The Shape of Things to Come: Incorporating Unproven Reserves of Efficiency Savings into Energy Models

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1. Marginal costs influence behavior
2. The shape of CSE curves matters
3. Unproven efficiency reserves are typically ignored
4. Unproven oil and gas reserves are not ignored
5. Research is needed to characterize technological change and unproven efficiency reserves
Regional Clean Energy Plans

These reports are available on the web:

www.repowermidwest.org
www.poweringthesouth.org
www.westernresourceadvocates.org/energy/bep.html
Xenergy, Generic curve

Generic Illustration of Energy-Efficiency Supply Curve

- Low Cost - High Potential
- Mid Cost - Mid Potential
- High Cost - Low to Mid Potential

Each point represents an individual measure in a particular application.
CSE Curve Data

- Xenergy, Generic curve
- Solar Energy Research Institute, 1981, US
- Tellus, 2002, Pacific NW
- American Council For an Energy-Efficient Economy, 1989, New York State (4)
- Marbek Resource Consultants and Willis Energy Services, 2003, British Columbia (2)
- LBL, 1999, US
- SERI, 1981, US
CSE Curve Data

- LBL, 1995, US
- Amory Lovins, 1989, US
- Optimal, 2003, New York State
- Xenergy, 2002, California
- Hewlett Energy Foundation, 2002, California
- Northwest Power and Conservation Council, 2002, Pacific NW
- Tellus, 2001, Interior West
- Tellus, 2001, Pacific NW
- Tellus, 2001, Utah
- NYSERDA, 2003, New York State (2)
Solar Energy Research Institute, 1981, US

- Average Cost of Electricity = 5.7¢/kWh

Cost of Conserved Energy (¢/kWh)

- Improved Dishwashers
- Improved Lighting
- Electric Dryers
- Room AC’s, ‘91-2000
- Manual/Partial Refrigerators, ‘91-2000
- Frost-Free Refrigerators, ‘91-2000
- Freezers, ‘81-‘90
- Frost-Free Freezers, ‘91-2000

Savings TWh/Year
- Year 2000 Annual Savings, at or below (1980) Average Cost > 221 TWh/Year.

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Figure 3.6 Electricity Supply Curve By End-Use for Buildings in 2010, High-Efficiency/Low-Carbon Case

2010 Buildings Sector Electricity Price - 7.4 cents/kWh

- Discount Rate: 7%
- Forecast Year: 2010
- Start Year: 1997
- Baseline Electricity Consumption for year 2010 = 2453 TWh

Cost of Conserved Electricity vs. Savings in 2010 (TWh)

16% of Baseline Use
American Council For an Energy-Efficient Economy, 1989, New York State
American Council For an Energy-Efficient Economy, 1989, New York State
American Council For an Energy-Efficient Economy, 1989, New York State

ELECTRICITY CONSERVATION SUPPLY CURVE
New York State - 6% Discount Rate

Cumulative electricity savings (GWh/yr)

$/kWh

0.15
0.125
0.1
0.075
0.05
0.025
0
Marbek Resource Consultants and Willis Energy Services, 2003, British Columbia

Exhibit 6.13: Supply Curve of Industrial Sector Actions—Cumulative Electricity Savings in the Milestone Year of 2015/16 for Upper Scenario, (GWh/yr.)
Exhibit 6.12: Supply Curve of Industrial Sector Actions—Cumulative Electricity Savings in the Milestone Year of 2015/16 for Most Likely Scenario, (GWh/yr.)

British Columbia

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United States

18% of primary energy use for total U.S. steel production in 1994

1994 weighted average price of fuel ($2.14/GJ)

Cost of Conserved Energy
Discount Rate = 30%

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SERI, 1981, US

[Graph showing cost of commercial energy vs. savings (TWh/Year)]

Average Cost of Electricity = 5.7¢/kWh

- Improved Dishwashers
- Improved Lighting
- Electric Dryers, 91-2000
- Room ACs, 91-2000

Year 2000 Annual Savings at or below 1990 Average Cost > 221 TWh/Year

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Total Cost of Saved Energy = 3.2 $/kWh
Utility Spending = $380 Million
Annual Energy Saved = 2,360 GWh/yr

Source: Eto et al. 1995
Figure 4

A Preliminary Estimate of the Full Practical Potential for Retrofit Savings of US Electricity at an Average Cost of about 0.64¢ per kW-hr

Note: The shaded areas are equal; thus net cost is zero.
Optimal, 2003, New York State

2012 Greenhouse Gas Target Supply Curve
Low Avoided Costs

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Figure 3-4
Energy-Efficiency Supply Curve—Potential in 2011

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Measures with Conservation Load Factors Greater than 50%
Reduced Sales during Baseload Time Block

Combined Cycle Baseload Turbine - $0.80/cent/kwh

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Northwest Power and Conservation Council, 2002, Pacific NW

Achievable Conservation in 2025 by Sector and Levelized Cost

Figure 3-2: Achievable Conservation in 2025 by Sector and Levelized Cost
Tellus, 2001, Interior West

Cost of Saved Energy vs. Lifetime GWh Savings for Measures Included in Interior West DSM Study

Real Levelized $/kWh Saved

GWh Lifetime Savings
Tellus, 2001, Pacific NW

Cost of Saved Energy vs. Lifetime GWh Savings for Measures Included in Pacific Northwest DSM Study
Tellus, 2001, Utah

Cost of Saved Energy vs. Lifetime GWh Savings for Measures Included in Utah DSM Study

Real Levelized \$/kWh Saver

GWh Lifetime Savings
Figure 1.10  Greenhouse Gas Target Supply Curve (2012, Low Avoided Costs)

Levelized energy avoided cost, $0.027/kWh

2012 Greenhouse Gas Target, 19,939 GWh
Figure 1.11  Greenhouse Gas Target Supply Curve (2022 Low Avoided Costs)

2022 Greenhouse Gas Target, 27,244 GWh

Levelized energy avoided cost, $0.029/kWh

GWh

Net $/kWh

$0.40

$0.35

$0.30

$0.25

$0.20

$0.15

$0.10

$0.05

$0.00

-0.05

-0.10

-10,000

-20,000

-30,000

-40,000

-50,000

-60,000

-70,000

-80,000
Source: Energy Information Administration, Office of Oil and Gas.
<table>
<thead>
<tr>
<th>Method</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volumetric</td>
<td>Applies to crude oil and natural gas reservoirs. Based on raw engineering and geologic data.</td>
</tr>
<tr>
<td>Material Balance</td>
<td>Applies to crude oil and natural gas reservoirs. Is used in estimating reserves. Usually of more value in predicting reserves, and reservoir performance.</td>
</tr>
<tr>
<td>Pressure Decline</td>
<td>Applies to nonassociated and associated gas reservoirs. The method is a special case of material balance equation in the absence of water influx.</td>
</tr>
<tr>
<td>Production Decline</td>
<td>Applies to crude oil and natural gas reservoirs during production decline (usually in the later stages of reservoir life).</td>
</tr>
<tr>
<td>Reservoir Simulation</td>
<td>Applies to crude oil and natural gas reservoirs. Is used in estimating reserves. Usually of more value in predicting reservoir performance. Accuracy increases when matched with past pressure and production data.</td>
</tr>
<tr>
<td>Nominal</td>
<td>Applied to crude oil and natural gas reservoirs. Based on rule of thumb or analogy with another reservoir or reservoirs believed to be similar; least accurate of methods used.</td>
</tr>
</tbody>
</table>
Hydrocarbon Resource Classification

Figure 3.7: Hydrocarbon-Resource Classification

- **Total petroleum initially in place**
  - Undiscovered petroleum initially in place
  - Discovered petroleum initially in place

- **Commercial**
  - Production
    - Proved (1P)
    - Proved + Probable (2P)
    - Proved + Probable + Possible (3P)

- **Sub-commercial**
  - Contingent Resources
    - Low estimate
    - Best estimate
    - High estimate
  - Unrecoverable

- **Increasing degree of geologic assurance and economic feasibility**

## US Oil and Gas (as of 1/1/2002)

<table>
<thead>
<tr>
<th></th>
<th>Crude Oil (billion barrels)</th>
<th>Natural Gas (trillion cubic feet)</th>
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<tbody>
<tr>
<td>Undiscovered</td>
<td>56</td>
<td>222</td>
</tr>
<tr>
<td>Inferred</td>
<td>49</td>
<td>232</td>
</tr>
<tr>
<td>Unconventional and assoc. gas</td>
<td>NA</td>
<td>611</td>
</tr>
<tr>
<td>Total lower 48 unproved</td>
<td>105</td>
<td>1064</td>
</tr>
<tr>
<td>Alaska</td>
<td>24</td>
<td>32</td>
</tr>
<tr>
<td>Total unproved</td>
<td>130</td>
<td>1096</td>
</tr>
<tr>
<td>Proven reserves</td>
<td>24</td>
<td>183</td>
</tr>
<tr>
<td>Total technically recoverable</td>
<td>154</td>
<td>1279</td>
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## Oil and Gas Math

<table>
<thead>
<tr>
<th>Undiscovered</th>
<th>Proven reserves</th>
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</thead>
<tbody>
<tr>
<td>+</td>
<td>Geological and engineering data demonstrate with reasonable certainty to be recoverable from known reservoirs under existing economic and operating conditions</td>
</tr>
<tr>
<td>+ Inferred</td>
<td></td>
</tr>
<tr>
<td>+ Proven reserves</td>
<td></td>
</tr>
<tr>
<td>= Technically recoverable reserves</td>
<td>Producible using current technology but without reference to economic profitability</td>
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IEA Regional Shares

Figure 3.9: Regional Share of Proven Oil Reserves

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Proven Reserves by Region

Figure 3.10: Proven Oil Reserves by Region

Figure 3.11: Ultimately Recoverable Resources of Oil and NGL by Region (mean value)

- Middle East: 33%
- Rest of the world: 18%
- Remaining: 2,628 billion barrels or 79%
- Already produced: 717 billion barrels or 21%
- Transition economies: 14%
- OECD: 14%
- Rest of the world: 5%
- Transition economies: 4%
- Middle East: 5%
- OECD: 7%

World Original Resource Base

Figure 1. Different Interpretations of a Hypothetical 6,000 Billion Barrel World Original Oil-in-Place Resource Base

Source: Energy Information Administration
Annual Production Scenarios

Figure 2. Annual Production Scenarios with 2 Percent Growth Rates and Different Resource Levels (Decline R/P=10)

USGS Estimates of Ultimate Recovery

<table>
<thead>
<tr>
<th>Probability</th>
<th>Ultimate Recovery BBl's</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low (95 %)</td>
<td>2,248</td>
</tr>
<tr>
<td>Mean (expected value)</td>
<td>3,003</td>
</tr>
<tr>
<td>High (5 %)</td>
<td>3,896</td>
</tr>
</tbody>
</table>

Source: Energy Information Administration
Note: U.S. volumes were added to the USGS foreign volumes to obtain world totals.
Ultimately Recoverable Oil

Figure 3.12: Ultimately Recoverable Oil Resources

<table>
<thead>
<tr>
<th>Year</th>
<th>USGS</th>
<th>Other</th>
</tr>
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<tbody>
<tr>
<td>1984</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1987</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1991</td>
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<tr>
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<td></td>
<td></td>
</tr>
<tr>
<td>2000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hiller 1999</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shell 2001</td>
<td></td>
<td></td>
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<tr>
<td>Odell 2004</td>
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</tbody>
</table>

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Generic CSE curve corrected

Generic Illustration of Energy-Efficiency Supply Curve

- Low Cost - High Potential
- Mid Cost - Mid Potential
- High Cost - Low to Mid Potential

Each point represents an individual measure in a particular application.
Research Ideas

• Analysis of CSE curves – past projections v. what actually happened
• Identify reasons for upturn in CSE price
• Characterize reasons and quantify to the extent possible – by technology.
• Apply concepts from oil and gas reserves?