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Shale Revolution in the Golden Age of Gas

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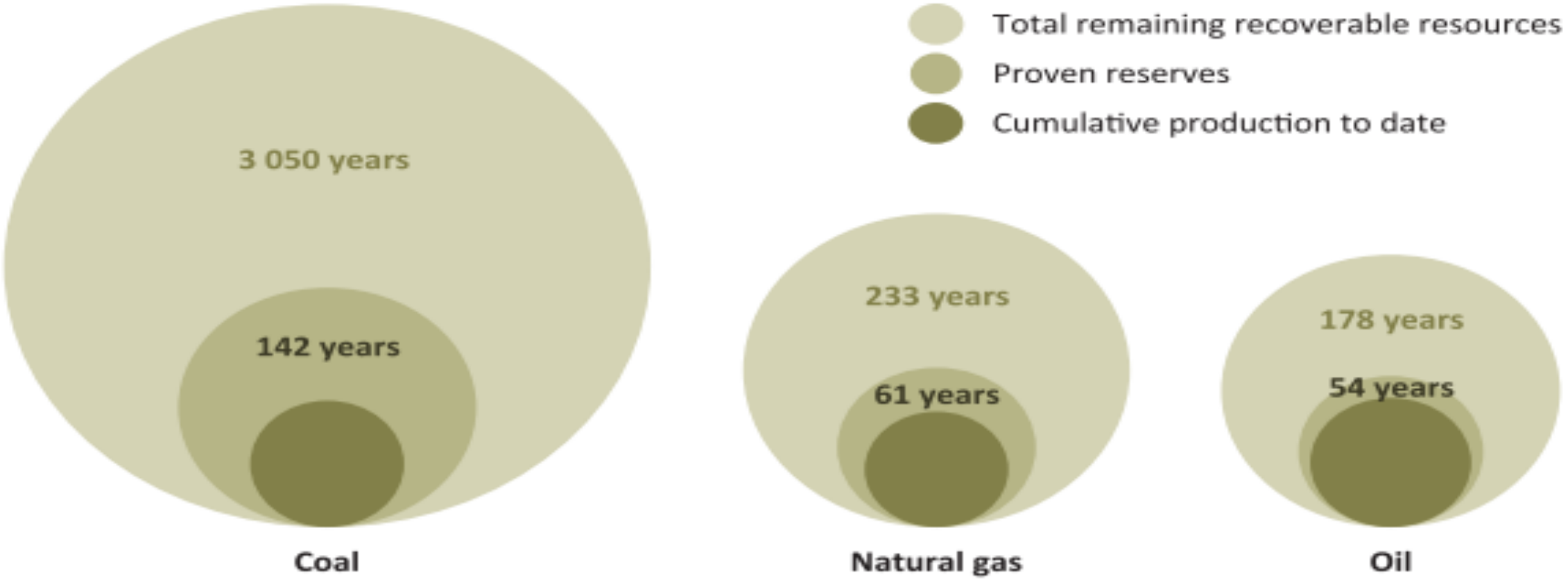
A presentation to the 10th Energy and Finance Conference 2015

Cass Business School, London

9-11 September, 2015

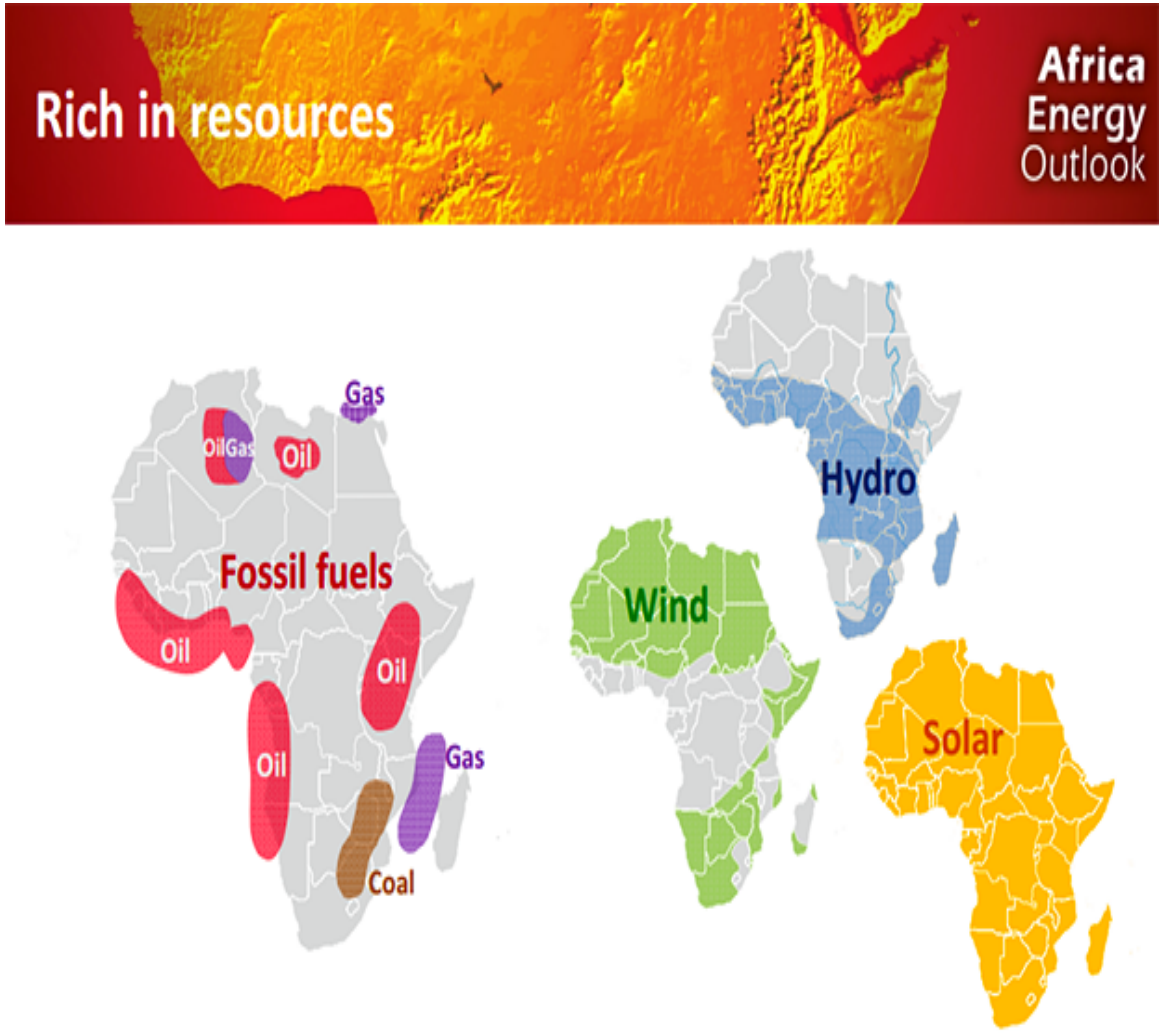
Peak Oil and Energy Depletion over-simplified

Figure 2.10 ▷ Fossil energy resources by type

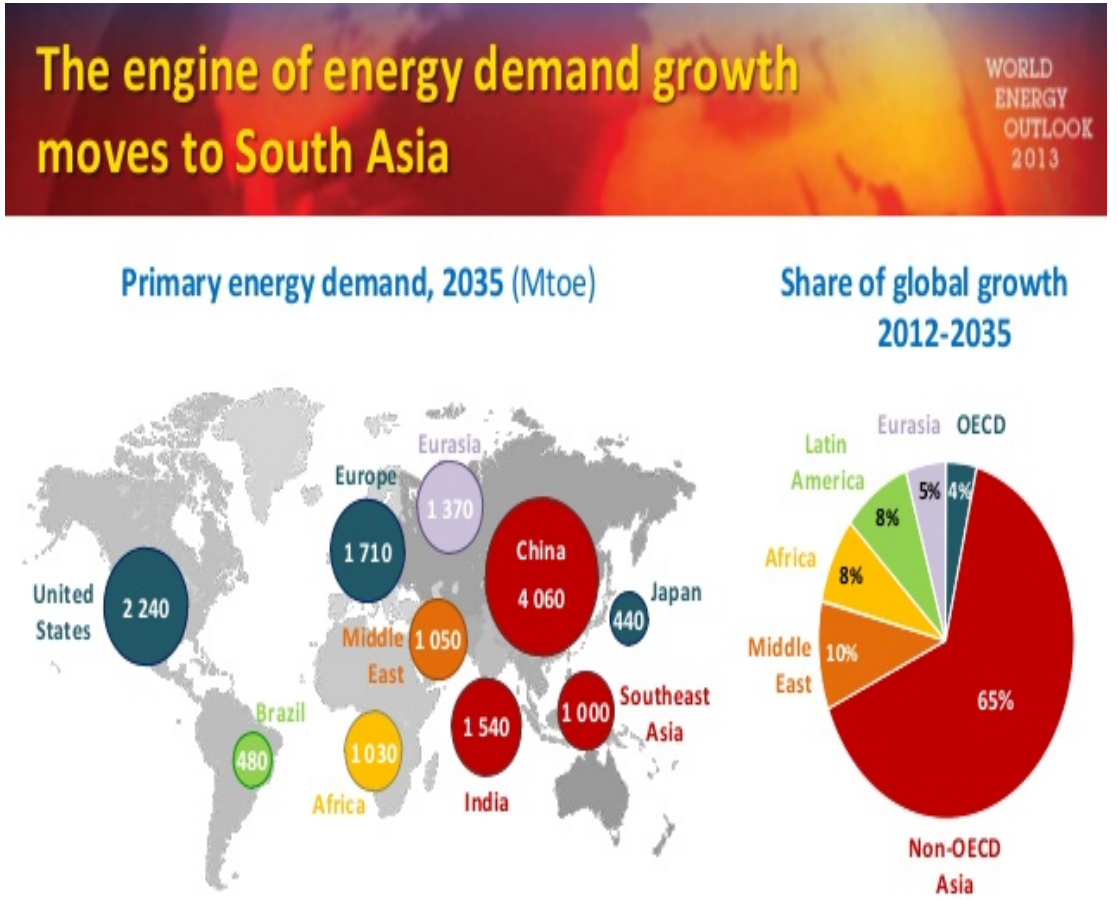


Notes: All bubbles are expressed as a number of years of production based on estimated production in 2013. The size of the bubble for total remaining recoverable resources of coal is illustrative and is not proportional to the others. The figure specifies the status of reserves for coal as of end-2011, and gas and oil as of end-2012. Sources: BGR (2012); O&GJ (2012); USGS (2000, 2012a and 2012b); IEA estimates and analysis.

But supply sources and demands mismatch

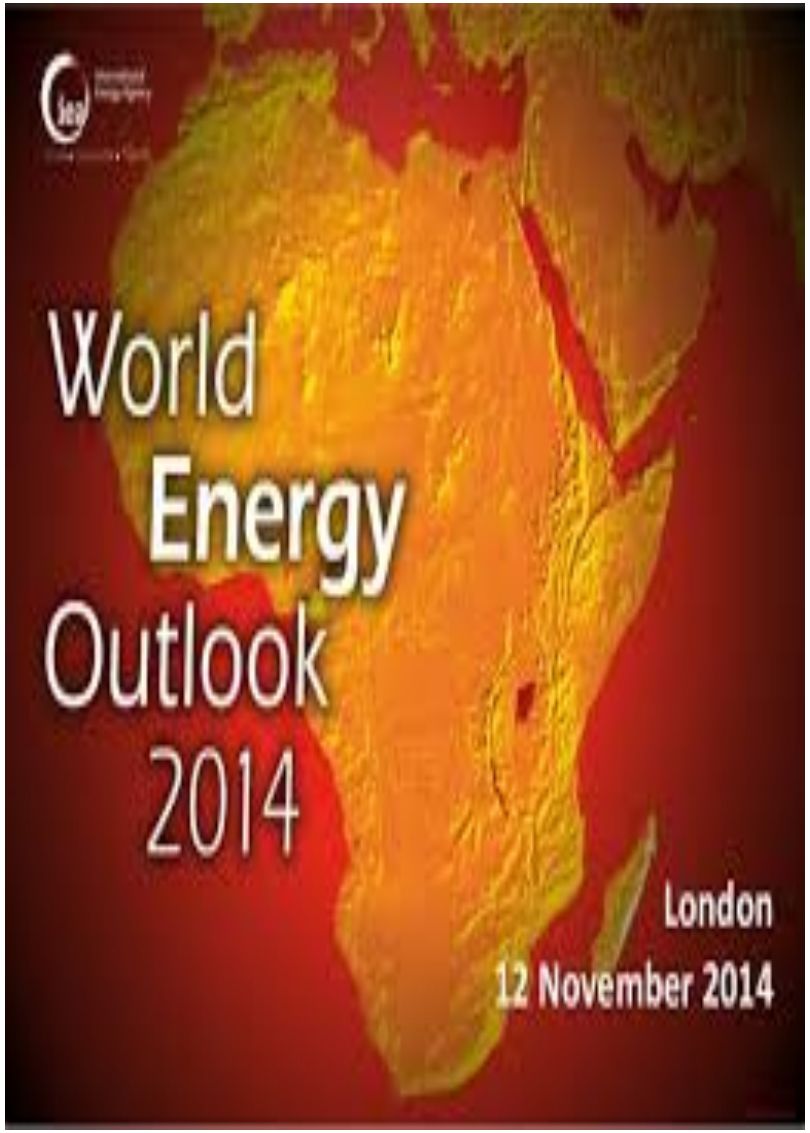


In the last 5 years, almost 30% of global oil & discoveries were in sub-Saharan Africa; the region has vast untapped renewables potential, notably hydro & solar



China is the main driver of increasing energy demand in the current decade, but India takes over in the 2020s as the principal source of growth

Geopolitics, Price Volatility, and Climate Change intervene



Navigating a stormy energy future

World Energy Outlook 2014

- Geopolitical & market uncertainties are set to propel energy security high up the global energy agenda
- Volatility in the Middle East raises short-term doubts on investment & spells trouble for future oil supply
- Nuclear power can play a role in energy security & carbon abatement – but financing & public concerns are key issues
- Without clear direction from Paris in 2015, the world is set for warming well beyond the 2 °C goal
- Far-sighted government policies are essential to steer the global energy system on to a safer course

Energy Security adds uncertainties

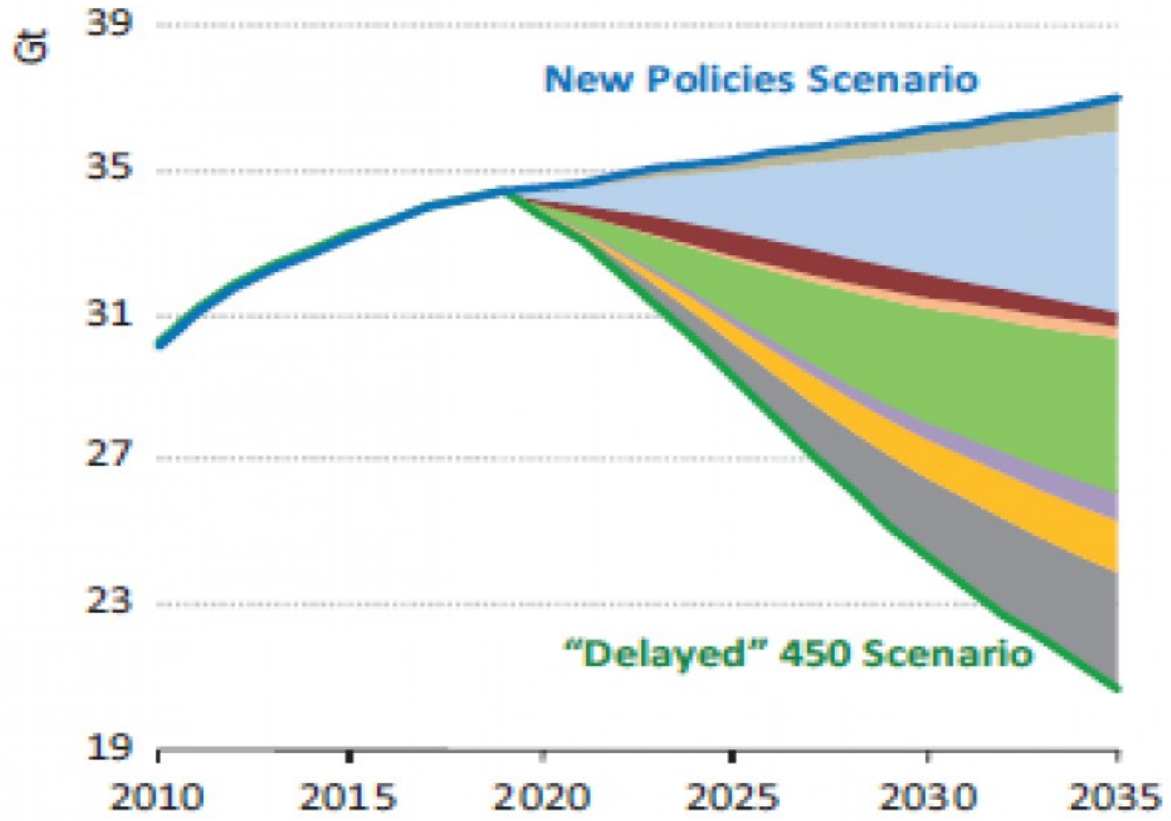
Russian pipelines to Europe

China's energy security

Climate Change challenges

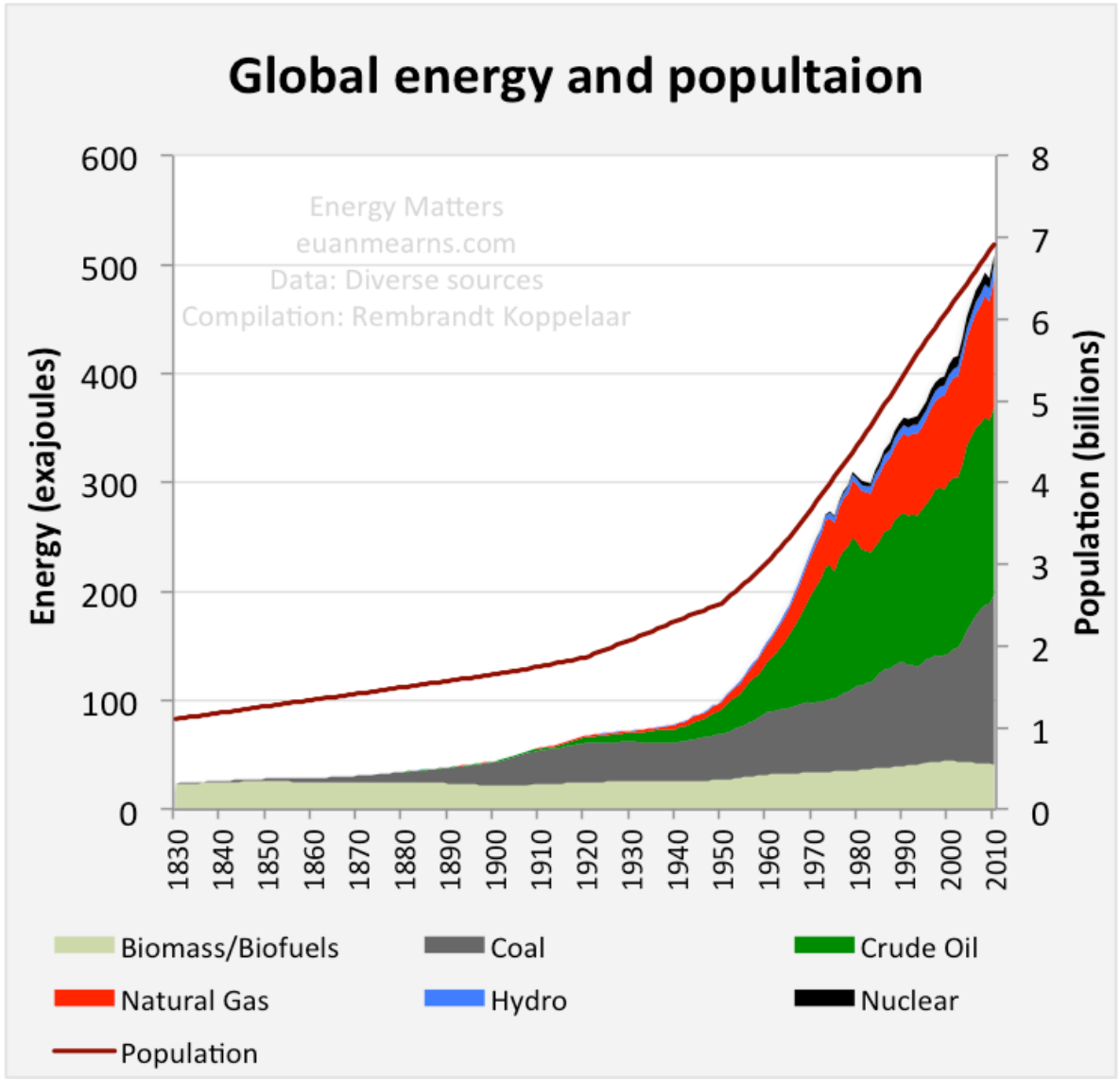
IEA's 450 ppm mitigation scenario to meet 2 degree target

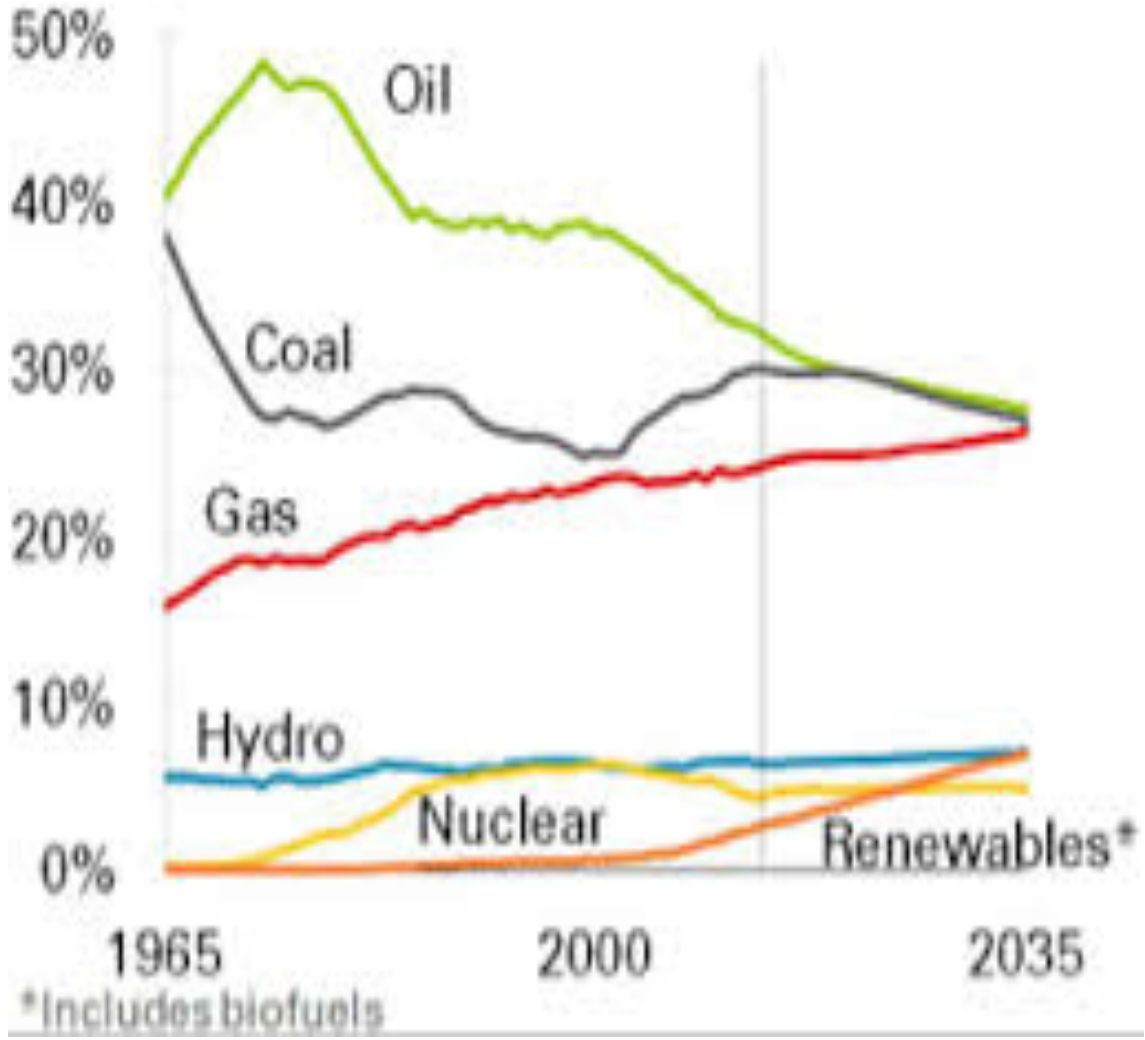
Figure 3.15 ▷ World energy-related CO_2 emissions abatement in a "delayed" 450 Scenario relative to the New Policies Scenario



CO_2 Abatement	2025	2035
Demand	5%	5%
End-use efficiency	27%	31%
Power plant efficiency	11%	3%
Fuel and technology switch	2%	2%
Renewables	25%	26%
Biofuels	5%	5%
Nuclear	9%	9%
CCS	15%	20%
Total (Gt CO_2)	**6.2**	**16.4**

Growth moving towards homeland and cleaner energies

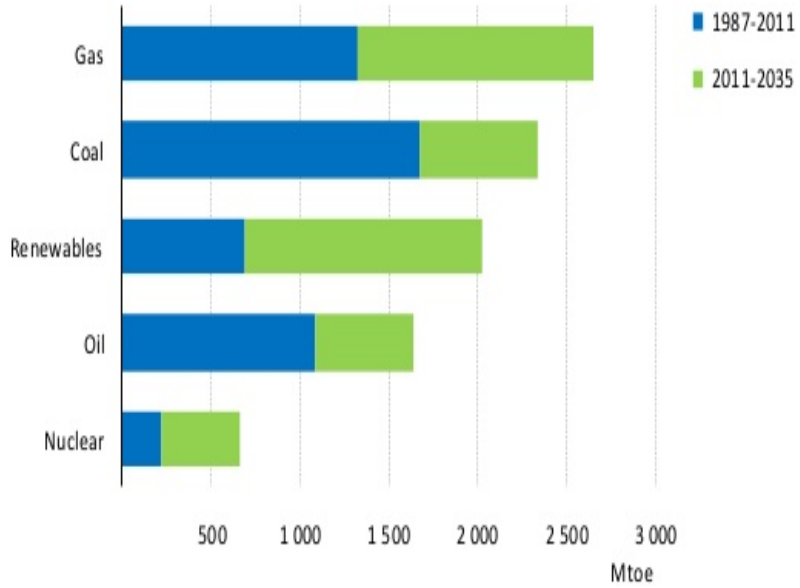




Source: BP Energy Outlook 2035

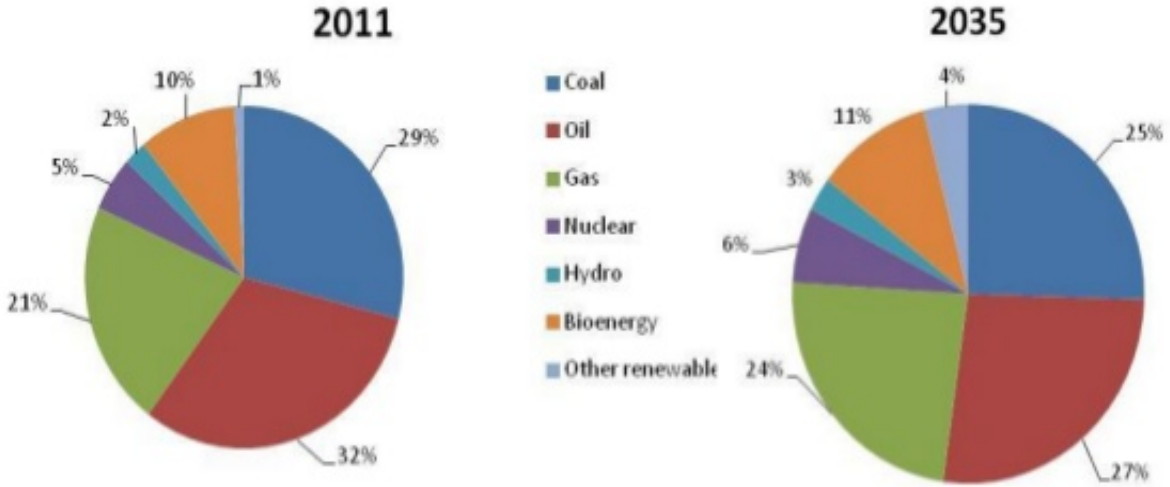
Gradually changing mix towards Gas

Growth in total primary energy demand



25 years ago the share of fossil fuels in the global mix was 82%; it is the same today & the strong rise of renewables in the future only reduces this to around 75% in 2035

World Energy Demand by Fuel Type

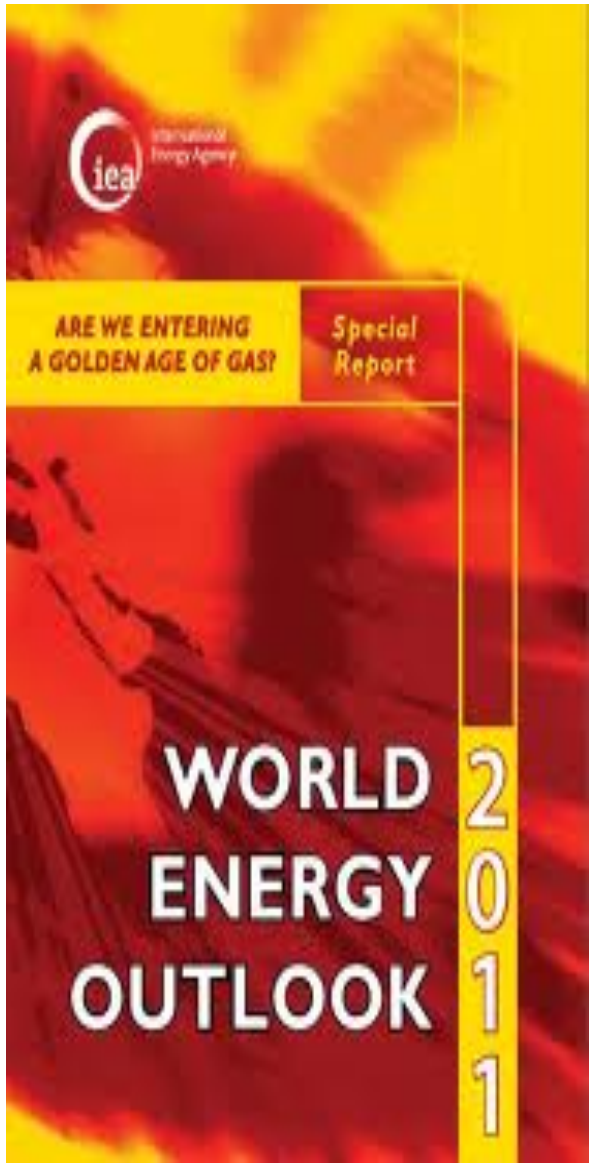


Global energy needs expected to increase by 30%

Oil use is expected to increase 13% to 101 million barrels per day

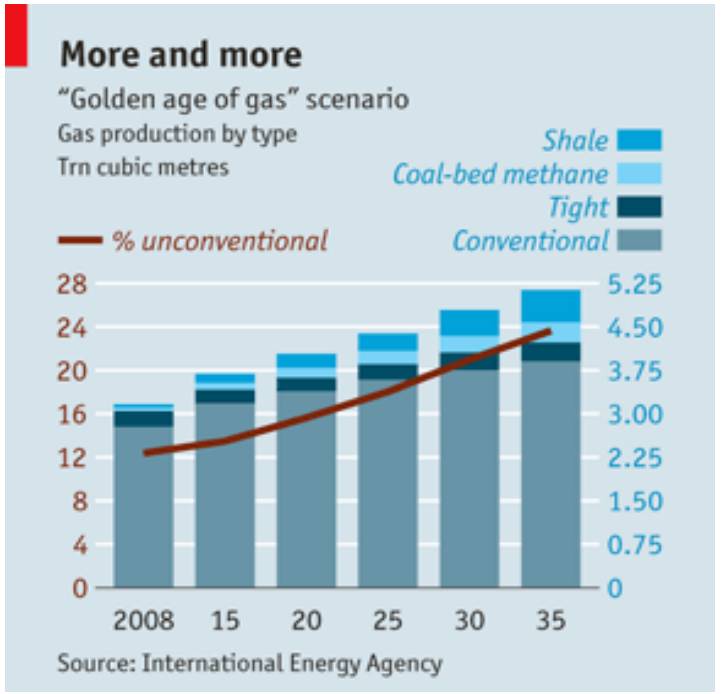
Source: International Energy Agency, World Energy Outlook 2013

Golden Age of Gas



- Global ***conventional*** gas resources = ***120 years*** current energy consumption
- ***Unconventional*** (*shale, tight gas* in sandstones, rocks of low permeability), *coal-bed methane* (CBM), *artic, and gas hydrates* - crystallized solids with methane molecules in permafrost and deep seabeds > all other carbon fuels combined).
- ***Total + unconventional – 250 years*** ; but discovery to production take decades
- Natural gas 45% ***less CO2 emission @ btu*** < coal; 30% < oil
- Natural gas use ***to rise by 50% to 25%*** of global energy demand ***by 2035***.
- ***CBM growing*** in Australia. China, India and Indonesia.
- Best practice mitigates ***environmental cost*** of hydraulic fracking
- ***By 2035, global primary gas demand*** to reach 5.1 tcm, energy mix from ***21% to 25%,*** overtaking coal; ***80% due to non-OECD***.
- ***China's demand*** = Germany 2010 ***to equate entire EU***; ME to double = China; India x4. Mainly power generation also industry, transport and buildings
- Overall global gas demand = 3x Russia current production. ***40% from unconventional***
- ***Strongest growth*** - North America, Russia, ME, Caspian, China and Africa
- ***Natural gas markets to converge***. ***Split between pipeline and LNG***
- $8 T needed for gas infrastructure, more LNG capacity in some regions

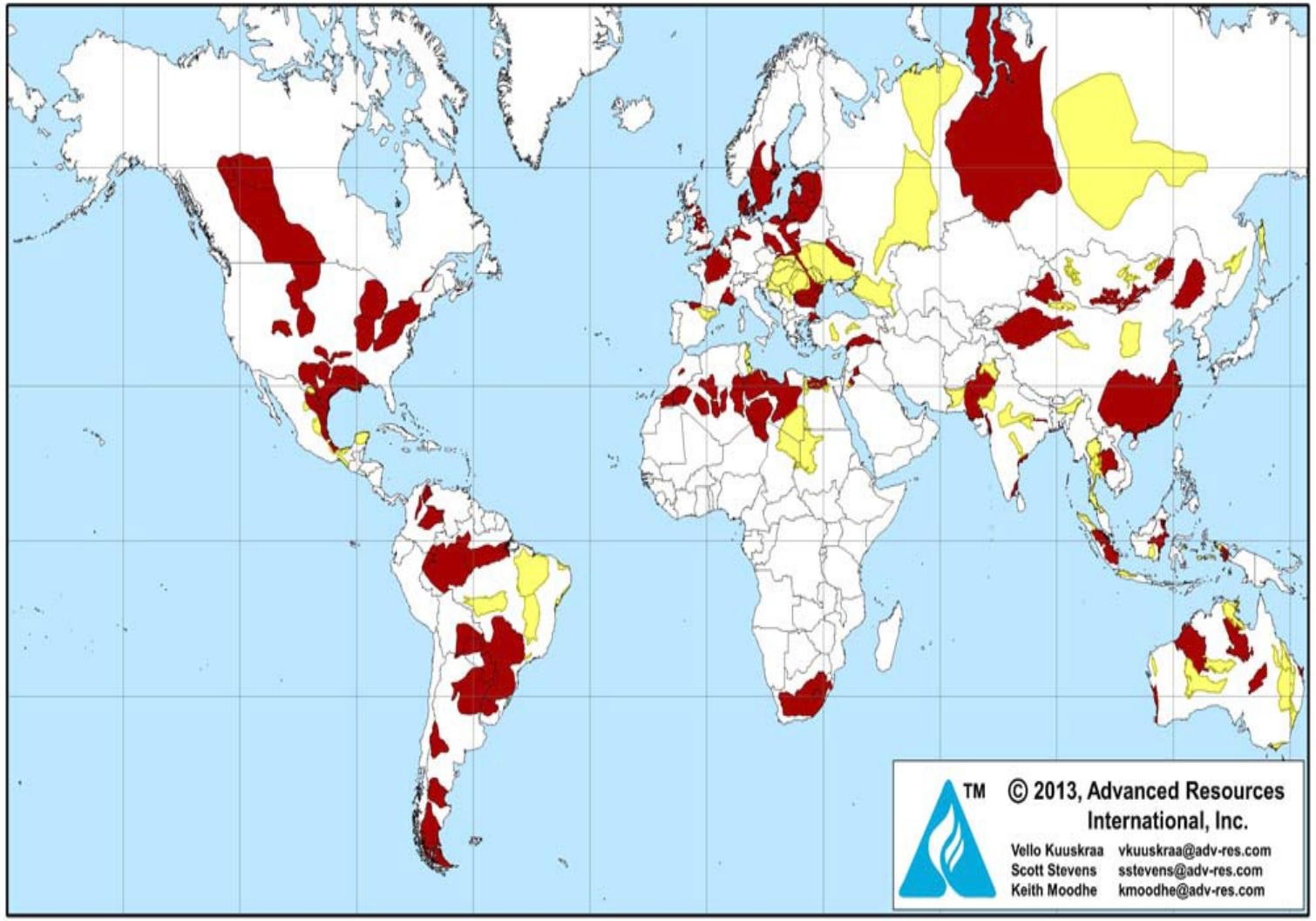
World Gas Reserves



- ***Conventional recoverable*** = ***120 yrs*** current consumption
- ***Total recoverable*** = ***250 yrs***
- ***All major regions*** at least ***75 yrs***
- ***Share of natural gas*** in global energy mix to increase from 21% to 25% overtaking coal by 2035, Non-OECD = 80% total increase

Technically recoverable shale resources

2/3 of assessed, technically recoverable shale gas resource concentrated in six countries - U.S., China, Argentina, Algeria, Canada and Mexico.

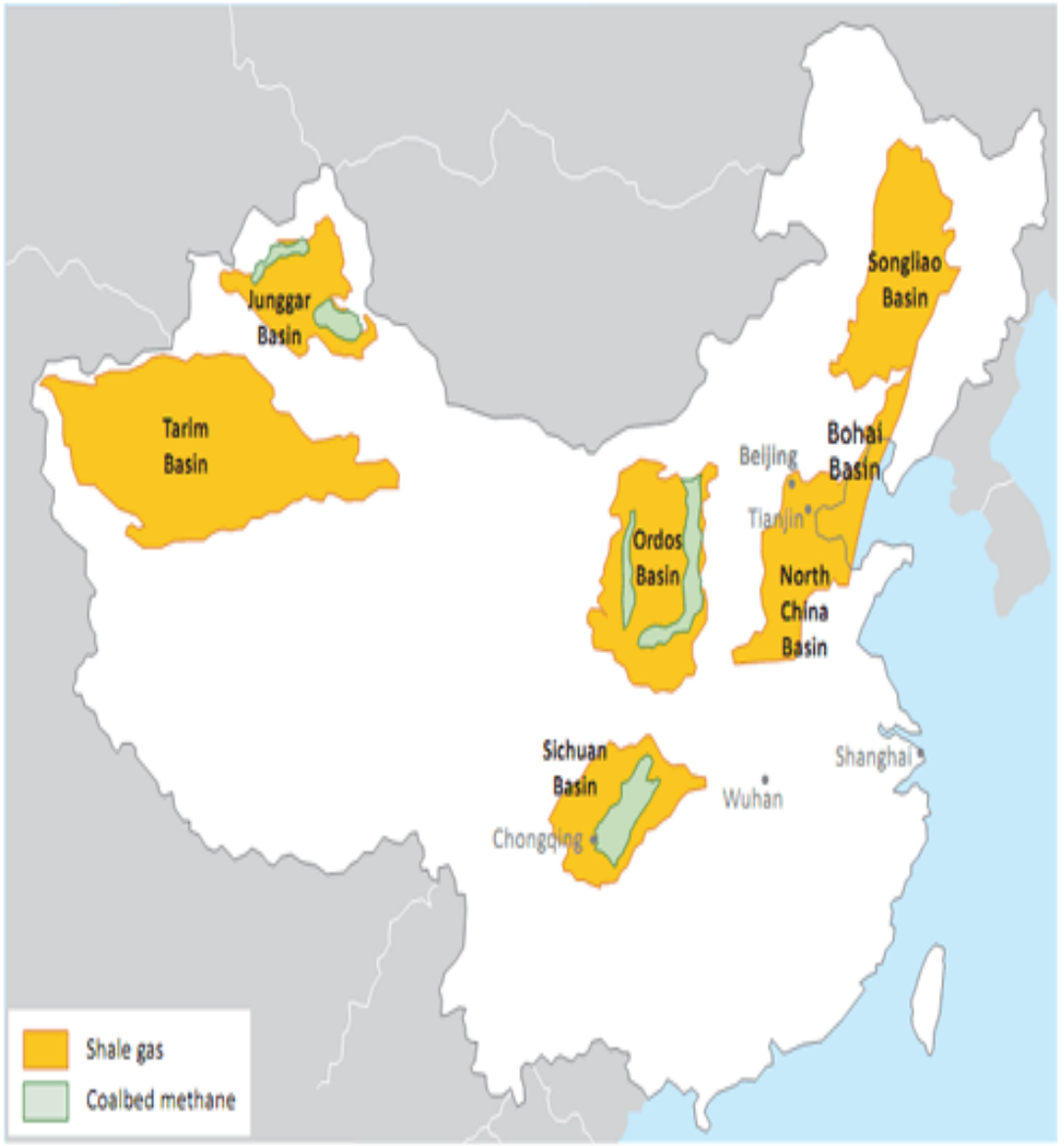


Technically Recoverable Shale Gas Resources (Tcf)	
1. U.S.	1,161
2. China	1,115
3. Argentina	802
4. Algeria	707
5. Canada	573
6. Mexico	545
7. Australia	437
8. South Africa	390
9. Russia	285
10. Brazil	245
11. Others	1,535
TOTAL	**7,795**

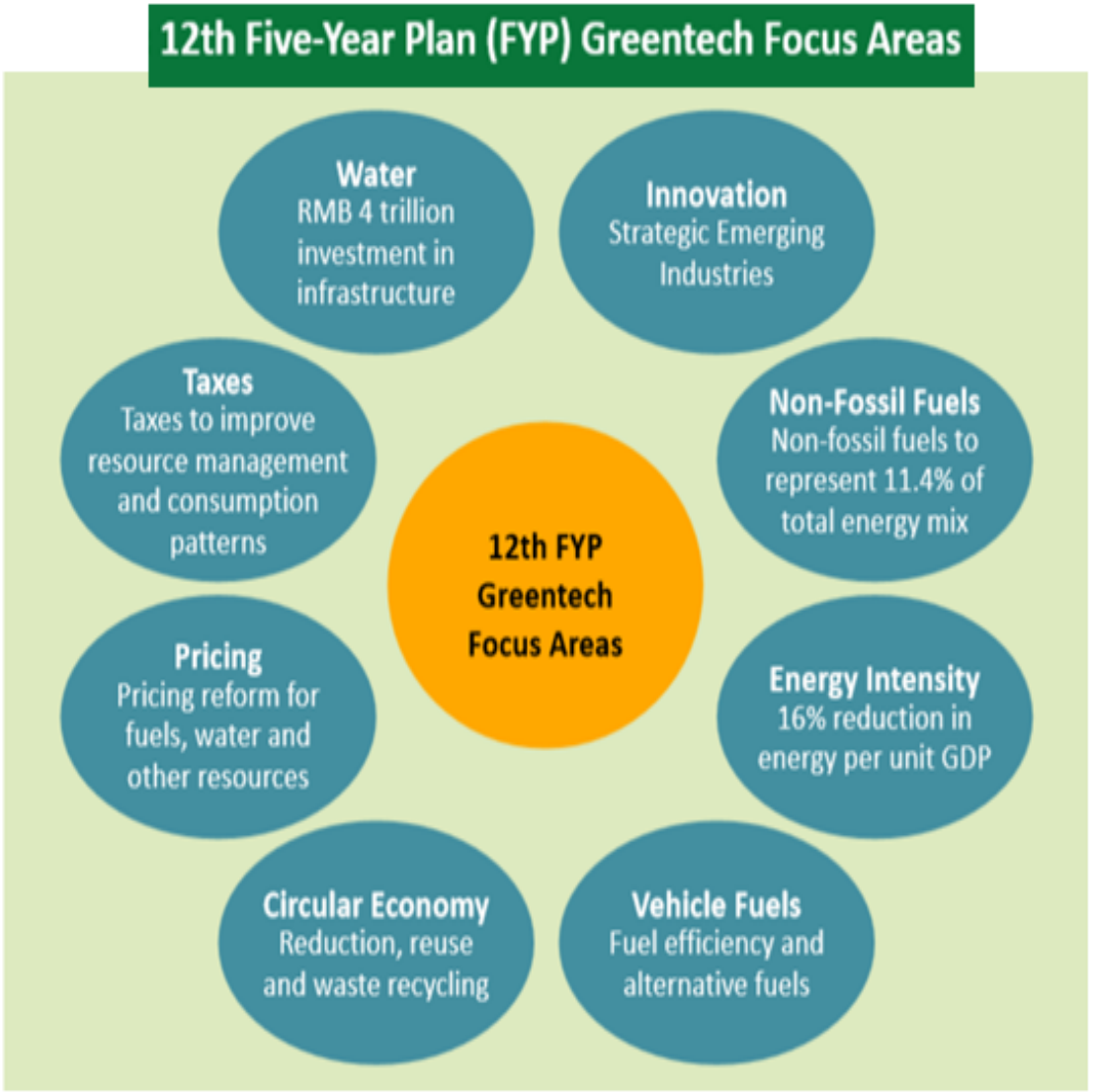
Technically Recoverable Shale Oil Resources (Billion Barrels)	
1. Russia	75
2. U.S.	48
3. China	32
4. Argentina	27
5. Libya	26
6. Australia	18
7. Venezuela	13
8. Mexico	13
9. Pakistan	9
10. Canada	9
11. Others	65
TOTAL	**335**

China's unconventional gas plans

- China plans ***coalbed methane production*** > 30 bcm and ***shale gas*** - 6.5 bcm by ***2015*** and 60 to100 bcm by 2020.
- Goal to add 1 tcm of coalbed methane and 600 bcm of shale gas to ***proven reserves of unconventional gas by 2015***.
- Major international oil companies already into ***partnership with state-controlled companies.*** Shale gas and coalbed methane classified as "***mineral resource***" outside CNPC/Sinopec exclusivity. Foreign projects. ***majority stake allowed in coalbed methane*** projects.
- ***Environmental compliance*** more stringent and ***water scarcity*** a major hurdle
- Domestic coalbed methane industry ***price subsidies*** between RMB 0.2/m3 ($0.03) and RMB 0.25/m3 ($0.04). Shale gas might receive a similar or higher subsidy.
- In the Golden Rules Case, ***by 2035, China's unconventional gas to attain 83% of total gas production,*** predominately from shale gas (56%), coalbed methane (38%), and tight gas (6%).
- By 2035, in the Golden Rules Case, China's ***unconventional gas imports amount to nearly 120 bcm, ~ 20% of total gas demand***. In the ***Low Unconventional Case,*** at 260 bcm or ~***60% of demand***.



China's energy profile



(from the China Greentech Initiative's 2013 China Greentech Report)

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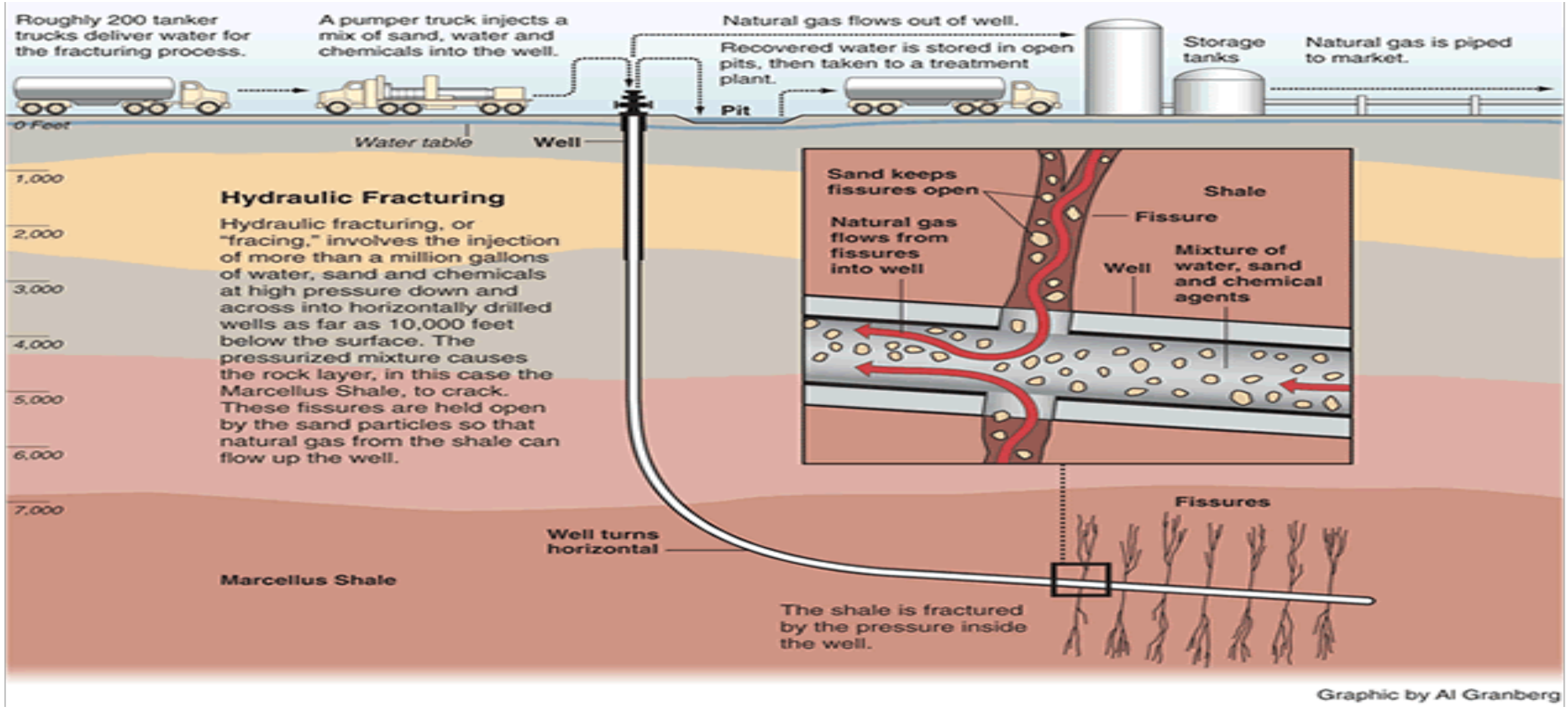
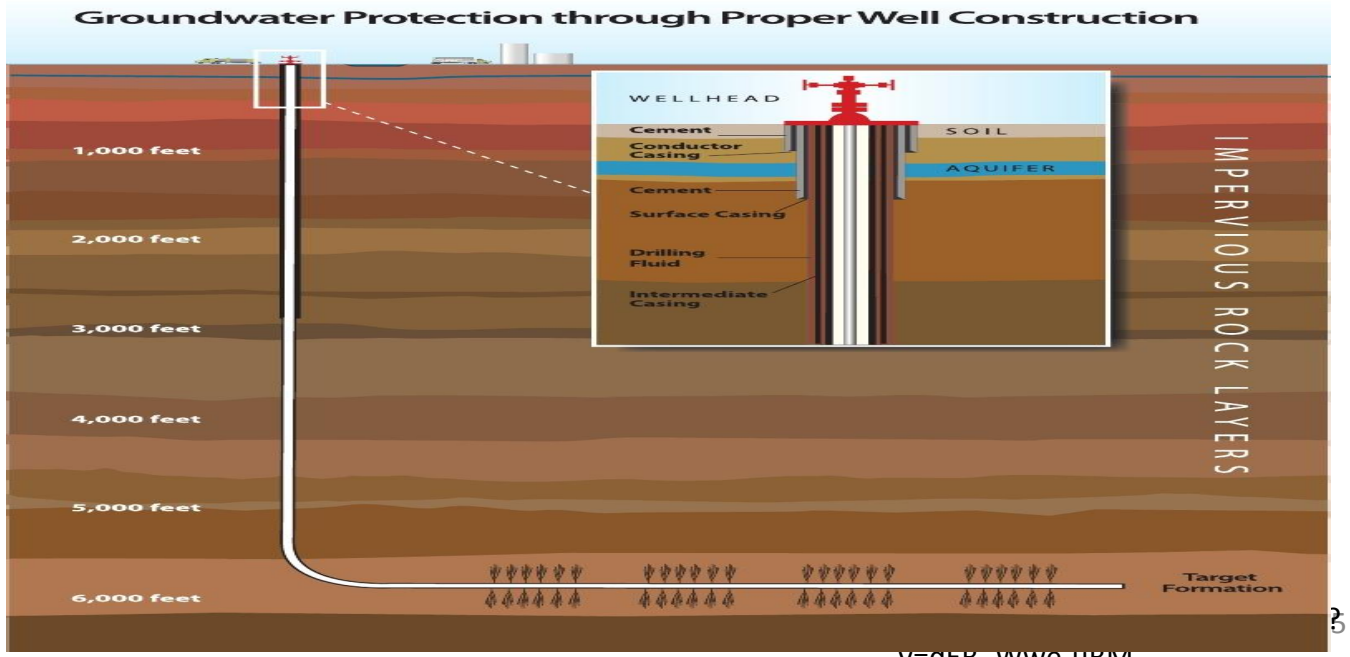
Fracking technology



M*assive injection of fluids with biocides and ceramic proppants* . Drilling well site ~ 100 sq meters. Steel and cement casing guards against leakage and seepage.

Fracking environmental challenges

- **Massive water usage** - 1 – 5 m gallons@; surface or aquiver water depletion; ecological/ bio-diversity impact; truckloads of water transport –congestion and emission. Xinjiang ***rich in shale but water scarce***. ***Coalbed methane*** needs de-watering in extraction, highly salty and sodic.
- ***Toxic fracking fluid*** ("múd") - 750 secret ingredients, such as methanol.
- ***Methane leakage*** during production and transportation
- Fluid ***leakage and seepage*** to ***aquifers***
- ***Treatment of waste water*** return rate (20 -50%, saline and slightly radioactive)
- ***Noise and fume***
- ***Abandoned walls***
- Liable to cause ***earthquakes***
- Highly energy- intensive, ***net energy- loser,*** worse than coal in lifecycle carbon footprint



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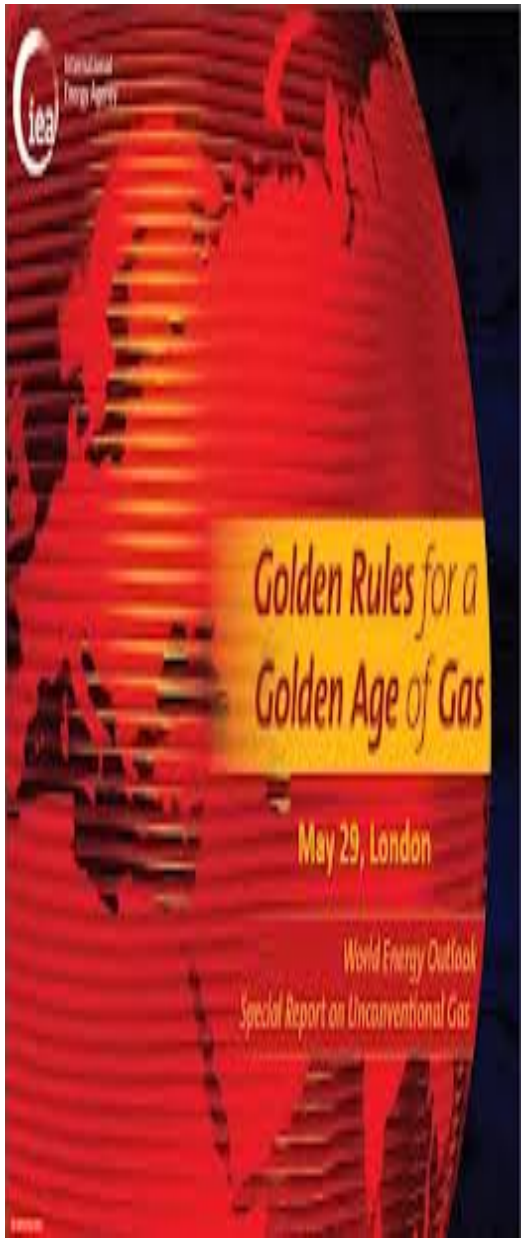
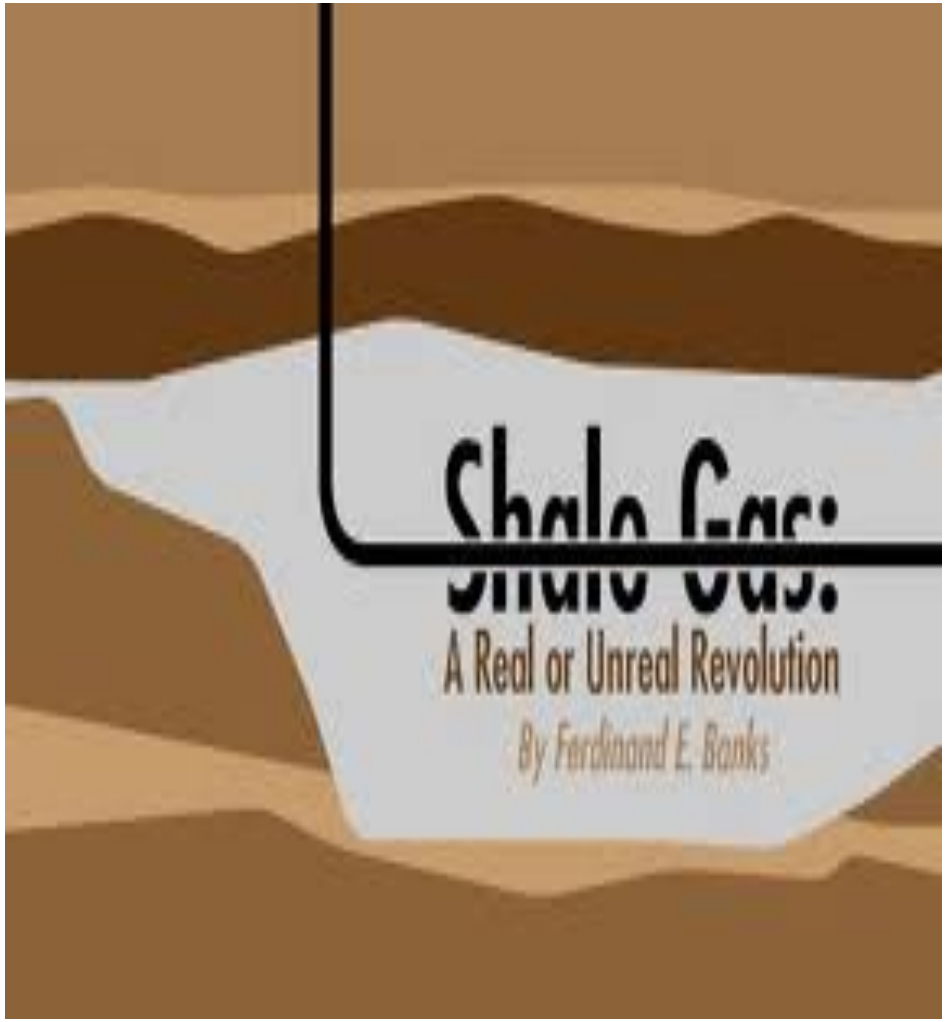
Golden Rules

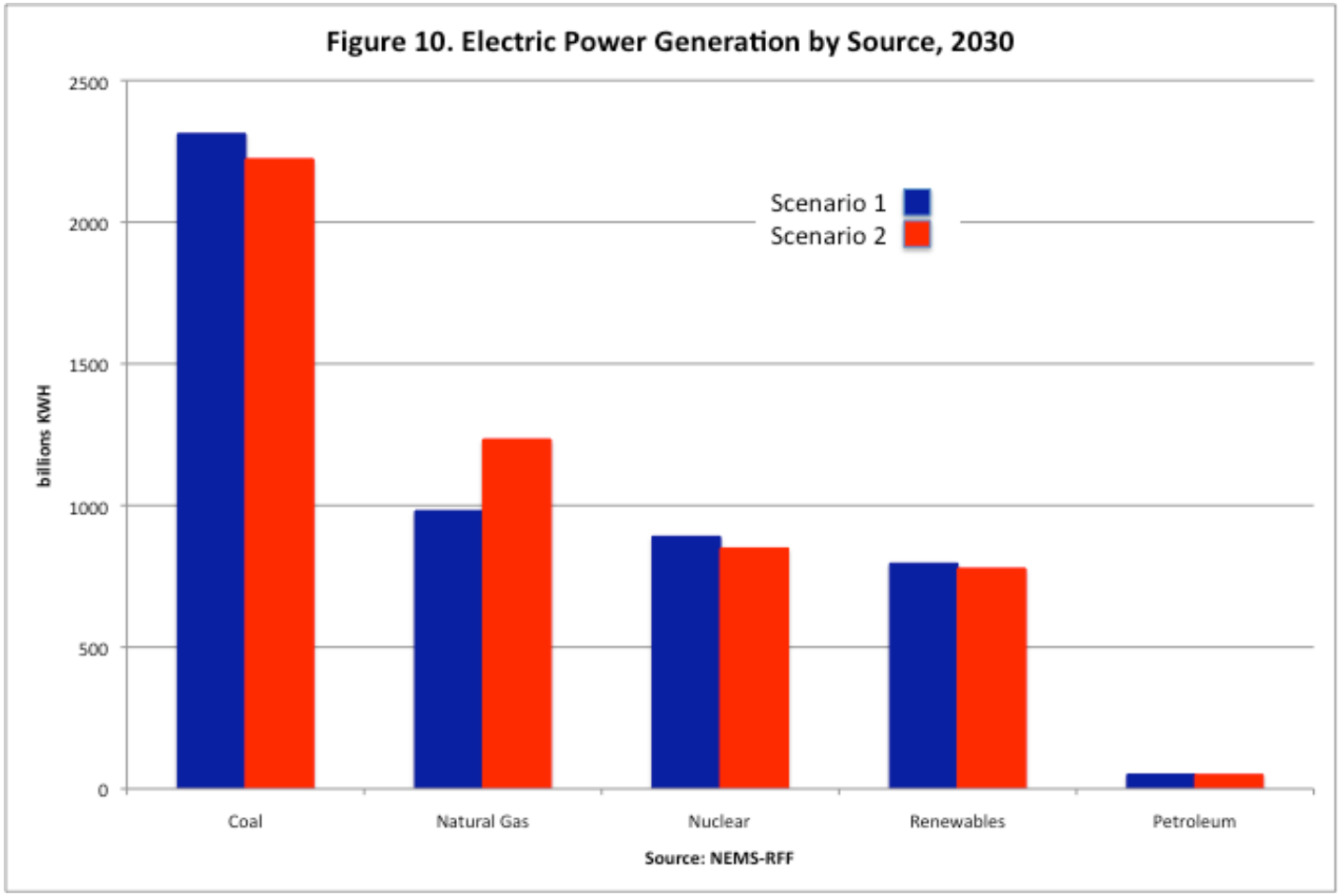


- Golden Age of Gas will come about ***only if vast unconventional resources developed profitably and in environmentally-acceptable manner***
- ***Golden Rules*** – Measure, Disclose and Engage; Watch where you drill; Isolate wells and prevent leaks; Reduce and Treat water responsibly; Eliminate venting, minimize flaring and other emissions, Think big in coordinated environmental impact containment especially water use and disposal, land use, air quality, traffic and noise; Ensure high quality performance including regulation, innovation, evaluation, verification, emergency response. Supporting infrastructure and market development including creation of economy of scale such as water pipelines and treatment facilities .
- ***Golden Rules no magic-*** Accessibility (In China, only 20% shale and 40% coal-bed methane accessible), regulation, technology, infrastructure, water, markets + pricing.
- Output in Golden Rules Case requires > 1 million new unconventional gas wells worldwide between now and 2035, 2X U.S. operating gas wells. Only 40% invested of $ 6.9 trillion required for ***infrastructure*** globally.
- ***Drivers are China and the U.S.*** By 2035, US (820 bcm) to overtake Russia (785 bcm) as largest gas producer. China to become largest importer and 2nd largest producer of unconventional gas, if environmental challenges overcome.
- ***Lack of public acceptance*** = Low Unconventional Case slightly above current levels by 2035, well < coal =1.3 % more CO2 emissions >Golden Rules Case
- ***Gas alone insufficient for 2-degree limit*** without vigorous wide-ranging policy framework – energy efficiency, clean energy sources and technologies such as CCS.

Policy implications

Without carbon policy, shale abundance likely to foster greater energy consumption and discourage increase use of renewables resulting higher CO2 emissions overall - Resources for the Future/National Energy Policy Institute Study, April 2010

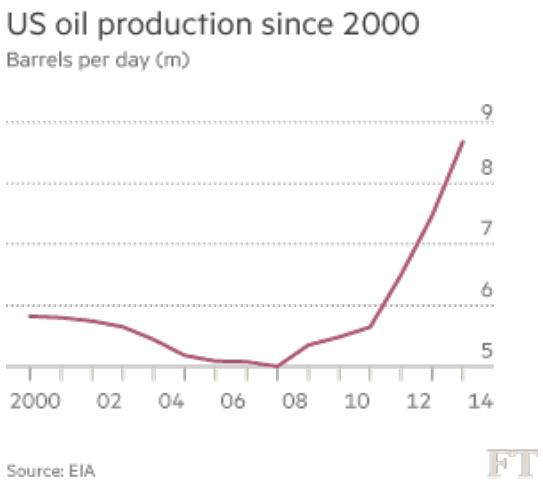


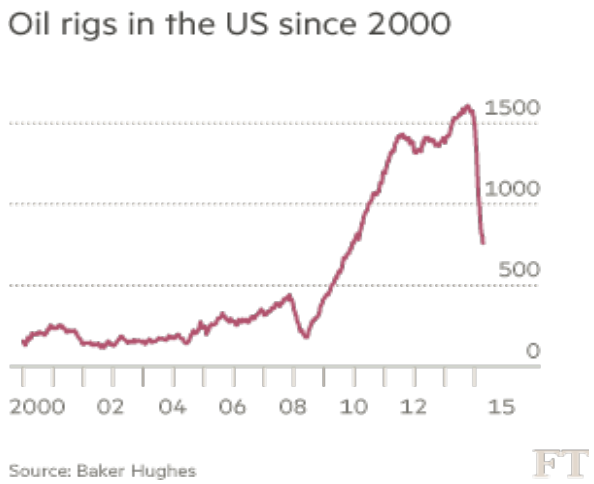


Scenario 2 - Business as usual with higher estimates of U.S. shale resources.

Shale Gas and Oil supply and price dynamics

- ***Exponential depletion rate*** –output declines 60% - 70% 1st year; maximum production a few years
- ***Need to drill more and more wells.*** Roughly 7,200 new shale gas wells to be drilled each year at simply to maintain current levels of production. As most productive locations are drilled, ***drilling rates and costs will only increase*** as time goes on.
- Upfront funding turns increasingly to ***high-interest junk-bonds*** (20% of market)
- Massive supply drops *crude prices below $60@barrel in May, 2015* > ~ ***$48 @barrel for shale drilling viability,*** while higher efficiency may lower threshold.
- ***China has 50% more shale gas reserve, though in much more difficult terrain.***
- ***US to share technology*** with China, likely biggest customer for US shale gas.





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