Transformative Technology
Impacting Traditional Energy Systems

C. Michael Ming
Shales Moving Forward
Oklahoma Geological Survey
Norman, Oklahoma
July 21, 2011
Designing An Optimal Energy System

• Begin With Traditional Fuels At Scale
• Determine System Constraints & Establish Objectives
• Maximize Efficiency
• Synergistically Add Renewables
• Make The System Smart, Very Smart
• Simultaneously Continue To Work On Energy Transformations

Integration, Not A Silver Bullet, Is The Key Today
Getting The Bigger Picture: Ball Bearings

It’s All About Optimizing Components
Optimizing Any Component Can Improve The System

Source: Hinrichs/Kleinbach, Energy – Its Use and the Environment
Figure 2.0 Primary Energy Flow by Source and Sector, 2009
(Quadrillion Btu)

Supply Sources

- Petroleum¹ 35.3
  - Percent of Source:
    - Transportation: 72%
    - Industrial: 22%
    - Residential & Commercial: 7%
    - Electric Power: 3%

- Natural Gas² 23.4
  - Percent of Source:
    - Transportation: 22%
    - Industrial: 32%
    - Residential & Commercial: 35%
    - Electric Power: 30%

- Coal³ 19.7
  - Percent of Source:
    - Transportation: 7%
    - Industrial: 93%
    - Residential & Commercial: 1%
    - Electric Power: 7%

- Renewable Energy ⁴ 7.7
  - Percent of Source:
    - Transportation: 12%
    - Industrial: 26%
    - Residential & Commercial: 9%
    - Electric Power: 53%

- Nuclear Electric Power ⁵ 8.3
  - Percent of Source:
    - Transportation: 100%
    - Industrial: 11%
    - Residential & Commercial: 22%
    - Electric Power: 48%

Demand Sectors

- Transportation: 27.0
- Industrial: 18.8
- Residential & Commercial: 10.6
- Electric Power: 38.3

Source: EIA, 2009
U.S. Energy Consumption by Energy Source, 2009

Total = 94.578 Quadrillion Btu

- Petroleum: 37%
- Natural Gas: 25%
- Coal: 21%
- Nuclear Electric Power: 9%
- Renewable Energy: 8%

Hydropower: 35%
Biofuels: 20%
Wind: 9%
Geothermal: 5%
Biomass waste: 6%
Solar: 1%

Note: Sum of components may not equal 100% due to independent rounding.
Exceeding Expectations

PHOTOGRAPH BY JEFF RIEDEL FOR TIME
The U.S. Gas Shale Ramp

- The Barnett grew 3000% from 1998 to 2007
- The Eagle Ford, Fayetteville, Haynesville, Marcellus, and Woodford will dwarf this
- Technology improvements in horizontal drilling and fracturing have economically enabled vast new unconventional and conventional resources.

Source: Smead, Navigant Consulting, June 2009; MIT, The Future of Natural Gas 2010
Natural Gas Demand

Resilience in gas use across sectors

Potential major growth areas:

Electricity
- Natural gas substitution for coal
- Intermittent sources/variability & uncertainty

Transportation
- Long term potential for CNG
- LNG not currently attractive

Source: MIT, The Future of Natural Gas 2010
Natural Gas, A 60-year Bridge (At Least)

Figure 3.9 Energy Mix in Electric Generation under a Price-Based Climate Policy, Mean Natural Gas Resources and Regional Natural Gas Markets (TkWh)

Source: MIT, The Future of Natural Gas 2010
Technology Has Driven The Growth

Source: Steve Holditch
Source: Worldwatch Institute, EIA
Designing Smarter, Flexible & Efficient Solutions
Natural Gas is the Least Cost Option for New Power Generation

Source: EIA Annual Energy Outlook 2009, EnCana
Comparative Efficiency By Sector

U.S. Energy Efficiency By Sector

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

Source: https://EED.LLN.L.GOV/FLOW/00FLOW.PHP
Efficiency Must Start At The Point Of Conversion

Source: EIA, 2007; GE Energy, 2009
An Optimal Energy System Lowers Emissions

At minimum a 60% reduction in CO₂ intensity, not even accounting for other potential efficiencies!

Source: American Clean Skies Foundation; EIA
New Supplies Are Fueling New Demands
The Resurgence Of US Oil?

Figure 3. Weekly rig counts and oil-to-gas ratios

Source: EIA, 2011
The Catalyst: Unconventional Gas Technology

Figure 2. Oil production from shale formations (thousand barrels per day)

Source: EIA, 2011
Reversing The Trend

Figure 1. U.S. oil production
million barrels per day (includes crude oil and lease condensate)

Source: U.S. Energy Information Administration

Source: EIA, 2011
Exponential Growth Of The U.S. Wind Industry

Source: EIA 2009
In CO & Elsewhere The Wind Blows Most Intensely At Night

Wind Blows Strongest Between 9:00 pm & 5:00 am, When Demand Is Weakest

Source: Bentek; Wind data - NREL WWIS 2006, PSCO load 2008 FERC 714
Making The System Smarter: Smart Everything

Source: The Smart Grid: An Introduction, DOE 2008
Transformative Technologies

- Hydrogen Economy (Emission Free)
- Nuclear Fusion (No Waste)
- Mobile Fuel Cells (Reusable)
- Advanced Generation Biofuels (Renewable)
- Utilizing CO2 For Fuels (CO2 Capture)
“You miss 100% of the shots you don’t take.”

Wayne Gretzky

michael.ming@doe.ok.gov