

# Sustainable Energy Generation: Is this Practical in the Short Term

## Keynote Speech

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PES ISGT Asia  
21 May 2014  
Kuala Lumpur, Malaysia

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**Slides will be available from:**

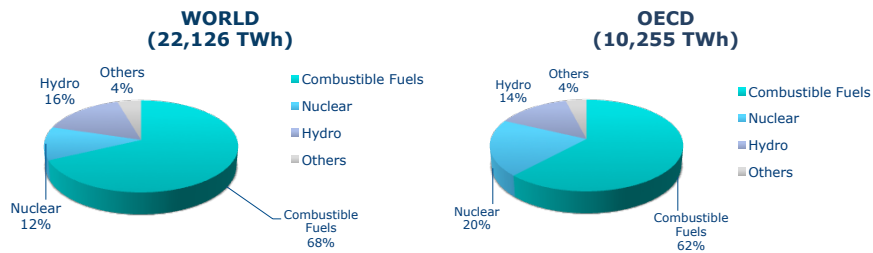
[www.saifurrahman.org/presentations](http://www.saifurrahman.org/presentations)

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2

## Global/OECD Electricity Generation Mix 2011 (TWhr)



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

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## 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

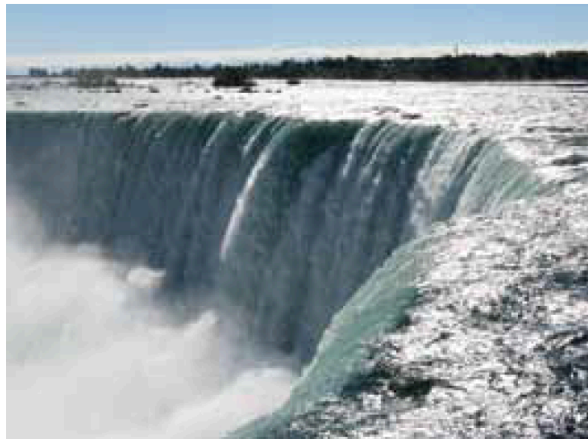


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## Why Is There This Interest in Renewables

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\_Jt

Source: Union of Concerned Scientists, Nov 2011

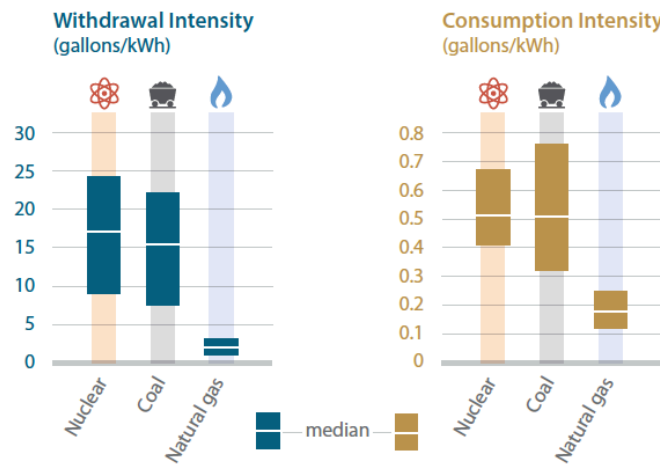
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Source: IPCC, 2011

## Freshwater usage by US Power Plants

A 1000-MW coal fired power plant consumes 10.8 million gallons of water/day



Source: Union of Concerned Scientists, Nov 2011

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7

## Impacts of Water Shortage

### 2007 drought in southeastern US

Duke Energy cut the output at its G.G. Allen and Riverbend coal plants on the Catawba River. **Customers faced blackouts**

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

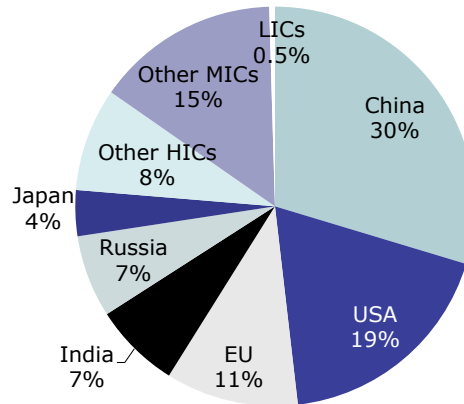
In Alabama, the Browns Ferry nuclear plant had to drastically cut its output to avoid exceeding the temperature limit on discharge water and killing fish in the Tennessee River.

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8

## Energy-Related CO<sub>2</sub> Emissions By Country



Source: IEA CO<sub>2</sub> Emissions from Fuel Combustion Statistics (2012)

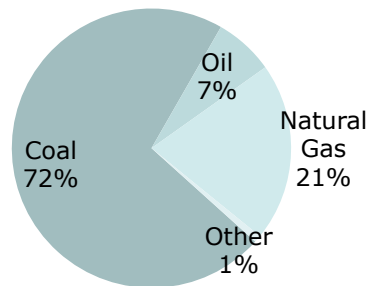
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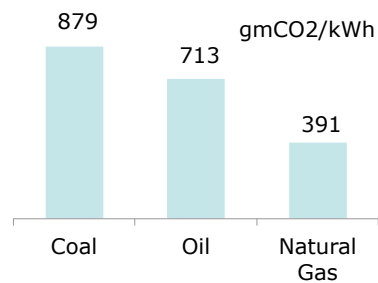
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## Emissions By Fuel Type

### Global Energy-Related CO<sub>2</sub> Emissions



### Carbon Intensity



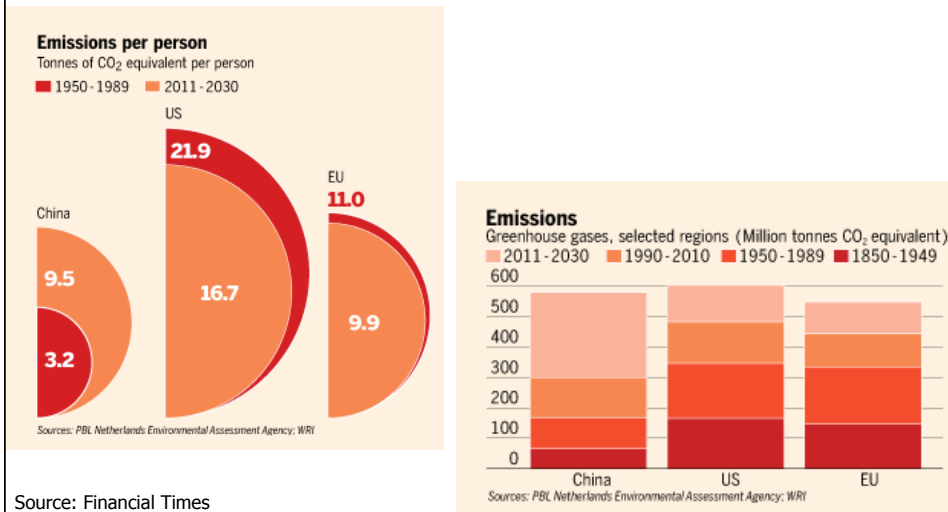
Source: IEA CO<sub>2</sub> Emissions from Fuel Combustion Statistics (2012)

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10

# Emissions By Country and Time

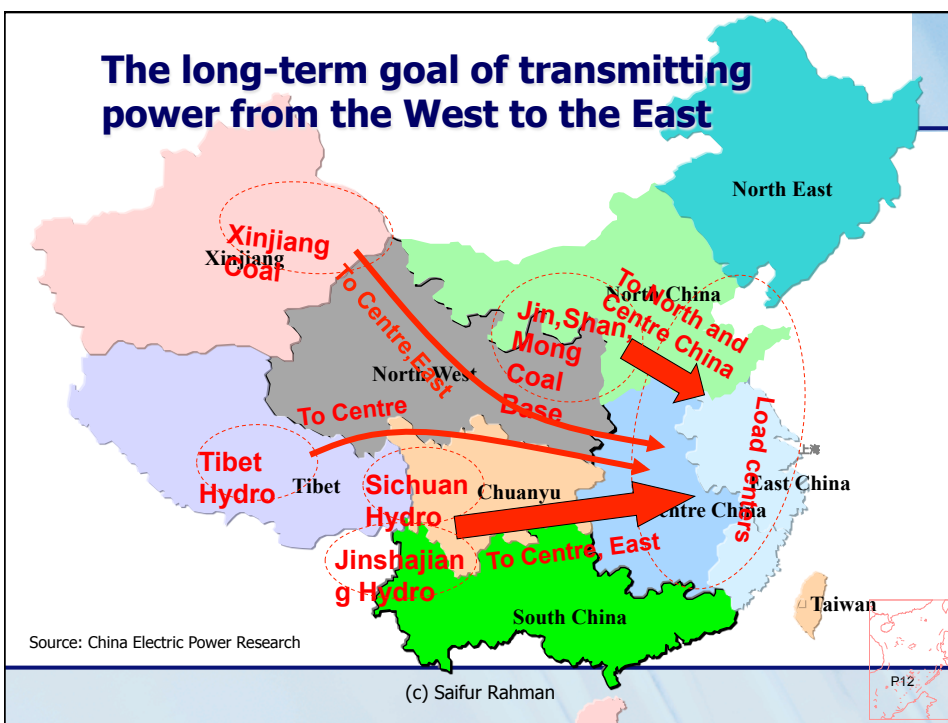


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11

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



## 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.

Source: IEEE Spectrum, May 2012

## 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



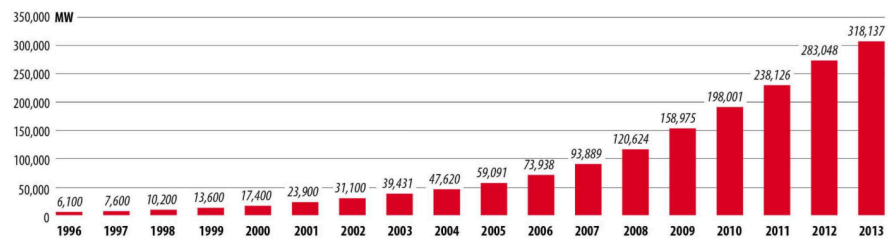
## Wind Energy

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

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15

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

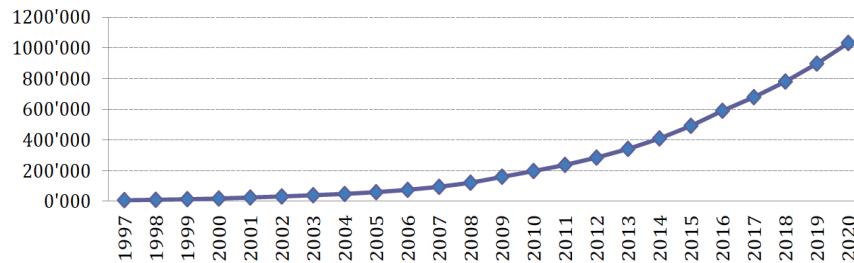


Source: Global Wind Energy Council, Global Wind Statistics (2013)

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## Future Wind Power Capacity (MW) 1997-2020

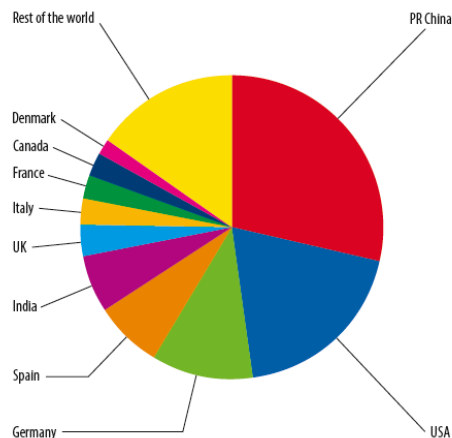


World Wind Energy Association, World Wind Energy Report 2012

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## Top 10 Countries (Installed Wind Capacity) by December 2013



Source: Global Wind Energy Council, Global Wind Statistics (2013)

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## Wildorado Wind Ranch-Siemens



Source: <http://www.nikkiphography.com/category/environmental-issues/>  
<http://www.cielowind.com/projects/completed-developments/wildorado-wind-ranc>

**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

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## 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.**

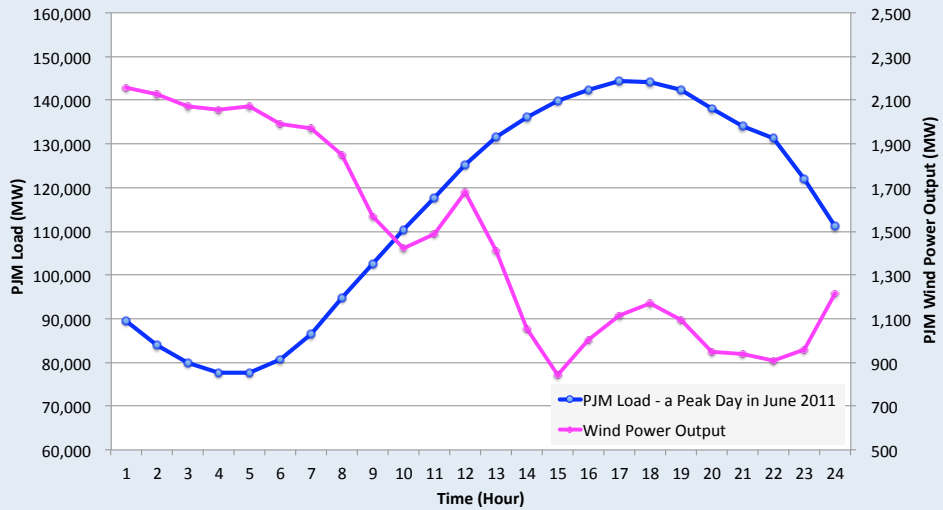
**Commercially handed over: Dec. 1<sup>st</sup>, 2004**

<http://www.dongenergy.com/Nysted/EN/Pages/index.aspx>

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## Wind Output & Load Mismatch (PJM)

(A peak day in June, 06/08/2011)

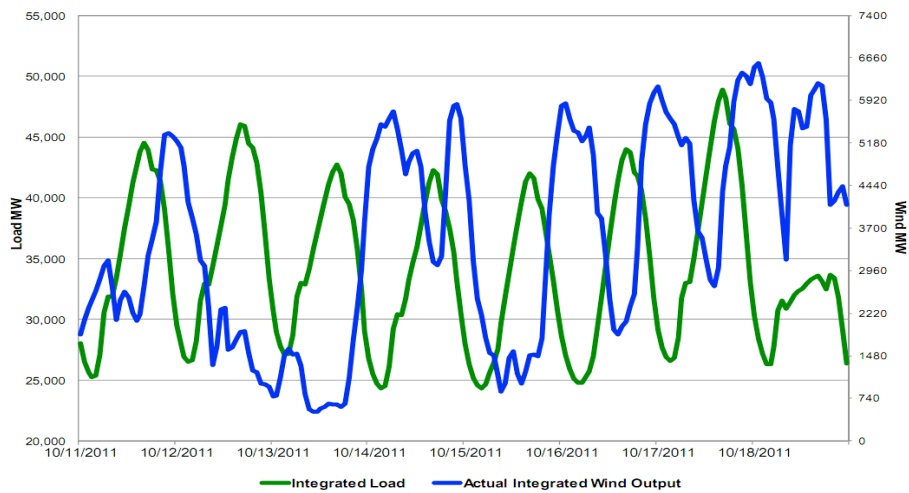


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21

## ERCOT (Texas) Load vs Actual Wind Output

(10/11/2011 - 10/18/2011)



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22

# Solar Photovoltaics



Central Station Solar Photovoltaics

Roof-top Solar Photovoltaics

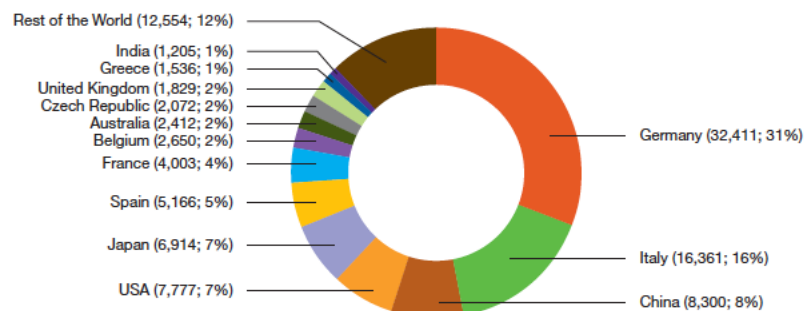


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23

## 2012 Global Cumulative Installed PV Capacity (MW)



Source: EPIA Global Market Outlook for PV 2013-2017

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24

## Solar PV Applications

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

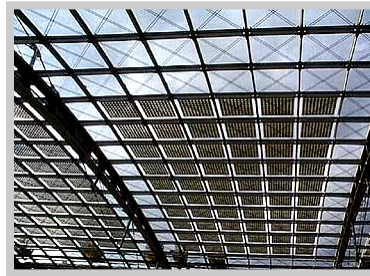
## 100 kW Grid-connected Project in China



## Lehrter Train Station, Germany (BIPV)



Number of module: 1,440  
Total area: 3,311 m<sup>2</sup>  
PV output: 325 kW  
Electricity generation:  
274,000 kWh/yr



Source: [http://www.cler.org/predac/article.php3?id\\_article=511](http://www.cler.org/predac/article.php3?id_article=511)

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27

## 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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30

# Hydroelectricity



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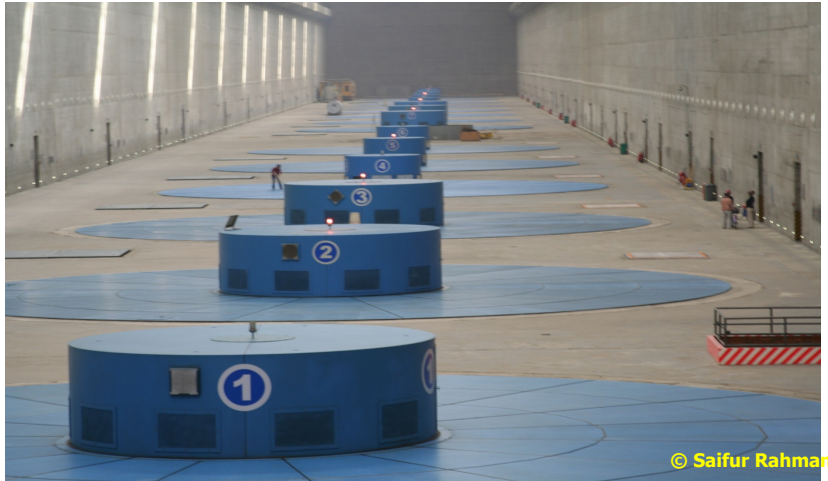
## Three Gorges Dam in China



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$$26 \times 700 = 18,200 \text{ MW}$$



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33

## Environmental Impacts of Hydro Power Plants

FLOODING OF TREES AND OTHER BIOMASS FROM DAMMING OF RIVERS CAUSES SIGNIFICANT CO<sub>2</sub> IMPACTS

FLOODED VEGETATION LOSES ITS ABILITY TO ABSORB CO<sub>2</sub>

THE ROTTING BIOMASS RELEASES SIGNIFICANT AMOUNTS OF METHANE, A GREENHOUSE GAS.

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34

# Societal Impacts of Large Hydropower



Edited by Margaret Barber and Grainne Ryder

## Contents

[Acknowledgements](#)  
[About the Contributors](#)  
[Foreword to 1st Edition](#)  
[Foreword to 2nd Edition](#)  
[Editors' Note to 2nd Edition](#)  
[Edition](#)  
[Introduction](#)

[Back to Chapter 2](#)

## 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).<sup>1</sup> 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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35

# Societal Impacts

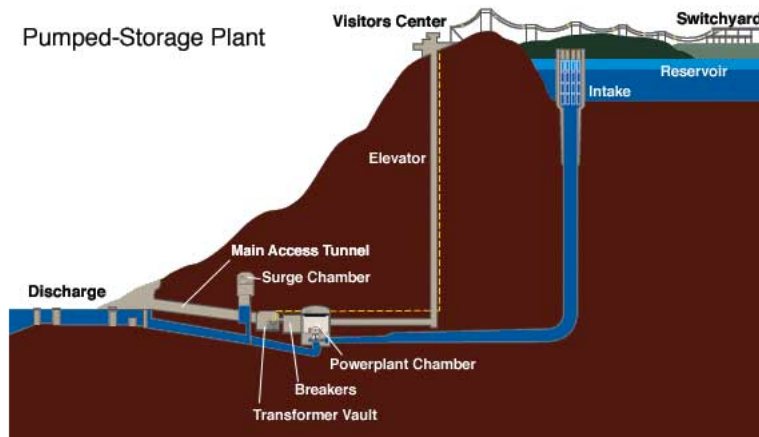
**Population movement**  
**New housing**  
**Employment**  
**Schools/hospitals/recreational facilities**

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36

## Pumped Storage Hydro



Source: [http://en.wikipedia.org/wiki/File:Pumpstor\\_racoon\\_mtn.jpg](http://en.wikipedia.org/wiki/File:Pumpstor_racoon_mtn.jpg)

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37

## Past Mistakes Lessons for the Future



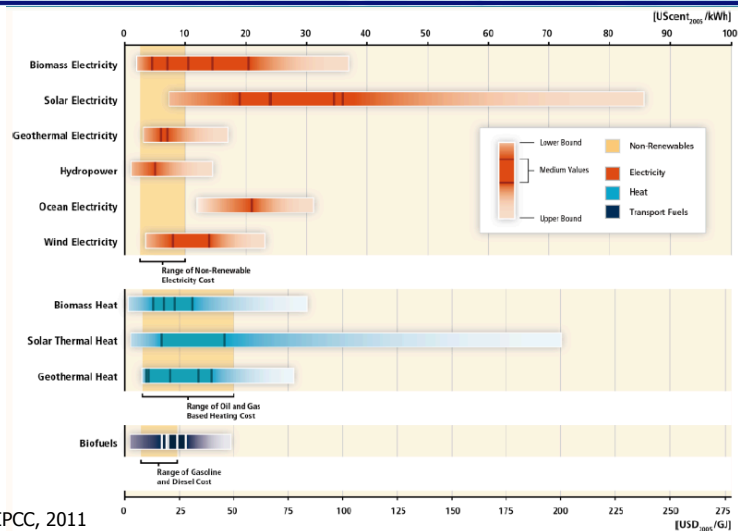
Each hydropower project is an ambassador for the whole sector.

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38

## Levelized Cost of Electricity



Source: IPCC, 2011

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Source: IPCC, 2011

## Integration of Renewables

Why some countries are more successful than others in integrating renewables into the electricity generation mix ?

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## Types of Programs to Encourage Renewables Penetration

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

Source: International Energy Agency (IEA Statistics 2007 data, available as of September 2010)

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41

## 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)

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42

## 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

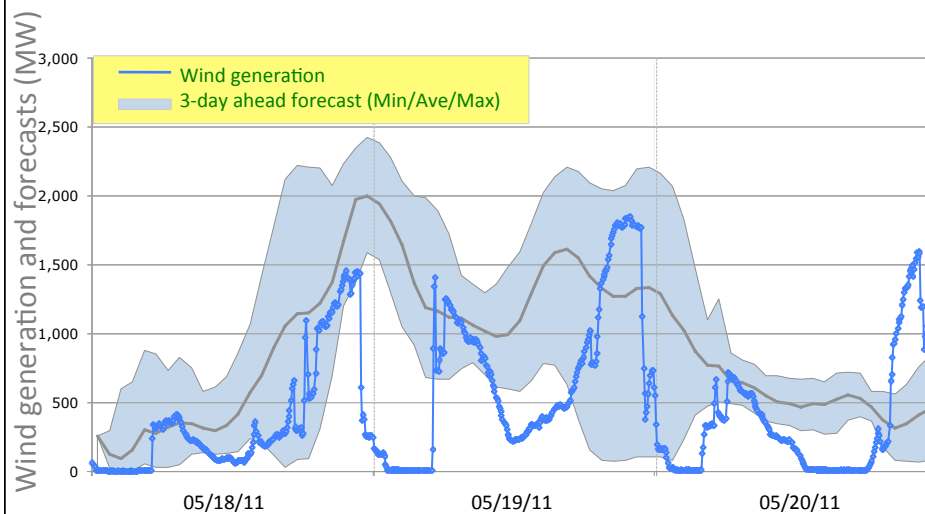
Add one-time incentive that is competitive

## Challenges for Renewable Energy Technologies

Intermittency  
Unpredictability  
Cost

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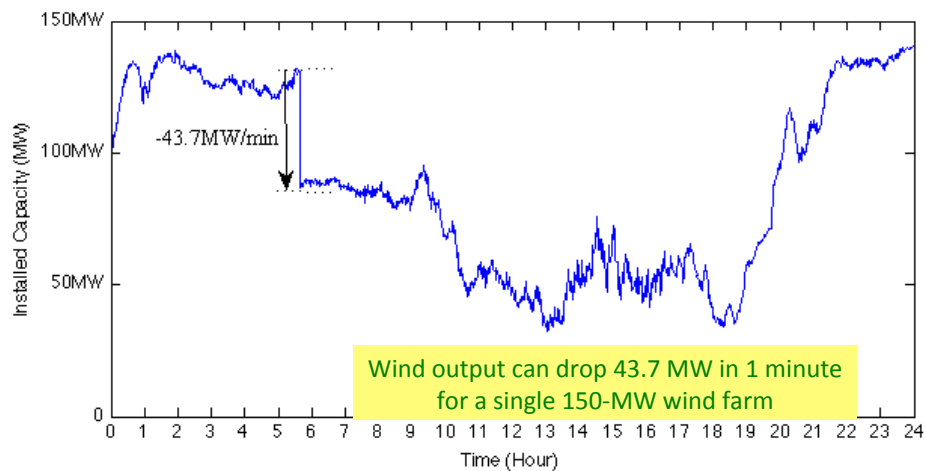
## BPA Total Wind Generation and 3-day Ahead Forecasts (May 18-20, 2011)



Data source: BPA

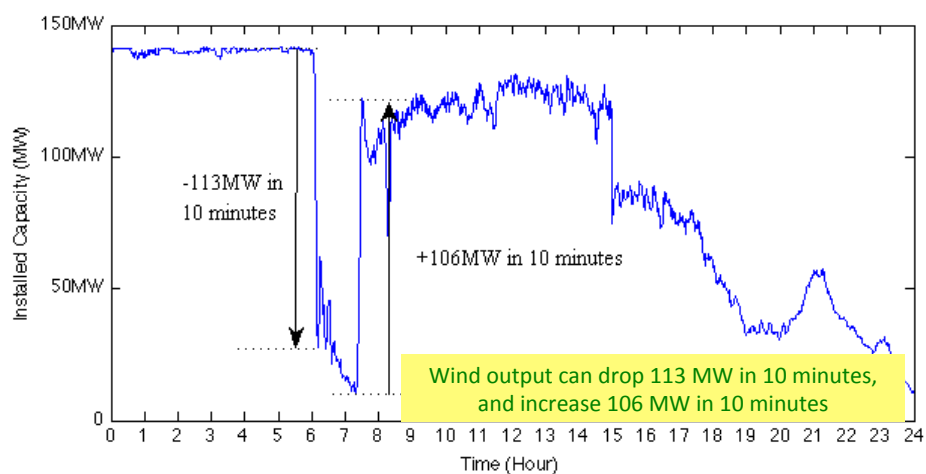
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## Minute-by-minute Variations in a 150MW Wind Farm Output in Texas, 2008



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



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## Possible Solutions

Storage

Battery (NaS)

Compressed Air Energy Storage (CAES)

Demand response

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## 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.

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## Teaching Opportunity

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

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## 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

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## Sustainable Energy Generation: Is this Practical in the Short Term ?

So, what is the Answer ?

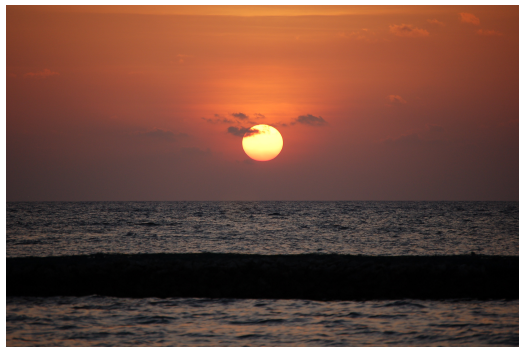
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### Short-term outlook

- 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

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Thank you



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