Energy Innovation that Can Make a Difference

Secretary Steven Chu
Emirates Palace Hotel
Abu Dhabi, United Arab Emirates
24 February 2010
Innovation can change the world

Bell Labs solar cell - 1954

First transistor

Pentium CPU

Ted Maiman and the first laser - 1961

The Internet
The Energy and Climate Challenge

(1) The global economy needs energy resources.

(2) Our long-term economic prosperity is tied to the sustainable use of energy.

(3) There are risks of adverse climate change for both our countries.

(4) We don’t have the luxury of focusing only on the short run or the long run; we must address both.
Energy densities of chemical fuels and the best commercial battery

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>Energy Density (Mj/kg)</th>
<th>Energy Density (Mj/liter)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body Fat</td>
<td>38</td>
<td>35</td>
</tr>
<tr>
<td>Kerosene, jet fuel</td>
<td>43</td>
<td>32</td>
</tr>
<tr>
<td>Lithium ion battery</td>
<td>0.54</td>
<td>0.9</td>
</tr>
</tbody>
</table>

**Graph:***
- **Energy Densities**: The graph illustrates the energy densities of various fuels and the lithium ion battery. Each point represents a fuel with its energy density plotted in Mj/kg on the x-axis and Mj/liter on the y-axis.
- **Key Fuels**: Notable fuels include Body Fat, Kerosene, and the lithium ion battery, each marked with their respective energy densities.
Question: What does a Boeing 777 have in common with a Bar-tailed Godwit?

Answer: Both can fly non-stop 11,000 km. At take-off, the fuel weighs ~ 50% of their total weight.
Top 5 Net Oil Exporters (2008)

- Saudi Arabia
- Russia
- UAE
- Iran
- Kuwait

Thousand barrels per day
Energy Information Administration Outlook 2010: Biofuels meet most of the growth in liquid fuels supply

Richard Newell, SAIS, December 14, 2009

Source: Annual Energy Outlook 2010
Huge growth in oil demand is projected from the developing world

Change in primary oil demand 2007 – 2030

IEA: World Energy Outlook 2009
We also need energy innovation to ensure our future prosperity.

Why?
Climate Change is real: the temperature record from 1880 – 2008.
Can the rise in temperature be due to an increase in solar energy reaching Earth?

What about Sun Spots?

Sunspots (blue)
Solar flares (green)
Radio emissions (purple)
Carbon Dioxide Concentration during the past 800,000 years

Since the beginning of the industrial revolution, the CO$_2$ in the atmosphere has increased by 40%.

The CO$_2$ equivalent has increased by 53%
Greenland Ice Mass Loss – 2002 to 2009

Ice mass loss from the Greenland and Antarctic ice sheets measured by GRACE (Gravity Recovery and Climate Experiment) mission.

If the world follows a “Business-as-usual” path, what do climate models predict will happen?
No emission reductions:
5 - 6 degree temperature increase in Middle East
Coastal areas at risk from sea-level rise

Areas in blue below 4 feet -- includes significant U.S. refining infrastructure
Predicted water stress areas around the world

- Damage to riparian ecosystems due to flood protection along the Elbe river
- Rural water supply affected by extended dry season in Benin
- Health problems due to arsenic and fluoride in groundwater in India
- Affected by cierras in Andes

Water stress indicator: withdrawal to availability ratio

- No stress
- Low stress
- Mid stress
- High stress
- Very high stress

Legend:

- Normal rainfall = 0
-Unavailable water resources = 0.8
The world is on an unsustainable energy path.

Both of our countries know we need to diversify our energy mix

We must work together to find new solutions that benefit us all.
The first Industrial Revolution taught us that wealth creation through technology is not a zero-sum game.

There is no law of physics that says prosperity is proportional to carbon emissions.
Human Development Index (GDP/capita, education level, health care, etc.) vs. Electricity Use

U.S. must reduce carbon emissions by at least 80% by 2050
The Department of Energy is a science-based agency.

We have funded the work of more than 100 Nobel Prize winners – more than any other organization in the world.

President Obama’s American Recovery and Reinvestment Act is making an $80 billion down payment on a clean energy economy – with an $8 billion investment in innovation.
We should work together

“It was innovation in Muslim communities that developed the order of algebra; our magnetic compass and tools of navigation; our mastery of pens and printing; our understanding of how disease spreads and how it can be healed.”

President Obama
Cairo, 4 June 2009
Masdar is thinking big

Masdar City is exemplary in its use of clean energy technologies

It will house the Masdar Institute of Science and Technology and International Renewable Energy Agency

Masdar has launched two clean energy investment funds and is developing a world-class CCS network

Masdar City and the Department of Energy can collaborate in the development and testing of innovative technologies.
To achieve our energy and climate goals, we need to:

- Use energy more wisely
Energy savings is greater than all of US solar and wind energy generation.
New York Times Building
- Active shading
- Dimmable lighting
- New products developed to meet specs

Federal Building San Francisco
- Natural convection cooling (chimney effect)
- Exposed concrete provides thermal inertia
Buildings consume 40% of energy in U.S.: A new way of designing and constructing buildings.

Conceptual Design ➔ Detailed Design ➔ Virtual Building integration ➔ Construction & Installation ➔ Operation ➔ Continuous real-time commissioning

Computer-aided design tools with Embedded Energy Analysis

Computer-controlled operation with Sensors and Controls for Real-Time Optimization

- Oxygen sensor
- Air pressure sensor
- Air temperature sensor
- Engine temp. sensor
- Throttle position sensor
- Knock sensor
Buildings consume 40% of energy in U.S.: A new way of designing and constructing buildings.

Computer-aided design and operation will lead to enhanced comfort, energy savings and cost savings.

Energy Efficiency ⇔ Money Saved

- Oxygen sensor
- Air pressure sensor
- Air temperature sensor
- Engine temp. sensor
- Throttle position sensor
- Knock sensor
To achieve our energy and climate goals, we need to:

- Use energy more wisely
- Develop and deploy renewables and other low carbon technologies
UAE’s electricity use is soaring

UAE’s electricity consumption (billion kilowatt hours)

Electricity generation sources

Natural gas 98%

Oil 2%

EIA
UAE has tremendous solar resources

Masdar is leading the way
Separate cSi and Thin Film Learning Curves

Historical Prices

1980
$1 per kWh equivalent PV electricity cost

$1.00/W @ <20 GW

$1.00/W @ >100 GW

Production line size (Megawatts per Year)

0.5 (1980)
2

5 (2000)
3

50 (2005)
4

100 (2010)
10

Cumulative Production (MWp)

Module Price (2006 $ / Wp)

Note: Based on Module Purchase Price Not Manufactured Cost

Source: Adapted from National Renewable Energy Laboratory
Balance of System costs must also be reduced

Module Price
- 50-55% Improvement

BOS Price
- 59-69% Improvement

2012 BOS
- OH
- Project
- Electrical Install
- Mechanical Install
- Inverter
- 2007 BOS

2007
- Efficiency
- Low Cost Location
- Spending
- Throughput
- Scale
- 2012
As turbines increase in size and move offshore, long term reliability will become more important:

- $25 million blade testing facility
- $45 million drive train testing facility
Nuclear Fission provides carbon-free base-load power

President Obama recently approved a loan guarantee for the first new U.S. nuclear reactor in decades

We must address used fuel and nuclear waste issues

We must assure nuclear power does not lead to nuclear proliferation

This will require international cooperation and strengthening the Non-Proliferation Treaty

The U.S. – U.A.E. 123 Agreement reflects U.A.E.’s strong commitment to nonproliferation
To achieve our energy and climate goals, we need to:

• Use energy more wisely
• Develop and deploy renewables and other low carbon technologies
• Improve energy storage
As wind and solar energy sources become a greater part of our electricity supply, we will need large scale energy storage and a smart grid to respond to variable generation.

Pumped storage is 70% - 85% efficient

Compressed air can be ~ 60% efficient
To achieve our energy and climate goals, we need to:

Aggressively pursue transformative technologies and truly out-of-the-box ideas
The invention and industrial production of ammonia synthesis by Haber and Bosch made possible artificial fertilizers.

The Population Bomb (1968)

1960: Population = 3 B

Norman Borlaug awarded Nobel Prize

2005: Population = 6.5 B

Source: Food and Agriculture Organization (FAO), United Nations
Carbon Nanotube
Carbon Nanotube Breakthrough

ULTRA-HIGHLY PERMEABLE SMALL DIAMETER CARBON NANOTUBE

- Frictionless, Atomically Precise Pore
- Enhanced Flux 1,000-10,000X vs. Conventional Pores

LOW COST MEMBRANE ARCHITECTURE

- SuperFlux™
- 10X Higher Membrane Permeability vs. Today’s State of the Art

Water Passes More Freely Through the Membrane

Requiring 30-50% Less Energy
Aluminum refining requires millions of watts of power.
Electricity is used to convert dissolved metal salts (green) into magnesium (Mg) and antimony (Sb) metal ions.

Battery Charging mode

Discharge mode

Mg (blue) and Sb (yellow) ions return to dissolved salts.
"We came all this way to explore the moon and the most important thing is that we discovered the Earth."

Bill Anders, Apollo 8 Astronaut
Martin Luther King (1967):

“....We are now faced with the fact, my friends, that tomorrow is today. We are confronted with the fierce urgency of now. In this unfolding conundrum of life and history, there is such a thing as being too late.”