Why Energy from Alternative Sources?

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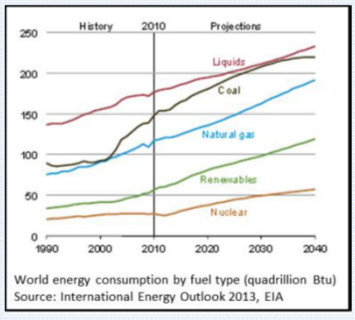
Outline

- ✓ Introduction
- ✓ Combating CO_2
- ✓ Why energy from alternative sources?
- ✓ Energy basics
- ✓ Overview of energy production
- ✓ Wind energy
- ✓ The future of wind energy

US Energy Information Administration Model



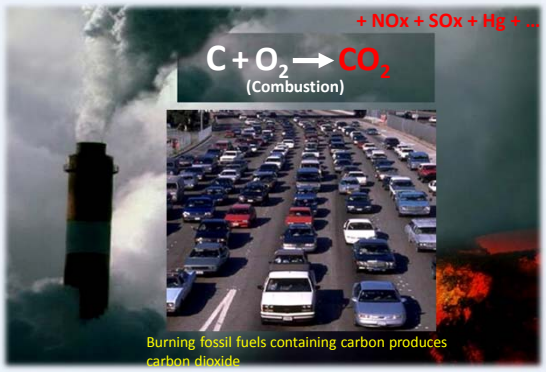
World energy consumption by fuel type (quadrillion Btu)
Source: International Energy Outlook 2013, EIA

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

Why Wind Energy?

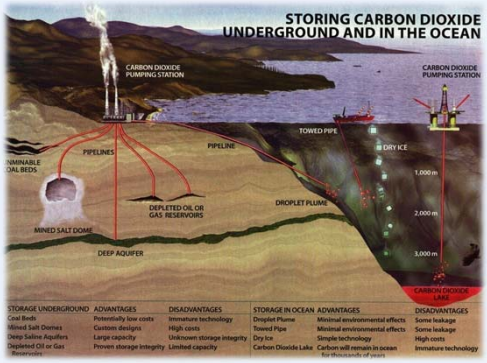
a) *Environment*
b) *Finite supply of fossil fuels*
c) *Lack of substitutes*
d) *Good for economy*

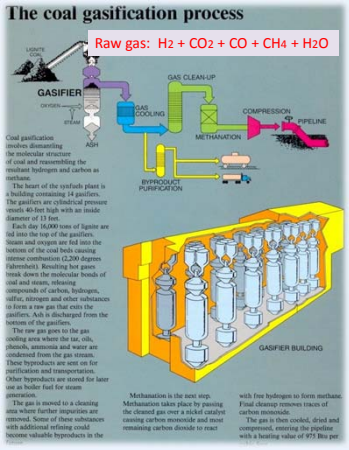
The Problem



Combating CO_2

CO_2 sequestration





Combating CO_2

Dakotas Gasification Co.

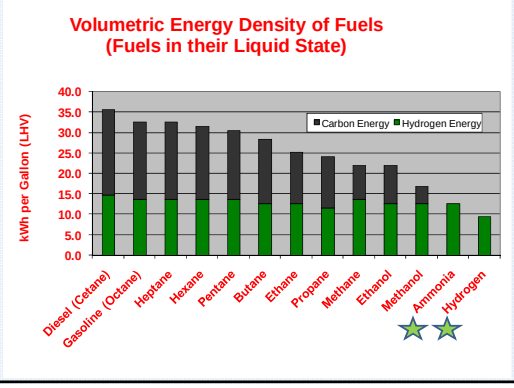
Beulah, ND

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

Fuel Basics



Zero Emission Combustion

- Only hydrogen and ammonia burn without emitting greenhouse gases (contain no carbon)
- Also, no CO, SOx, or NOx
- Hydrogen combustion:

$$H_2 + O_2 \rightarrow H_2O$$

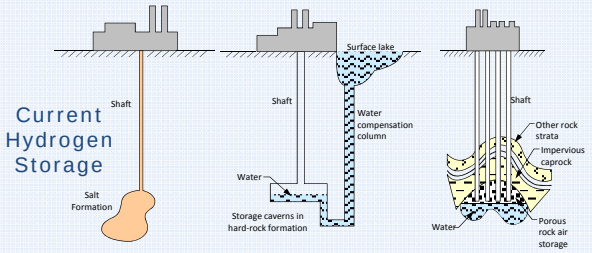
(water only combustion product)

- Ammonia combustion:

$$4NH_3 + 3O_2 \rightarrow 2N_2 + 6H_20$$

(nitrogen and water only combustion products)

Hydrogen Can Be Stored Underground at Low Cost

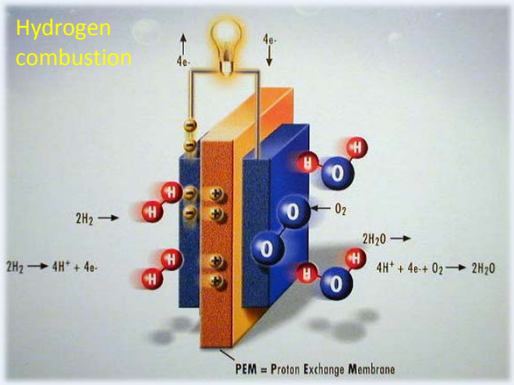


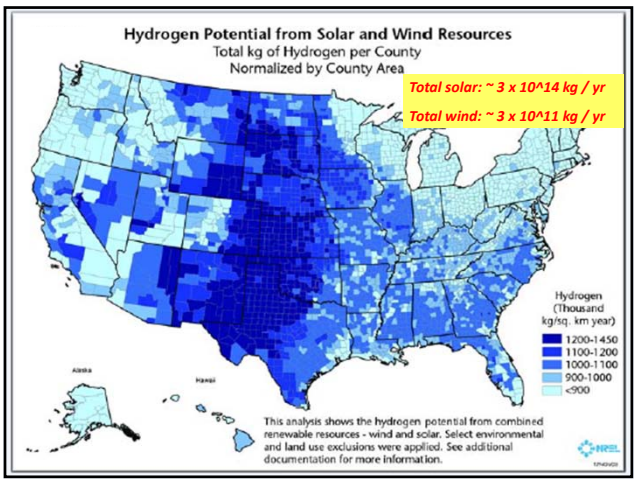
Natural Gas Stored Underground

Island for Storing Wind Energy to be Built in Belgium

http://www.renewableenergyworld.com/rea/news/article/2013/01/belgium-plans-to-build-island-to-store-excess-wind-energy?cmpid=WNL-Wednesday-January23-2013

Fuel Cell

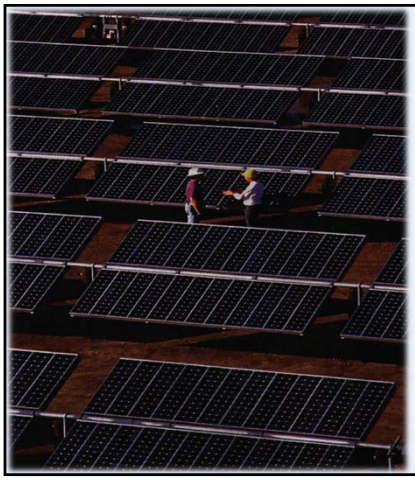




Solar Energy

Stirling Energy Systems, Inc.

Model solar thermal power plant, NM Completed May 2005



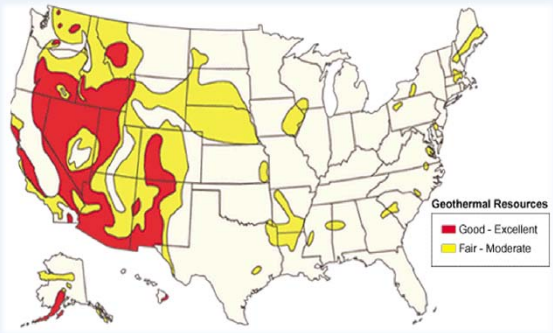
Photovoltaic

Photovoltaic (PV)

- Small
- Medium
- Large

Recent advances
http://www.solyndra.com

Geothermal Resources



Geothermal

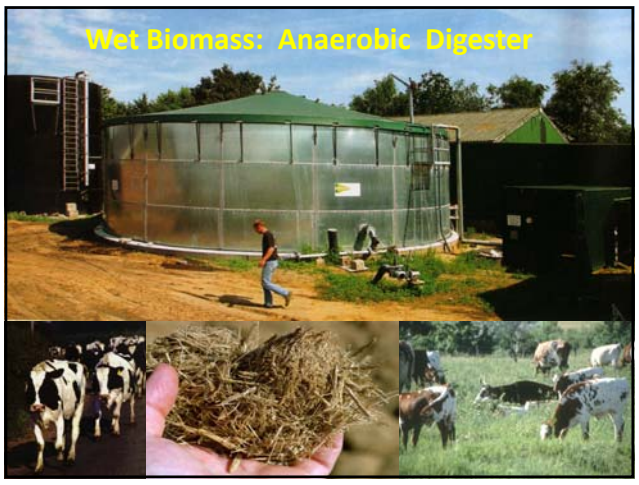
Nesjavellir Power Plant, Iceland; 90 MW

Hydro

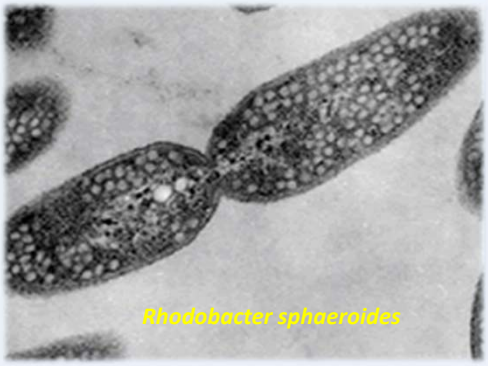
Hoover Dam

Dry Biomass

Wet Biomass: Anaerobic Digester



Photobiological



Algae

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)

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 coal-CCS-BEVs (tied with nuclear-BEVs)
- ✓ Corn-E85
- ✓ Cellulosic-E85

http://www.sciencedaily.com

Wind Energy

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

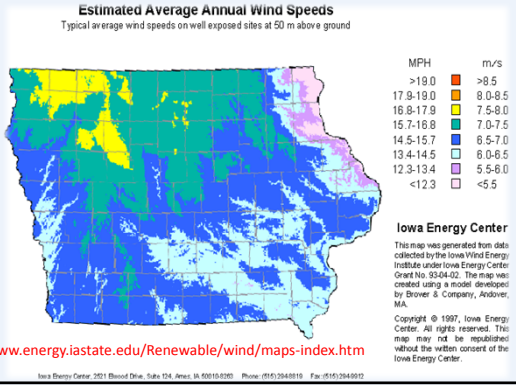
Example

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.

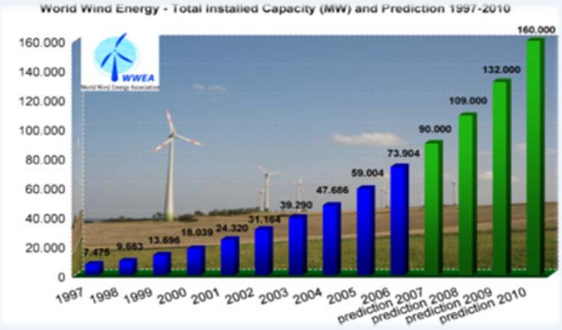
http://www.sciencedaily.com

Wind Resources: Iowa



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

World's Wind Energy Production



http://www.midamericanenergy.com/wind/html/default.asp

Horizontal Axis Turbine

Large wind

Wind Farms

Wind parks

Wind Turbine Manufacturing

Wind Turbine Manufacturing

Blade

Wind Turbine Manufacturing

Blade

Vertical Axis Turbine

Small wind

Vertical Axis

Small wind

Nheowind 3D 100 3.5 KW

http://www.nheolis.com/en

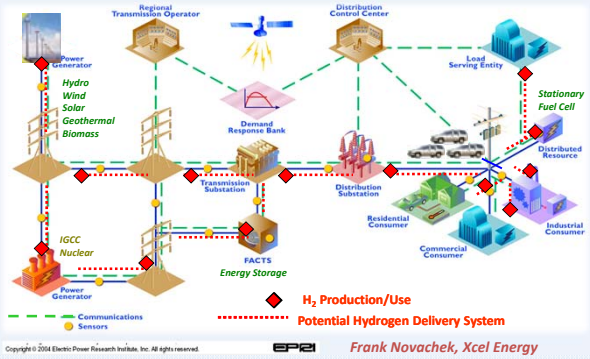
Limiting Factors: Infrastructure

Wind Energy: Transmission Lines

Limiting Factors: Infrastructure

Hydrogen: Distribution Network

Distribution of Energy in Future



Frank Novachek, Xcel Energy

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.

Wind Turbine

http://www.galileoscientific.com/wind_energy.jpg

Basic Wind Power Equation

Power contained in the wind:

$$P = 0.5 \times \rho \times A \times v^3$$

P = power
ρ = air density
A = rotor swept area, exposed to the wind
v = wind speed

Power Produced by the Turbine

$$P = 0.5 \times \rho \times A \times v^3 \times E$$

$$E = E_{rot} \times E_{ger} \times E_{gen} \times E_{p\text{-}conv}$$

where: E = **Wind Turbine System Efficiency**
= **ERotor x EGearbox x EGenerator x E PowerConverter**

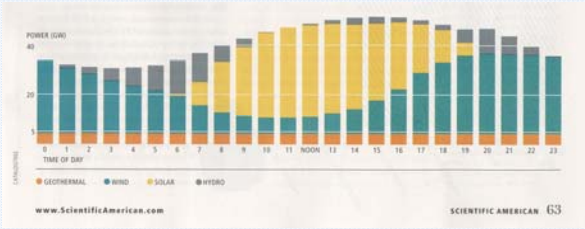
States by Wind Energy Potential

State	Capacity Ranking	Wind Capacity (MW)	Under Construction	Wind Energy Potential Ranking	Wind Energy Potential: Average Power Output (MW)	Wind Energy Potential: Annual kWh:
North Dakota	14	344.77	327	1	138,400	1,210 B
Texas	1	5,604.65	3,162.35	2	136,100	1,190 B
Kansas	12	465	548.5	3	121,900	1,070 B
South Dakota	20	98.26	141	4	117,200	1,030 B
Montana	17	165.03	*	5	116,000	1,020 B
Nebraska	22	73.38	81	6	99,100	868 B
Wyoming	13	349.35	109.2	7	85,200	747 B
Oklahoma	10	689	18.9	8	82,700	725 B
Minnesota	4	1,366.15	249.5	9	75,000	657 B
Iowa	3	1,375.28	1,586.6	10	62,900	551 B
Colorado	6	1,066.75	0	11	54,900	481 B
New Mexico	11	495.98	100	12	49,700	435 B
Idaho	21	75.32	71.4	13	8,290	73 B
Michigan	25	55.39	60	14	7,460	65 B
New York	9	706.8	588.5	15	7,080	65 B
Illinois	8	735.66	171	16	6,980	61 B
California	2	2,483.83	295	17	6,770	59 B
Wisconsin	15	327.25	121.65	18	6,440	56 B
Maine	26	42.1	57	19	6,390	56 B
Missouri	18	162.5	0	20	5960	52 B

Wind Today, Vol. 3, No. 3, 2008

What Would it Take?

California Study



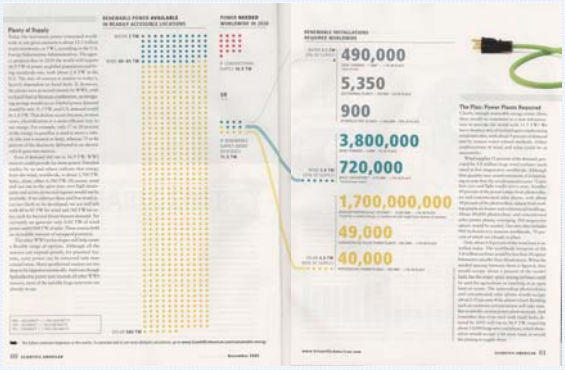
Scientific American, Nov 2009, p. 63

What Would it Take?

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

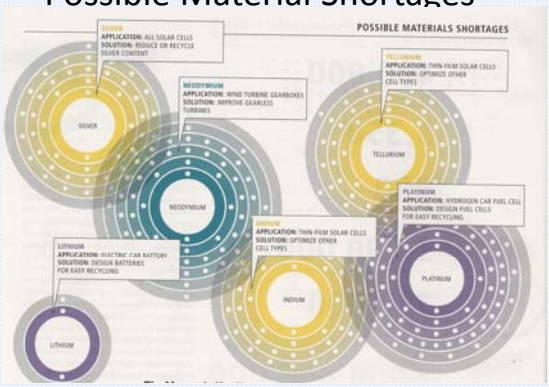
Scientific American, Nov 2009, p. 59

What Would it Take?



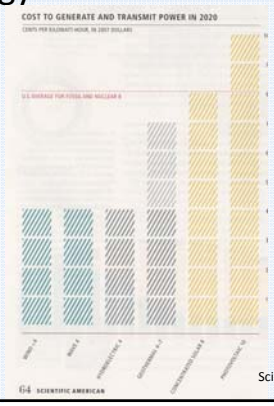
Scientific American, Nov 2009, p. 60

Possible Material Shortages



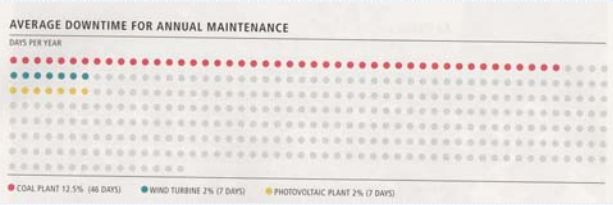
Scientific American, Nov 2009, p. 62

Energy Generation Cost in 2020



Scientific American, Nov 2009, p. 64

Technology Reliability

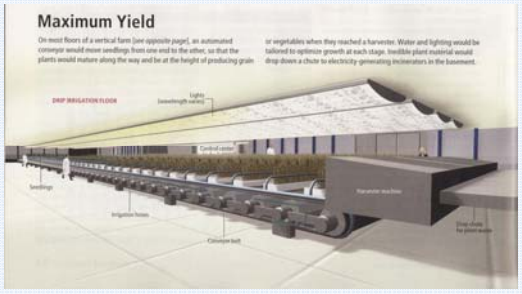


Scientific American, Nov 2009, p. 63

Closing the Loop

Scientific American, Nov 2009, p. 85

Closing the Loop



Scientific American, Nov 2009, p. 82

Closing the Loop

Scientific American, Nov 2009, p. 82

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 off-shore wind energy platforms (similar to oil rigs) to produce hydrogen applied, e.g., as transportation fuel

Wind Energy Information

✓ American Wind Energy Association (AWEA)

http://www.awea.org/faq/wwt_basics.html

✓ National Renewable Energy Laboratory (NREL)

http://www.nrel.gov/wind/publications.html

✓ Iowa Energy Center (IEC)

http://www.energy.iastate.edu/renewable/wind/wem-index.htm

Software

✓ Wind Farm Design Software
http://awsopenwind.org

✓ Winnipeg, Manitoba, Canada
https://pscad.com/home/
https://pscad.com/success_stories/energy_utilities/windfarminrush
https://pscad.com/success_stories/resear/kinetic_turbine_power_converter
https://pscad.com/products/pscad/simulations/#Sim1

✓ NREL
http://wind.nrel.gov/designcodes/simulators/fast
http://www.garradhassan.com/products/ghbladed
http://www.nrel.gov/wind/facilities_research.html

✓ Turbine design
http://www.wmc.eu/focus.php

✓ General simulators
http://www.simapp.com/index.php
http://www.simpack.com/

Software

WindSim www.windsim.com Downloadable demos

WindFram 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

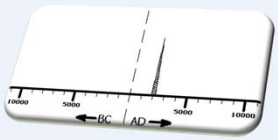
EPA: Green Power Partnership

http://www.epa.gov/greenpower/toplists/index.htm

Check out who is there

National Top 50
100% Purchasers
Top 20 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