An overview of the 2009 Indiana Renewable Energy Resources Study

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State Utility Forecasting Group

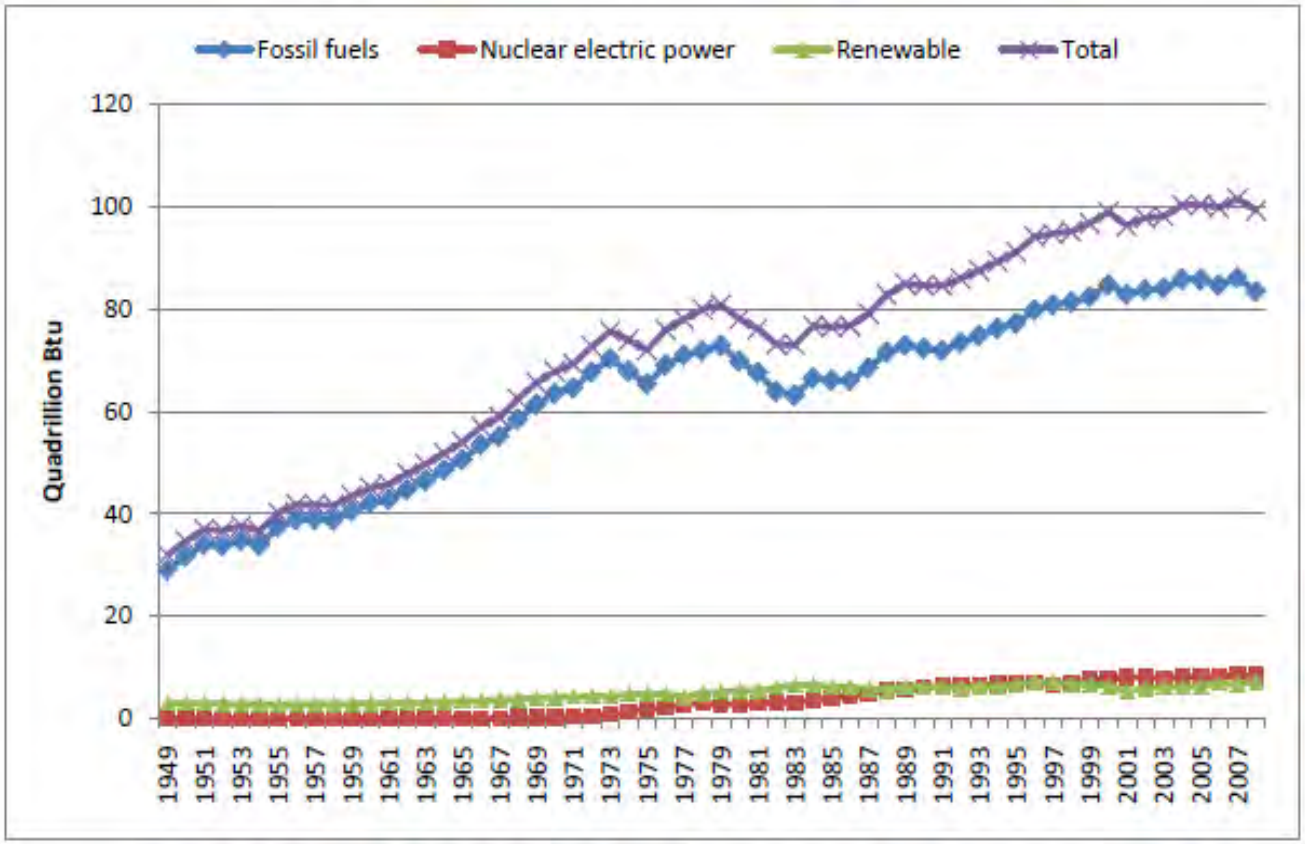
- 1985 Statute of Indiana General Assembly
- Primary task – forecast electricity demand and capacity needs
- Other tasks as assigned by the Indiana Utility Regulatory Commission
  - *Deregulation*
  - *Natural gas merchant plants*
  - *Renewable resource study*

Report layout

- **Indiana General Assembly Utility Regulatory Commission**
- **Annual report**
  First report done in 2003
- **Available at www.purdue.edu/dp/energy/SUFG/**

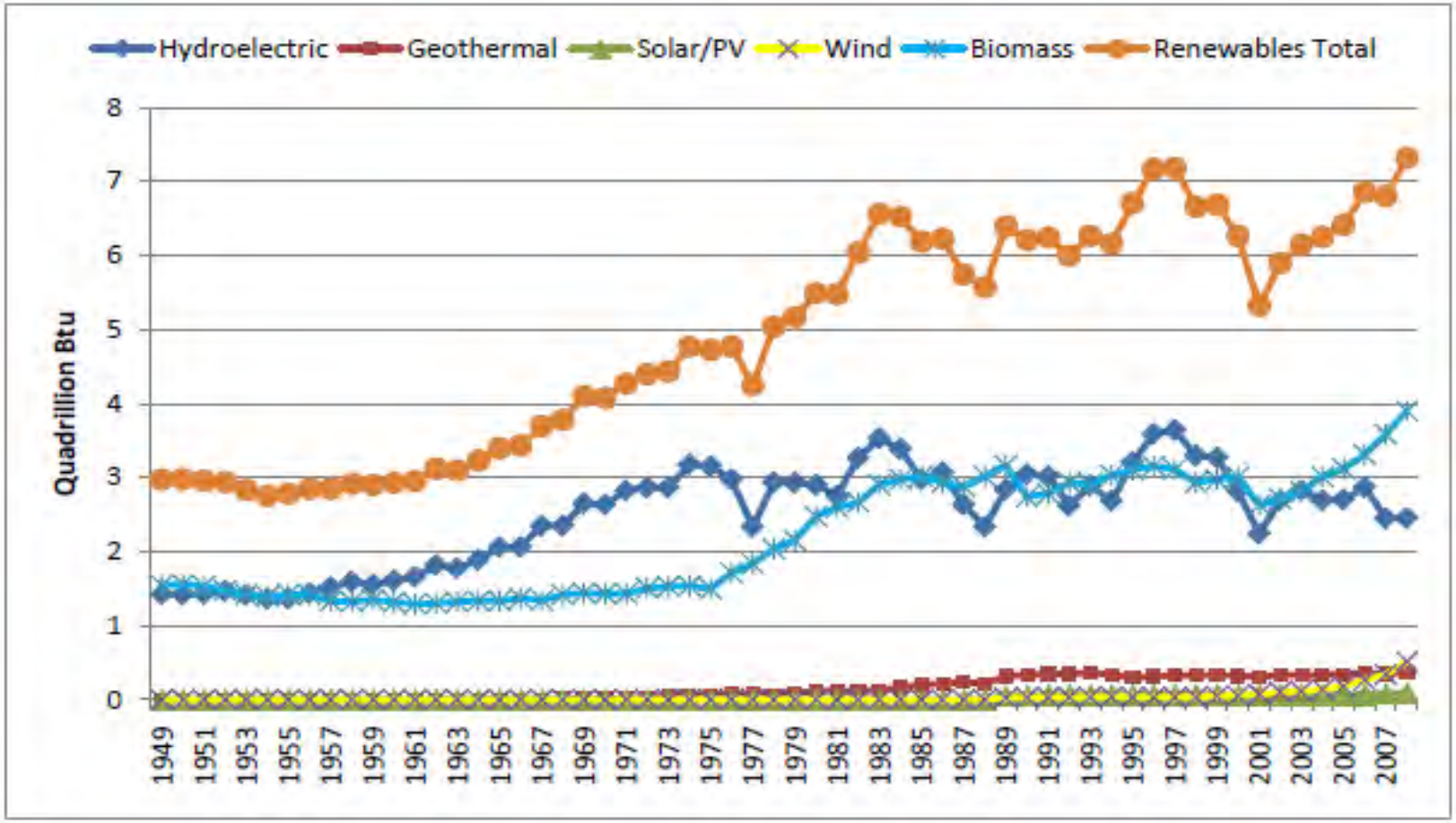
1. *Overview*
2. *Energy from wind*
3. *Dedicated energy crops*
4. *Organic waste biomass*
5. *Solar (thermal) energy*
6. *Photovoltaic cells*
7. *Fuel cells*
8. *Hydropower from existing dams*
9. *Energy from algae*

Overview (Section 1)



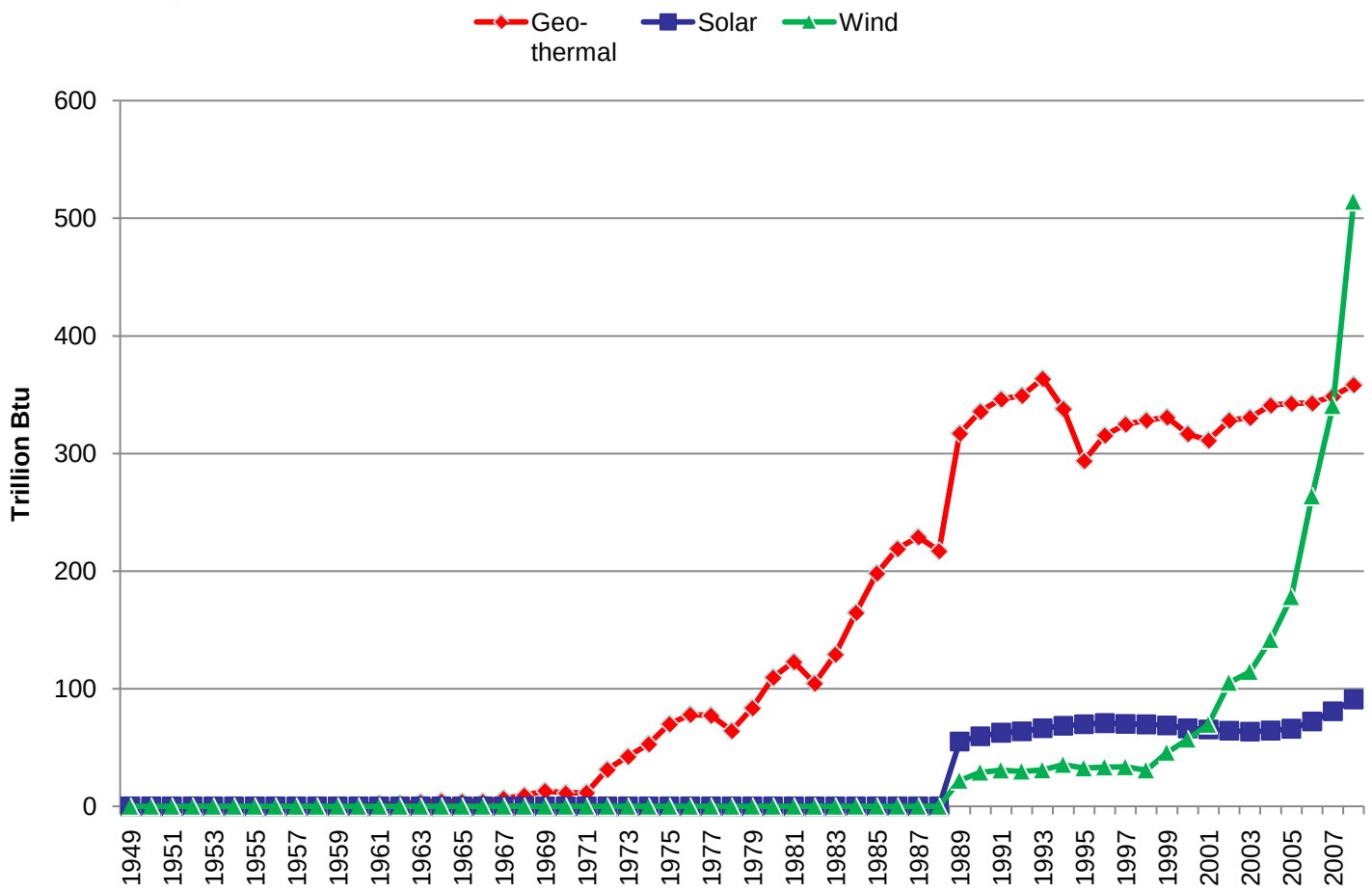
U.S. total energy consumption

Source: EIA



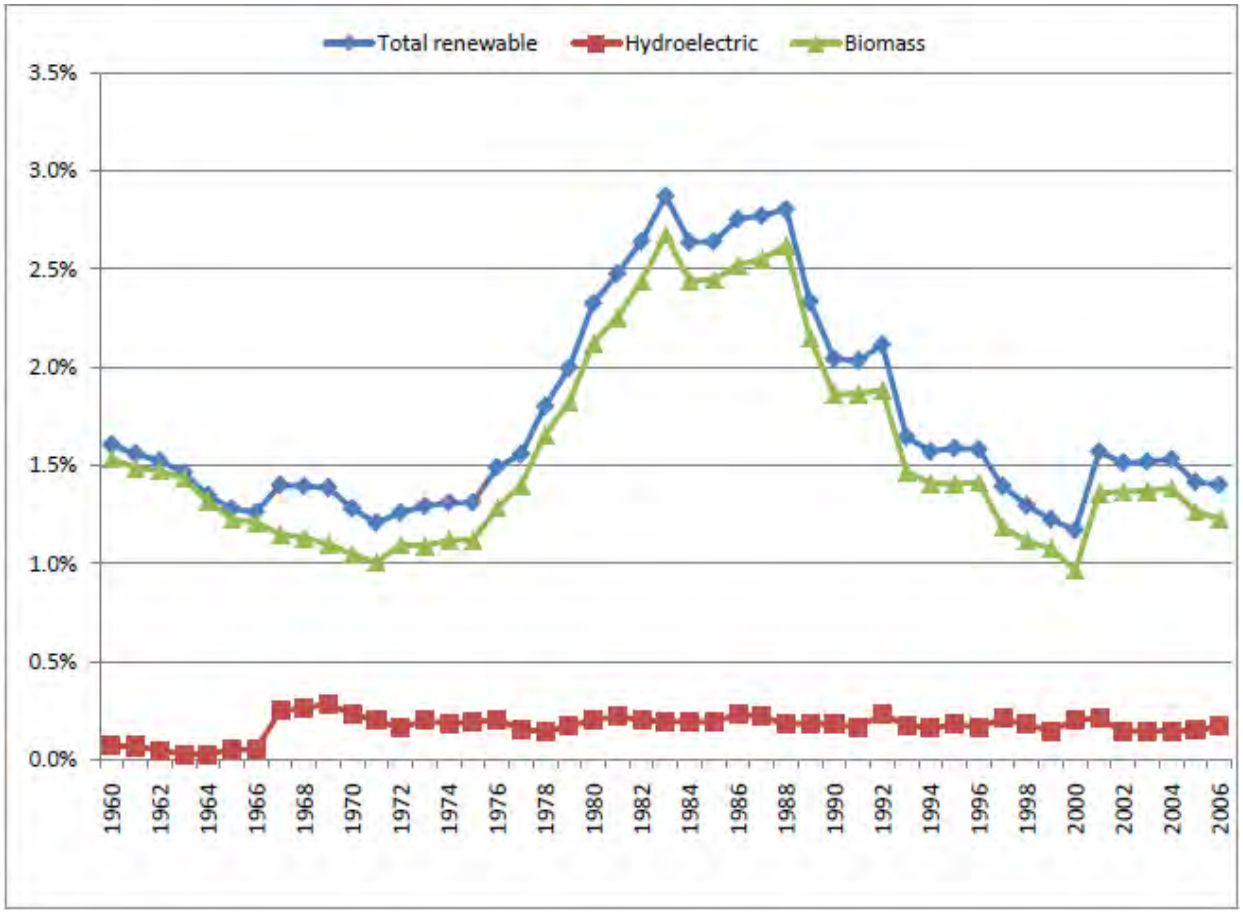
U.S. Renewable energy consumption

Source: EIA



Geothermal, Solar and Wind in U.S.

Source: EIA

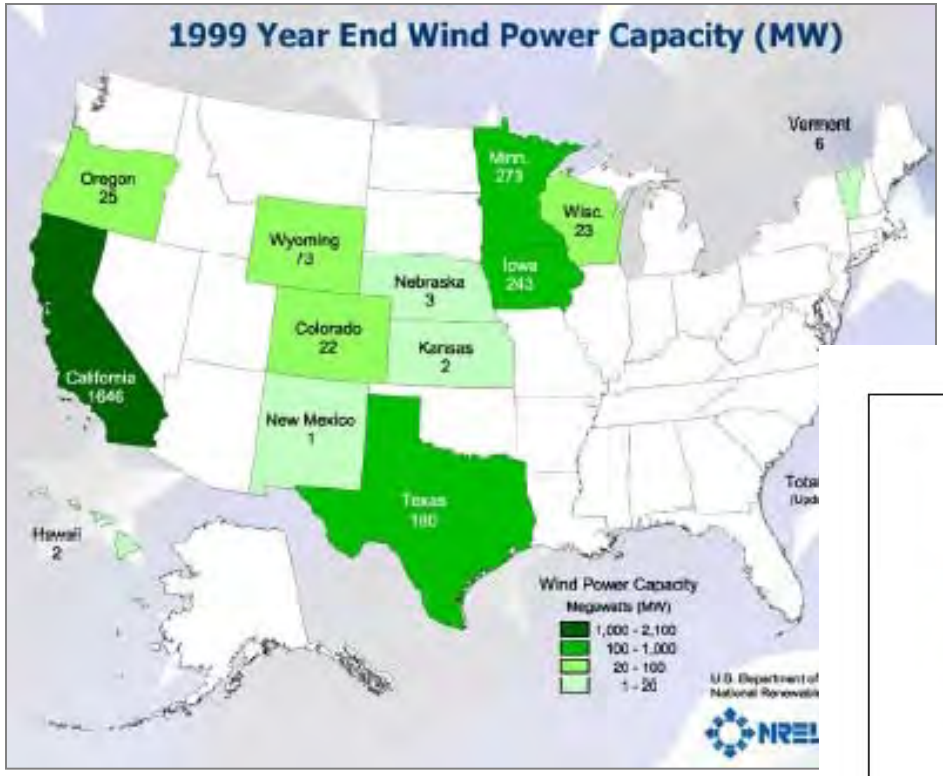


Renewables share of Indiana total energy consumption

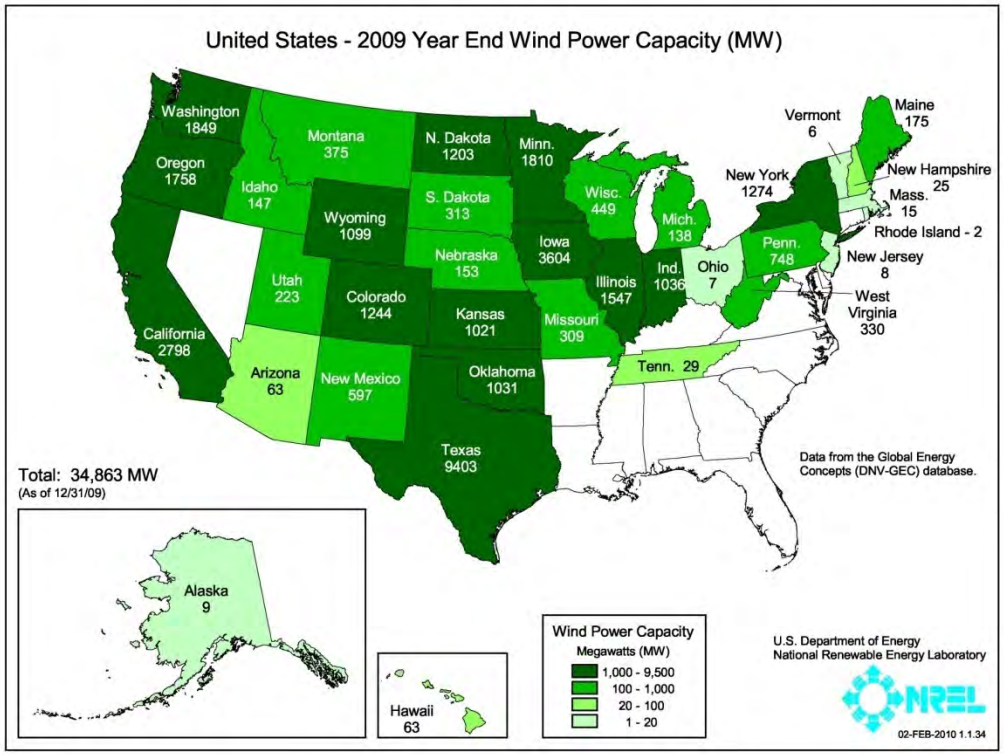
Source: EIA

Wind Energy (Section 2)

- Wind energy has been growing rapidly in last ten years (U.S. and Indiana)
- Wind is plentiful in U.S. mid-section
- Wind development is hindered by lack of transmission infrastructure
- Indiana's access to MISO and PJM attracts Developers to Indiana

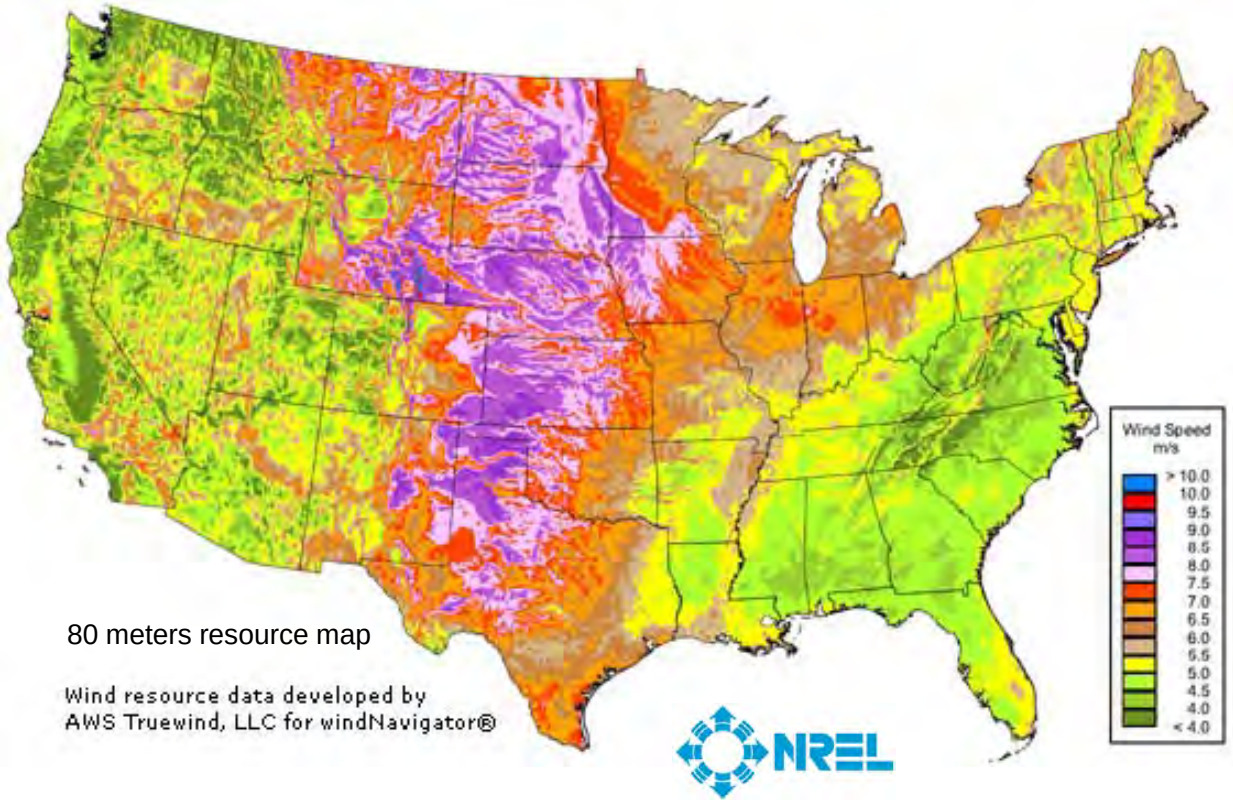


- U.S. ~0 in 1980 to > 35,000 MW today
- Indiana ~0 in 2007 to >1,000 MW today

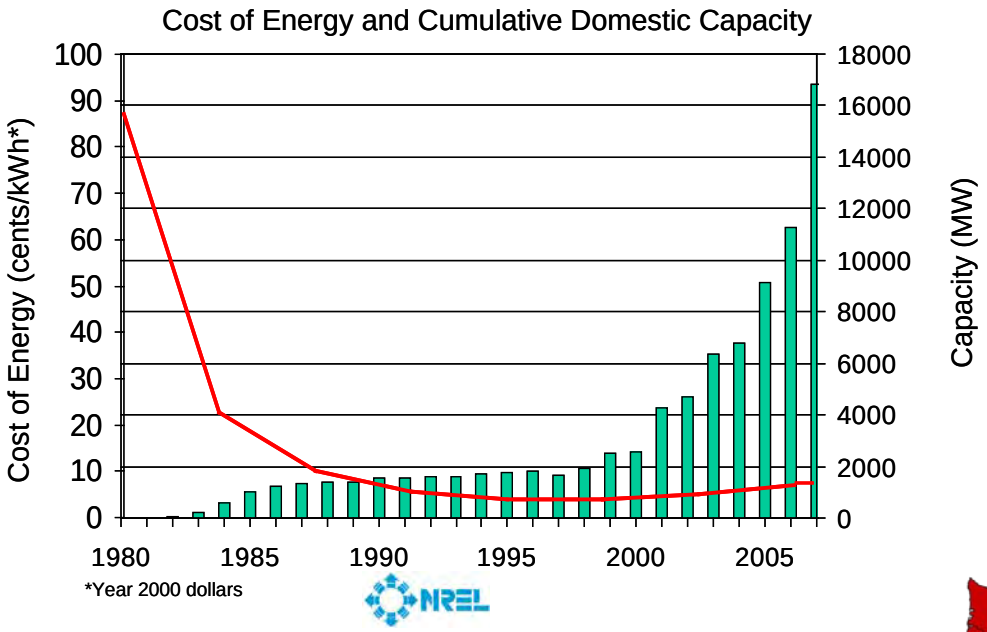


Wind is plentiful

DOE estimate
37 million GWh ~= 9 times US electric energy in 2009



Why rapid growth in U.S.



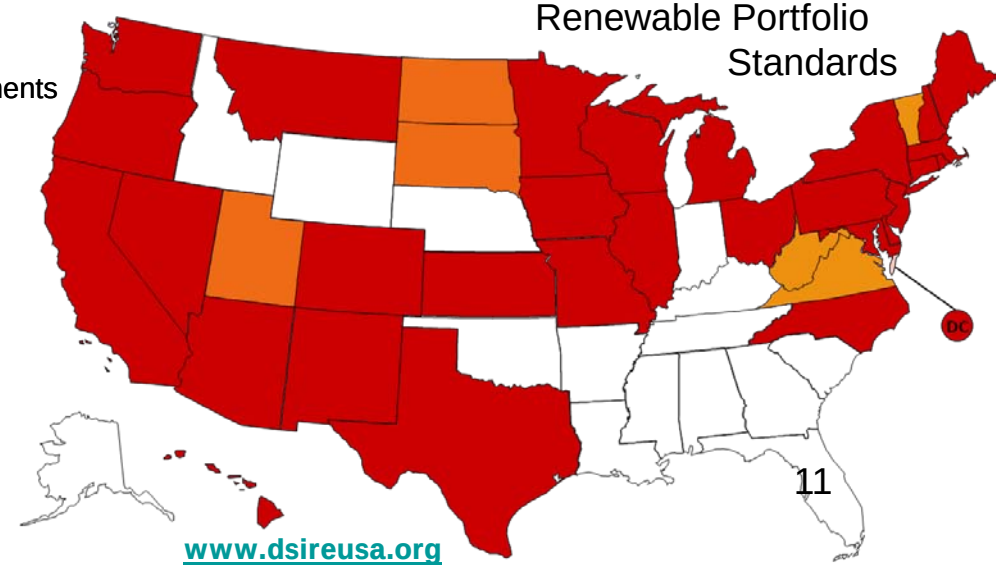
Increased Turbine Size - R&D Advances - Manufacturing Improvements

The Federal Production Tax Credit

2.1 cents/kWh in 2009 for ten years

ARRA 2009
30% Investment Tax Credit
Or Treasury grant

Renewable Portfolio Standards



www.dsireusa.org

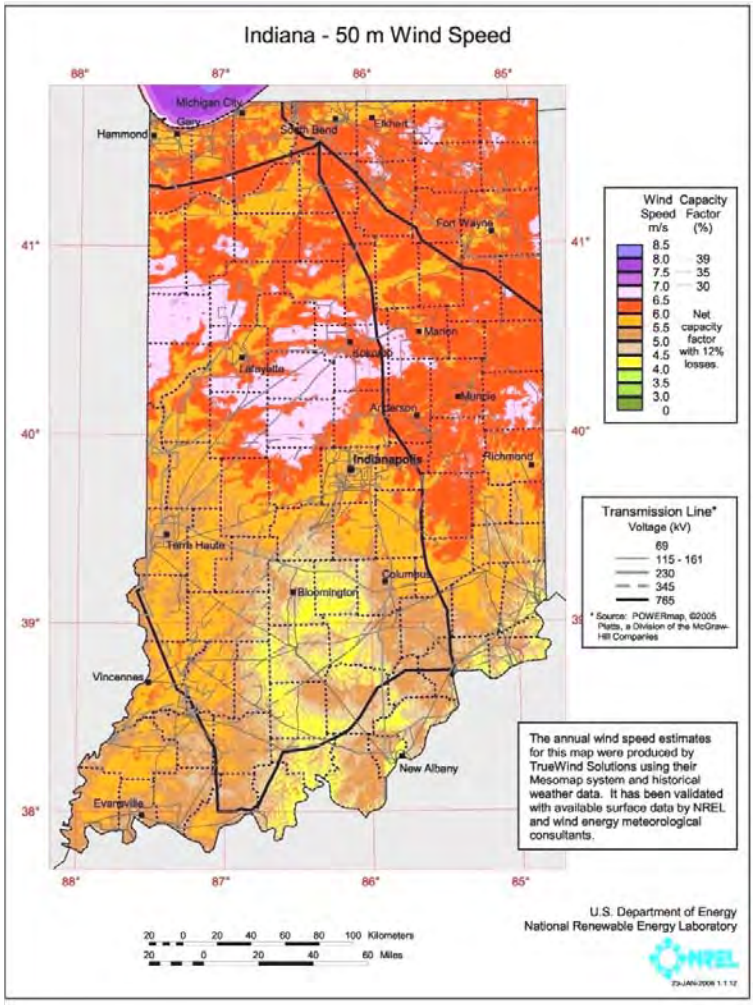
Disadvantages and limitations

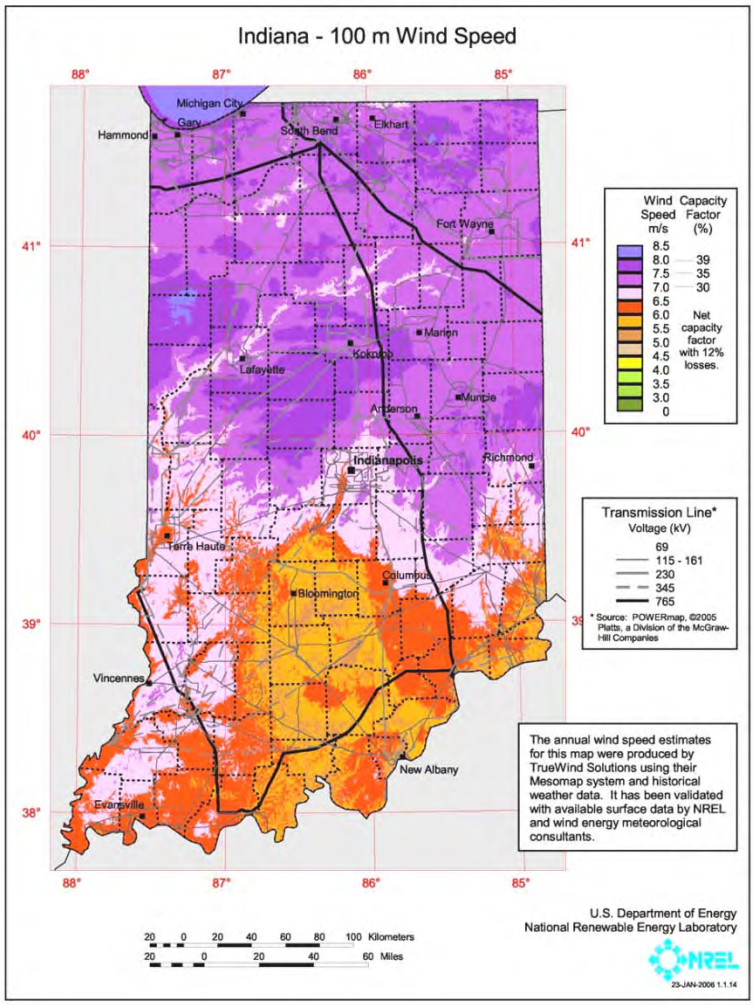
- Wind resource far from demand centers
- Wind blows when wind blows
  - Its contribution to peak capacity is uncertain
  - Cannot be dispatched by system operator
  - Adds variability to system
- There is a cost to integrating wind to a system

Wind integration cost studies

Date	Study	Wind Capacity Penetration (%)	Regulati on Cost ($/MWh)	Load Following Cost ($/MWh)	Unit Commit-ment Cost ($/MWh)	Gas Supply Cost ($/MWh)	Total Operating Cost Impact ($/MWh)
May 03	Xcel-UWIG	3.5	0	0.41	1.44	na	1.85
Sep 04	Xcel-MNDOC	15	0.23	na	4.37	na	4.60
Nov 06	MN/MISO	35 (25% energy)	0.15	na	4.26	na	4.41
July 04	CA RPS Multi-year Analysis	4	0.45	na	na	na	na
June 03	We Energies	4	1.12	0.09	0.69	na	1.90
June 03	We Energies	29	1.02	0.15	1.75	na	2.92
2005	PacifiCorp	20	0	1.6	3.0	na	4.6
April 06	Xcel-PSCo	10	0.20	na	2.26	1.26	3.72
April 06	Xcel-PSCo	15	0.20	na	3.32	1.45	4.97

Why rapid growth in Indiana





Biomass

(Section 3, 4)

- Energy Crops (*Section 3*)
  Switch grass, fast-growing trees etc

- Dual Use Crops
  Corn, soybeans etc

- Organic Waste Biomass (*Section 4*)
  Wood industry residues, farm residues, MSW etc

Dedicated Energy Crops

(Section 3)

- Grasses & quick growing trees
  - Switch grass, sorghum, hybrid willows and poplars etc
- Not yet here
  - Has to compete for land with current food crops (ranches etc)
- Switch grass best for Indiana
  - is native grass in Midwest

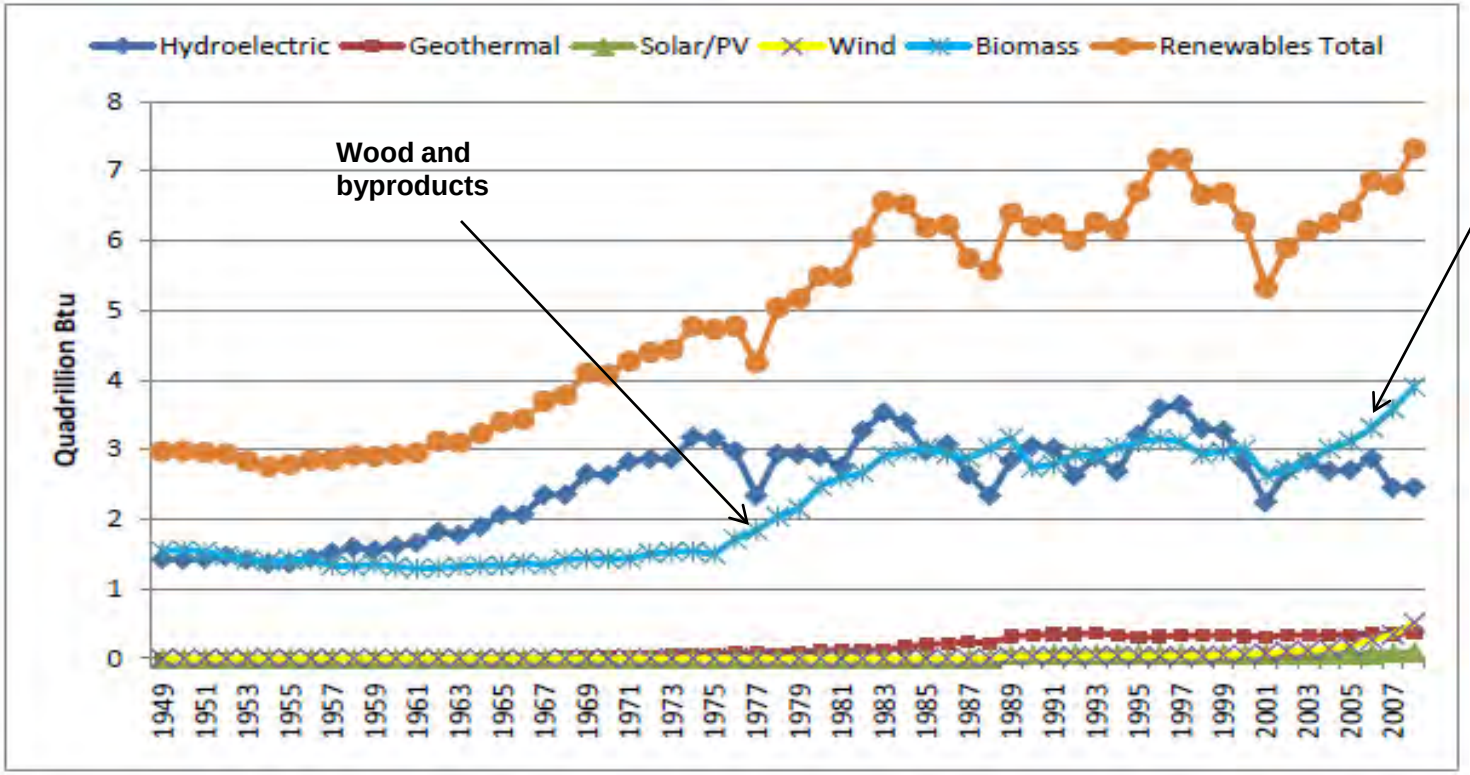
Dual Use Crops

- Corn ethanol plants boom in Indiana
  - Indiana from one to eleven plants 2000 to 2008
  - Boom over – corn prices
- Biodiesel
  - Zero to 5 plants in same period
- Why boom
  - MTBE dropped in 2005 Energy Act
  - RFS in 2005 Energy Act
  - Indiana tax incentives also

Organic Waste Biomass

(Section 4)

Biomass (mostly organic waste) provides about ½ of U.S. renewable energy



What is Organic Waste Biomass

1. Residues from forestry industry
   - Forest and timber industry leftovers
   - Paper and pulp industry byproducts
2. Municipal solid waste (waste paper, yard wastes etc)
3. Methane from waste stream
   Landfills, animal farms, wastewater treatment plants
4. Food and other biomass processing industry residues
5. Agricultural crop residues (corn stover etc)

Economics

1. Residues from forestry industry
   - Paper and pulp industry has favorable economics because of co-location of heat and electricity load, access to grid through 1978 PURPA

2. Municipal solid waste
   - Close proximity to heating load

3. Methane from waste streams
   - Landfill gas electricity most economically viable (48 MW in Indiana)
   - Concentrated animal feeding farms – not as viable (2.1 MW in Indiana)
   - Wastewater treatment plants – not as viable (195 kW in Indiana)

4. Food and other biomass byproducts

5. Agricultural crop residues

   Harvesting and transportation cost vs. low price on receiving end

Biomass processing Issues

- Biomass co-firing in coal plants faces barriers
  - Alkaline compounds corrodes boiler heat transfer surfaces
  - Biomass inconsistency (energy density, moisture content etc) makes it difficult to handle with coal material handling equipment

- Research (DOE-NREL) to overcome biomass handling and energy conversion by developing a gasification platform

Solar Thermal & Solar Photovoltaic

(Section 5) (Section 6)

Sun's radiation heats up a fluid

Utility scale power plants (354 MW)

Not enough radiation in Indiana

sunlight converted directly to electricity

"Roof top" kW –sized units

Enough radiation in Indiana

Solar Thermal (Section 5)

- Flat plate collectors
  small scale – domestic water heating etc
- Three types of CSP
  (trough, power tower, and dish engine)
- Trough CSP most common for utility scale electricity
  (SEGS 354 MW, Nevada solar one 64 MW)

Solar Thermal (Section 5)

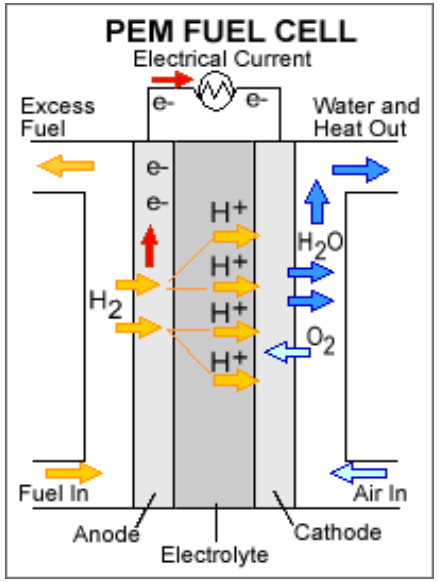
	Cost of energy (1997 cents/kWh)		
	1997	**2000**	**2010**
Parabolic Trough	17.3	11.8	7.6
Power Tower	--	13.6	5.2
Dish Engine Hybrid	--	17.9	6.1
Dish Engine solar only	134.3	26.8	7.2

Source: Sandia

Photovoltaic (Section 6)

- Typically kW sized units (~1 – 10 kW)
- High cost electricity
  - 5,000 to 11,000 $/kW
  - 20 to 50 cents/kWh
- Approximately 60 kW grid connected PV in Indiana
- There are two utility scale plants in U.S.
  - Nellis Air force base, Nevada – 13 MW
  - DeSoto Energy Center, Florida – 25 MW

Fuel Cells (Section 7)



- Chemical process (like battery)
  - High energy conversion efficiency (80%)
  - Waste stream (water and heat!)
  - Dual use (automobiles and electricity)
- Still under development
  - Estimated cost $2,500/kW
  - Current fuel cells use fossil fuels
  - Hydrogen production using renewable resources only not yet here
- 2 MW Fuel cell at WVPA gasification plant?

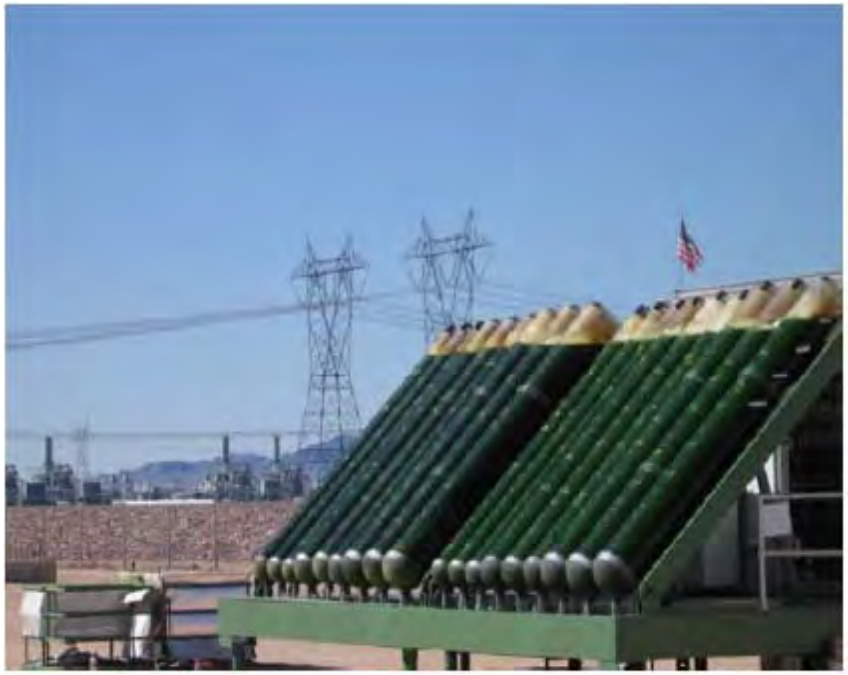
Hydroelectric Power (Section 8)

- Indiana has about 60 MW of hydroelectric generating capacity.
  - Mostly run-of-the-river (no dam)
  - Largest source of renewable electricity

- The U.S. Department of Energy identified another 66 MW of potential hydropower at existing dams
  - Only about 42 MW was considered viable (spread out over 27 sites)

Algae (Section 9)

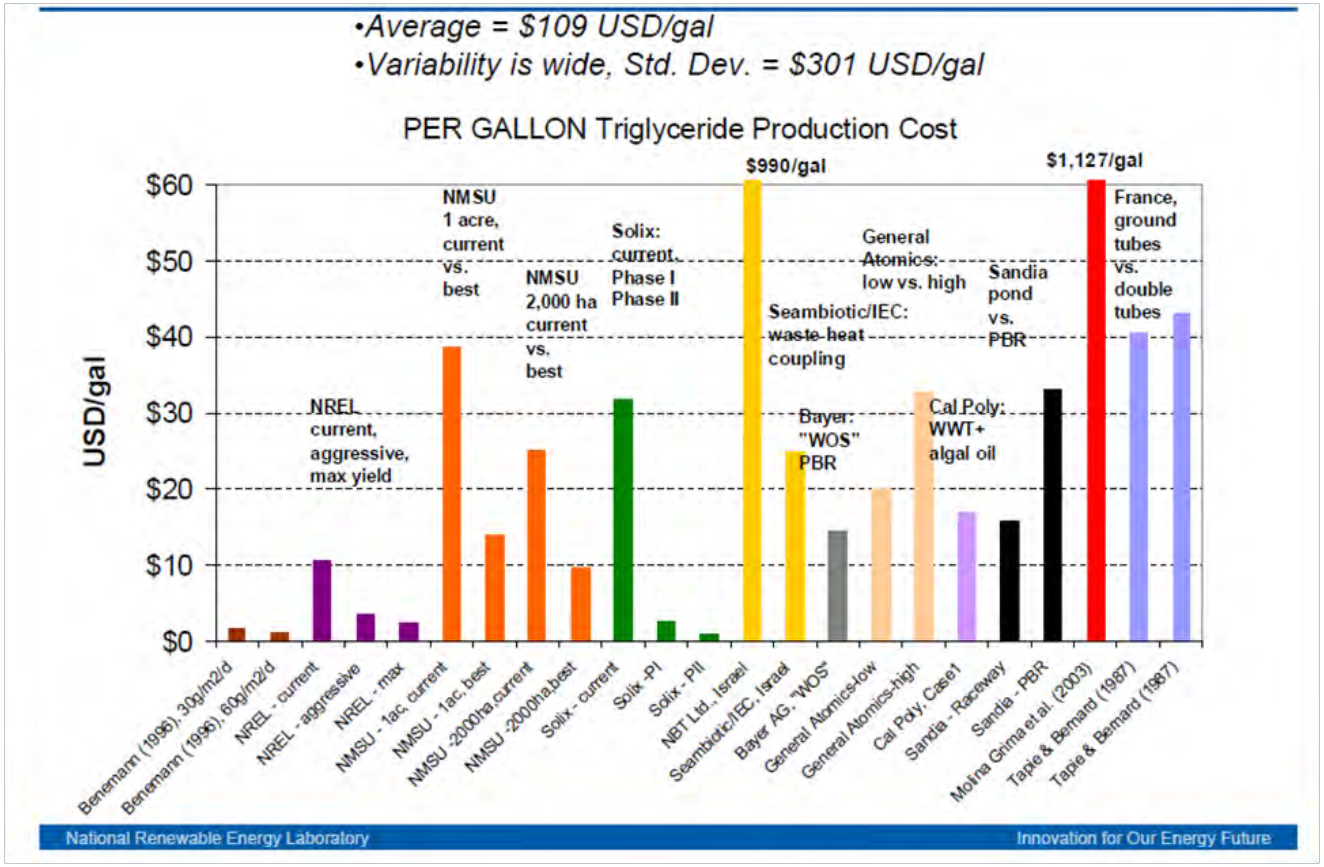
Crop	Oil Yield (Gallons/Acre/Year)
Soybean	48
Camelina	62
Sunflower	102
Jatropha	202
Oil palm	635
Algae	1,000-4,000



Algae at an Arizona power plant

Algae

(Section 9)



Estimated cost of energy
(2004 cents/kWh)

Technology	Overnight Capital Cost ($/kW)	Fixed Charge Factor	Fixed O&M cost ($/kW)	Total Fixed Cost ($/kW)	Capacity Factor	Total Fixed Cost ($/kWh)	Variable O&M ($/kWh)	Total Cost of Energy (cents/kWh)
Biomass	$1,731.00	10.50%	$46.47	$228.23	83%	$0.03	$0.00296	3.77
MSW-Landfill Gas	$1,477.00	12.50%	$99.57	$284.20	90%	$0.04	$0.00001	3.96
Geothermal	$2,203.00	10.50%	$79.28	$310.60	86%	$0.04	$0.00000	4.53
Wind	$1,015.00	12.50%	$26.41	$153.29	39%	$0.04	$0.00000	4.93
Solar thermal	$2,916.00	10.50%	$49.48	$355.66	15%	$0.27	$0.00000	29.74
Photovoltaic	$4,401.00	10.50%	$10.08	$472.19	24%	$0.22	$0.00000	24.68

?

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http://www.purdue.edu/dp/energy/SUFG/