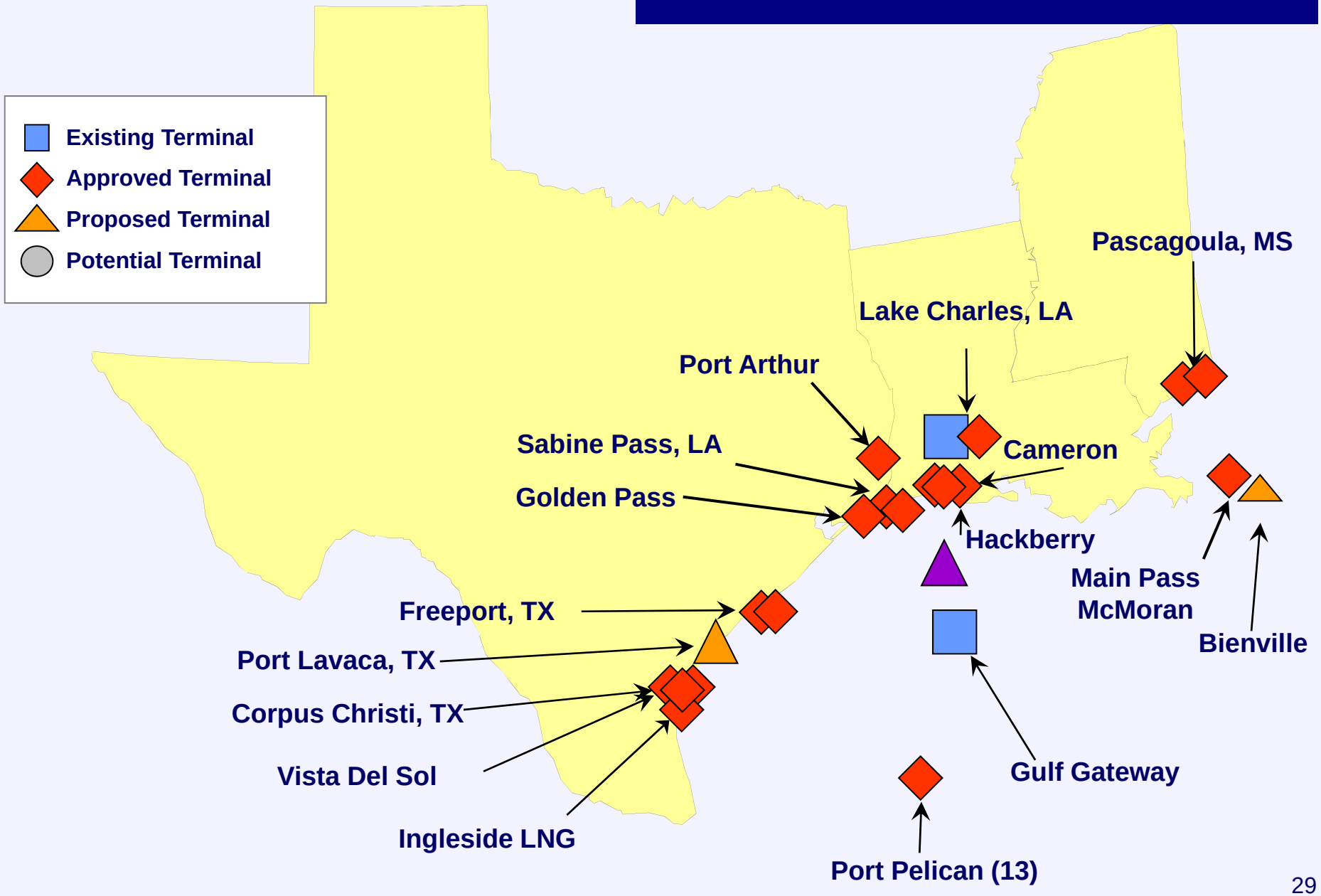
No new coal plants is becoming the norm in most states.
Nuclear takes too long and costs too much – too much uncertainty.
Carbon sequestration (stack) expensive and inefficient.

(4) Renewables are in kW not in MW – scale issue and regional limitations.

(5) Large scale hydroelectric facilities very limited and unlikely.

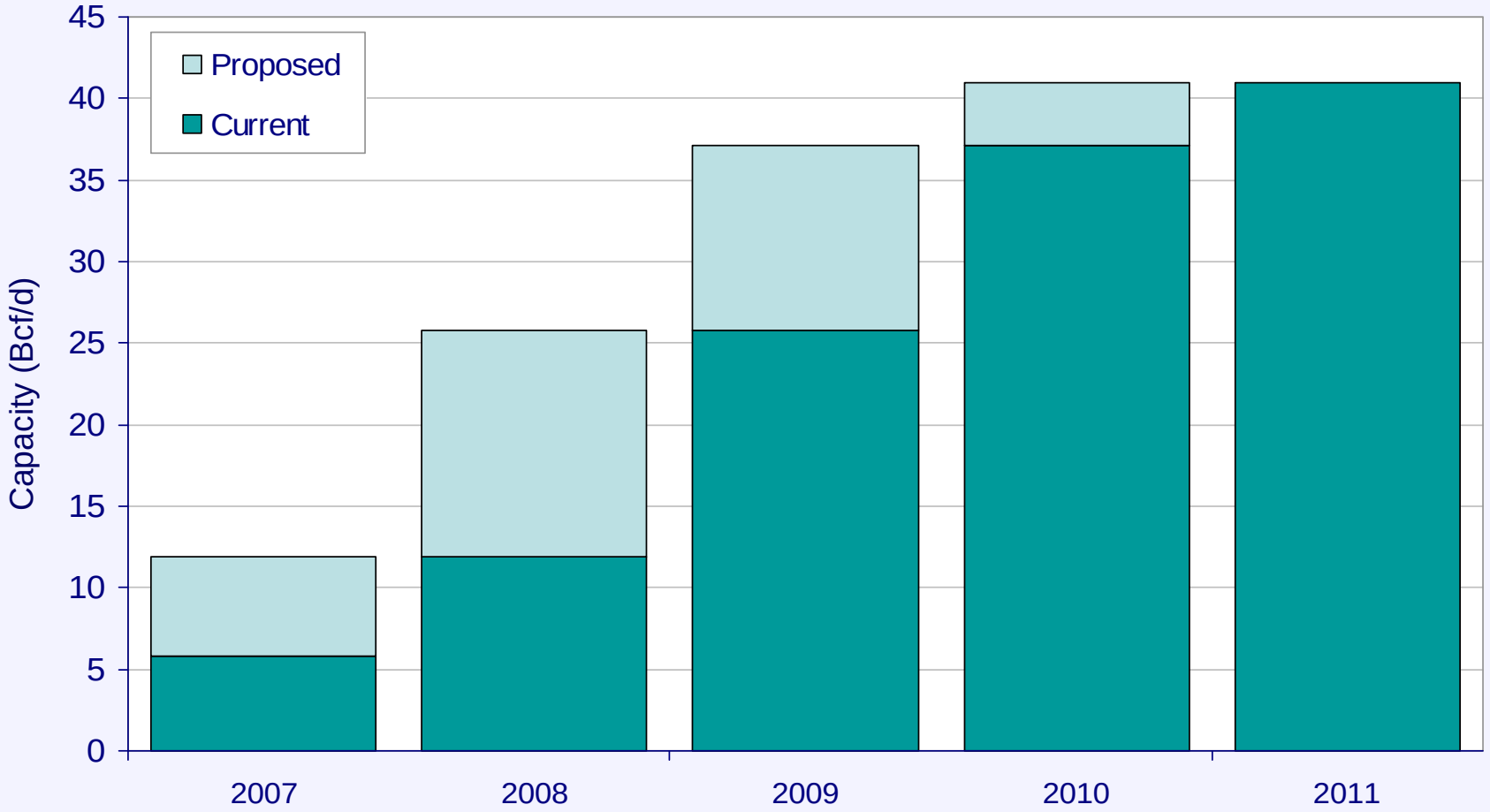
LNG Considerations

Gulf Coast LNG Terminals



Planned LNG Capacity Additions and Expansions (2007-2010)

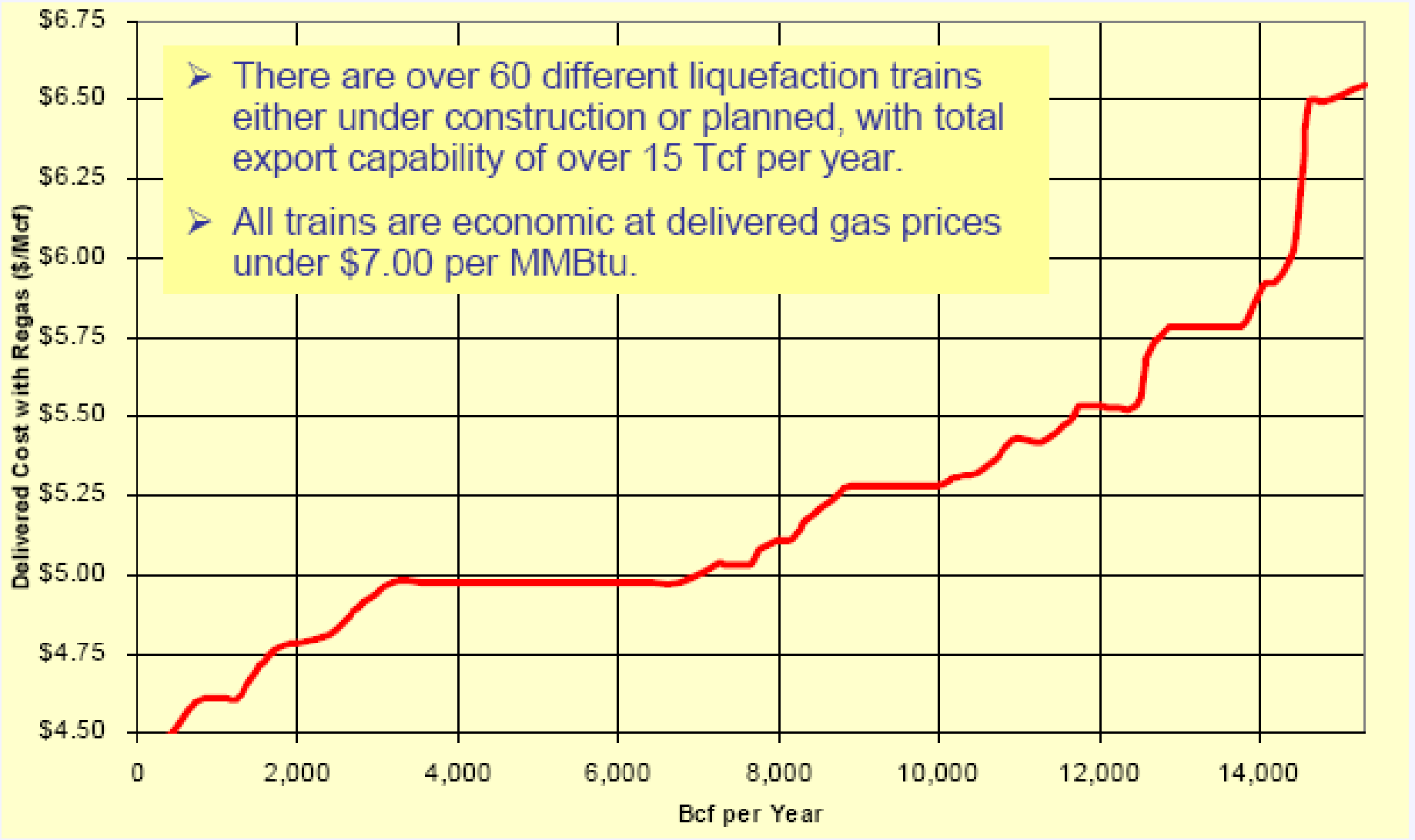
Most LNG regasification capacity on line within the next 5 years.



Note: New capacity includes terminals that have been approved, or are pending approval.
Source: FERC and various tradepress and company websites


Constructed Regasification Facilities
Canaport, 2008, 1.0 Bcfd
Everett, 1994, 0.7 Bcfd
NE Gateway, 2008, 0.8 Bcfd
Cove Point, 2003, 0.75 Bcfd
2008 Expansion to 1.5 Bcfd
Cameron LNG, 2008, 1.5 Bcfd
2023 Expansion to 2.65 Bcfd
Sabine Pass, 2010, 2.6 Bcfd
Lake Charles, 1994, 1.0 Bcfd
2006 Expansion to 2.1 Bcfd
Golden Pass, 2009, 2.0 Bcfd
2018 Expansion to 4.0 Bcfd
Freeport LNG, 2009, 1.5 Bcfd
Elba Island, 2002, 0.45 Bcfd
2005 Expansion to 1.2 Bcfd
2011 Expansion to 2.4 Bcfd
Costa Azul, 2008, 1.0 Bcfd
2011 Expansion to 2.0 Bcfd
Altamira, 2006, 0.5 Bcfd
2010 Expansion to 1.0 Bcfd
Gulf LNG Energy, 2011, 1.0 Bcfd
Manzanillo, 2016, 0.75 Bcfd
2020 Expansion to 1.5 Bcfd
Gulf Gateway, 2005, 0.5 Bcfd
Lazaro Cardenas, 2019, 0.5 Bcfd

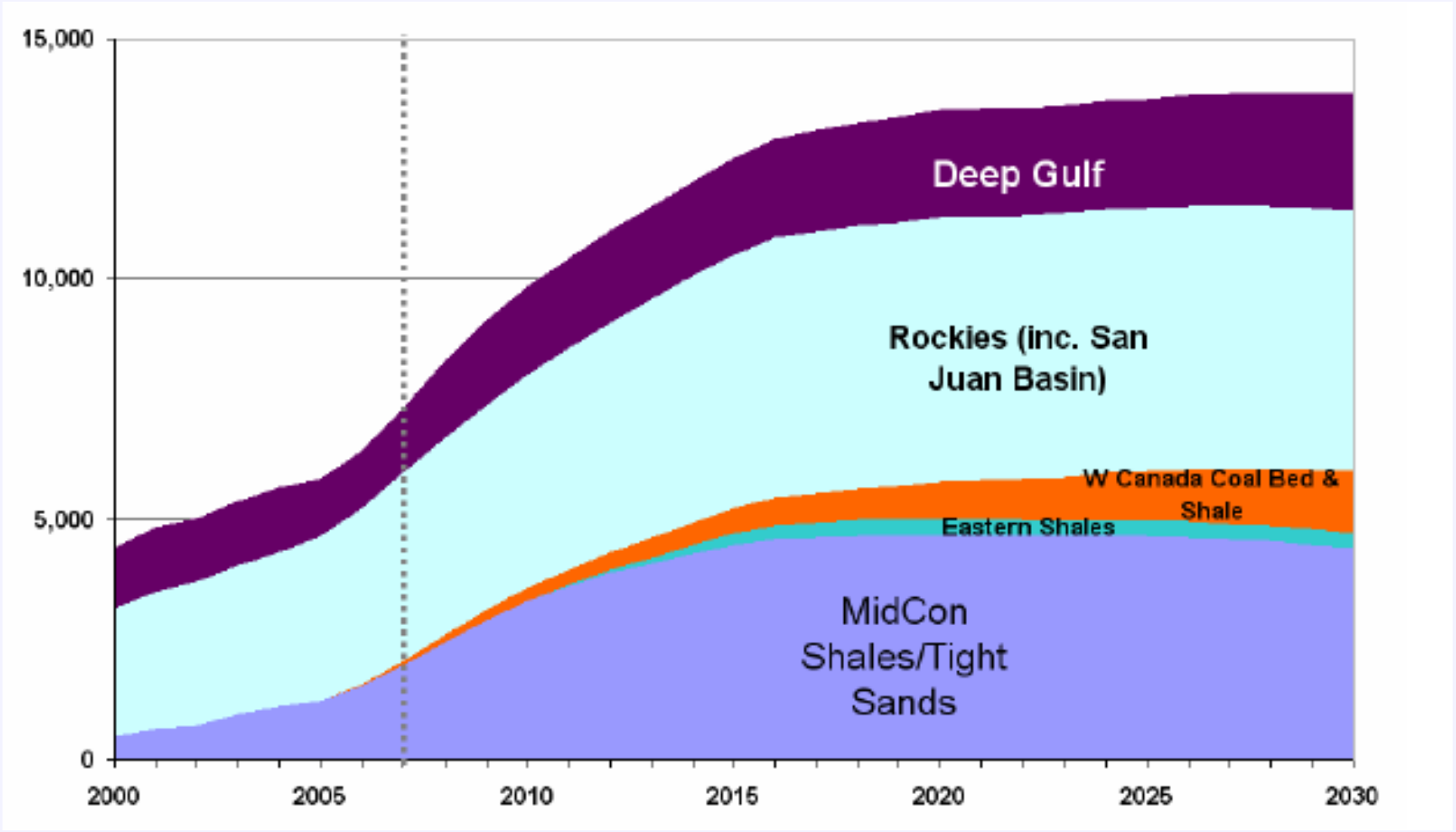
LNG Supply Curve



Source: ICF Consulting

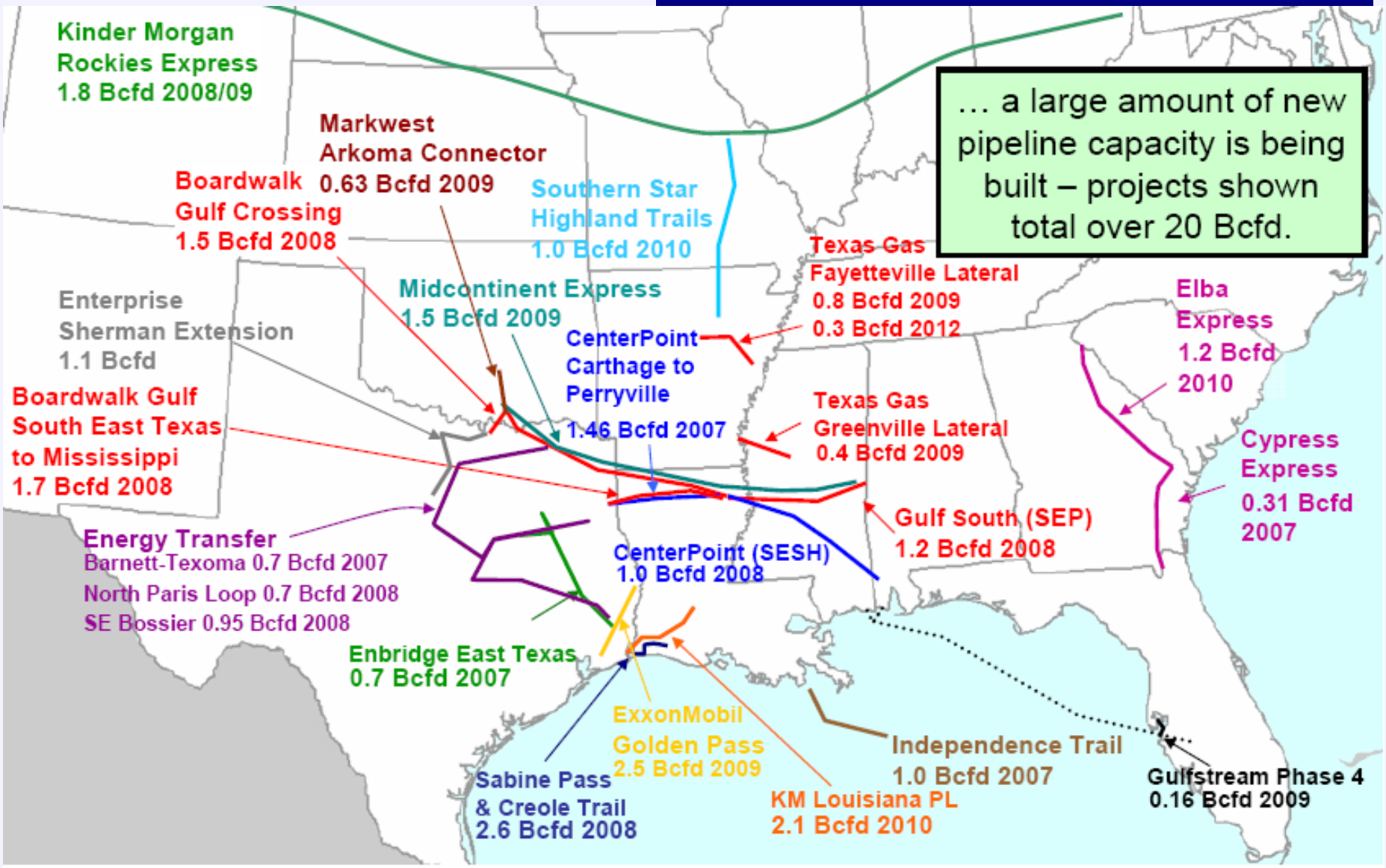
Production & Transportation Considerations

Unconventional Gas Production



Energy Information Administration.

Unconventional Gas Production



Source: ICF Consulting.

Cost Considerations

Recent Acquisition Costs

Field Name Date	Operator Location	Capacity (Bcf) Cost in Million $ per Bcf	Deliverability (MMcfd) Cost in 1000s $ per MMcfd	Purchaser Purchase Price in Millions $
Blue Water Aug-2005	Blue Water Gas Storage LLC Michigan	24.5 $10.2	700 $357	Plains All American/Vulcan Gas Storage $250
Lodi (50% Interest) Dec-2005	Lodi Gas Storage California	17 $14.7	500 $500	Arclight Energy Partners Fund II $125
Suffield, and Countess Mar-2006	AECO Hub Alberta	125 $9.1	3,050 $402	Riverstone Holdings and the Carlyle Group $1,500
Wild Goose Mar-2006	Wild Goose Storage California	24 $9.1	480 $402	Riverstone Holdings and the Carlyle Group Included in above price
Salt Plains (Manchester) Mar-2006	Niska Gas Storage Oklahoma	15 $9.1	200 $402	Riverstone Holdings and the Carlyle Group Included in above price
Lodi and Kirby Hills Phase 1 Jul-2007	Lodi Gas Storage - ArcLight Energy Partners California	22.5 $19.0	600 $713	Buckeye Partners $428
Adrian (Steuben) Sep-2007	Steuben Gas Storage Company New York	6.2 $8.7	60 $650	Inergy Propane $104
Thomas Corner Sep-2007	DTE Northeast LLC New York	5.7 $8.7	100 $650	Inergy Propane Included in above price
Caledonia May-2008	Caledonia Energy Partners Mississippi	11.7 -	330 -	ENSTOR - Iberdrola Renewables Unannounced
Total Projects **Average Cost**		252 $10.0	6,020 $423	$2,407

Note: All fields above are depleted reservoirs.

Source: ICF Consulting.

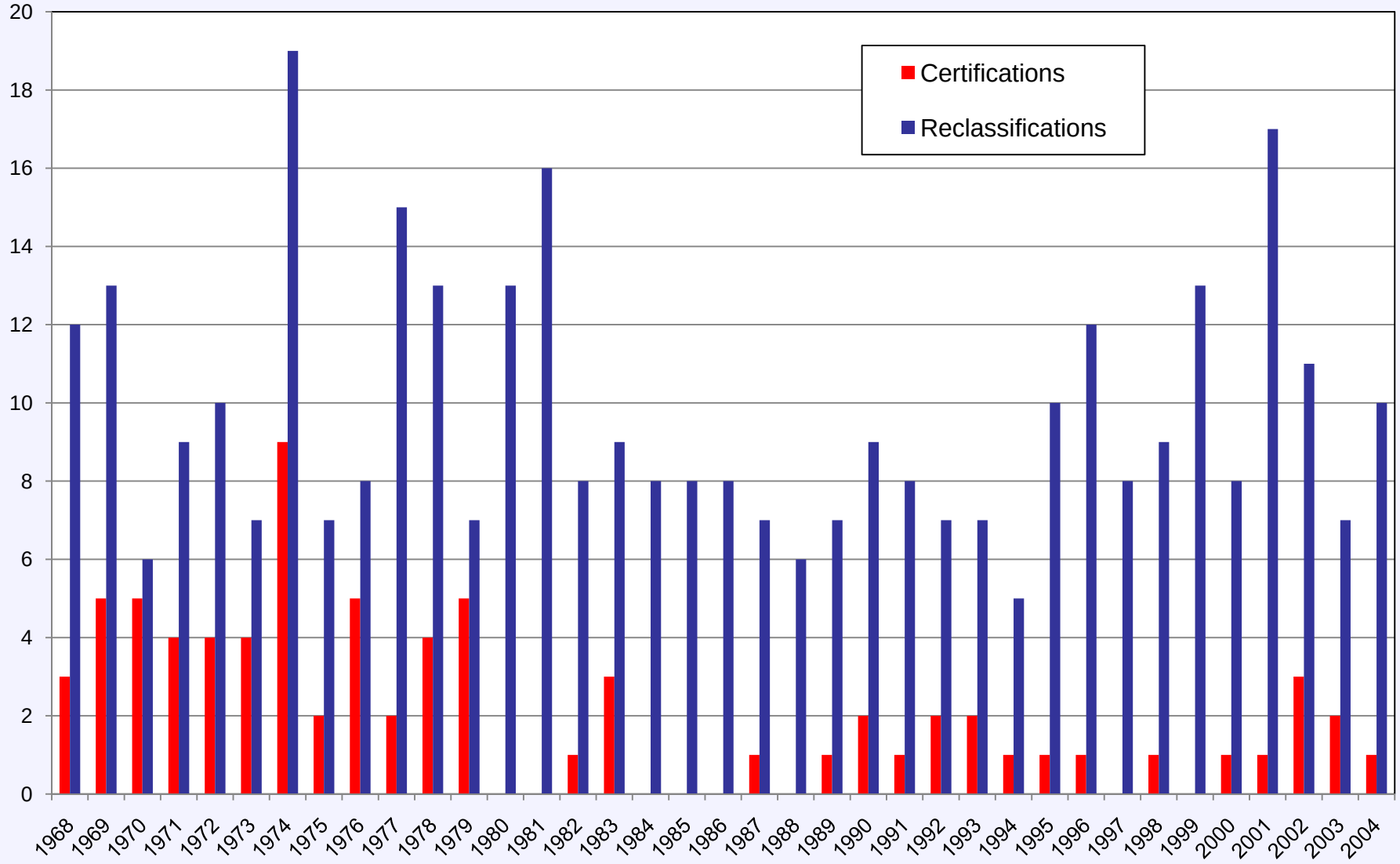
Reported Development Costs

Field Name In Service Date	Operator Location	Capacity (Bcf) Cost in Million $ per Bcf	Deliverability (MMcfd) Cost in 1000s $ per MMcfd	Field Type Expansion Cost in Millions $
Expansions				
Petal Salt Dome	Petal Gas Storage (Enterprize PP)	2.4	950	Salt Dome
Nov-2005	Mississippi	$6.3	$16	$15
Midland - Expansion	Texas Gas Transmission	6.75	90	Depleted Reservoir
Nov-2007	Kentucky	$5.3	$400	$36
Kirby Hills Phase 2	Lodi Gas Storage - ArcLight Energy Partners	12	100	Depleted Reservoir
Nov-2008	California	$4.3	$520	$52
Jackson Prairie Phase 5	Puget Sound Energy	3.25	300	Aquifer
Nov-2008	Washington	$12.9	$140	$42
Total Expansion Projects		24	1,440	$145
Average Cost		$5.9	$101	
New Fields				
Pine Praire Energy Center	SG Resources Louisiana LLC	24	2,400	Salt Dome
Oct-2008	Louisiana	$10.8	$108	$260
Port Barre	Bobcat Gas Storage	12	1,200	Salt Dome
Oct-2008	Louisiana	$10.4	$104	$125
Cold Springs 1	ANR Pipeline	14	200	Depleted Reservoir
Aug-2008	Michigan	$5.5	$387	$77
Sacramento Natural Gas Storage	Sacramento Natural Gas Storage	7.5	200	Depleted Reservoir
Apr-2009	California	$4.0	$150	$30
Total New Projects		58	4,000	$492
Average Cost		$8.6	$123	

Source: ICF Consulting.

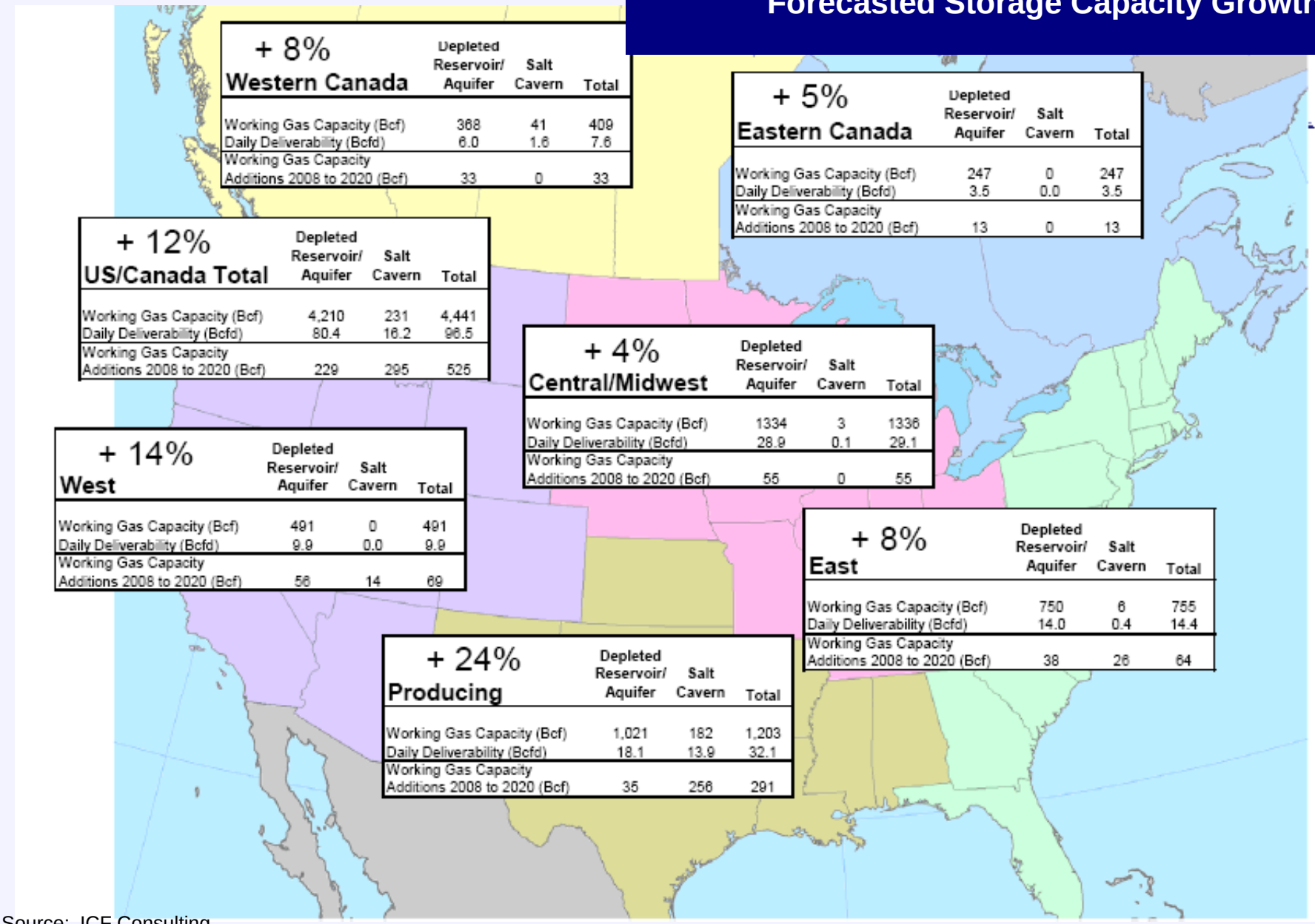
Conclusions & Outlook

FERC Certification & Reclassifications



Source: Federal Energy Regulatory Commission.

Forecasted Storage Capacity Growth



+ 8% Western Canada	Depleted Reservoir/ Aquifer	Salt Cavern	Total
Working Gas Capacity (Bcf)	368	41	409
Daily Deliverability (Bcfd)	6.0	1.6	7.6
Working Gas Capacity Additions 2008 to 2020 (Bcf)	33	0	33

+ 5% Eastern Canada	Depleted Reservoir/ Aquifer	Salt Cavern	Total
Working Gas Capacity (Bcf)	247	0	247
Daily Deliverability (Bcfd)	3.5	0.0	3.5
Working Gas Capacity Additions 2008 to 2020 (Bcf)	13	0	13

+ 12% US/Canada Total	Depleted Reservoir/ Aquifer	Salt Cavern	Total
Working Gas Capacity (Bcf)	4,210	231	4,441
Daily Deliverability (Bcfd)	80.4	16.2	96.5
Working Gas Capacity Additions 2008 to 2020 (Bcf)	229	295	525

+ 4% Central/Midwest	Depleted Reservoir/ Aquifer	Salt Cavern	Total
Working Gas Capacity (Bcf)	1334	3	1336
Daily Deliverability (Bcfd)	28.9	0.1	29.1
Working Gas Capacity Additions 2008 to 2020 (Bcf)	55	0	55

+ 14% West	Depleted Reservoir/ Aquifer	Salt Cavern	Total
Working Gas Capacity (Bcf)	491	0	491
Daily Deliverability (Bcfd)	9.9	0.0	9.9
Working Gas Capacity Additions 2008 to 2020 (Bcf)	56	14	69

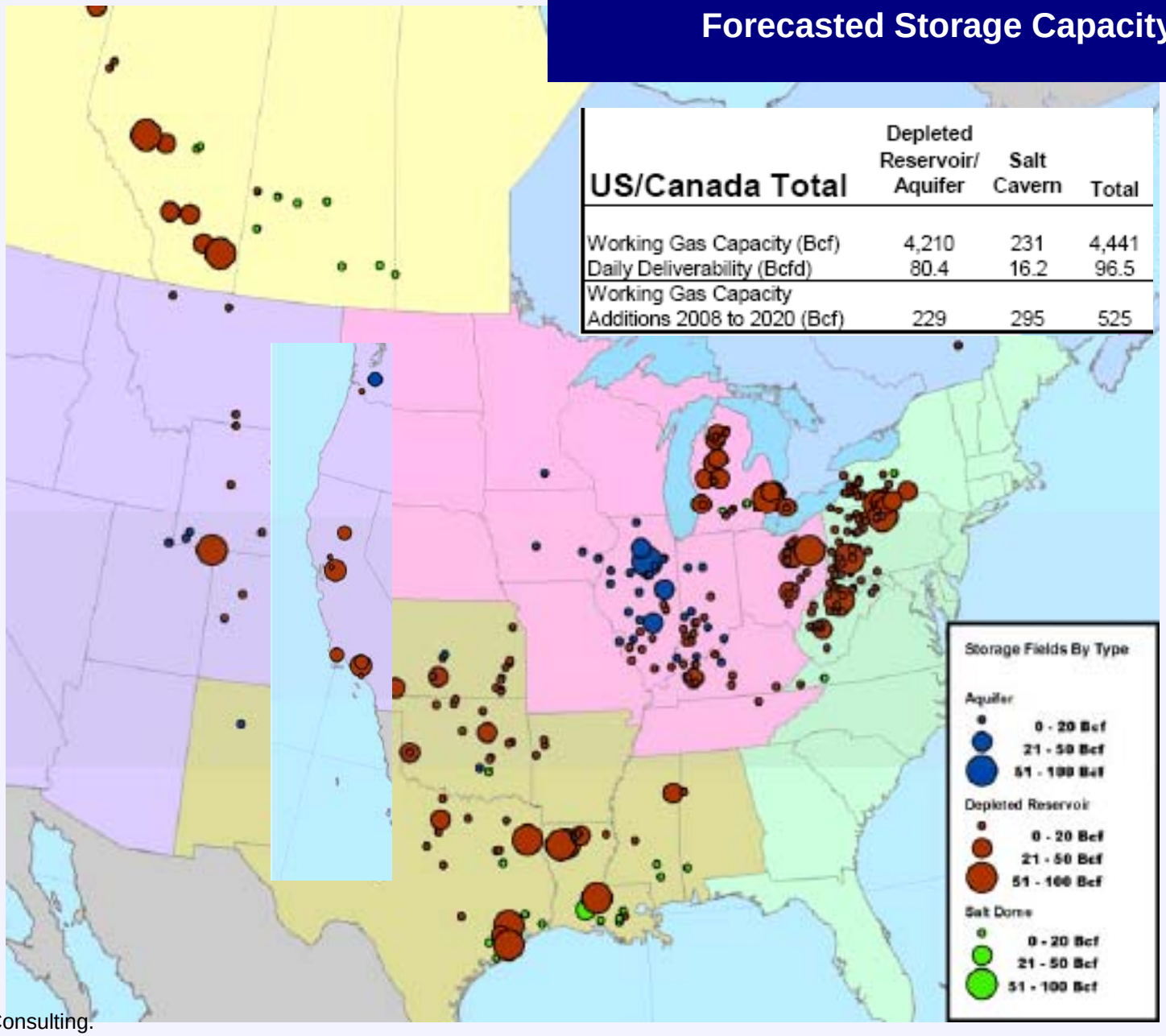
+ 8% East	Depleted Reservoir/ Aquifer	Salt Cavern	Total
Working Gas Capacity (Bcf)	750	6	755
Daily Deliverability (Bcfd)	14.0	0.4	14.4
Working Gas Capacity Additions 2008 to 2020 (Bcf)	38	26	64

+ 24% Producing	Depleted Reservoir/ Aquifer	Salt Cavern	Total
Working Gas Capacity (Bcf)	1,021	182	1,203
Daily Deliverability (Bcfd)	18.1	13.9	32.1
Working Gas Capacity Additions 2008 to 2020 (Bcf)	35	256	291

Source: ICF Consulting.

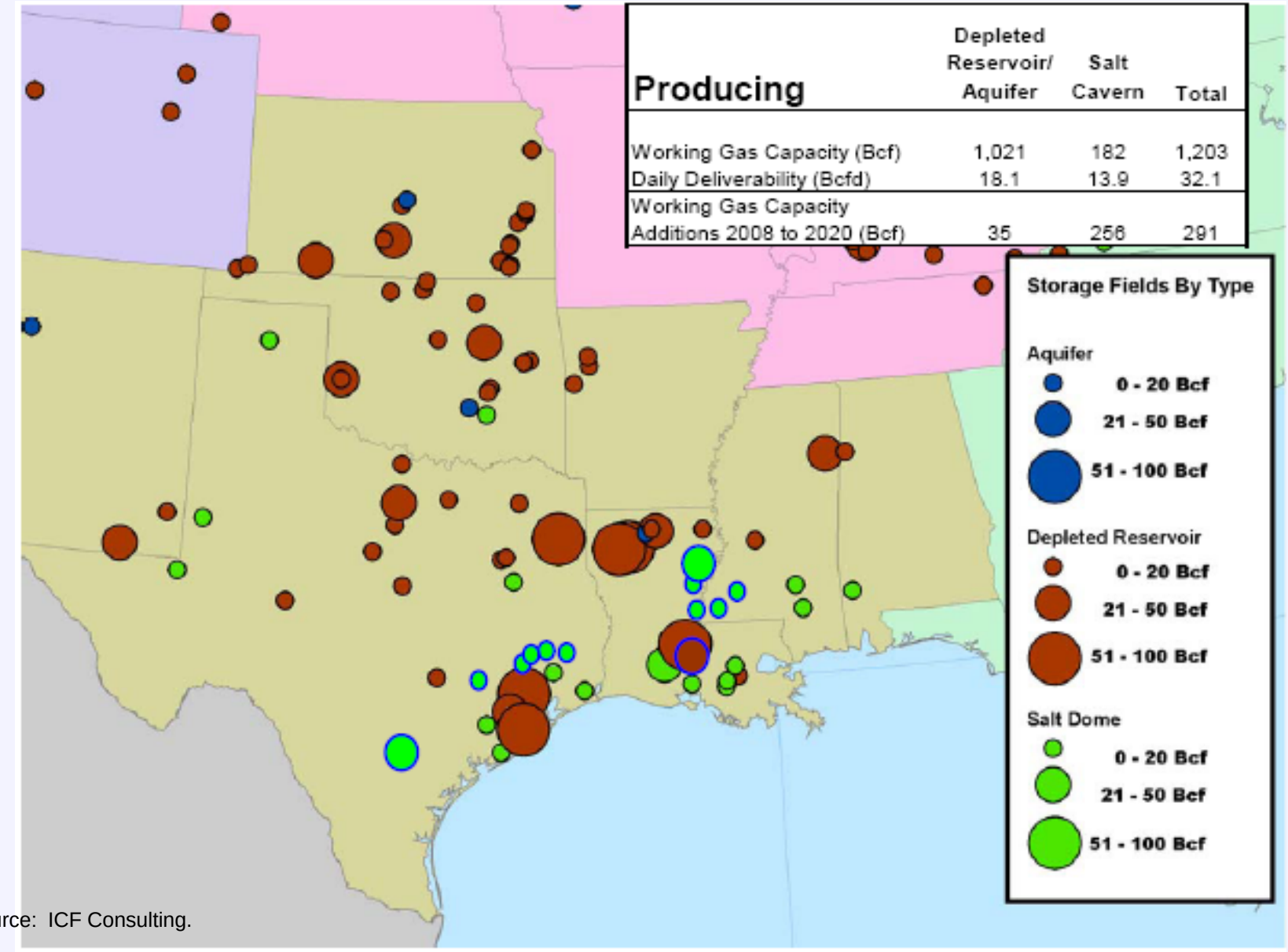
Forecasted Storage Capacity Growth

US/Canada Total	Depleted Reservoir/ Aquifer	Salt Cavern	Total
Working Gas Capacity (Bcf)	4,210	231	4,441
Daily Deliverability (Bcfd)	80.4	16.2	96.5
Working Gas Capacity Additions 2008 to 2020 (Bcf)	229	295	525



Source: ICF Consulting.

Forecasted Production Area Storage Capacity Growth



Source: ICF Consulting.

Louisiana Development Issues

(1) Changing production opportunities (Haynesville) will have big impact on facility location.

(2) Salt cavern availability.

(3) Cost escalation issues.

(4) Water use issues.

(5) Regulatory and tax issues.

(6) State lands development.

(7) Resource competition for other forms of underground storage (NGLs, crudes, product, CO2)

Questions, Comments, & Discussion

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