Environmental Costs of Energy and the Basics on Shale Development in America

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Introductory Thoughts

- Understanding Environmental Costs of Energy
- Energy in America
- Example ECOE Analysis
- Shale Resource Basics
- Concluding Remarks
Apples-to-Apples
The Environmental Cost of Energy
“Environmental Cost” as presented herein is a euphemism for **Impact**

Impacts are a change – the physical demonstration of the effect of energy production or use on the environment

The public often associates impacts as negative. However, not all are, and this should not mean that energy use has an overall detrimental impact on society.

*Quite the opposite: the advantages to civilization of energy systems are vast.*

Hydroelectric impoundments may alter river ecosystems, but they also provide new recreational opportunities. Glen Canyon Dam, Lake Powell, AZ.
Clockwise from top to left

1. Wind farm in San Gorgonio Pass, CA (3,218 turbines – 615 MW installed capacity, ~70 sq. miles)
2. BP oil spill, Gulf of Mexico (4.9 Mbbl spilled, ~ 8.33 MWh lost)
3. Sempra Energy Solar Farm, El Dorado, NV (10 MW installed capacity on 80 acres)
4. Mountaintop removal coal mine in southern WV (~625 – 1,000 acres)
5. Nuclear Reactor (Three-mile Island) (802 MW installed capacity, ~225 acres)
Facts About Environmental Costs

- All energy resources have associated impacts (either direct or indirect)
- Each requires materials, manufacturing and construction
- Most require land for facilities
- Energy resources tend to have regional density variations & characteristics
Regional Energy Characteristics

- Coal Areas
- Oil and Gas Reservoirs
- U.S. Geothermal Resource Map
- Agricultural Production
- Solar Potential
- United States Wind Class and Turbine Generation Capacity by County
Concerns regarding energy sources and energy use are high!
Public concerns exist for every energy source and every method of power generation.
Scientifically sound information that crosses all energy/power sources is scarce (virtually non-existent).
Decisions on our energy future are being made without understanding environmental costs across energy resources/types.
Energy in America

The Environmental Cost of Energy
Energy Sources and Types

Renewables

- Biomass Fuels
- Solar Thermal
- Wind, Hydro
- Geothermal
- Photo-voltaics

Non-renewables

- Fossil Fuels
  - Gas
  - Oil
  - Coal
- Nuclear Fuels
  - Fission
- Chemistry
- Nuclear

Types

End Uses:
- Transportation
- Residential & Commercial
- Industrial
- Electricity

Some Sources are Primarily Suited for Certain Uses
- Nuclear – Electric
- Coal – Electric
- Petroleum – Transportation

Some Sources are More Versatile
- Renewables
- Natural Gas

Source: Adapted from Energy Information Administration, Annual Energy Review 2008, June 2009, Table 1.3 and Figure 2.0.
Current Energy Use

- Fossil fuels supply 84% of current energy use
- Renewables supply about 7%
- Wind, geothermal, and solar supply less than 1%
- In 2008 the United States consumed over 99.2 quadrillion Btu’s of energy.

Energy Use by Source

**Future Energy Use Projections**

- United States energy consumption is expected to grow 21% by 2035
- Much of the increased demand will be for the transportation and industrial sectors – which affects the energy sources that can meet that demand
- Highlights the need to be able to make well-informed decisions in order to meet the energy and environmental challenges of the future

*Projection of Energy Consumption by Sector, 1980 – 2035 (quadrillion Btu)*

*U.S. primary energy consumption, 1980-2035 (quadrillion Btu)*

Energy is Critical to the Economy

- U.S. Economy is dependent upon secure, abundant, reliable, and affordable energy
- Natural gas is a key component of the U.S. energy supply
  - Provides 24% of U.S. energy needs
  - Has significant expansion potential

Advantages of Natural Gas

- **Clean burning**
  - About 50% less CO$_2$ than coal
  - About 30% less CO$_2$ than oil

- **Secure**
  - 88% of our natural gas is produced in the U.S.
  - Imports come from Canada and Mexico

- **Versatile**
  - Heating
  - Electricity
  - Transportation
Sample ECOE Analyses

- Water Intensity
- Surface Disturbances
- Visual Impacts
- Air Emissions
Raw fuel water intensity is the amount of water needed to extract, mine, or grow materials that are processed and later used for electrical generation or transportation fuels.

Not all energy sources have raw fuel (e.g., wind, solar, geothermal, hydroelectric)

Natural gas and coal have the lowest water intensity of any raw fuels.

Corn ethanol and biodiesel have the highest water intensity.

Surface Disturbance Considerations

- Includes the acreage disturbed in the course of acquiring the fuel (e.g., mine, well, crop field, etc.) as well as the surface disturbance required for fuel processing and/or for electrical generation.

- Surface Disturbance have different temporal impacts:
  - Some surface disturbances are short term (e.g., pipeline installation).
  - Some disturbances are essentially permanent.
  - Some disturbances “move” over longer periods of time e.g. surface mines with continuous reclamation.
Panther Creek Wind Farm
(305 Turbines, 457.5 MW Installed Capacity)

Howard Glasscock Oil Field
(Production initiated in 1925, current average production per well is 30 bbl/day/well or ~ 15,555 MW equivalence)
- Biodiesel from soy has the highest surface disturbance/1,000 MW
- Solar surface disturbance is 10 X higher than for geothermal, oil, natural gas, surface mined coal and wind.
- Nuclear has the lowest surface disturbance/1,000 MW

The spatial dimension of energy development equals the sum total number of acres disturbed by the fuel harvesting, the fuel processing, and the electrical generation to arrive at the total acreage disturbed for the generation of 1,000 MW per hour annually.
Visual impacts can be highly subjective
CO₂ EMISSIONS – ELECTRICAL GENERATION

• Wood/Biomass fired generation emits the most CO₂/MW generated, but accounts for less than 4% of US electricity

• Coal emits about twice as much CO₂/MW as natural gas and 25% more than oil

All comparisons are for “Light Duty Vehicles” as expressed in Pounds of emissions per 1,000 miles traveled.

- Gasoline emits the most GHGs (in CO$_2$ equivalents)
- CNG emits the least GHGs

Source: Board on Environmental Studies and Toxicology, Board on Energy and Environmental Systems, and Board on Science, Technology, and Economic Policy, Hidden Costs of Energy.
Shale O&G holds tremendous potential for energy supply.

Environmental considerations, especially those related to high volume hydraulic fracturing (HVHF), have generated spirited debate.

The environmental considerations for shale gas should not be viewed in isolation.

In order to make sound energy decisions for the future, we must make apples-to-apples comparisons of the various energy sources available.
Shale Gas History

- First Commercial Gas well – Fredonia, NY (1821)
  - New York’s “Dunkirk Shale” at a depth of less than 30 feet
- Ohio Shale – Big Sandy Field (1880)
- Antrim Shale commercially produced (1930s)
- Hydraulic Fracturing used in the Oil & Gas Industry (1950-60s)
- Horizontal wells in Ohio Shales (1980s)
# Shale Gas Play Characteristics

<table>
<thead>
<tr>
<th>Gas Shale Basin</th>
<th>Barnett</th>
<th>Fayetteville</th>
<th>Haynesville</th>
<th>Marcellus</th>
<th>Woodford</th>
<th>Antrim</th>
<th>New Albany</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimated Basin Area, square miles</td>
<td>5,000</td>
<td>9,000</td>
<td>9,000</td>
<td>95,000</td>
<td>11,000</td>
<td>12,000</td>
<td>43,500</td>
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<tr>
<td>Depth, ft</td>
<td>6,500 - 8,500</td>
<td>1,000 - 7,000</td>
<td>10,500 - 13,500</td>
<td>4,000 - 8,500</td>
<td>6,000 - 11,000</td>
<td>600 - 2,200</td>
<td>500 - 2,000</td>
</tr>
<tr>
<td>Net Thickness, ft</td>
<td>100 - 600</td>
<td>20 - 200</td>
<td>200 - 300</td>
<td>50 - 200</td>
<td>120 - 220</td>
<td>70 - 12</td>
<td>50 - 100</td>
</tr>
<tr>
<td>Depth to Base of Treatable Water, ft</td>
<td>~1200</td>
<td>~500</td>
<td>~400</td>
<td>~850</td>
<td>~400</td>
<td>~300</td>
<td>~400</td>
</tr>
<tr>
<td>Rock Column Thickness between Top of Pay and Bottom of Treatable Water</td>
<td>5,300 - 7,300</td>
<td>500 - 6,500</td>
<td>10,100 - 13,100</td>
<td>2,125 - 7,650</td>
<td>5,600 - 10,600</td>
<td>300 - 1,900</td>
<td>100 - 1,600</td>
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<tr>
<td>Total Organic Carbon, %</td>
<td>4.5</td>
<td>4.0 - 9.8</td>
<td>0.5 - 4.0</td>
<td>3 - 12</td>
<td>1 - 14</td>
<td>1 - 20</td>
<td>1 - 25</td>
</tr>
<tr>
<td>Total Porosity, %</td>
<td>4 - 5</td>
<td>2 - 8</td>
<td>8 - 9</td>
<td>10</td>
<td>3 - 9</td>
<td>9</td>
<td>10 - 14</td>
</tr>
<tr>
<td>Gas Content, scf/ton</td>
<td>300 - 350</td>
<td>60 - 220</td>
<td>100 - 330</td>
<td>60 - 100</td>
<td>200 - 300</td>
<td>40 - 100</td>
<td>40 - 80</td>
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<tr>
<td>Water Production, Barrels water/day</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>5 - 500</td>
<td>5 - 500</td>
</tr>
<tr>
<td>Well spacing, Acres</td>
<td>60 - 160</td>
<td>80 - 160</td>
<td>40 - 560</td>
<td>40 - 160</td>
<td>640</td>
<td>40 - 160</td>
<td>80</td>
</tr>
<tr>
<td>Original Gas-In-Place, Tcf</td>
<td>327</td>
<td>52</td>
<td>717</td>
<td>1,500</td>
<td>52</td>
<td>76</td>
<td>160</td>
</tr>
<tr>
<td>Reserves, Tcf</td>
<td>44</td>
<td>41.6</td>
<td>251</td>
<td>262 - 500</td>
<td>11.4</td>
<td>20</td>
<td>19.2</td>
</tr>
</tbody>
</table>
Two technologies have made shale gas economically viable:

- **Horizontal Drilling**
  - Allows greater contact with the “pay zone”
  - Reduces the number of wells that must be drilled

- **High Volume Hydraulic Fracturing (HVHF)**
  - Allows gas to flow to the well in tight formations
ENVIRONMENTAL CONSIDERATIONS

- New Development Areas/Urban
- Well Site Selection
- Traffic
- Wildlife
- Noise
- NORM
- Air Emissions
- Hydraulic Fracturing
- Water Sourcing/Management

Mark Raffalo & Pete Seeger address lawmakers at NYS capital regarding moratorium, July 2010

NY EPA Scoping Meeting 9/13/10

Quebec protester “Shale gas a moratorium now” 8/30/10
Fear and lack of knowledge creates trepidation among mineral and non-mineral owners.

Education of public takes time.

Lack of infrastructure.

Misinformation abounds.
Urban Development...

- Scrutiny and greater concern because of proximity to populous
- Local government ordinances:
  - Restrict operation times
  - Reduced noise levels
  - Lighting restrictions
  - New setbacks
  - Restrict truck traffic
Noise blankets and barriers are often used for noise mitigation in sensitive areas.
Lighting...

- Directional lighting has become common.
- Illuminates well sites for worker safety.
- Directed downward and shielded to prevent illumination of residences, public roads, and buildings.
Options vary by location and operator

Competing water users and availability must be considered

Groundwater Use in Barnett shale counties ranges from 1.95 percent in to 85 percent, depending on the specific area
HVHF Environmental Issues

- Groundwater protection
- Fracturing fluid chemistry
- Water sourcing
- Water disposal and reuse
Examples
Pre-Fracturing Evaluations

- Geology & lithology
- Coring and core analysis
- Geophysical logging
- 3D Seismic
- Correlation Analysis
- Fracture gradient analysis
- Etc.
HVHF Operations

- Fracturing a horizontal well uses 3 to 7 million gallons of water
  - Delivered by truck or temporary pipeline
  - Stored in tanks, or local or centralized impoundments
- Fracturing job takes a few days
- Typically 10% to 30% of the fracture fluid is recovered in the first few weeks (flowback)
- Produced water may continue long term.
Monitoring Approaches

• During a fracturing event, each stage is continuously monitored to assure a successful fracture treatment. Some of the items monitored include:
  – Pressures at the Wellhead, Bottom Hole, in Flow lines
  – Slurry properties such as viscosity and density
  – Injection Rate Volumes
  – Additives in fracture fluids

• These properties are measured by:
  – Computer Sensors
  – Inline Meters
  – People (an injection job may have as many as 45 people onsite)
Disclosure becoming a non-issue with FracFocus and agency disclosure rules

There is a growing trend toward reduction in the number of chemicals used

There is a push to develop “Green” chemicals
**WATER DISPOSAL**

- Underground Injection
- Treatment and Discharge
- Treatment and Reuse
- Municipal/Commercial Treatment Plants
- Commercial Disposal Facilities
Closing

Value of Using an ECOE Approach

Key Messages on Shales

Technical Recommendations on Shale Development
Environmental Cost of Energy (ECOE)

- All energy sources have environmental costs
- Sound decisions about our energy future require that the environmental costs of all energy options be compared on an equal basis – “apples-to-apples”
- Energy decisions will require trade-offs
  - e.g., one source may have lower air emissions than another, but may have higher water demands – both must be considered
Typical analyses tend to focus on:
- Only one energy source, such as coal, natural gas, wind, or solar, or
- Only one environmental aspect such as water use, air emissions, or surface disturbance

Many analyses do not consider practical limitations of different sources
- e.g., wind and solar are not effective in all areas, and have seasonal or daily peaks that require some sort of back-up capacity
The Advantages of ECOE

- Can serve as the basis for objective evaluation of different energy sources
- Can help us get past emotion-laden rhetoric and allow reasoned discussion of the trade-offs involved.
- Can help us make smart decisions that will ensure abundant, reliable, and affordable energy supplies that also protect the environment.
Key Messages on Shales

- Shale O&G Resources are widespread in North America
- A game changing national resource
- Shale play development growing rapidly
- Potential environmental impacts viewed as concern by the public and E-NGOs
- Opportunity for leadership by the USA!
- The rest of the world is watching...
Technical Recommendations for Shale Development

- Pre-site assessments and planning are imperative for success!
- Developing baseline information is critical
- The process of completing a well must include similar levels of detail and planning for the shallow portion of the well as for the production zone.
- Incorporate environmental considerations into planning at the well and regional levels.
- Don’t ignore or downplay environmental issues – they are key to successful development!
Looking at the environmental considerations associated with only shale gas development doesn’t really tell us much

We need energy and we need to protect the environment

If we are going to eliminate shale gas, what will we use to replace that energy?

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- Only one environmental aspect such as water use, air emissions, or surface disturbance

Natural Gas (particularly gas from shales) carries a desirable environmental footprint, is abundant, and has the ability to very positively change the economy and our reliance on foreign energy sources.
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