Resources – Gas

Outline

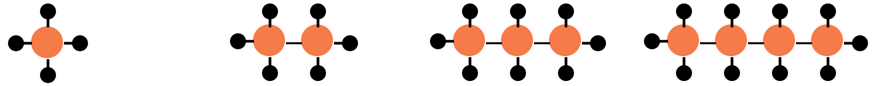
- **Resources**
- **Prices**
- **Trades**
- **Coal Resources, Prices, Trades**

Based on

- Chapters 1-2 of **Future of Natural Gas** by MITEI, 2010.
- Natural Gas, Chapter 2.1 of **Energy Trading and Investing** by David Edwards, 2010.

Composition of Natural Gas at Various Locations

Alkane gases are saturated with Hydrogen and all connections are covalent (electron sharing) bonds:

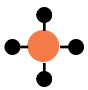


	Methane CH_4	Ethane C_2H_6	Propane C_3H_8	Butane C_4H_{10}	Pentane et al.
Carthage Field, TX	92.5	4.7	1.3	0.8	0.6
Panhandle, TX	91.3	3.2	1.7	0.9	0.6
Velma, OK	82.4	6.3	4.9	2.2	1.2
Hugoton, KS	74.3	5.8	3.5	1.5	0.6

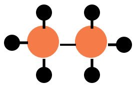
- Natural gas reservoirs can include
  - water (H_2O), carbon dioxide (CO_2), helium (He is a light, inert, noble gas),
  - hydrogen sulfide (H_2S, Sulfur is similar to Oxygen as sulfur is immediately below oxygen in the periodic table), Recall from oil discussion, Sulfur is corrosive/undesirable.
- Except for Pentane, the alkanes above are gas under regular temperatures (say 20 ^oC) and pressure. Boiling point of Pentane = 36 ^oC > Boiling point of Methane, Ethane, Propane and Butane. Temperatures and pressure are higher in the rock formations.
- Natural gases can be found
  - in liquid phase in reservoirs if the pressure is high,
  - in gas phase in reservoirs if the temperature is high.
- As brought up, natural gas (6-8 carbons) cools: gas → liquid (called condensate).
- Confusing Terminology:
  - For a person in gas industry: Dry gas is basically Methane. Wet gas is combination of Methane with others.
  - For a geologist: Dry (nonassociated) gas is found by itself in a reservoir, wet (associated) gas comes with liquids.

Energy from Burning Gas:
Enthalpy of Combustion

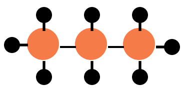
Gas + Oxygen $\longrightarrow$ Carbondioxide + Water + Energy



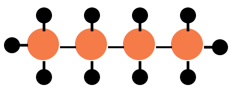
$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$ $\Delta H = -890$ kJ/mole



$C_2H_6 + (7/2)O_2 \longrightarrow 2CO_2 + 3H_2O$ $\Delta H = -1560$ kJ/mole



$C_3H_8 + 5O_2 \longrightarrow 3CO_2 + 4H_2O$ $\Delta H = -2200$ kJ/mole



$C_4H_{10} + (13/2)O_2 \longrightarrow 4CO_2 + 5H_2O$ $\Delta H = -2874$ kJ/mole

Bigger molecule more energy.

1 Joule=1 N * m

1 kilo Joule (kJ) = 1000 Joule = 0.95 Btu. Btu (British thermal unit) = 1 pound water ↑ 1 Fahrenheit (^oF).
1 Btu = 1052 Joule = 1.052 kJ. 1 mole of Methane releases 845 Btu (= 0.95*890 kJ).

1 mole of methane molecule is 16 gr; 1 mole of ethane molecule is 30 gr. Energy released per gram:

Methane: 890/16=55.62 kJ/gr > Ethane: 52 kJ/gr=1560/30.

1 methane molecule and 1 ethane molecule both take 24.6 liter (=1*0.08205*300/1) at 27 ^oC and 1 atm. Energy released per liter:

Methane: 890/24.6=36.18 kJ/liter < Ethane: 63.41 kJ/liter=1560/24.6.

Trading unit for gases is not weight or volume
but the energy content: $ per million Btu = $/MMBtu in US.

BTUs spent in daily activities?

- Ex: Seth Kaffee drinks his coffee from a mug that holds 0.5 pound of water and heats his water from 50 ^oF to 210 ^oF.
  - How many Btu's does he need for each cup?
    - » **80 Btu** $= 0.5 * 160 = 0.5 * (210 - 50)$
  - How many cents does it cost to heat up the coffee water if Seth uses a gas powered heater and pays $3 per million Btu (MMBtu)?
    - » **0.024 ¢** $= 24/1000 = 300 * (80/1{,}000{,}000)$

➢ Managerial question:

Can Starbuck's energy costs constitute a big portion of its cost-of-goods-sold?

- Ex: Lynn Dushy takes two showers every day and needs 100 pounds (12.2 gallons) of water heated by 100 ^oF for each shower. Suppose 1 gallon of gasoline costs $4 and gives 0.114 MMBtu.
  - How many MMBtu's does she need each month?
    - » **0.6 MMBtu** $= 600{,}000 = 100 * 100 * 2 * 30$
  - How much would she pay per month if she uses a gasoline based heater?
    - » **$21** $= 4 * (0.6/0.114)$
  - How much would she pay per month if she uses a gas based heater and buys gas at $3/MMBtu?
    - » **$1.8** $= 3 * 0.6$

➢ Managerial implication:

Use gas rather than gasoline – e.g., natural gas powered car → gasoline powered car.

Gas Reserves, Reservoirs, Permits, Accounting, Drilling Similar to Oil Except for Recovery Factor

- √ Discussion of oil reserves, reservoirs, permits, accounting, drilling apply to natural gas.
- √ In many cases, gas an oil come out of the same well.

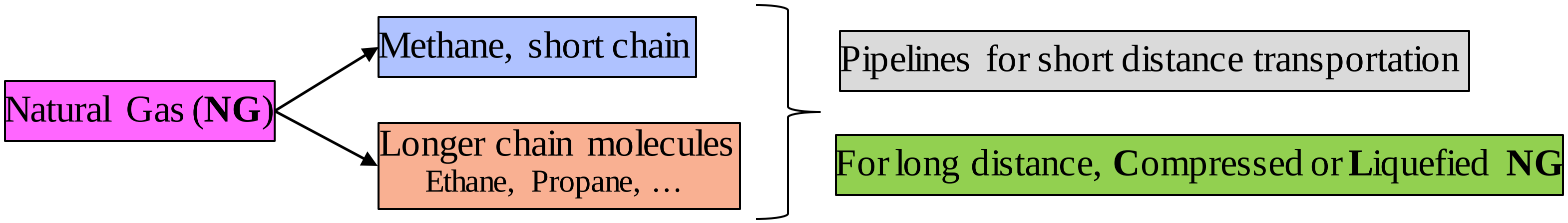
- Gas has little viscosity & high pressure in gas reservoirs. It flows up naturally in the pipes.

- As the gas moves out of a reservoir, the pressure ↓ because
  - Boyle's ideal gas law:

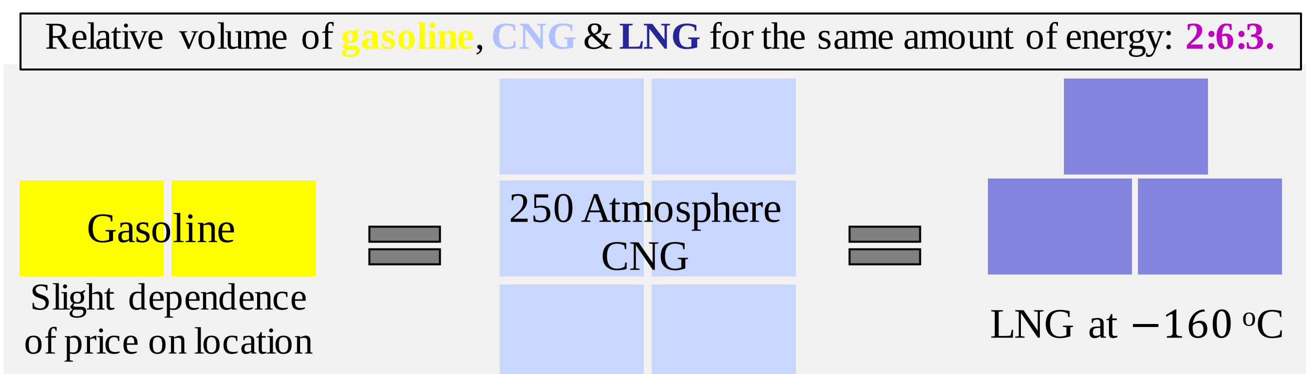
$$\frac{P}{n} = \frac{RT}{V}$$

    - » P: pressure in terms of atmosphere – drops as gas is pulled out.
    - » n: Number of moles – drops as gas is pulled out.
    - » V: Volume in terms of liters
    - » T: Temperature in terms of Kelvin. 0 Celsius is 273 Kelvin. Add 273 to convert Celsius to Kelvin
    - » R: Universal gas constant, 0.08205 in terms of (liter*atmosphere)/(moles*Kelvin).
  - Pressure in the reservoir is an indication of remaining reserves.
    - » If the pressure drops by 60% during production, recovery factor is ~ 60%.
- Recovery factor for gas reservoirs: generally 80%; For oil is 30−40%.

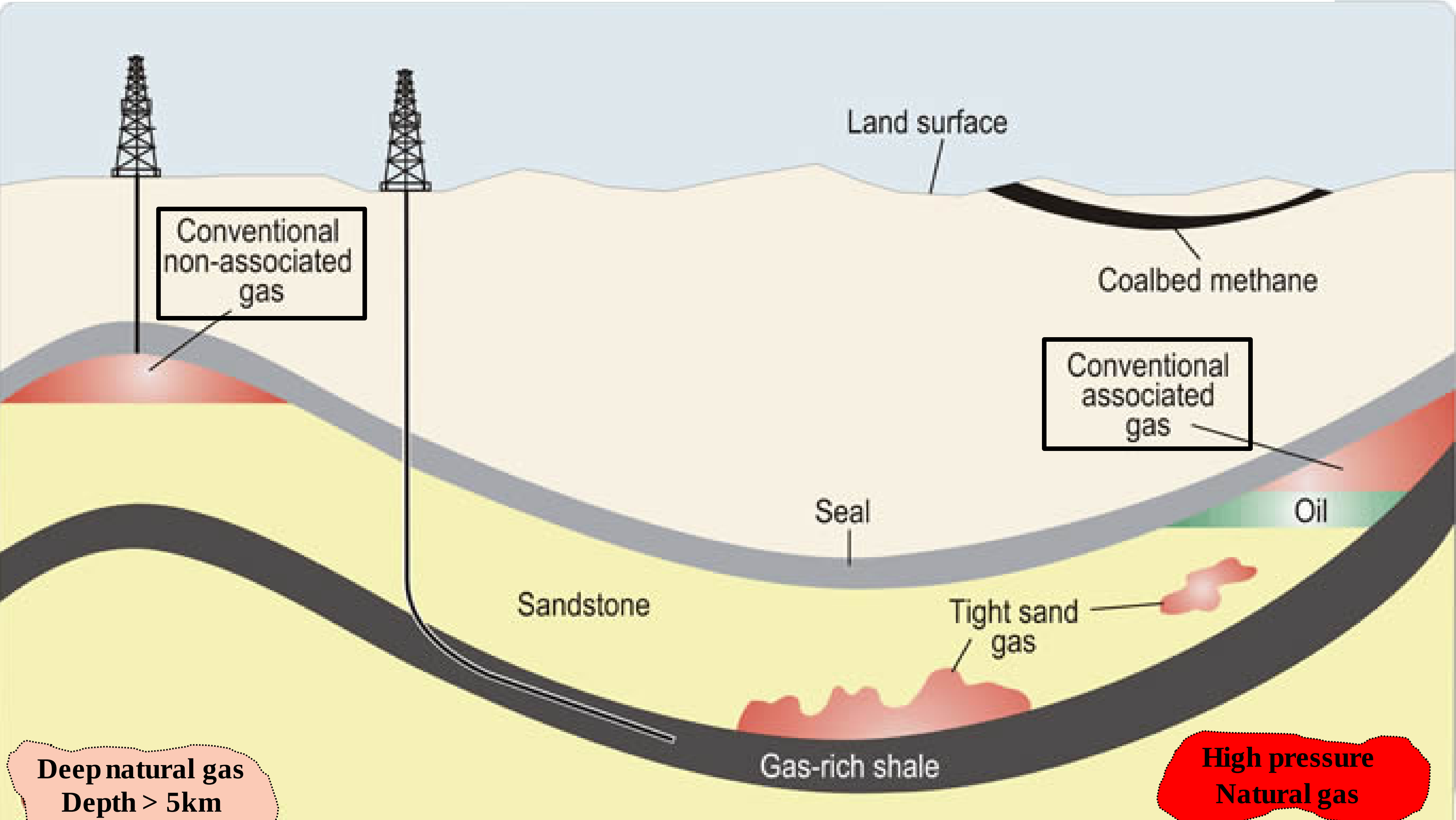
Efficient Transportation Gasoline, CNG or LNG



- 1 gallon of gasoline costs
  - Price: \$4, Volume: 0.13 cubicfeet (cf) and Energy: 114,000 Btu = 0.114 Million Btu (MMBtu).
  - To obtain 0.114 MMBtu (114,000/845=135 moles or 135*22.4=3200 litres for methane), 100 cf NG at atmospheric pressure.
  - Too large!!
- **C**ompressed NG (CNG): The pressure: 1 ↑ 250, then the volume: 100 ↓ 100/250=0.4 cf =**3***0.13 cf.
  - This pressure is similar to the pressure of diving tubes.
  - CNG requires **3** ∗ the volume of gasoline to deliver the same energy.
- **L**iquefied NG (LNG): The temperature ↓ to −160 °C, the resulting liquid is 500 ∗ denser than the gas.
  - To obtain 0.114 MMBtu, 0.2=100/500 cf NG at atmospheric pressure. 0.20 cf=**1.5***0.13 cf of LNG.
  - LNG requires **1.5** ∗ the volume of gasoline to deliver the same energy.



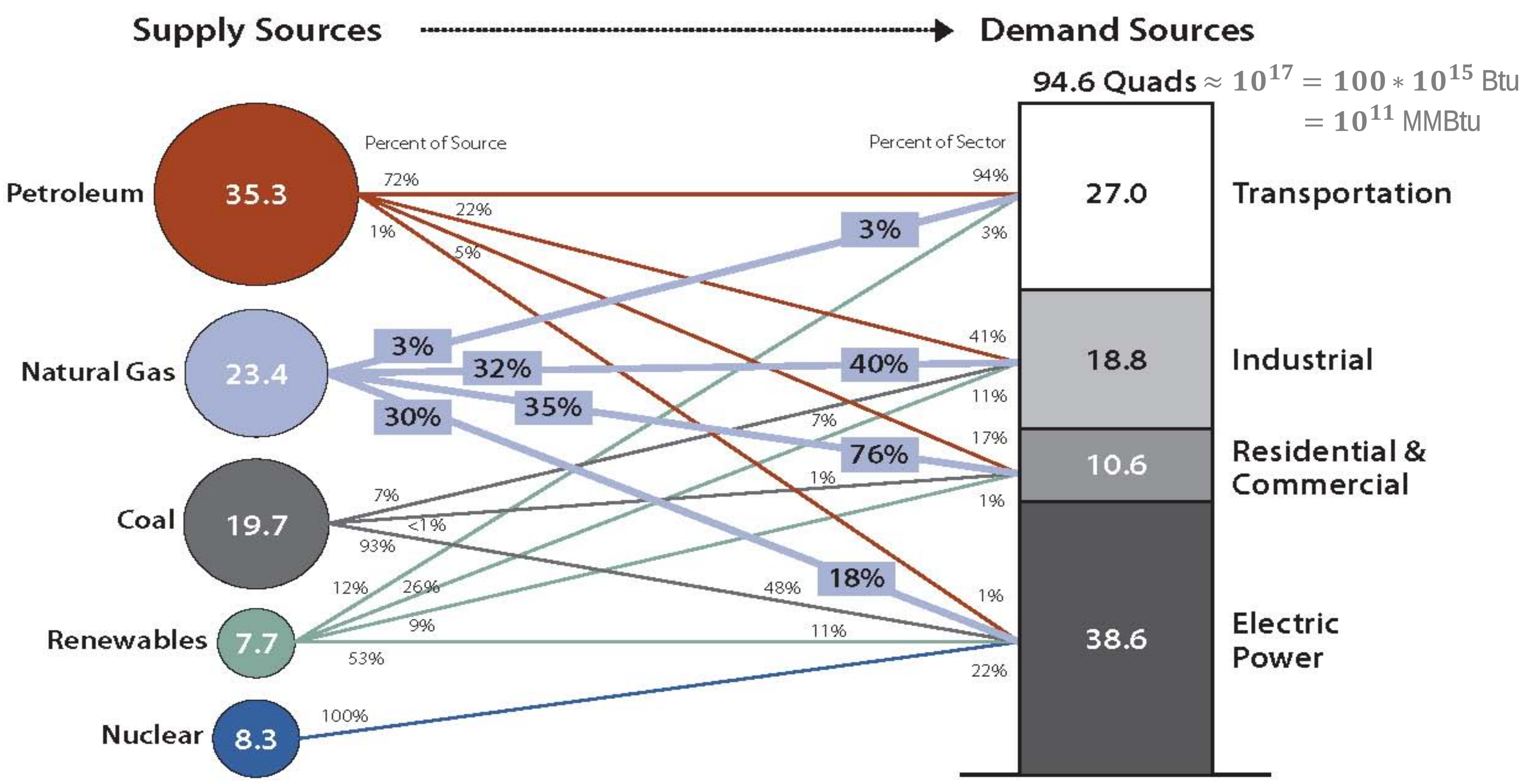
Gas Resources:
Conventional / Unconventional (briefly) Gas



Source: A modified EIA figure.

Energy Supplies and Demands
Importance of Natural Gas

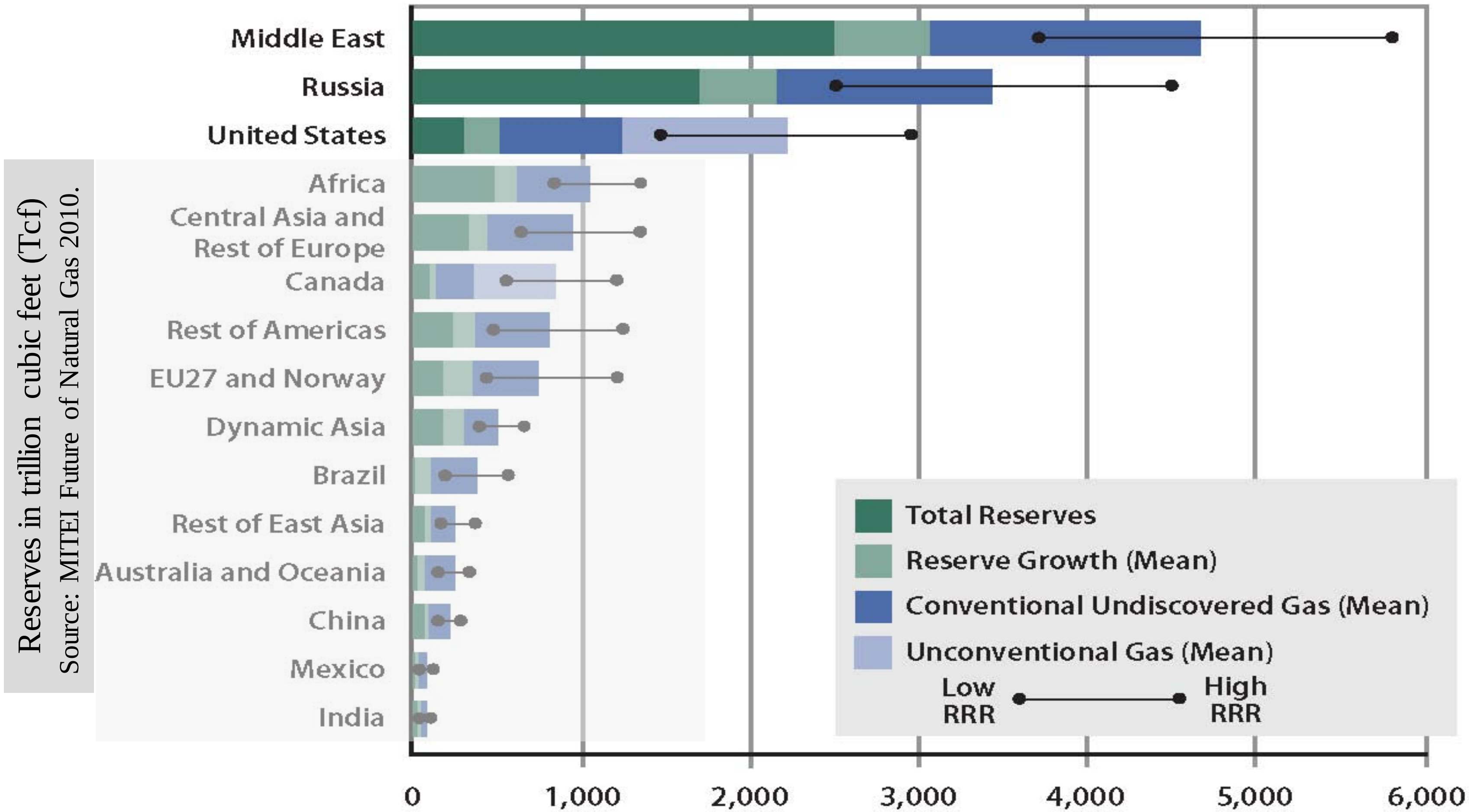
2009 supplies and demands in quadrillion Btu: 10^{15} Btu.
1 cubic feet of gas sold in USA must give 1035 Btu ±5%.
Source: MITEI Future of Natural Gas 2010.



- Natural gas supplied 15.6% of global energy in 1965 and 23.4% in 2009. In absolute terms, consumption of natural gas has grown from 23 trillion (10^{12}) cubic feet (Tcf) to 104 Tcf.
- Use of Natural gas in Industrial, Residential & Commercial and Power generation is almost equal: 32%, 35% and 30%, respectively. 3% use in transportation (including powering pipelines) is minimal, where growth is expected; see Chesepeake presentation on course website.
- 40% of Industrial energy is supplied by natural gas, which is an efficient fuel, clean and convenient. Gas prices affect competitiveness of US manufacturing.

Where are the Gas Resources?

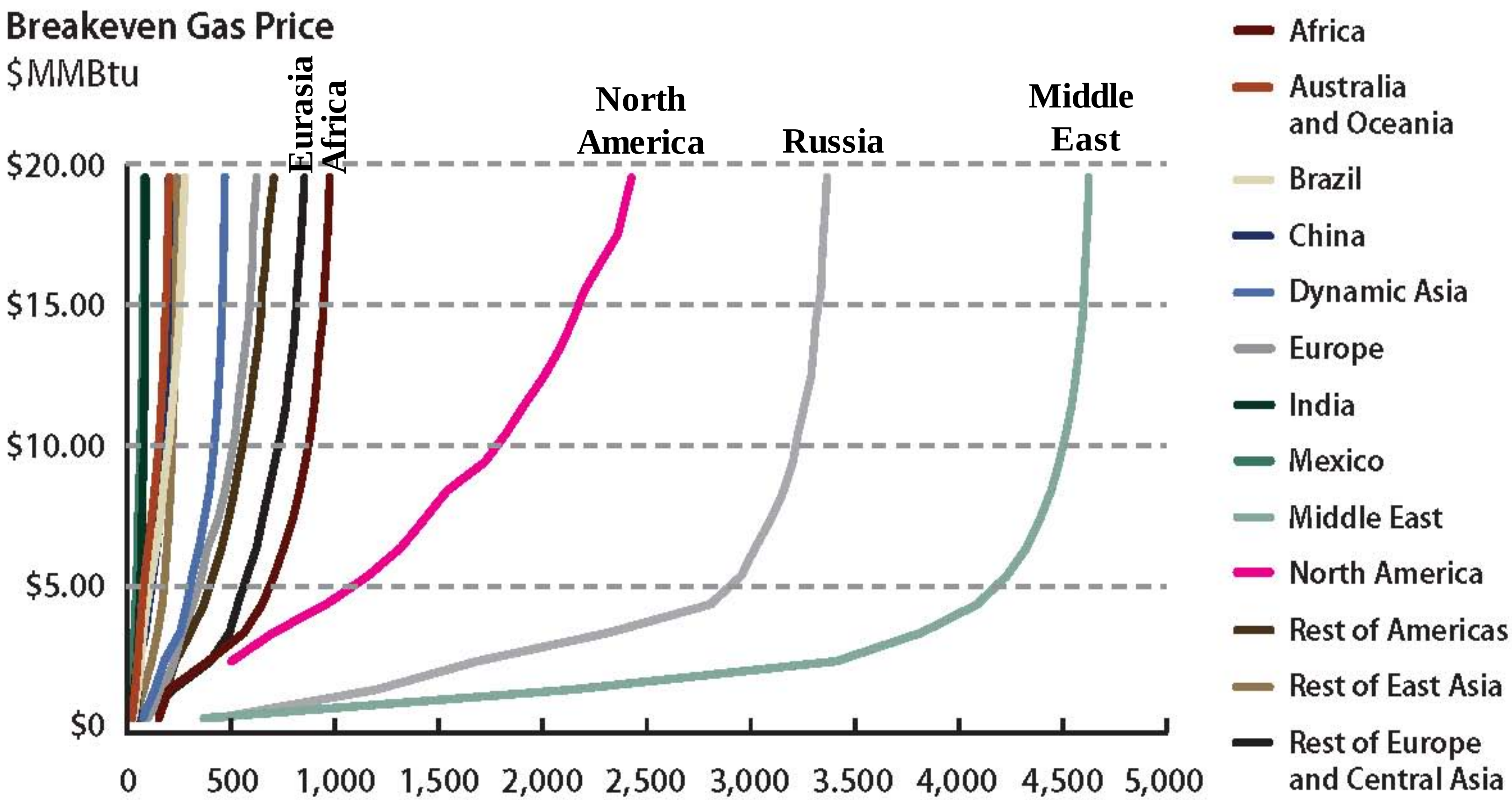
- Global resource estimate is 16,200 Tcf. P90 (proven) is 12,400 Tcf. P10 (proven+probable+possible) is 20,800 Tcf.
- Three regions have 70% of resources: Middle East, Russia and North America. Natural gas resources are more geographically concentrated than oil resources. There is not an efficient global natural gas market but rather local ones.



- Dynamic Asia: Republic of Korea; Malaysia; Philippines; Singapore; Taiwan, Province of China; and Thailand.

Supply Increases with Price

Reserves increase with price, but at different rates in different regions. Resources in Middle East, Russia, United Sates, North America, Africa, Eurasia (Central Asia and Eastern Europe) will increase relatively faster than other places.

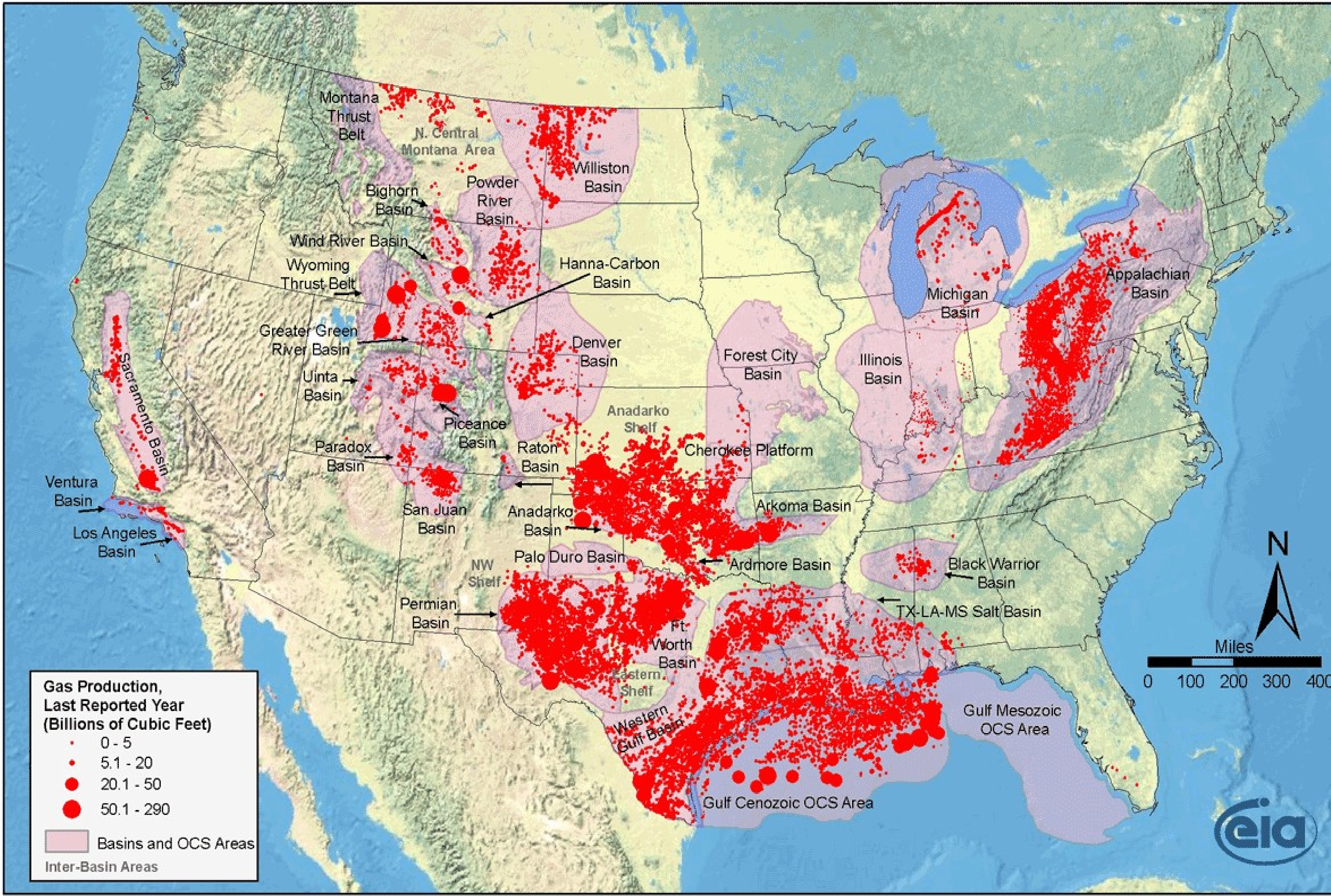


Reserves in trillion cubic feet (Tcf)

Source: MITEI Future of Natural Gas 2010.

Picture of Exuberance: Plenty of Natural Gas in US

Gas Production in Conventional Fields, Lower 48 States



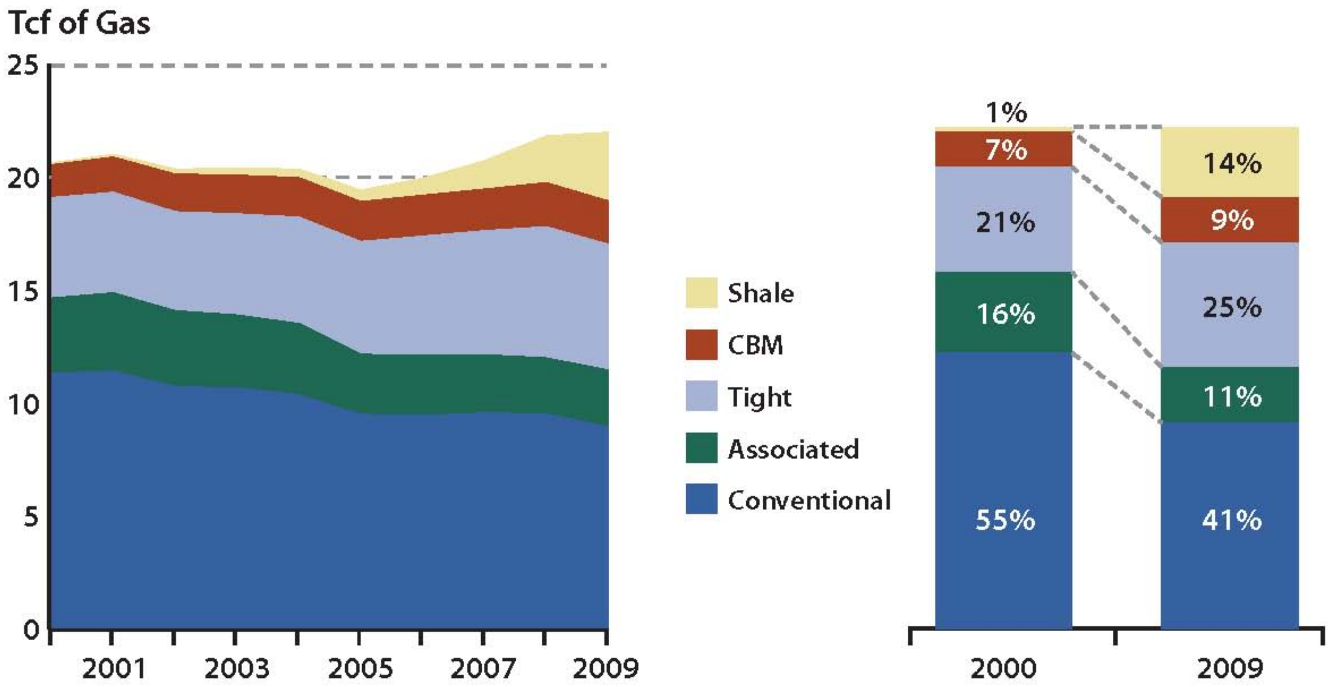
Source: Energy Information Administration, updated April 8, 2009.

Zigzagging Path of Natural Gas History in the USA

- Before 1970s, the main use of natural gas is in heating.
  - Significant investment into pipeline system, a major method of gas transportation then and now.
  - Pipeline company is a monopoly that charged according to cost of service.
  - Production and use grows over 1950-1970.
- First oil embargo led to a supply scarcity.
  - Low incentives for domestic gas development because of regulations.
  - In 1978, Congress passed power plant and industrial Fuel Use Act (FUA) to virtually outlaw gas fired power plants (to produce electricity).
  - FUA remains in place until 1987
    - » In the meantime, USA adds 172 Gigawatts (GW) of power generation capacity.
      47% coal-fired = 26% of 2010's coal-fired power plants. 25% nuclear.
- Mid 1990s,
  - Deregulation of gas prices
  - Deregulation of wholesale electricity markets; efficient and relatively inexpensive combined cycle gas turbines.
  - New exploration and production technologies, and development of offshore gas resources.
- In contrast, over 1989 - 2009, USA adds 306 GW of capacity: 88% gas-fired and 4% coal-fired.
- Early 2000s, adequacy of supplies is questioned and a long-term shortage perception is developed.
  - LNG import infrastructure expanded and reached about 35% of daily gas requirement.
- Last few years, unconventional gas resources has led to a belief of abundant supply.
  - LNG import infrastructure underutilized or being converted to export facilities!
  - Supply exuberance: "Oil and Gas Boom Lifts U.S. Economy" by R. Gold, WSJ Feb 8, 2012.

Takeaways: 1. Estimating reserves is difficult. 2. Current supply exuberance can be ephemeral.

US Natural Gas Production by Type of Resource

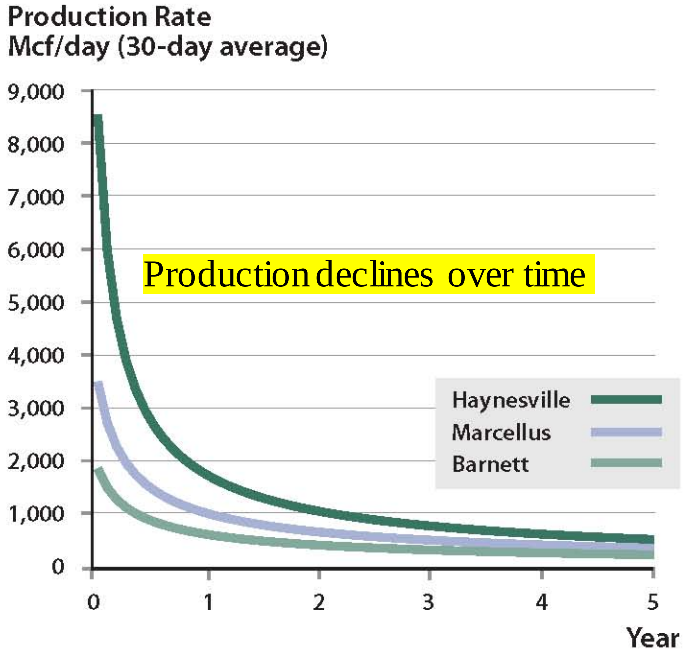


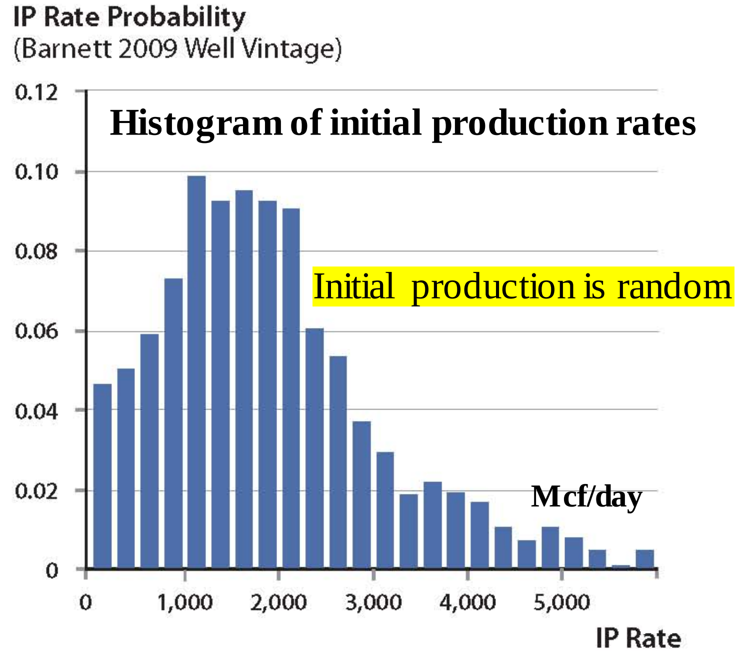
Source: MITEI Future of Natural Gas 2010.

Conventional gas production dropped in the last several years.
Instead, gas production from shale has increased from 1% to 14%.
80% of the growth in shale gas by 2010 is due to Barnett Shale in Forth Worth.

Other shale plays becoming active are Fayetteville and Woodford shales in Arkoma Basin, Oklahoma, Haynesville shale in East Texas Basin and Marcellus shale in Appalachian Basin.

Variability in Production Rates





Source: MITEI Future of Natural Gas 2010.

Initial Production (IP) rates in Mcf/day shows variability both among shales on the left and within shales on the right panel. No matter what technology is used, there still is plenty of randomness.

	Forth Worth, TX		Fayetteville, AR		East TX		Pennsylvania		Oklahoma	
	Barnett		Fayetteville		Haynesville		Marcellus		Woodford	
	IP Mcf/d	BEP $/Mcf	IP Mcf/d	BEP $/Mcf	IP Mcf/d	BEP $/Mcf	IP Mcf/d	BEP $/Mcf	IP Mcf/d	BEP $/Mcf
P20 80th percentile	2700	$4.27	3090	$3.85	12630	$3.49	5500	$2.88	3920	$4.12
P50 50th percentile	1610	$6.53	1960	$5.53	7730	$5.12	3500	$4.02	2340	$6.34
P80 20th percentile	860	$11.46	1140	$8.87	2600	$13.42	2000	$6.31	790	$17.04

3920 or more with 20% chance

790 or more with 80% chance

Among new shales Haynesville (East TX) seems most productive
⇒ requires least breakeven price (BEP) along with Marcellus.

Geography Question: If we put the corners of a rectangle at Barnett, Fayetteville Haynesville and Woodford, which research university remains in the rectangle?

Gloom in the Eastern Hemisphere Then and Now

- EU buys quarter of its gas from Gazprom, Russia
  - Italy: gas deliveries fell 29 percent below requested amount from Gazprom on Feb 3, 2012
  - EU: activates emergency energy council, plans for consuming from stocks and gas transshipments between states.
  - Gazprom and Naftogaz Ukrainy blame each other for drawing heavily.

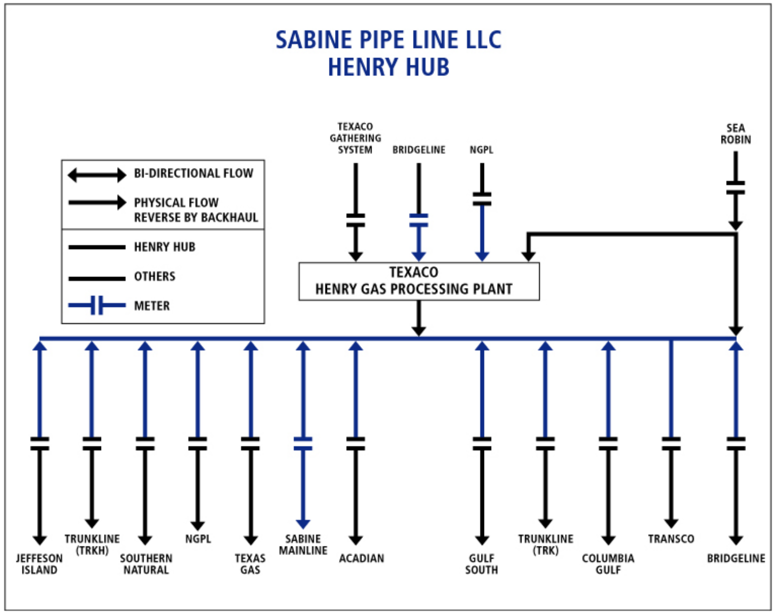
Source: "As Europe Shivers, Russia and Ukraine Point Fingers Over Natural Gas Supply to the West" by A.E. Kramer, NYT Feb 3, 2012.

- Hundreds die in Europe from cold spill in the first week of February, 2012.
- Gazprom, Russia's export monopoly, rejected requests for extra gas from European buyers as Putin ordered Gazprom to make domestic supplies a priority. Gazprom Officer A. Kruglov: Shipments were cut by 10% from contracted volumes "for a few days".
- The story from the other side:
  - EON AG (Germany's biggest utility) and OMV AG (central Europe's biggest energy producer), both said imports from Gazprom are still down about 30%.
  - GDG Suez SA (Europe's biggest utility by market value) said the shortfall had narrowed to 20% from 30%.
  - Snam Rete Gas SpA (Italian pipeline operator) requested 103.4 MMcm (million cubic meter) but to receive 84.9 MMcm per day.
  - Polskie Gornictwo Naftowe i Gazownictwo (Poland's dominant gas company) says demand eased down to 72.3 MMcm per day.
  - Bulgaria's gas supplies restored on Feb 3, 2012.
  - Turkey drew more gas from Russia as her gas supplies from Azerbaijan and Iran dropped due to technical problems related to cold weather. Supplies from Azerbaijan and Iran should have been 40 MMcm but were only 6 MMcm per day on Feb 6.
- Spot market prices increased: Austrian natural gas prices jumped by more than a third, while rates at the German and Dutch hubs also climbed. U.K. day-ahead delivery rose to its highest in more than five years, as much as 19%.
- Medvedev: "Despite an increase in spot prices, Europe was unable to meet its needs under long-term contracts using the spot market. All the talk about a liquid spot market is, to put it mildly, a significant exaggeration."

Source: "Gazprom Says EU Gas Gap Narrowing as Cold Keeps Demand High" by A. Shiryaevskaya, Bloomberg.com , Feb 6, 2012.

- **Prices and Trades**

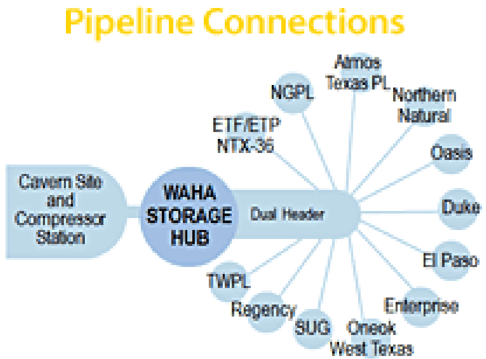
Gas Prices: Spot vs. Forwards (Futures)



- Henry Hub is in Erath, LA. Sabine Pipeline (sabinepipeline.com) owns the pipelines.
- NYMEX (New York Mercantile Exchange) contracts are based on deliveries at the Henry Hub.
- Natural gas futures on NYMEX for Henry Hub Delivery:
  - Feb 7, 2012 trade: \$2.60 per MMBtu in Mar 2012, \$2.76 in Apr 2012, \$3.17 in Oct 2012 (last settlements).
  - Jan 28, 2015 trade: \$2.87 per MMBtu in Feb 2015, \$2.84 in Mar 2015, \$2.97 in Oct 2015.
- Most gas forward prices depend on Henry Hub prices.
  - Nat Gas traders quote a basis (incremental) price in relation to Henry Hub price.
  - If Henry Hub price is \$2.76 for April, it can be \$2.94 for Waha, West Texas. Traders may speak of only \$0.18 as the basis price for Waha.
    $$2.94 = 2.76 + 0.18$$
  - Waha has storage facilities and connected pipelines.

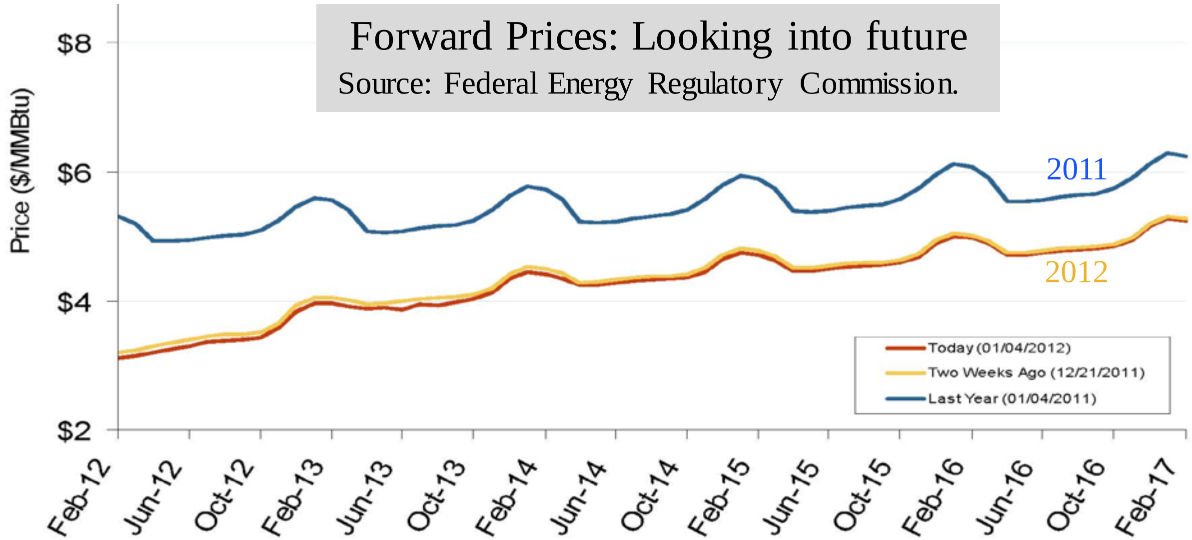
- All-in price = Henry Hub price + Basis price.

Basis price is a (location) spread = All-in price – Henry Hub price

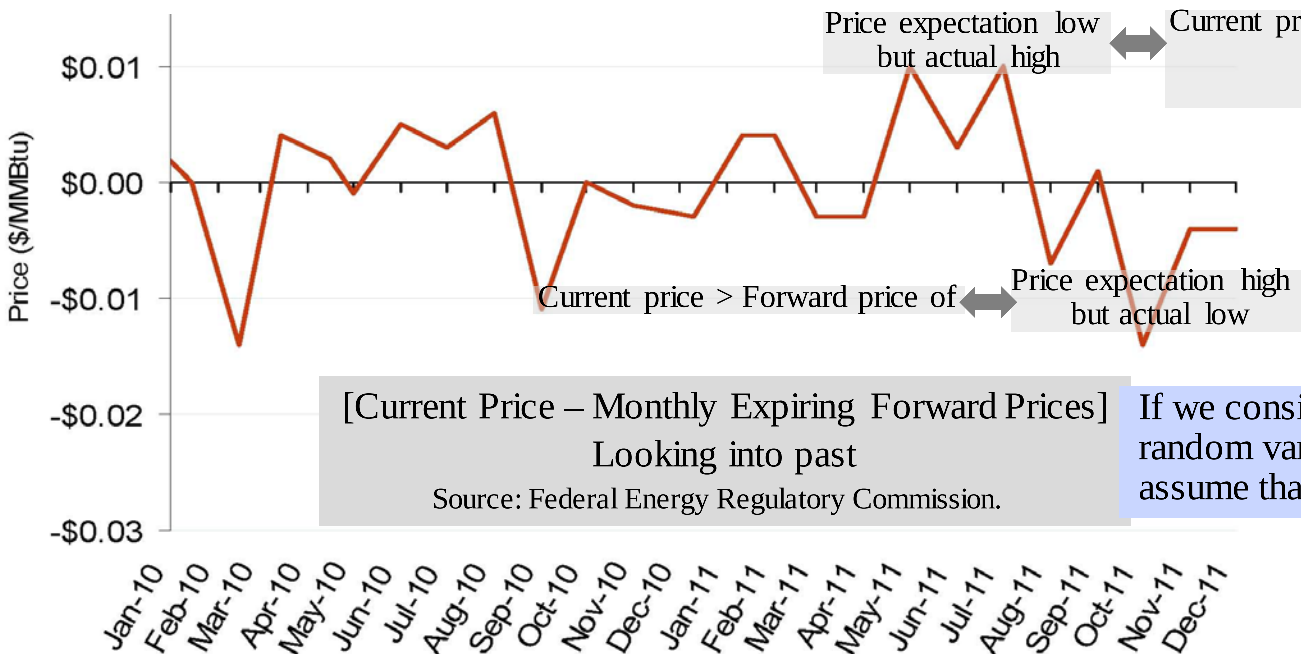


- Gas can also be bought without a forward contract by paying the current prices that is realized in the market.
- Buying with forward contracts or from the spot market.

Natural Gas Forwards (Futures) and Actual Prices

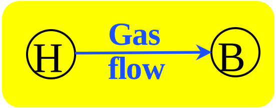


Drop in forward prices in a year from 2011 to 2012



If we consider this series as a random variable, we can safely assume that it is centered at 0.

Benefits of Forwards
Gas flow away from Henry Hub



Consider a company with two forward contracts

1) to buy gas at Henry Hub in April, 2) to deliver gas in Boston.

The company is exposed to the basis price risk.

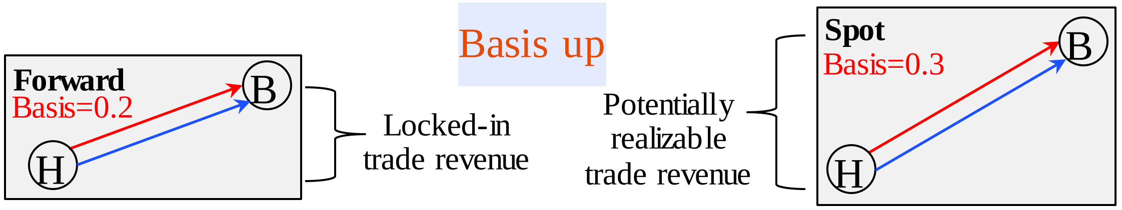
Without forward, use the spot market

- Buy at spot price @Henry Hub & sell at spot price @Boston:
- Profit w spot = [B spot price – H spot price] – Transport cost
  = [Spot basis price] – Transportation cost

With forward (frwd) contract

- Buy at forward price @Henry Hub, sell at forward price @Boston:
- Profit w frwrd = [B frwd price – H frwd price] – Transport cost
  = [Frwd basis price] – Transportation cost

- Benefit of forward: Profit with forward – Profit with spot = Forward basis price – Spot basis price
- 1) Basis up scenario

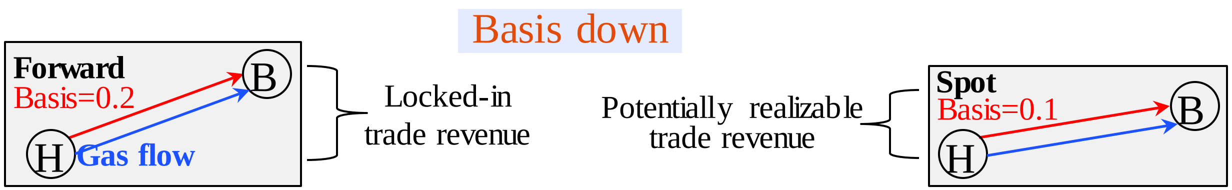


1. Basis Up: forward basis price = $0.2/MMBtu and spot basis price = $0.3/MMBtu.
- Henry Hub price is lower with forwards and significantly lower in spot market.
- Locking in profits with a contract hurts when the profits rise without a contract.

Benefit of forwards = – $0.1/MMBtu

Benefits of Forwards
Gas flow away from Henry Hub

- Benefit of forward: Profit with forward – Profit with spot
  = Forward basis price – Spot basis price
- 2) Basis down scenario



2. Basis Down: forward basis price = \$0.2/MMBtu and spot basis price = \$0.1/MMBtu.
- Price is cheaper at Henry Hub; significantly cheaper in forward contracts and little cheaper in spot market.
- The profit is proportional to the basis price when gas flows away from Henry Hub.
- Locking in profits with a contract helps when the profits drop without a contract.

Benefit of forwards = 0.2 – 0.1 = \$0.1/MMBtu

When gas flows away from Henry Hub,
1. Basis price rises in the spot market $\Longrightarrow$ Benefit of forwards < 0
2. Basis price drops in the spot market $\Longrightarrow$ Benefit of forwards > 0

Benefit of Forward	Basis↑	Basis↓
Away from Henry Hub	-	+

Trading

Speculative traders bet on the price of natural gas.

- Next week price of gas is speculated to be $4 per MMBtu, buy now if price is $3.90 per MMBtu.
- This type of direct bet is not very interesting, because price is seasonal.

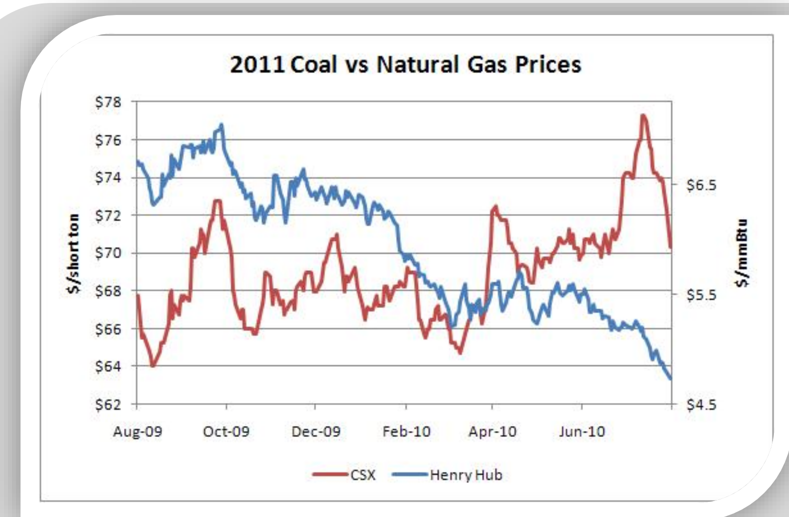
Spread trades: Trader uses the price difference (spread) between two securities.

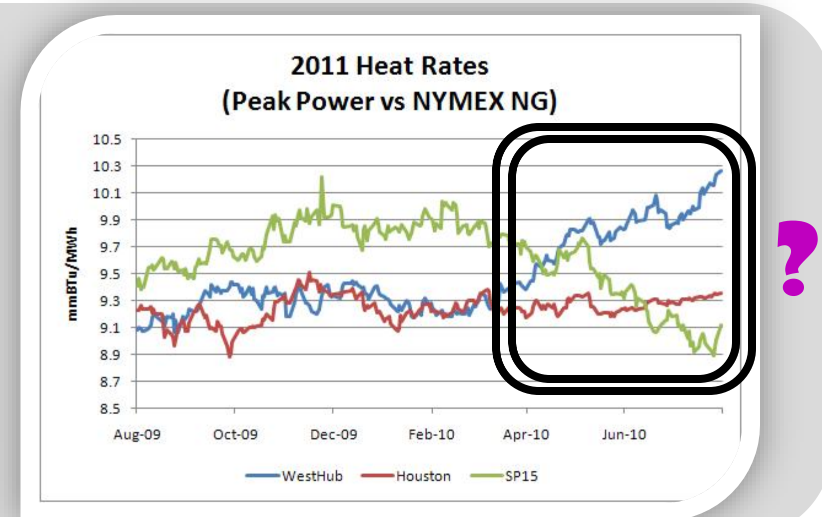
- **Location spreads:** Prices differ across locations. Recall All-in Price = (Henry Hub Price + Basis Price).
  - Transportation takes time, storage is limited, pipelines and tankers have limited capacity so price differences exist.
  - Location spread can be less in forward markets than spot markets as logistics can be arranged for in advance.
- **Time spreads:** Price difference between far apart periods of high (winter) and low (summer) demands.
  - This spread decreases with larger storage capacity and cheaper storage cost.
  - This spread increases with a colder winter.
- **Swing spread:** Price difference between closer periods of high and low demands.
  - A lot of gas is used on Monday mornings to restart industrial facilities and to reheat offices.
  - Much less gas is used on Saturday nights as less industrial and residential (sleeping people) demand.
  - Buy gas on Saturday night store it and sell on Monday mornings.

Heat Rate Spreads based on Heat Rates

Heat rate: Ratio of (Electricity price) / (Gas price) = ($/MWh) / ($/MMBtu) = MMBtu / MWh. Nothing to do with efficiency.

- Electric & gas prices are related ⇐ natural gas is used to generate power in many regions.
- In coal regions (e.g., West Virginia), coal is used to generate electricity. There coal price affects the electricity prices.
- Ex: A Louisiana generator uses only gas powered plants for electricity. It currently sells electricity at $50/MWh and buys natural gas at $2.5/MMBtu, what is the heat rate? Heat rate = 20 = 50/2.5 MMBtu / MWh.
  - A West Virginia generator uses only coal powered plants for electricity. It currently sells electricity at $50/MWh and buys natural gas at $2.5/MMBtu, what is the heat rate? Heat rate = 20 = 50/2.5.
  - Ex: Gas price ↑ $3/MMBtu, Louisiana price ↑ $60/MWh & West Virginia price ↑ $54/MWh. Lousiana is more exposed to natural gas prices. Heat rates? Louisiana generator heat rate = 20; West Virginia generator heat rate = 18.
  - Ex: Gas price ↓ $2/MMBtu, Louisiana price ↓ $40/MWh & West Virginia price ↑ $46/MWh. Heat rates? Louisiana generator heat rate = 20; West Virginia generator heat rate = 23.





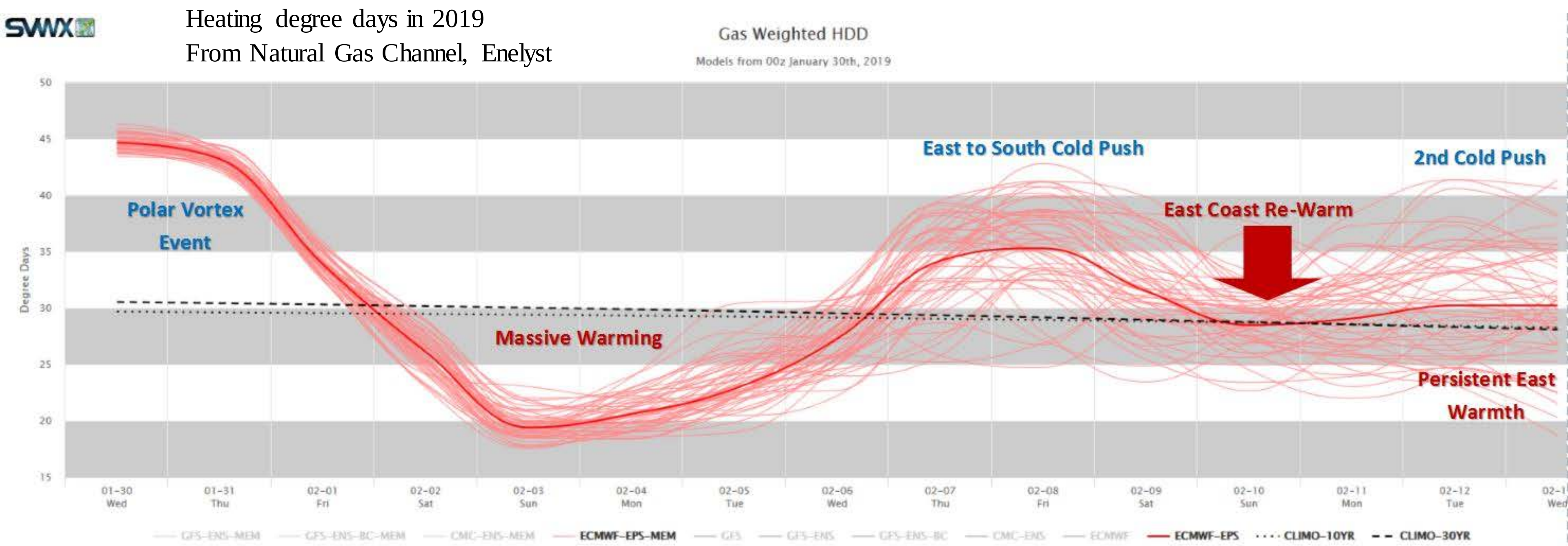
- If gas price ↓, heat rate computed with the price of electricity generated from coal-powered plants ↑.
  Case in point: Heat rate in Eastern United States called WestHub.
- If gas price ↓, heat rate computed with the price of electricity generated from gas-powered plants is stable.
  Case in point: Heat rate in Houston or Louisiana in the examples above.

Trading with Temperature

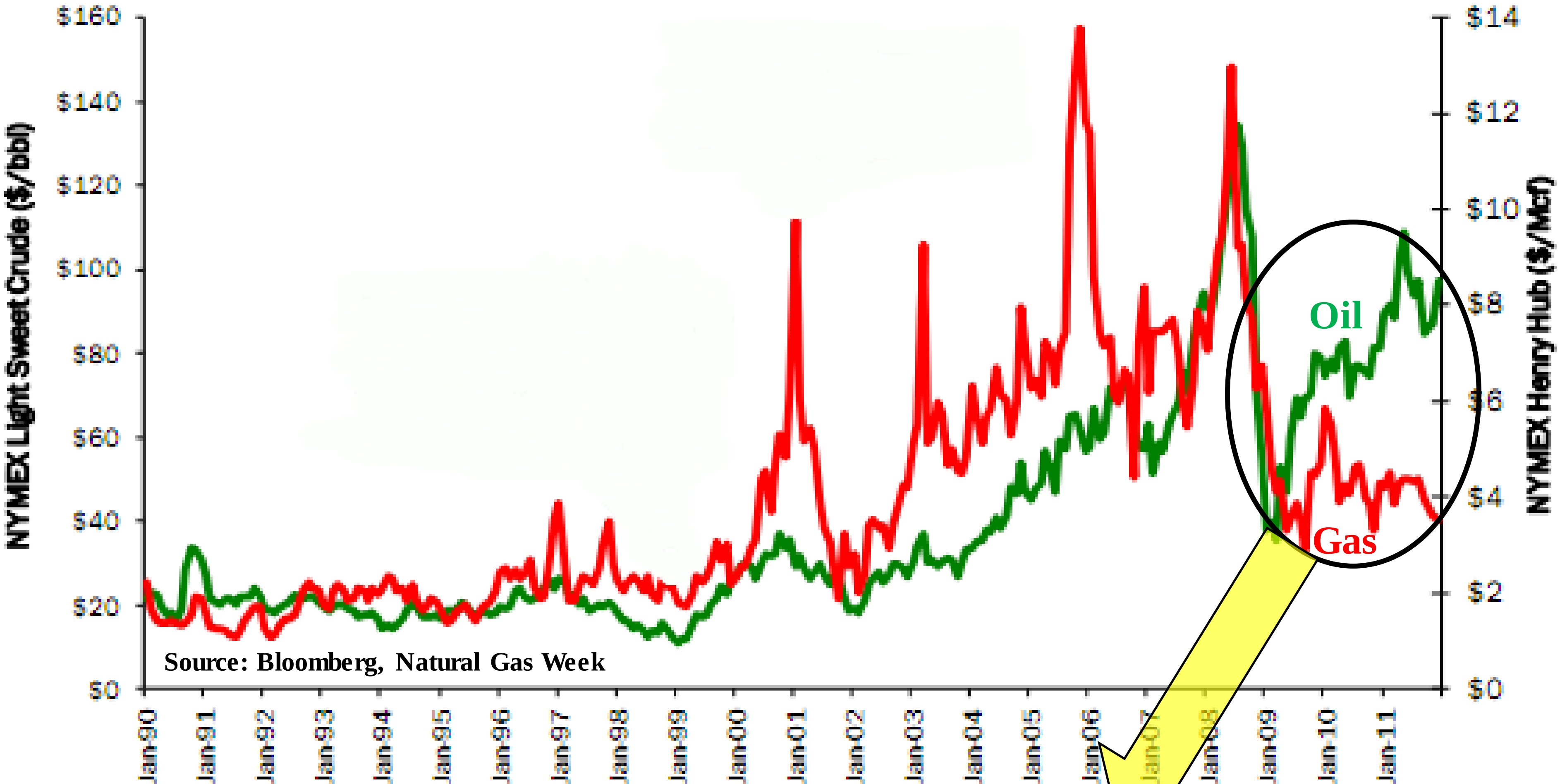
- Temperature affects natural gas demand. Colder weather means more demand.
  - Natural gas price can be regressed against heating degree days (HDD).
    - HDD on a particular day = max {65-average daily temperature}
    - Similarly, CDD (cooling degree days) on a particular day = max {average daily temperature-65}
  - HDD in Dallas in Jan: sum over 31 Jan days [max {65-average daily temperature}]
  - Correlation coefficient between gas price and HDD at various regions (all are in the east of Rocky mountains) is at least 0.78 in Table 4 of Timmer and Lamb (2007).

R.P. Timmer and P.J. Lamb (2007). Relations between Temperature and Residential Natural Gas Consumption in the Central and Eastern United States. *Journal of Applied Meteorology and Climatology*, Vol.46: 1993–2013.

Heating degree days in 2019
From Natural Gas Channel, Enelyst



Oil & Gas Price History



Historically low gas prices due to glut of natural gas in the US.

Chesapeake chief executive A. McClendon: "An exceptionally mild winter to date has pressured U.S. natural gas prices to levels below our prior expectations and below levels that are economically attractive for developing dry gas plays in the U.S., shale or otherwise," Chesapeake will reduce drilling activity this year [2012] as gas prices have reached a 10-year low. Source: Chesapeake Energy Pulls Back Amid Natural-Gas Glut by B. Lefebvre, WSH on Jan 23, 2012.

- **Coal**

Next few pages contain a summary of "coal" discussion from coal.pptx

At the request of Class of 2018, the coal coverage is

- **reduced significantly and**
- **integrated into gas coverage.**

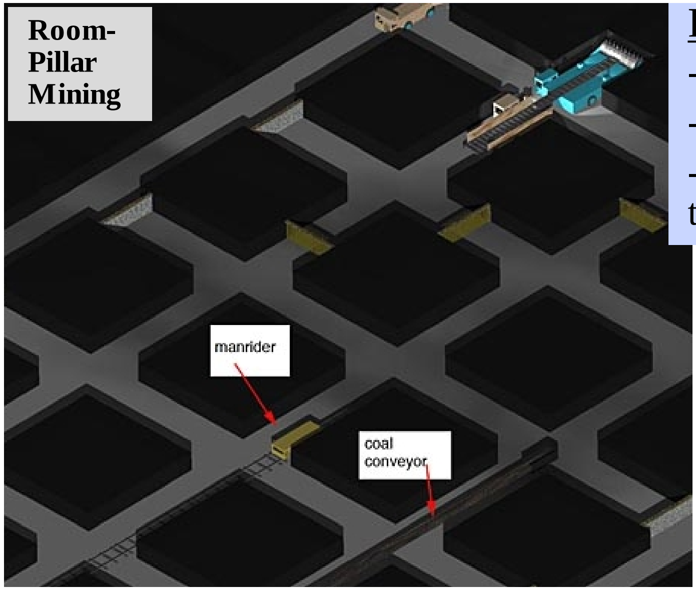
Fossil Fuel: Coal

- Coal, like oil and gas, forms from organic materials. Coal formation started during the Carboniferous Period (360-290 million years ago).
- Coal contains much less hydrogen than oil or gas, but it still is a hydrocarbon.

	Carbon molecule ratio	BTU per pound	kCal per kg	
Peat	●<40	●<6300	●<3503	**Brown**
Lignite	40<●<50	6300<●<8300	3503<●<4615	**Brownish**
Bituminous	50<●<85	8300<●<14000	4615<●<7784	**Black**
Anthracite	85<●<98	14000<●	14000<●	**Glossy black**
Graphite	98<●	14000<●	14000<●	**Pencil lead**

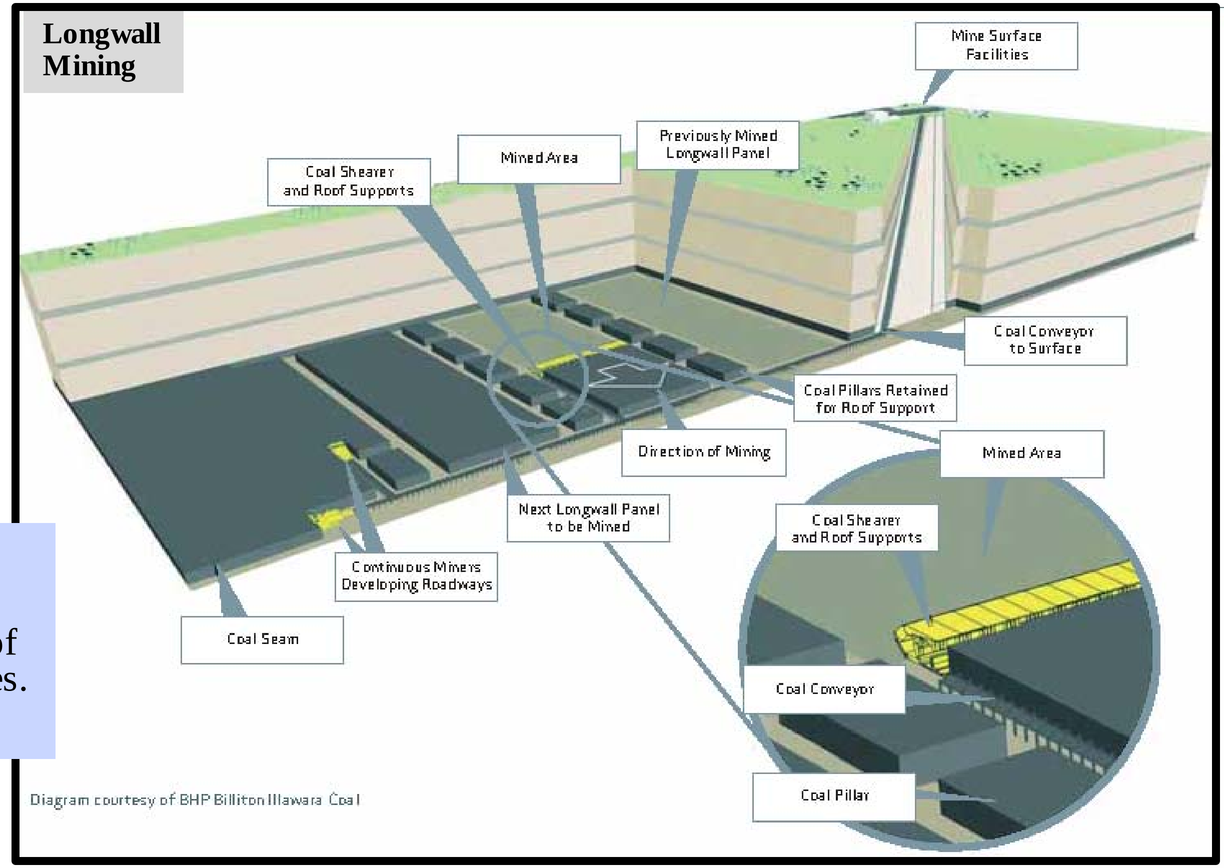
- Significant amount of coal is used for power generation. In 2002, 39% of global electricity is generated from coal. This percentage is expected to drop slightly to 38% in 2030.
- Use of coal depends on country
    - US: 91% of coal for electric generation
    - China: 55% of coal for electric generation

Production: Coal Mining



Room-Pillar Mining:

- Pillars support the rocks/soil (overburden) above the mine.
- Pillars can consume up to 40% of coal, so 60% coal recovery.
- To improve recovery, use retreat mining: remove coal from pillars as exiting the mine. Dangerous but possible.

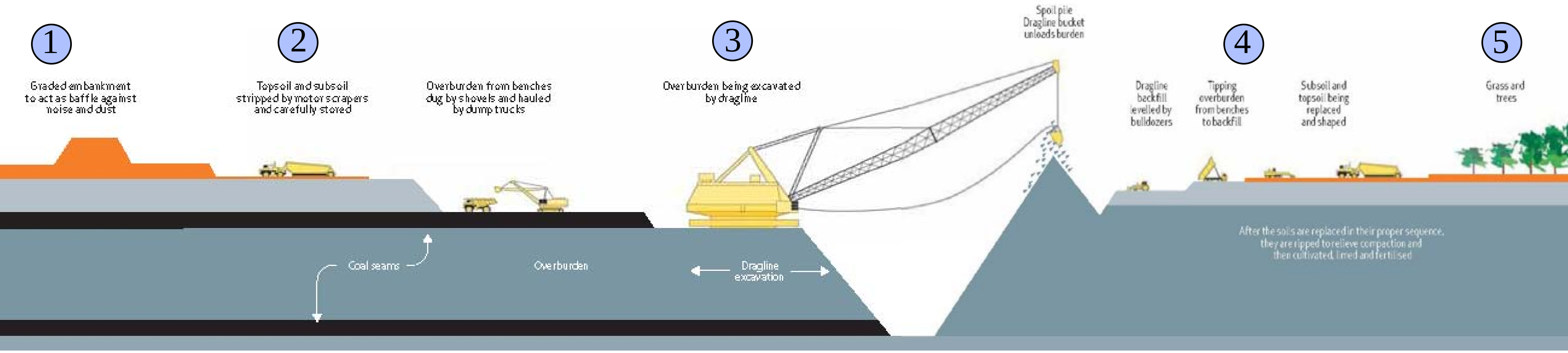


Longwall Mining:

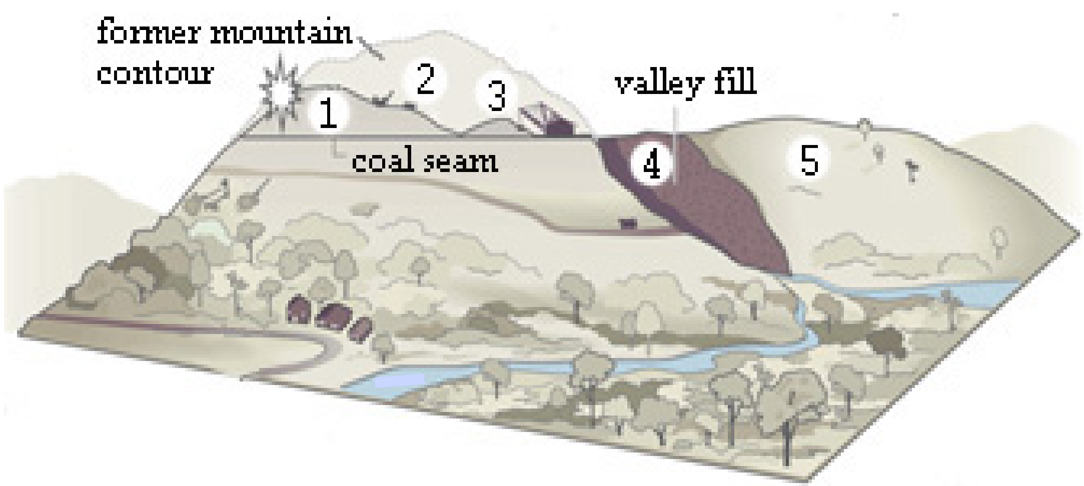
- Coal shearer has roof supports.
- After the shearer is done with a panel, roof supports move away and the panel collapses.
- 75% of the coal can be extracted.

Both Retreat and Longwall mining cause a collapse underground; effects over the ground?

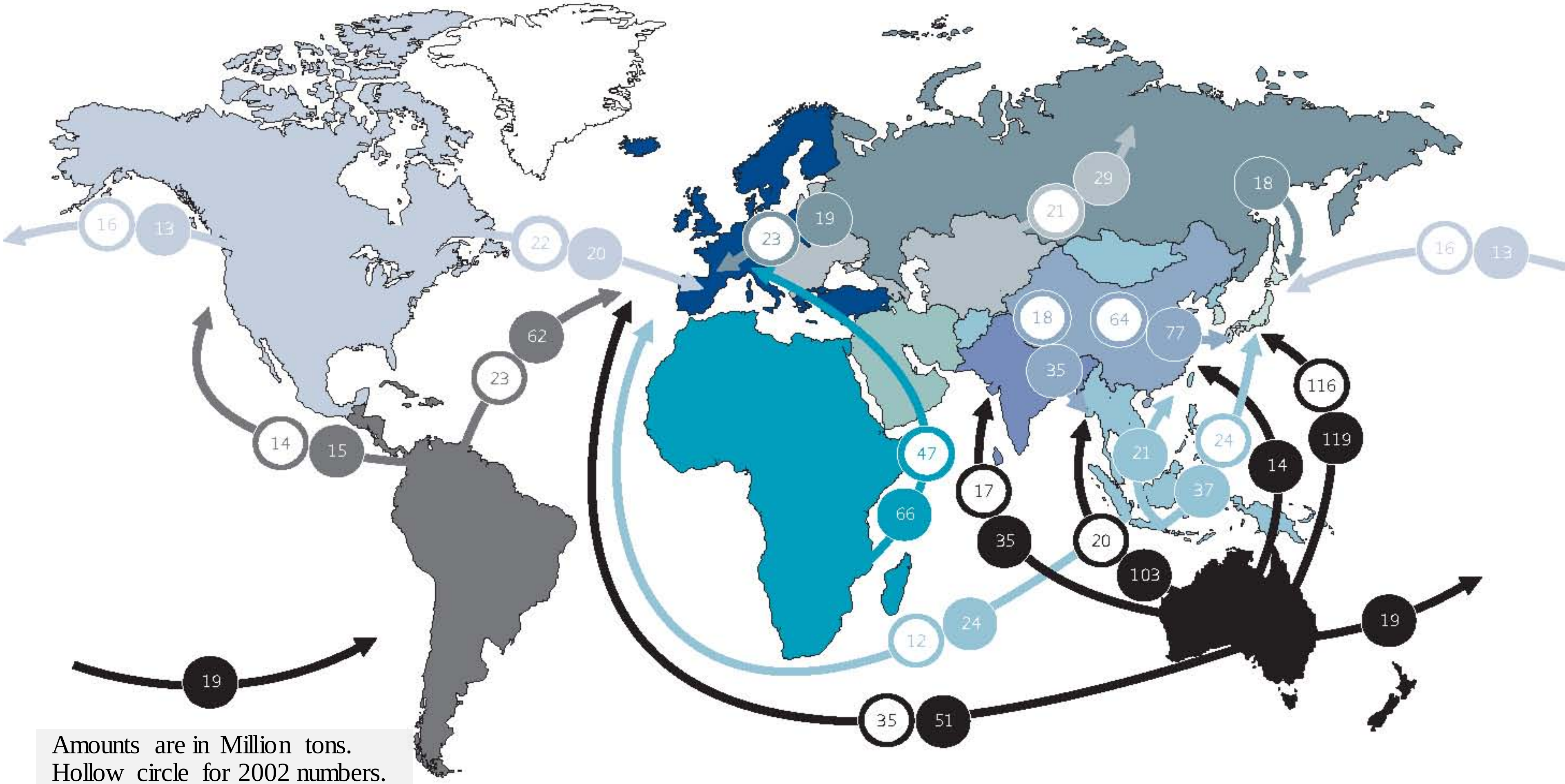
Surface Mining: 5 steps



Surface mining is safer and can be used when coal I closer to the surface. But it can change the mountain contours.



Global Coal Trade: Coal is shippable

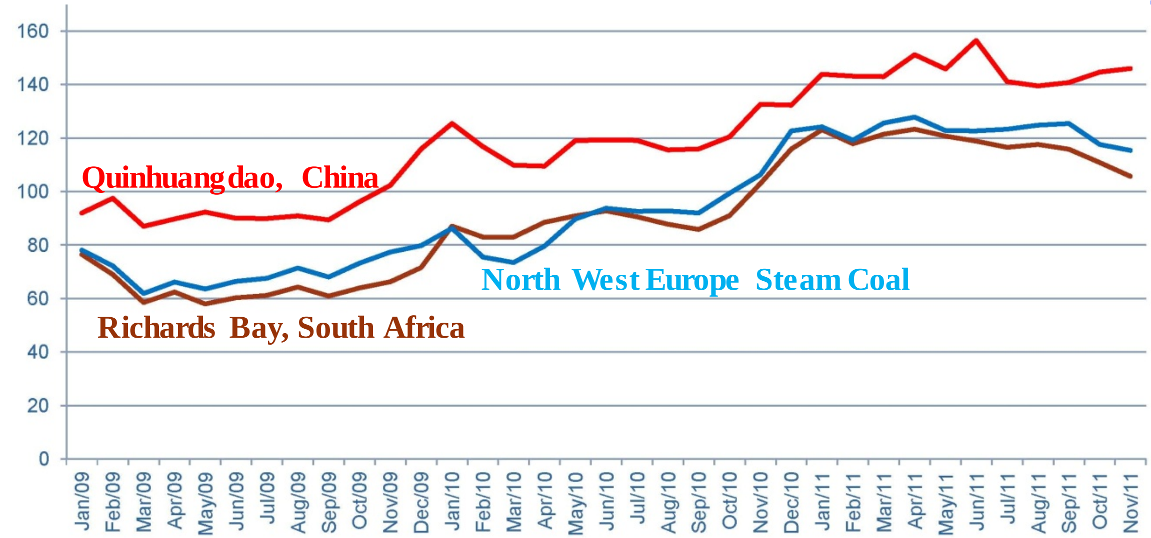


Amounts are in Million tons.
Hollow circle for 2002 numbers.
Solid circle for 2030 forecasts.

Largest exporter Australia sells to Pacific Market (Japan, Korea, Taiwan, India).

Atlantic Market (UK, Germany, Spain) buys from Africa, Australia, North America, Russia, Indonesia. Atlantic market is expected to get smaller.

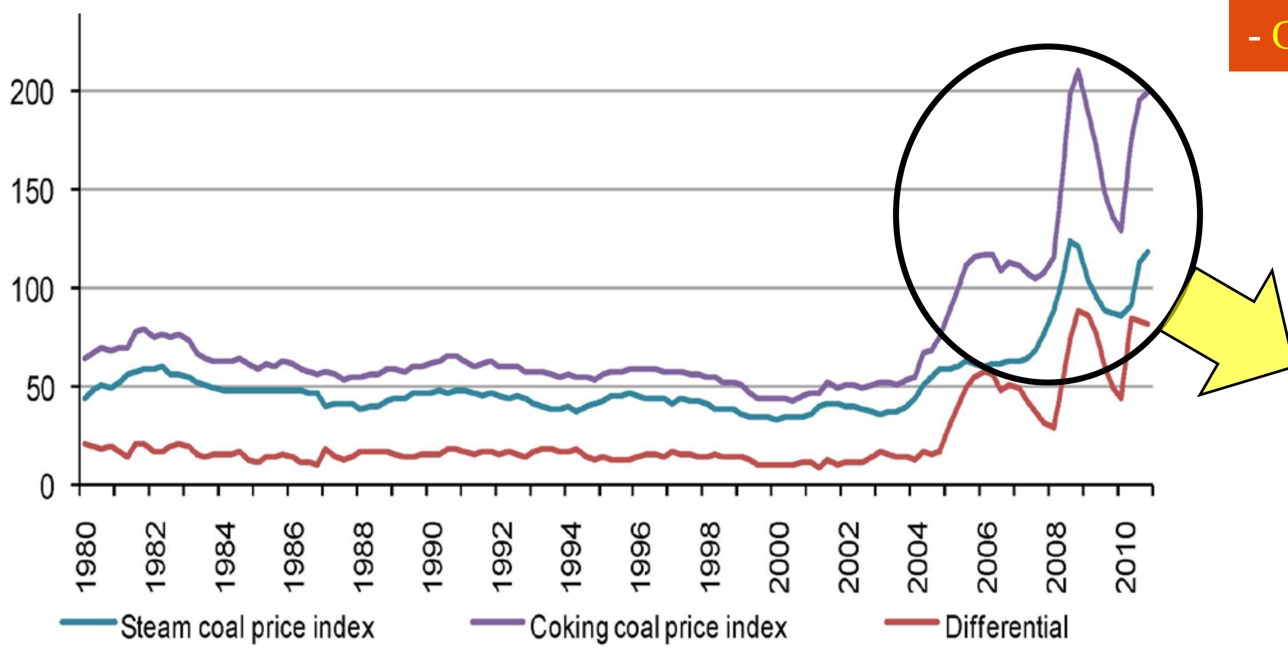
Coal is Cheap
Coal Prices $ per ton



Price is $ per ton for Mid-range Bituminous coal that gives about 6400 kCal per kg.
Or 11500 Btu=0.0115 MMBtu per pound.
Or about 0.025 MMBtu per kilogram.
Or 25 MMBtu by paying about $120/ton.
Or 1 MMBtu by paying $4.80.

For 1 MMBtu,
- Pay $35 for gasoline;
- Pay $3-16 for natural gas;
- Pay $4-5 for coal.

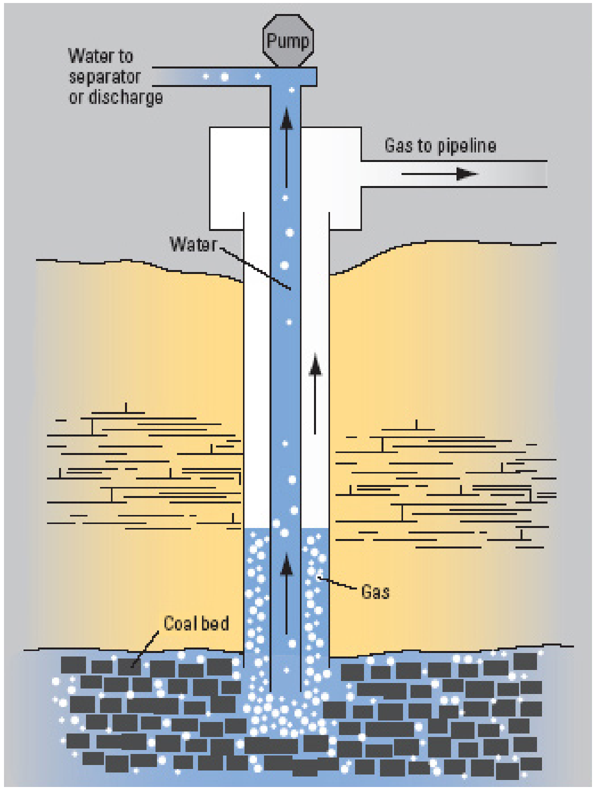
- Gas is now the cheapest!!
- Gasoline is the most expensive.

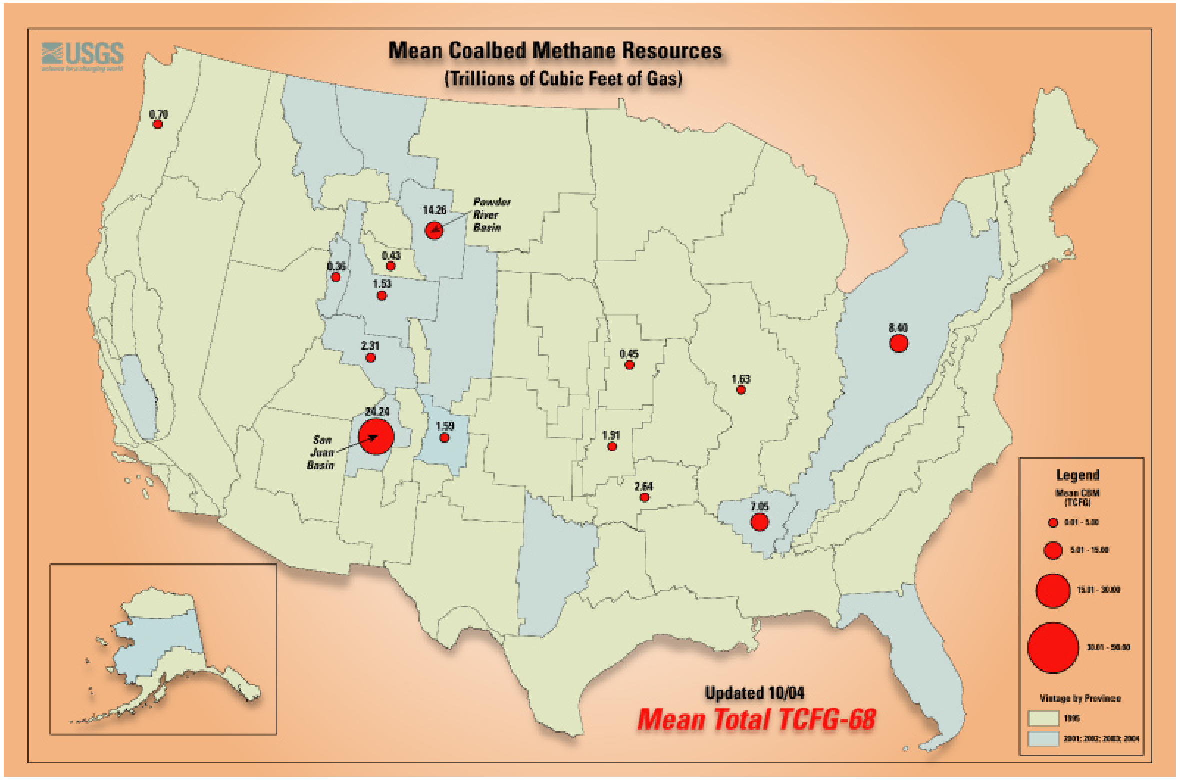


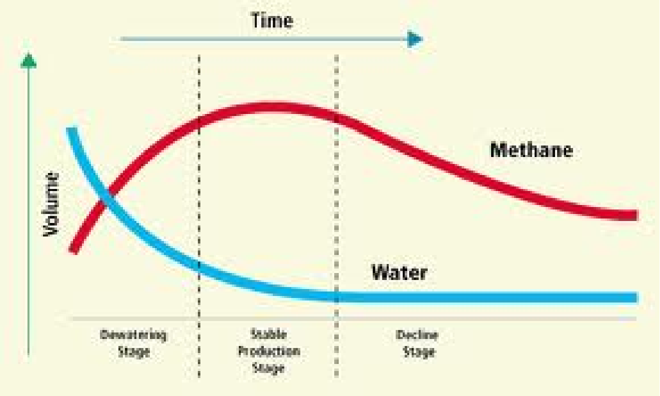
Steam coal for power generation, Coking coal for iron & steel manuf.
Steam coal is appreciating faster than coking coal. Steam and coking coal prices are decoupling!

Coal Bed Methane (CBM) and Production

- Recall Oil and Gas have H along with C; while coal has mostly C.
- **Coal Bed Methane:** H remains as methane gas CH_4 in a coal reserve.
  - CBM is natural, common and causes explosion in coal mines.
  - Coal has more surface area than other reservoir rocks to hold methane
  - Water holds methane in the reservoir
- Production is by pumping the water out to reduce the pressure in the reserve. This releases gas which goes up to the surface.



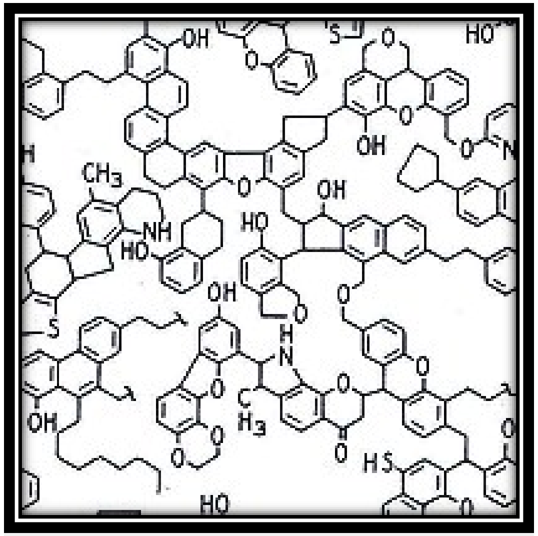




Conversions among Hydrocarbons

Conversions from cheap & available → expensive & scarce

- Coal → Oil Conversion: Fischer-Tropsch technology
  - An assembly of H_2 to CO to obtain CH_2 groups, long-chain HCs.
    - The first two steps involve the manufacture of synthesis gas (**CO** and **H_2**) from coal.
  - In 1925, Franz Fischer and Hans Tropsch developed a catalyst for this conversion.
  - By 1941, Fischer-Tropsch plants produced ~700,000 tons of oil per year in Germany.
  - Post WW II, Fischer-Tropsch technology was under study in most industrial nations. The low cost and high availability of crude oil led to a decline in interest the process. The technology leader is Sasol, South Africa.
  - 2015, Sasol has a Lake Charles, LA plant project to turn natural gas into ethylene. A bigger project to turn natural gas to diesel fuel cancelled in 2015 due to low oil prices.



Formulas for coal
$C_{137}H_{97}O_9NS$ for bituminous,
$C_{240}H_{90}O_4NS$ for anthracite.

Oryx Plant, Qatar.
Based on "Gas to Liquids" by O. Glebova, Nov 2013. Oxford Institute for Energy Studies.

Some Gas-to-Oil plants in Malaysia and Russia. Methanol to Oil in New Zealand.

- Gas → Oil Conversion
  - An assembly of H_2 to CO_2 to obtain CH_2 groups, long-chain HCs.
    - The first step involve the manufacture (**CO_2** and **H_2**) from gas
    - This is licensed by the Danish company Haldor Topsoe.
  - Oryx Plant, Qatar.

Summary

- Resources
- Prices
- Trades
- Coal

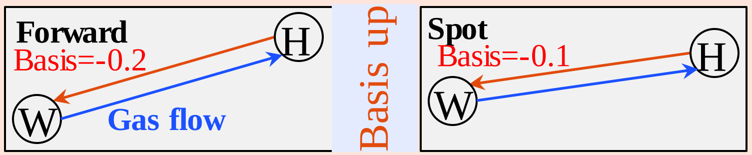
Benefits of Forwards
Gas flow towards Henry Hub

- Consider a company with two forward contracts
  1) to buy gas at Waha in April, 2) to deliver gas at Henry Hub.

- The company is exposed to the basis price risk.
  - Buy at forward price at Waha, sell at forward price at Henry Hub:
  - Profit with forward = [H forward price – W forward price] – Transport cost= [−Forward basis price] – Transport cost
- Without forward contracts, use the spot market
  - Buy at spot price at Waha and sell at spot price at Henry Hub:
  - Profit with spot = [H spot price – W spot price] – Transport cost= [– Spot basis price] – Transport cost
- Benefit of forwards: Profit with forward – Profit with spot = Spot basis price – Forward basis price
- Two scenarios: 1) Basis up or 2) Basis down

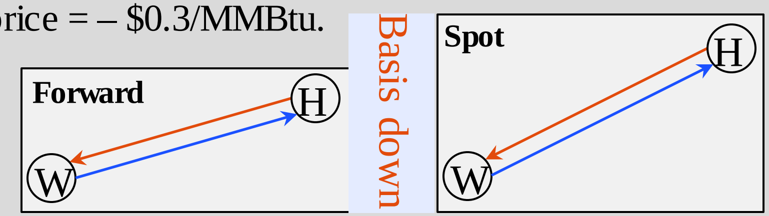
1. Basis Up: forward basis price = – \$0.2/MMBtu and spot basis price = – \$0.1/MMBtu.
- Price is cheaper at Waha; significantly cheaper in forward contracts and little cheaper in spot market.
- The profit (with forward or spot) is proportional to the negative of the basis price when gas flows towards Henry Hub.
- Locking in profits with a contract helps if the profits drop without the contract.

Benefit of forwards = $-0.1 - (-0.02)$ = **\$0.1/MMBtu**



2. Basis Down: forward basis price = – \$0.2/MMBtu and spot basis price = – \$0.3/MMBtu.
- Waha price is lower with forwards and significantly lower in spot market.
- Locking in profits with a contract hurts if the profits rise without the contract.

Benefit of forwards = – \$0.1/MMBtu



When gas flows towards Henry Hub,
1. Basis price rises in the spot market ⟹ Benefit of forwards > 0
2. Basis price drops in the spot market ⟹ Benefit of forwards < 0

Benefit of Forward	Basis↑	Basis↓
Away from Henry Hub	-	+
Towards Henry Hub	+	-