Forecasting and Impacts of our Energy Future

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Materials online at: http://rael.berkeley.edu

NAS/IoM Climate Change and Human Health,
San Francisco, CA September 10, 2007
Efficiency Improvements and New Technology Vitally Needed, Under-Emphasized

Assumes *Significant Advances*:
- Energy intensity
- Nuclear
- Renewables

Gap Technologies:
- Carbon capture and storage
- H₂ novel storage and advanced transportation
- Nano/Bio-technologies
- Next generation solar

The “Gap”
High and low carbon pathways

- Current coastline
- High emissions coastline

Theoretical carbon emissions profiles published in IPCC 3rd Assessment Report

2002 IEA reported fossil emissions plus correction for unsustainable biomass & deforestation.

Thanks to the World Business Council for Sustainable Development

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High and low carbon pathways

Theoretical carbon emissions profiles published in IPCC 3rd Assessment Report

>900 ppm Trajectory
Energy by 2050:
- Coal over 2x, no Carbon Capture & Storage (CCS), some coal to liquids.
- Oil up 50%
- Gas over 2x
- Biofuels make up 10% of vehicle fuel mix.
- Electricity 1/3 of final energy.
- Modest increase in nuclear.
- Renewables provide 1/3 of electricity generation.
- Vehicle efficiency up 50%.

<550 ppm Trajectory
Energy by 2050:
- Coal up 50%, but half of power stations use CCS.
- Oil down 10-15%.
- Gas nearly 2-3x (note: adds volatility)
- Biofuels make up 20% of vehicle fuel mix.
- Green Hydrogen in use
- Strong shift to electricity as final energy (~50% final energy).
- Large increase in nuclear.
- Renewables provide half of electricity generation.
- Vehicle efficiency up 100%
- Sustainable biomass practices

2002 IEA reported fossil emissions plus correction for unsustainable biomass & deforestation.

WRE1000 - we start planning now
WRE 550 - we start acting now
WRE 450 - we started to act in 2000, or …
Global Forecasts, Economics and Energy

Impact $\propto$ Population $\times$ GDP/capita $\times$ carbon/GDP

**Population**
- Billions

**GDP**
- Trillion (2000$)

**Energy Demand**
- MBDOE

<table>
<thead>
<tr>
<th></th>
<th>1950</th>
<th>1990</th>
<th>2030</th>
<th>Average Growth / Yr. 2000 - 2030</th>
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<tbody>
<tr>
<td>OECD</td>
<td></td>
<td></td>
<td></td>
<td>0.4%</td>
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<tr>
<td>Non-OECD</td>
<td></td>
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<td>1.1%</td>
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</thead>
<tbody>
<tr>
<td>GDP</td>
<td></td>
<td></td>
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<td>2.2%</td>
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<tr>
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<tbody>
<tr>
<td>Energy Demand</td>
<td></td>
<td></td>
<td></td>
<td>1.6%</td>
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New Coal by the Decades

<table>
<thead>
<tr>
<th></th>
<th>2003-2010</th>
<th>2011-2020</th>
<th>2021-2030</th>
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<tbody>
<tr>
<td>Other Developing</td>
<td>43</td>
<td>90</td>
<td>128</td>
</tr>
<tr>
<td>India</td>
<td>16</td>
<td>48</td>
<td>79</td>
</tr>
<tr>
<td>China</td>
<td>150</td>
<td>168</td>
<td>226</td>
</tr>
<tr>
<td>Transition</td>
<td>1</td>
<td>11</td>
<td>19</td>
</tr>
<tr>
<td>OECD</td>
<td>12</td>
<td>184</td>
<td>218</td>
</tr>
</tbody>
</table>

Source: IEA, WEO 2004

>$1 trillion in capital
Athabasca basin tar sand mine:  
10% bitumen by weight in the soil.  
~ $30/barrel of energy required to refine
CH₄ → H₂S separation, then H₂ & elemental sulfur separation
We are running out of atmosphere *much* faster than fossil fuels ... at *all* price points.
Global Energy Supply by Fuel

**Fossil Energy**

- **MBDOE Average Growth / Yr. 2000 - 2030**
  - Oil: 1.3%
  - Gas: 1.6%
  - Coal: 1.7%
  - Other: 1.6%

**Other Energy**

- **MBDOE**
  - Biomass / Other: 1.0%
  - Nuclear: 1.4%
  - Hydro/Geo: 2.2%
  - Biofuels: 7.2%
  - Wind & Solar: 20.5%

**Wind, Solar & Biofuels**

- **MBDOE**
  - Biofuels: 7.2%
  - Solar: 8.4%
  - Wind: 12.5%
  - Total: 8.8%
Since 1970, **energy efficiency** has met 77% of new energy service demands in the U.S, while **new energy supplies** have contributed only 23% of new energy service demands.

This could be just the beginning.
Energy Efficiency

Take action with ClimateSmart™ and make your energy use "climate neutral"

Find Over $1800 IN REBATES to Make Your Home Smarter

Smart Home Rebate Booklet

Over $1,800 in potential rebates

Save energy, save money, save the environment.
The Many Values of Efficiency:

$400,000 saved per year with new lights

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Amory Lovins’ Soft Energy Path: 1976

- "hard path" projected by industry and government around 1975
- "soft path" proposed by Lovins in 1976

- primary energy consumption (quadrillion BTU/year)
- actual total consumption reported by USEIA
- oil and gas
- coal
- soft technologies (which do not include big hydro or nuclear)
- nuclear renewables

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Per Capita Electricity Consumption
kWh/person

[Graph showing per capita electricity consumption for different regions over time.]

Savings: Energy, $, carbon

Documented savings larger than imports from the Middle East

Danish average

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Solar Energy for Many Applications

Moscone Center, SF: 675,000 W

Residential Solar: 1000 - 4000 Watts/home

CA Solar Initiative/Million Solar Roofs: 3,000 - 10,000 MW of solar to be built

Kenyan PV market: Average system: 18W

Largest penetration rate of any nation

<table>
<thead>
<tr>
<th></th>
<th>California</th>
<th>Japan</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005 Annual PV Installations</td>
<td>50 MW</td>
<td>290 MW</td>
</tr>
<tr>
<td>Average Cost for Residential System</td>
<td>$8.8/Wac</td>
<td>$7.4/Wac</td>
</tr>
<tr>
<td>Average Cost Reduction from 99-04</td>
<td>5.2%/year</td>
<td>8.9%/year</td>
</tr>
</tbody>
</table>
Actual Growth vs. Historic Forecasts

European Commission
Directorate-Generale for Energy
Photovoltaics in 2010

Made in 1994
Projected 26.6 MWp
too low (21%) for 1997

Actual
market
development
Japanese “Sunshine” Program
Roll on PV cells.

Solar photovoltaic installations of thin film cells, in Germany
Ethanol Can Contribute to Energy and Environmental Goals

Alexander E. Farrell, Richard J. Plevin, Brian T. Turner, Andrew D. Jones, Michael O’Hare, Daniel M. Kammen

Open access, online, biofuel calculator tools: http://rael.berkeley.edu/ebamm

ERG Biofuel Analysis Meta-Model (EBAMM) - Mozilla Firefox

The ERG Biofuel Analysis Meta-Model (EBAMM) was developed by students and faculty of the Energy and Resources Group and Richard & Rhoda Goldman School of Public Policy at UC Berkeley to review the current state of biofuel energy analyses.

The paper was published in Science on January 27, 2006 and is available here. Use the links below to download the paper, the spreadsheet model, and the supplemental materials.

- Download the paper (175 KB)
- Download the model (595 KB)
  Contains energy and greenhouse gas (GHG) analyses of all papers reviewed, plus summary sheets facilitating comparison between studies.
  Requires Microsoft Excel or work-alike.
- Download the Supplemental Online Materials (361 KB)
  Contains detailed model descriptions and a summary of errors and omissions found in the studies reviewed.
  Requires PDF file viewer.
- Download a zipped archive (1.1 MB)
  Contains both the model and the supplemental materials.
An Alternative Fuel is Not Necessarily a Low-Carbon Fuel, but it can be
Low Carbon Fuel developments worldwide

- **Renewable Fuel Standard (RFS)**
  - United States: double biofuel use by 2012 to ~6% of gasoline.
  - UK Renewable Transportation Fuel Obligation (RTFO): 5% by 2010

- **Low Carbon Fuel Standard (LCFS)**
  - California: regulations to be in effect 2010
  - Federal bills: Boxer, Feinstein, Obama, Inslee, etc.
  - United Kingdom: RTFO requires GHG monitoring, pilot in 2007
  - Others: BC, WA, OR, AZ, NM, MN, and…?

- **Current and forthcoming analysis**
  - *Draft Carbon Reporting Methodology under the RTFO*. E4Tech. Dec06
  - *Sustainability Reporting within the RTFO*. ECOFYS. Feb07
  - *Creating Markets for Green Biofuels*. UC Berkeley study. April07
  - *AB1007 Well-to-Wheels Analysis*. CEC/CARB study. May07
Illness Reduction Observed in Kenya
(ARI = acute respiratory infection)

Average Daily Exposure ($\mu g / m^3$)

Probability (ARI)

- Ceramic Wood Stoves
- Charcoal
- 3-Stone Fire
- All ARI
- ALRI, Lower respiratory Infections only

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Sub-Saharan Africa’s wood-energy consumption is the highest in the world

Primary production of biomass energy in 2000 ($10^{18}$ Joules)

- Sub-Saharan Africa: 10.2
- China: 8.9
- India: 8.4
- Latin America: 3.2

Source: IEA, 2003

Charcoal is not just an African issue.
Expected Annual Deaths: Leading Causes for African Child and Women

Millions of avoidable deaths; biofuels can be comparable to fossil fuels

BAU = business as usual
C = charcoal
F = fossil fuels
R = RAPID

Bailis, Ezzati & Kammen (2005) Science
Plug In Partners / e.g. CalCars.org
Federal R&D Investments, 1955 - 2004

Margolis & Kammen, Science, 1999
If you think US public sector energy R&D funding is doing poorly …

Kammen and Nemet (2005)
“Reversing the incredible shrinking energy R&D budget,” Issues in Science & Technology, Fall, 84 - 88.
And Nemet, dissertation, 2007
Renewable Energy Portfolio Standards

23 states + DC, and counting

State Goal
- PA: 18% by 2020
- NJ: 22.5% by 2021
- CT: 10% by 2010
- MA: 4% by 2009 + 1% annual increase
- WI: requirement varies by utility; 10% by 2015 Goal
- IA: 105 MW
- MN: 10% by 2015 Goal + Xcel mandate of 1,125 MW wind by 2010
- TX: 5,880 MW by 2015
- *NM: 10% by 2011
- AZ: 15% by 2025
- CA: 20% by 2010
- NV: 20% by 2015
- HI: 20% by 2020
- IL: 8% by 2013

Increased credit for solar or other customer-sited renewables
- PA: 8% Tier I (renewables)

Solar water heating eligible
- WA: 15% by 2020
- MT: 15% by 2015
- CO: 10% by 2015
- HI: 20% by 2020
- TX: 5,880 MW by 2015
- ME: 30% by 2000; 10% by 2017 goal - new RE
- MA: 4% by 2009 + 1% annual increase
- RI: 15% by 2020
- CT: 10% by 2010
- NY: 24% by 2013
- NJ: 22.5% by 2021
- PA: 18% by 2020
- *MD: 7.5% by 2019
- *DE: 10% by 2019
- DC: 11% by 2022
Solar & Distributed Generation
Provisions in RPS Policies

PA: 0.5% solar PV by 2020
TX: 500 MW non-wind
NM: triple credit for solar electric
AZ: 4.5% DG by 2025
NV: 1% solar by 2015; 2.4 to 2.45 multiplier for PV
WA: double credit for DG
CA: 3,000 MW or more via SB1 & Million solar roofs
CO: 0.4% solar electric by 2015
NJ: 2.12% solar electric by 2021
NY: 0.1542% customer-sited by 2013
DE: triple credit for solar electric
MD: double credit for solar electric
DC: 0.386% solar electric by 2022

DG: Distributed Generation
Solar water heating counts towards solar set-aside

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Summary of GHG Emissions for Typical U.S. Household (LEAPS Results) 50 Metric tons of CO₂ equivalent gases


Housing: Gasoline 7, Natural gas 8, Electricity 20, Other fuels 1, Construction 3, Financing 1, Public trans. 1.

Food: Meats 1, Eating out 3, Snack food 3, Cereals 2, Dairy 1, Fruit & veg. 1, Alcohol & tobacco 1.

Goods: Meat 1, Clothing 1.

Services: Education giving 1, Healthcare 1, Cleaning supplies entertainment, household equip. 1.
Greenhouse Gas Emissions:
Lifecycles & Lifestyle Sources
(Jones, Horvath & Kammen, in press)

Key:
- meat
- dairy
- fruit & veggies
- snack & other
- cereals & bakery
- drinks
- goods

Area of circle = % of annual average U.S. household consumption

gC equivalent / gProduct

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The California commitment - scaled to the nation

Kammen, “September 27, 2006 – A day to remember”, San Francisco Chronicle, September 27,
Solar roofing & off-site wind purchases

All materials from reclaimed former building
The Path Ahead

- Clean energy sources today are evolving rapidly, but are a small component of our overall energy system.
- Rapid growth of the clean energy sector will require a coordinated commitment to technology push and demand pull.
  - Aggressive R&D will need to be coupled with strong support for clean energy market expansion.
  - Business and consumer involvement is vital.
- Pricing carbon/greenhouse gas emissions is vital to moving from sector support strategies to long-term sustainability policies.
The Cost of Nuclear Power from the U. S. Civilian Reactor Fleet