The Global Energy and Environmental Challenge and the Opportunities for Research

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Outline

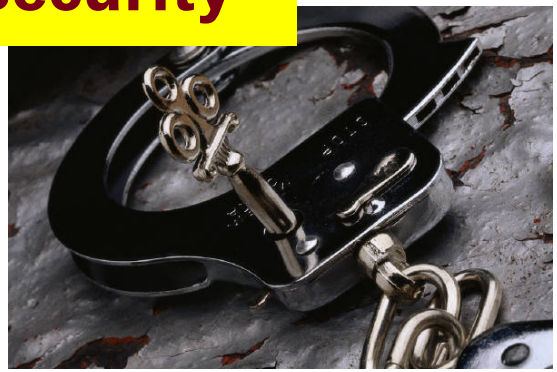
- The global energy/environmental challenge
  - Supply, security, and environment
- MIT Energy Initiative (MITEI)
- New CNRS-MIT Collaboration
- Summary

The Perfect Storm

Supply

- Energy supply and demand
- Energy and security
- Energy and the environment

Security



Impacts

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The “Perfect Storm”

- Energy supply and demand
  - 500 EJ/year (15.8 TW)/18 T kWh-electric/year
  - 86% fossil fuel/enough oil? enough air for coal?…
  - Projected doubling of energy use and tripling of electricity use by 2050 in business as usual
  - 1.4 Billion people without electricity in 2030
  - 50 year time scale for major shifts in energy

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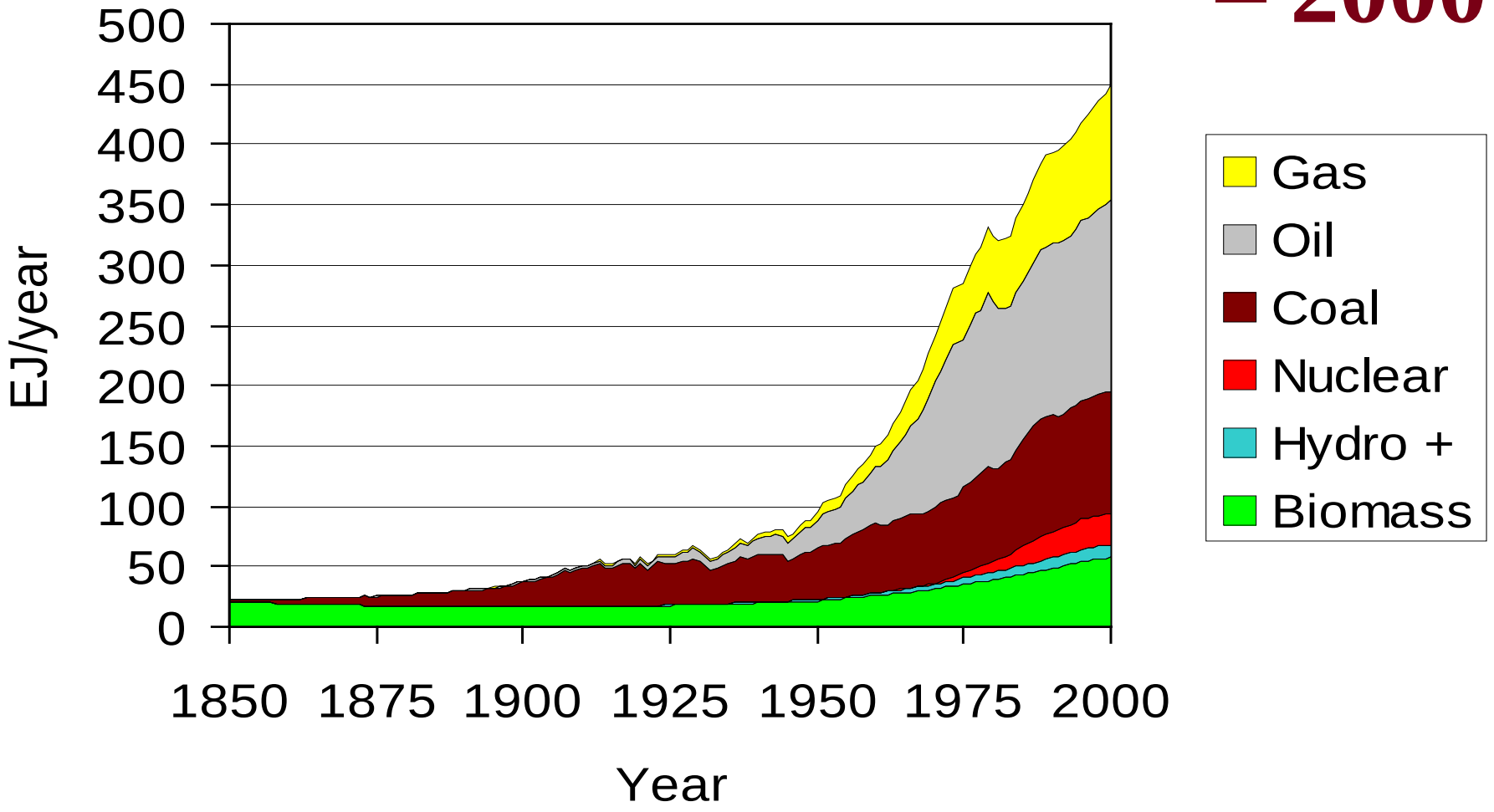
World Energy Consumption 1850 – 2000



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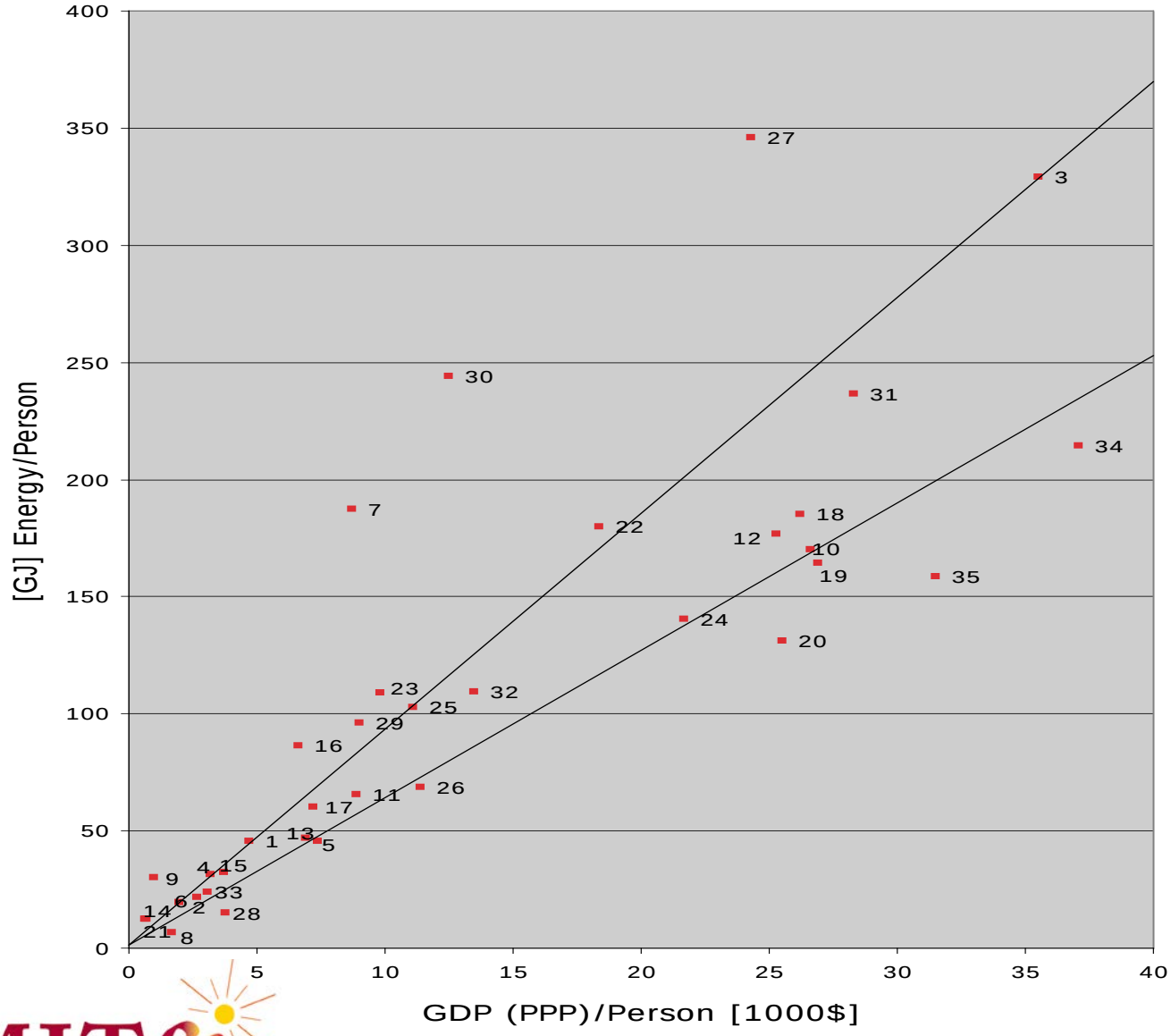
Primary Energy Use Per Person



1 China
2 India
3 US
4 Indonesia
5 Brazil
6 Pakistan
7 Russia
8 Bangladesh
9 Nigeria
10 Japan
11 Mexico
12 Germany
13 Turkey
14 Ethiopia
15 Egypt
16 Iran
17 Thailand
18 France
19 UK
20 Italy
21 Dem Rep. Congo
22 South Korea
23 South Africa
24 Spain
25 Poland
26 Argentina
27 Canada
28 Morocco
29 Malaysia
30 Saudi Arabia
31 Australia
32 Hungary
33 Nicaragua
34 Norway
35 Ireland

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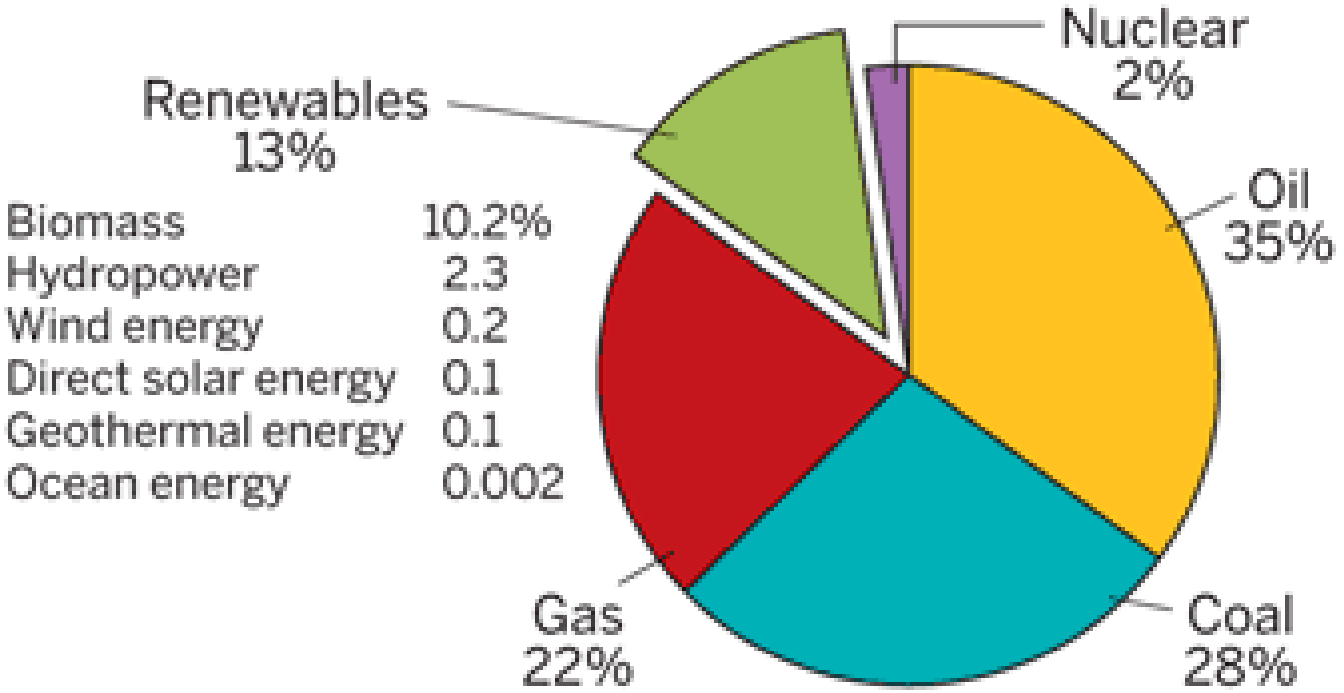
ENERGY SOURCES Renewable energy accounted for 13% of the world's primary energy supply in 2008.



2008 global primary energy supply = 4.92 x 10^{20} joules

IPCC Summary Report, May 2011; C&ENews 2011

The “Perfect Storm”

- Energy and security
  - Geological and geopolitical realities of oil and gas supply
  - Oil (and natural gas) adequate and reliable supply
  - Vulnerability of extended energy delivery systems
  - Nuclear weapons proliferation facilitated by worldwide nuclear power expansion
  - Dislocation from environmental impacts, such as from climate change

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Oil and Energy Security

- Core Issue: inelasticity of transportation fuels market, together with geographical and geophysical realities of oil
- Addressing sudden disruptions
  - Strategic reserves
  - Well-functioning markets
- Increasing and diversifying supplies
  - Enhanced production from existing fields
  - Arctic E&P
  - “Unconventional” oil (tar sands,…)
- Weakening the “addiction”
  - Very efficient vehicles
  - Alternative fuels (coal, NG, biomass)
  - New transportation paradigm (electricity as “fuel”? H_2?)

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The “Perfect Storm”

- Energy and environment
  - Risk of climate change
  - 50+ years of CO_2 “emissions budget”
  - “De-carbonizing” of energy?

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The Average Temperature of the Earth is Rising

- Up 0.8±0.4°C in last 140 years (instrumental records)
- 2010, 2005 and 1998 were the warmest years in the instrumental record and probably the warmest in 1,000 years (tree rings, ice cores); 2002 was the second warmest
- The last 50 years appear to have been the warmest half century in 6,000 years (ice cores)
- It is approximately as warm now as the Holocene maximum and within ~1°C of the maximum temperature of the past million years*

*Hansen, *et al.*, *PNAS*, **103**, 14288-14293 (2006).

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Climate Change Technology/Policy Pathways

- Efficiency
- Low carbon or “carbon-less” technologies/fuels
  - Fuel switching, e.g., coal to natural gas
  - Nuclear power (fission, possibly fusion in long term)
  - Renewables (wind, geothermal, solar,…)
    - Note: scale matters
- Carbon dioxide capture and sequestration

Climate control policy is not new. As early as 1306 Edward I of England prohibited the burning of coal in craftsman’s furnaces. Later Elizabeth I banned burning of coal in London while Parliament was in session.

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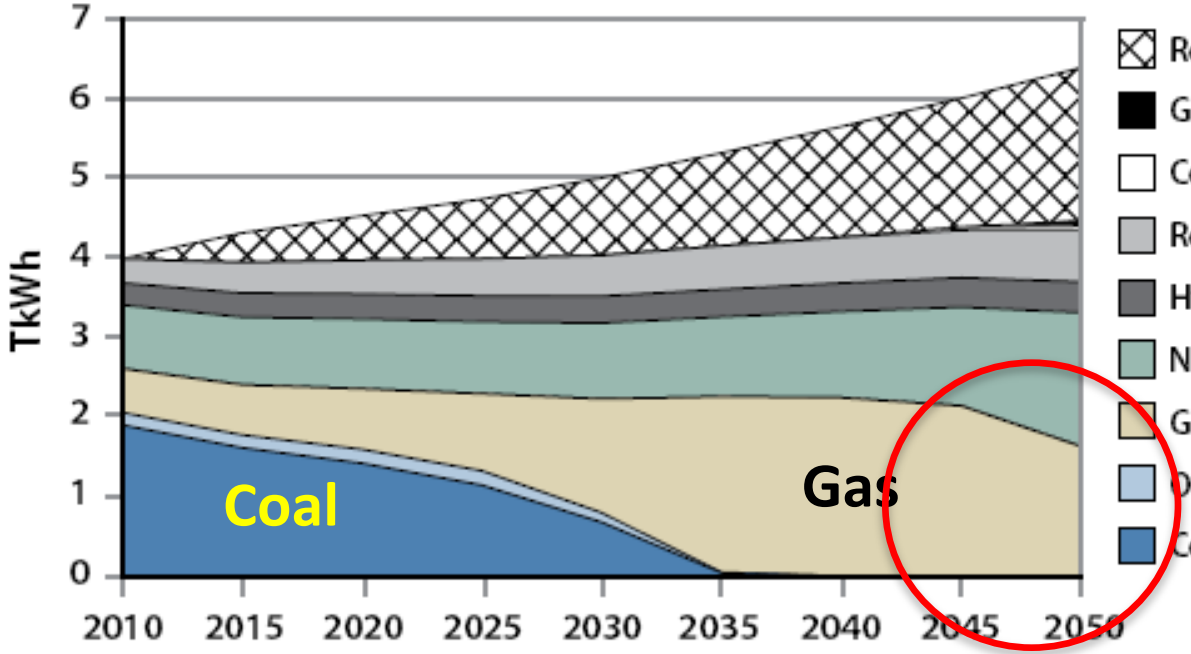
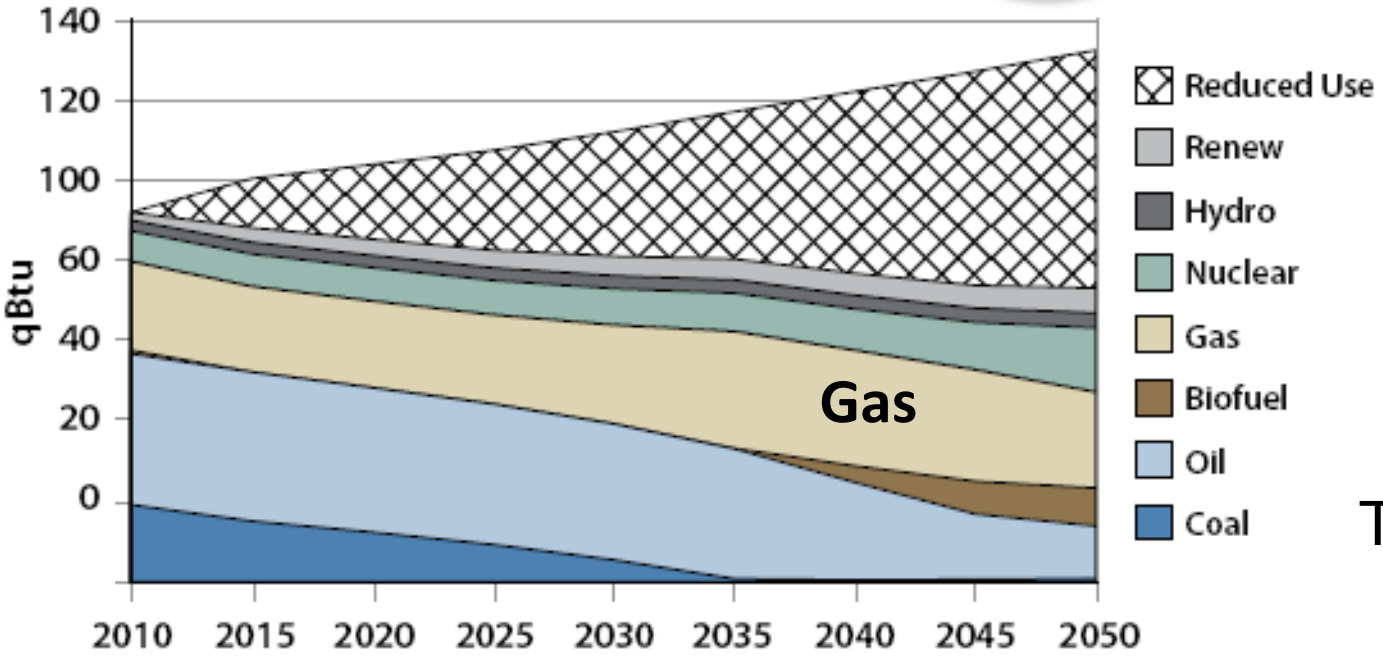
Price-based mitigation

50% by 2050

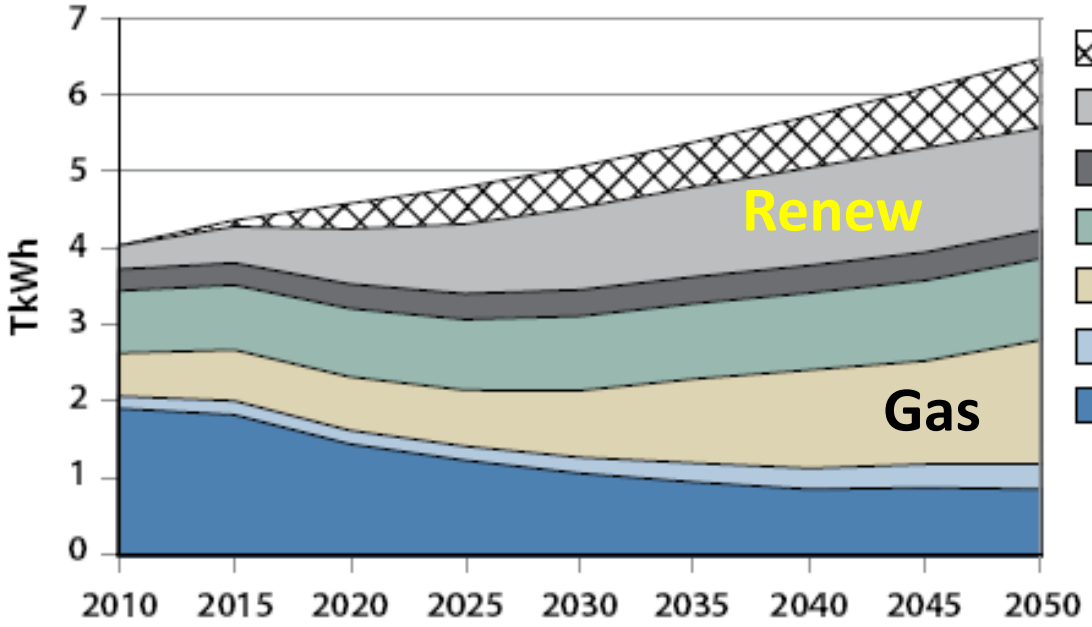
No offsets



Electric sector



Total energy

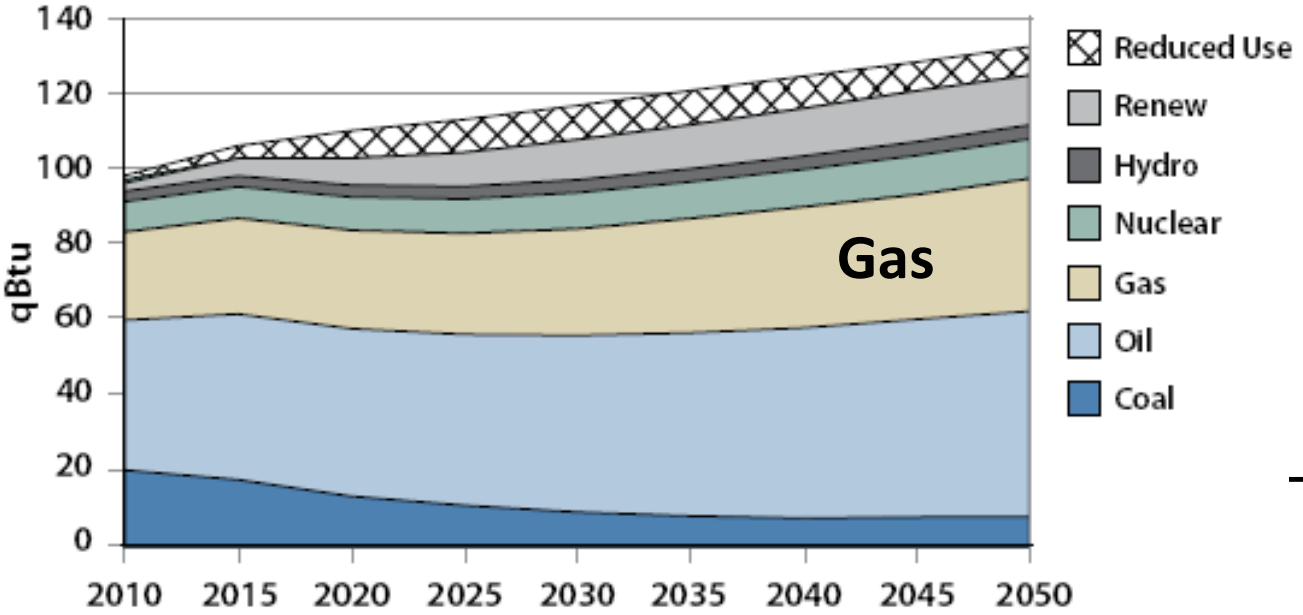


Regulatory mitigation

25% RES 2030

55% coal retire

Electric sector



Total energy

Uncertainty on a 50-year time scale

- Future scenarios highly uncertain on mid-century time scale
  - 50-year time scale characteristic of significant change in energy infrastructure, of greenhouse gas concentrations approaching twice pre-industrial,…
- Multiple uncertainties
  - Resource availability?
    - fossil fuels, land for renewables, effects of renewables at scale…
  - Science and technology advances?
    - technology breakthroughs, climate change impacts
  - Geopolitical considerations?
    - Middle East, climate protocol participation,…
- MITEI is a broad initiative pursuing multiple technology and policy options

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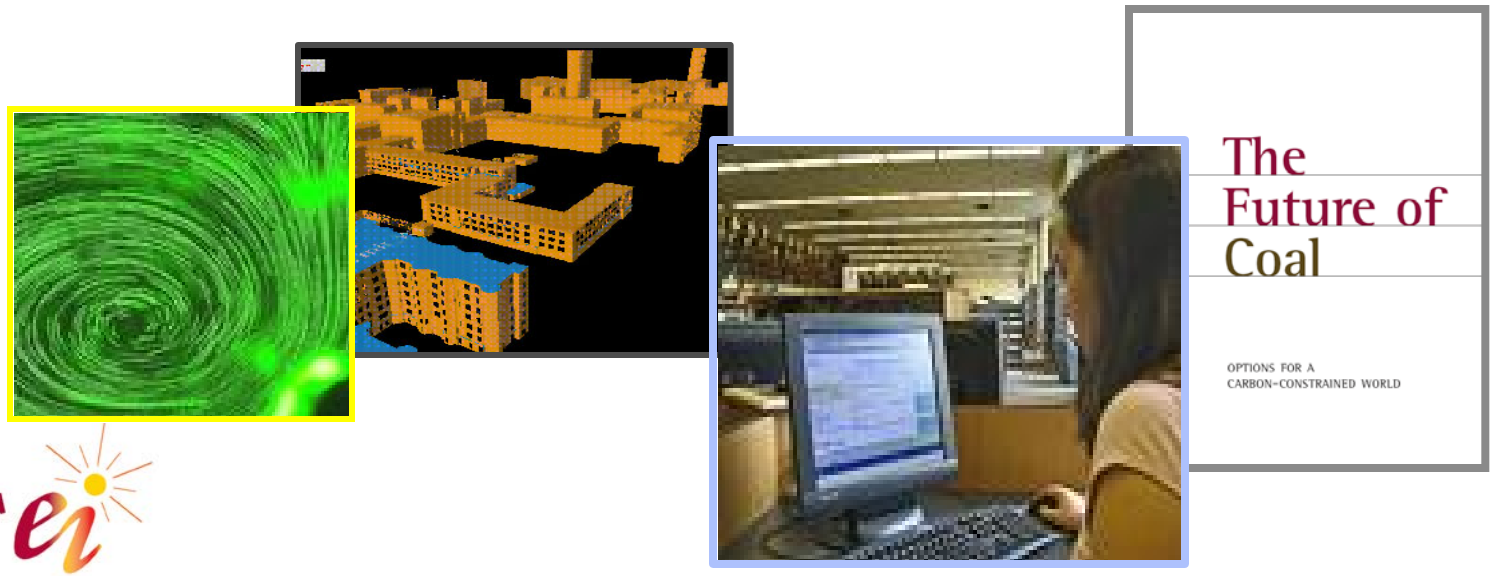
MITEI Components

MITEI has four components

- Research
- Education
- Campus energy management
- Outreach/"honest broker"



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MITEI Research Focus Areas

- Innovations: Improving today's energy systems

  Evolving today's energy systems to higher efficiency, lower cost, less environmental impact (nuclear, subsurface, electricity systems, conversion,….)

- Transformations: Science and technology for a clean energy future

  Enabling research to underpin critical breakthroughs (solar, storage, biofuels,…)

- Global Systems: Energy systems for a rapidly developing world

  Opportunities for new energy development technologies/models (global change, buildings and cities, vehicles and transportation systems,…)

- Tools

  Basic research for breakthrough concepts (catalysis by design, multi- electron transfer,…) and accelerated application of cutting-edge scientific, engineering, and analytical tools to energy problems

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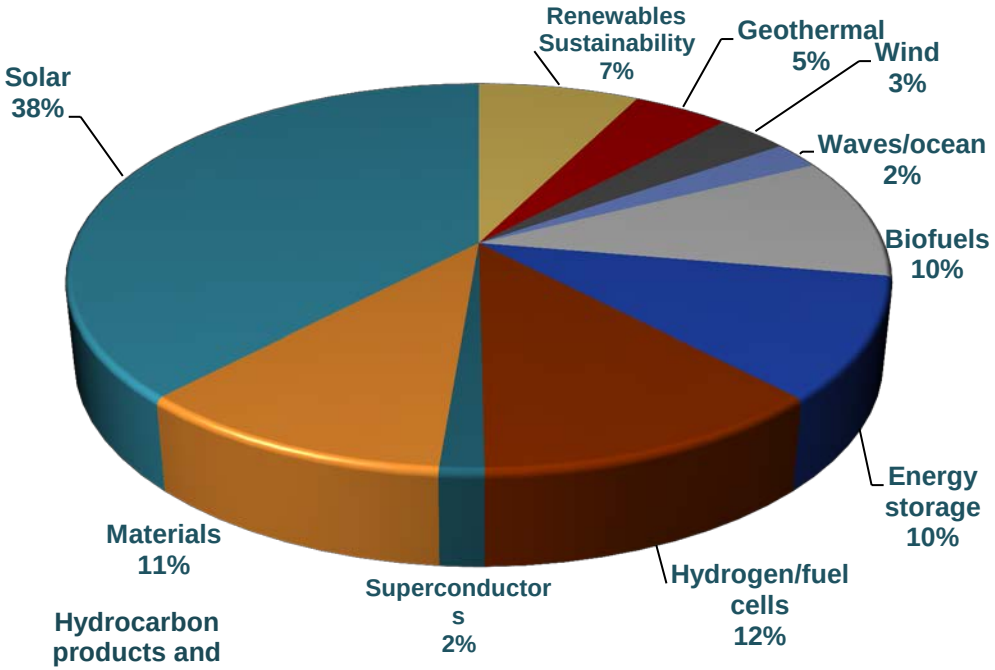
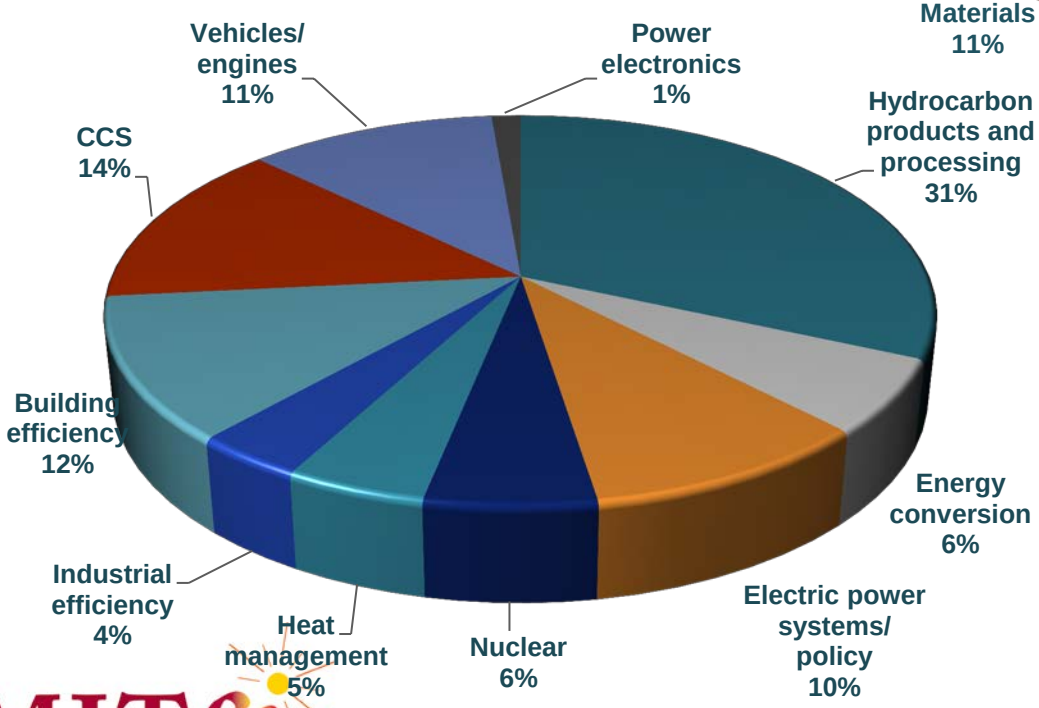
MITEI Research Portfolio

- PIs 275
- Projects 671
- Focus areas 36
  - Solar, hydrocarbons, nanotechnology, modeling/simulation, CCS, building efficiency, … storage
- Departments 22
- Labs and Centers 24

Transformations

- *267 projects**
- *Solar*
- *Hydrogen/fuel cells*





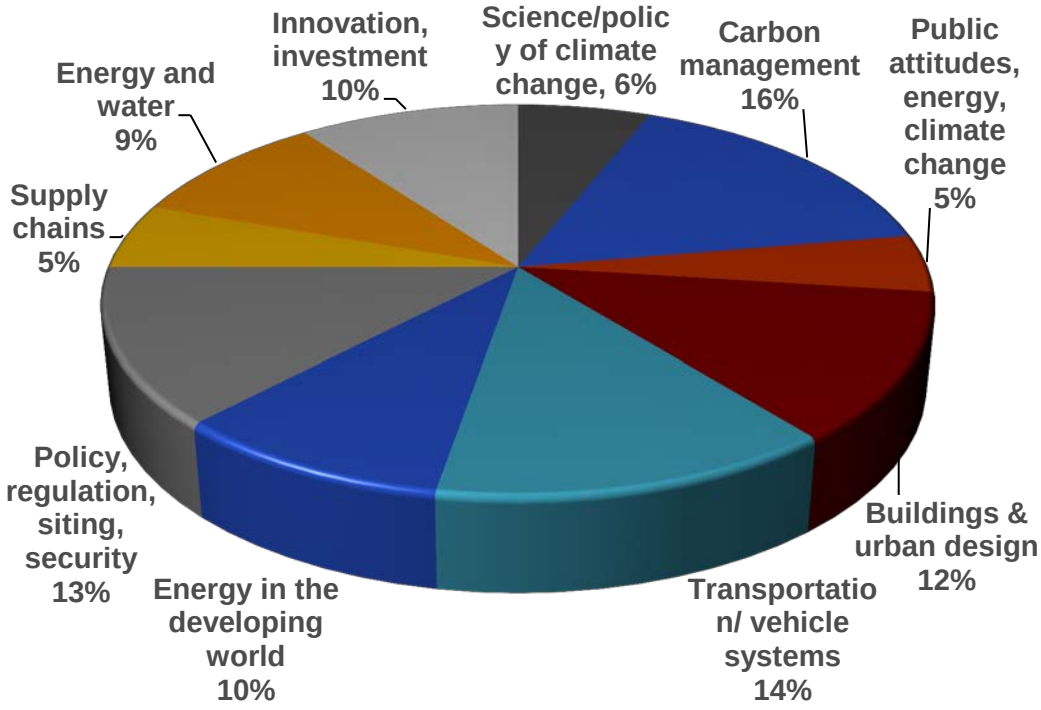
Innovations

- *297 projects**
- *Hydrocarbon products/processing*
- *CCS*

*Projects may have more than one focus area; total projects by focus area exceed total projects supported

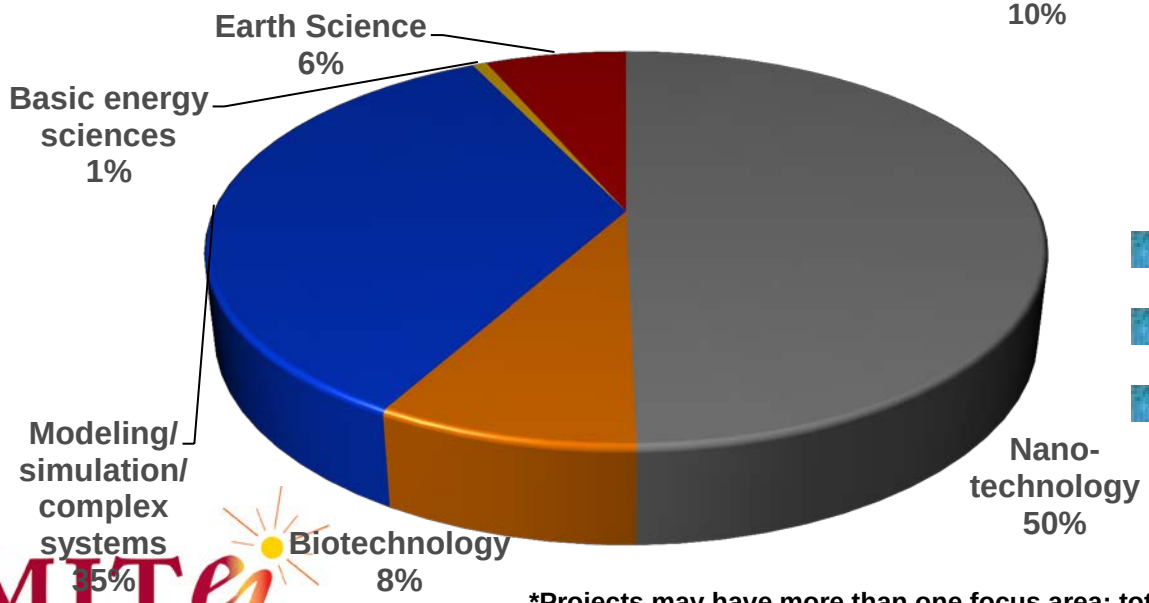
Global Systems

- *149 projects**
- *Carbon management*
- *Transportation*



Tools

- *153 projects**
- *Nanotechnology*
- *Modeling/simulation*



**Projects may have more than one focus area; total projects by focus area exceed total projects supported*

New Research Opportunities between France and MIT

- Commitment to form a International Joint Research Unit
  - Summer 2011
  - CNRS and MIT
  - Focus on multi-scale materials science for energy and environment
    - Shale gas
    - Cement materials
    - Nuclear solid fuels

Closing Observations

- Most likely, in the near term we cannot rely on carbon policy to mitigate global climate change
- Instead, we must pursue three coupled thrusts
  - Demand reduction through increased efficiency
  - Coal to gas switching
  - RD&D for low/zero carbon technologies
    - Include enabling technologies, e.g., grid, materials, *storage*, etc.
- A broad portfolio and long time horizon are important

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Questions?