Fueling the Marine Industry
“Well to Waves”

February 13, 2013

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Director, Gaseous Fuels Partnerships

About Clean Fuels Ohio

CleanFuelsOhio

- Founded in 2002
- Headquartered in Columbus, Ohio
- U.S. Department of Energy designated Clean Cities Coalition
- Ohio Green Fleets Program works directly with fleets to deploy advanced fuels and technologies

1 GET EDUCATED

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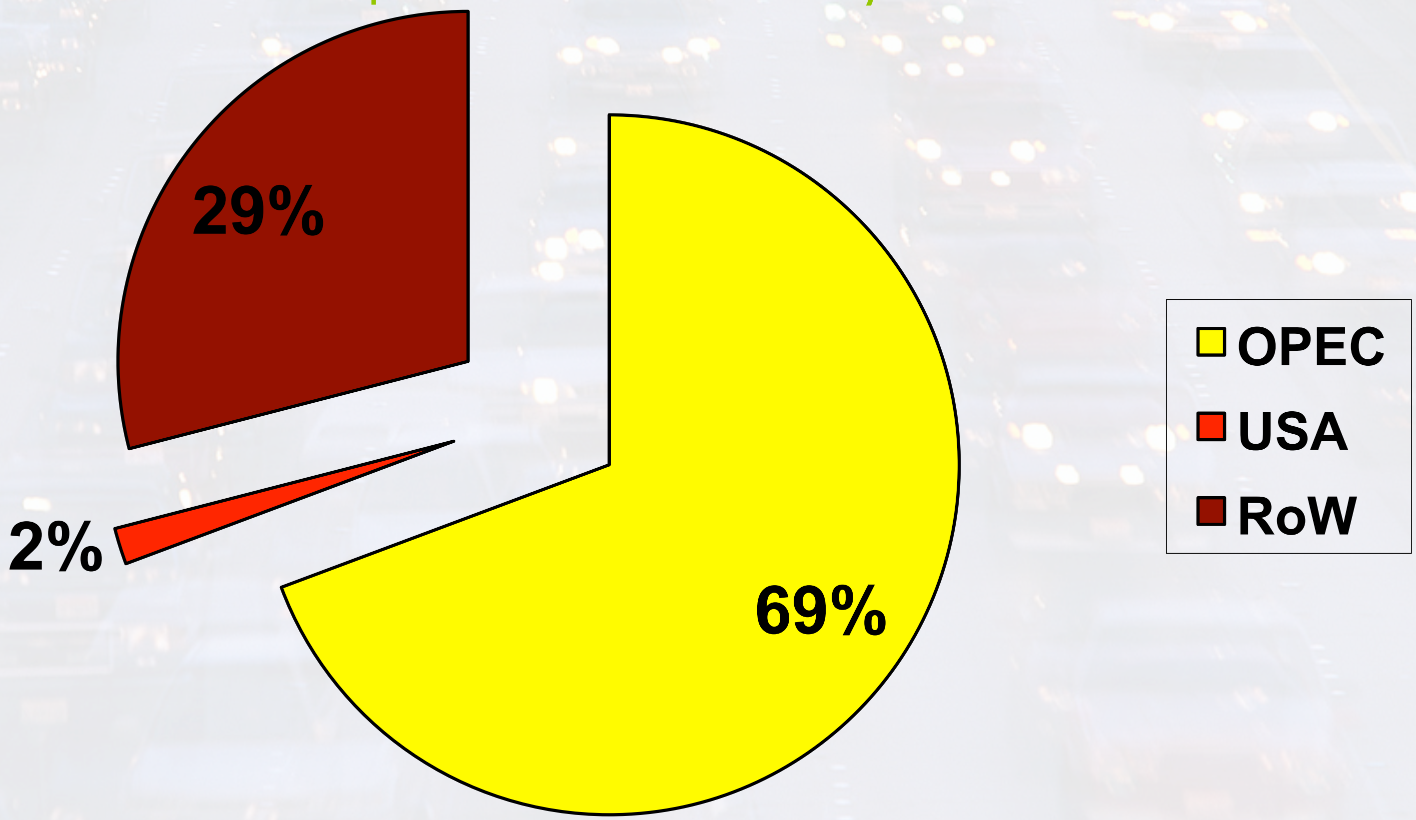
- Workshops & Seminars
- Fuel & Tech Trainings
- Technology Showcases
- Individual Consulting

Energy Security

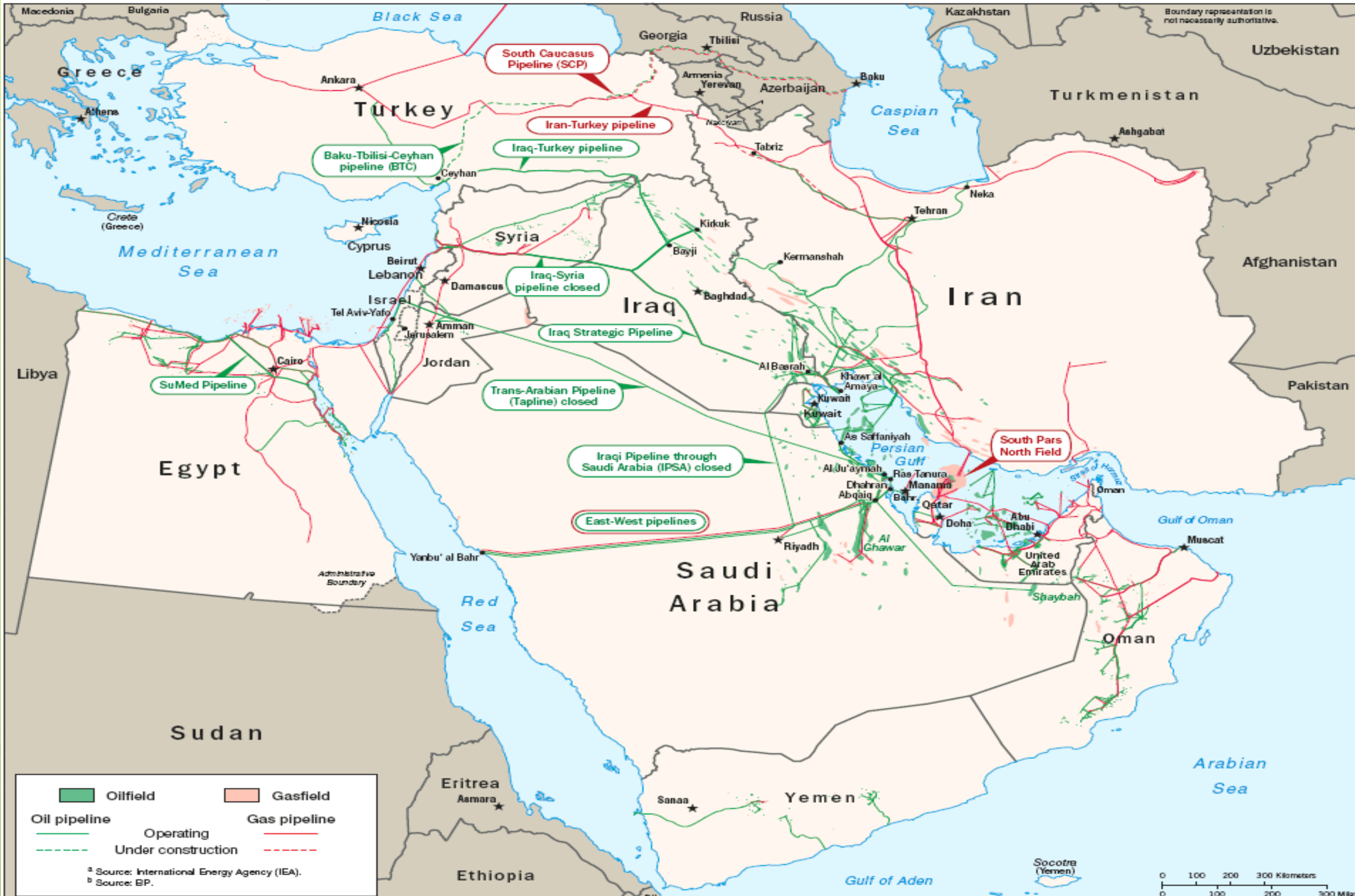
Ownership of proven oil reserves

(state-owned oil companies own 81%)

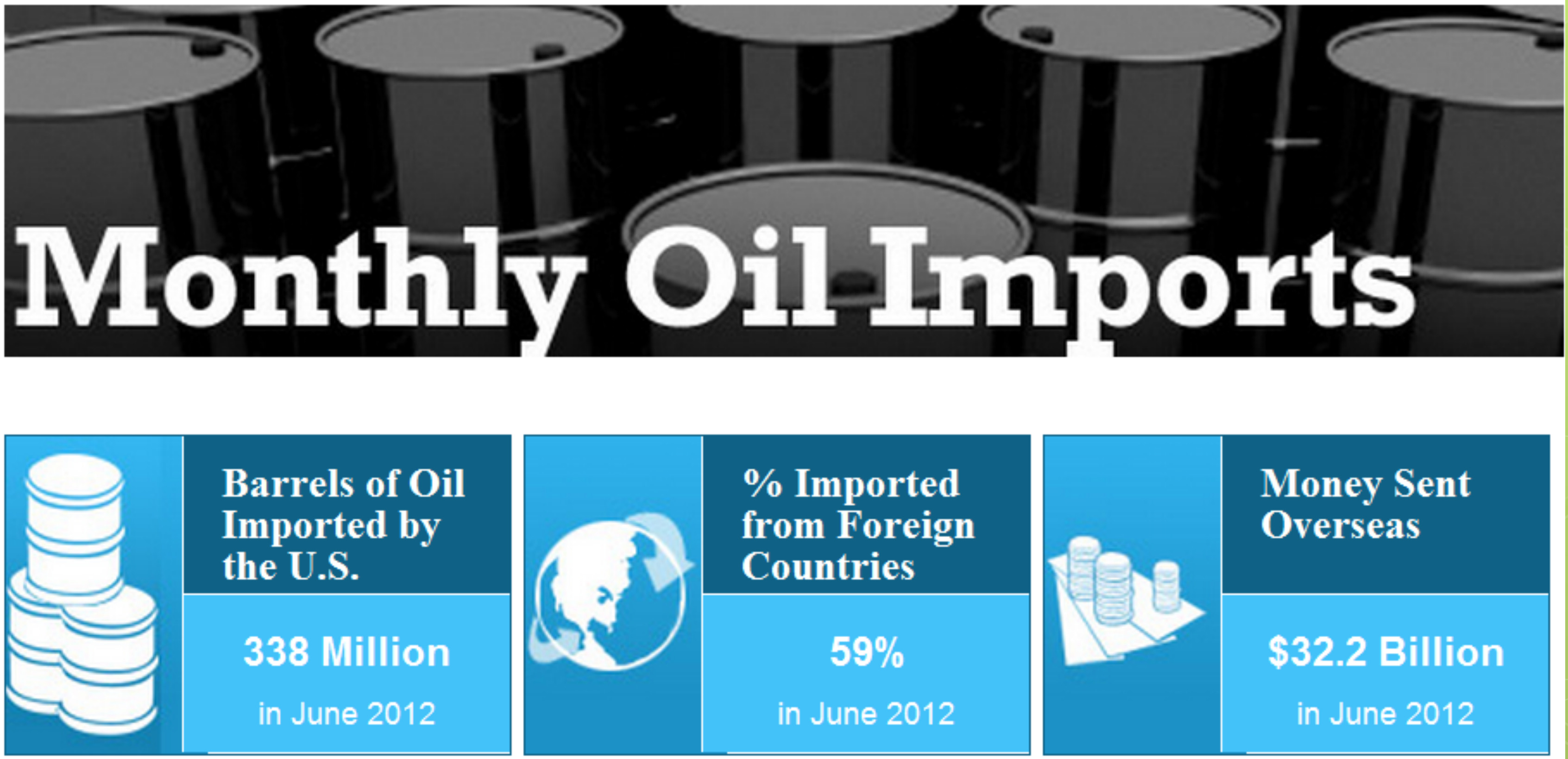


Source: U.S. Energy Information Administration, 2009.
http://www.eia.doe.gov/emeu/international/reserves.html

Selected Oil and Gas Pipeline Infrastructure in the Middle East



Market Drivers for LNG



Who is the oil and gas industry

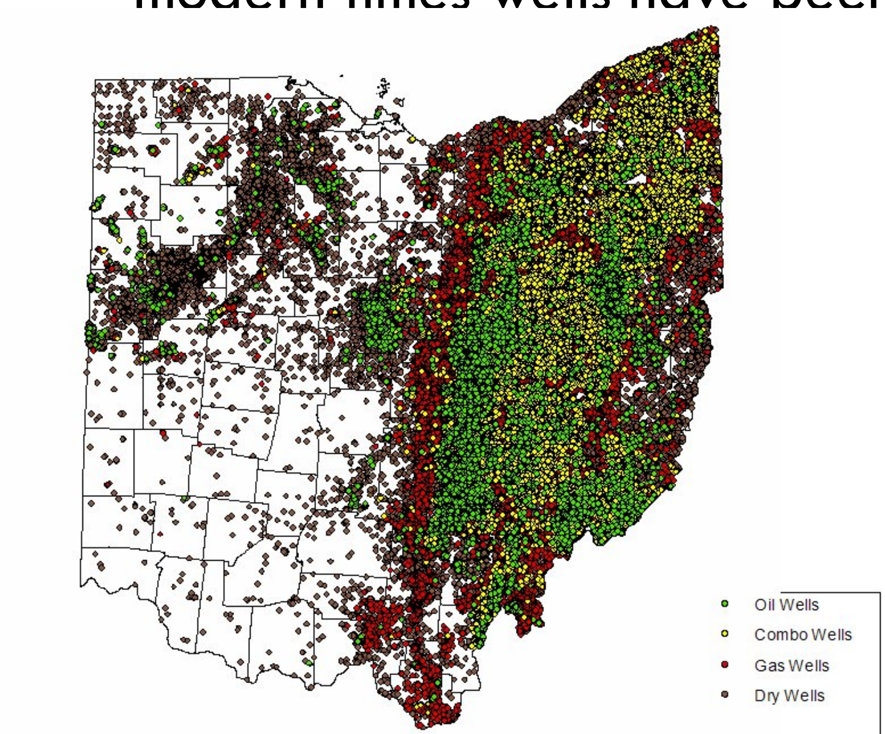
- The ultimate upstream of the industry
- Independent producers: A non-integrated company that receives nearly all revenues from wellhead production.
- Drill 80% of American wells
- Produce 65% of American natural gas
- Produce 54% of American oil
- Employ 2.3 million upstream jobs

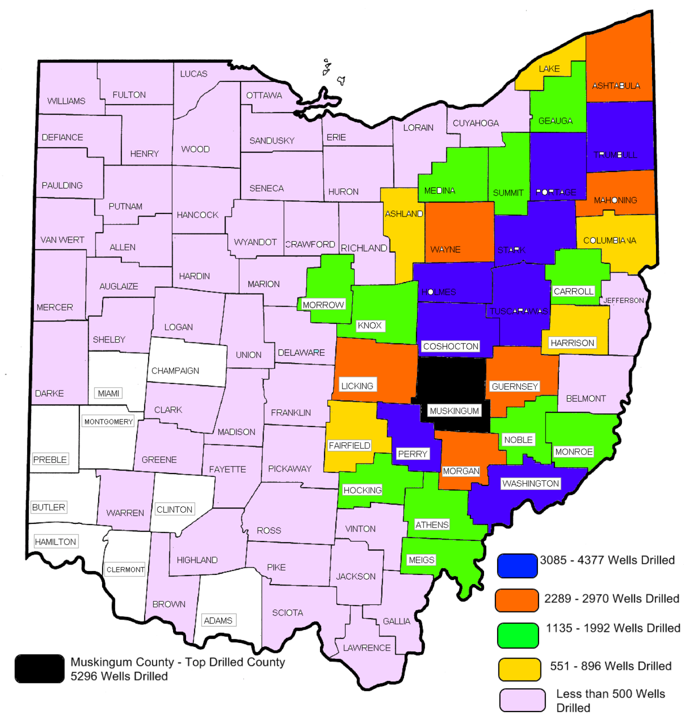
Oil & gas wells in Ohio

- Over time there have 275,774 wells drilled for oil and gas in Ohio
- Today, there are 64,378 wells in production in Ohio
- Across all of Ohio the drill bit has tested oil and gas reservoirs at depths ranging from less than 100 feet to over 13,700 feet
- A new Ohio record for deepest well ever drilled was established in 2010 in Belmont County, a basement test to the Granite drilled to 13,727 feet

Oil and Gas in Ohio

- Ohio well spot map shows significant development in three of four Ohio quadrants.
- And, while geology dictates that eastern Ohio is dominant, in modern times wells have been drilled in 79 of 88 counties.



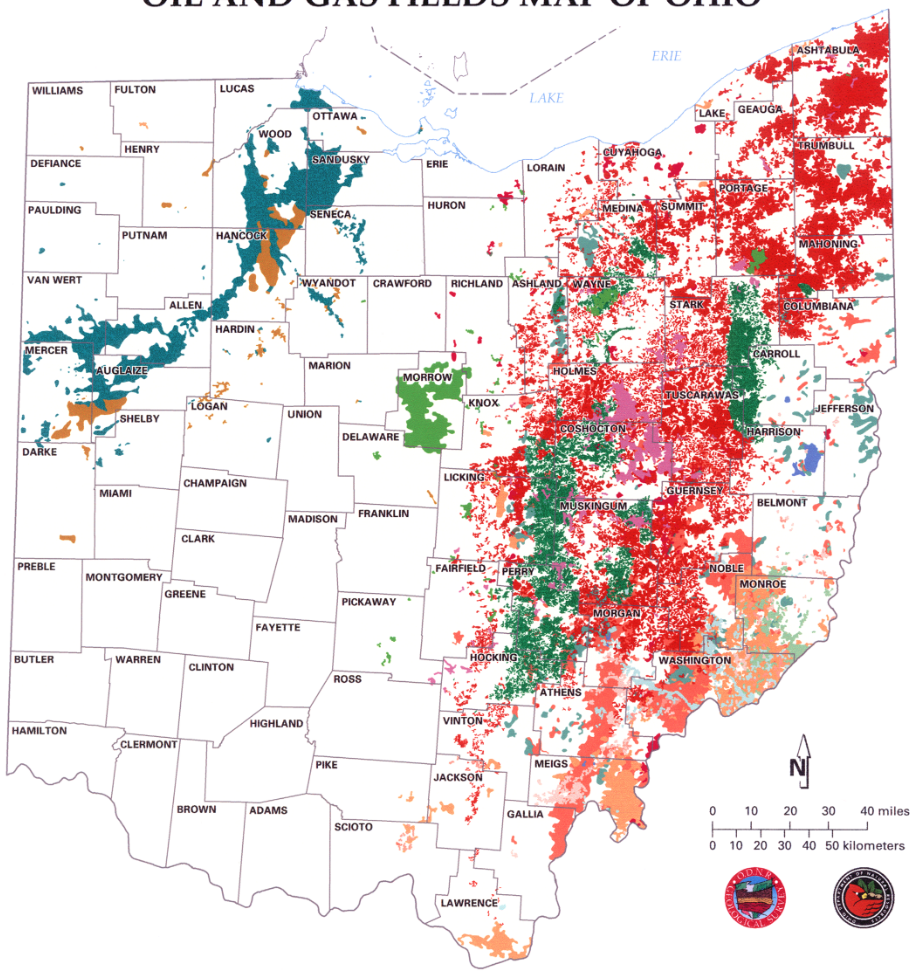


STATE OF OHIO
Bob Taft, Governor

DEPARTMENT OF NATURAL RESOURCES
Samuel W. Speck, Director

DIVISION OF GEOLOGICAL SURVEY
Thomas M. Berg, Chief

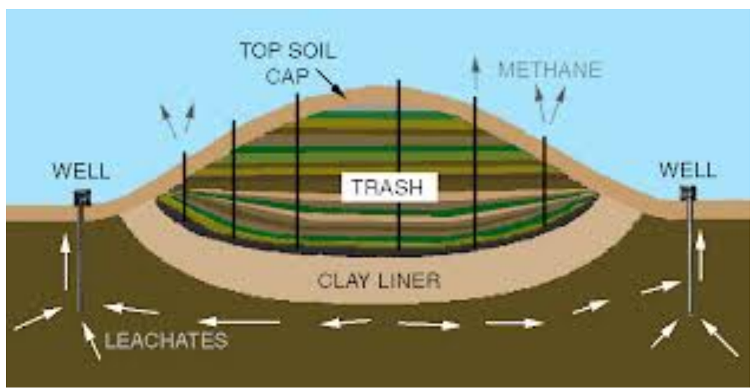
OIL AND GAS FIELDS MAP OF OHIO

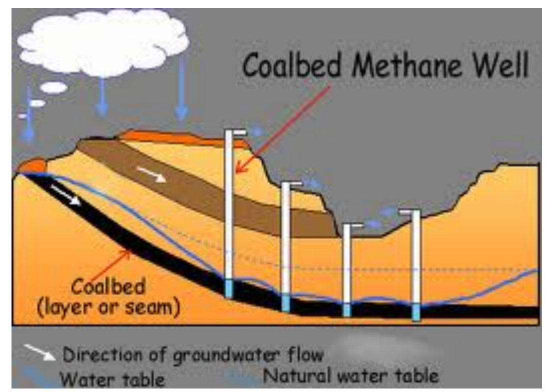


EXPLANATION

OIL FIELD	GAS FIELD	COALBED METHANE	PRODUCING HORIZON(S) GROUPED BY STRATIGRAPHIC INTERVAL
			Pennsylvanian undifferentiated sandstones and coals
			Mississippian undifferentiated sandstones and Maxville Limestone
			Devonian Berea Sandstone and Cussewago Sandstone
			Devonian Ohio Shale and siltstones
			Silurian-Devonian "Big Lime" interval
			Silurian "Clinton/Medina" sandstone and "Packer Shell"
			Ordovician fractured shale, Trenton Limestone, Black River Group, and Wells Creek Formation
			Cambrian-Ordovician Knox Dolomite

Sources of Natural Gas



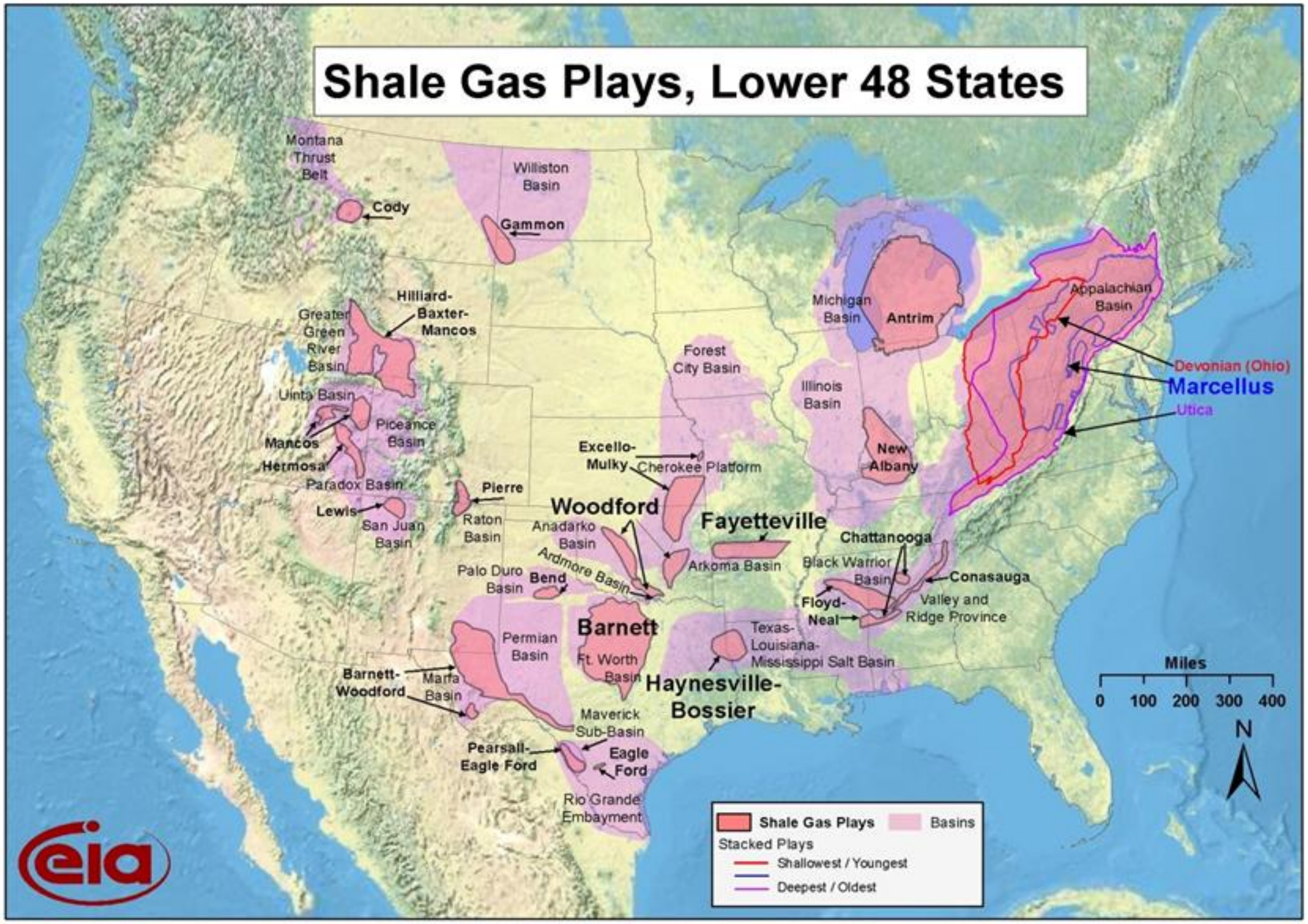


Alternative Gas Sources

- Landfill gas can easily be upgraded* to pipeline quality prior to liquefaction
- LFG is renewable and carries a tax credit of approximately $1.00 per MMBTU
- The acquisition of LFG is very low or zero cost
- The LNG produced from LFG is therefore very low in cost (under $.35 gallon; under $4.20 per MMBTU)
- The LNG product is suitable for pipeline injection or vehicle fuel

* GEI has upgraded LFG to pipeline quality gas at five U.S. landfills

Shale – Growing Impact



Source: Energy Information Administration based on data from various published studies.
Updated: March 10, 2010

Types of Unconventional Gas

Tight Gas

- Occurs in ‘tight’ sandstone
- Low porosity = Little pore space between the rock grains
- Low permeability = gas does not move easily through the rock

Shale Gas

- Natural gas trapped between layers of shale
- Low porosity & ultra-low permeability
- Production via triggered fractures

Coalbed Methane

- Natural gas in coal (organic material converted to methane)
- Permeability low
- Production via natural fractures (“cleats”) in coal
- Recovery rates low

Source: Shell

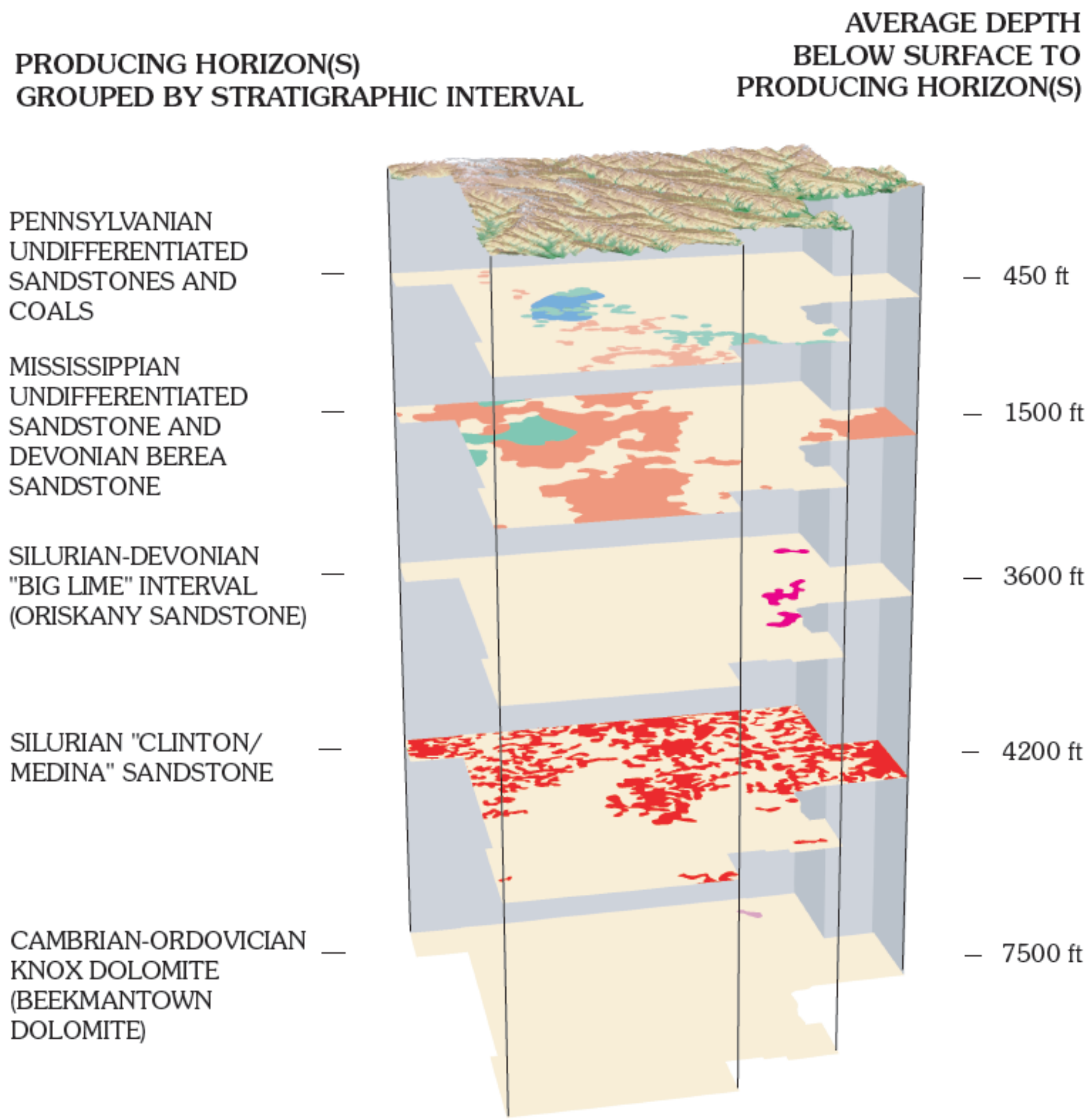
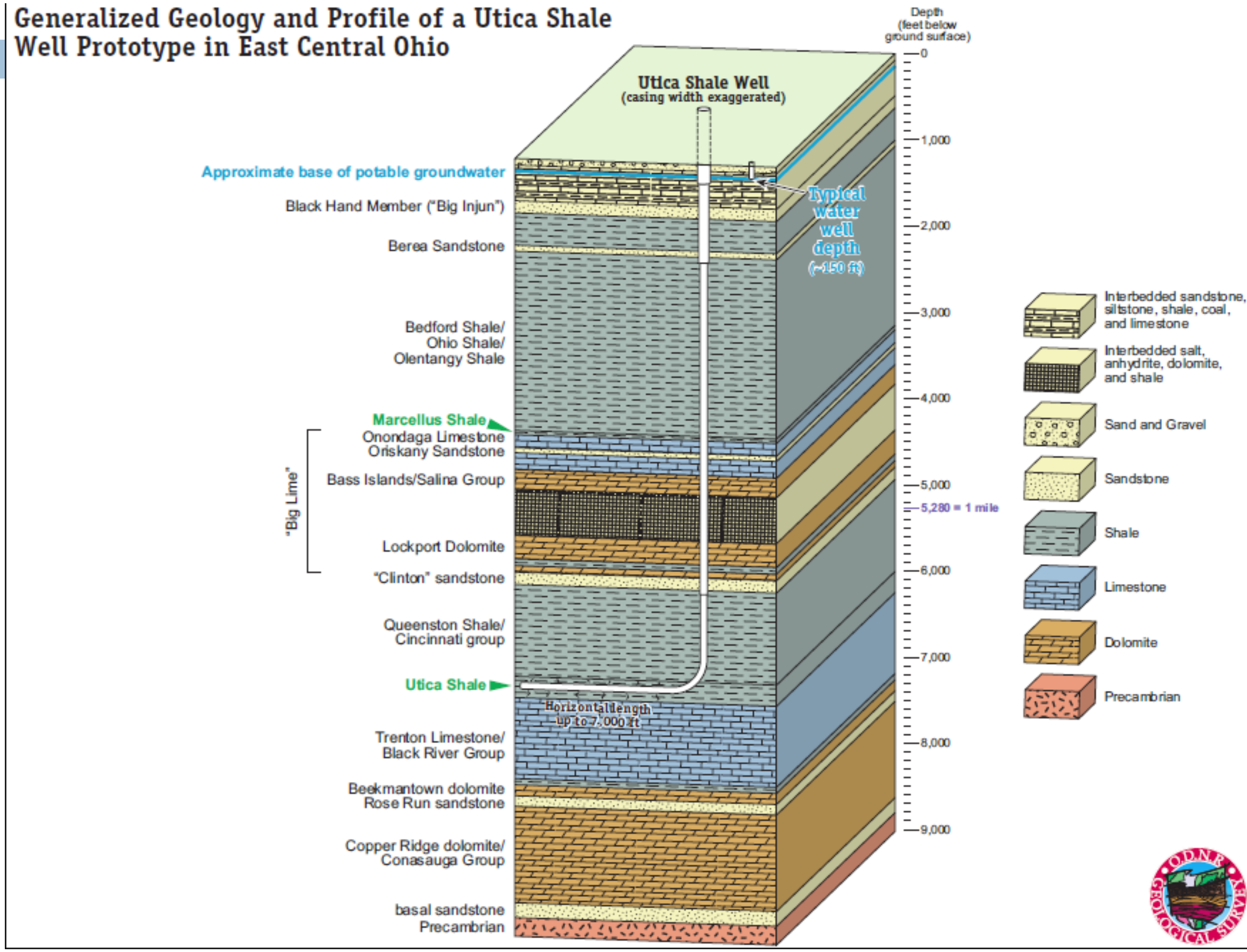


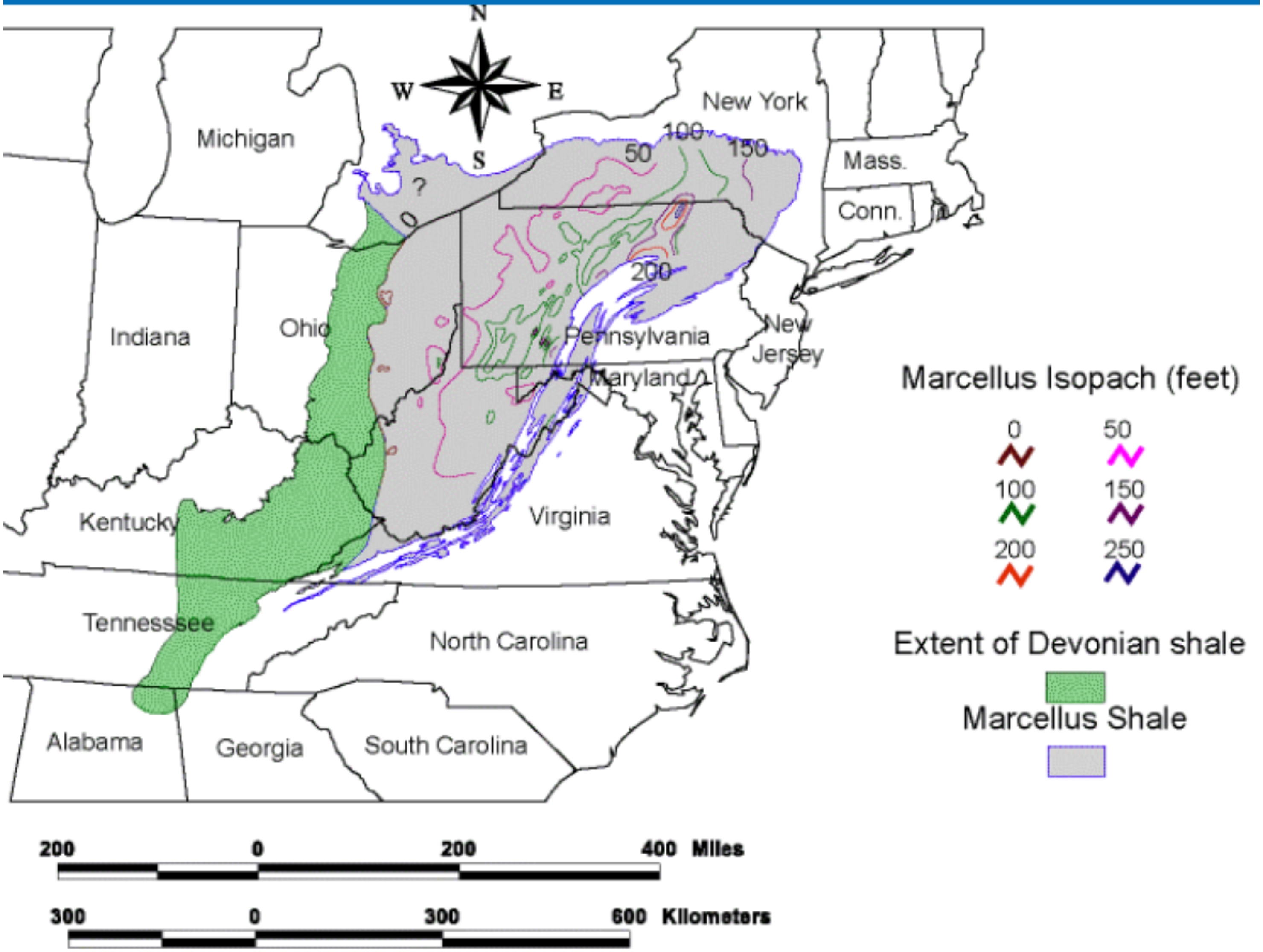
Figure 1. Three-dimensional block diagram in Morgan County illustrating the multiple, stacked, overlapping pool and field boundaries from producing horizons ranging in age from Cambrian to Pennsylvanian. The vertical scale is variable and has been exaggerated for display purposes.

Shale



Generalized Geology and Profile of a Utica Shale Well Prototype in East Central Ohio
Utica Shale Well
(casing width exaggerated)
Depth (feet below ground surface)
0
1,000
2,000
3,000
4,000
5,000
5,280 = 1 mile
6,000
7,000
8,000
9,000
Approximate base of potable groundwater
Black Hand Member ("Big Injun")
Berea Sandstone
Bedford Shale/ Ohio Shale/ Olentangy Shale
Marcellus Shale
Onondaga Limestone
Oriskany Sandstone
Bass Islands/Salina Group
Lockport Dolomite
"Clinton" sandstone
"Big Lime"
Queenston Shale/ Cincinnati group
Utica Shale
Horizontal length up to 7,000 ft
Trenton Limestone/ Black River Group
Beekmantown dolomite
Rose Run sandstone
Copper Ridge dolomite/ Conasauga Group
basal sandstone
Precambrian
Typical water well depth (~150 ft)
Interbedded sandstone, siltstone, shale, coal, and limestone
Interbedded salt, anhydrite, dolomite, and shale
Sand and Gravel
Sandstone
Shale
Limestone
Dolomite
Precambrian
ODNR GEOLOGICAL SURVEY

Marcellus Shale



opach map of the Marcellus Shale in the Appalachian basin.
rom: Milici, R.C., 2005, Assessment of undiscovered natural gas resources in Devonian black shales, Appalachian Basin, eastern U.S.A.: U.S. Geological Survey Open-File Report 2005-1268, l p., last accessed September 10, 2010, at <http://pubs.usgs.gov/of/2005/1268/>.)

Utica/Point Pleasant Recoverable Reserve Potential Estimate for Ohio

IF we assume 1/3 of volume will be gas and 2/3 is oil…

%R = 1.2 percent – recoverable from the interval
Qt = 1.96 billion barrels equivalent
= **3.75 TCF gas and 1.31 Billion barrels oil**

%R = 5 percent - recoverable from the interval
Qt = 8.2 billion barrels equivalent
= **15.7 TCF and 5.5 Billion barrels oil**

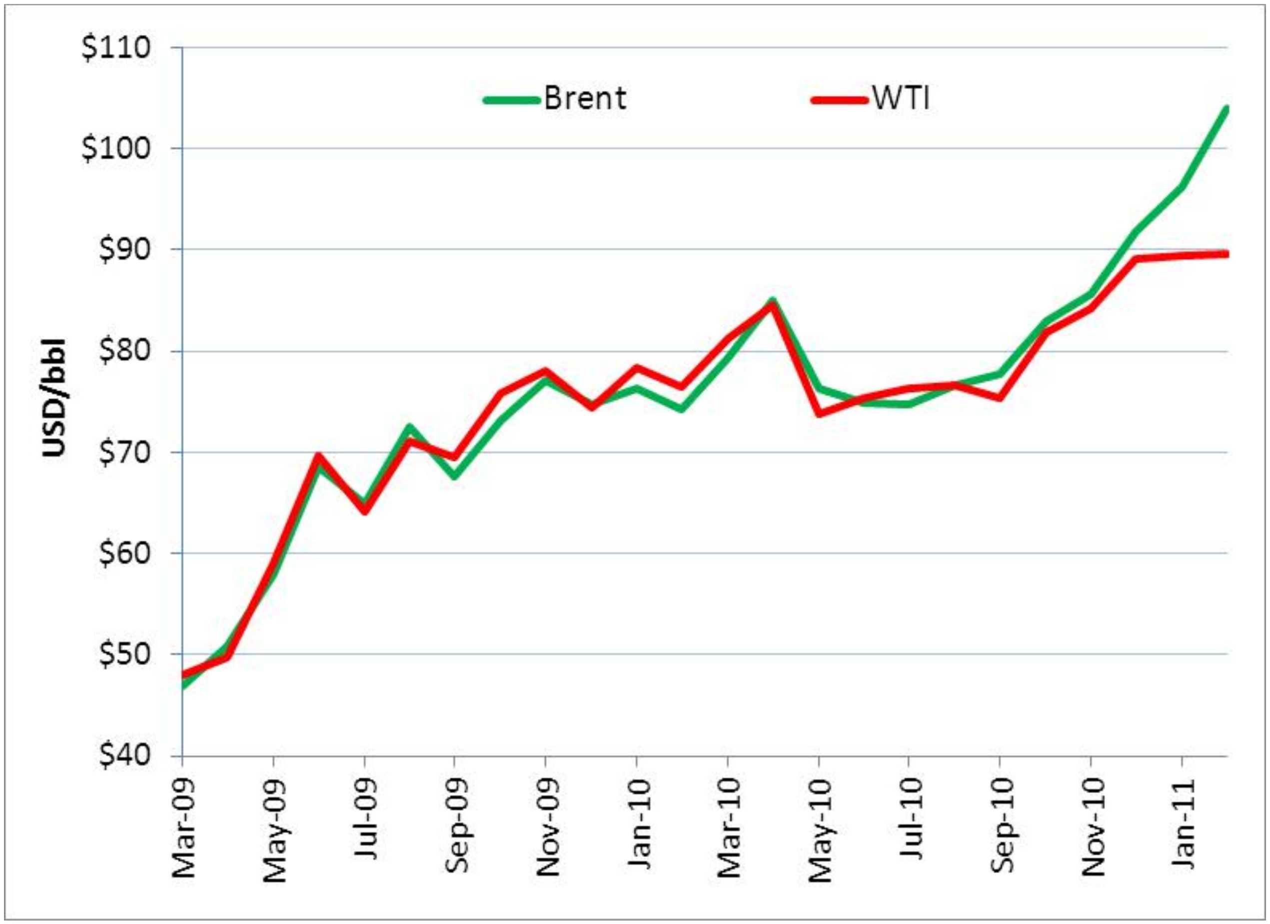
The prospects of shale gas

- Shale gas is so far only produced in North America. Its true potential is still a matter of uncertainty.
- Environmental concerns revolve around ground water contamination resulting from hydraulic fracturing. Governments, together with industry, are addressing new regulation for shale extraction to protect public health and environment.
- Energy used for production and its CO_2 emission is higher than for conventional gas.

Does it really make a difference??

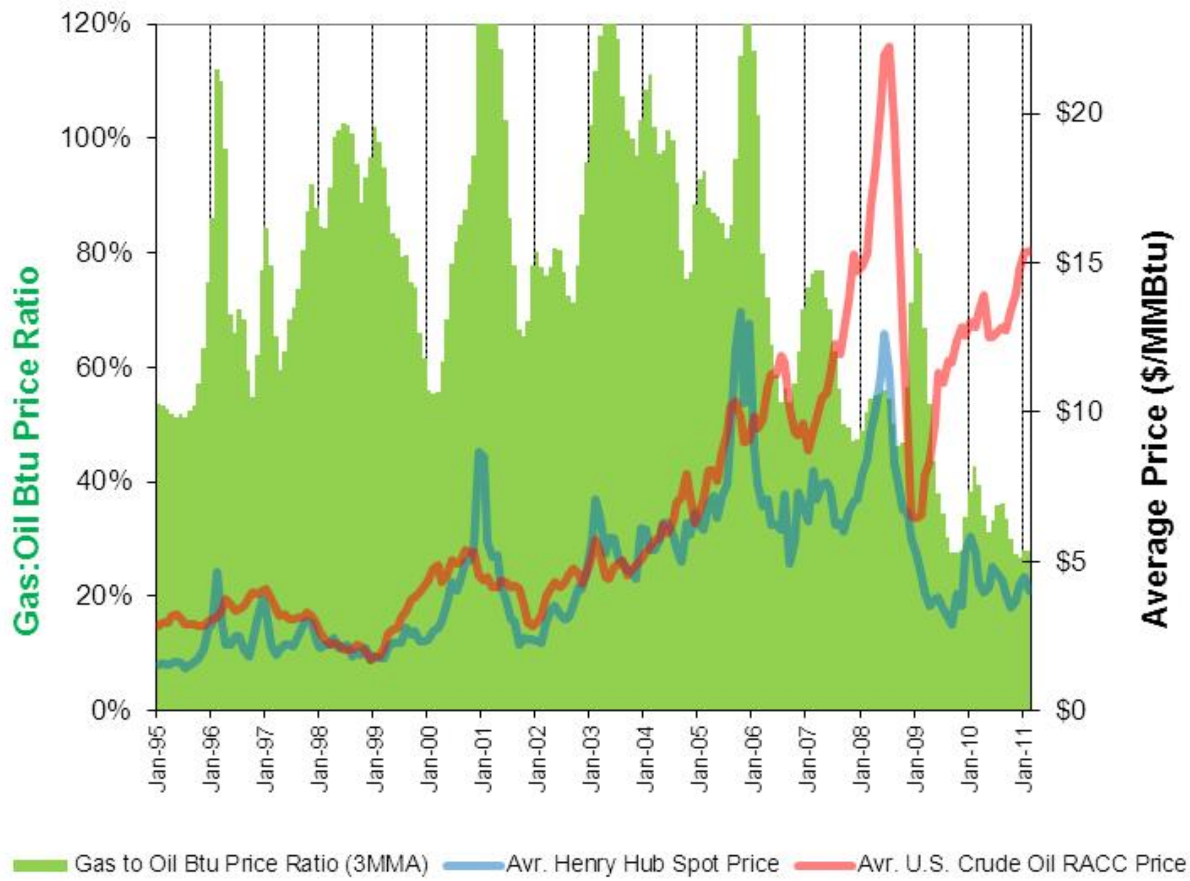
World Oil Prices: last 24 months

Source: Bloomberg



Does it really make a difference??

U.S. Gas and Oil Prices (1995- Feb. 2011)

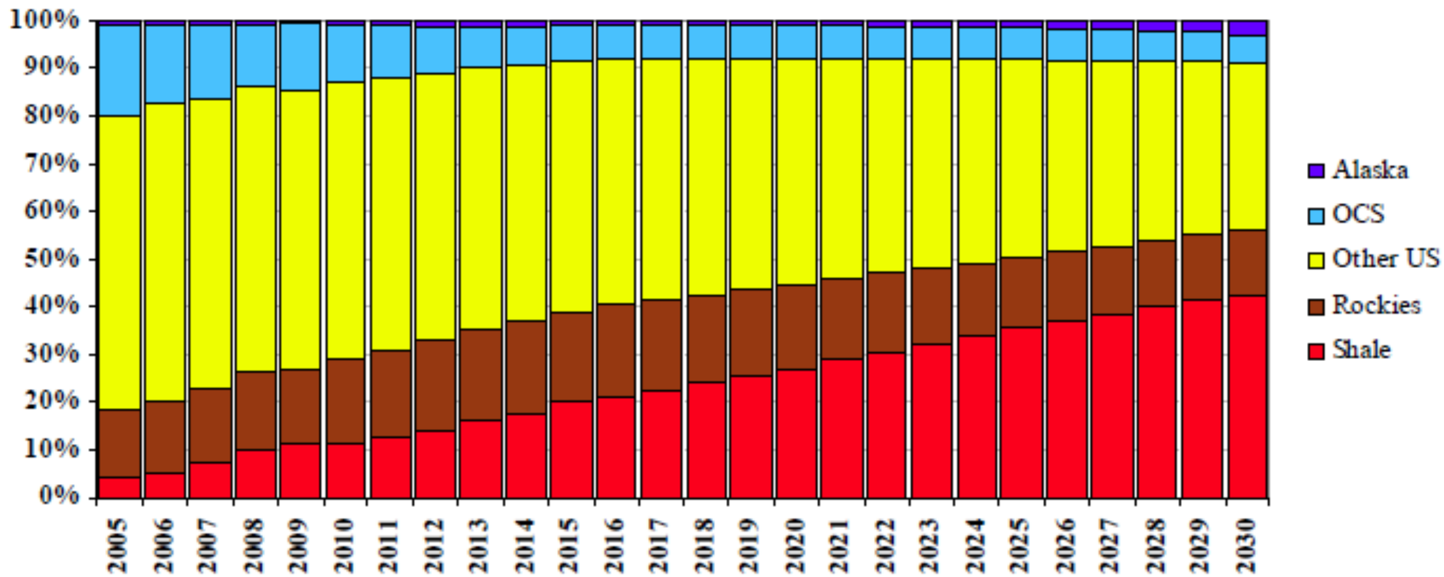


Does it really make a difference in Ohio ??

- **Local Supply = Less Disruptions = Less Volatility**
- Local production – natural gas produced in our own backyard – is a safeguard that offers market protections against pipeline capacity and delivery constraints, particularly during peak demand periods. This represents a unique value to a state, such as Ohio, that is an industrialized large consumer of natural gas.
- Also, because of local production feeding into the eastern Ohio distribution system, Ohio citizens tend not to experience the extreme price swings caused by short-term peak-demand volatility that many other high-population centers suffered during recent years.
- Saves Ohio $60 million in avoided interstate costs
- Saves Ohio $5 million in price reduction effect

Growth of unconventional gas production
Impact on US supply

Developments of shale production in the United States have a major effect on the US market and will impact rest of the world



US shale production grows to about 45 % of total production by 2030

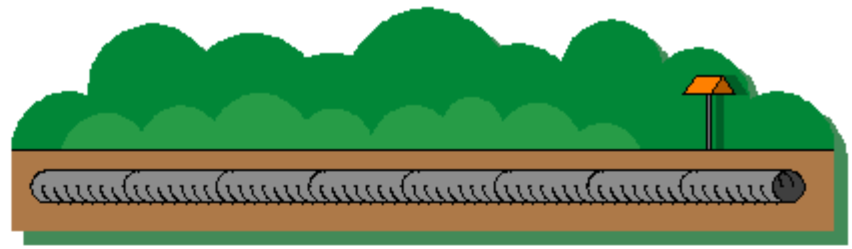
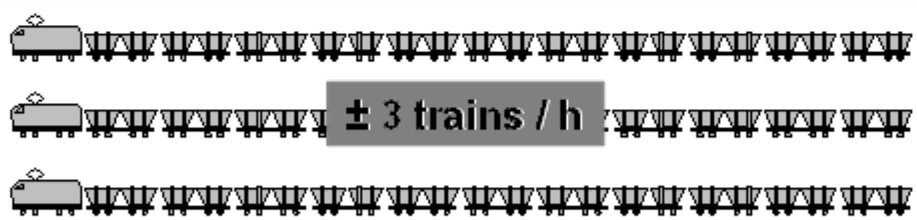
Source: James Baker Institute, Rice, 2010

Energy Transportation

daily equivalents

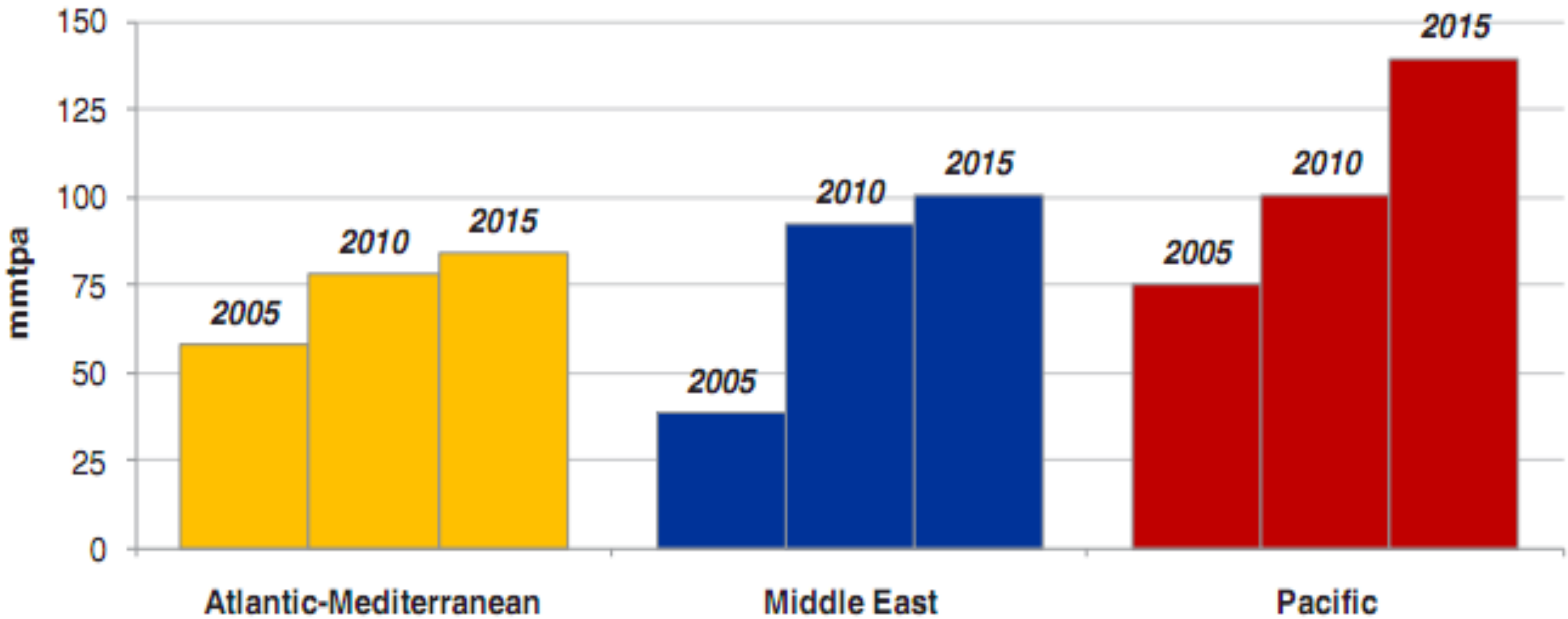
Basis: equivalent of 50 million m³/day of natural gas

(1 large pipeline 48” or 56”)

Natural gas	1 underground pipeline	
gasoil (diesel)	1465 gasoil trucks	
coal	1518 wagons (69 trains)	

Source: Energy Delta Institute

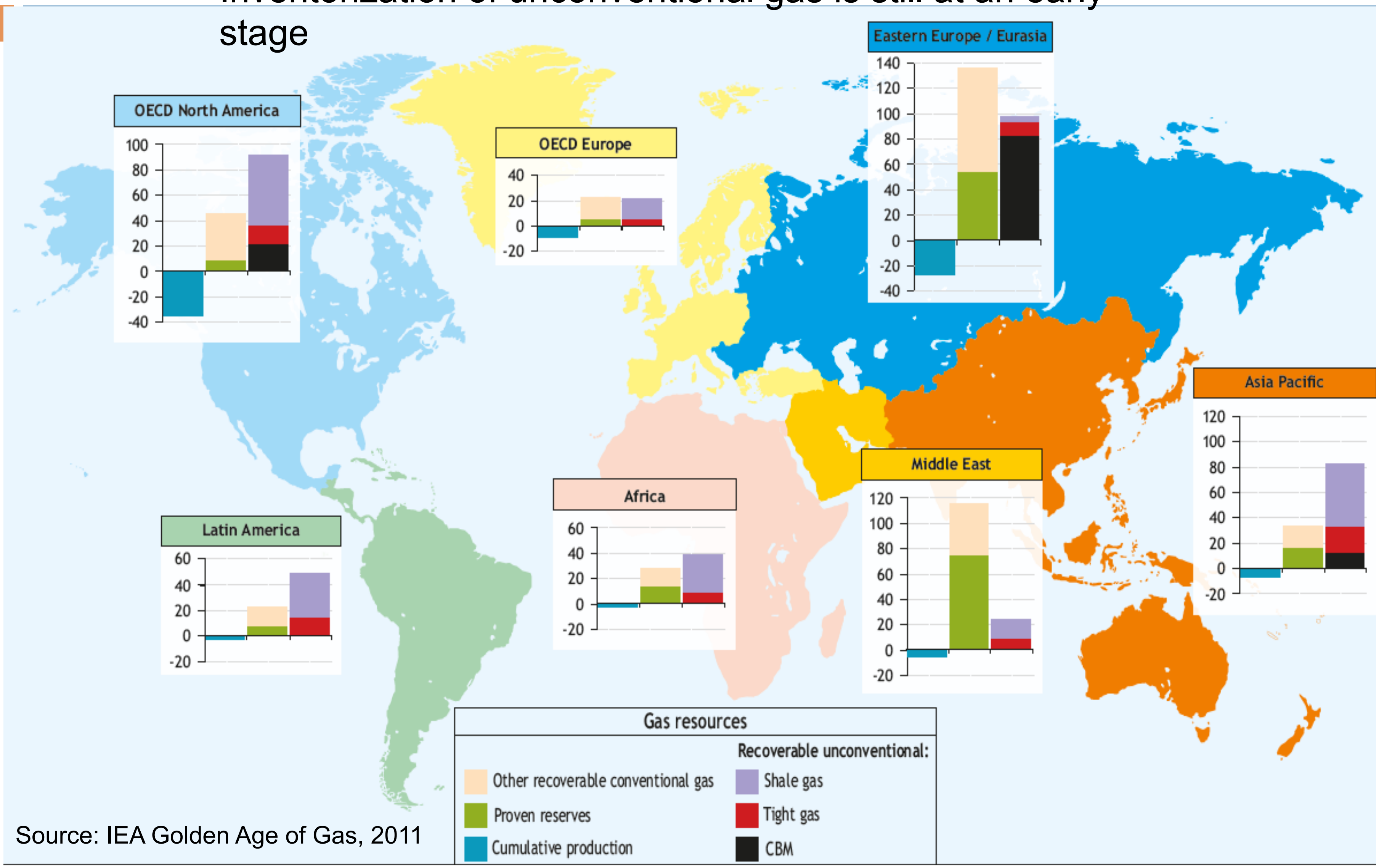
LNG Production Growing in all Global Regions



Source: IGU World LNG Report, June 2011 (PFC)

World gas resources by major region (tcm) significant unconventional prospects world-wide

Inventorization of unconventional gas is still at an early stage



Source: IEA Golden Age of Gas, 2011

Hydraulic Fracturing OOAG

- Conditions needed to complete a economically successful oil an gas well:
- Porosity: Oil and gas trapped in the pore spaces of a reservoir rock
- Permeability: The pore spaces are connected allowing fluid to move through the rock
- Most productive wells have good porosity but poor permeability

Hydraulic Fracturing OOAG

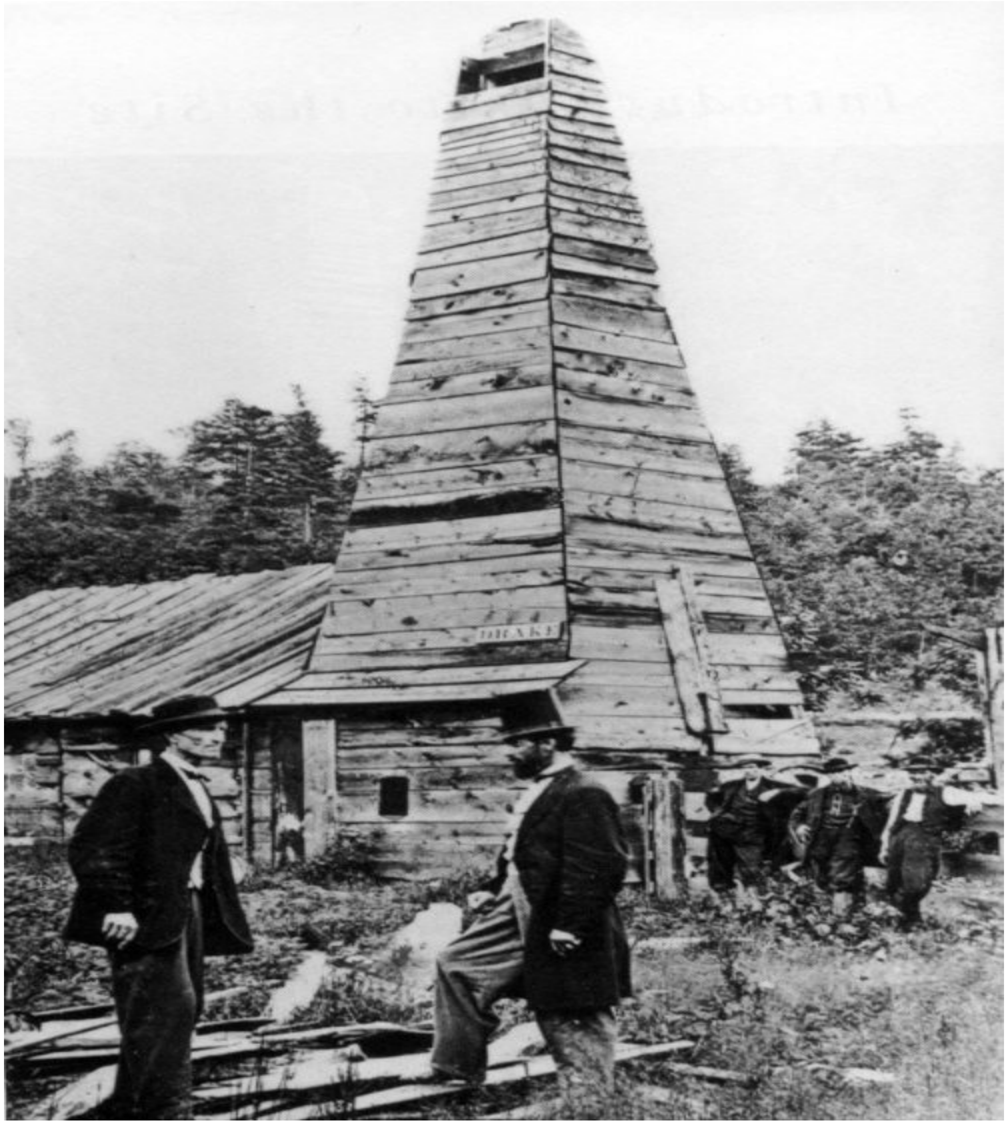
- A producer “fracs” a well to increase the flow of oil and gas from the rock, known to contain oil and gas, but where the rock’s natural permeability does not allow oil and gas to reach the wellbore in sufficient volumes.
- Hydraulic fracturing is “well stimulation” - the process of applying hydraulic force, using water, to induce and extend a fracture in a reservoir rock.
- To frac a well is to create a drainage ditch – a pathway - that penetrates horizontally into the oil and gas bearing reservoir rock.
- Hydraulic fracturing makes the impossible possible by allowing us to reach oil and gas trapped in rock beds that would not otherwise naturally produce.

Hydraulic Fracturing in Ohio OOAG

- 1951 – First Ohio frac job
  - 1958 Study - as a result of fracturing, the Clinton dry hole rate of 42% in 1951 decreased to 15% by 1957 and that, "as a result of the success of hydraulic fracturing, many submarginal areas which would have been economically undesirable, are now being produced profitably."
- Today – over **80,000 wells have been fraced** in Ohio oil and gas formations ranging from 1,000' to 10,000'.

- "*After 25 years of investigating citizens complaints, DMRM (ODNR) geologists have not documented a single incident involving contamination of ground water attributed to hydraulic fracturing*"
  - Scott Kell, deputy chief, ODNR/DMRM in testimony submitted to the Committee on Natural Resources, Energy and Mineral Resources Subcommittee, U.S. House of Representatives, June 4, 2009.

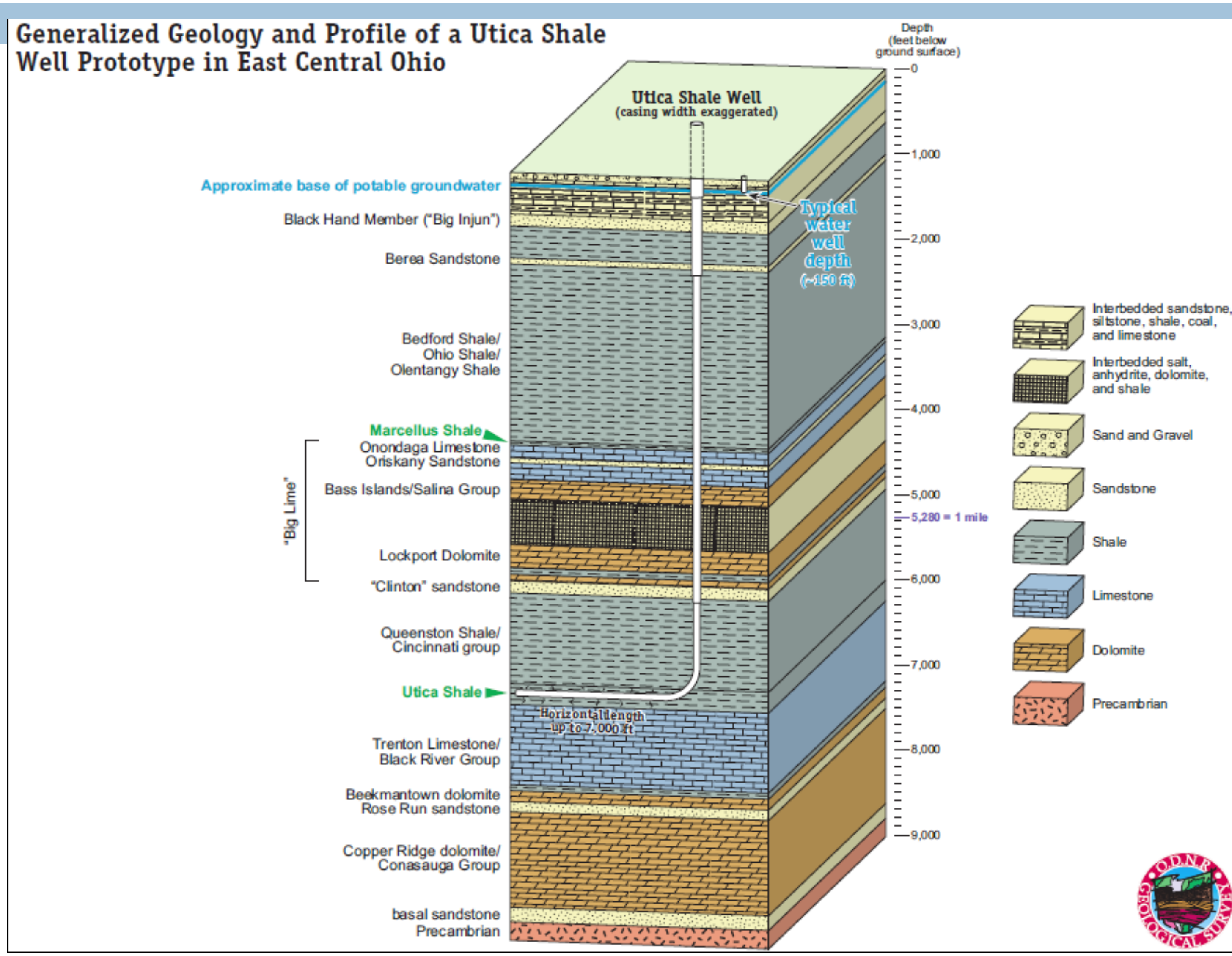
Early Drill Site




ROEBLING'S


Rig
#12

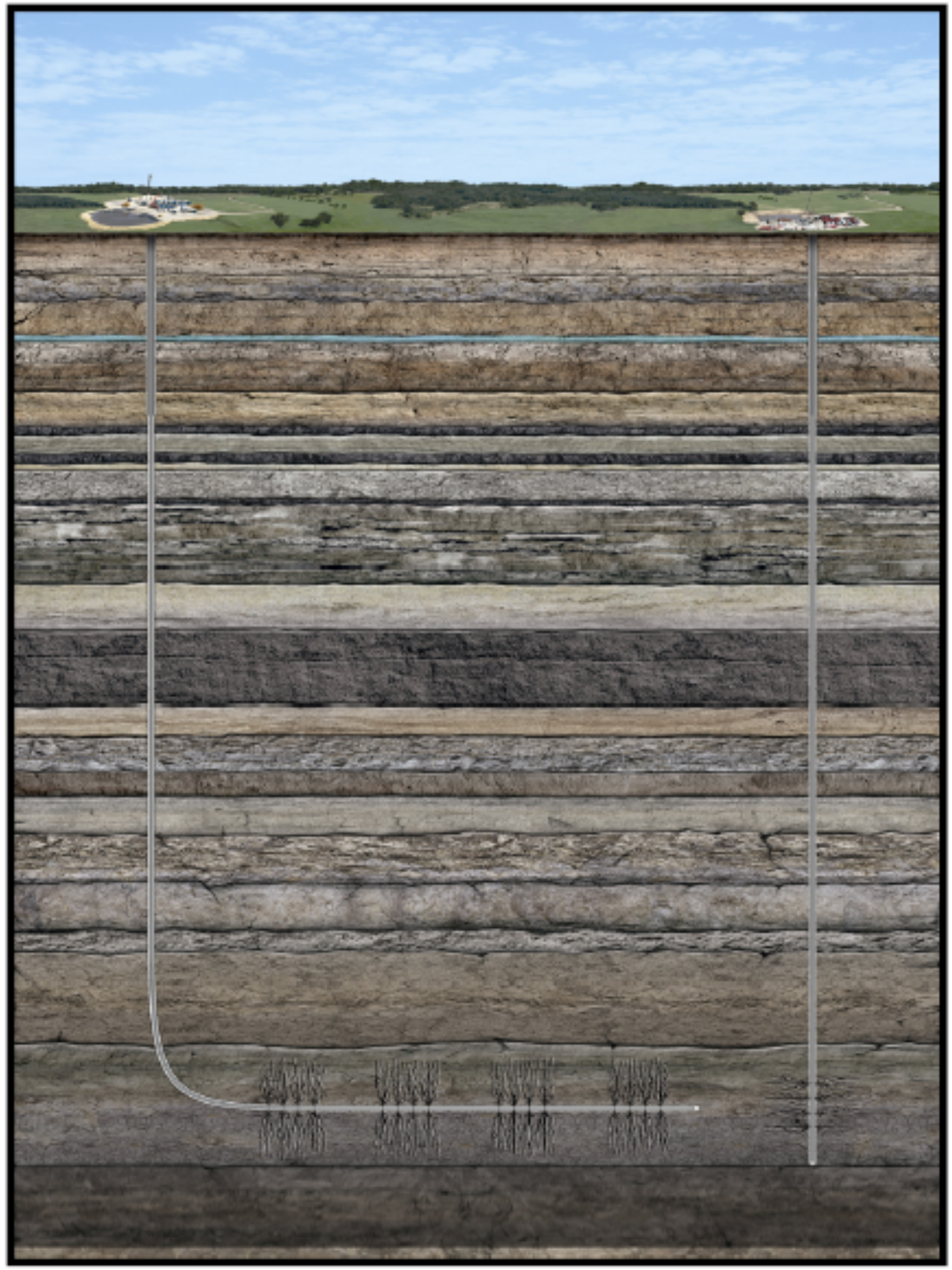
Lithostatic Overburden & Frac Gradient



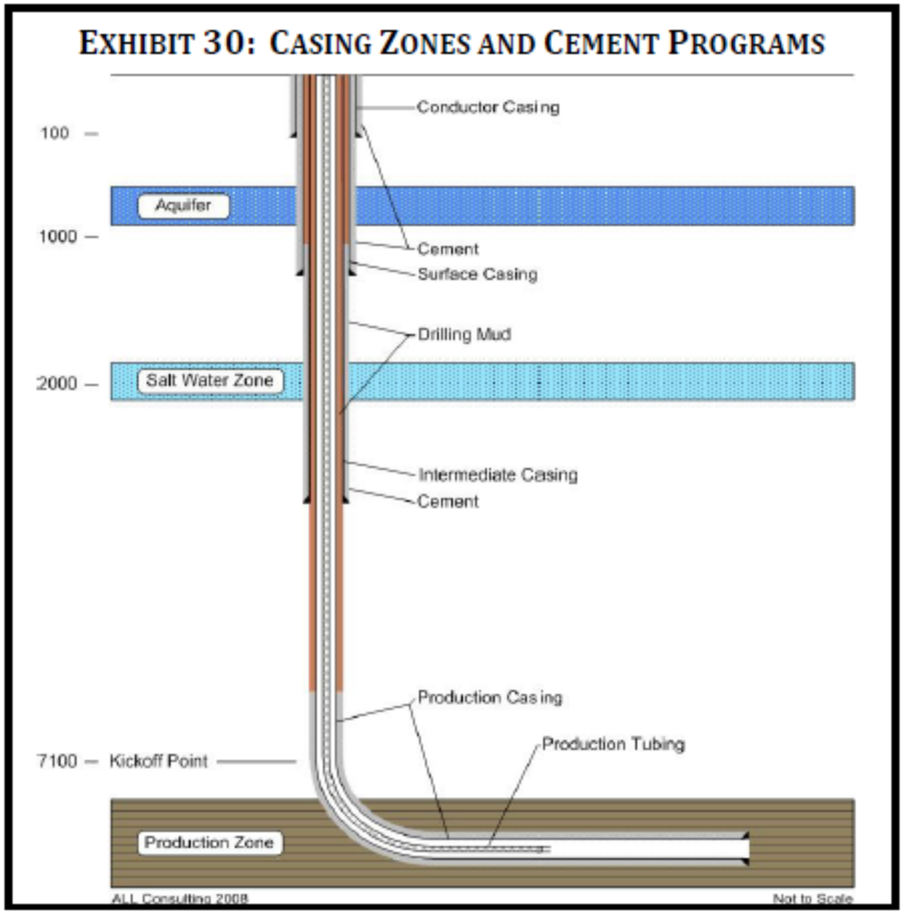
Well Types

- Vertical
- Horizontal

- A horizontal well is in reality many wells within one wellbore



Well Construction



Pump Jack

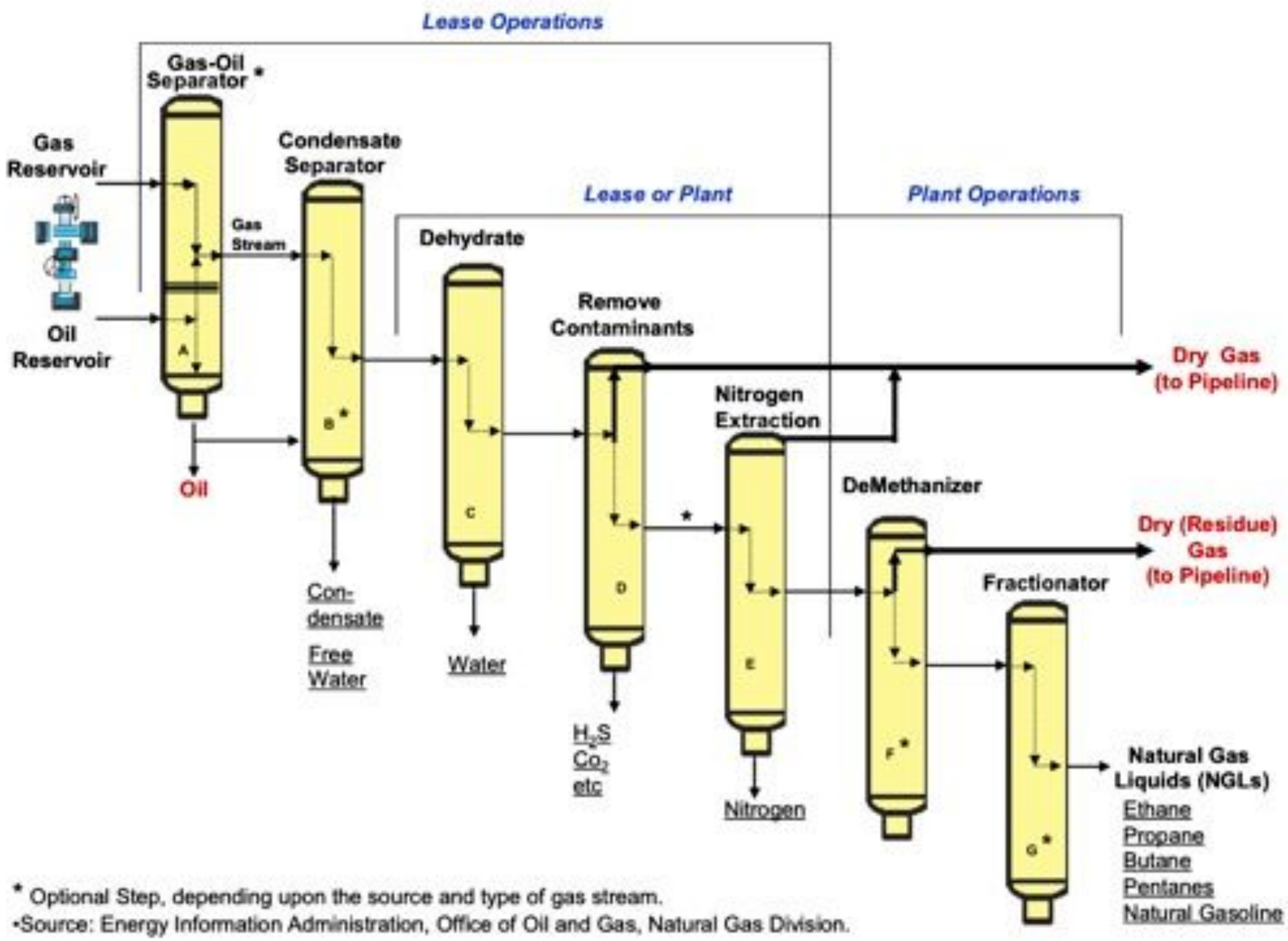
Pump Jack

- A pumpjack is the overground drive for a reciprocating piston pump in an oil well.
- It is used to mechanically lift liquid out of the well if there is not enough bottom hole pressure for the liquid to flow all the way to the surface. The arrangement is commonly used for onshore wells producing little oil. Pumpjacks are common in oil-rich areas.
- Depending on the size of the pump, it generally produces 5 to 40 litres of liquid at each stroke. Often this is an emulsion of crude oil and water. Pump size is also determined by the depth and weight of the oil to remove, with deeper extraction requiring more power to move the heavier lengths of sucker rods.
- A pumpjack converts the rotary mechanism of the motor to a vertical reciprocating motion to drive the pump shaft, and is exhibited in the characteristic nodding motion. The engineering term for this type of mechanism is a walking beam. It was often employed in stationary and marine steam engine designs in the 18th and 19th centuries.

Key Natural Gas Properties

- Natural Gas Mixture of Gases
- Methane - usually > 90%, CH_4, -257.8 degree F
- Ethane, C_2H_6, -127 degree F
- Propane, C_3H_8, -44 degree F
- Butane, C_4H_{10}, 31.1 degree F
- Nitrogen, N_2, -320 degree F
- CO_2 – Not in LNG, Dry Ice at -108 degree F
- F (no liquid state at pressures below ~ 5 atmospheres)

Natural Gas Processing



Refining of Natural Gas

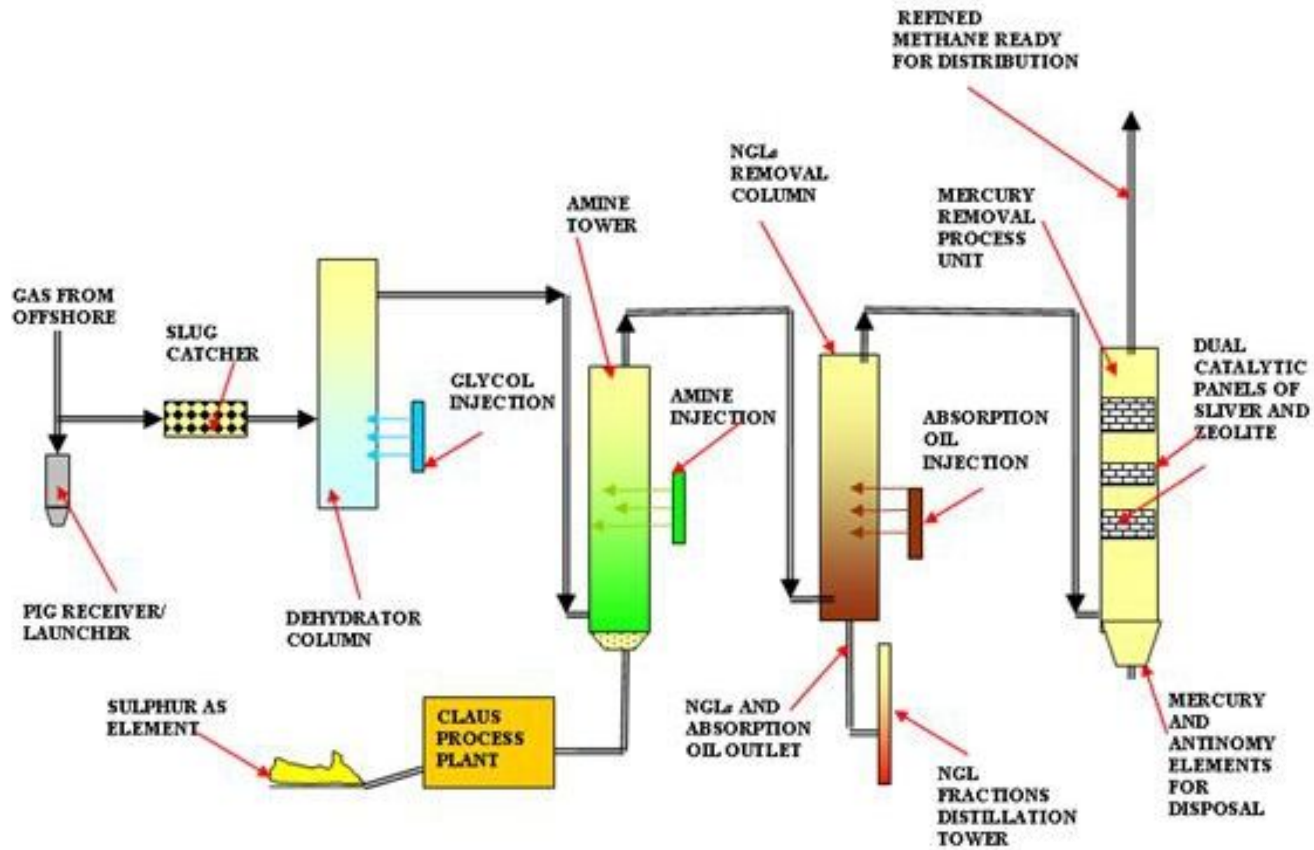
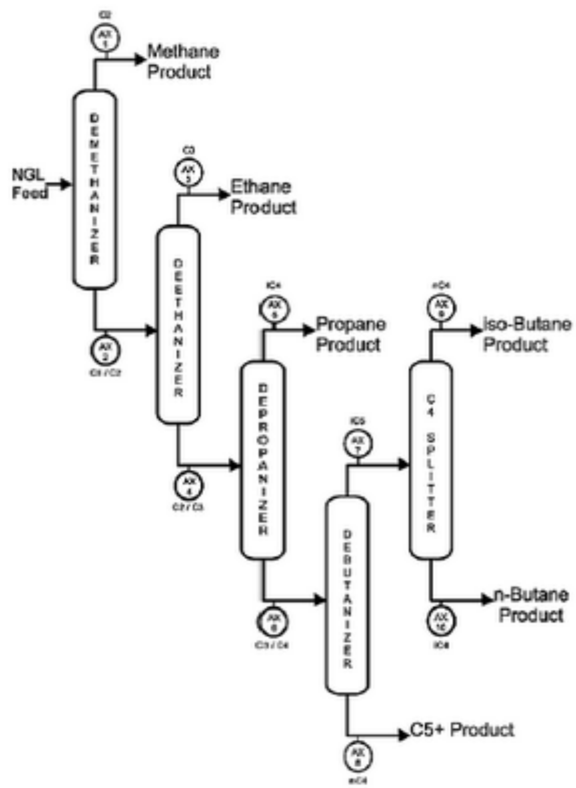
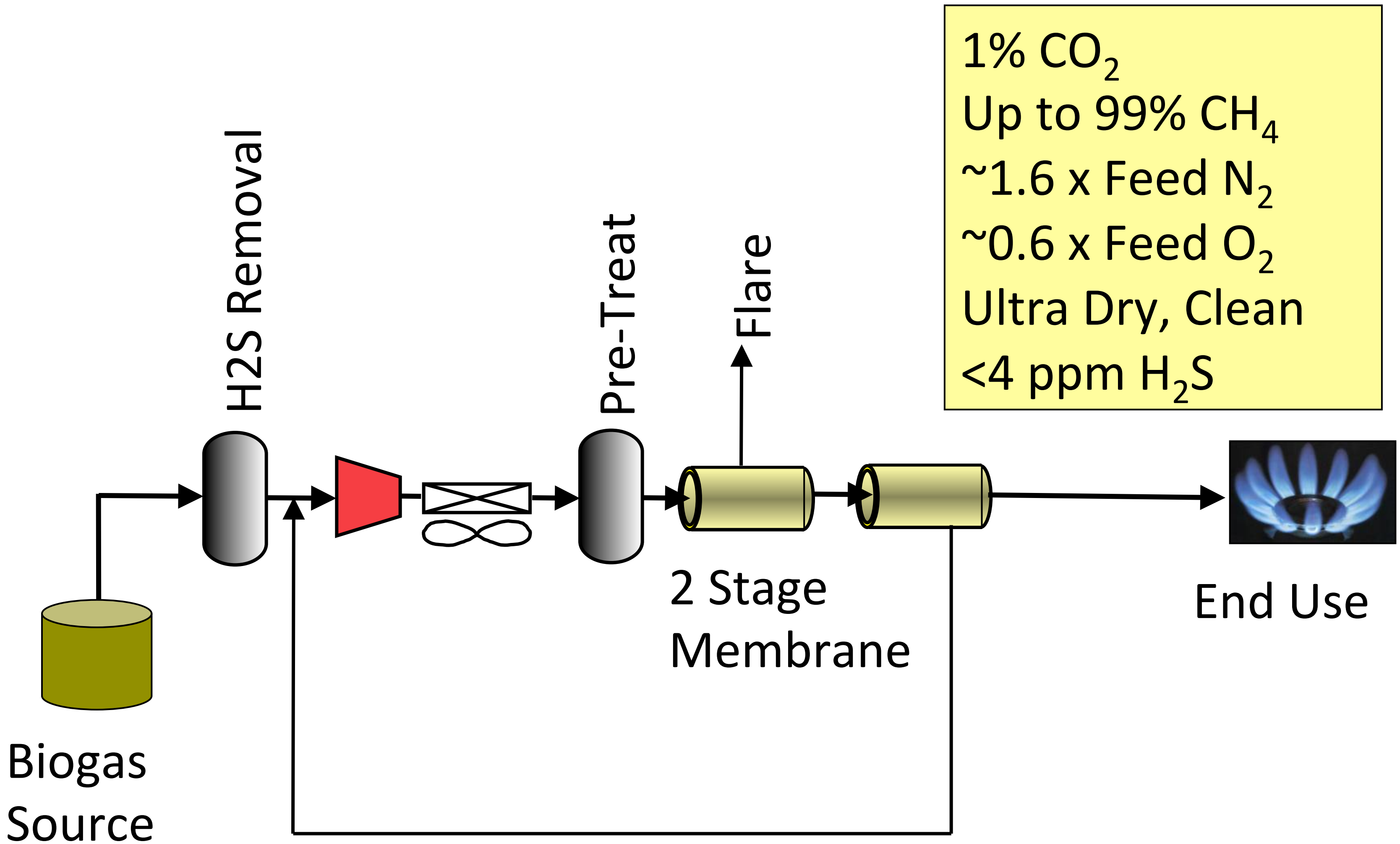


Diagram NGL Separator

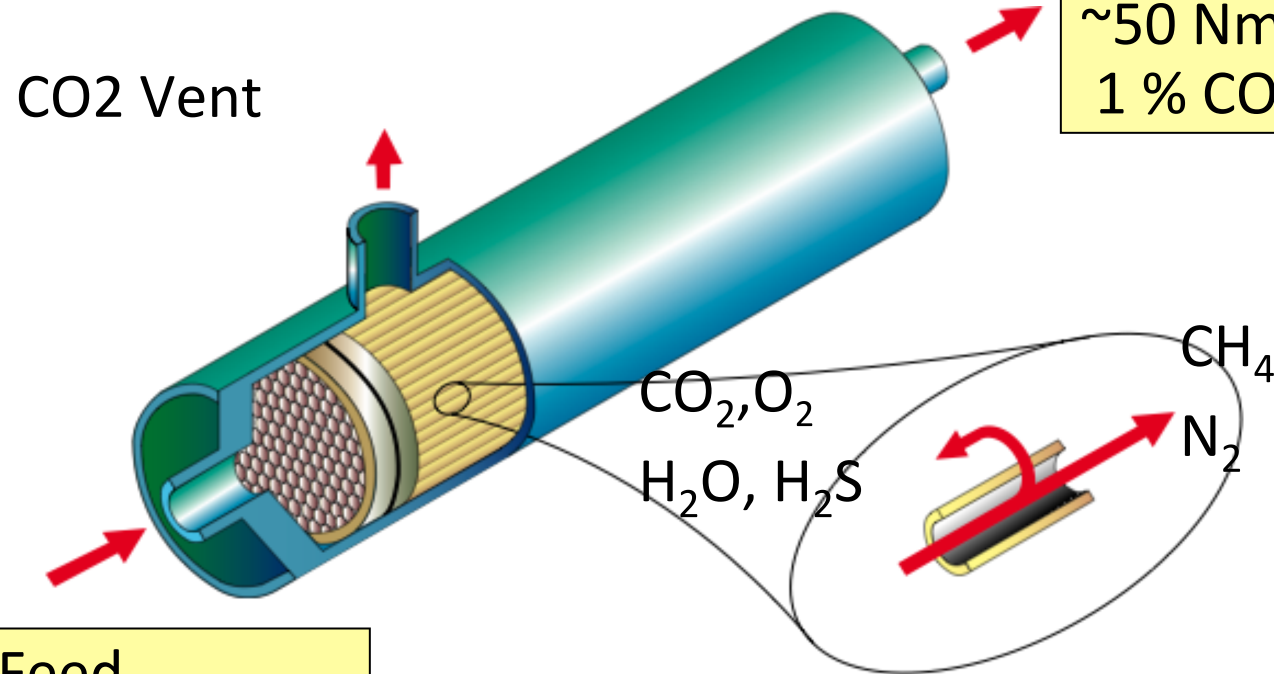


Air Liquide Simplified Biogaz System



How the Biogaz Membrane Works

Product
~50 Nm3/h
1 % CO_2



Biogaz Feed
100 Nm3/h
7-14 Barg
55/45% CH_4 /CO_2

Natural Gas Liquid Separator

H2S Removal

Natural Gas Compression for Transmission

Putting Advanced Fuels to Work in Marine Fleets

Codes and Standards

- NFPA 30A: Code for Motor Fuel Dispensing Facilities and Repair Garages
- NFPA 30: Flammable and Combustible Liquids Code
- NFPA 52: Vehicular Gaseous Fuel Systems Code
- NFPA 57: Liquefied Natural Gas (LNG) Vehicular Fuel Systems Code
- NFPA 59A: Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG)
- NFPA 70: National Electrical Code®
- NFPA 88b: Standard for Repair Garages
- CSA Alternative Energy Standards http://www.csaamerica.org/standards/alternative_energy/
- ASME Section VIII, Division 1: Design and Fabrication of Pressure Vessel http://www.asme.org/products/courses/section-viii--division-1---design-and-fabrication-
- SAE J 1616 Recommended Practice for Compressed Natural Gas Vehicle Fuel http://standards.sae.org/j1616_199402/
- Clean Vehicle Education Foundation http://www.cleanvehicle.org/index.shtml
- NGV America http://www.ngvc.org/
- Natural Gas Quality Standards & Pressure LDC http://ferc.gov/industries/gas/indus-act/lng/gas-qual.asp http://www.beg.utexas.edu/energyecon/lng/documents/CEE_Interstate_Natural_Gas_Quality_Specifications_and_Interchangeability.pdf
- State and Local Codes Fire Marshall

Terminology

- CNG– Compressed Natural Gas. CNG is compressed at the station to 5000 psig and is stored on the vehicle at 3600 psig all at 70*F. This gas has an odorant added.

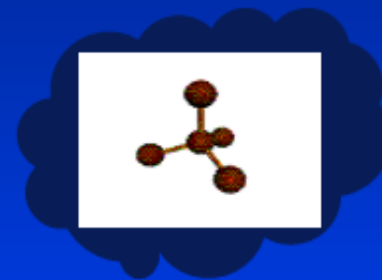
- LNG – Liquefied Natural Gas. LNG is natural gas that has been cooled to -259 degrees Fahrenheit (-161 degrees Celsius) and then condensed into a colorless, odorless, non-corrosive and non-toxic liquid. LNG is characterized as a cryogenic liquid. Odorant is not present.

NG Engine Terminology

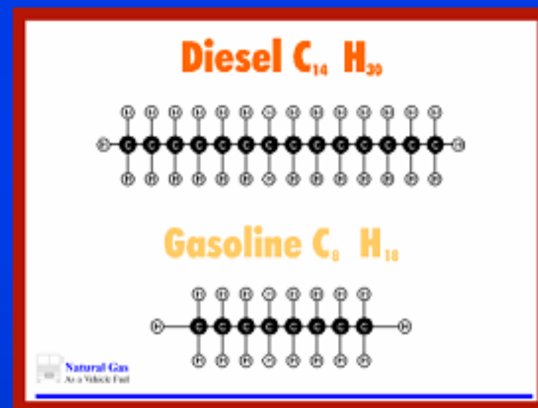
- Dedicated- This engine operates on only one fuel.
- Bi-Fuel- This engine can operate on either natural gas or gasoline. This is a SING engine (Spark ignited natural gas).
- Dual fuel- This engine operates on both natural gas and diesel at the same time, with varying percentages of each fuel. DING (Diesel ignited natural gas).

Benefits of Natural Gas/NGVs

- Natural gas is an inherently clean fuel
  - Natural gas is low-carbon fuel (CH4)
  - Less NOx, PM and GHGs
- Natural gas is very safe
  - Lighter than air; Limited combustion ratio (5-15%)
  - High ignition temperature: 1000+F
  - Colorless, odorless, non-toxic substance
  - Doesn't leak into groundwater
- NGVs are proven and reliable
  - 12+ million worldwide;
- NGVs are quiet
  - HDVs are 80-90% lower db than comparable diesel
- NGV life-cycle costs are significantly lower
  - Fuel costs are far lower!
  - Maintenance costs are =/< than gas or diesel



Methane Molecule



NGVAMERICA
Natural Gas Vehicles for America

Market Drivers for NGVs

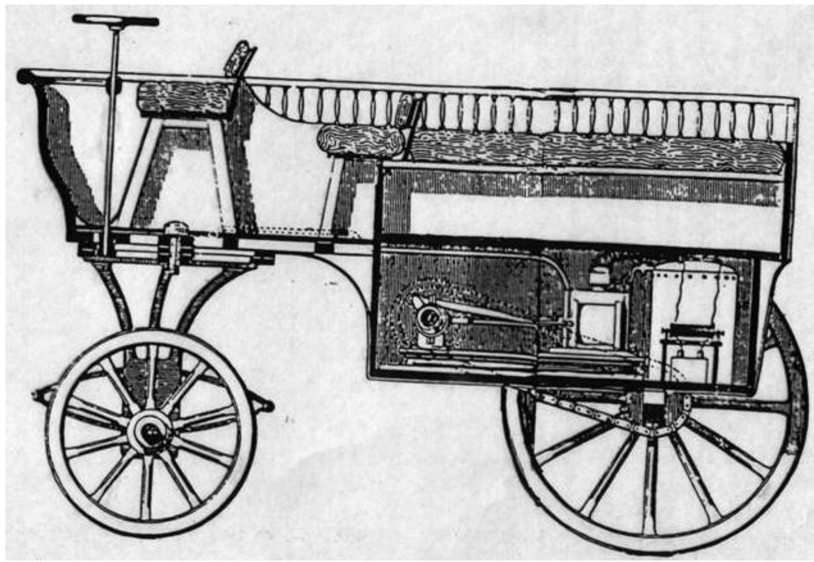
•**CNG (GGE/DGE) National Average = $2.06 - $2.30 (DOE April 2011)**

•Basis: $X.XX MCF @ city gate,
•$.10 LDC transportation fee,
•$.15kWh/gge compression,
•$.25/gge maintenance,
•$.35-.60/gge capital
equipment amortization

1000 cubic feet, a unit of measures written **Mcf**

Differential between Diesel/CNG as high as $2.00 in Summer '12

CNG's/NGV's HUMBLE BEGINNINGS



The First Natural Gas Vehicle 1860 Source: NGSA

Natural gas has long been considered an alternative fuel for the transportation sector. In fact, the first internal combustion engine vehicle to run on natural gas was created by Etienne Lenoir in 1860!

Onboard CNG Storage

CLEAN VEHICLE EDUCATION FOUNDATION

NGVAMERICA
Natural Gas Vehicles for America

CNG Cargo Ship

Source: Neptune Gas Technologies Ltd. ship designs provided by BMT TITRON (UK) Ltd.

CNG Cylinders

- Most onboard vehicle cylinders in service today operate at 3600psi

- 4 types of onboard cylinders; although of different materials and construction methodologies, all meet same stringent safety standards.
  - Type I (all metal)
  - Type II (metal liner, partial wrap)
  - Type III (metal liner, full wrap)
  - Type IV (plastic liner, full wrap)

- FMVSS 304 requires label detailing end-of-useful life date at which point they must be removed from service and decommissioned (no recertification process)
  - Current life spans may be 15, 20 or 25 years; old cylinders had 15 year life

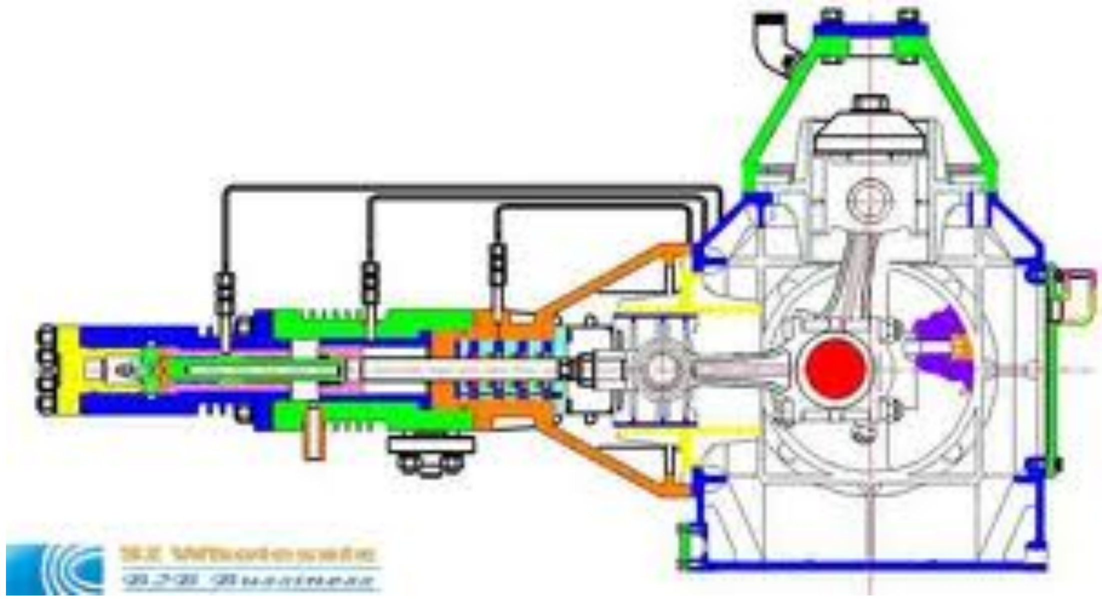
- Label also states that cylinders should be visually inspected every 36 months or 36K miles (whichever is earlier) or after accident or fire. Inspection should be performed by “Qualified” or “CSA-certified” personnel

- End-of-life decommissioning and disposal; venting, purging, destroying

NGVAMERICA
Natural Gas Vehicles for America

NGV Station Components

Compression Cross Head Design



Compressor Truncated

Compressor Pack

Compression Horizontal Opposed

Gas Pressure Compression Stages

Stage 1 - inlet 20 psig to 200 psig (1.4 kg/cm2 to 14 kg/cm2)
Stage 2 - 800 psig (56 kg/cm2)
Stage 3 - 2400 psig (169 kg/cm2)
Stage 4 - 5800 psig (408 kg/cm2)

CNG Storage Sphere

CNG Storage ASME

Single Stage Regenerative Dryer

Natural Gas Fuel Station Types

Development, Ownership and Operations Options

Sizing/Design Considerations

Station Considerations

•Station Location Options:

- •Offsite – use existing public access station (either full public access or limited public access); development usually driven by anchor fleet
- •Onsite - private access only
- •Onsite - with public access “outside the fence”

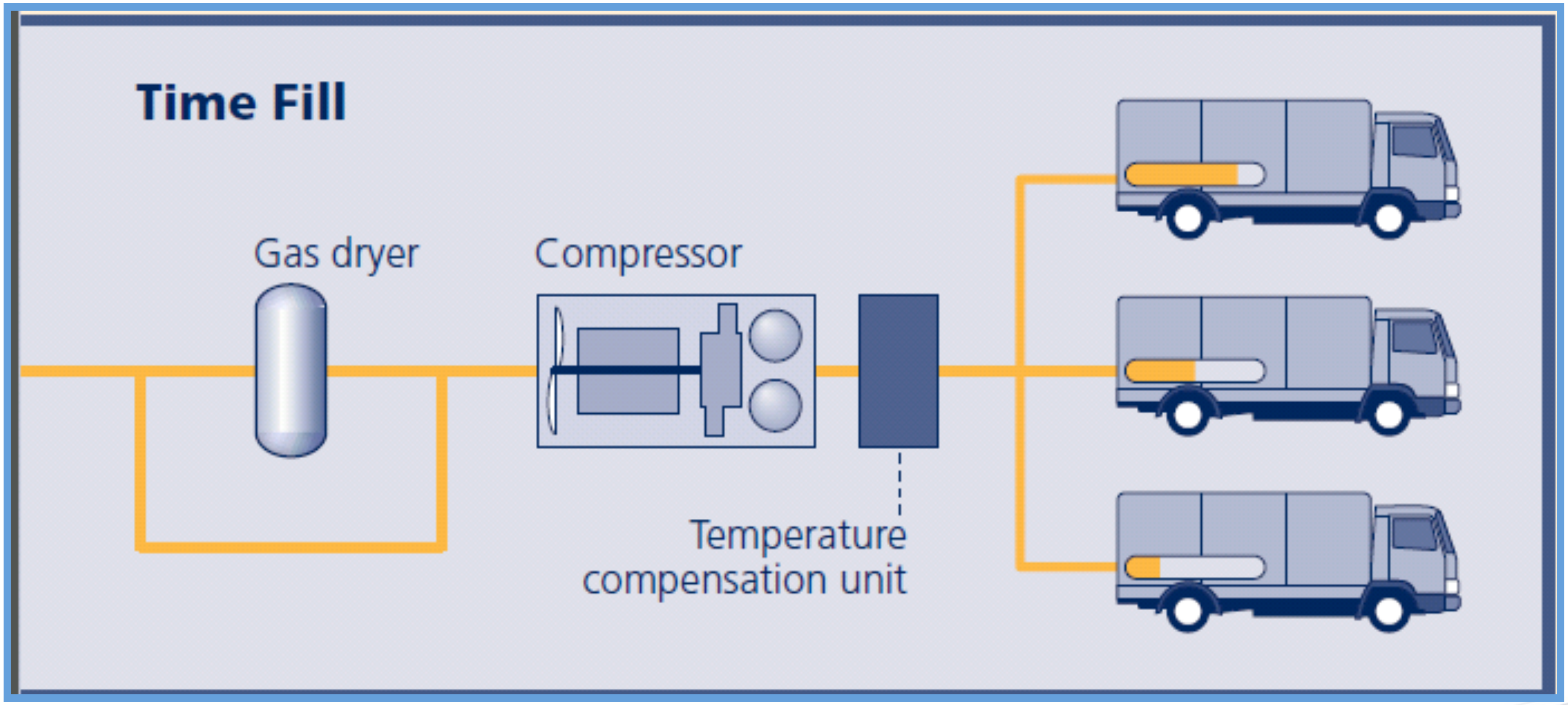
•Different ownership & operations options available depending on throughput, funding:

- •Fleet owned & operated station
- •Outsource station O&O entirely via independent fuel provider and contract gas price
- •Fleet owned/leased station but contracted out operations for a fee (usually on a GGE basis)

Station Considerations

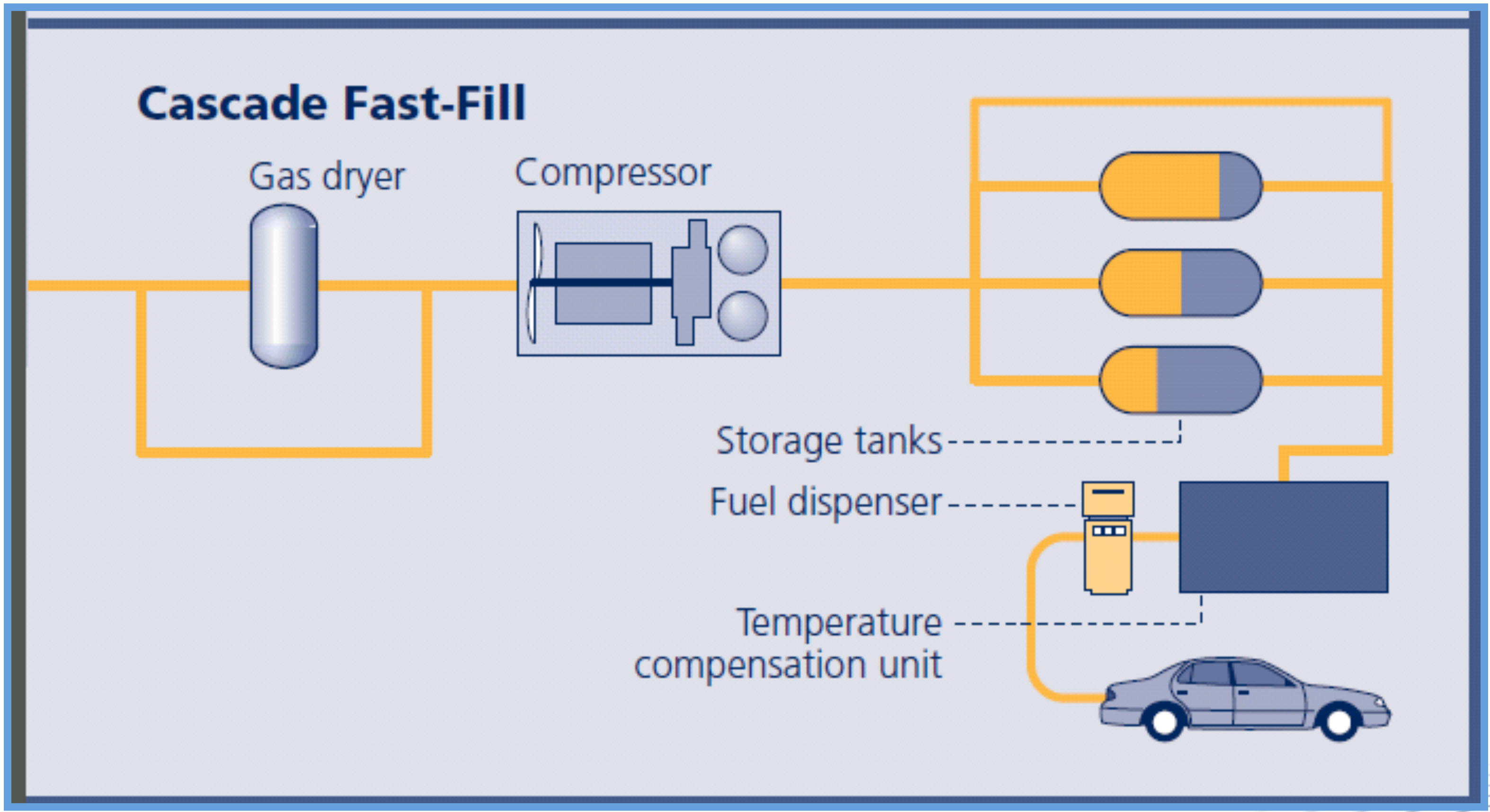
- Station Size and Design Considerations
    - Time-Fill, Fast-Fill, Combo Fill
    - Number of vehicles per day
    - Fueling pattern of vehicles
    - Maximum daily flow
    - Maximum hourly flow
    - Available back-up fueling, redundancy?
    - Metering/Data/Payment needs
    - Amount of space available
    - Create initial anchor network (airports, refuse, transit)
    - Modular approach to fueling capacity as fleet grows

Station Types

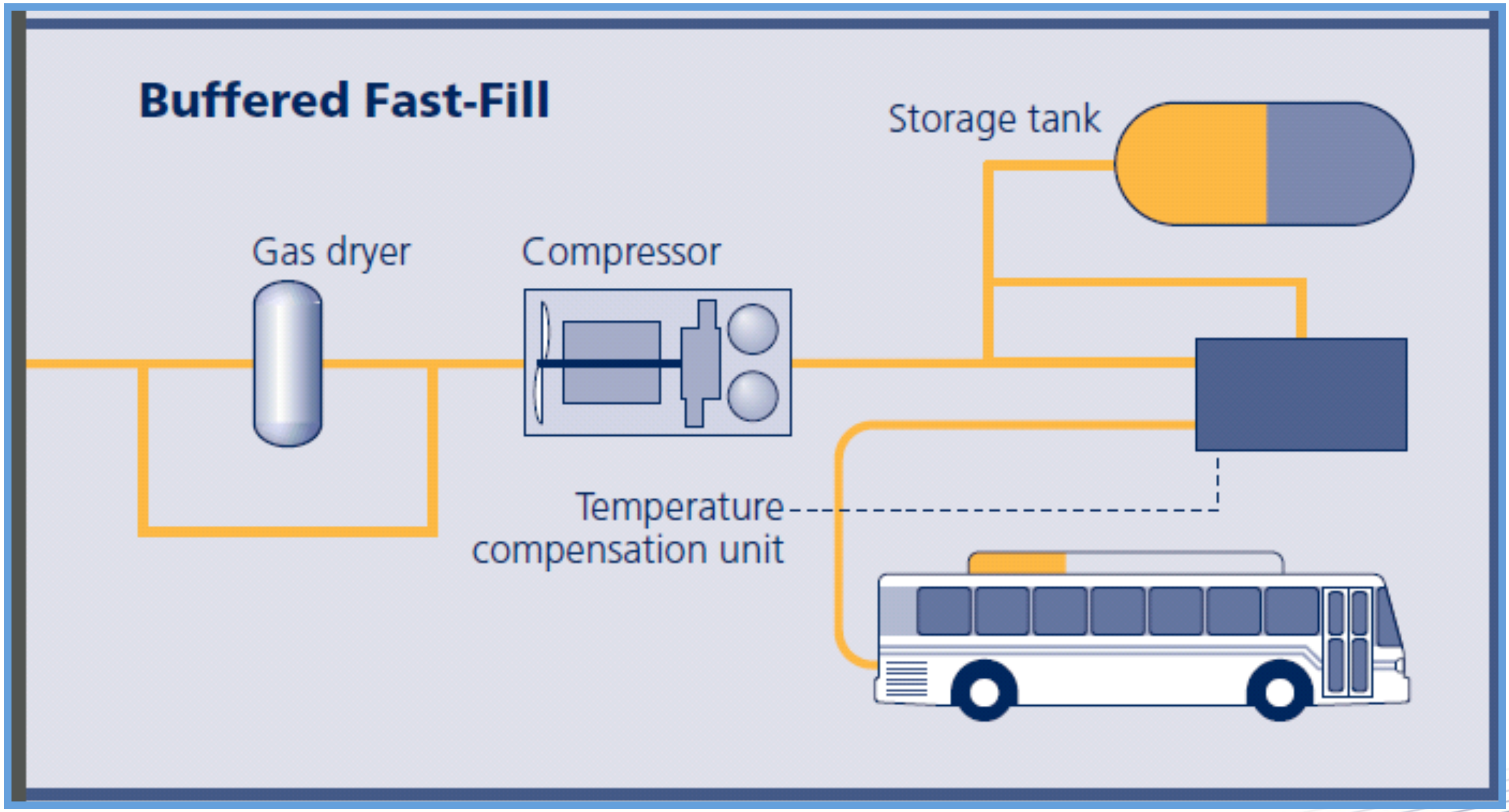


Rumpke of Ohio Compressed Natural Gas Time-Fill Fueling

Station Types



Station Types



SARTA CNG Canton, Ohio

CNG Pressure Chart

Compressed Natural Gas
Vehicle Fill Pressure
Temperature Compensation Chart

Deg F	3000 PSI	3600 PSI
100	3400	4125
80	3125	3775
70	3000	3600
60	2850	3425
40	2600	3100
20	2325	2750
0	2075	2400

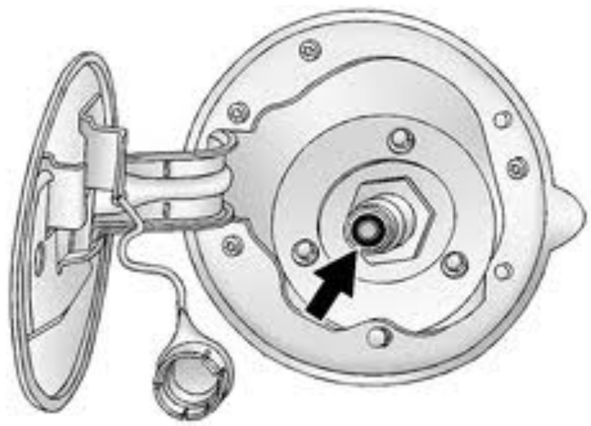
NGV Dispenser

NGV Fueling Nozzle 3000psig

NGV Fueling Nozzle 3600psig

NGV Pull Release 3600 and 3000psig

NGV Fueling Receptacle



Two way Fueling Valve/Nozzle

LNG

LNG Value Chain

Exploration and Production

- Natural gas is found in the earth's crust.
- Most of the time natural gas is discovered during the search for oil.
- Worldwide proved reserves of natural gas about 6000 Tcf.
- Much of this natural gas is stranded, a long way from market.
- Production operations delivers the gas to users.


Source: BG

The Problems

- Very large quantities of Marcellus and Utica shale natural gas are available along the western slopes of the Appalachian Mountains
- This gas is stranded because very few pipeline connections exist to transport the gas
- The high cost of new natural gas pipelines and difficulty with permitting make this option unattractive
- Traditional natural gas transportation in high pressure cylinders for pipeline injection is prohibitively expensive

Solution: Dedicated LNG Plants for Liquefaction of Marcellus and Uitca Shale Gas

- Cost of Marcellus and Utica shale gas is usually lower than Henry Hub index price

- “Stranded” Marcellus and Utica gas liquefaction provides a cost effective way to
  monetize

- Eliminates pipeline construction and transportation costs

- Liquefied natural gas is easily transportable at low cost

- Cost of liquefaction is less than $0.20 per gallon in most cases

- LNG product is suitable for pipeline injection as well as vehicle fueling

- LNG can be transported to pipeline injection sites where it is pumped and vaporized at any desired pressure prior to injection into pipelines

Cryogenic Liquids

- Cryogenic Liquids - are gases that liquefy at reduced temperatures
- The Greek work ***kyros*** means icy cold
- USDOT – defines a cryogenic liquid as a refrigerated liquefied gas with a boiling point colder than –130°F (-90°C)

Physical Properties

- A gas can be converted to a liquid by decreasing its temperature and/or increasing pressure
- Critical temperature - The highest temperature at which pressure can be used to condense a gas to its liquid state
- Critical pressure - The pressure required at the critical temperature to condense the gas to a liquid

Critical Pressure and Temperatures

	Critical T	Critical T	Critical P
Gas	^{o}C	^{o}F	psi
Propane	96.7	206	617
Nitrogen	-146	-231	485
Oxygen	-118	-180	735
Methane	-161.6	-116.8	666.59

Hazards of Cryogenic Materials

- High Expansion Rate - When a liquid changes to a gas there is a tremendous increase in volume
  - 1 ft^3 of methane$_{(liquid)}$ $\longrightarrow$ 600 ft^3 gas
  - A large volume of air can be displaced creating a hazardous situation
  - Containers of cryogenic liquids must be vented to release vapors

Hazards of Cryogenic Materials

- Cryogenic liquids may liquefy other gases
  - Air can be liquefied by cryogenic hydrogen
  - This can block the venting tubes and dangerous internal pressure will build in the container

Hazards of Cryogenic Materials

- Living Tissue can be damaged
  - Tissue can freeze
  - Blood circulation in the affected tissue will be reduced
  - Skin burns can occur and resemble first-, second-, or third-degree thermal burns

Plant Design Basis

- Capacity: 25,000 gallons per day. Can be scaled down to 5,000 GPD or scaled up to 50,000 GPD
- Natural gas drive; no electricity or water required
- Temperature: -252°F
- Storage pressure: 35 PSIG
- Storage: 60,000 Gallons
- LNG subcooling: 20°F
- Product purities are vehicle grade

UGLI LNG Facility Financials

Basis: 10 Year Amortization; 8% Interest, 100% Debt)
On-Site Power Generation, Molecular Sieve Plant

		25,000 GPD Wellhead Gas	10,000 GPD LFG Source
Daily Capacity (tons per day)	LNG	45	18
	Gallons/Day	25,000	10,000
	SCFD	2,085,000	835.000
Turnkey Plant Cost, approx.		$6.5 MM	$5.00 MM
Operating and Maintenance		$0.30 MM	$0.25 MM
Annual Capital Charge		$0.95 MM	$0.73 MM
Fuel and Feedgas Charge*		$3.6MM	$0.18 MM**
Total Annual Cost		$4.85 MM	$1.16 MM
LNG Unit Cost, $ gallon		$0.54	$0.32
LNG Unit Cost, $ MMBTU		$6.50	$3.90

* Based on a $4.00 per MMBTU natural gas cost

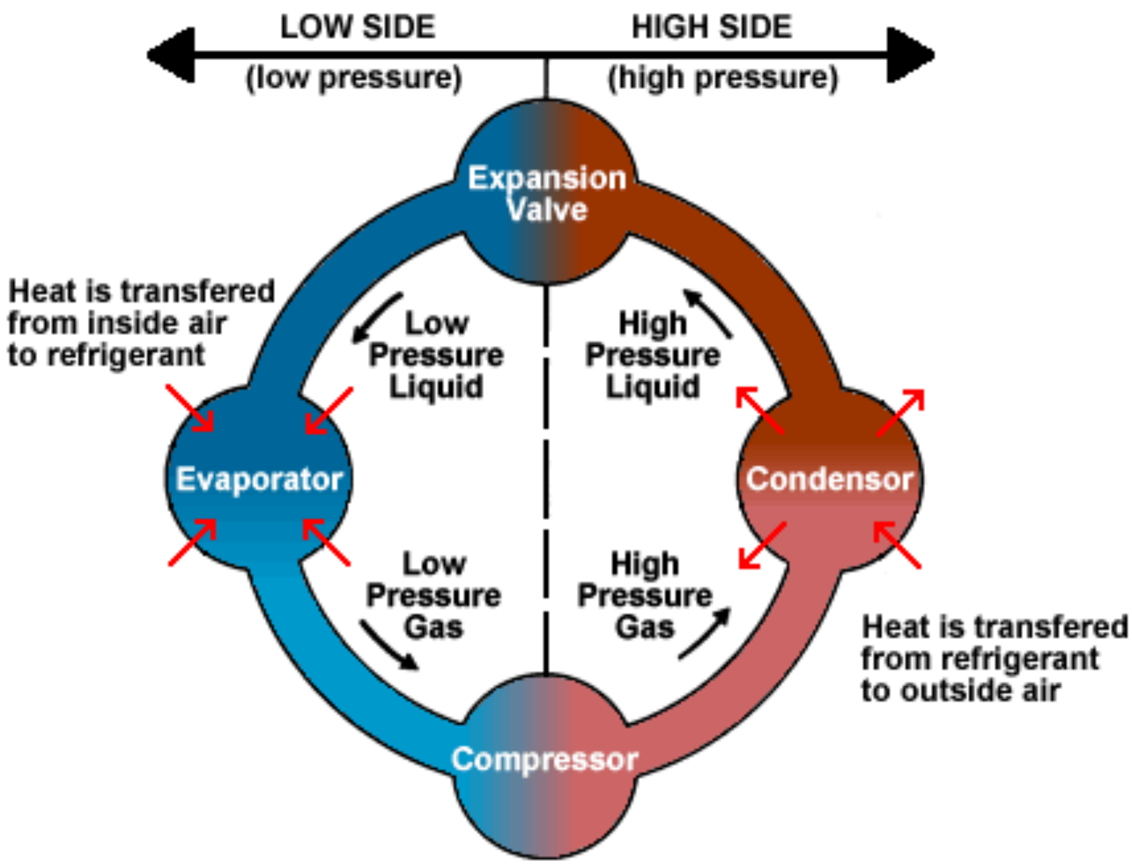
** Based on a $0.50 per MMBTU LFG cost

LNG Equipment

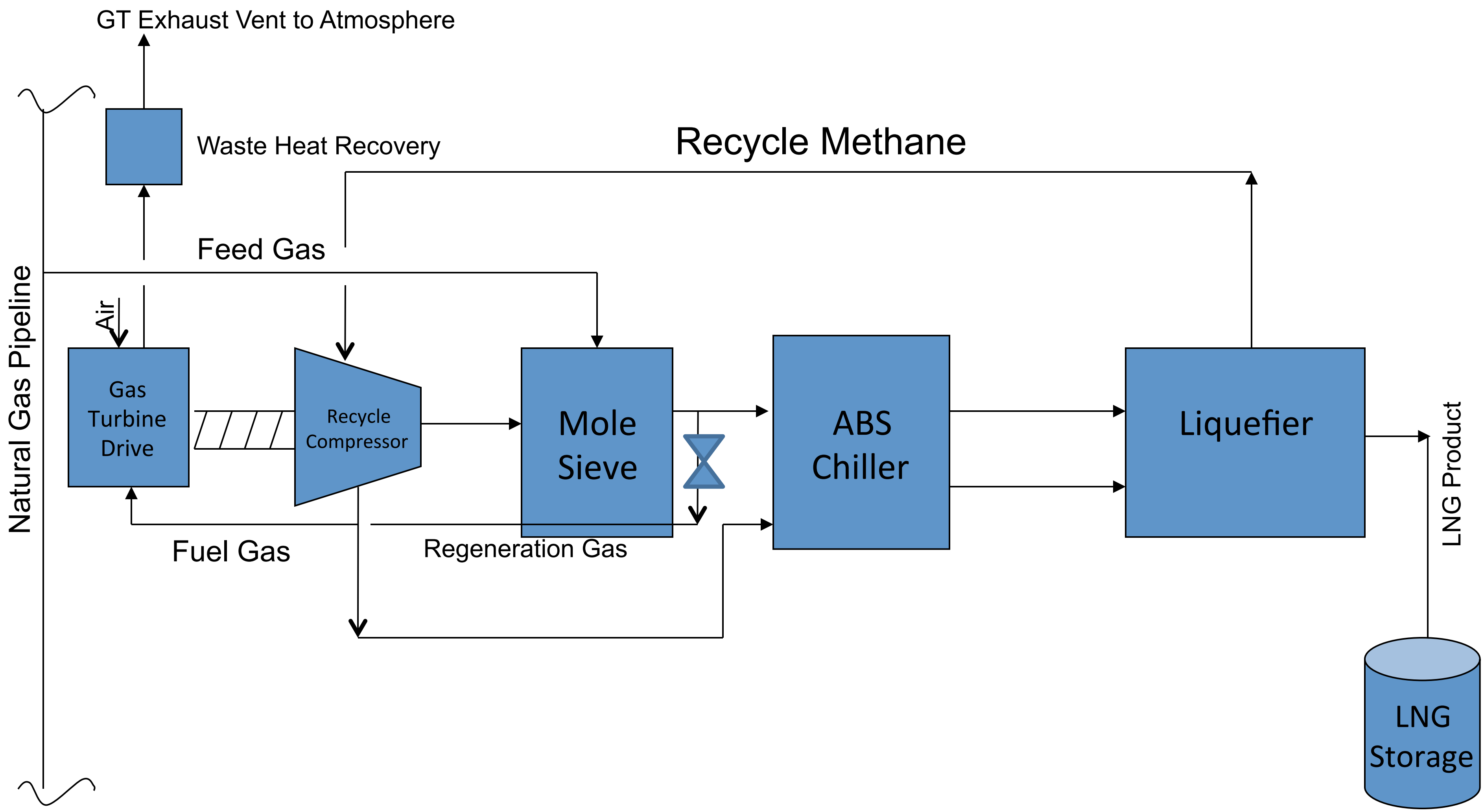
Basis: Production of Vehicle Grade Purity LNG

- Proven patented design
- Low cost; low fuel gas consumption
- Designed for 20 year minimum service life
- Includes 3 days of storage capacity
- Integrated with on-site fueling station

Cooling Cycle



LNG Plant Ralph Greenberg



LNG stations usually require LNG storage from 3 bars/-153°C (43.5 PSI/-243°F) to 18 bars/-110°C (260 PSI/-166°F).

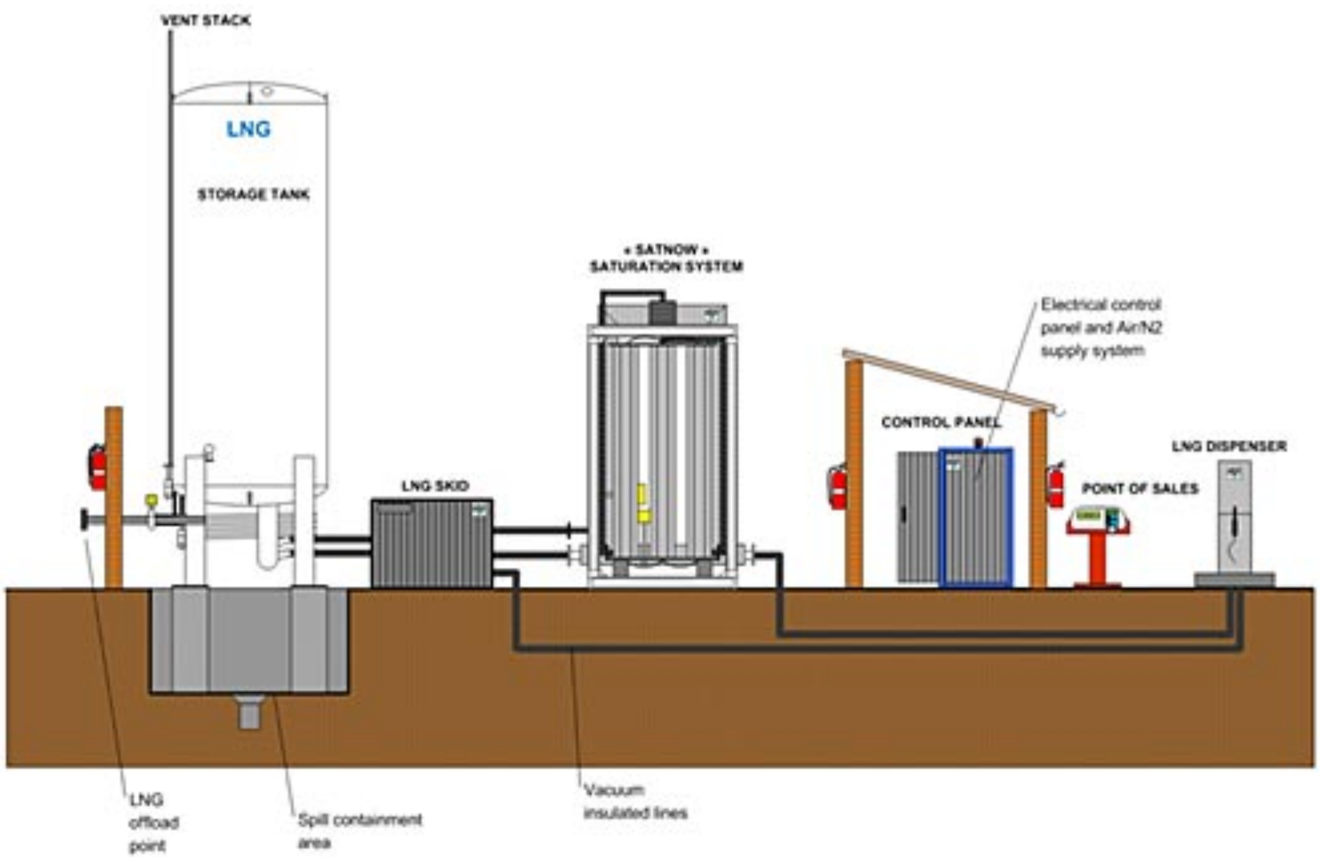
LNG at 3 bars and -153°C (43.5 PSI and -243°F) : « cold LNG »

LNG at 8 bars and -130°C (116 PSI and -202°F) : « saturated LNG »

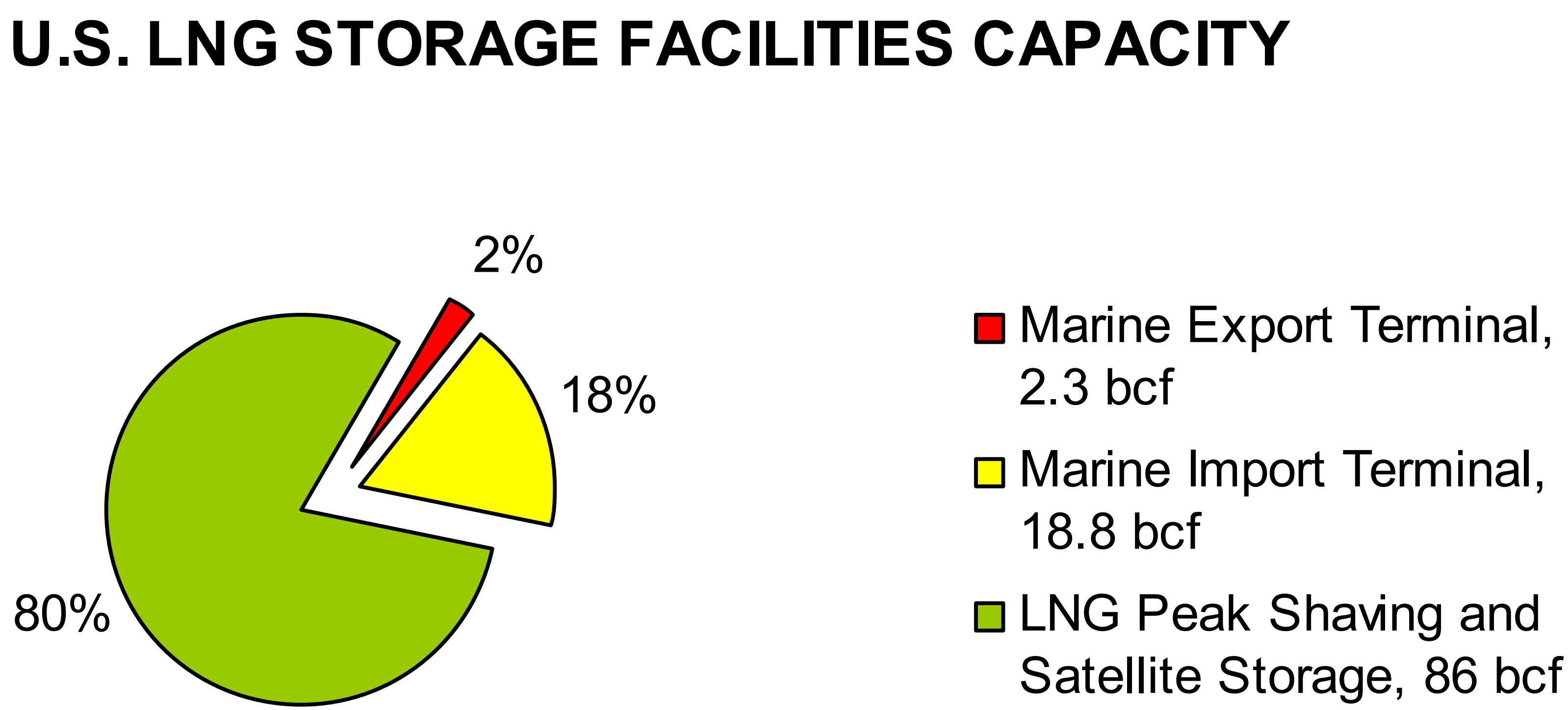
LNG at 18 bars and -110°C (260 PSI and -166°F) è « super saturated LNG »

LNG is 2.4 times heavier than that of CNG or 60% of that of diesel fuel.

LNG Stations



LNG Facilities in the U.S.



Source: EIA

LNG Facilities in the U.S.

Satellite LNG facilities do not contain liquefaction units, but only storage and re-gasification equipment. Some of these units are used for satellite peak-shaving duties, while others are dedicated to vehicle fuel transfer systems. LNG is delivered from marine terminals or satellite facilities, usually by truck.

39 LNG Storage facilities in the U.S.

Clean Energy Liquefied Natural Gas (LNG) Infrastructure in Seville, OH

LNG Fuel Dispenser Nozzle

LNG Source Parker Hannifin

LNG Tank Source: NexGen Chart

LNG Truck Delivery

LNG Supply

U.S. COAST GUARD

Shore Supply - Mobile

- Tank Trucks
- Hose connections
- Area where transfer takes place
  - Regulated 33 CFR Part 127
  - Same Requirements Apply
- Tank Truck regulated by
  - DOT/PHMSA 33 CFR Part 177


CHART
FEROX

LNG Tanker

LNG Boil Off Propulsion

Since natural gas liquefies at cryogenic temperatures, i.e. temperatures well below -100°C, there is continuous boil-off of a small portion of the liquefied natural gas during transportation and storage. This is termed natural boil-off gas (NBOG). Specialised equipment is required in order to handle this boil-off on both land and marine storage facilities. On ocean-going LNG carriers, this NBOG is frequently used to provide a source of fuel for the vessel propulsion, using boilers feeding steam turbines, or feeding directly to dual fuel diesel engines coupled to electric propulsion units. In case that additional fuel is required, additional cargo is vaporised to make up the shortfall.

LNG as fuel for ships

LNG propelled ferry, Norway

CleanFuelsOhio

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