Why Energy from Alternative Sources?

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Outline

✓ Introduction  
✓ Combatting CO2  
✓ Why energy from alternative sources?  
✓ Energy basics  
✓ Overview of energy production  
✓ Wind energy  
✓ The future of wind energy

US Energy Information Administration Model

The US Energy Information Administration (EIA) predicts a 56% rise in worldwide energy consumption from 2010 to 2040.

Why Wind Energy?

a) Environment  
b) Finite supply of fossil fuels  
c) Lack of substitutes  
d) Good for economy
The Problem

Burning fossil fuels containing carbon produces carbon dioxide:

\[ C + O_2 \rightarrow CO_2 \] (Combustion)

+ NOx + SOx + Hg + ...

Combating CO2

Sustainable

“Meeting our needs without compromising the ability of future generations to meet their own needs”

United Nations Commission on Environment and Development (UNCED)
“Our Common Future”, 1987

Dakotas Gasification Co.
Beulah, ND
**Fuel Basics**

Volumetric Energy Density of Fuels (Fuels in their Liquid State)

**Zero Emission Combustion**

- Only hydrogen and ammonia burn without emitting greenhouse gases (contain no carbon)
- Also, no CO, SOx, or NOx
- **Hydrogen combustion:**
  \[ \text{H}_2 + \text{O}_2 \rightarrow \text{H}_2\text{O} \]
  (water only combustion product)
- **Ammonia combustion:**
  \[ 4\text{NH}_3 + 3\text{O}_2 \rightarrow 2\text{N}_2 + 6\text{H}_2\text{O} \]
  (nitrogen and water only combustion products)

**Hydrogen Can Be Stored Underground at Low Cost**

- Current Hydrogen Storage
- Natural Gas Stored Underground

**Island for Storing Wind Energy to be Built in Belgium**

- Island for storing excess wind energy to be built in Belgium
Fuel Cell

Solar Energy

Stirling Energy Systems, Inc.
Model solar thermal power plant, NM Completed May 2005

Photovoltaic

Photovoltaic (PV)
- Small
- Medium
- Large

Recent advances
http://www.solyndra.com

Hydrogen Potential from Solar and Wind Resources
Total kg of Hydrogen per County normalized by County Area

Total solar: \(~ 3 \times 10^{14}\) kg / yr
Total wind: \(~ 3 \times 10^{11}\) kg / yr

This analysis shows the hydrogen potential from combined renewable resources—wind and solar. Selected environmental and land use exclusions were applied. See additional documentation for more information.
Geothermal Resources

Geothermal

Nesjavellir Power Plant, Iceland; 90 MW

Hydro

Hoover Dam

Dry Biomass
1/22/2015

Wet Biomass: Anaerobic Digester

Photobiological

Rhodobacter sphaeroides

Algae

Chlamydomonas reinhardtii

Photo: Tasios Melis, PhD, UC Berkeley

Ratings of Energy Sources

Best to worst sources of electric power:
- Wind power
- Concentrated solar power (CSP)
- Geothermal power
- Tidal power
- Solar photovoltaics (PV)
- Wave power
- Hydroelectric power
- A tie between nuclear power and coal with carbon capture and sequestration (CCS)

http://www.sciencedaily.com

Best to worst vehicle options:
- Wind BEVs (battery electric vehicles)
- Wind HFCVs (hydrogen fuel cell vehicles)
- CSP BEVs
- Geothermal BEVs
- Tidal BEVs
- Solar PV BEVs
- Wave BEVs
- Hydroelectric BEVs
- A tie between nuclear BEVs and coal-CCS BEVs
- Corn-E85
- Cellulose-E85
- Coal-CCS BEVs (tied with nuclear-BEVs)

http://www.sciencedaily.com
Wind Energy

Wind, water, and sun are cleaner energy sources than biofuels, nuclear, and coal

Example

A battery-powered U.S. vehicle fleet could be charged by energy produced by 73,000 to 144,000 five-megawatt (5MW) wind turbines.

FYI: US has produced 300,000 airplanes during World War II. Many agree that wind turbines are easier to build than airplanes.

http://www.sciencedaily.com

World’s Wind Energy Production


Wind Resources: Iowa

http://www.energy.iastate.edu/Renewable/wind/maps-index.htm

Horizontal Axis Turbine

Large wind
**Vertical Axis Turbine**

Small wind

**Vertical Axis**

1.8 KW

Nheowind 3D 50

Small wind

Nheowind 3D 100 3.5 KW

http://www.nheolis.com/en

**Limiting Factors: Infrastructure**

Wind Energy: Transmission Lines

**Limiting Factors: Infrastructure**

Hydrogen: Distribution Network
Distribution of Energy in Future

What is a Wind Turbine?

A wind turbine converts wind (fuel) energy into electricity. It is the opposite of a fan that uses electricity to produce wind.

In the wind turbine, the wind turns the blades, which spin a shaft connected to a generator and generates electricity. The electricity is transmitted to a substation and then to the electric grid.

Basic Wind Power Equation

Power contained in the wind:

\[ P = 0.5 \times \rho \times A \times v^3 \]

- \( P \) = power
- \( \rho \) = air density
- \( A \) = rotor swept area, exposed to the wind
- \( v \) = wind speed
Power Produced by the Turbine

\[ P = 0.5 \times \rho \times A \times v^3 \times E \]

where: 
- \( E \) = Wind Turbine System Efficiency
- \( E_{\text{rotor}} \times E_{\text{gear}} \times E_{\text{generator}} \times E_{\text{power converter}} \)

States by Wind Energy Potential

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What Would it Take?

California Study

Scientific American, Nov 2009, p. 63

What Would it Take?

- The authors' plan calls for 3.8 million large wind turbines, 90,000 solar plants, and numerous geothermal, tidal and wavepower offshore installations worldwide.
- The cost of generating and transmitting power would be less than the projected cost per kilowatt-hour for fossil and nuclear power.
- Shortages of a few specialty materials, along with lack of political will, doom as the greatest obstacles.

Scientific American, Nov 2009, p. 59
**Did You Know It?**

- An average U.S. household uses about 10,655 kWh of electricity per year
- 1 MW of wind energy powers 225 - 300 households

http://www.awea.org
Wind Energy and Transportation

- Battery charging
  Lithium-ion battery replacing the nickel-metal-hydride battery used in many currently operating hybrid vehicles

  **Advantage:**
  - Durability
  - Reliability
  - Suitability for plug-in vehicle

  **Disadvantage:**
  - Cost (about $10k per battery in 2008)

- Hydrogen production
  Use of offshore wind energy platforms (similar to oil rigs) to produce hydrogen applied, e.g., as transportation fuel

Wind Energy Information

- American Wind Energy Association (AWEA)

- National Renewable Energy Laboratory (NREL)

- Iowa Energy Center (IEC)
  [http://www.energy.iastate.edu/renewable/wind/wem-index.htm](http://www.energy.iastate.edu/renewable/wind/wem-index.htm)

Software

- Wind Farm Design Software
  [http://awsopenwind.org](http://awsopenwind.org)

- Winnipeg, Manitoba, Canada
  [https://pscad.com/home/](https://pscad.com/home/)
  [https://pscad.com/success_stories/energy_utilities/windfarmrush](https://pscad.com/success_stories/energy_utilities/windfarmrush)
  [https://pscad.com/success_stories/research/kinetic_turbine_power_converter](https://pscad.com/success_stories/research/kinetic_turbine_power_converter)
  [https://pscad.com/products/pscad/simulations/#Sim1](https://pscad.com/products/pscad/simulations/#Sim1)

- NREL

- Turbine design
  [http://www.wmc.eu/focus.php](http://www.wmc.eu/focus.php)

- General simulators

Software

- WindSim
  [www.windsim.com](http://www.windsim.com) Downloadable demos

- WindFarm
  [www.resoft.co.uk](http://www.resoft.co.uk)
Good News (1)

In May 2008, the U.S. Department of Energy reported that wind could provide 20% of U.S. electricity by 2030, supporting 500,000 jobs and reducing greenhouse gas emissions as much as taking 140 million vehicles off the road, and saving 4 trillion gallons of water (a 40-year supply for the city of Phoenix).

The January 20th 2009 policy is to ensure that 10% of our electricity is generated from renewable sources by 2012, and 25% by 2025

www.NewWindAgenda.org

Good News

EPA: Green Power Partnership
http://www.epa.gov/greenpower/toplists/index.htm

Check out who is there

- National Top 50
- Top 100 Purchasers
- Top 50 Retail
- Fortune 500
- Top 10 Federal Government
- Top 20 Local Government
- Top 20 College & University

Conclusion

- Non-fossil fuel option is feasible
- Many options are available
- Wind energy is to stay for an extended time
- Major advantage: Free fuel
- The rate growth in wind energy is 20% - 40% a year
- Exciting area to research and work