Sustainable Energy Generation: Is this Practical in the Short Term

Keynote Speech

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Slides will be available from:

www.saifurrahman.org/presentations

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Global/OECD Electricity Generation Mix

2011 (TWhr)

<table>
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<th>WORLD (22,126 TWh)</th>
<th>OECD (10,255 TWh)</th>
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<tbody>
<tr>
<td><strong>Combustible Fuels</strong></td>
<td>68%</td>
<td>62%</td>
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<tr>
<td><strong>Nuclear</strong></td>
<td>12%</td>
<td>20%</td>
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<tr>
<td><strong>Hydro</strong></td>
<td>16%</td>
<td>14%</td>
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<tr>
<td><strong>Others</strong></td>
<td>4%</td>
<td>4%</td>
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Combustible Fuels include coal, peat, oil and natural gas
Others include solar, wind, geothermal, biofuels and waste, and heat

Source: International Energy Agency (IEA) 2013 Key World Energy Statistics
Monthly Electricity Statistics for December 2012

Issues with Conventional Power Generation

- Fuel availability and location
- Water usage in power plants
- Environmental impacts of thermal power plants
- High voltage power transmission

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Why Is There This Interest in Renewables

Fukushima Dai-ichi Nuclear Power Plant, Japan

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Source: IPCC, 2011

Why Is There This Interest in Renewables

Take the average amount of water flowing over Niagara Falls in a minute. Now triple it. That’s almost how much water power plants in the United States take in for cooling each minute, on average.

Flickr/Williams Jr

Source: Union of Concerned Scientists, Nov 2011

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Source: IPCC, 2011
A 1000-MW coal fired power plant consumes 10.8 million gallons of water/day.

**2007 drought in southeastern US**


The utility was scrambling to keep the water intake system for its McGuire nuclear plant underwater.

In Alabama, the Browns Ferry nuclear plant had to drastically cut its output to avoid exceeding the temperature limit on discharge water and killing fish in the Tennessee River.
Energy-Related CO2 Emissions
By Country


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Emissions By Fuel Type

Global Energy-Related CO2 Emissions

Carbon Intensity


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Emissions By Country and Time

Emissions per person
Tonne of CO₂ equivalent per person
1950-1989 2011-2030

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<tr>
<th>Country</th>
<th>US</th>
<th>EU</th>
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<tr>
<td>China</td>
<td>9.5</td>
<td>3.2</td>
</tr>
<tr>
<td>21.9</td>
<td></td>
<td></td>
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<tr>
<td>16.7</td>
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Source: PBL Netherlands Environmental Assessment Agency (RIVM)

Emissions
Greenhouse gases, selected regions (Million tonnes CO₂ equivalent)

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Source: PBL Netherlands Environmental Assessment Agency (RIVM)

The long-term goal of transmitting power from the West to the East

Source: China Electric Power Research

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Germany Plans 3800-Kilometer, $25 Billion Transmission Network for Wind Power

The goal is to build 3800 kilometers (more than 2300 miles) of high-voltage lines—2100 km direct current lines and 1700 alternating current lines—stretching from the coasts of the Baltic and North Seas toward the southern parts of the country.


Opportunities from Renewables

- **Large-scale hydropower** – uncertain future
- **Low-head hydropower** may be easier to develop
- **Geothermal energy** is a small local contributor
- **Biomass** will present modest opportunities
- **Ocean Energy Systems** are in early stages
- **Wind and solar** will play more important roles
Wind Energy

Off-shore Wind turbines, Blyth, U.K.

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Global Installed Wind Capacity (MW)
1996-2013 (Cumulative)


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Future Wind Power Capacity (MW) 1997-2020

Top 10 Countries (Installed Wind Capacity) by December 2013

Wildorado Wind Ranch-Siemens

LOCATION: Wildorado, TX
25 miles west of Amarillo in Oldham, Potter and Randall Counties

SIZE: 161 MW

COMMERCIAL OPERATIONS
DATE: April 2007

UTILITY: Xcel Energy
(Southwestern Public Service Company)

TURBINE EQUIPMENT:
70 Siemens 2.3 MW Mk II

Source: http://www.cielowind.com/projects/completed-developments/wildorado-wind-ranch

Nysted Wind Farm-Siemens

Nysted Wind Farm, located in the Baltic Sea, is one of the world’s largest wind farms. Owner: DONG Energy, Denmark (80%) and E.ON Sweden (20%).

The wind farm is made up of 8 rows of 9 turbines, of which the nearest are placed some ten kilometers offshore.

Every turbine can generate an output of 2.3 MW. The combined effect is 165.6 MW.

Commercially handed over: Dec. 1st, 2004

Source: http://www.dongenergy.com/Nysted/EN/Pages/index.aspx
Wind Output & Load Mismatch (PJM)
(A peak day in June, 06/08/2011)


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ERCOT (Texas) Load vs Actual Wind Output
(10/11/2011 - 10/18/2011)

Data source: http://www.ercot.com/gridinfo/generation/windintegration/

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Solar Photovoltaics

Central Station Solar Photovoltaics

Roof-top Solar Photovoltaics

2012 Global Cumulative Installed PV Capacity (MW)

Source: EPIA Global Market Outlook for PV 2013-2017
Solar PV Applications

- Grid connected central station
- Roof-top applications
- Building Integrated PV (BIPV)
- Remote area applications

100 kW Grid-connected Project in China
Lehrter Train Station, Germany (BIPV)

Number of module: 1,440
Total area: 3,311 m²
PV output: 325 kW
Electricity generation: 274,000 kWh/yr

Source: http://www.cler.org/predac/article.php3?id_article=511

Roof-top Solar in Virginia, USA (BAPV)

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Roof-top Solar Photovoltaics in Japan

Source: EnergyBiz Magazine

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Remote Area Application in Bangladesh

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Hydroelectricity

Three Gorges Dam in China
Environmental Impacts of Hydro Power Plants

Flooding of trees and other biomass from damming of rivers causes significant CO2 impacts

Flooded vegetation loses its ability to absorb CO2

The rotting biomass releases significant amounts of methane, a greenhouse gas.
CHAPTER THREE

Resettlement Plans for China's Three Gorges Dam

by Philip M. Fearnside, Ph.D.

The Three Gorges Project would produce the world's largest dam-displaced population (500,000 – 1,200,000 people), even at the lowest reservoir operating level nominally under consideration. Other Chinese dams have forced major resettlements – for example, the Danjiangkou Dam on the Han River (380,000), and the Sanmenxia Dam on the Yellow River (320,000). Outside China, the governments of Egypt and Sudan displaced 100,000 people to make way for the Aswan High Dam.

Source: http://journal.probeinternational.org/three-gorges-probe/

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Societal Impacts

Population movement
New housing
Employment
Schools/hospitals/recreational facilities
Pumped Storage Hydro


Past Mistakes
Lessons for the Future

Each hydropower project is an ambassador for the whole sector.
Levelized Cost of Electricity

Source: IPCC, 2011

Integration of Renewables

Why some countries are more successful than others in integrating renewables into the electricity generation mix?
Types of Programs to Encourage Renewables Penetration

- Renewable Portfolio Standards (RPS)
- Feed-in Tariff (FIT)
- Grid parity plus upfront incentive


Renewable Portfolio Standards (RPS)

State regulators mandate certain percentage of renewables mix in generation

For Example,

**California 2020**: 20% non-hydro renewables mix by 2020

**EU**: 20-20-20 (RE-EE-CO2)
Feed-in Tariff (FIT)

FIT is a renewable energy policy that offers **guaranteed payments** to renewable energy developers for the electricity they produce.

FITs are responsible for approximately 75% of global PV and 45% of global wind deployment.

India: Grid Parity Plus Incentive (Launched – 2013)

Wholesale PV purchase price is same as blended grid-level supply price

Add one-time incentive that is competitive
Challenges for Renewable Energy Technologies

Intermittency
Unpredictability
Cost

BPA Total Wind Generation and 3-day Ahead Forecasts (May 18-20, 2011)

Data source: BPA
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Minute-by-minute Variations in a 150MW Wind Farm Output in Texas, 2008

Wind output can drop 43.7 MW in 1 minute for a single 150-MW wind farm

10-minute Variations in a 150MW Wind Farm Output in Texas, 2008

Wind output can drop 113 MW in 10 minutes, and increase 106 MW in 10 minutes
Possible Solutions

Storage
Battery (NaS)
Compressed Air Energy Storage (CAES)
Demand response

Demand Response: A broader definition

“Demand Response is a customer action to control load to meet a certain target. Here the customer chooses what load to control and for how long”.

This is different from Demand Side Management (DSM) where the load is controlled by the electric utility and the customer has no control beyond the initial consent.
Teaching Opportunity

Renewable energy
Grid interconnection issues
Power systems
Power electronics
Controls, Communications, Computers

Research Opportunity

Grid Related:

Grid integration
Grid-scale storage
Large scale transmission optimization

Distribution Level: (generally require industry collaboration)

Electric vehicle charging infrastructure
Smart Grid
Micro-grid demonstration
Energy efficiency
Renewable energy projects
Sustainable Energy Generation: Is this Practical in the Short Term?

So, what is the Answer?

Short-term outlook

- Renewable energy plants are compared to legacy large thermal power plants
- Fossil and nuclear plants' environmental impacts are not quantified
- The economics is currently unfavourable for renewables
- But citizens remain suspicious about the safety of nuclear power plants and are concerned about greenhouse gas emissions
- Citizen awareness and desire for change will drive government policies towards renewables
Thank you

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