



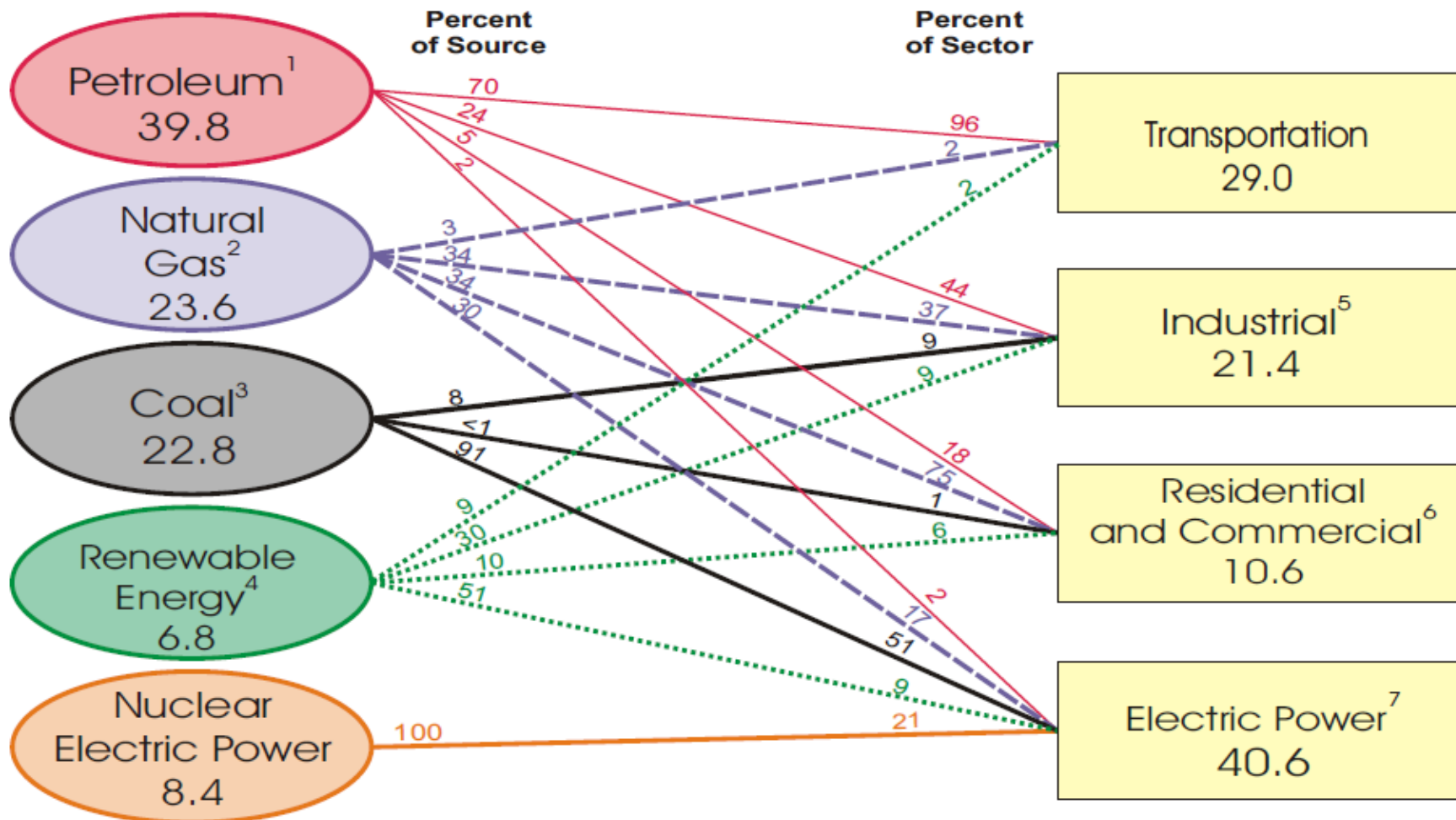
•
• **Research**
• **Partnership to**
• **Secure Energy**
• **for America**
•

**Natural Gas – An
Unconventional Future with
Renewables & Efficiency**

**C. Michael Ming
Clean Tech 2009
May 5, 2009
Houston, TX**

SECURE ENERGY FOR AMERICA

U.S. Primary Energy Consumption by Source and Sector, 2007 (Quadrillion Btu)



¹Does not include 0.6 quadrillion Btu of fuel ethanol, which is included in "Renewable Energy."

²Excludes supplemental gaseous fuels.

³Includes less than 0.1 quadrillion Btu of coal coke net imports.

⁴Conventional hydroelectric power, geothermal, solar/PV, wind, and biomass.

⁵Includes industrial combined-heat-and-power (CHP) and industrial electricity-only plants.

⁶Includes commercial combined-heat-and-power (CHP) and commercial electricity-only plants.

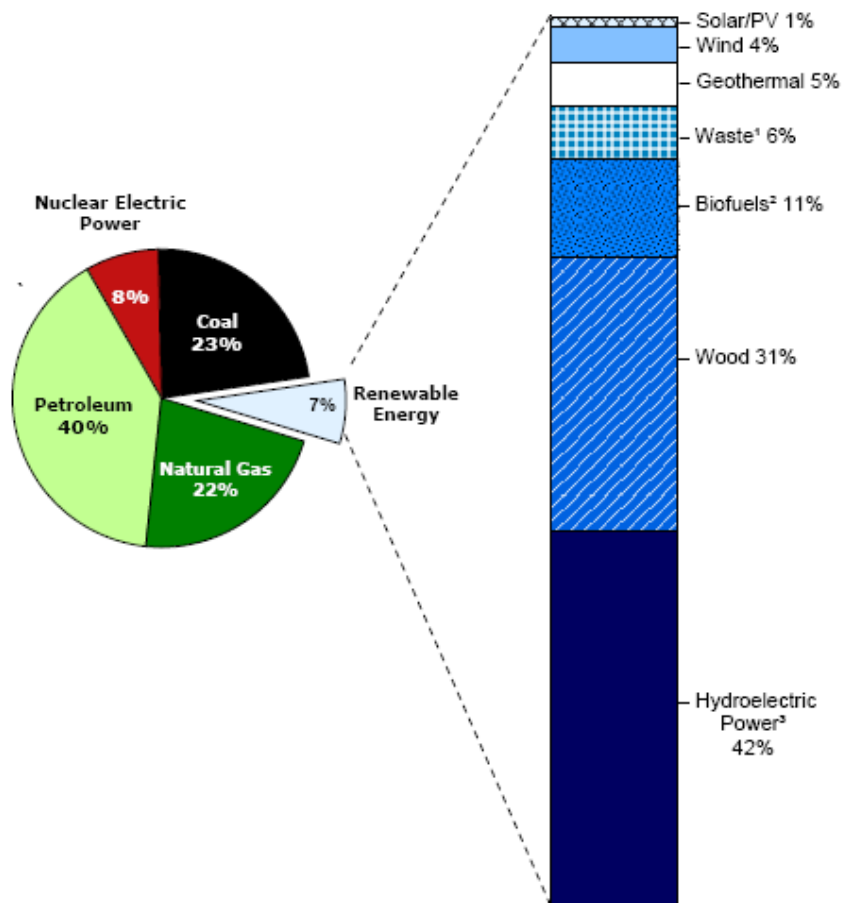
⁷Electricity-only and combined-heat-and-power (CHP) plants whose primary business is to sell electricity, or electricity and heat, to the public.

Note: Sum of components may not equal 100 percent due to independent rounding.

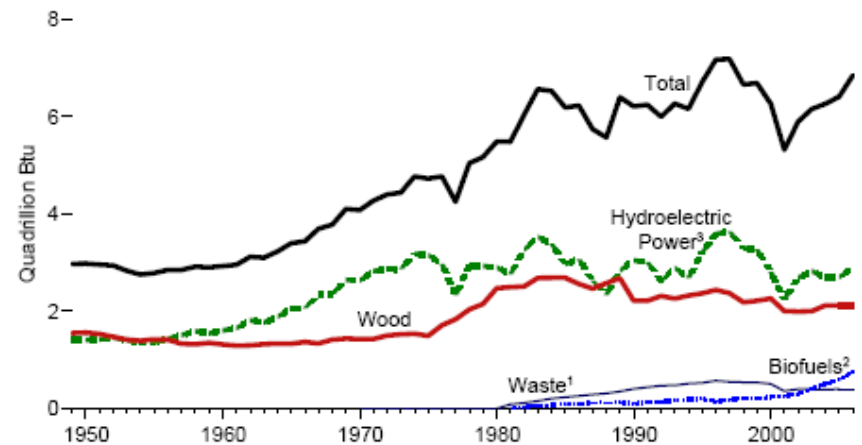
Sources: Energy Information Administration, *Annual Energy Review 2007*, Tables 1.3, 2.1b-2.1f and 10.3.

Figure 10.1 Renewable Energy Consumption by Major Sources

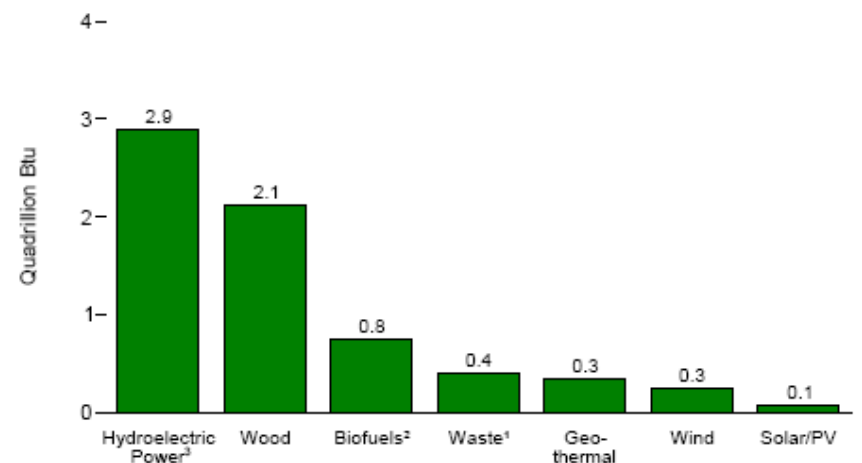
Renewable Energy as Share of Total Energy, 2006



Renewable Energy Total Consumption and Major Sources, 1949-2006



Renewable Energy Consumption by Source, 2006



¹ Municipal solid waste from biogenic sources, landfill gas, sludge waste, agricultural byproducts, and other biomass. Through 2000, also includes non-renewable waste (municipal solid waste from non-biogenic sources, and tire-derived fuels).

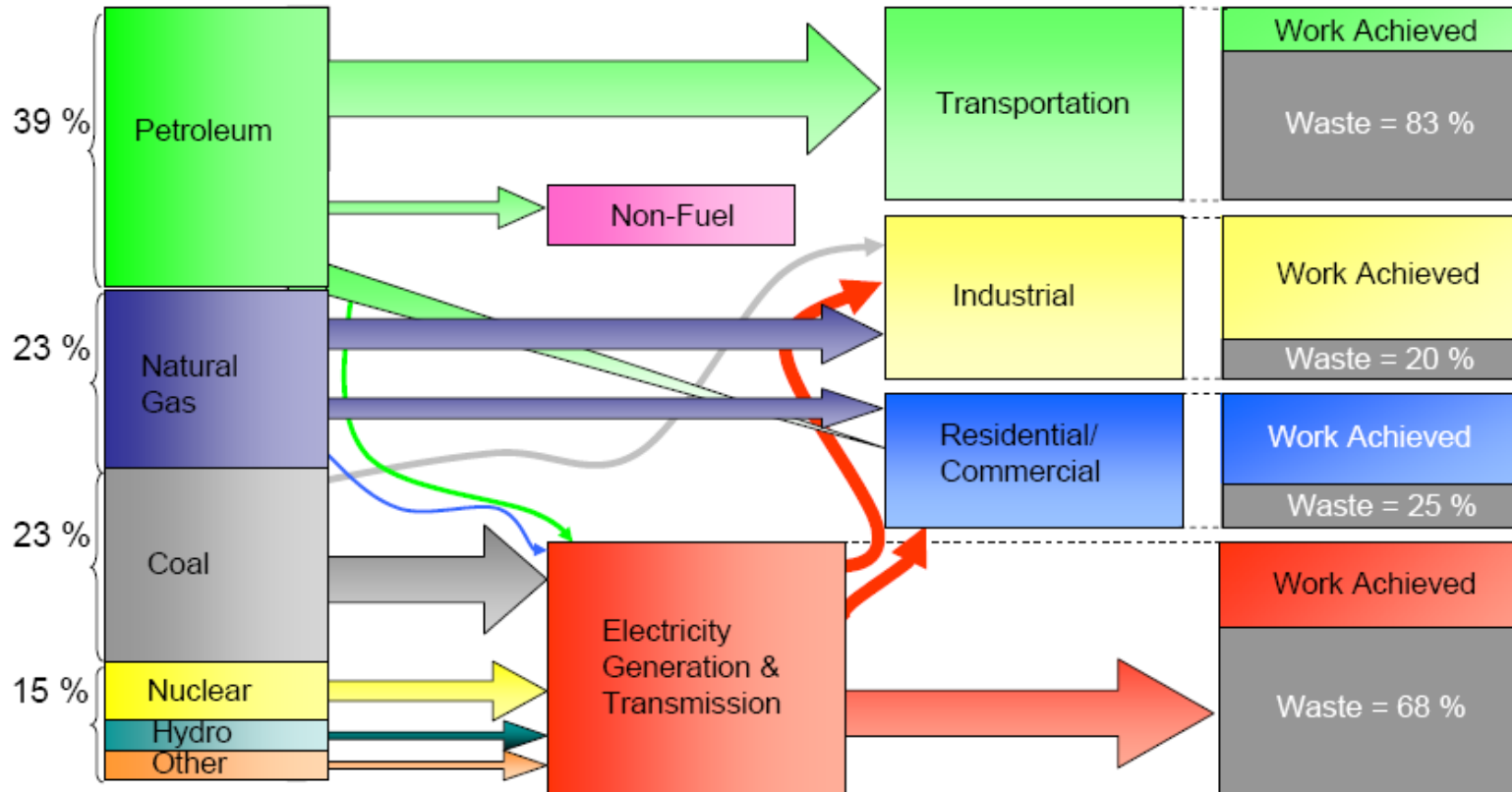
² Fuel ethanol and biodiesel consumption, plus losses and co-products from the production of fuel ethanol and biodiesel.

³ Conventional hydroelectric power.

Note: Because vertical scales differ, graphs should not be compared.

Sources: Tables 1.3 and 10.1.

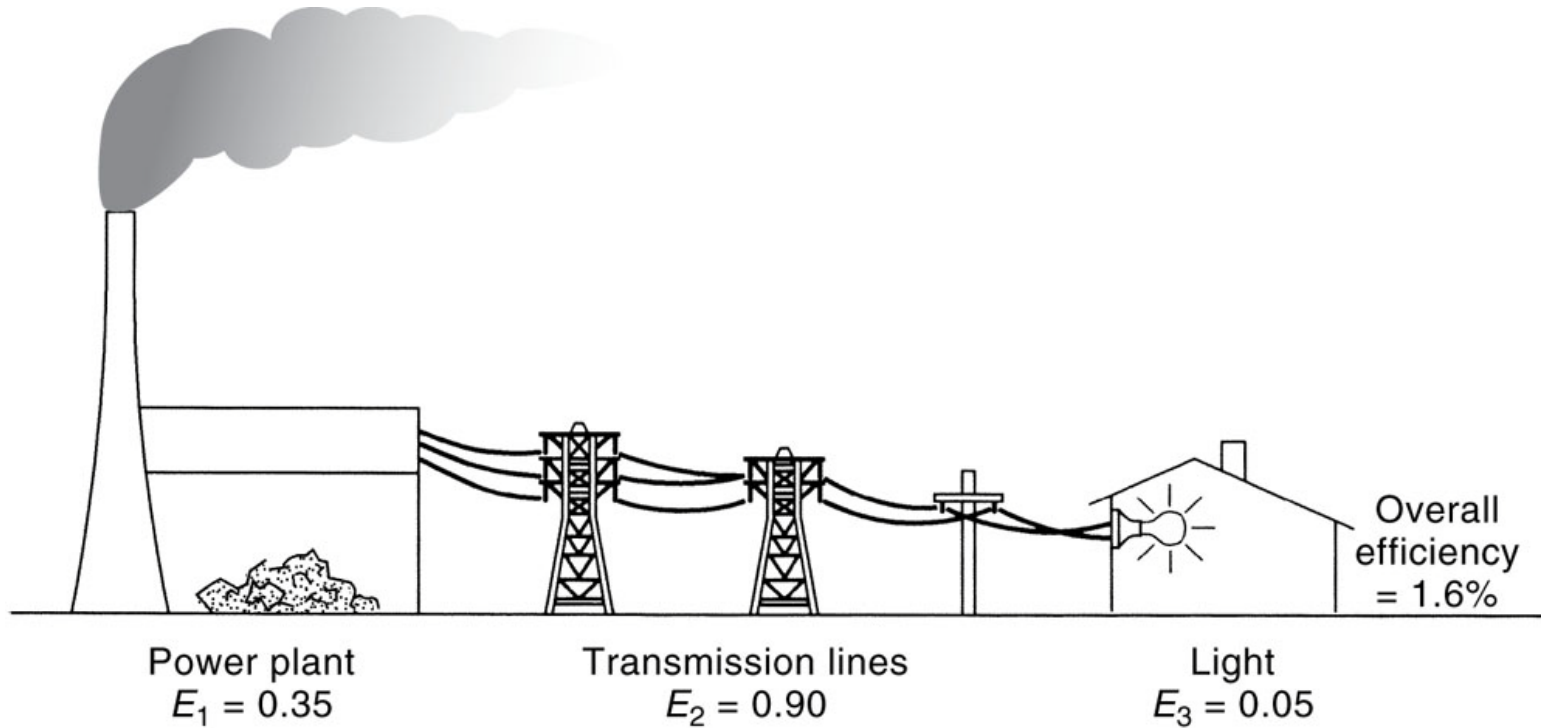
High Potential Efficiency Opportunities Leverage All Forms of Supply



- Overall energy efficiency for U.S. is only 45%
- Transportation and power generation have greatest opportunities for improvement

Source: LLNL/DOE

And Efficiency Multiplies Backwards

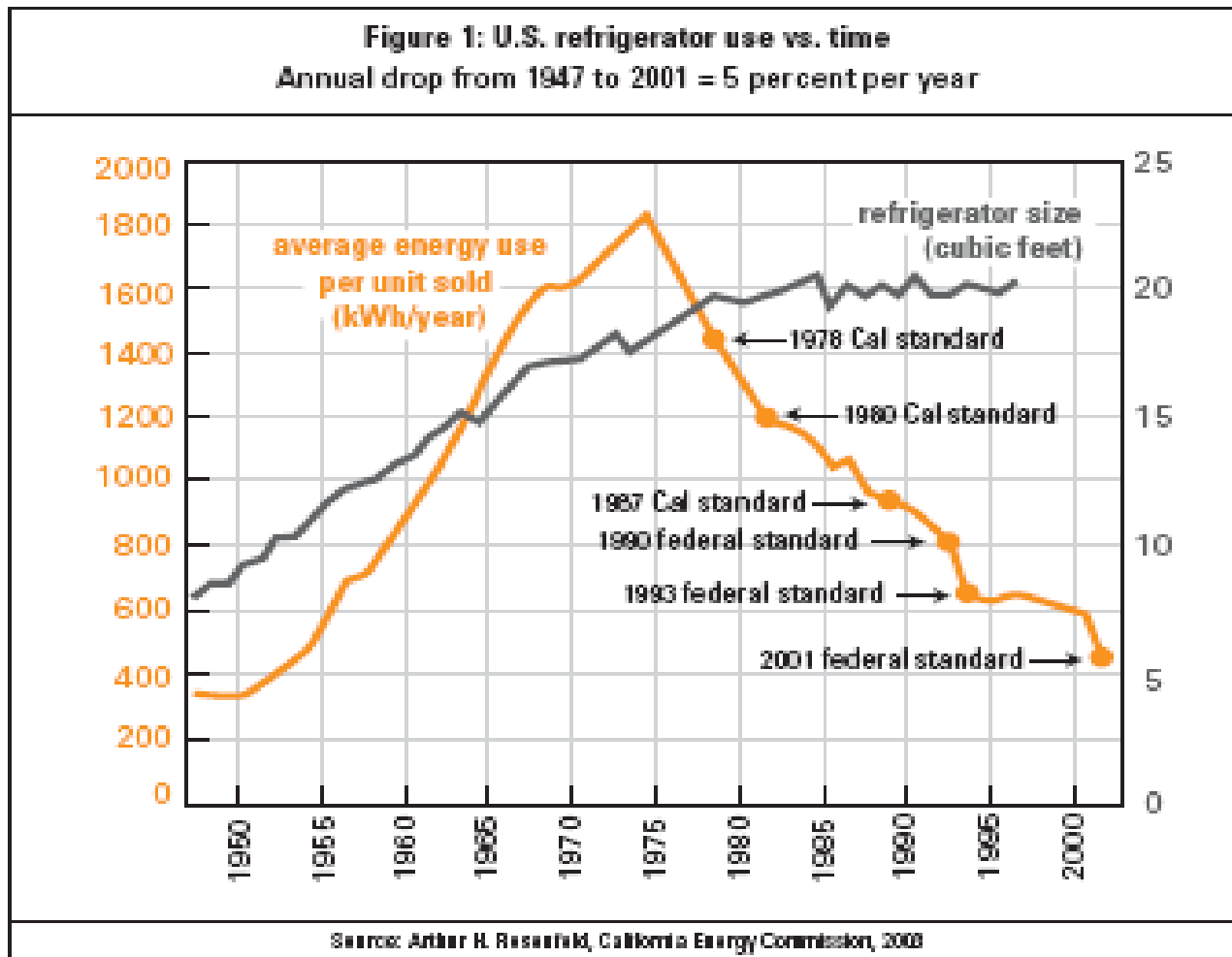


Overall efficiency
for
chemical energy
to light energy conversion

$$= E_1 \times E_2 \times E_3 = 0.35 \times 0.90 \times 0.05 = 0.016$$

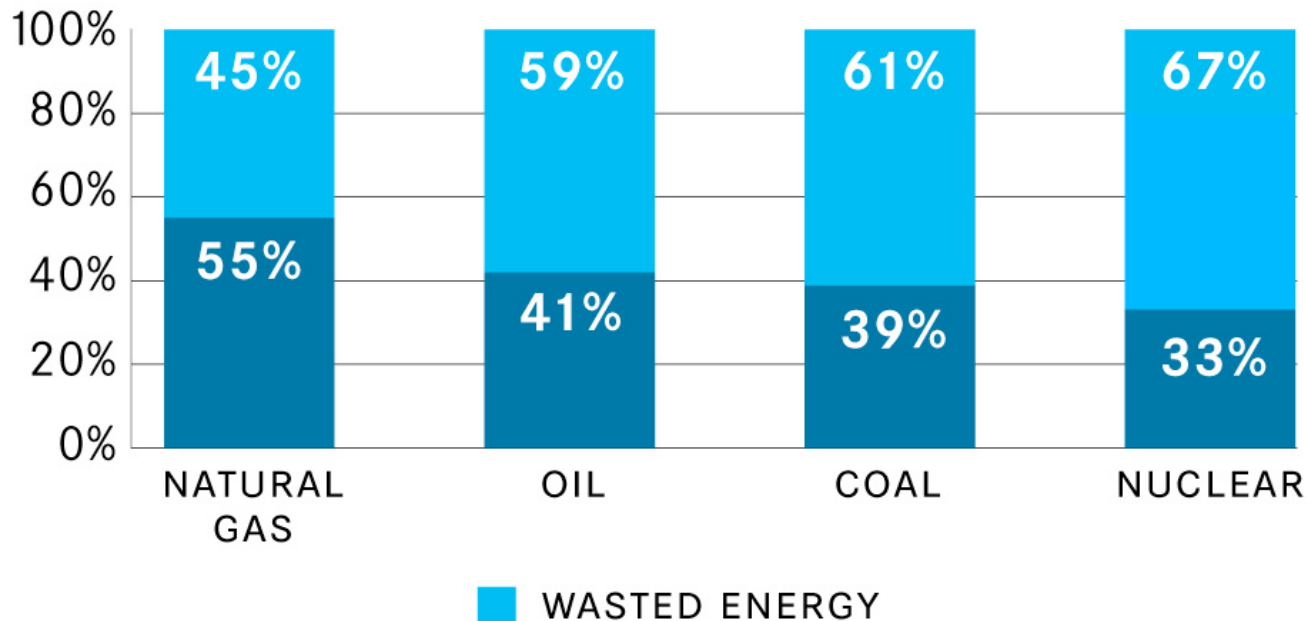
© 2006 Thomson Higher Education

Meaningful Efficiency is Obtainable



Comparative Efficiency

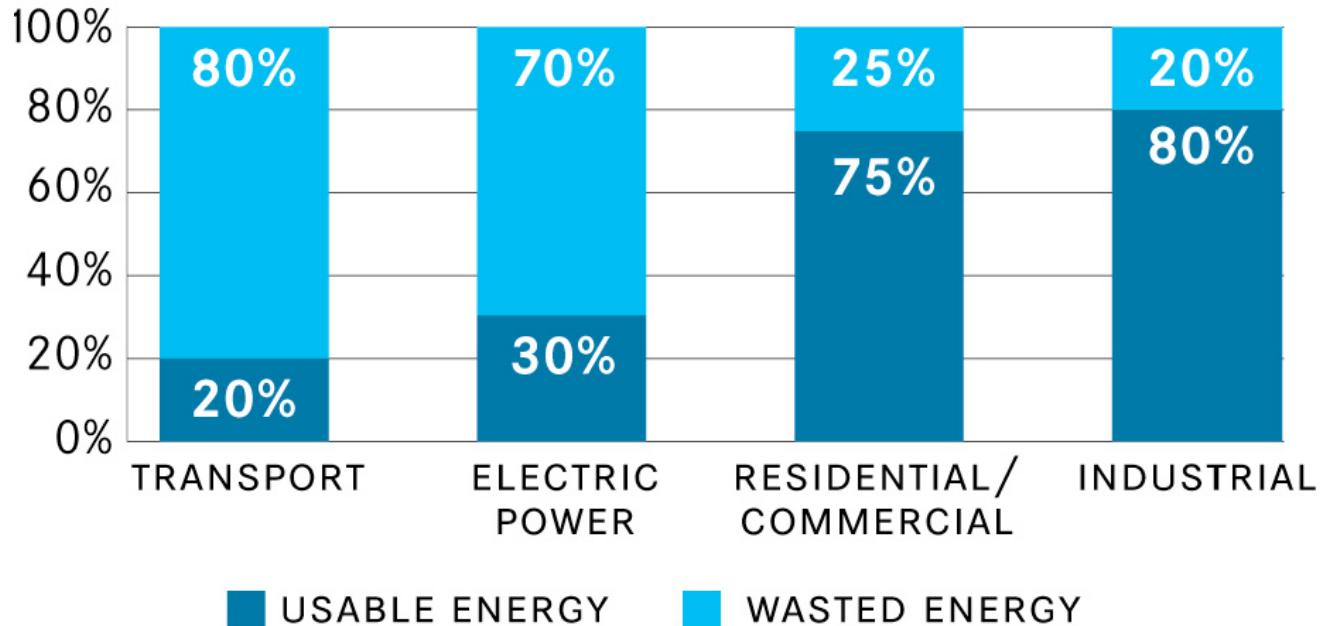
Power Generation Efficiency By Fuel



Comparative Efficiency

U.S. Energy Efficiency By Sector

“More Than 60% Of The Fuel We Use Is Wasted”



SOURCE: [HTTPS://EED.LLNL.GOV/FLOW/00FLOW.PHP](https://eed.llnl.gov/flow/00flow.php)



Comparative Emissions

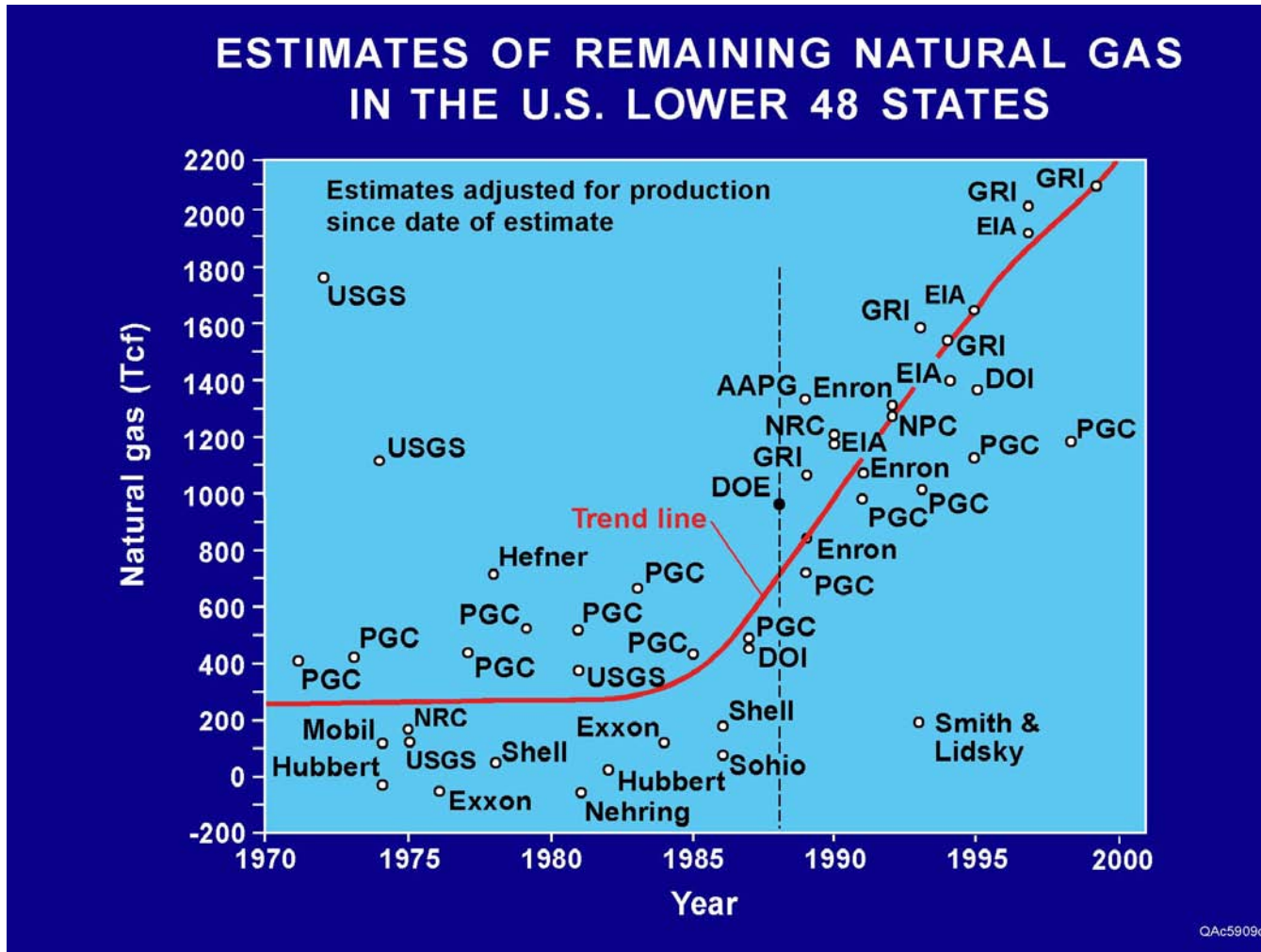
Emission Levels: Natural Gas vs. Oil & Coal

Pounds per Billion Btu of Energy Input

| POLLUTANT | NATURAL GAS | OIL | COAL |
|------------------|--------------------|------------|-------------|
| CARBON DIOXIDE | 117,000 | 164,000 | 208,000 |
| CARBON MONOXIDE | 40 | 33 | 208 |
| NITROGEN OXIDES | 92 | 448 | 457 |
| SULFUR DIOXIDE | 1 | 1,122 | 2,591 |
| PARTICULATES | 7 | 84 | 2,744 |
| MERCURY | 0.000 | 0.007 | 0.016 |

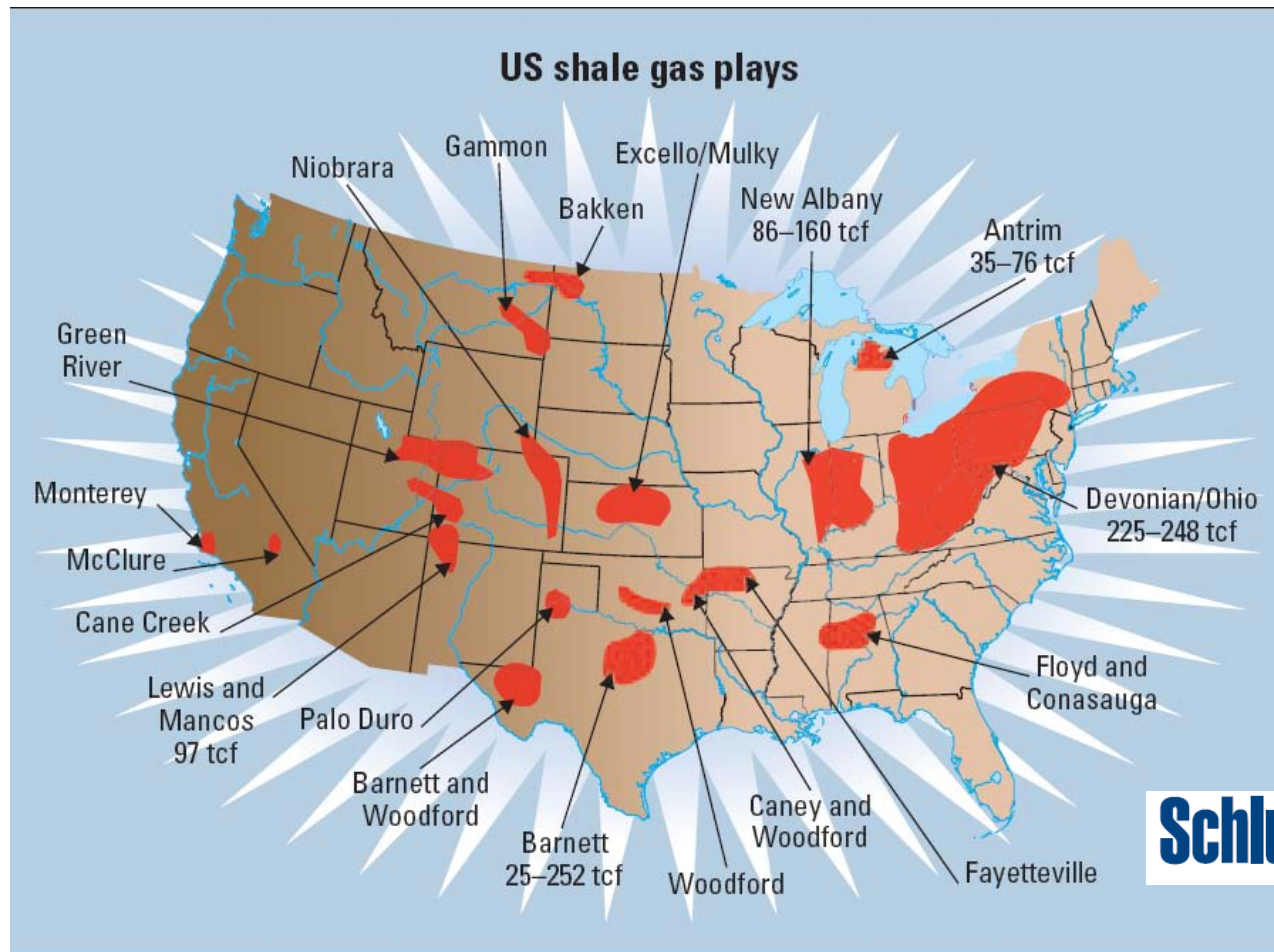
SOURCE: EIA-NATURAL GAS ISSUES AND TRENDS

US Gas Resource Estimates Continue to Increase



William Fisher
COGA 2006

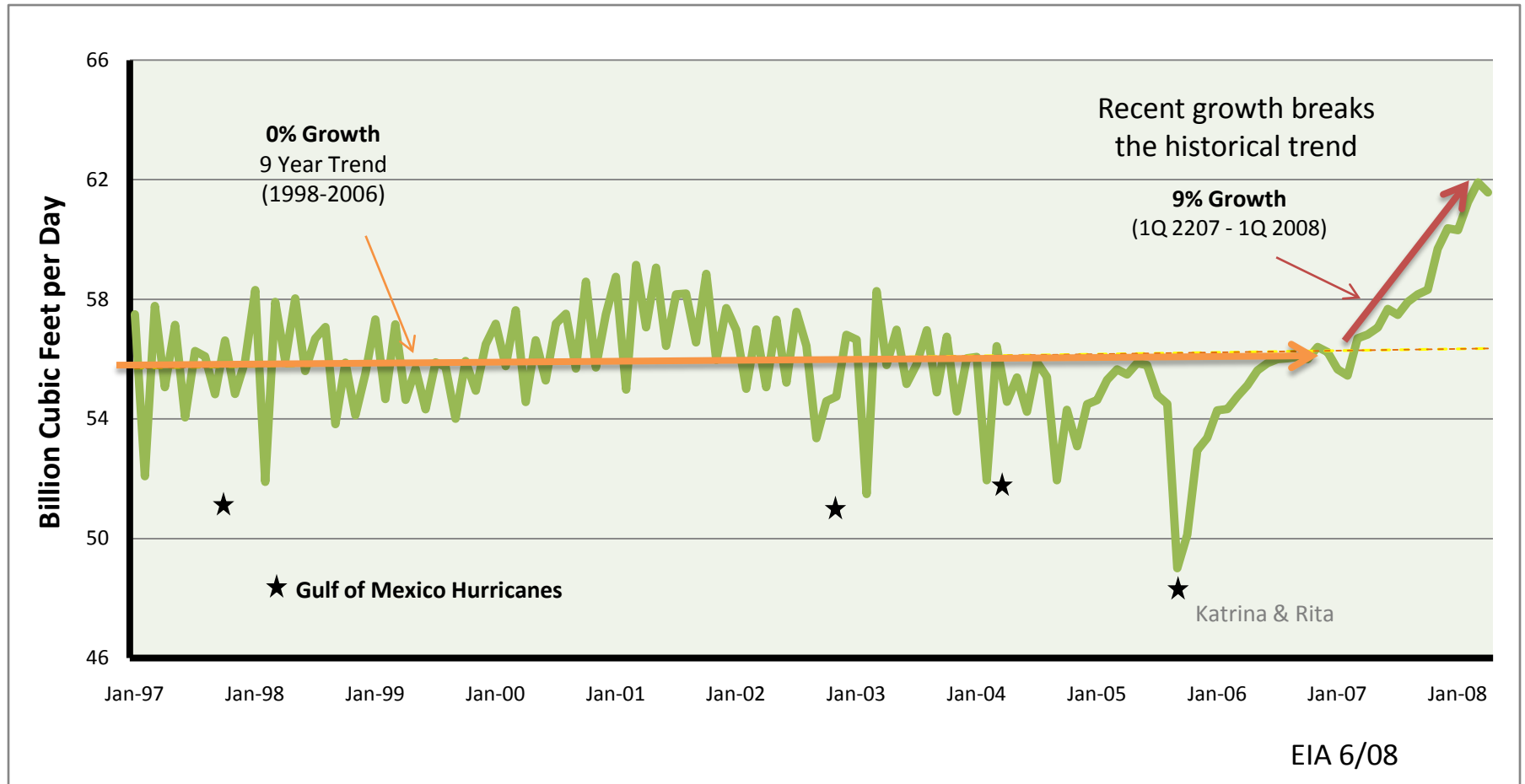
Once only geologic correlation markers, gas shales have redefined the resource base!



Schlumberger

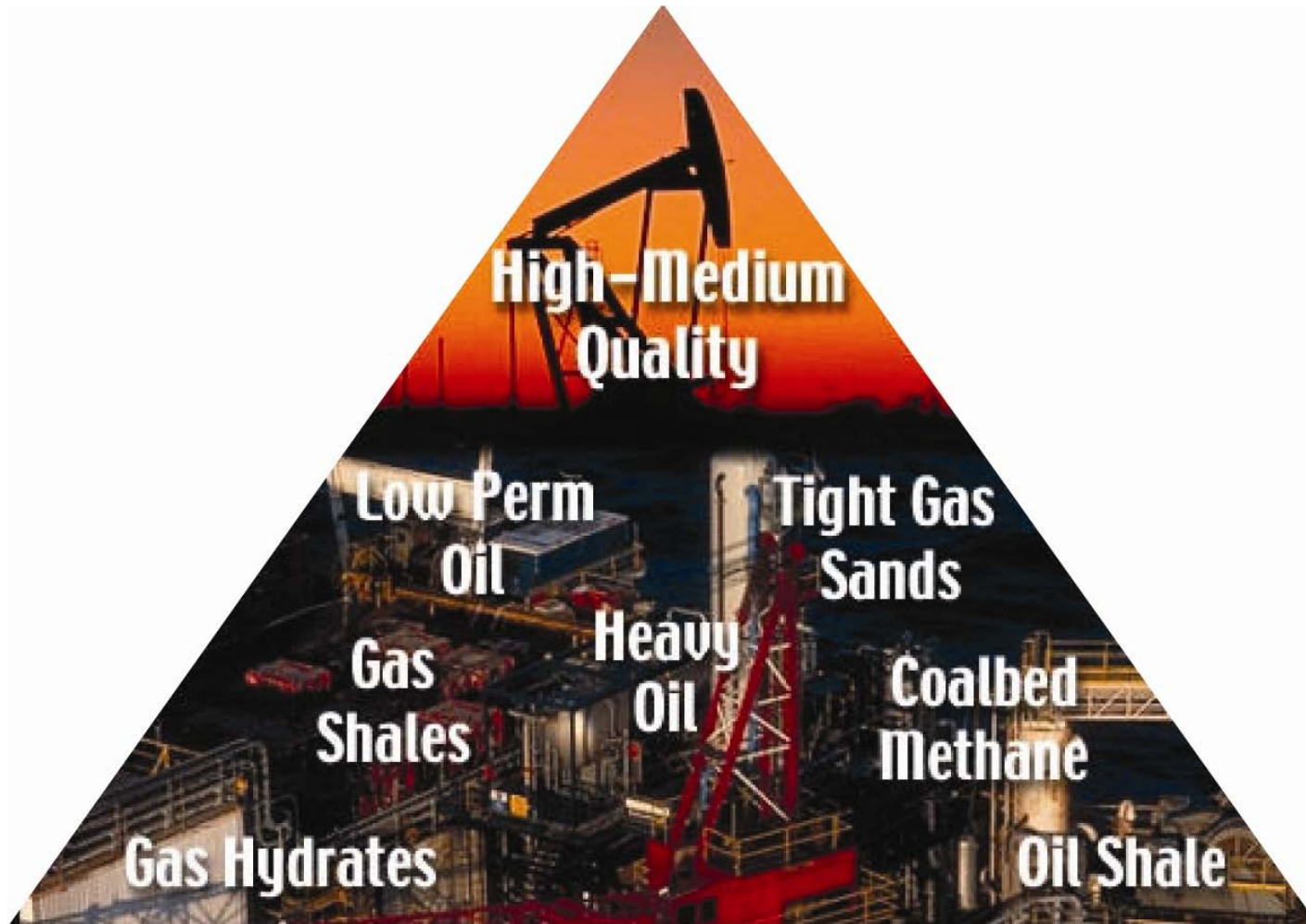


Lower 48 Gas Production is Growing



EIA 6/08

Technology has Driven the Growth

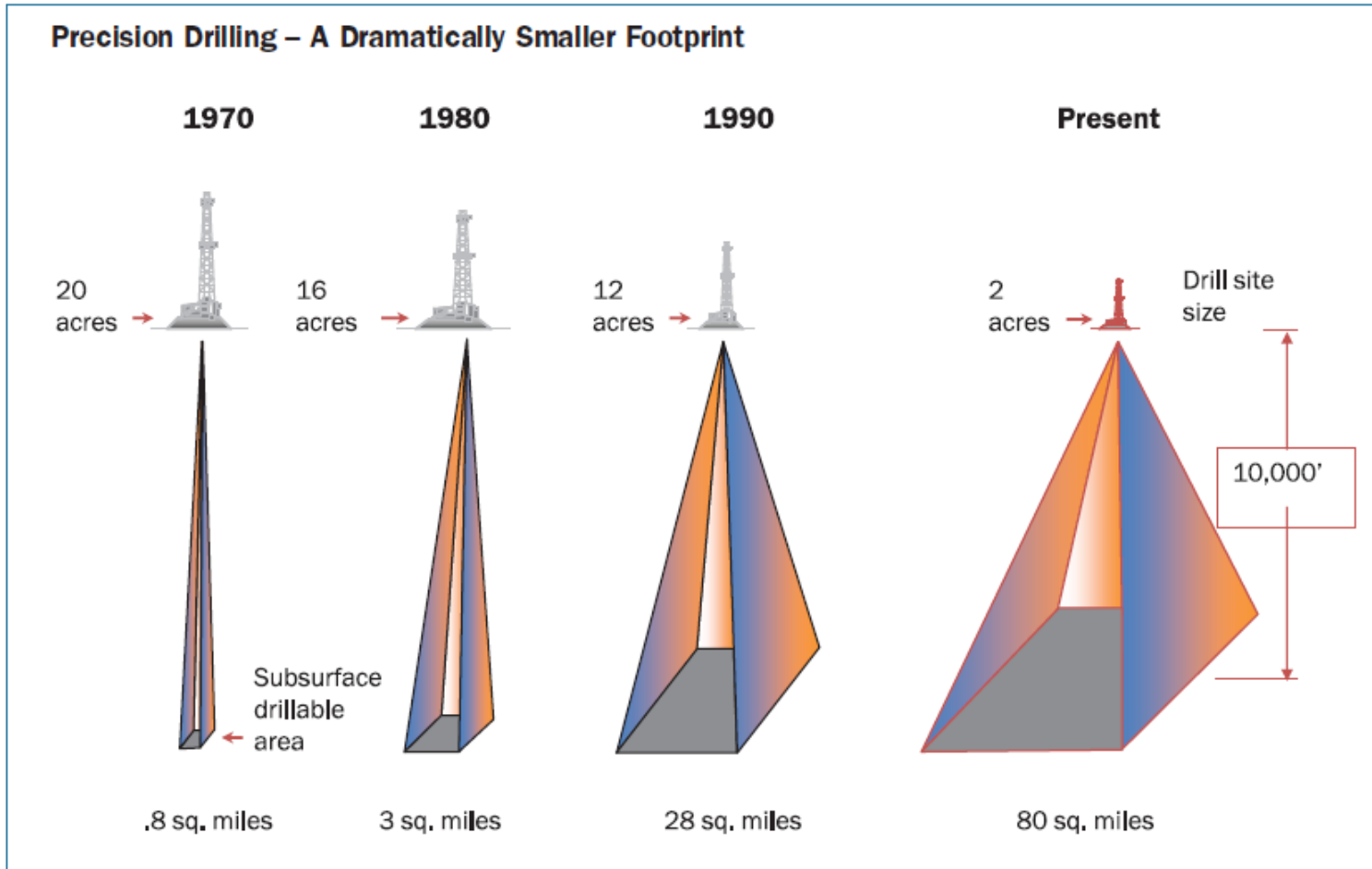


Increased Cost & Risk

Improved Technology

Steve Holditch

Technology improvements in drilling



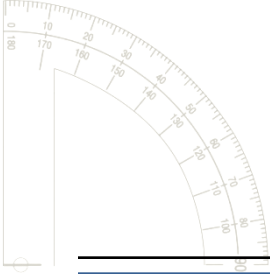


NPC 2007 Global Gas Resources Will Develop with U.S. Technology

*Table T-IX.1. Distribution of Worldwide
Unconventional Natural Gas Resources
(Trillion Cubic Feet)*

| Region | Coalbed Methane | Shale Gas | Tight-Sand Gas | Total |
|-------------------------------------|----------------------------|----------------------|---------------------------|--------------|
| North America | 3,017 | 3,840 | 1,371 | 8,228 |
| Latin America | 39 | 2,116 | 1,293 | 3,448 |
| Western Europe | 157 | 509 | 353 | 1,019 |
| Central and Eastern Europe | 118 | 39 | 78 | 235 |
| Former Soviet Union | 3,957 | 627 | 901 | 5,485 |
| Middle East and North Africa | 0 | 2,547 | 823 | 3,370 |
| Sub-Saharan Africa | 39 | 274 | 784 | 1,097 |
| Centrally Planned Asia and China | 1,215 | 3,526 | 353 | 5,094 |
| Pacific | 470 | 2,312 | 705 | 3,487 |
| Other Asia Pacific | 0 | 313 | 549 | 862 |
| South Asia | 39 | 0 | 196 | 235 |
| World | 9,051 | 16,103 | 7,406 | 32,560 |

Source: Kawata and Fujita 2001 (??)



“Do or do not, there is no try.”

Yoda

