Global Energy Assessment

Thomas B Johansson
Co-Chair, GEA Executive Committee
Need for an Energy Assessment

- The world is at a critical juncture for energy policy, new challenges have emerged, while old ones remain.

- Previous studies do not identify the strategies and solutions needed to comprehensively address today’s major energy and energy-related challenges in an integrated way.
Challenges requiring actions on Energy

a. **equity** in energy services (the 2 billion w/o)
b. **affordable** energy services (@$100/bbl??)
c. **secure** supplies
d. **local and regional environmental challenges**
e. **climate change mitigation**
f. **ancillary risks**

*Major Energy System Changes Needed!*
These **challenges** must be addressed

jointly

adequately

timely
GEA Objectives include:

- **Science based, comprehensive, integrated, and policy-relevant** analysis of issues and options related to:
  - Energy and sustainability challenges
  - Resource and technology options, demand and supply
  - System issues, scenarios
  - Policy options

- Local, Regional, and Global dimensions
integration of knowledge clusters

- **Cluster I** characterizes nature and **magnitude** of challenges, and express them in selected indicators.
- **Cluster II** reviews existing and future resource and technology options.
- **Cluster III** integrates cluster II elements into systems, and links these to indicators from Cluster I.
- This will include energising of rural areas, land use, water, urbanisation, life-styles, etc.
- Scenarios, using numerical models and storylines, will be used for the **integration**, in an **iterative** fashion.
- **Cluster IV** assesses policy options, and specifically identifies **policy packages** that are linked to scenarios meeting the needs, again in an **iterative** fashion.
Updating reasons for concern

Source: Smith et al. PNAS, 2009
Category I

350 - 400 ppm CO₂
445 - 490 ppm CO₂ eq.

n = 6 Scenarios
peaking year 2000-2015
Russian-Roulette Chance ($p = \frac{5}{6}$) of Holding $2^\circ\text{C}$-Line:

80% Reduction of Global GHG Emissions by 2050, Relative to 1990 Levels
(According to GCM-Ensembles Calculations)

Negative Emissions after 2070!

Source: Schellnhuber, Copenhagen 2009
Trajectory of Global Fossil Fuel Emissions

Raupach et al. 2007, PNAS

Actual emissions: CDIAC
Actual emissions: EIA
450ppm stabilisation
650ppm stabilisation
A1FI
A1B
A1T
A2
B1
B2

50-year constant growth rates to 2050
B1 1.1%
A1B 1.7%
A2 1.8%
A1FI 2.4%

Observed 2000-2006 3.3%


CO₂ Emissions (GtC y⁻¹)

Raupach et al. 2007, PNAS
this translates into a need for a major energy system transformation

Main elements:
- Energy end-use efficiency
- Renewable energies
- Carbon Capture and Storage

Efficiency and Renewables are INSTRUMENTS for addressing all the challenges at the same time!
Think
solar resources in the Middle East/North Africa region

A solar thermal power plant of the size of Lake Nasser (Aswan) could harvest energy equivalent to the annual oil production of the Middle East.
Energy from deserts
not just energy technology

- Urban planning
- Transportation systems
- Material use
- Land use
- Consumption patterns
- …..
Global Energy Assessment

- unique and timely
- comprehensive and integrated
- process going beyond a report
- policy relevant
- options and strategies for the way forward
Thank you!

www.GlobalEnergyAssessment.org
Global Energy Challenges

- Sustainable access to energy and food (a prerequisite for reaching MDGs)
- Energy and ecosystems services
- Security and reliability of systems
- Deep GHG emissions reductions
- Technology R&D and deployment
- Integrated policy frameworks
Towards a more Sustainable Future

- The *magnitude of the change* required in the global energy system will be huge.

- The challenge is to find a way forward that addresses *simultaneously* climate change, security, equity and economics issues.

- *Paradigm change is needed*: radical improvements in energy end-use efficiency, new renewables, advanced nuclear and carbon capture and storage.

- Needs to be *globally integrated* but with maximum support of countries and local levels.

- In the best spirit of science: *fact-based and peer-reviewed*
GEA Knowledge Clusters

• **Cluster I: Major Global Issues and Energy**
  1. An Introduction to Energy (Goals, Visions, Why?)
  2. Social Issues, MDGs and Energy
  3. Environment and Energy
  4. Health and Energy
  5. Security, Interdependence, Markets and Energy
  6. Energy, Economy and Investment

• **Cluster II: Energy Resources and Technological Options**
  7. Energy Resources (Fossil, Nuclear and Renewable)
  8. Energy End-Use (Efficiency): Industrial Sector
  9. Energy End-Use (Efficiency): Transport
  10. Energy End-Use (Efficiency): Buildings (commercial and residential)
  11. Renewable Energy
  12. Fossil Energy Systems (Conventional and Advanced)
  13. Carbon Capture and Storage
  14. Nuclear Energy
  15. Energy Supply System Operation
  16. Synthesis module: End-use and Supply Linkages and Synthesis
GEA Knowledge Clusters

(cont’d)

● **Cluster III: Describing Possible Sustainable Futures**
  17. Global and Regional Scenarios, Normative Futures, and Major Uncertainties
  18. Urbanization
  19. Rural Energy and Increasing Access
  20. Trade-Offs, Land and Water
  21. Energy Services and Human Well Being (Lifestyles, consumption patterns)

● **Cluster IV: Realizing Energy for Sustainable Development**
  23. Policies for Energy Access
  24. Policies for Innovation
  25. Policies for Capacity Building 'and more'
  26. Sustainable Energy Policy Portfolios
  27. Epilogue
<table>
<thead>
<tr>
<th>Factor</th>
<th>1800</th>
<th>2000</th>
<th>Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population (billion)</td>
<td>1</td>
<td>6</td>
<td>x6</td>
</tr>
<tr>
<td>GDP PPP (trillion 1990 $)</td>
<td>0.5</td>
<td>36</td>
<td>~x70</td>
</tr>
<tr>
<td>Primary Energy (EJ)</td>
<td>12</td>
<td>440</td>
<td>~x35</td>
</tr>
<tr>
<td>CO$_2$ Emissions (GtC)</td>
<td>0.3</td>
<td>6.4</td>
<td>~x20</td>
</tr>
</tbody>
</table>
PM10 Exposures in 3200 Cities

Exposure: PM$_{10}$ concentration*City population (capita.$\mu$g/m$^3$)
Size of circle indicates exposure (Quintiles)
Color of circle indicates underlying PM$_{10}$ Concentration ($\mu$g/m$^3$) range:
7-358 $\mu$g/m$^3$

Source: C. Doll, 2009, based on World Bank data
Global Build-Up Area
2070
Global Arable Land

2070
Global Bioenergy Land

2070
Global CO$_2$ Emissions

Source: IIASA, 2008 & IPCC, 2007
Total Energy-related Investments (World, short & long-term)

- “Upfront” Investments (~2 trillion)
- Long-term Investment Savings ~40 trillion

Chart showing investments over the years 2000-2030 and 2000-2100, with comparison between scenarios A2 and B1.
Share of public budgets for energy R&D in total R&D significantly fell over the last two decades. Private-sector R&D is increasingly focused on projects with short-term payoffs.

Source: IEA Databases, Doornbosch, et al., 2008
History of US Federal Government R&D

- JFK Apollo Program
- Reagan “Star Wars” Program
- Carter Energy Program
- Homeland Security

Source: after Margolis and Kammen, 1999
“Energy RD&D programs are not commensurate in scope and scale with the energy challenges & opportunities the 21st century will present.”

Source: PCAST, 1997
# Investments Themes in Stimulus Packages

**Green New Deals? Climate Change Investment Themes In 2008 Stimulus Packages (USD bn)**

<table>
<thead>
<tr>
<th>Country</th>
<th>Stimulus Package</th>
<th>Total Package</th>
<th>Low Carbon Power (Renewables, CCS)</th>
<th>Energy Efficiency, R&amp;D, Modal Shift</th>
<th>Waste, Water Treatment &amp; Pollution Control</th>
<th>Green Investments (%)</th>
<th>Other Infra</th>
<th>Period</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chile</td>
<td>Anti-crisis stimulus package</td>
<td>4.0</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.7</td>
<td>2009</td>
<td>Pending</td>
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<tr>
<td>China</td>
<td>NDRC Stimulus Package</td>
<td>581.2</td>
<td>-</td>
<td>-</td>
<td>147.6</td>
<td>50.9</td>
<td>34%</td>
<td>39.9</td>
<td>2009-2010</td>
</tr>
<tr>
<td>EU</td>
<td>Recovery Plan</td>
<td>253.6</td>
<td>19.0</td>
<td>15.5</td>
<td>-</td>
<td>-</td>
<td>14%</td>
<td>8.0</td>
<td>2009-2010</td>
</tr>
<tr>
<td>France</td>
<td>Revival Plan</td>
<td>32.9</td>
<td>0.8</td>
<td>2.0</td>
<td>-</td>
<td>-</td>
<td>8%</td>
<td>18.7</td>
<td>2009-2010</td>
</tr>
<tr>
<td>Germany</td>
<td>Stimulus Plan</td>
<td>63.4</td>
<td>-</td>
<td>-</td>
<td>11.9</td>
<td>-</td>
<td>19%</td>
<td>-</td>
<td>2009-2010</td>
</tr>
<tr>
<td>India</td>
<td>Stimulus Package</td>
<td>6.8</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2.0</td>
<td>2009</td>
</tr>
<tr>
<td>Israel</td>
<td>Stimulus Plan</td>
<td>5.0</td>
<td>-</td>
<td>-</td>
<td>0.1</td>
<td>-</td>
<td>2%</td>
<td>2.3</td>
<td>2010 onwards</td>
</tr>
<tr>
<td>Italy</td>
<td>Emergency Package</td>
<td>101.4</td>
<td>-</td>
<td>-</td>
<td>1.2</td>
<td>-</td>
<td>1%</td>
<td>-</td>
<td>2009 onwards</td>
</tr>
<tr>
<td>Japan</td>
<td>Stimulus Package</td>
<td>476.0</td>
<td>-</td>
<td>-</td>
<td>11.0</td>
<td>-</td>
<td>2%</td>
<td>2.2</td>
<td>2009 onwards</td>
</tr>
<tr>
<td>Poland</td>
<td>Stimulus Package</td>
<td>30.0</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2009 onwards</td>
</tr>
<tr>
<td>South Korea</td>
<td>Green New Deal</td>
<td>38.1</td>
<td>-</td>
<td>-</td>
<td>8.5</td>
<td>17.8</td>
<td>69%</td>
<td>-</td>
<td>2009-2012</td>
</tr>
<tr>
<td>Spain</td>
<td>Stimulus Package</td>
<td>13.9</td>
<td>0.8</td>
<td>0.6</td>
<td>-</td>
<td>-</td>
<td>10%</td>
<td>11.2</td>
<td>2009</td>
</tr>
<tr>
<td>Thailand</td>
<td>Stimulus Package</td>
<td>8.7</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2009</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>Pre-budget report 2008</td>
<td>29.7</td>
<td>0.6</td>
<td>1.4</td>
<td>-</td>
<td>-</td>
<td>7%</td>
<td>26.5</td>
<td>2009</td>
</tr>
<tr>
<td>United States</td>
<td>Emergency Economic Stabilization Act</td>
<td>700.0</td>
<td>12.0</td>
<td>1.7</td>
<td>-</td>
<td>1%</td>
<td>2%</td>
<td>9.9</td>
<td>Next 10 years</td>
</tr>
<tr>
<td></td>
<td>Economic Stimulus Package</td>
<td>825.0</td>
<td>10.4</td>
<td>85.9</td>
<td>32.3</td>
<td>16%</td>
<td>9.2</td>
<td>321.5</td>
<td>Available from 2 to 10 yrs</td>
</tr>
<tr>
<td><strong>Total Funds Unveiled</strong></td>
<td></td>
<td><strong>3170</strong></td>
<td><strong>43.5</strong></td>
<td><strong>287.4</strong></td>
<td><strong>101.0</strong></td>
<td><strong>14%</strong></td>
<td><strong>321.5</strong></td>
<td><strong>Available from 2 to 10 yrs</strong></td>
<td></td>
</tr>
</tbody>
</table>

Source: HSBC 2009
Implications for Policy and Capacity Building

- Develop new ways to stimulate investment in risky processes of disruptive technological change and build the capacity to do so
  - at the level of the firm – through the promotion of business models such as open innovation and the research and development capacities required to participate in them,
  - at the international level – by using existing mechanisms, the CDM, for example, to promote technology transfer, strengthen local innovation capacity and finance the energy future in Developing Countries

- Build capacity at local and national levels to create new institutional and regulatory frameworks that involve greater actor participation in collaborative projects and more consensual bottom-up processes to complement traditional top down policy approaches.
Shonali Pachauri
Rural Energy

www.GlobalEnergyAssessment.org
Rural Poverty in Decline
(Good News ... ?!)

Data Source: Ravallion et al. (2007), Adapted
Final Energy Split In Households

Data Source: Pachauri & Jiang 2008
Learning from China, India and Latin America
- energy access across rural household groups


Data Source: CEPAL, Chile.
Share of Non-Solid Fuels by Income in Rural Households

Data Source: Pachauri & Jiang 2008
Electricity

Electricity for All in the Medium Term (may be achievable)

- Use of both grid-extension and decentralized systems + conventional and renewable energy technologies
- Strong national (and local) + public (and private) delivery models
- Smart use of subsidies and other innovative financing mechanisms (global effort would be required)
Traditional Biomass

- Limits to “modern fuels”
- Cleaner/more efficient use of biomass may be the key MT option
- Key challenge remains how to scale-up best practice/technologies

Mechanical Power

- Single-focus / single-objective programs predisposed to fail – multi-tracked approaches may be required
- Emphasis on productive uses may hold key to accelerating access in rural areas
- Rural development is key
Some Annual Cost Comparisons to 2015

- Clean Fuels Access: $1 billion
- G8 ODA Commitment: $50 billion
- OECD ODA: $80 billion
- Energy Price Subsidies: $215 billion
- OECD Farm Support: $225 billion
- Global Energy Investment: $500 billion

Providing LPG Stoves and Canisters to 2.5 billion

Data Source: Various
Key Messages

- Integrating energy into rural development and recognizing diversity of approaches in service delivery

- Demanding more institutional leadership and critical roles for the public sector also in public-private partnerships

- Widening the policy “spectrum” and putting more emphasis on learning-by-doing capacity development
Arnulf Grubler
Urbanization

www.GlobalEnergyAssessment.org
GEA KM18 Urbanization

- Why urbanization focus?
  -- rapid urbanization (6-8 billion urbanites by 2050)
  -- ~2/3 of current final energy use is urban
  -- cities as policy and innovation centers

- Assessment:
  -- current urban energy use (GIS and city energy DB)
  -- energy/carbon accounting:
    methodology & uncertainty
  -- explaining differences in urban energy use (→policies)
  -- efficiency and emission improvement potentials (→policies)
  -- systemic view (urban form, systems integration)
Urban vs. Rural Population Scenarios in 4 Macro-Regions
(IIASA GGI, 2007, and UN WUP, 2007, in Billion)

OECD

ASIA

ME-AFR

Data source: Riahi et al., 2007; UN, 2007
Vienna - 1st and 2nd Law Efficiencies

Secondary Exergy: 171 TJ  100%
Secondary Energy: 45 TWh  100%

Final Exergy: 140 TJ  82%
Final Energy: 38 TWh  84%

Useful Exergy: 31 TJ  18%
Useful Energy: 23 TWh  50%

Gas
Heat, Liquids
Renewables

Electricity
Motor fuels

Households
Traffic

L.T. heat
Process heat
Light, motion
1. The world is already today predominantly urban (~2/3 of final energy) and will become even more so.
2. Rural populations are likely to peak at 3.5 billion and decline after 2020.
3. **Urban population projected to continue to grow to 6-8 billion by 2050 with largest growth in settlements <0.5M**
4. Shrinking cities new phenomenon of demographic decline.
5. Cities have specific sustainability challenges (high density calls for ~zero-impact systems).
6. Many still do not have access to basic energy services, which need to be supplied based on economic, social, and environmental sustainability.
7. **Vast improvement potentials, but most require demand-supply integration and systemic changes (recycling, cascading, transport systems integration,..)**
8. “Upstream” energy and CO₂ emission accounts fraught by uncertainty and system boundary ambiguity.
9. New sustainability criteria needed, considering the functional interdependence among different systems that are geographically separated.
10. **Governance Paradox:**
    - largest leverage from systemic change, but
    - most difficult to implement in view of policy fragmentation and dispersed, decentralized decision taking.
Arnulf Grubler
Innovation

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GEA KM24 Policies for Energy Technology Innovation Systems

- Why? Innovation as main leverage for sustainability transition
- Broad concept of technology and innovation (hardware, software, institutions)
- Systemic view of innovation (emphasizing feedbacks and interaction between supply and demand factors)
- Literature synthesis plus case studies (successes and failures)
- Policy myths and lessons for policy design
Japan PVs 1975-2007 (in MW)
Importance of demand pull AND supply push factors

Data: Watanabe, 2003, and JPEA, 2009
KM24 Case Studies to Analyze Drivers of TC

- Wind turbines (comparative assessment US-Europe-Mexico-India-China)
- PVs (comparative assessment EU-US-Japan)
- Solar thermal electricity
- US synfuels programs
- Coal gasification & upscaling in China
- Hybrid cars
- Solar heaters
- Solar cooling
- Ethanol in Brazil
- Negative C-emissions technologies (e.g. BECS)
- Weyburn project
- Role of standards: ex. Building efficiency
- Methods for innovation risk hedging and technology portfolio design
Factors in US PV Cost Declines 1979-2001:
Economies of Scale (43%), R&D (35%), Learning by Doing (5%), Others (17%)

Source: Nemet, 2008
GEA KM24 Draft Key Messages

- Substantial and accelerated innovation needed
- Drivers of innovation as well as the policies that support it are complementary rather than substitutable
- Innovation systems change needed rather than (more) individual innovations
- Innovation policies need to be:  
  -- aligned  
  -- consistent  
  -- patient
- Key importance of “granularity”: Success from many small scale (end-use) innovations (efficiency) rather than few, big supply side innovations (fusion) minimizes risks and allows for necessary failures
Energy End-Use in Buildings

www.GlobalEnergyAssessment.org
Sustainable energy in the buildings sector: global significance

- Buildings are responsible for approximately 1/3 of energy-related CO$_2$ emissions and 2/3 of halocarbon emissions.
- In most countries, they consume 35 – 45% of TPES (~50% in developing countries).
- Largest GHG mitigation potential in short- to mid-term at low costs.
Example of savings by reconstruction

Before reconstruction

Reconstruction according to the passive house principle

-90%

over 150 kWh/(m²a)

15 kWh/(m²a)

If so attractive, why is it not happening?

- The market barriers to energy-efficiency are perhaps the most numerous and strongest in the buildings sector
- These include:
  - imperfect information
  - Limitations of the traditional building design process
  - Energy subsidies, non-payment and energy theft
  - Misplaced incentives (agent/principal barrier)
  - Small project size, high transaction costs
  - others
Co-benefits of GHG mitigation in buildings (selection)

- Co-benefits are often not quantified, monetized, or identified
- Overall value of co-benefits may be higher than value of energy savings
- A wide range of co-benefits, including:
  - Improved social welfare
    - Fuel poverty: In the UK, about 20% of all households live in fuel poverty. The number of annual excess winter deaths is estimated at around 30 thousand annually in the UK alone.
    - Energy-efficient household equipment and low-energy building design helps households cope with increasing energy tariffs
Pushing the frontiers: provisional highlights from the KM

- Low- and zero-energy buildings are dynamically growing
- Often at no extra cost; typically at little extra cost
- Low-energy retrofits are also becoming possible - > paradigm shift
- Ambitious policies and targets are spreading; showing the way for other policy fields
- The industry is playing a leadership role - visionary presence also in GEA