The Future of Natural Gas*

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Abstract

The history of global energy use through the 160 years of the western industrial revolution shows a progression of fuel substitution, with one resource being partly or largely displaced by a more efficient, versatile and generally cheaper source. If trends in carbon reduction and hydrogen increase continue, methane should constitute the dominant fuel in the global energy mix, representing a long-term bridge to a non-fossil, probably hydrogen economy. Is this likely? Probably, but not without the substantial uncertainties attendant to any major transition.

For any energy source to assume a dominant part of the global energy mix it must be abundant and available at a competitive price. The estimated proved reserves of global natural gas are substantial, most of it conventional and much of it stranded. LNG will compete with non-conventional sources of natural gas—tight gas, coal bed methane, and shale gas. How much of these non-conventional resources prove to be recoverable and at what price are major uncertainties. If history teaches us anything, it speaks to resource elasticity as geologic understanding increases and as technology advances. Cost and availability of natural gas will not constrain a global methane economy.

Over the past 25 years global natural gas demand has increased at an average annual rate approaching 4%. Several projections show growth continuing over the next 30 years and beyond and, if correct, a clear realization of a global methane economy. In the United States residential and commercial consumption has been flat and industrial demand has declined in recent years. Transportation demand has grown, albeit off a small base, but natural gas in power-generation consumption has doubled in recent years. With or without emission limits, natural gas will continue to fare well in power generation where it competes with coal and nuclear.

The much larger potential for natural gas use is in transportation, although displacing oil is a challenge given its tremendous efficiency, density and versatility. CNG vehicles will continue to expand and gas-to-liquid transportation fuels hold promise. The real penetration of natural gas in the transport market likely will hinge on the timing and development of an efficient hydrogen fuel cell. The principal method of producing hydrogen now is through steam reforming of methane, and as such methane could be the principal raw material for hydrogen.

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THE FUTURE OF NATURAL GAS

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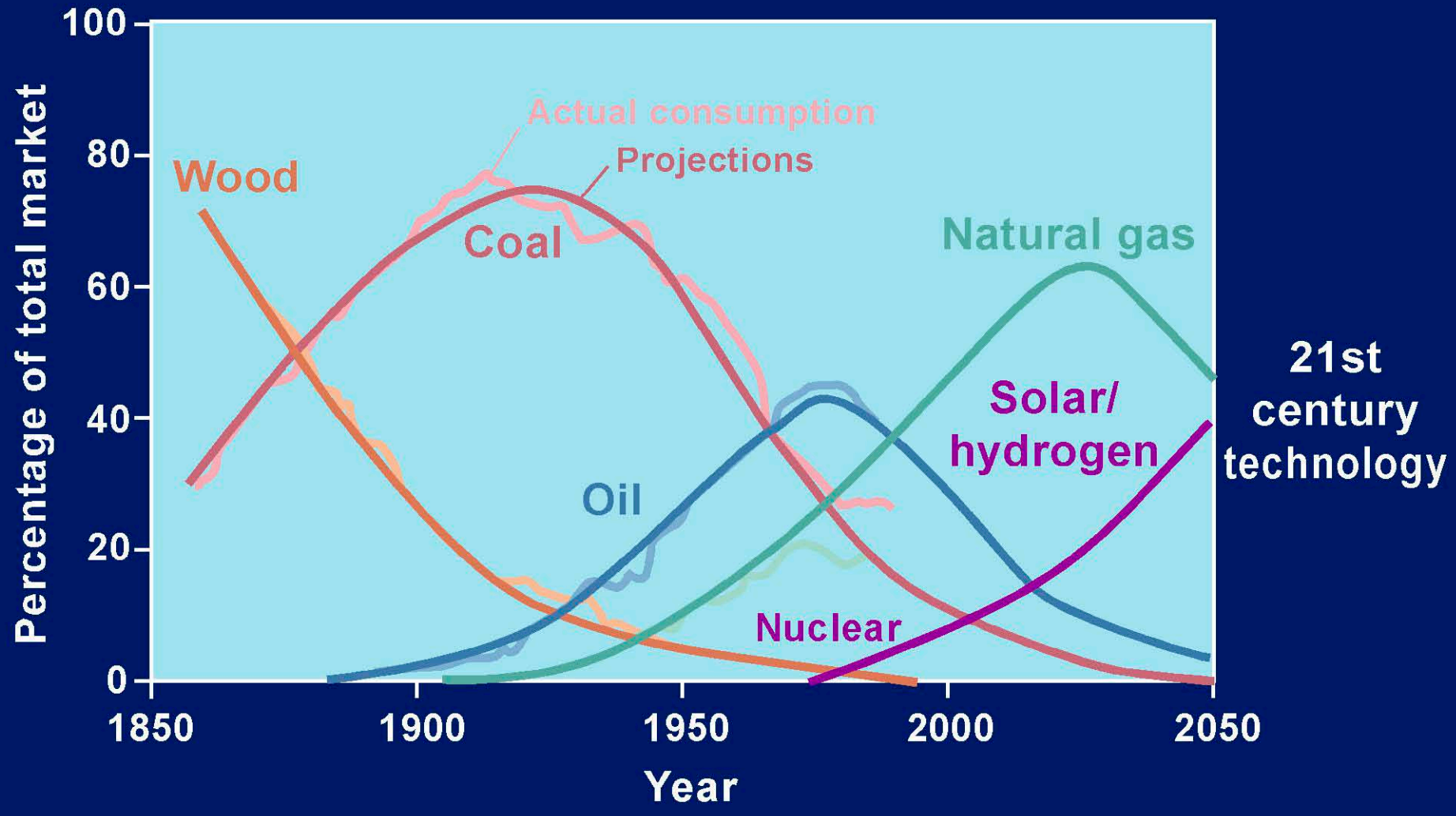
ANNUAL MEETING

HOUSTON, TEXAS
APRIL 12, 2011

WORLD PRIMARY ENERGY SUBSTITUTION



Marchetti and Nakicenovic (1994)

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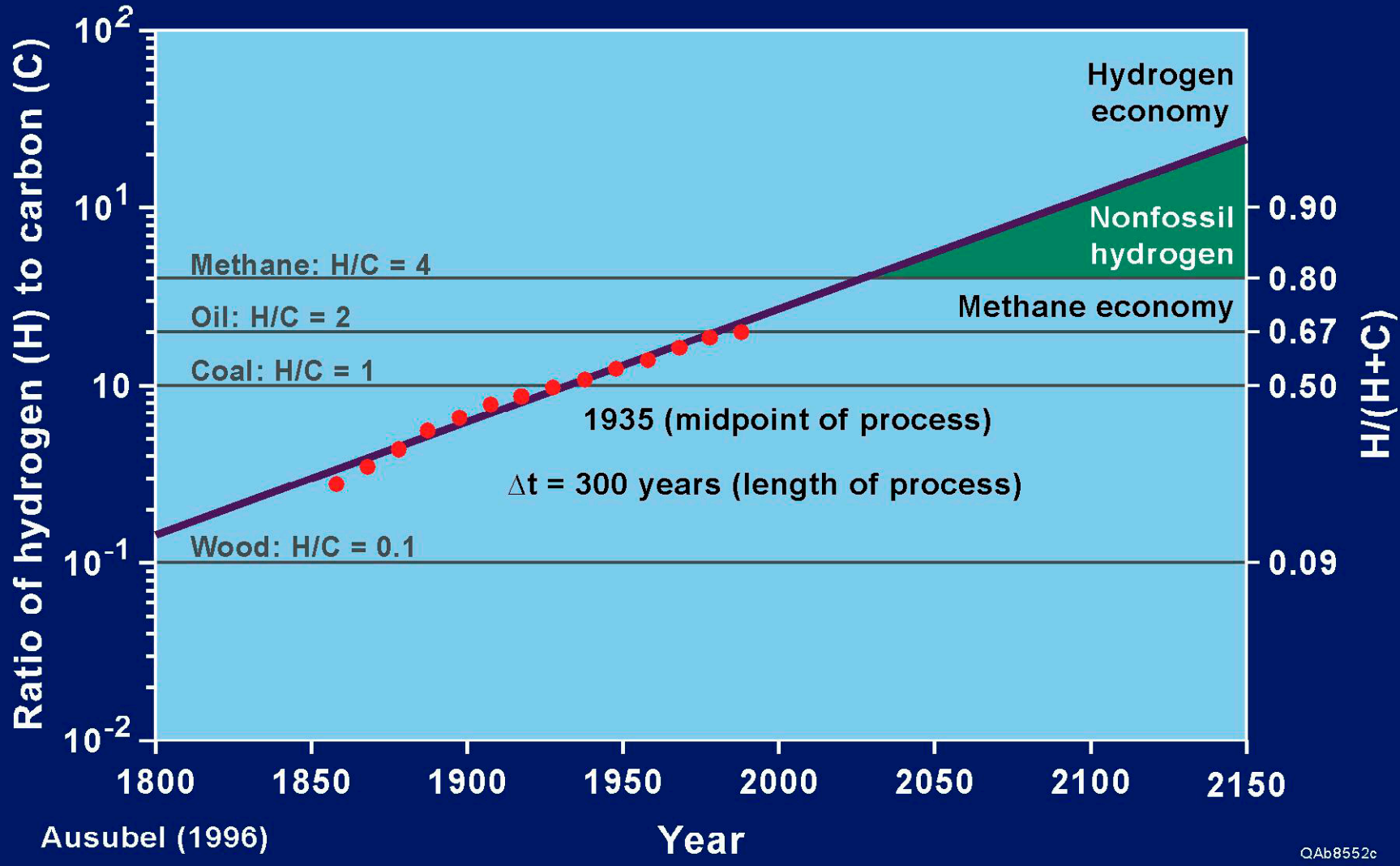
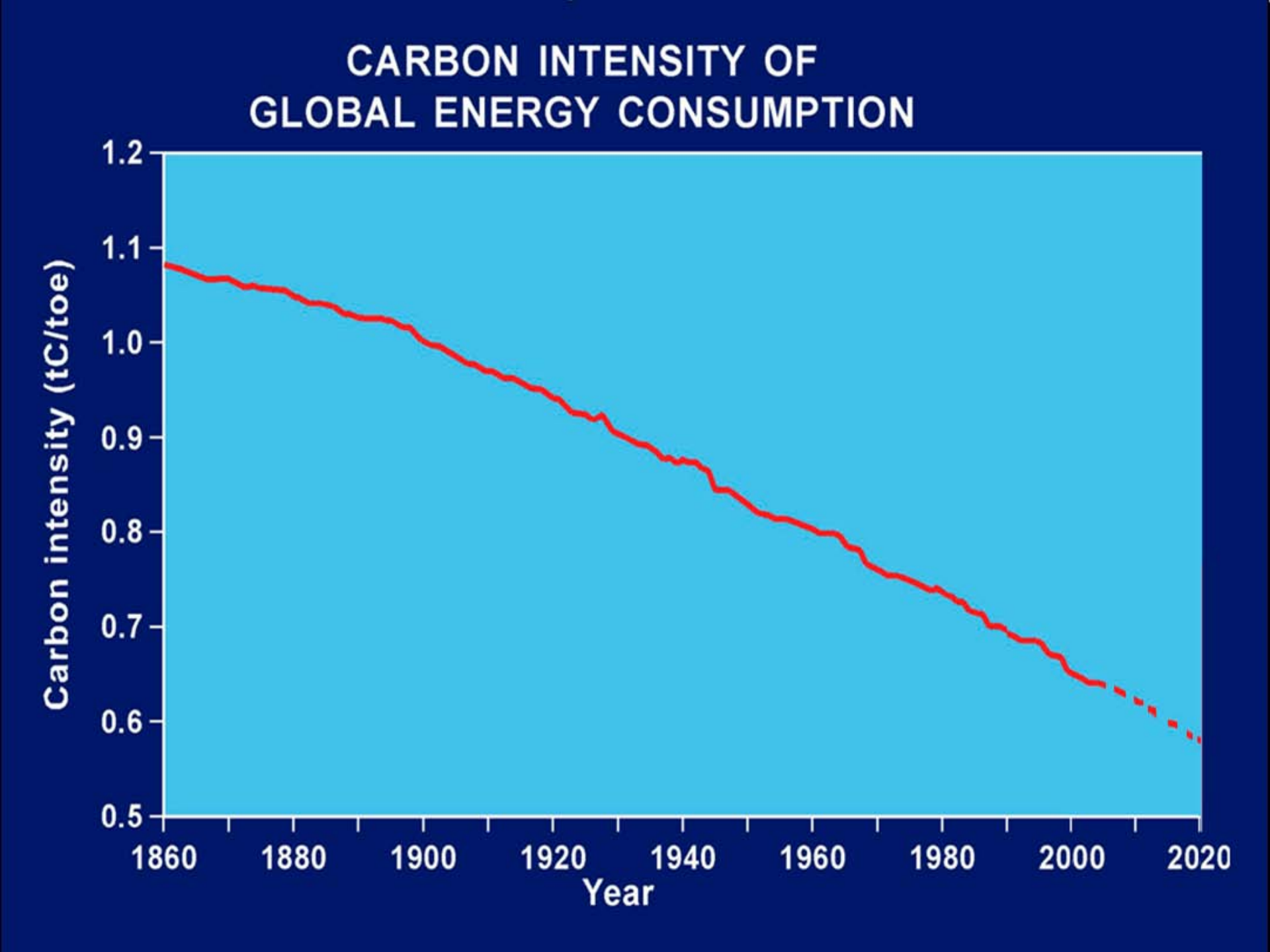
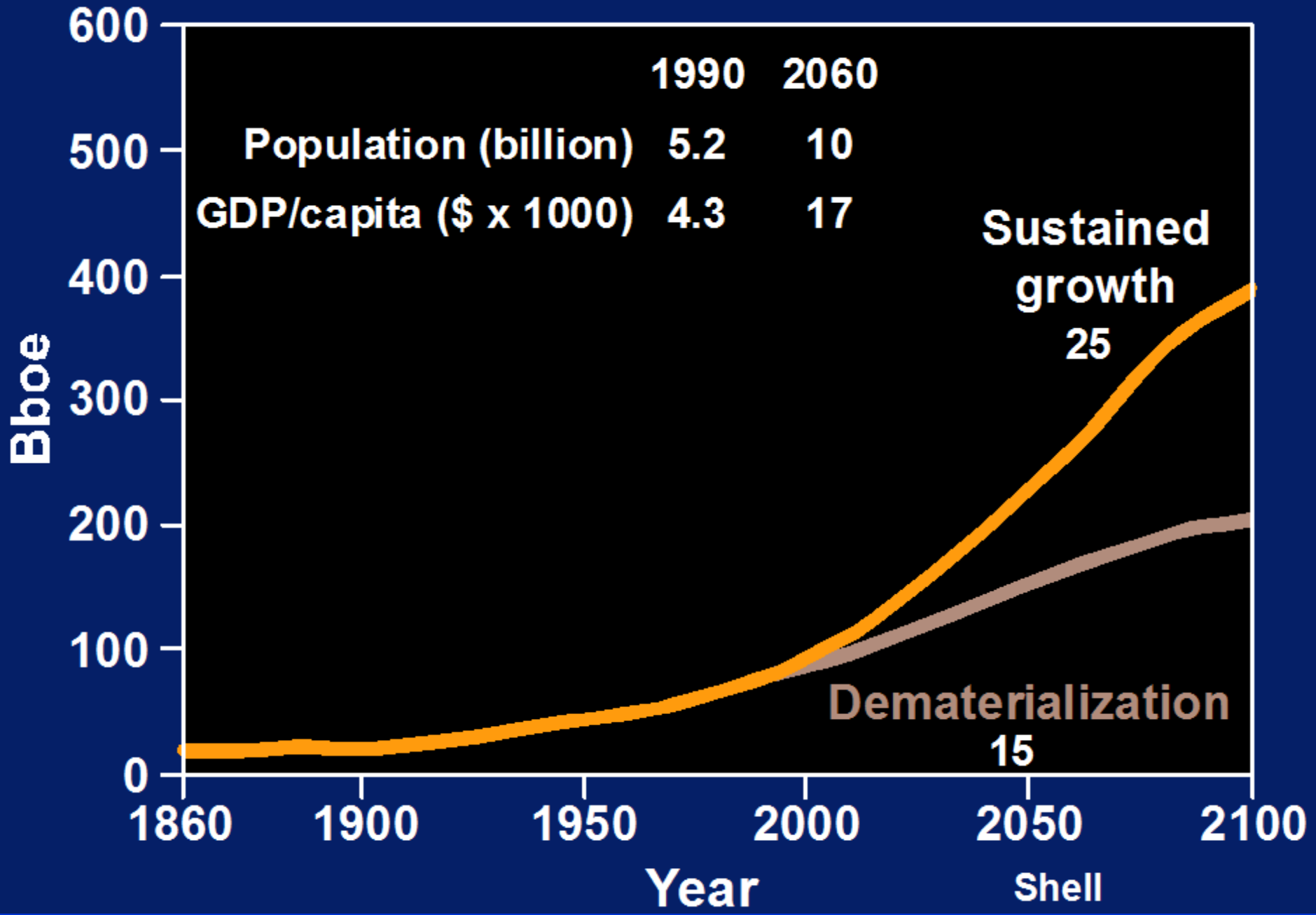
RATIO OF HYDROGEN (H) TO CARBON (C) FOR GLOBAL PRIMARY ENERGY CONSUMPTION SINCE 1860 & PROJECTIONS FOR THE FUTURE




CARBON INTENSITY OF
GLOBAL ENERGY CONSUMPTION
Carbon intensity (tC/toe)
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
1860
1880
1900
1920
1940
1960
1980
2000
2020
Year

FUTURE SCENARIOS



CALCULATING IMPLIED FUTURE DEMAND OF FOSSIL FUELS FOR 21ST CENTURY

- ASSUME HISTORICAL ENERGY SUBSTITUTION CONTINUES

- ASSUME DEMATERIALIZATION SCENARIO OF SHELL (15 TBOE)
  1) 3% ECONOMIC GROWTH
  2) 10 BILLION POPULATION BY 2060
  3) 2% ANNUAL INCREASE IN ENERGY EFFICIENCY

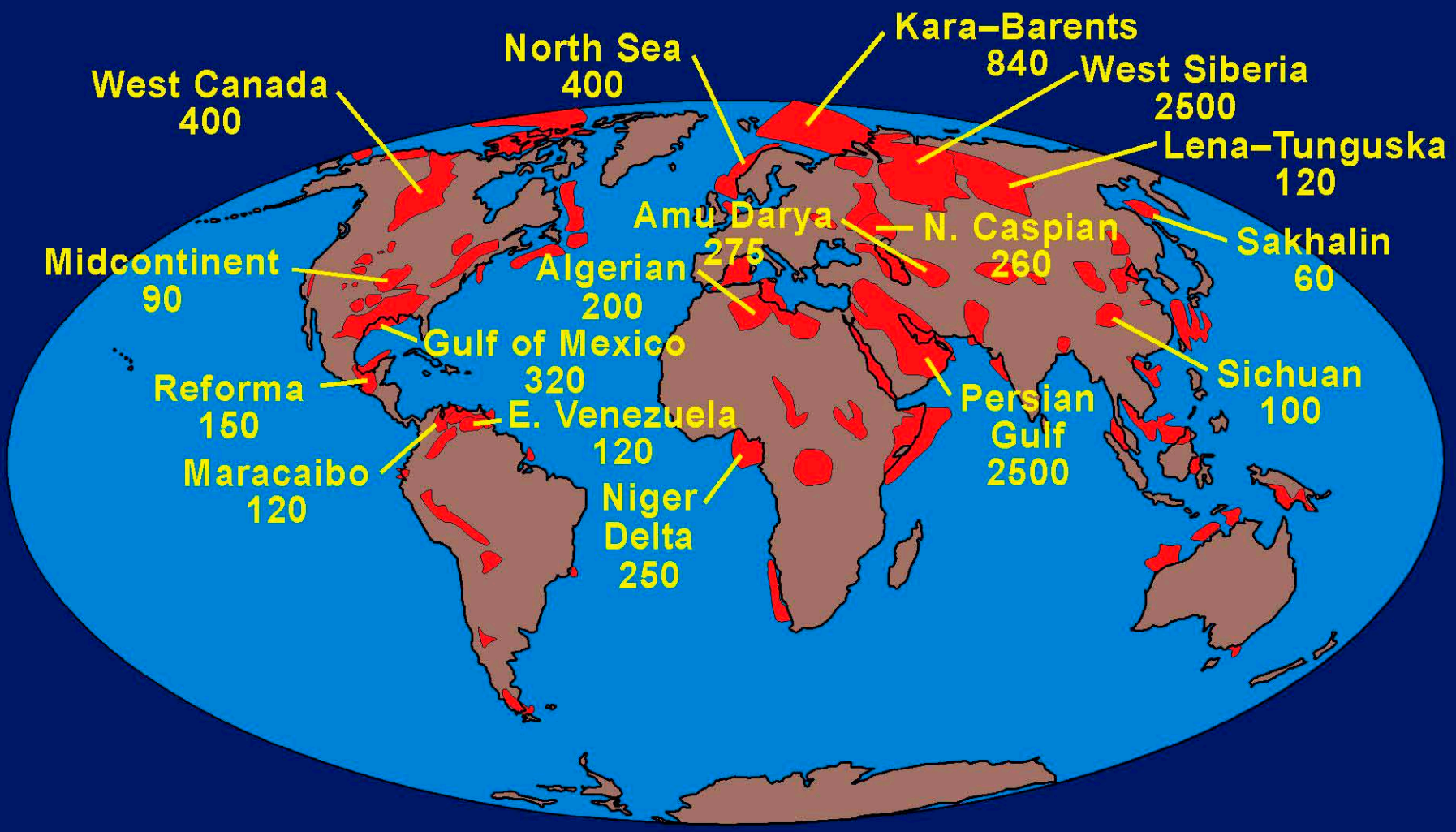
WORLD ENERGY BALANCE

	HISTORICAL USE	CURRENT USE	IMPLIED FUTURE DEMAND	RESOURCE BASE REMAINING	CURRENT ADEQUACY
OIL	1.050 TB	31 BB	2.0 TB	3.0+ TB	Plenty
GAS	2,100 Tcf	100 Tcf	25,000 Tcf	25,000+ Tcf	Bare
COAL	310 BT	6.0 BT	120 BT	1,080 BT	Much more

QAd2021(b)c

GLOBAL

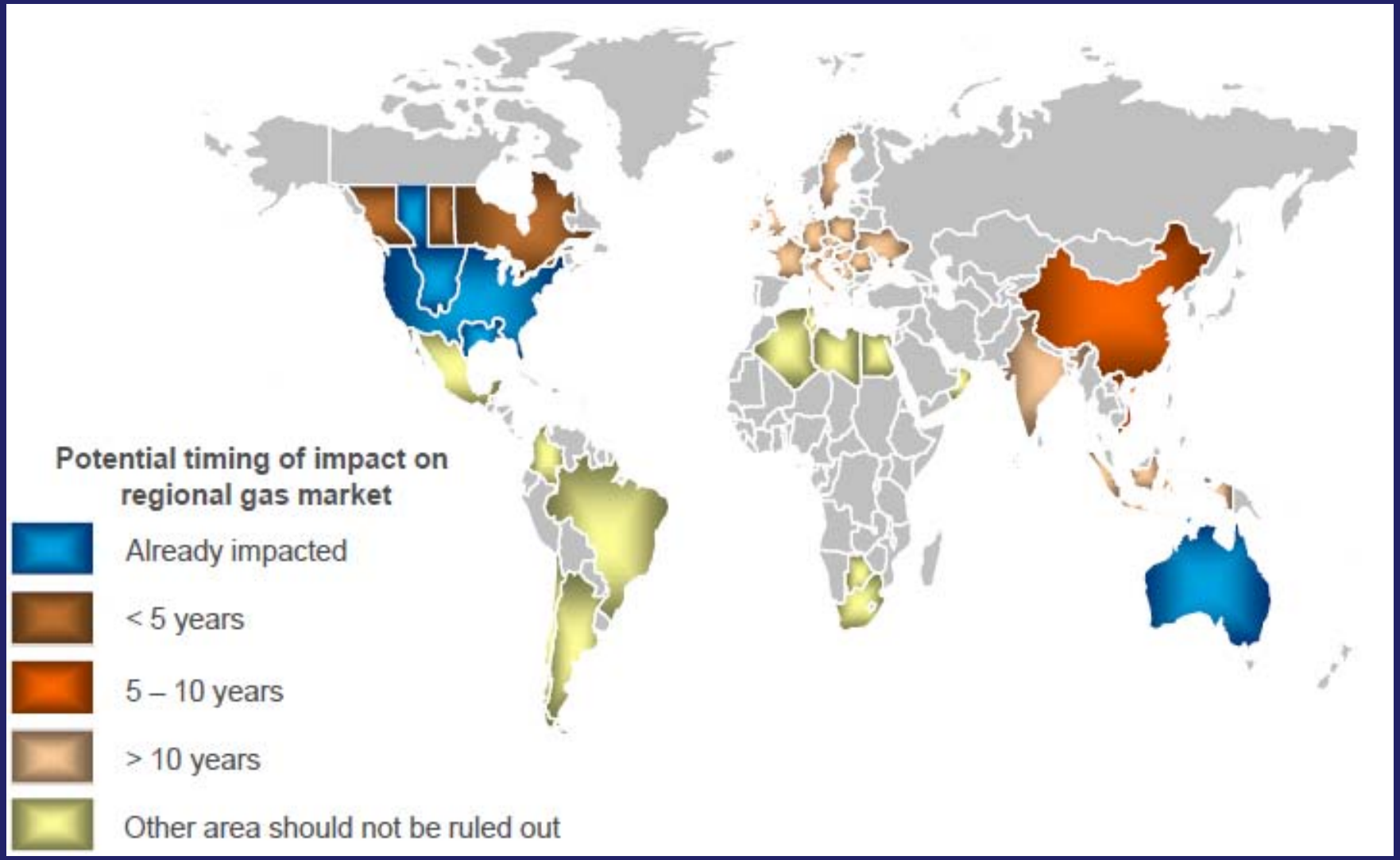
MAJOR GAS BASINS OF THE WORLD
(Volume in Tcf)



From Masters in U.S. Geological Survey Circular 1115 (1994)

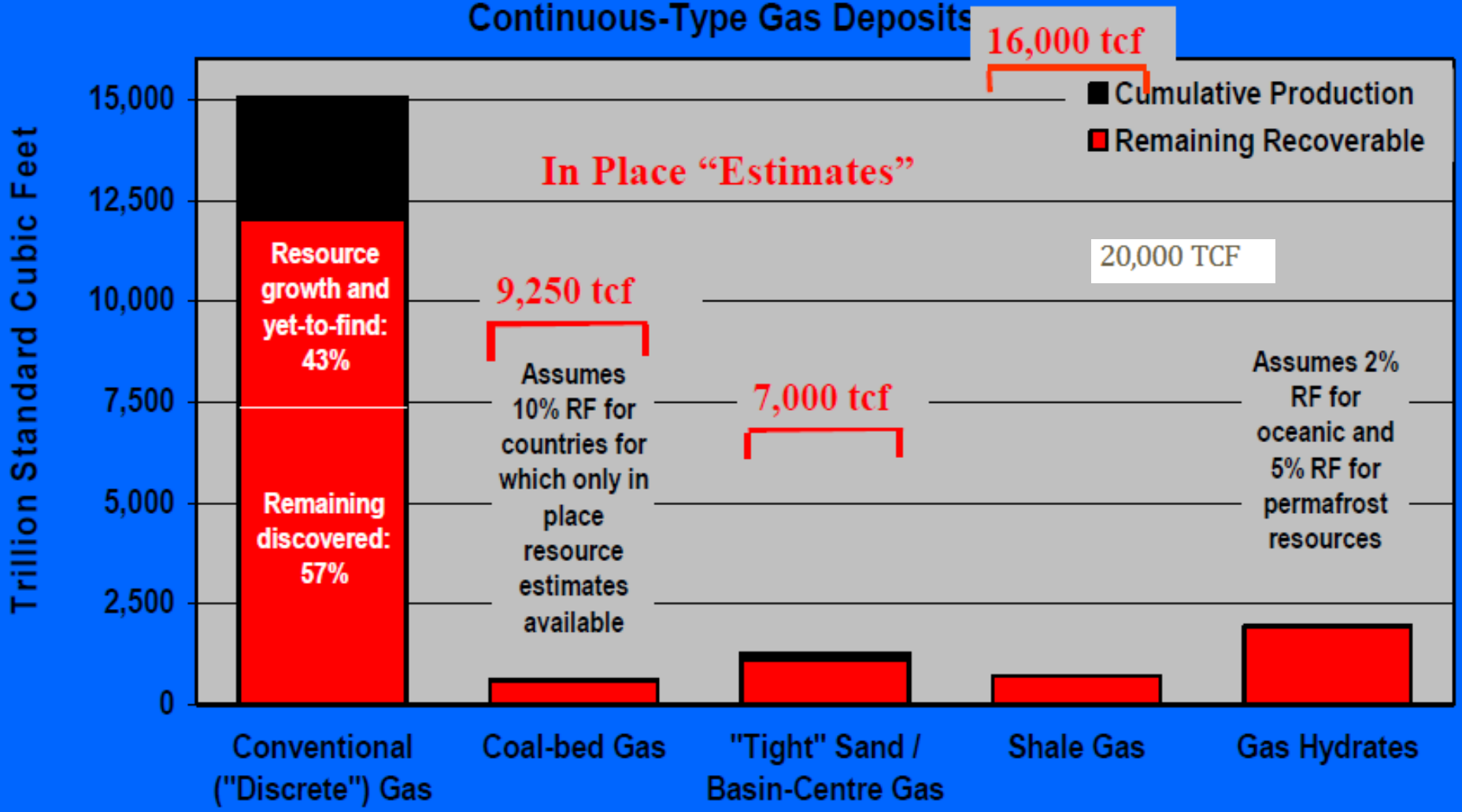
QAa6586c

NON-CONVENTIONAL GAS IMPACT
(WOOD MACKENZIE 2010)



Global Gas Resources
Conventional & Unconventional

Conventional Gas Resources Compared with Potential Resources of Continuous-Type Gas Deposits



IHS, 2009; Kawata SPE 68755

The Future: Unconventional Gas Resources

Remaining recoverable discovered conventional gas
- 6,750 trillion cf

Ultimate remaining recoverable conventional gas
- 11,800 trillion cf

Ultimate recoverable natural gas from coal (CBM)
- 1,000 trillion cf

Ultimate recoverable tight lithologies plus BCG
- 550 - 700 trillion cf (North America)

TOTAL 20,100-20,250 TCF

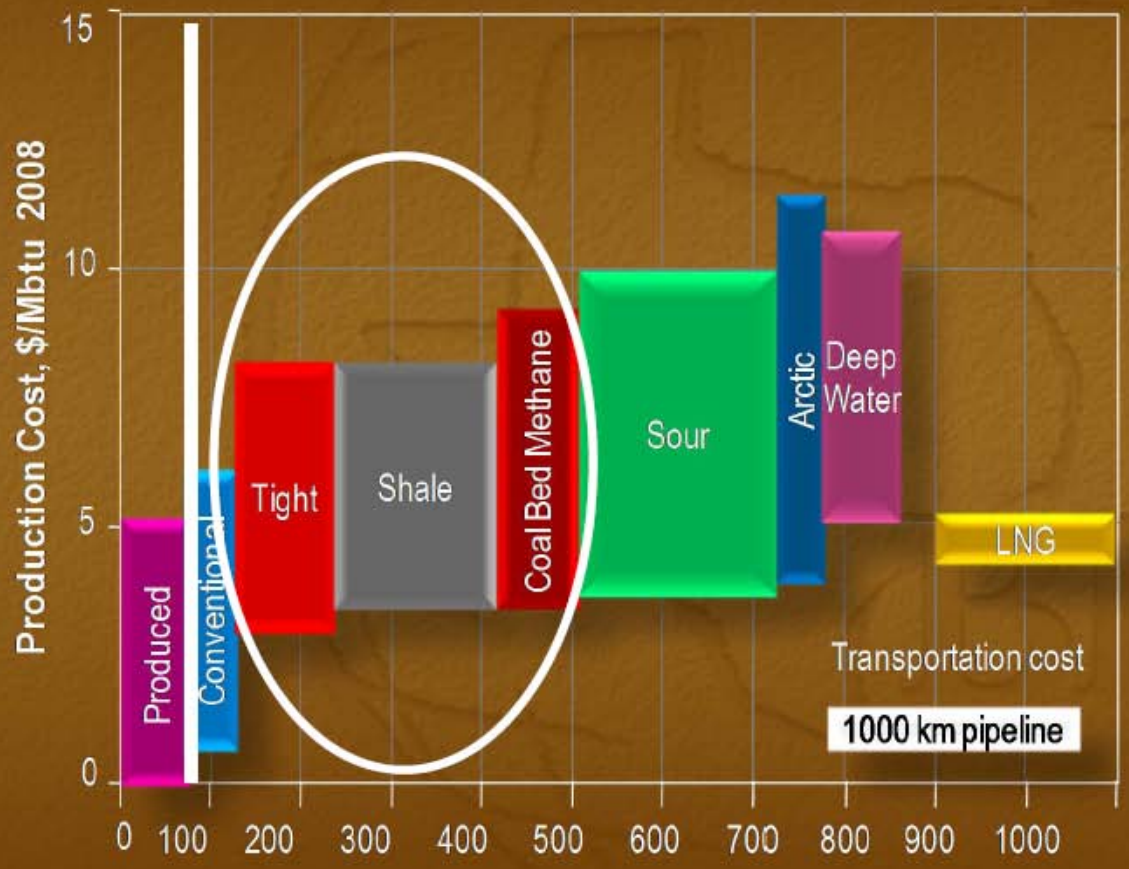
Gas hydrate resource in-place

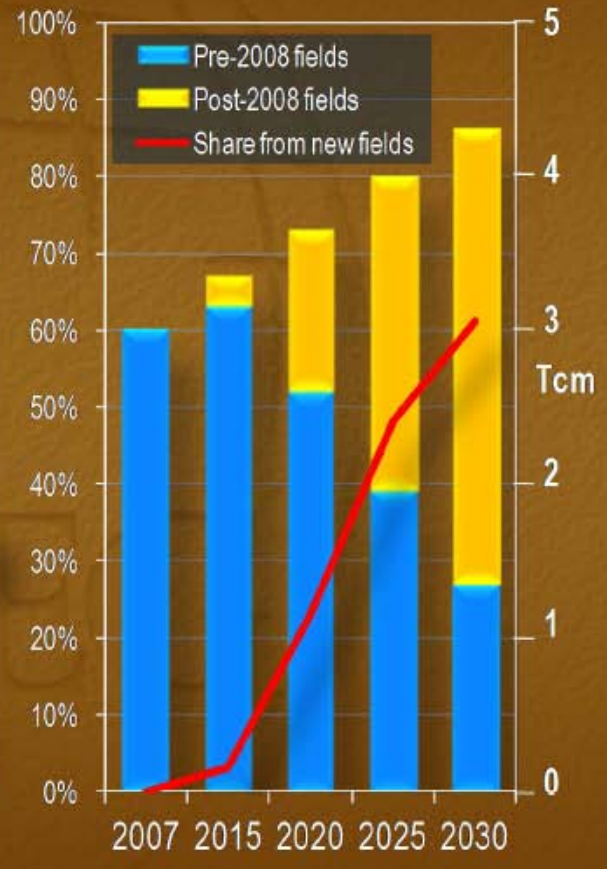
- 700,000 trillion cf (but only the 3,000 trillion cf in-place permafrost resource likely to be developed in near term)

IHS ENERGY

Long-Term Gas Supply - Resources and Production

Tinker, 2010





22,750 TCF

Source: IEA World Energy Outlook 2009

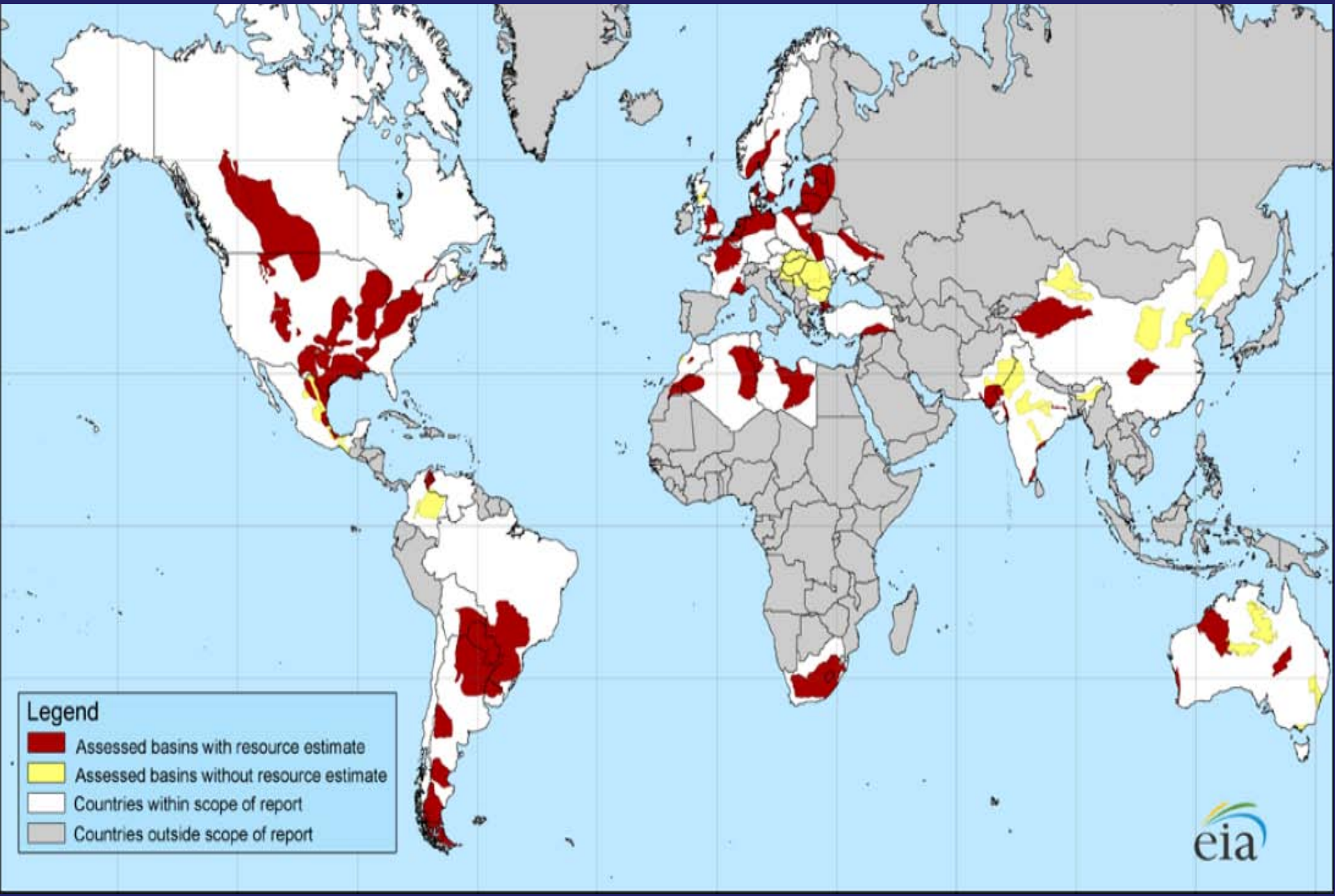
Schlumberger

GLOBAL NATURAL GAS (TCM)
(NEHRING, 2009)

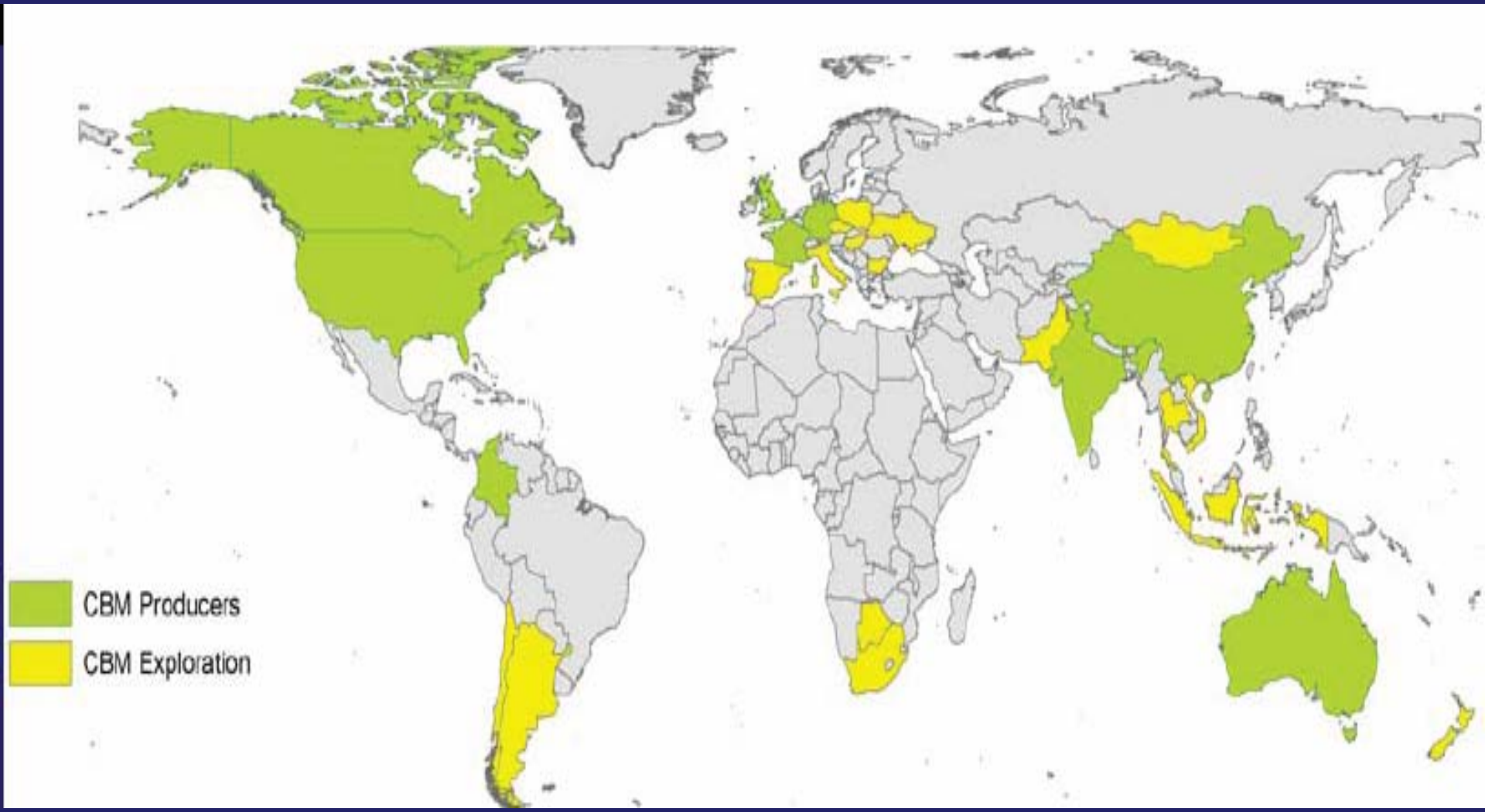
region	cumulative production	reserves	estimated ultimate recovery
USA/ Canada	33.20	7.39	75–95–115
Eurasia (FSU)	22.20	48.80	90–105–140
Europe	9.60	5.69	18–22–26
Asia/ Oceania	5.17	11.09	40–50–65
Middle East	3.34	73.01	100–120–150
Africa	1.84	13.76	20–26–36
Latin America	3.46	7.56	14–21.5–39
world	78.81	167.30	357–440–571

12,495-15,400-19,985 TCF

GLOBALSHALE GAS ASSESSED (6,622 TCF, INCLUDING 862 TCF FOR U. S.) ARI FOR EIA (2011)



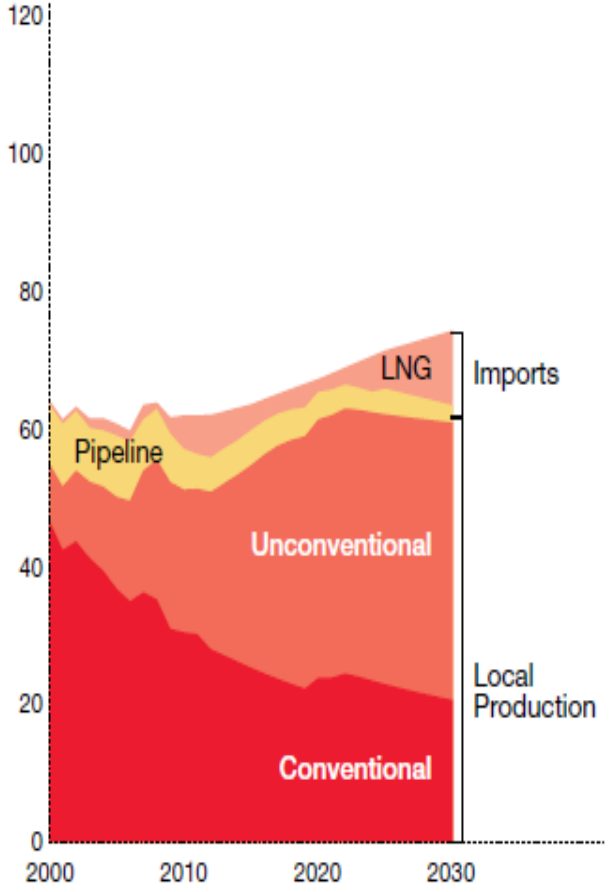
GLOBAL COAL-BED METHANE



Natural gas supply and demand balance

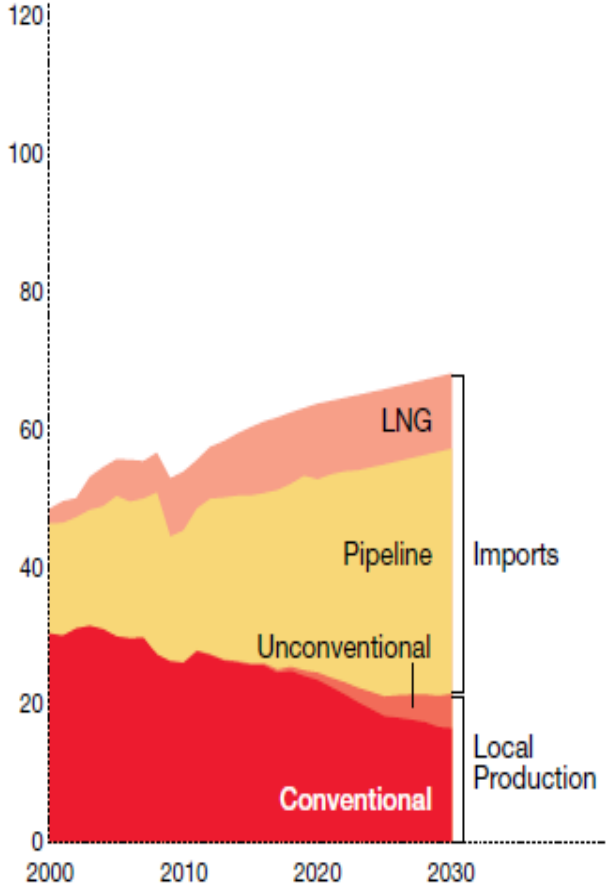
United States

Billions of Cubic Feet per Day



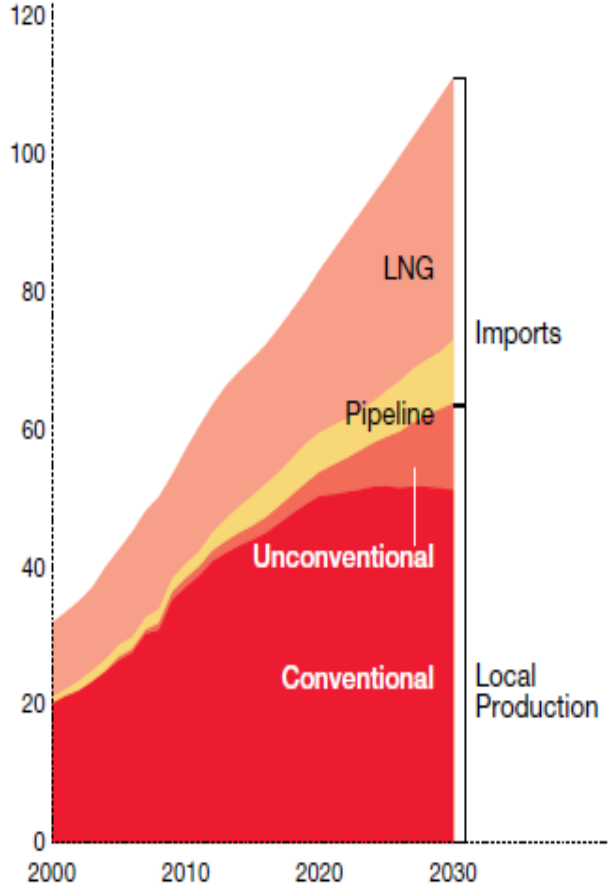
Europe

Billions of Cubic Feet per Day



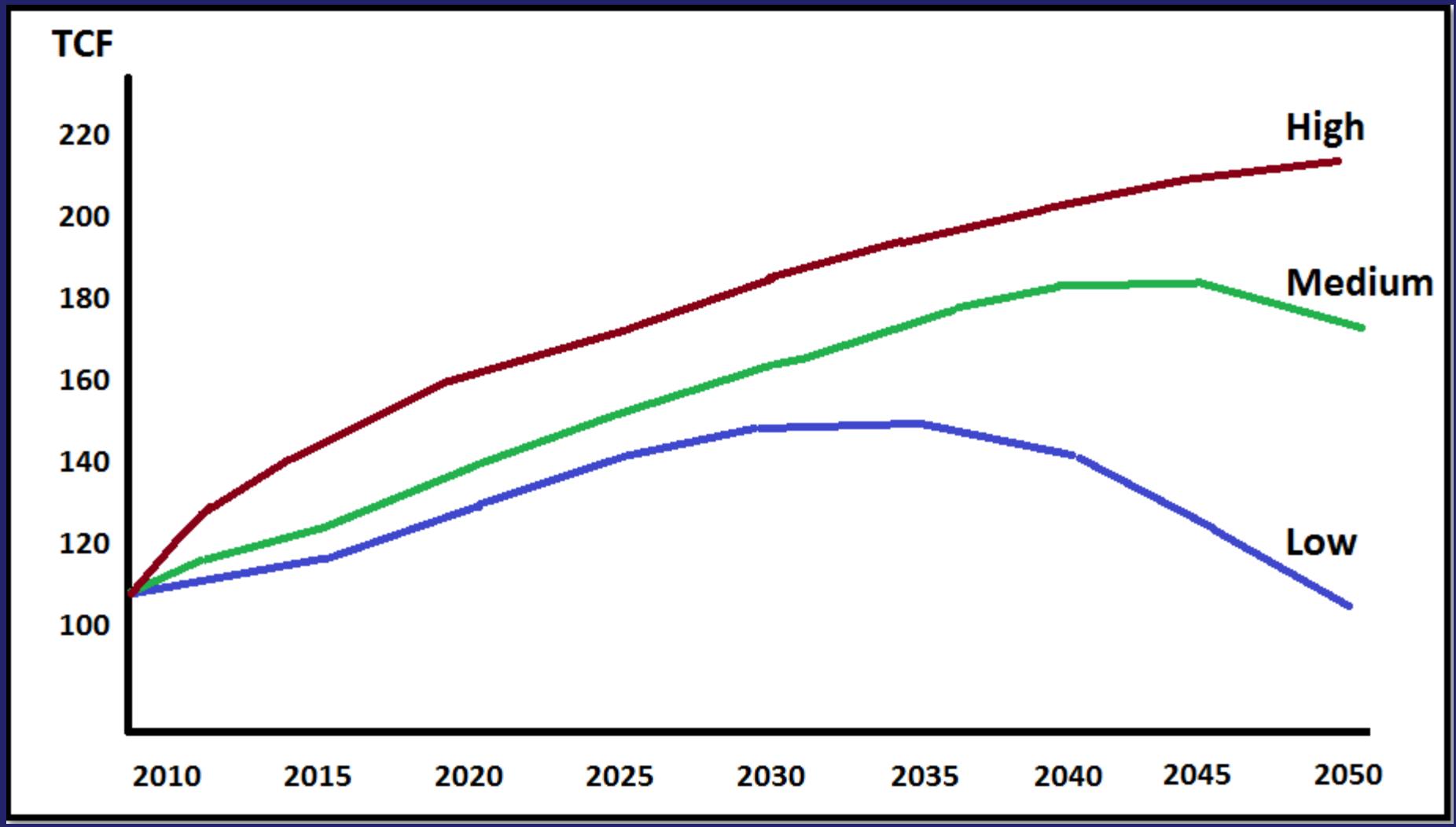
Asia Pacific

Billions of Cubic Feet per Day



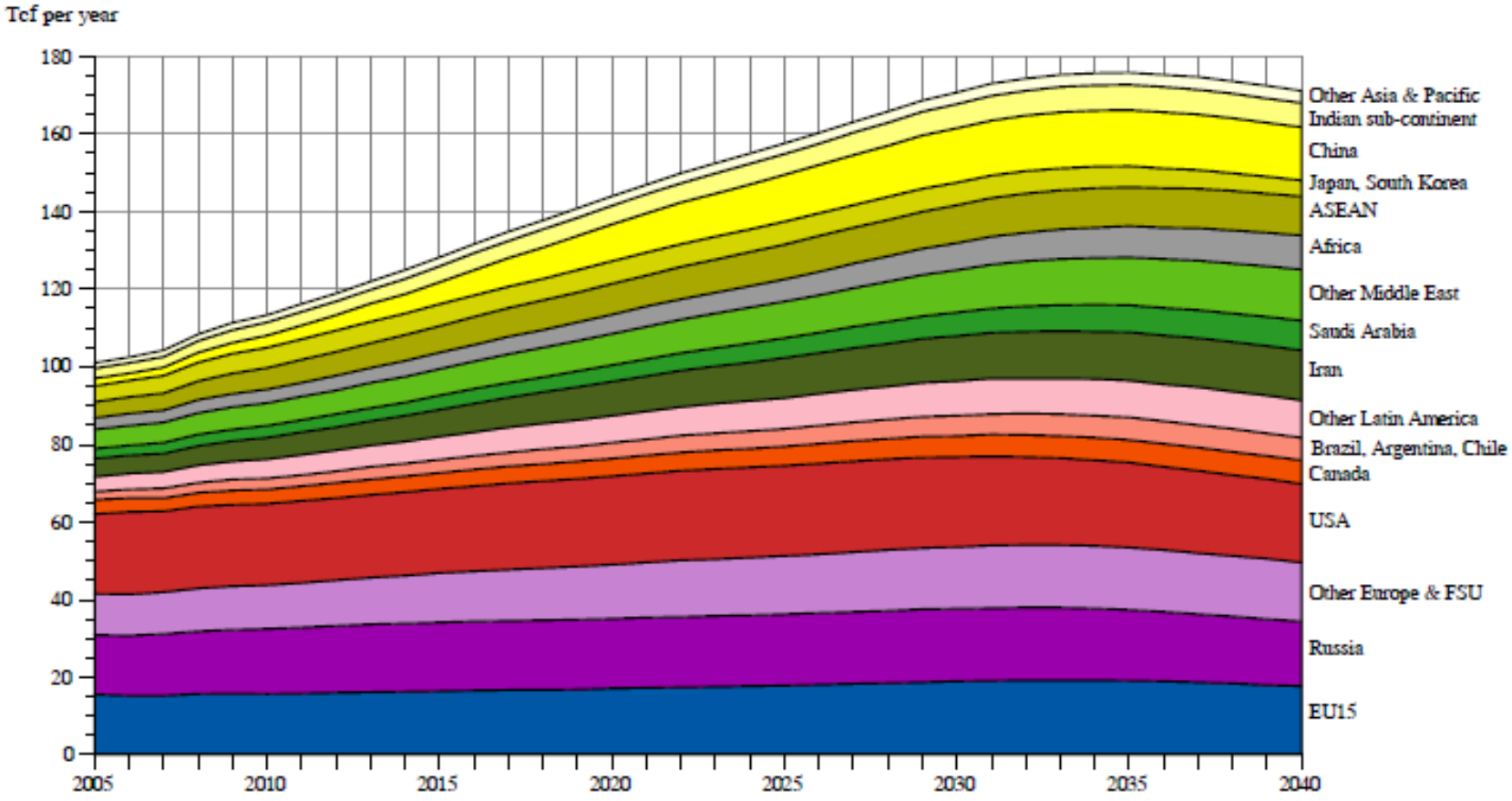
PROJECTED NATURAL GAS PRODUCTION (TCF)

NEHRING (2009)



Reference Case: Global Demand

- Demand growth rates are strongest in Asia and the Middle East.
- Alternatives emerge more quickly post-2030, especially in EU and North America
- Demand in Russia grows to a max of 19.6 tcf in 2030 (about 0.8% p.a.)



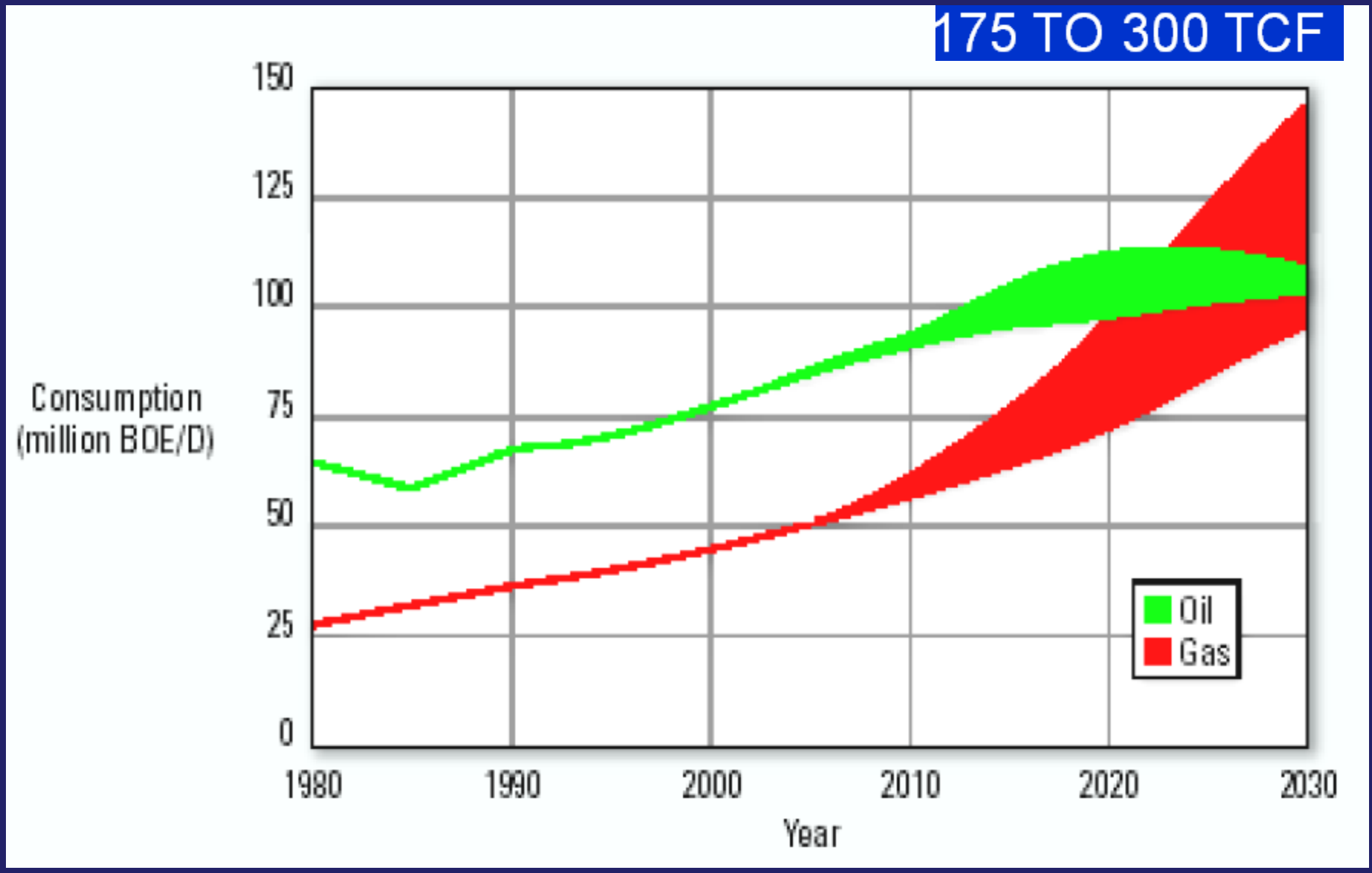
GLOBAL GAS PRODUCTION PROJECTIONS (TCF,2035)

- EIA 156.3
- IEA 154.1
- RICE 173.0
- NEHRING 163.8
- EXXON (2030) 160.0

- CURRENT PRODUCTION 107 TCF

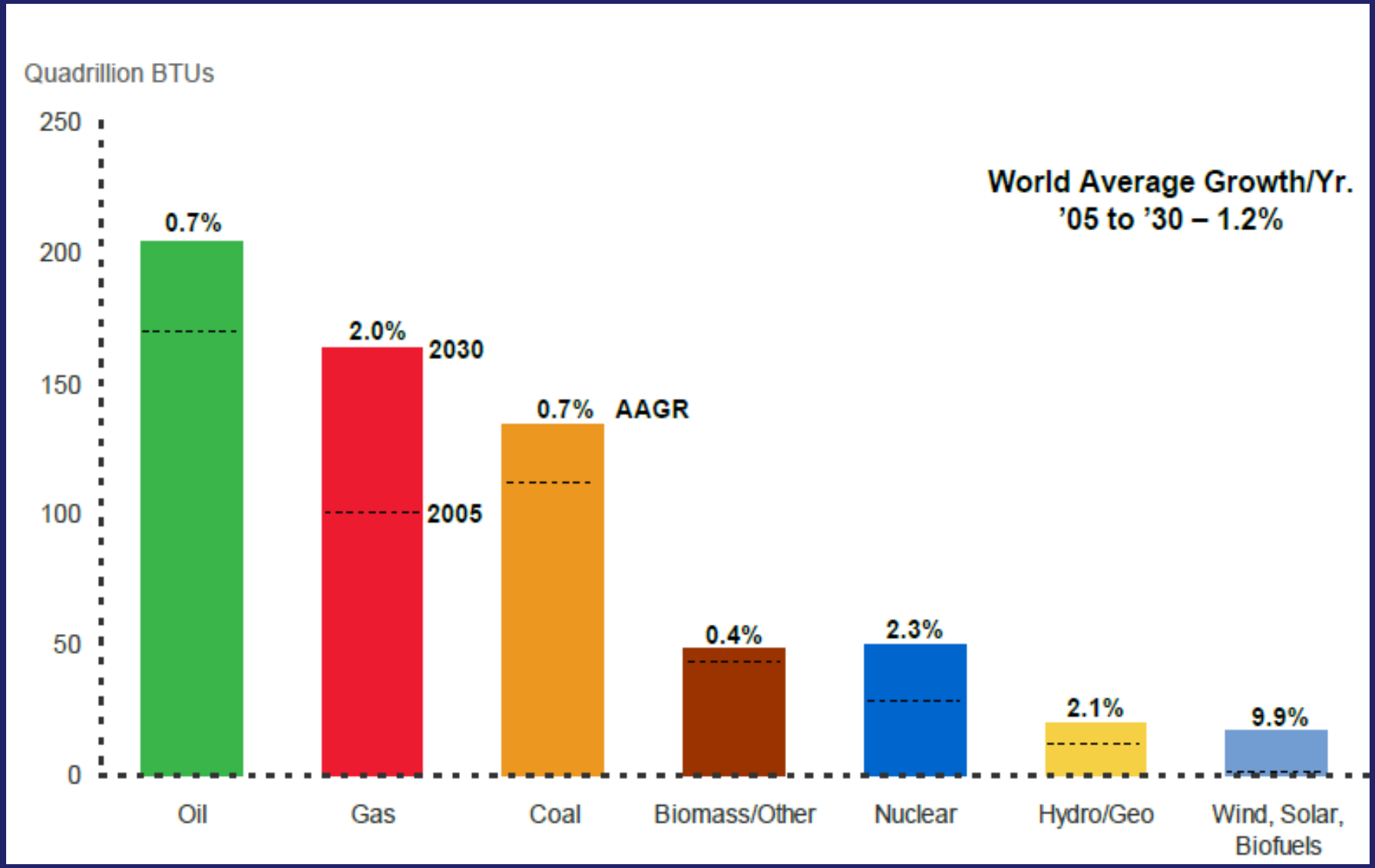
WHEN DOES METHANE BECOME THE DOMINANT ENERGY SOURCE?

WORLD GAS CONFERENCE (2003)

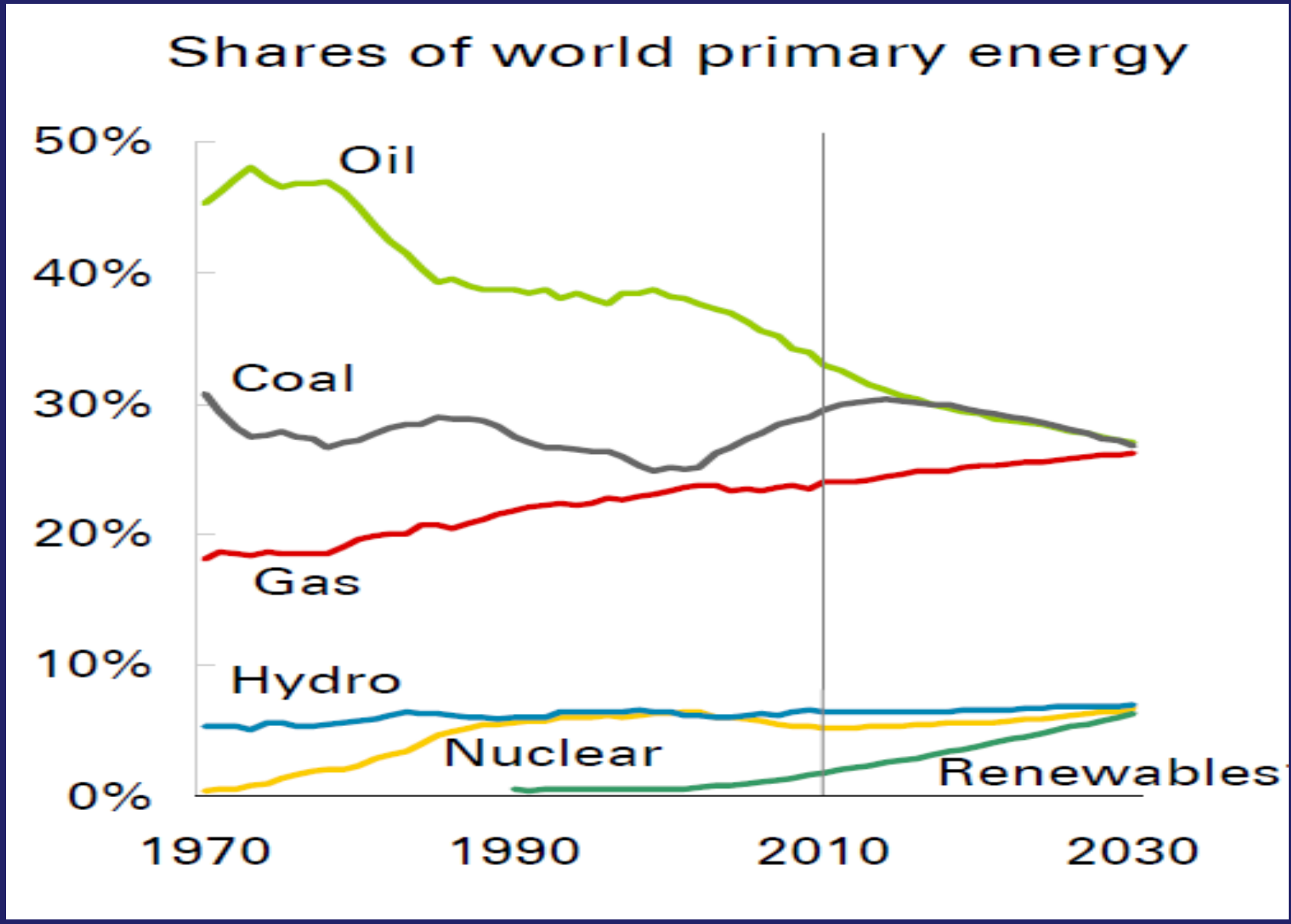


GLOBAL FUEL MIX 2030

ExxonMobil (2011)

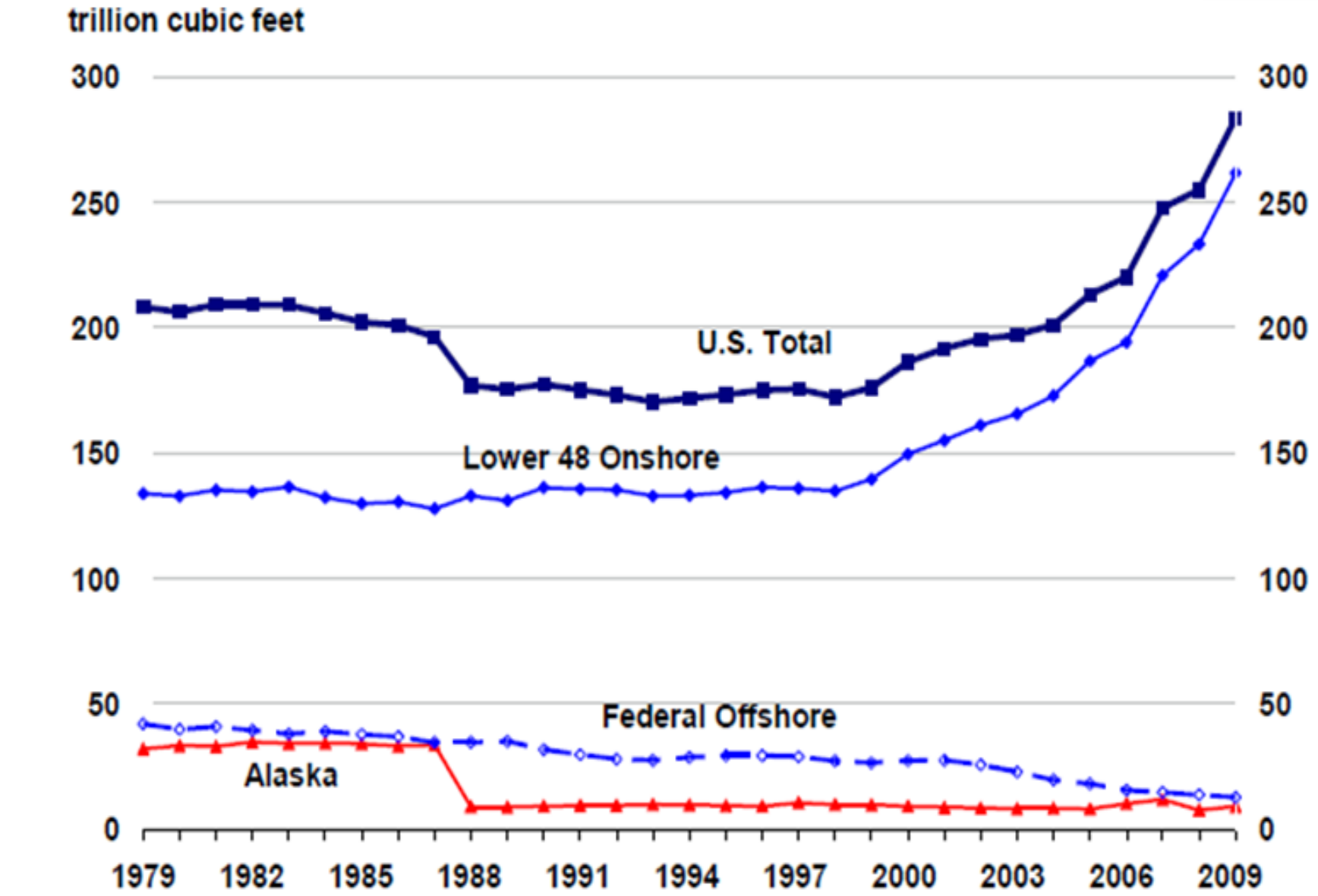


BP ENERGY OUTLOOK (2011)

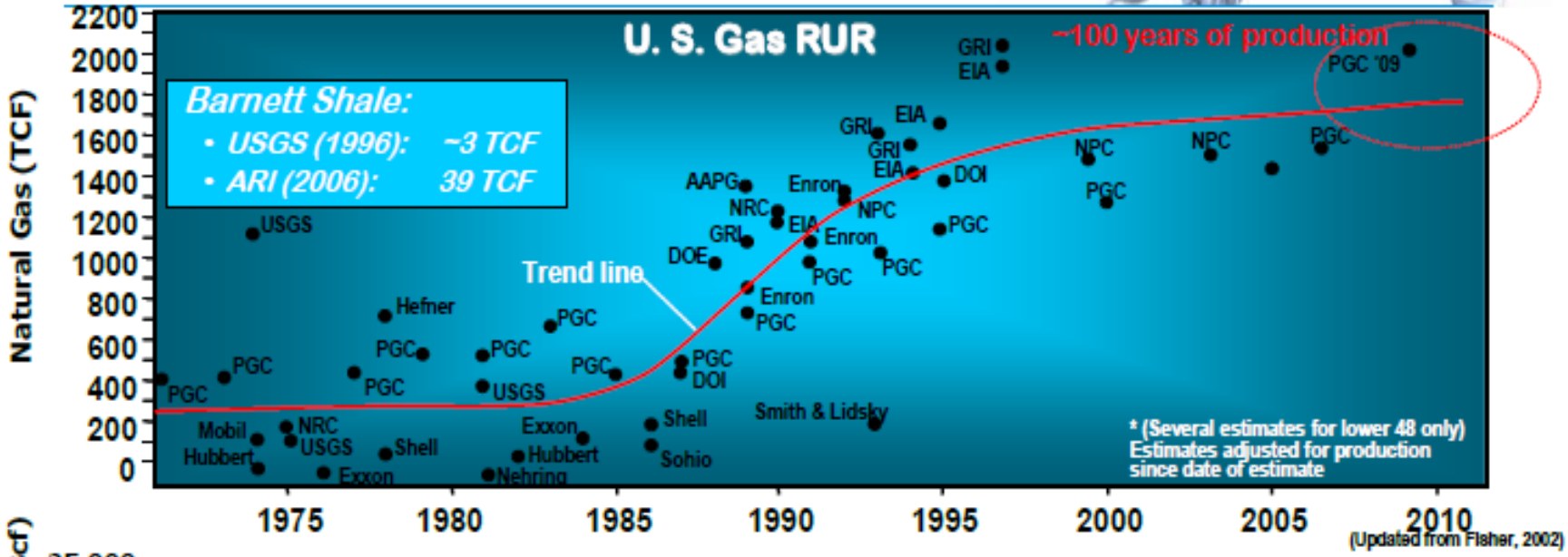


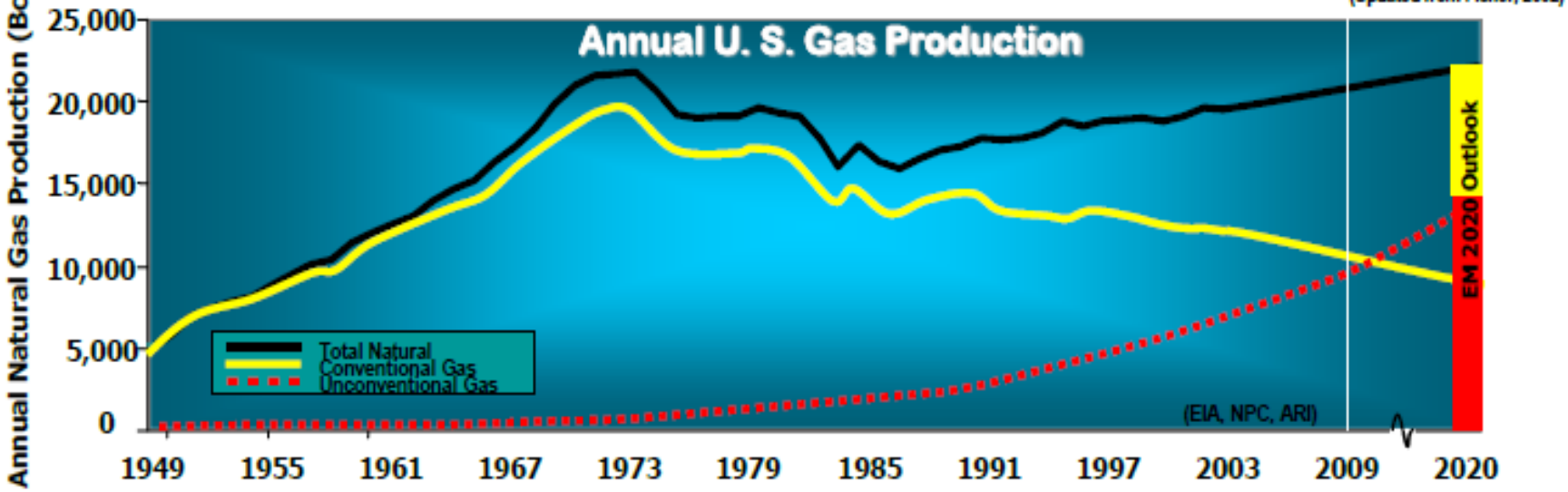
U. S.

U. S. GAS RESERVES (EIA 2010)



Technology Responding to Demand

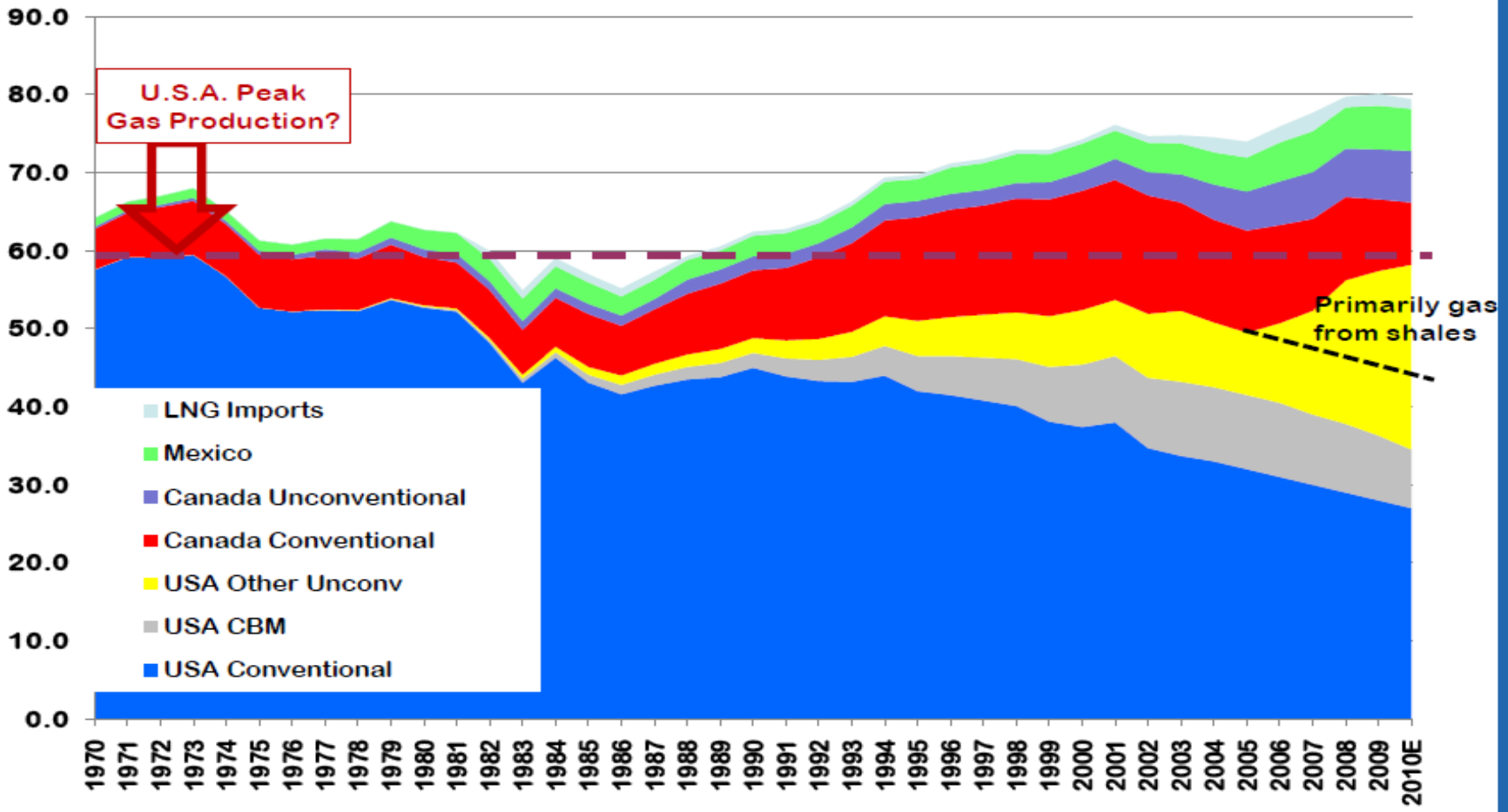




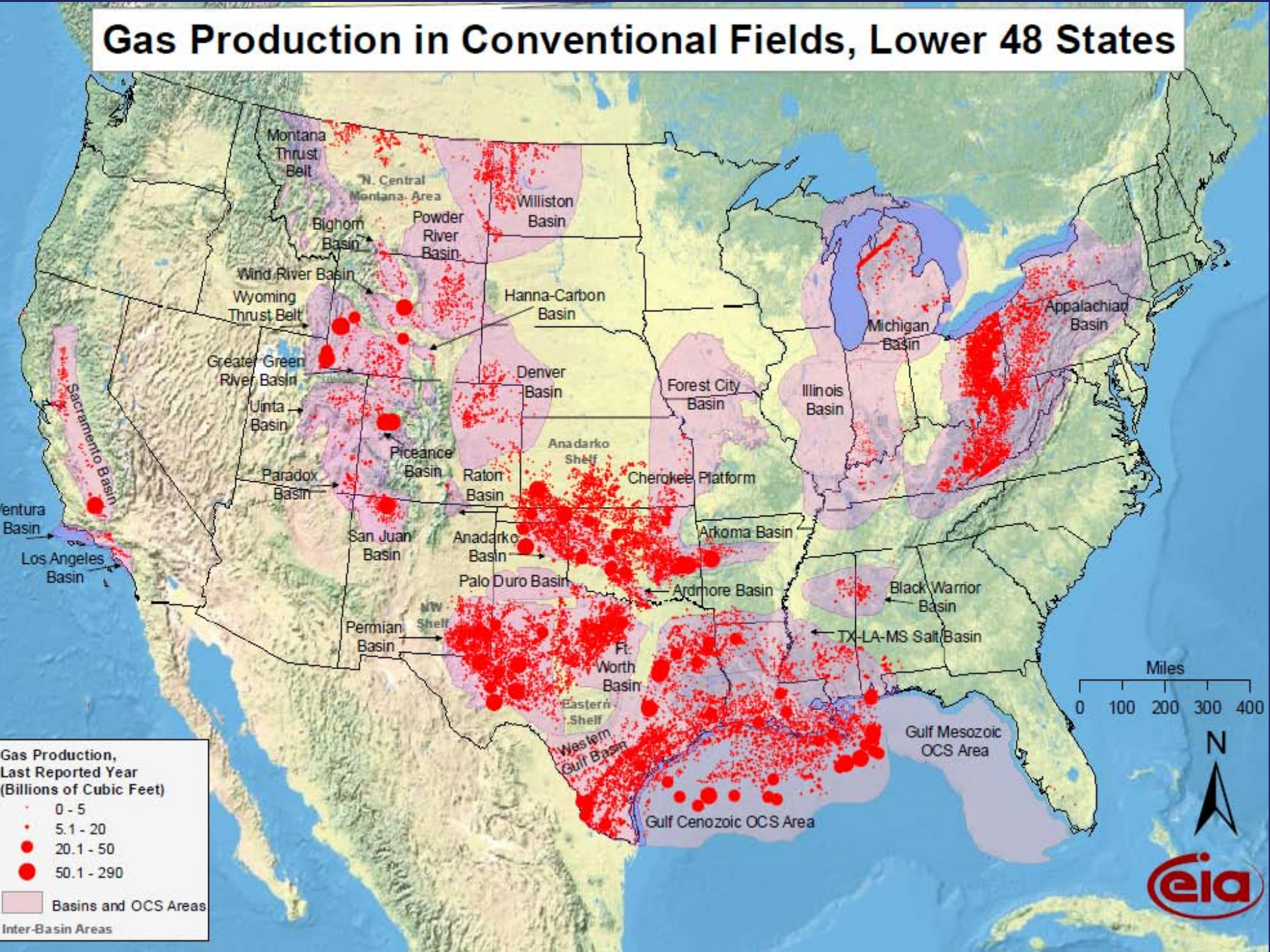
ExxonMobil

Russum (2010)

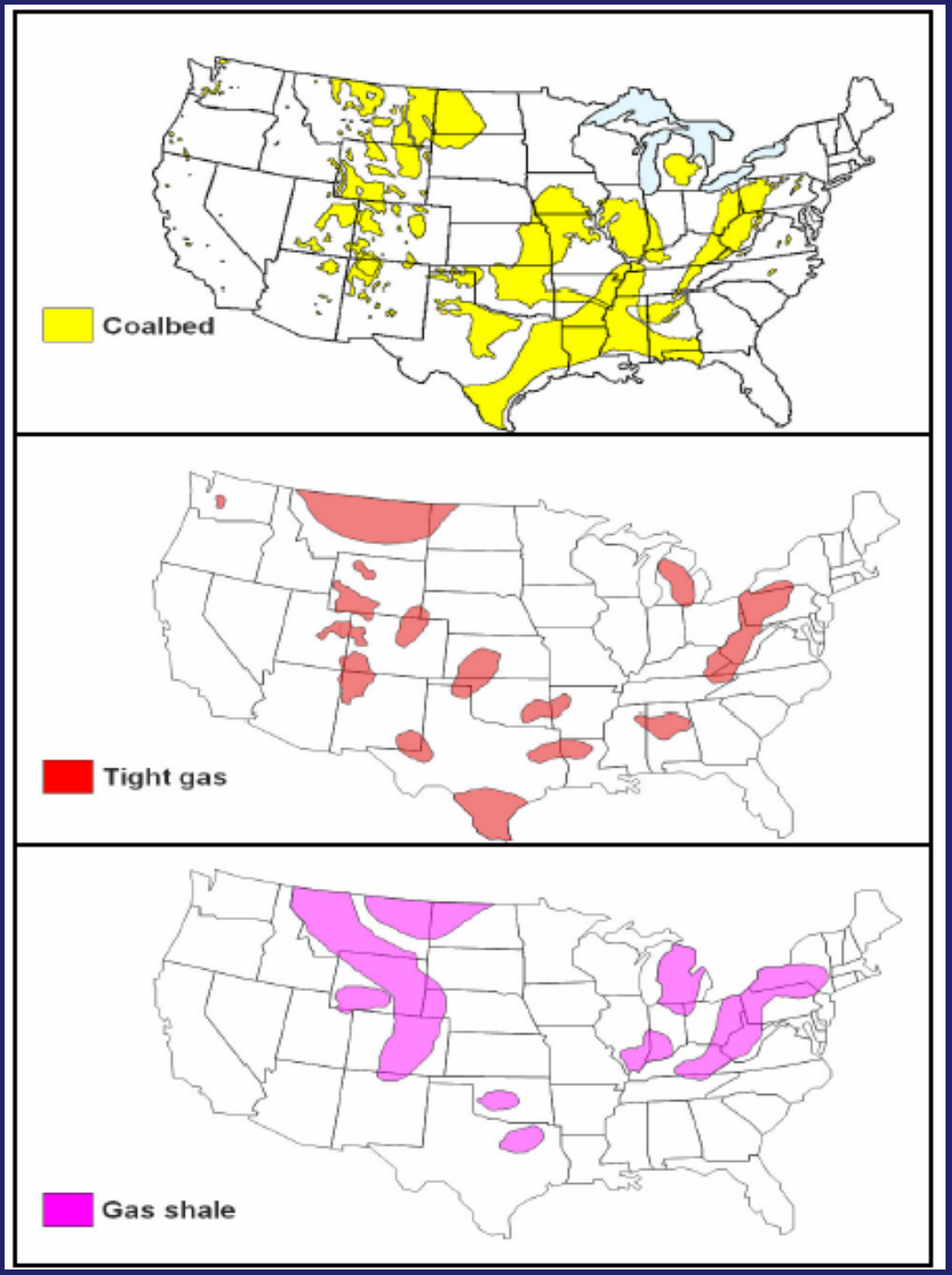
Impact of Unconventional Gas on North American Supply (Bcf/d)



Gas Production in Conventional Fields, Lower 48 States



GTI



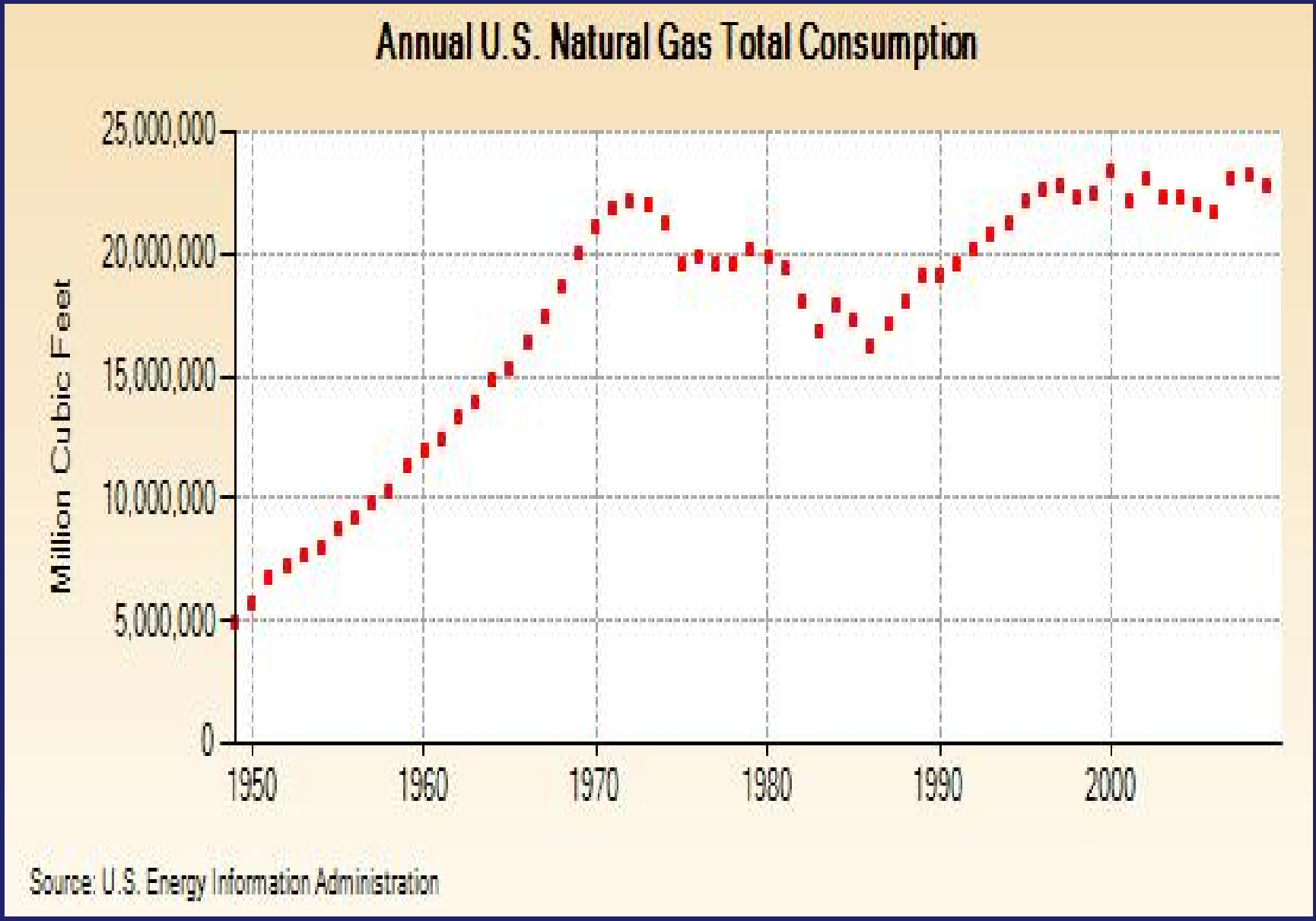
RESOURCE COMPARISONS
WITH PROVED RESERVES ADDED

EIA	1781 TCF
NPC	1857 TCF
PGC	2081 TCF
NCI	2281 TCF

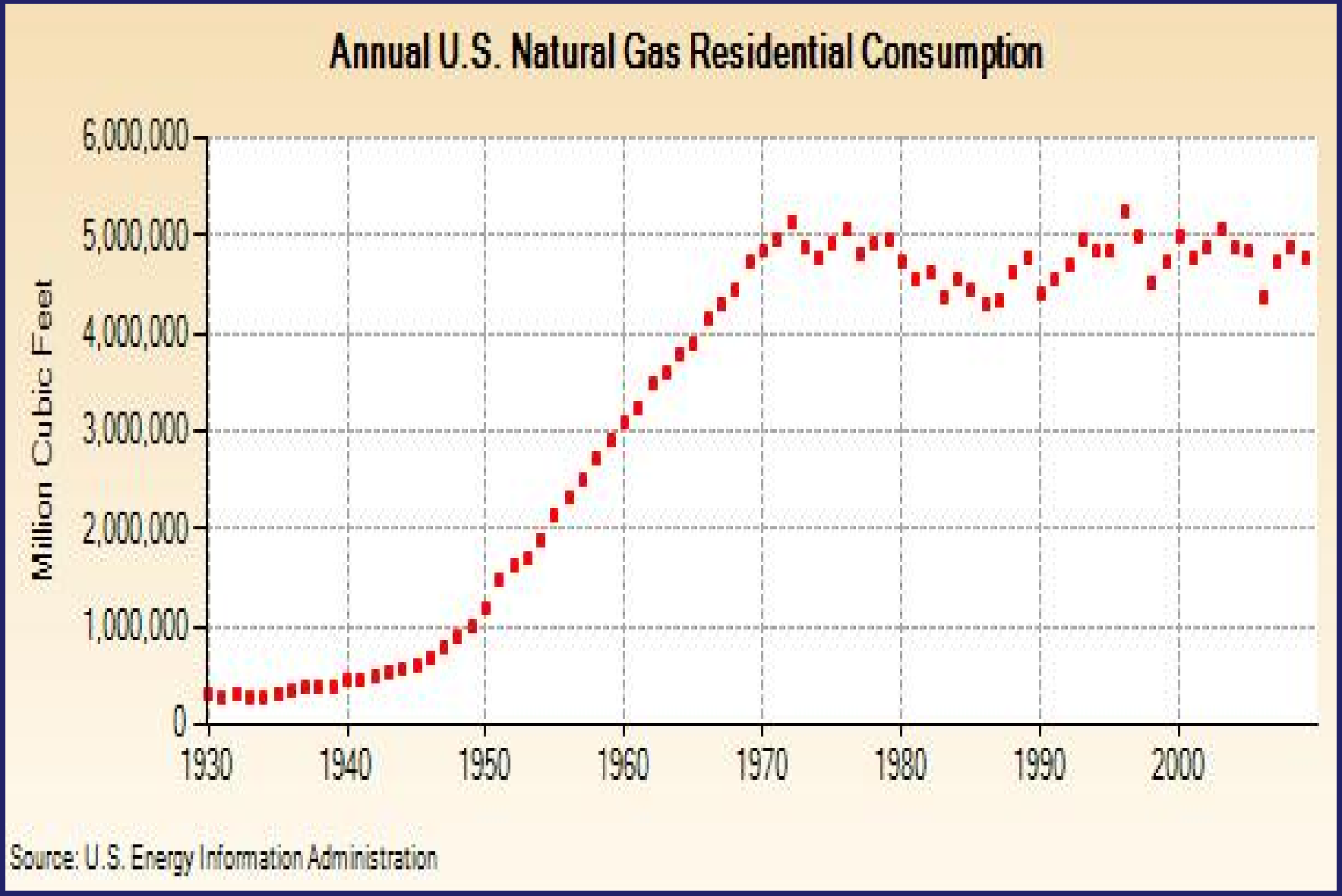
U.S. NATURAL GAS RESOURCE BASE IS LARGE AND IN MY VIEW SUFFICIENT TO BOOST THE U. S. TO A METHANE ECONOMY (35 TCF)

BUT WHAT ABOUT NEAR AND LONG TERM DEMAND?

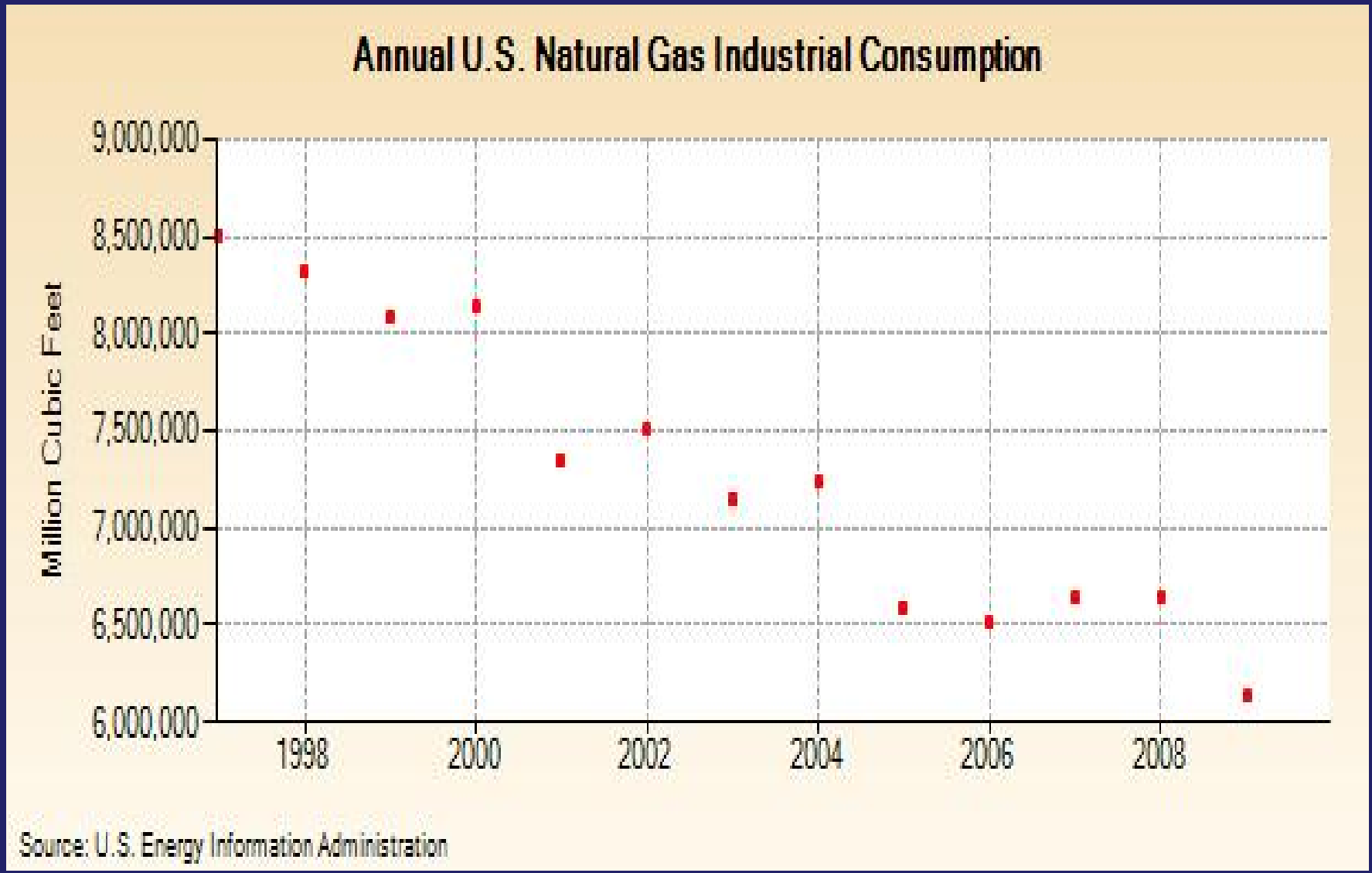
THE 23 TCF CEILING



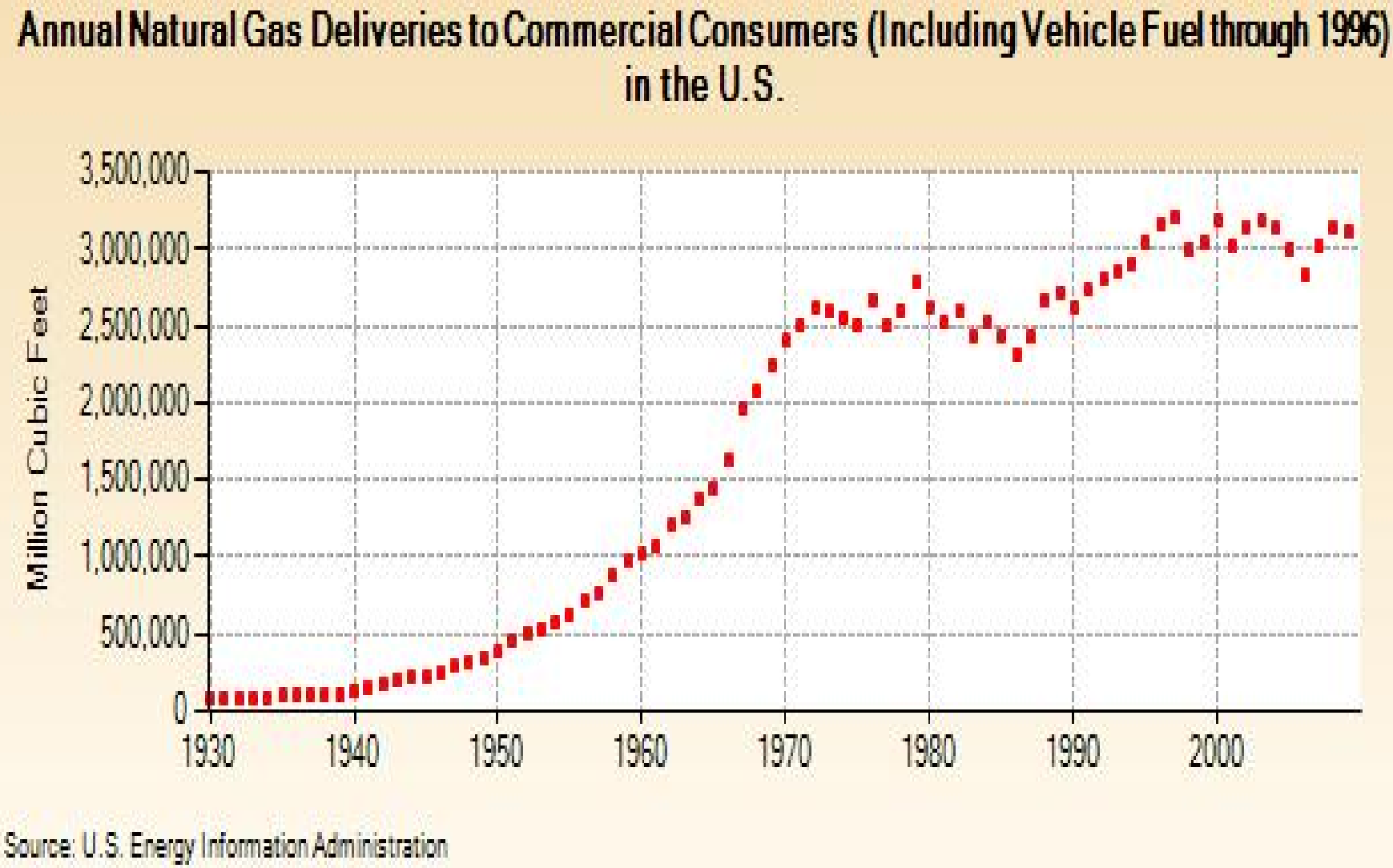
THE 5 TCF CEILING



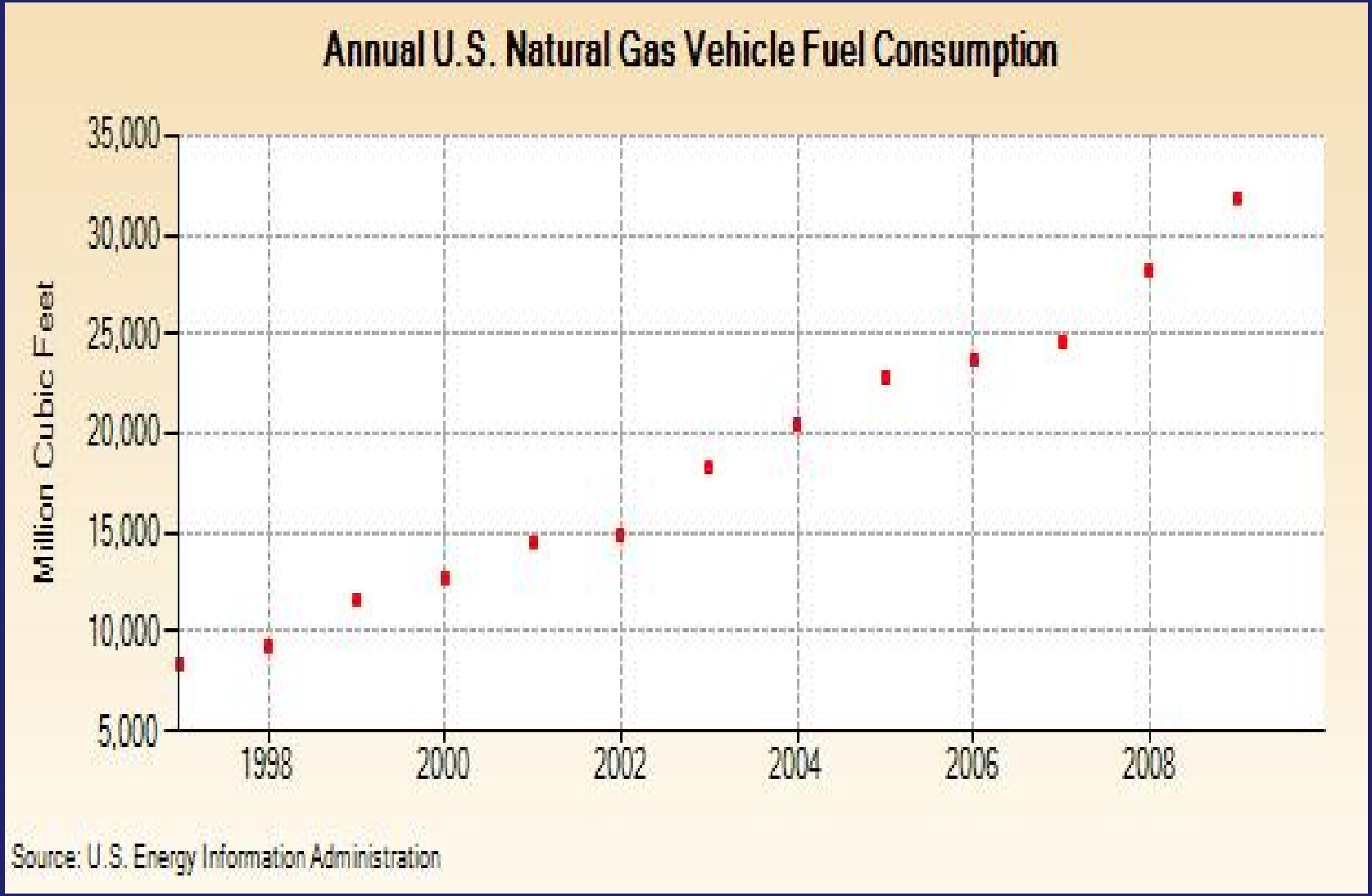
A CASE OF DECLINE



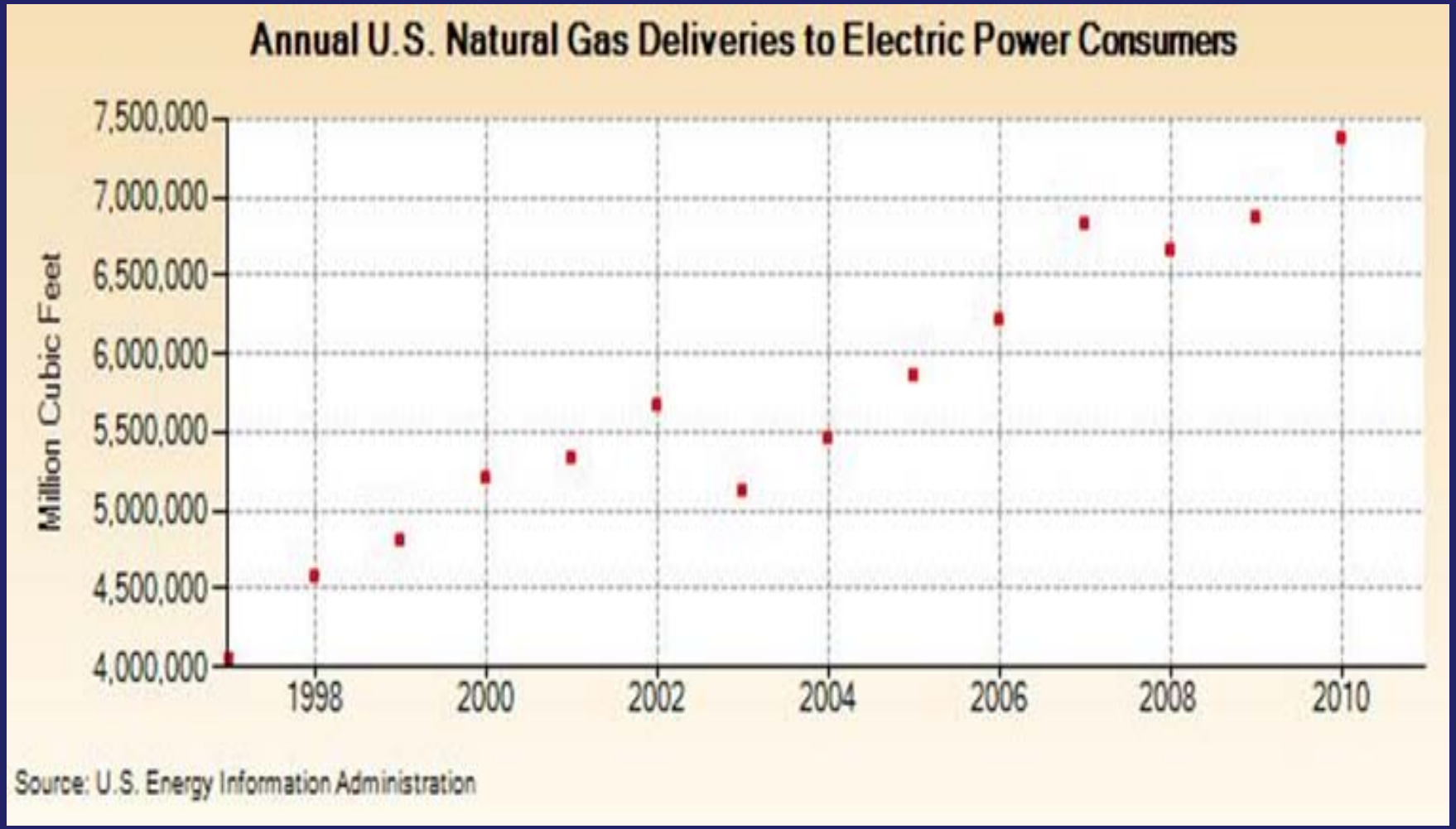
ANOTHER CEILING AT 3 TCF



GROWING OFF OF A VERY SMALL BASE



THE BIG ONE—CAN IT BE SUSTAINED?

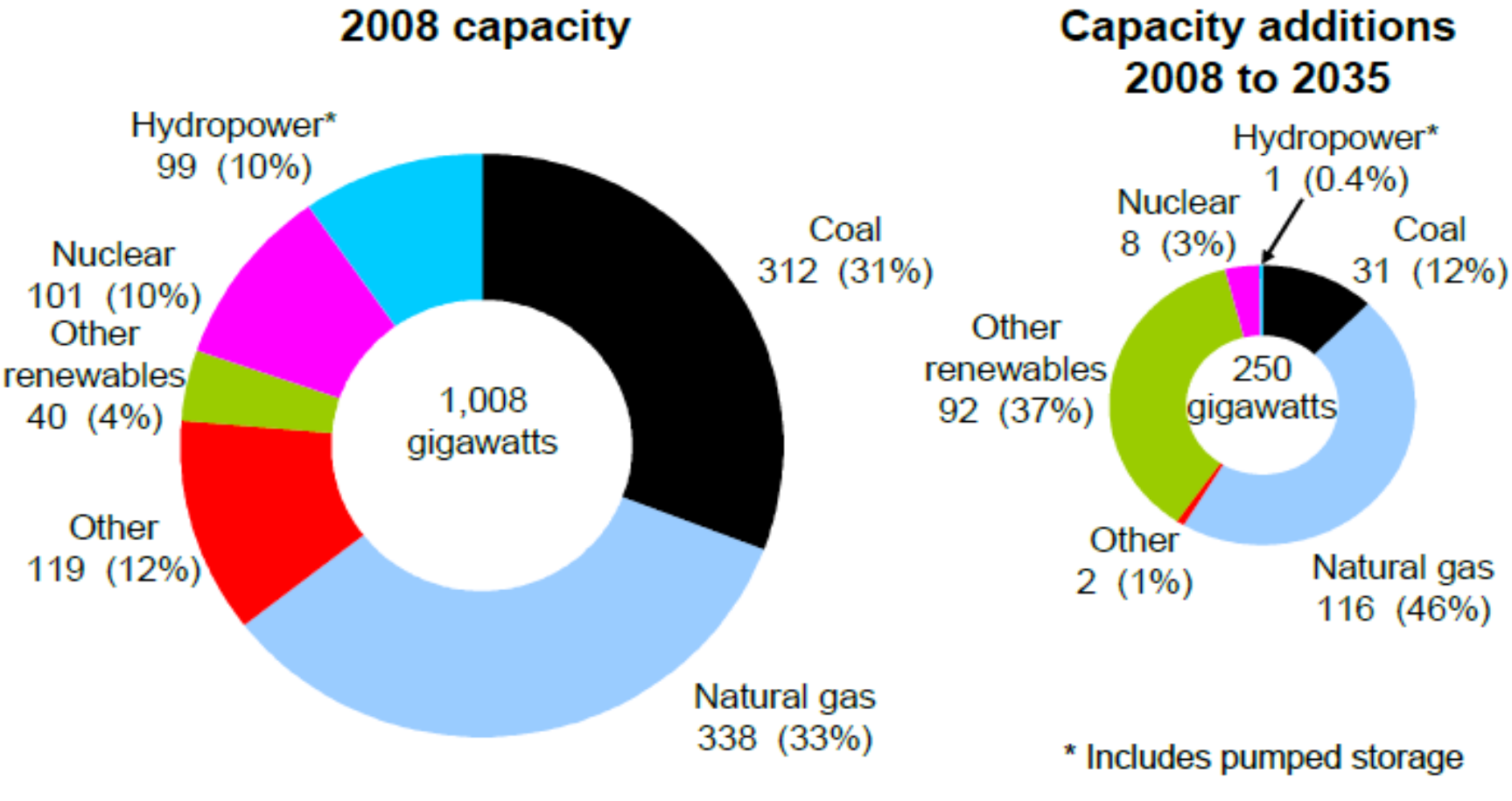


NATURAL GAS PROVIDES 7.5 TCF FOR POWER GENERATION COMPARED TO COAL PROVIDING 14.7 TCF EQUIVALENT

IF GAS BACKED OUT A FOURTH TO HALF OF COAL, THAT WOULD TRANSLATE TO 3.5 TO 7 TCF INCREASE IN NATURAL GAS DEMAND TO AS MUCH AS 30 TCF

SUBSTANTIAL BUT PROBABLY NOT A METHANE ECONOMY

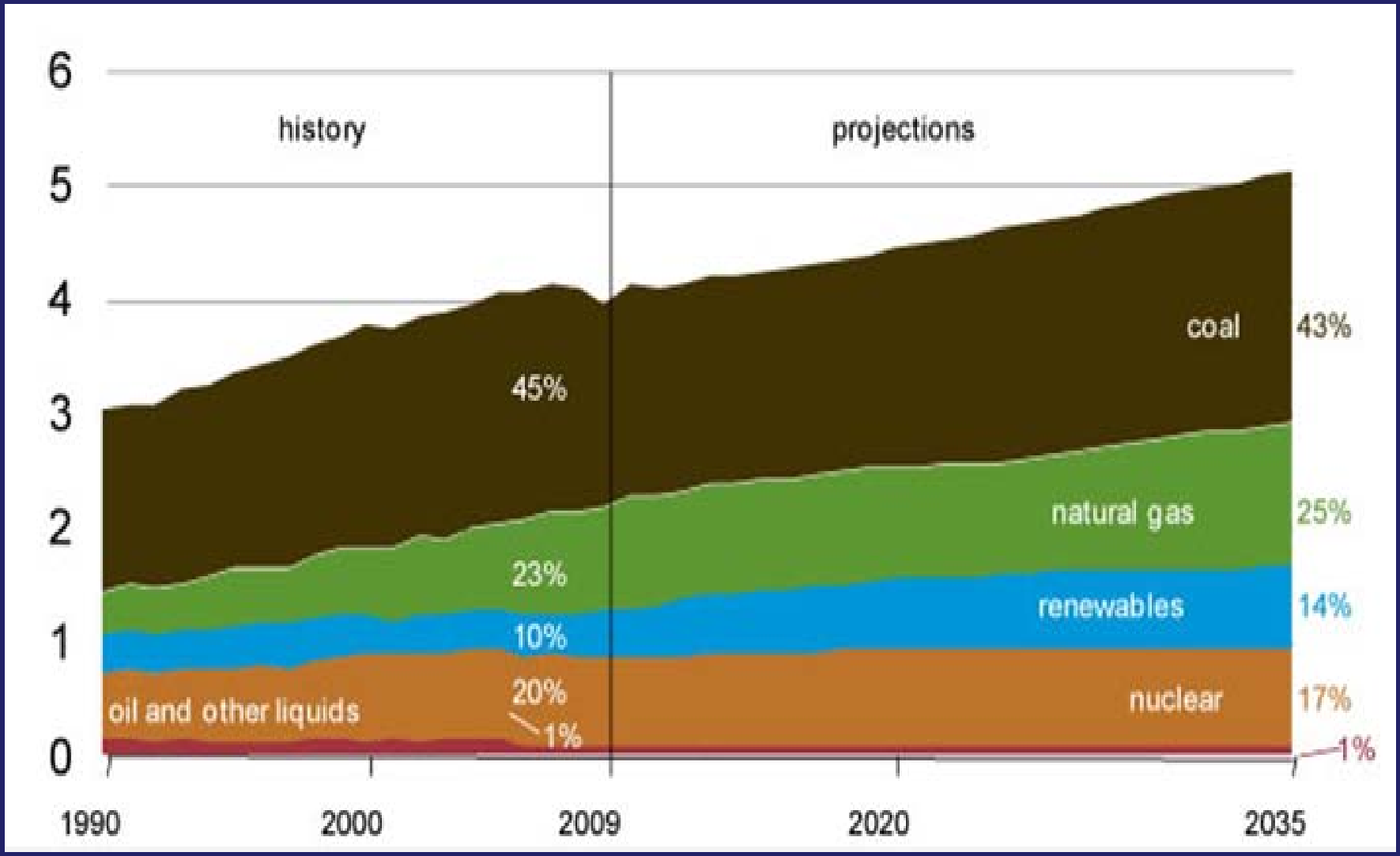
Natural gas and renewables account for the majority of capacity additions from 2008 to 2035



Source: *Annual Energy Outlook 2010*

U. S. POWER GENERATING MIX

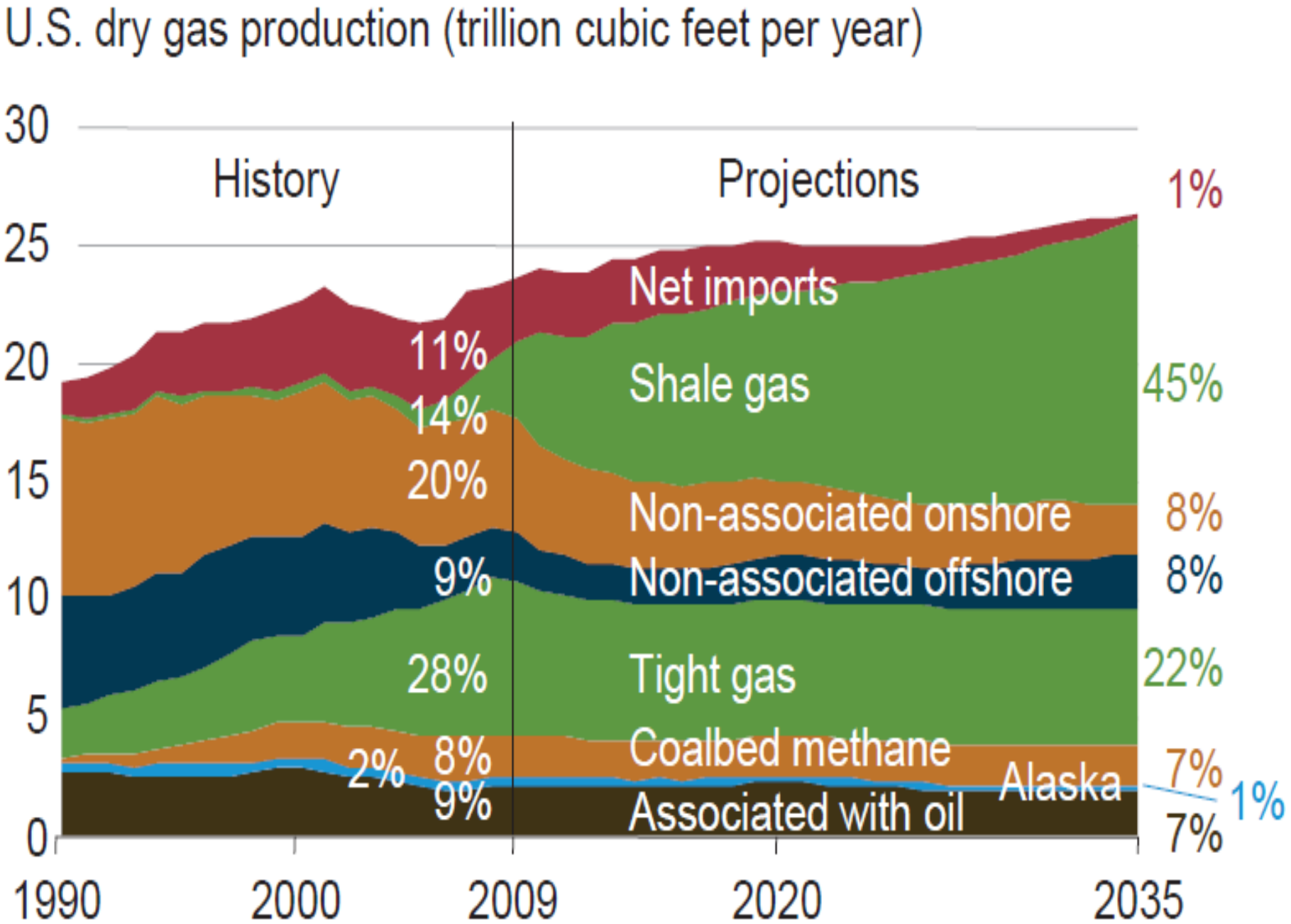
(EIA, 2010)



TRANSPORTATION POTENTIAL

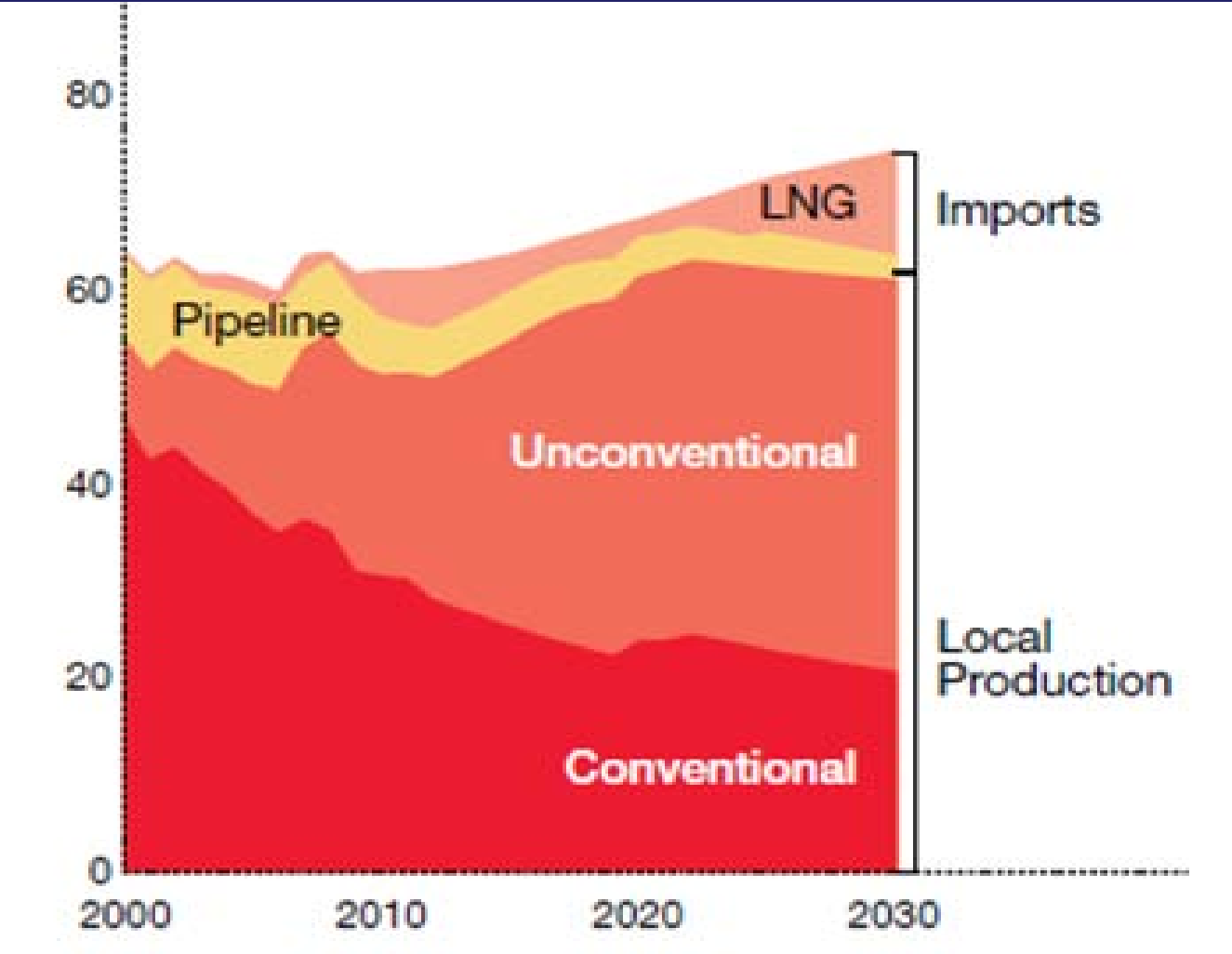
- CNG NOW LARGELY A NICHE FUEL, LIMITED LARGELY TO CITY CENTRAL HEAVY DUTY VEHICLES
- PICKENS WANTS TO ENLARGE BY INCENTIVIZING CROSS-COUNTRY 18 WHEELERS TO CNG, BUT INFRASTRACTURE IS HUGE IMPEDIMENT
- SIGNIFICANT TRANSPORTATION DEMAND FOR NATURAL GAS LIKELY AWAITS ADVANCEMENT AND WIDESPREAD USE OF THE HYDROGEN FUEL CELL WHERE METHANE BECOMES THE SOURCE OF HYDROGEN THEREBY USHERING IN A FULL BLOWN METHANE ECONOMY

2035 DEMAND OF 25 + TCF EIA (2010)



U. S. NATURAL GAS SUPPLY (27.4 TCF, 2030)

EXXONMOBIL (2011)



THANK YOU!