Suggestions for Minnesota's Energy Future

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in collaboration with
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and
The Minnesota Futurists

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Today's topic is so broad and the implications so far reaching, that we plan to ration discussion time on each subject. We will then try to rank suggestions on energy supply and demand by timeliness and achievability.

Suggestions for Minnesota's Energy Future

Tentative Agenda, Goals & Timeline 10:00-10:10

1. Problem, background and data -UB :20

2. Discussion of solutiond to energy crisis

- **Decr. demand by conserv'n.** -D.Saunders :40
- **Incr. supply of renewables & non-renew.** -UB
- **Increase supply of new sources H2, geo, hydro, fusion, …, breeder reactor** -UB 11:00 -BrianT/UB :10

3. Conclusions DS & UB :20

4. Proposed solutions and suggestions

- **Consensus on 1-year, 5-year, 10-year priorities.** -All :50
- **Gov. intervention/mandates, subsidies, … Community-based develop. corp., credit** :20 **unions, H_2-energy web, …, public utilities, (CDCs, CCUs, HEW, DGAs, …, POUs)**

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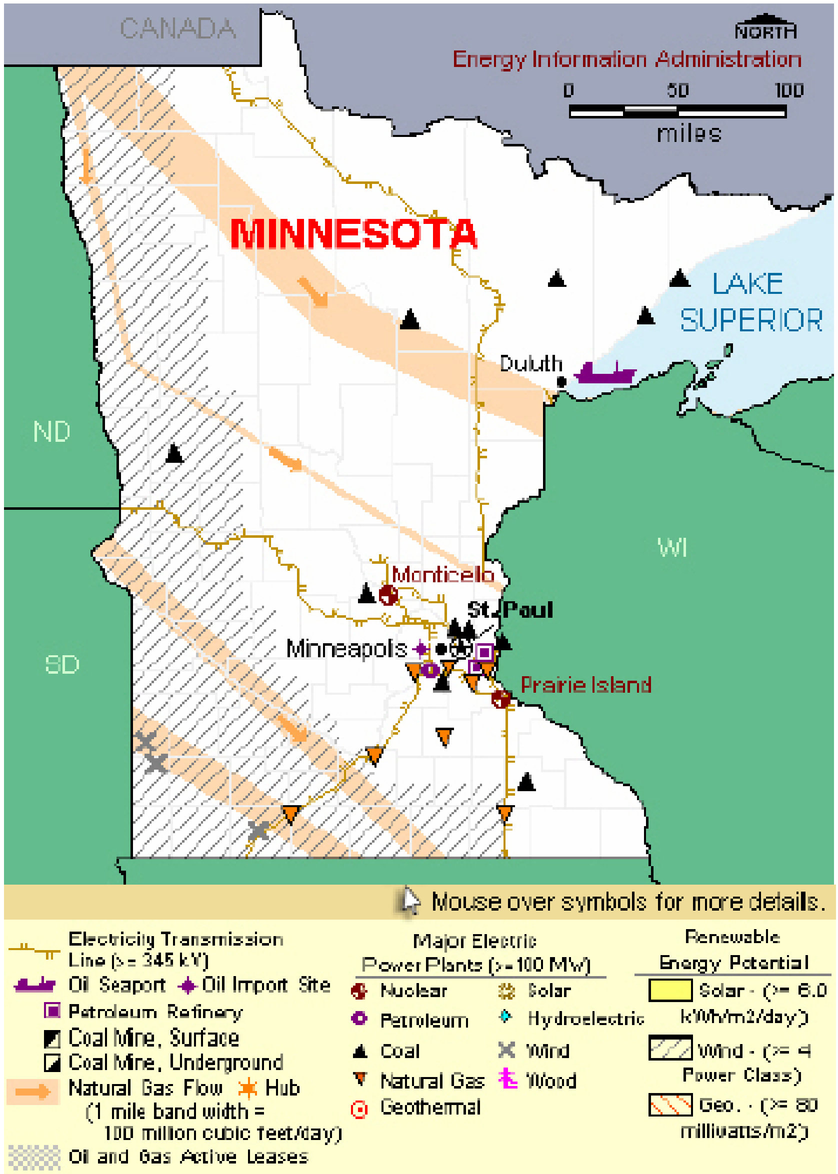
1. Minnesota's Energy Status (Rev. 26 June 2008[1])



Minnesota Quick Facts

- Minnesota is a leading producer of ethanol and has over a dozen ethanol production plants primarily in the southern half of the State.
- Minnesota is the only State that requires the statewide use of oxygenated motor gasoline blended with 10 percent ethanol.
- Minnesota ranks among the top States in wind power generation.
- Over two-thirds of Minnesota households use natural gas as their primary heating fuel during the State's long, cold winters.
- Two nuclear power plants near the Twin Cities generate nearly one-fourth of the electricity produced in the State.

Population: 5.4 million
GDP: 245 B$
State budget 2008-09: ~ 35 B$
Average income: 45 k$/capita/y
Farm area: 27.5 M acres
Energy produced: Nat.gas 240 TBtu/y
Wind & biomass: 59 & 43 TBtu/y
Total energy use: 1,852 TBtu/y
Energy independence: 6.2% = 100/16

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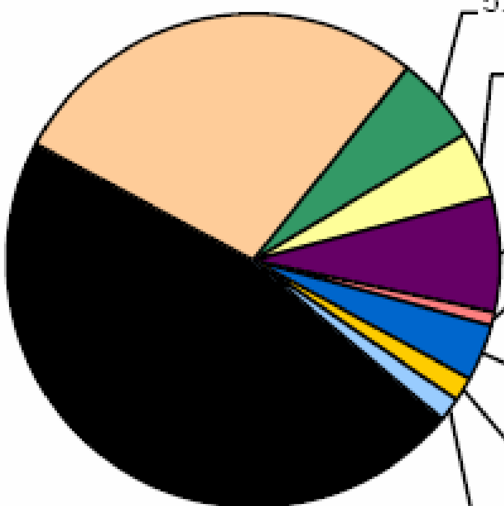
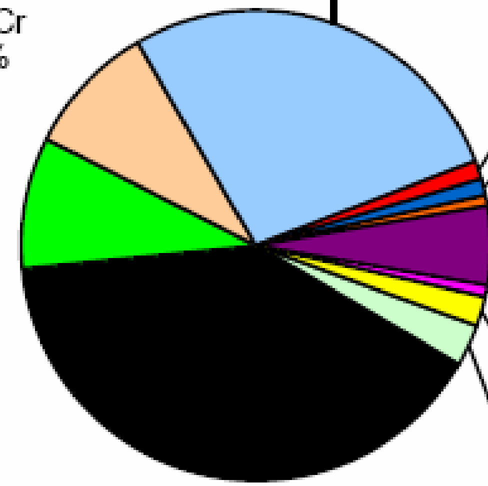
[1] http://tonto.eia.doe.gov/state/state_energy_profiles.cfm?sid=MN

Minnesota Revenues and Expenditures
$ 35.1 Billion, 2008-2009 Biennium





Economic Development: 1.1% or $ 386 M
Env., Energy & Nat. Res: 1.3% or $ 456 M

7 c/kWh el.power	2.46 $/GGE
4 $/gal gasoline	4.00 $/GGE
12 $/Mbtu NG	1.44 $/GGE
1.57 $/Mbtu coal	0.19 $/GGE

http://www.finance.state.mn.us/budget/summary/charts/080605_piecharts.pdf

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1. Minnesota's & US's Energy Use & Cost

	Coal	Nat.Gas	Gasoline	Total oil der.	Nuclear	Hydro	Biomass	W,S,Geo	Total
Minn. TBtu/y	379.1	372.2	337.6	722.2	133.8	7.7	58.8	42.9	**1,852**
Billion GGE/y	3.2	3.1	2.8	6.0	1.1	0.1	0.49	0.36	**15.4**
M$/y	595	4,466	11,253	24,073	2,230	26	1,960	715	**34,066**
US TBtu/y	22,795	22,645	17,445	40,733	8,149	2,703	2,631	669	**100,369**
BillionGGE/y	190.0	188.7	145.4	339.4	67.9	22.5	21.9	5.6	**836.4**
M$/y	35,788	271,738	581,483	1,357,757	27,164	9,010	87,683	11,157	**1,800,296**

[1] http://www.eia.doe.gov/emeu/states/sep_sum/html/sum_btu_tot.html

[2] http://tonto.eia.doe.gov/state/state_energy_profiles.cfm?sid=MN

[3] http://www.nrel.gov/docs/fy00osti/28082.pdf 2000

[4] Wikipedia/Economics of new power plants; Moody Inv. Serv.

[5] http://www.eesi.org/publications/Fact%20Sheets/EC_Fact_Sheets/Wind_Energy.pdf

Minn. Power announced in March 2007 the installation of 2 2.5 MW wind turbines--the largest ever erected in Minnesota. Manufacturer Nordex has ~ 3,000 wind turbines in service worldwide and > 20 years of experience in the wind energy industry. Each of its N90 turbines will spin atop a 88-m-tall tower and feature a 100-m wingspan. 100 MW ~ 40 turbines on ~ 86 acres. Presently operating 3 wind-farms deliver ~ 100 MW nominal capacity each.

EESI states that 2004 US wind power capacity is 6,740 megawatts (MW). The cost of wind power started to then to be competitive: With the Production Tax Credit of 0.019 $/kWh, wind power costs between $0.03 and $0.06 per kWh, declining from $0.80 per kWh in 1980 [5].

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1. World Wind Turbine and Cost, 2004/6[1]

RePower turbines have a power output of **5 MW,** and have been in operation since 2004 in Brunsbüttel, Germany requiring a 1,300 cubic metre concrete foundation constructed of 40 24 metre long concrete piles and 180 tons of steel. A further two **5MW offshore wind turbines** have recently (December 2006) been erected on the DEWI-OCC test field in Cuxhaven, Germany.   Maximum power output is achieved at around 30 mph, but start turning at around 7 mph, and are braked at 70mph. Rotor blade diameter is 126 metres sweeping an area of over 12,000 m2. Each turbine weighs over 900 tonnes including the 120 metre tall tower which has to be anchored in the deep water. Each **turbine blade** weighs a low 18 tonnes, made by *LM Glasfiber.* Expected off-shore load factors: Run time ~96% (8440 h/y), and at **5MW** full power 38% of the time (3300 h/y). Install.Cost: **1,363 MW for 300 millionEuro or 0.35 $/peak-W[2] or 1.17 $/avg-W.**

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[1] http://www.reuk.co.uk/Worlds-Largest-Wind-Turbine-Generator.htm

1. Reserve Life of Crude Oil in Years*

Summary of Reserve Data as of 2007

Country	Reserves [1]		Production [2]		Reserve life [3]
	10^9 bbl	10^9 m^3	10^6 bbl/d	10^3 m^3/d	years
Saudi Arabia	260	41	8.8	1,400	81
Canada	179	28.5	2.7	430	182
Iran	136	21.6	3.9	620	74
Iraq	115	18.3	3.7	590	101
Kuwait	99	15.7	2.5	400	108
United Arab Emirates	97	15.4	2.5	400	107
Venezuela	80	13	2.4	380	91
Russia	60	9.5	9.5	1,510	17
Libya	41.5	6.60	1.8	290	63
Nigeria	36.2	5.76	2.3	370	43
United States	21	3.3	4.9	780	12
Mexico	12	1.9	3.2	510	10
Total	1,137	180.8	48.2	7,660	65

Notes: 1 Claimed or estimated reserves in billions (10^9) of barrels (converted to billions of cubic metres). (Source: Oil & Gas Journal, January, 2007)
2 Production rate in millions (10^6) of barrels per day (converted to thousands of cubic metres per day) (Source: US Energy Information Authority, September, 2007)
3 Reserve life in years, calculated as reserves / annual production. (from above)

Conclusion: Global reserve life of oil is too short to allow market forces to develop alternatives. Need gov. interventn.
Question: Is there general agreement that we have a crisis?

* http://en.wikipedia.org/wiki/Oil_reserves

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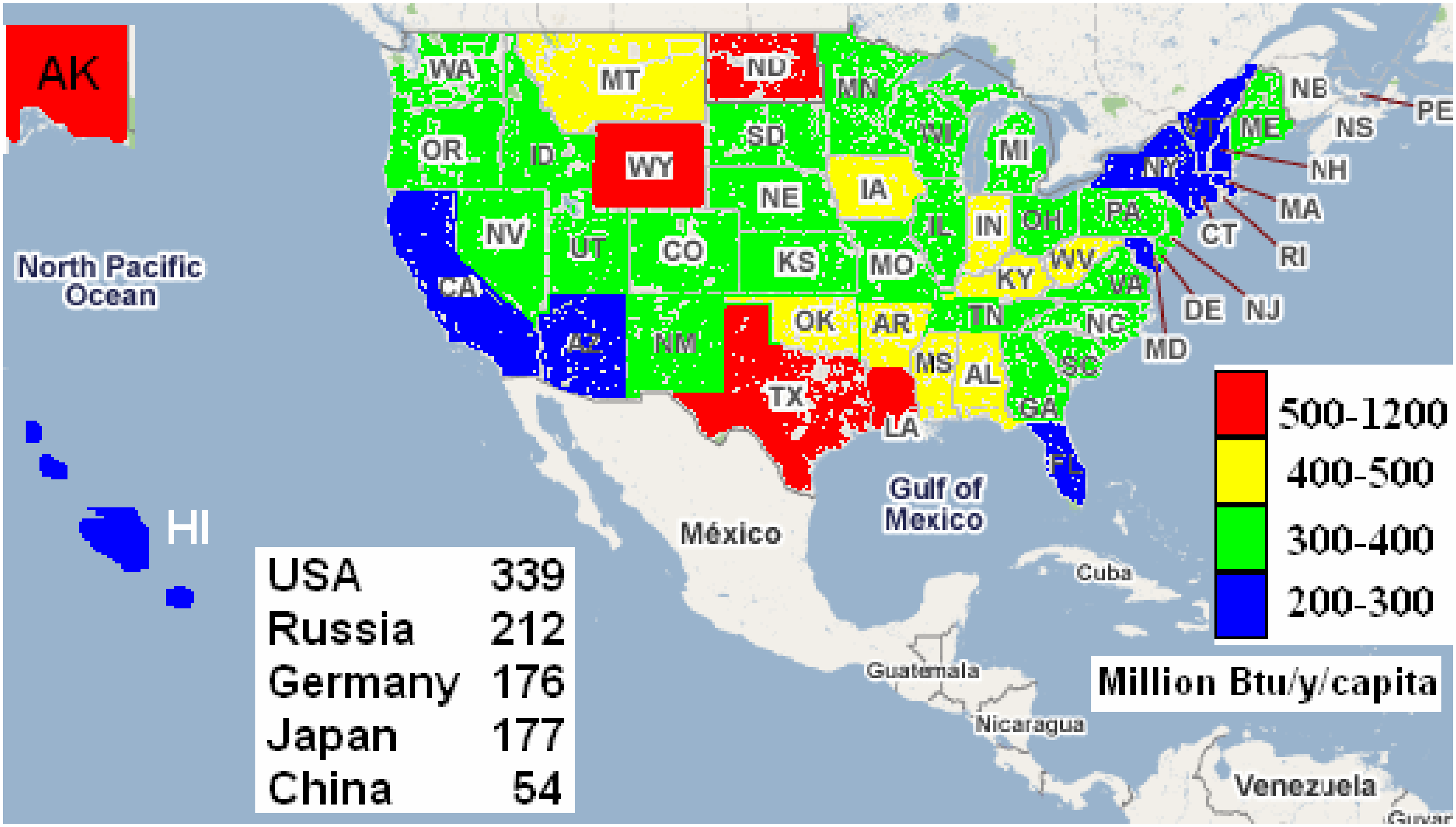
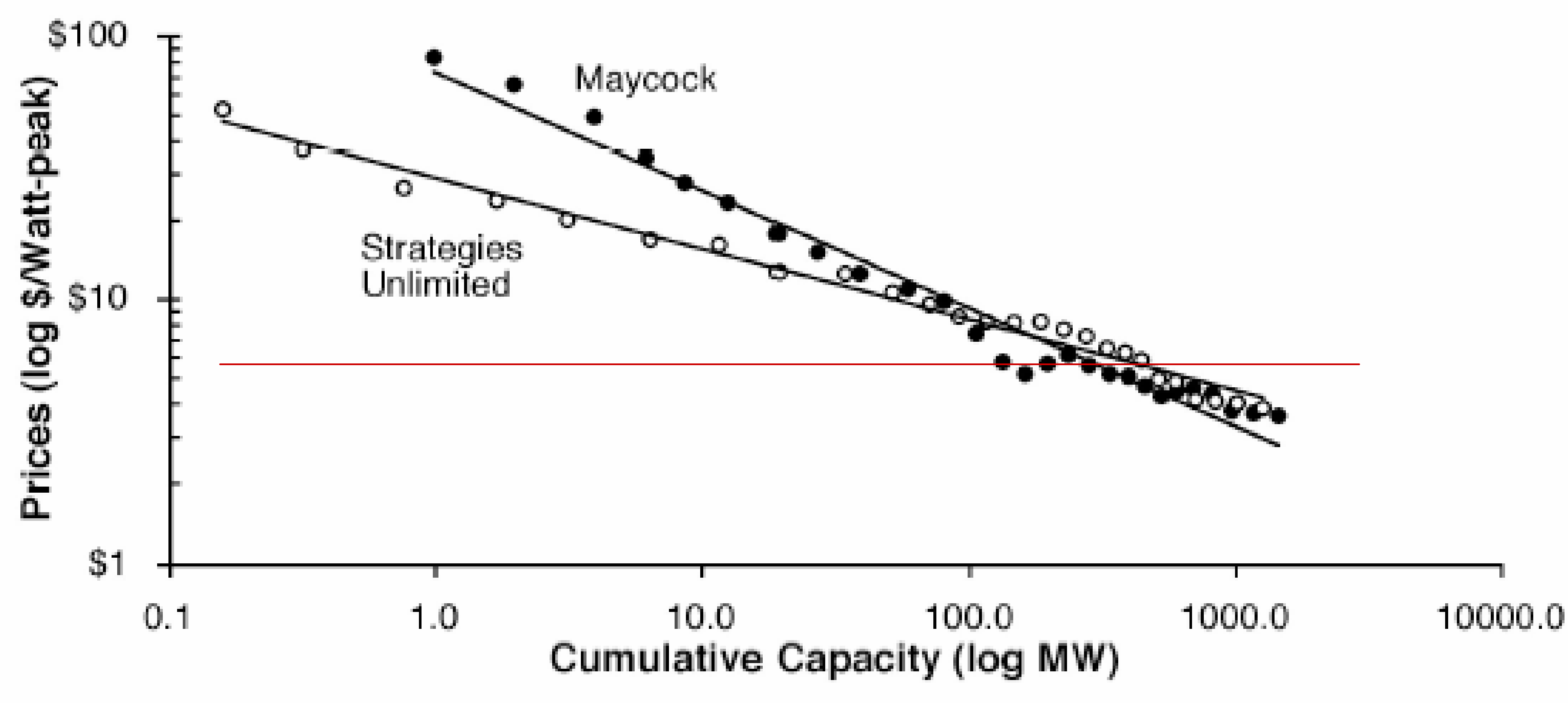
1. Energy Use per Capita per Year*



Conclusion: Allowing for climate-imposed energy use, some states are more thrifty energy users than others

*http://www.eia.doe.gov/emeu/states/p_sum/plain_html/rank

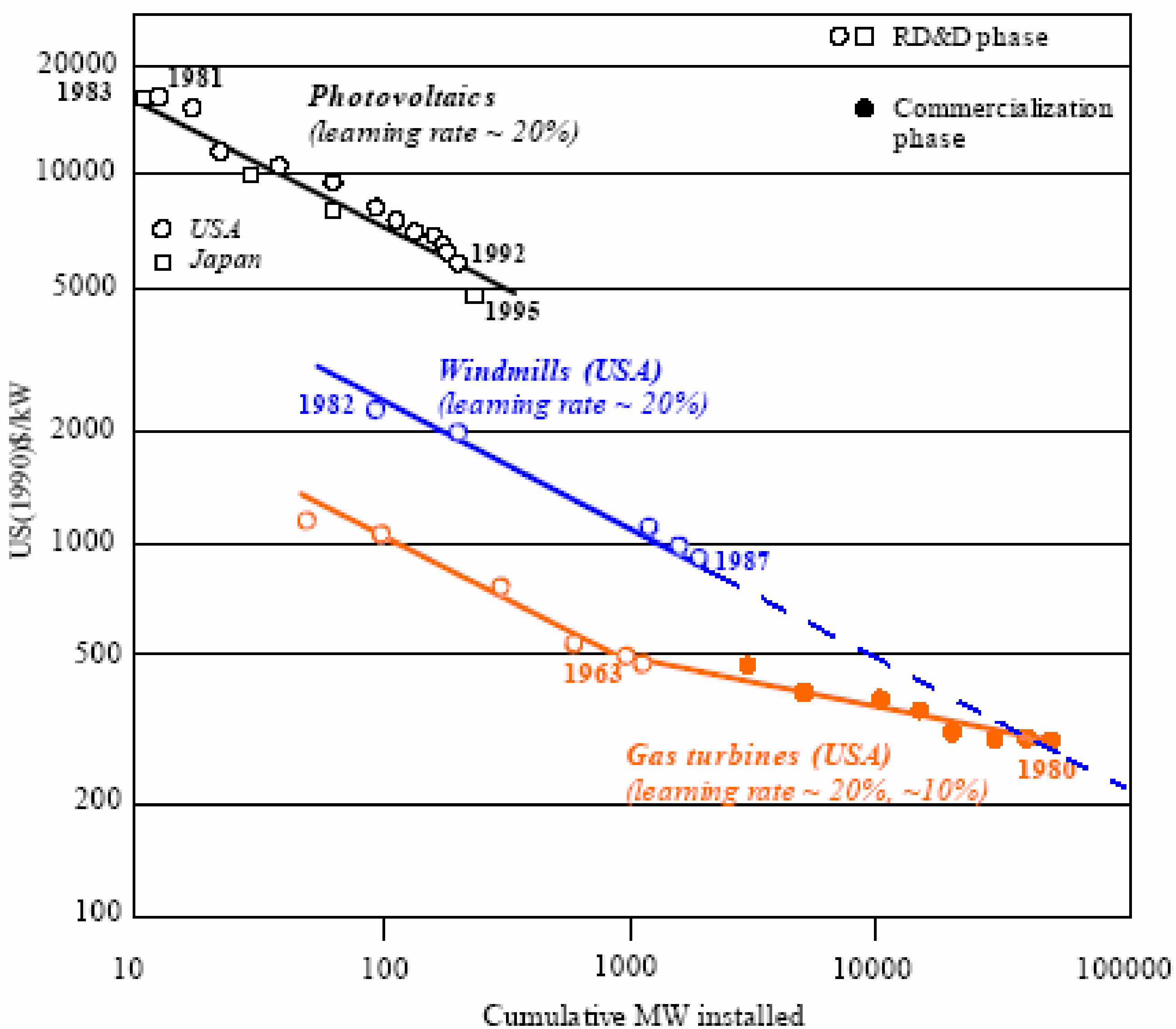
1. Solar-PV & Wind Learning/Experience Curve



Experience curves for PV modules and sensitivity of learning rate to underlying data by Maycock (2002); and Strategies-Unlimited (2003). From G.F.Nemet, UC-B, 2006.

Conclusion: Solar PV (& wind) power costs are dropping as $1/CC^{0.5 - 0.29}$ or to 71 - 82 % for each capacity doubling

1. Solar PV & Wind Cost -- Experience/Learning Curve



Source: IIASA, 2000 in **Wim C. Turkenburg,** libdigi.unicamp.br/document/?down=1037

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1. More Energy Perspective

- Global energy demand: May grow at 1.6%/y or 50% by 2030, according to DOE
- Senator Amy Klobuchar writes in a 17-May-08 StarTrib p. A19 Op-Ed "Counterpoint" article on "The energy crisis: Only bold steps will help", w/o getting into details about HOW TO achieve clean, renewable, sustainable, and "independent" energy, that we need "not a silver bullet but a silver buckshot."
- USDA released an economic analysis on May 20 that showed higher energy prices, increased worldwide demand and the weather are the primary factors contributing to the increas in food prices, rather than bio-fuels[1].
- US Annual Crude Imports: ~$200 B to import 60% of US crude oil needs
- IEA projects that by 2015: U.S. foreign oil dependency is expected to fall from 60% to 50%, and biofuel production is scheduled to approach 15 billion gallons (=10% of US gasoline use in 2007), in line w/wimp Energy Independence and Security Act of 2007
- MN PUC advised to nix Big Stone II, SD, coal power plant, by disallowing power lines
- Oil supplies have peaked, as per Paul Roberts' book (2004) on interviews with Saudis
- Population control: Population control on a Global basis, as has been practiced/attempted in China, is key for meeting future energy and food supply to everyone.

Conclusion of MNFs: Balancing supply & demand of "sustainable energy" is US and World public affairs priority #1.

- MNF Goals: The above and this presentation is in line with MNF's 2008 goals to:
  - a) Find or create media opportunities to educate the public about the "future" and
  - b) Develop recommendations for legislators on how to solve the energy crisis

[1] http://www.biofuelsbusiness.com/news/enews_stories.asp?ArticleID=93675

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1. Goals of This Workshop

Identify and prioritize suggestions for MN's energy future based on

A) Conservation,
B) Renewable and
C) New energy sources.

Select priorities for time frames corresponding to
2-,
5-, and
10-years from now.

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2. Discussion Topics

Facts needed for informed decisions:

- **US energy use by sector: 40% res. & comm., 30% transportation; 30% industrial**
- **How would public transportation reduce MN gasoline and Diesel fuel consumption**
- **Is dedication of land to grow energy crops a good or bad idea; and is an annual harvest of 15 (switch grass) vs. 3.5 (corn stover) tons/acre/y good enough?**
- **What are the gasoline retail cost components of 4 $/gal we pay at the pump Jul.'08? (Well, tanker, refiner, taxes, retailer….. futures trader?)**
- **What gov. intervention or legislative action would MNFs recommend, such as:**
  - **Mandate that new passenger cars or SUVs sold or licensed in MN achieve an EPA mileage > 40 miles/gal by 2010**
  - **Mandate for new homes starting in 2009 1) solar water heaters (see CA), 2) solar PV panels, and 3) Insulation levels now required only for heat pump homes**
  - **Subsidize capital equipment for anyone who installs residual biomass conversion systems, solar or wind generators to make fuels or fertilizers**
  - **Subsidize renew. energy install. & prod. – based on what criteria & how calculated?**
  - **Update incentives for solar, wind, nuclear; introduce carbon tax now and "trade" later**
  - **Incentivise reduction in paper use (for advertising, billing, phone-books, newsprint)**
  - **Other???**
- **How would the Minnesota economy benefit if it produced locally 1 billion gal gasoline per year (of the total 2.8 used in 2007), or all fuels, rather than relying on imports?**
- **3x economic multiplier: Biomass conversion contributed 6.5 Bgal to US in 2007, or $47.6B (3x multiplier) and 238,541 new jobs @ $200k each.** Biobusiness (29-May-08)

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2. Reduce Demand by Conservation

Proposed Action	Ease of Implementation	Downside Risks/Threats	% Savings
1) Establish max. energy conservation practices among business, govt, public;	A	State loses some tax revenues	
2) Reduce highway speed limits to 60mph	A	Decr. productivity of drivers	20*
3) Decrease driving; use public transit;	A-B	Some need cars/trucks for biz.	
4) Buy alternative-fueled cars, buses, truck fleets;	B	Initial costs? Payback time?	
5) Decrease leisure flying, LD vacation travel	A	Tough "sell"	
6) Implement minimum housing insulation	B	Need to maintain min. ventil.	>30**
7) Other			

* Gasoline use drops by 1.18x when car speed drops from 70 to 60 mph[1]
1.52x when car speed drops from 80 to 60 mph[1]

** Assuming savings realized when converting homes to meet heat pump insulation standards

[1] DOE: http://www.fueleconomy.gov/feg/driveHabits.shtml

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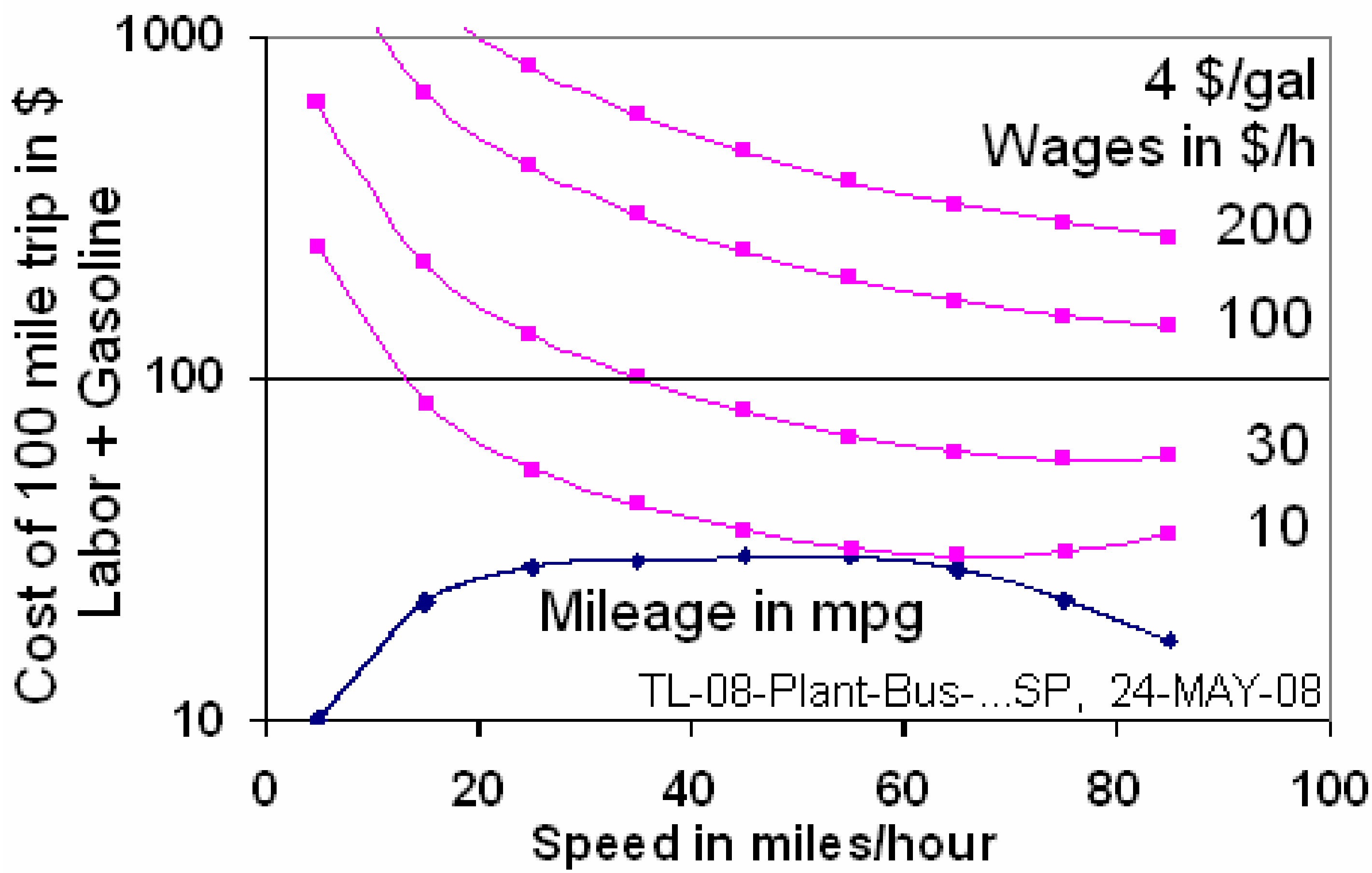
2. “Cost-Effective” Driving



Cost = 100 (W / v + C / M)

Conclusion: Speed limits need to be regulated for safety, because cost-effective speed may be very high for some.

DOE: http://www.fueleconomy.gov/feg/driveHabits.shtml

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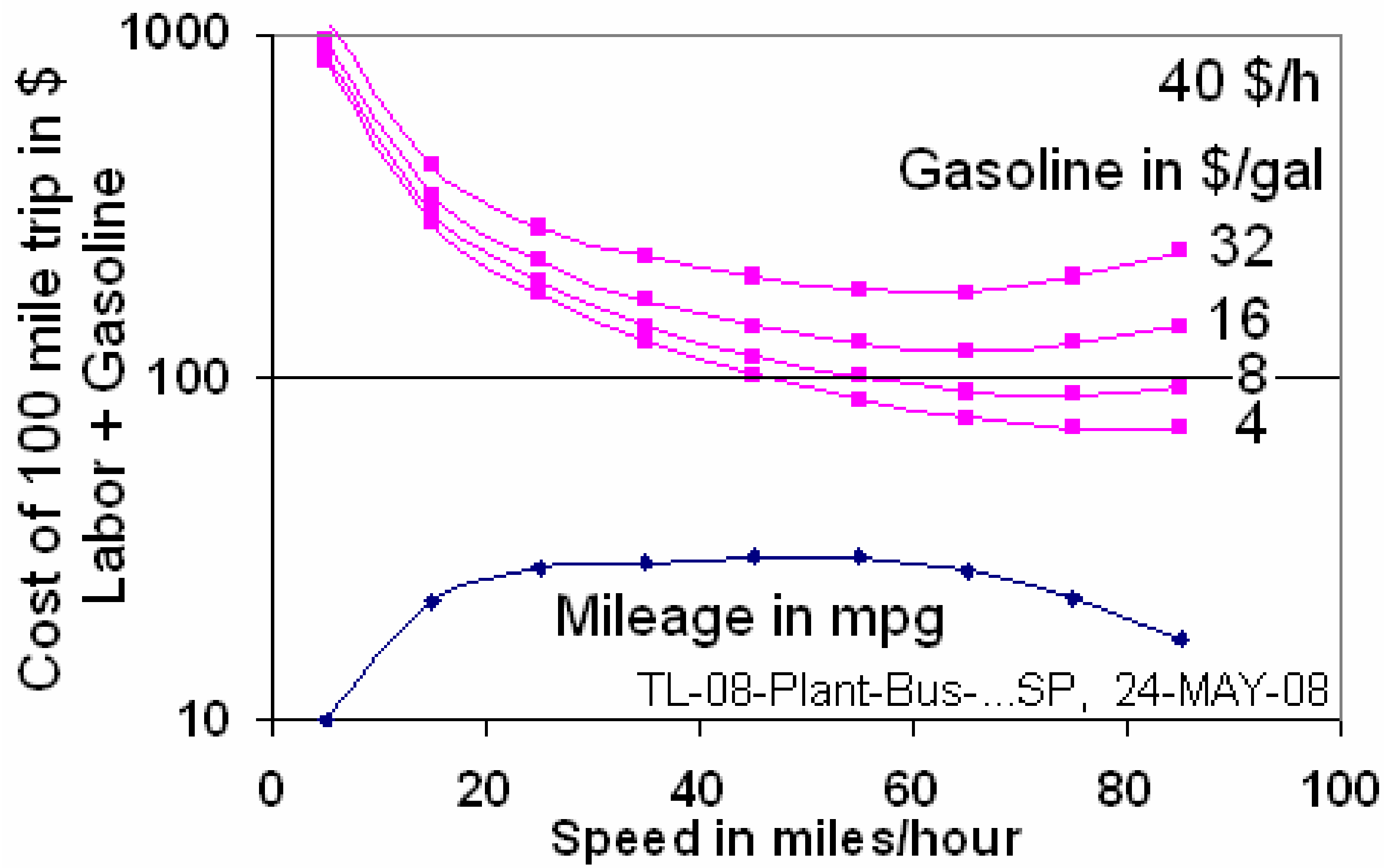
2. “Cost-Effective” Driving



Cost = 100 (S / v + C / M)

Conclusion: Future high gasoline prices will reduce cost-effective speeds for all.

DOE: http://www.fueleconomy.gov/feg/driveHabits.shtml

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2. MN Rebates for High Efficiency Equipment

Available Commercial Rebates

Equipment or Service	Rebate	Benefit[4]
Continuous Modulating Burners	25% of equip. cost up to $15,000/burner	
High Eff. Power Furnaces >=92% AFUE	$200	$1216
High Eff. Power Furnaces >=94% AFUE	$250	$1459
Single Pipe Steam Balancing	25% of equipment cost up to $1,000 cap	
Steam to Hydronic Distribution	25% of equipment cost up to $15,000 cap	
Vent Dampers	≤ 50% of equip. cost up to $500 cap/boiler	
Commercial Energy Audits*	≤ 50% of audit cost up to $250 - 350 cap	
Commercial Energy Audits*	≤ 50% of audit cost up to $350 cap	

Available Residential Rebates

Equipment or Service	Minimum Efficiency	Rebate	Benefit[4]
Gas Furnace	92-93.99% AFUE[1]	$200	$600
Gas Furnace	94% AFUE[1] or greater	$250	$700
High Efficiency Boiler	90% AFUE[1]	$200	$600
Integrated Space and Wtr Htg Syst	90% CAE[3]	$250	>$600
Set-Back Thermostat - Electronic	Energy Star Rated	$40	
Water Heater	0.64 EF[2]	$45	

GAMA ratings will be used to determine the AFUE, EF, and CAE for heating purposes.
[1]AFUE: Annual Fuel Utilization Efficiency; [2]EF: Energy Factor; [3]CAE: Combined Annual Efficiency
[4]Over a 1-10 year period. Assumed hi-eff commercial furnace cost $1000 more for 10% higher AFUE, operating 20% of 5600 htg.hours/year at 0.2 MBtu/h and 8 $/MBtu at a cost of 0.2/0.94*0.2*5600*8*0.10 = 190 $/year. At economic multiplier of 4x, 8% taxation and 20-year life, economic **benefit to MN-State = $1216 if fuel prices stay constant**

Conclusion: Justifiably, rebates could be higher and tied to 1) energy cost index and 2) equipment size

MN: http://www.minnesotaenergyresources.com/home/rebates.aspx ulrichbonne@msn.com

2. Minnesota's Electricity Status

	MN Electricity Generation Jan-08[2]				Realized	Nominal	Capital	Capital
		GWh/mo	% of US	% of Minn	MW Cap	MW Cap	cost, $/W	cost in M$
	Oil	13	0.3	0.25	18.1			to add 10%
	Nat. Gas	224	0.3	4.34	311.1			to tot cap.
	Coal	3,187	1.7	61.73	4,426.4			
	Nuclear	1,251	1.8	24.23	1,737.5		2 - 6[4]	3,795
	Hydro	48	0.2	0.93	66.7			
	W, (+S-PV, Geo.)	406	4.2	7.86	563.9	2,819	1.1	1,392
	Total GWh/mo	**5,163**	**1.4**	**100.00**	**7,170.8**	**12,650**		
	(Total in TBtu/y	212	)					
	(Ethanol Mgal/y	400	)	14.3				
MN wind potential[3]		40,833		791	56,050	295,000		
MN wind today, % of pot.		0.99			1.01	0.96		

If US total energy were:	Load Fac	Wpk/acre	Wav/acre	Acres	Area %	Mile x Mile	T$	$/Wavg
Wind (2.5 MW turb.2001)	30	7,029	2,109	1.6E+09	69.1	1564	10	3
Solar-PV(150acres,11MW,75M	20	73,333	14,667	2.3E+08	9.9	593	113	34
Biomass @ 7 tons/year/acre; 30% conv.eff.			1,263	2.6E+09	115.4	2020	5	2
Total US use of 100 Quad Btu/y = 3.3 TWavg				2.3E+09	100.0	1881	14	='07 GDP

Minn. Power announced in March 2007 the installation of 2 2.5 MW wind turbines--the largest ever erected in Minnesota. Manufacturer Nordex has ~ 3,000 wind turbines in service worldwide and > 20 years of experience in the wind energy industry. Each of its N90 turbines will spin atop a 88-m-tall tower and feature a 100-m wingspan. 100 MW ~ 40 turbines on ~ 86 acres. Presently operating 3 wind-farms deliver ~ 100 MW nominal capacity ach

Conclusion: Wind is presently best new energy value, with free "feedstock" & side-by-side food production

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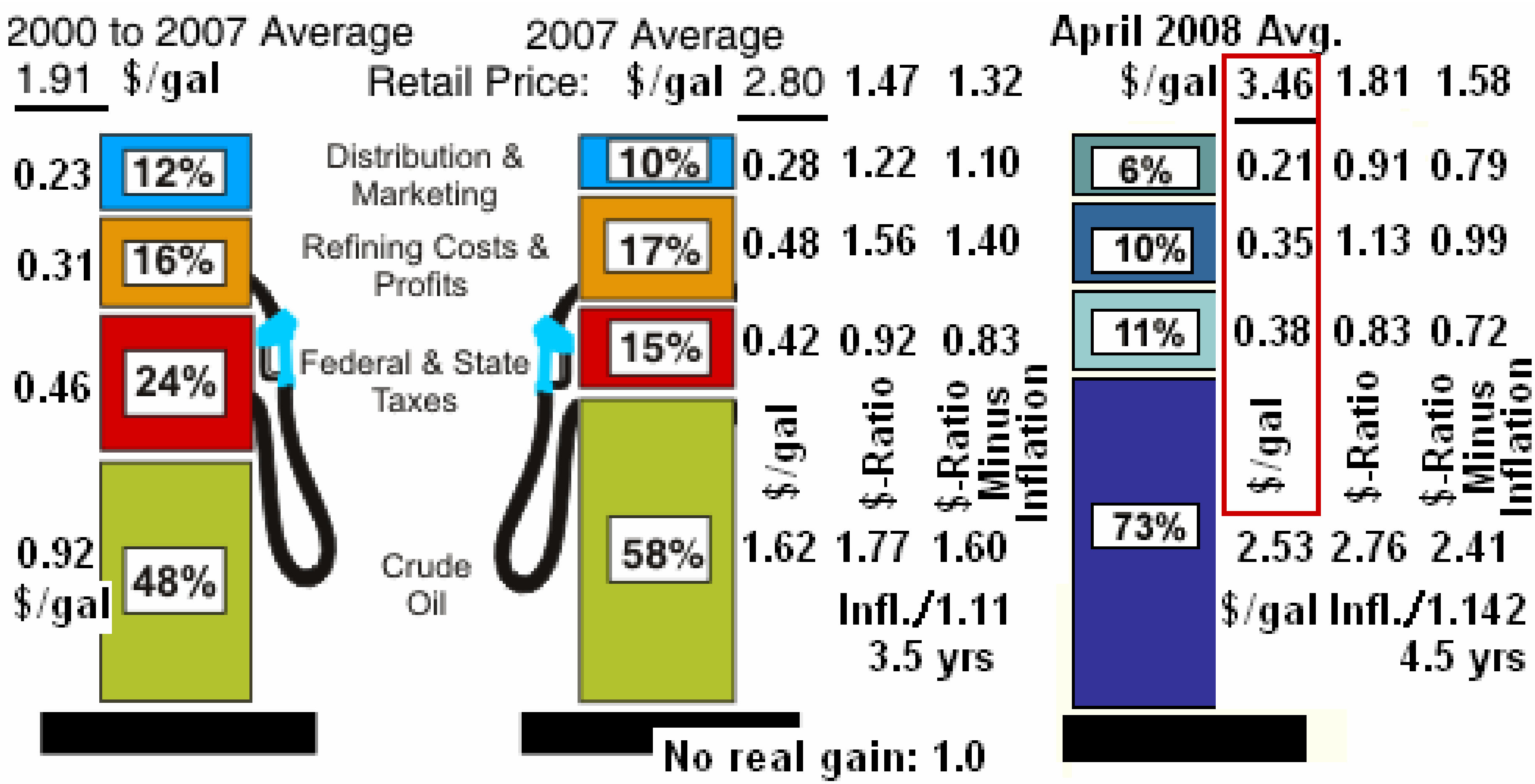
http://tonto.eia.doe.gov/state/state_energy_profiles.cfm?sid=MN

2. Comprehend Gasoline Retail Cost Components

US gasoline consumption was about **142 billion gal in 2007** , or an average of about 61% of all the energy used for transportation, 44% of all petroleum consumption, and 17% of total U.S. energy consumption. Gasoline energy amounts to 47% of its original crude oil.



Question: Is it true that speculators add ~40 $/barrel to costs? If so, can this be changed?

http://www.eia.doe.gov/bookshelf/brochures/gasolinepricesprimer/

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2. Energy Title in 2008 US Farm Bill

The new Energy Title in the 2008 Farm Bill received

- **$1.04 billion in mandatory appropriations.**

- $348 million in new tax credits to spur **production of advanced cellulosic biofuels**

- $255 million over four years for Rural Energy for America Program (REAP). REAP funding has been more than doubled and improves the Farm Bills successful Section 9006 **clean energy development program for locally-owned wind power, energy efficiency, solar energy, and other clean energy projects** REAP now includes Energy Technical Assistance funding to help farmers save money, improve margins and reduce fuel use.

- $320 million for Biorefinery Assistance. Grants and loan guarantees to help **build advanced biorefineries**, critical to jumpstart advanced biofuels production

- $70 million for the Biomass Crop Assistance Program (BCAP). A first-ever energy crop program to encourage farmers to **grow sustainable energy crops such as switchgrass**

- $35 million for Repowering Assistance, which, assists boilers at biofuels plants to **burn energy crops instead of coal**, cutting pollution and creating new markets for energy crops

- $300 million for Advanced Biofuels, i.e. incentives for **advanced biofuels production**

- $118 million for **Biomass R&D**. New investments for biomass fuel and power R&D

Conclusion: $1B may at best add 1 GW of new energy. Is this enough? US ‘06 electricity generating capacity is ~ 1000 GW.

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2. Compare Hydrogen, BM, Solar-PV & Wind

Hydrogen production costs

For 75% efficiency for electrolysis; ~ 0.05 $/kWh[1]; 1 GGE = 120 kBtu, then

- **Cost of H2 = (0.05/0.75)(4.184*252*120/3600) = 2.34 $/GGE w/o electrolysis eq.**

For el. equip.cost ~ 1 $/(GGE/y) or +0.18- 0.27 $/GGE to amortize eq. in 20- 8 y

Electrolysis: $H_2O \rightarrow H_2 + ½O_2$; Eo = 1.229 V; E = Eo + (0.059/z)log(200/14.5) = Eo+0.034

Costs of	-------------------------Capital------------	----------Product--------
Corn-Ethanol plant at	1 $/(gal/y) = 0.4 $/W	1.4 $/gal eth, 6000 h/y
Cellulosic-Eth. plnt at	6 $/(gal/y) = 2.2 $/W	3.2 $/gal eth
Cellulosic Gasol. plt.	6 $/(GGE/y)= 1.5 $/W	3.4 $/GGE
Solar PV-H2 plant at	10 $/(GEE/y) = 4.0 $/W[1]	3.3 $/GGE w/6000 h/y
at MN average 19%	16 $/(GGE/y) = 4.0 $/W[1]	12.3 $/GGE w/1612 h/y
Wind - H2 plt. at 28%	8 $/(GGE/y) = 2.0 $/W[4]	4.1 $/GGE w/2453 h/y

Solar PV costs[3] and subsidies[2]

3 kW home roof system for $17,000, or 5.66 $/W [3]. MN solar avg.: 4.53 h/day

- **Colorado Aquila: 5 $/watt (10 kW); Xcel: 4.5 $/watt (10 kW); Utah's is 2 $/watt**
- **Minnesota MDC: 2 $/watt (20 kW); Owatonna/Rochester PU: 1 $/watt (40 kW);**
- **Idaho NWSC: 100 % Tax credit.**

[1] Jeremy Rifkin, "The Hydrogen Economy," Penguin-Putnam, Inc. 2002
[2] http://www.solarhome.org/solartaxincentivesbystate.html
[3] http://www.solarhome.org/sunwizegridtiesystems.html [4] www.ceere/cerl

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2. Wind Turbine Example: Hull, MA, 2001

Renewable Energy Research Laboratory

University of Massachusetts at Amherst

160 Governors Drive
Amherst, MA 01003
413–545–4359
rerl@ecs.umass.edu
www.ceere.org/rerl/

Economics

As a town with a good wind resource and a municipal electric company, Hull is especially well placed to benefit economically from wind power. Here is a brief overview of the economics of the project:

Annual energy production:	1,590,000 kWh
Capacity factor Dec. 2001-2003	**27 %**
Annual average wind speed	**5.5 miles/h**
Revenue	
Value of energy purchases avoided*:	$0.08/kWh
Value of REC's**:	$0.03/kWh
Value of REPI:	$0.018/kWh
Total Current Value of Energy :	$0.128/kWh
Costs **of 660 kW–peak or 1.14 $/W-peak**	
Capital cost, incl. inst.***:	$753k; **i.e. 3.8 $/W-avg**
Operations, Maintenance & Insurance:	~$30,000/yr **or 4%/y**
Economic indicators	
Cost of producing energy:	~6 ¢ /kWh
Simple payback:	4-5 years
Net present value of savings:	$2-3 million, depending on inflation rates.

Windmill Farm: 30% cap.; 1 MW-peak; 100-m rotors; 600 m spacing >> 2.7 W/m2-peak =

1327 GEE/year/acre = 840 GGE/year/acre

Corn Farm : < 350 GEE/year/acre or 90-100 GEE/year/ton

Conclusion: Wind was not economical in 2001 but is today for Minnesota & Dakotas, w/capacity factors of 35-45%

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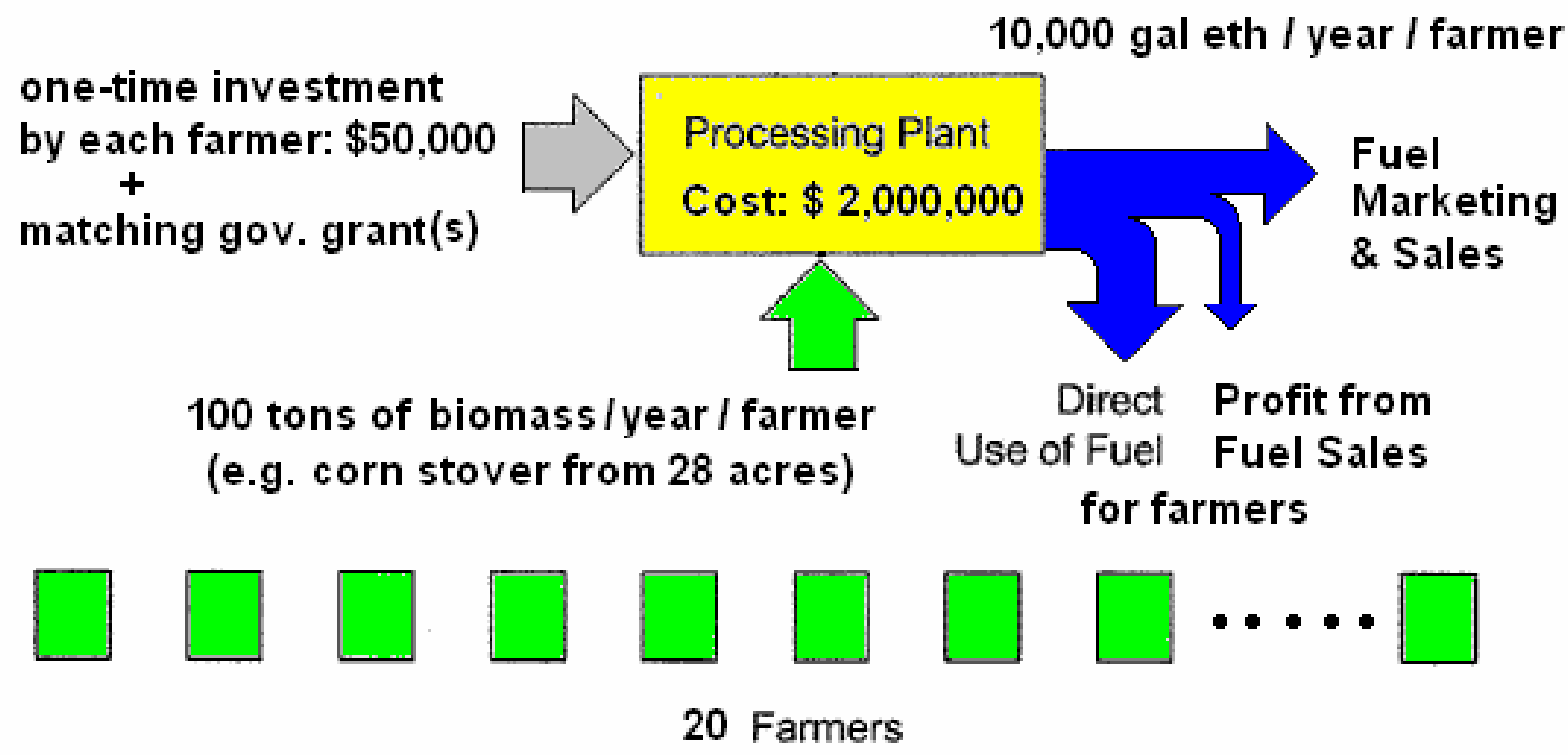
2. Coop Financing of Modular Biomass Plants



- A farm cooperative "sponsors" a biomass plant and finds 20 farmers seeking to use/buy or market 10,000 gal of fuel/year.
- Farmers contribute $ 50,000 each (once), and annually ~ 100 tons of biomass
- Farmers buy 10,000 gal fuel / year at cost or receive the net profits from such fuel sales

2. Energy Policies

- **Solar:** Assemblywoman Lori Saldana, D-San Diego, is sponsoring legislation to require home designs such that they would take no more electricity out of the grid than they put into it, averaged over a year. Environmental groups support it. Opposition from the building industry (business groups, contractors, engineers and manufacturers), and local Republican lawmakers. House price would increase by $40,000 for a 2,000-square-foot home, i.e. less than 10%.
- **Energy Investments:** Should we open more US areas for oil drilling? Some say that we need it to bridge the time between now and self sufficiency, and should only be permitted in conjunction with equal investment to achieve equivalent outputs in renewable energies: conservation, biomass, solar and wind. [UB]
- **Taxing Strategy:** Businesses thrive during stable and predictable pricing and market environment. Some countries in Europe provide stable energy prices by adjusting energy taxation to even out world fuel price fluctuations and invests the tax revenue to grow renewable domestic sources and boost energy security
- **Immigration:** Does it influence energy situation? World population growth control would help solve the energy and food crisis.
- **Nuclear:** According to http://www.neis.org/literature/Brochures/npfacts.htm, plant construction costs now est. at 10-12 $/W. Decommissioning: 4 $/W. Cost of uranium ore has soared from ~$6/ton 5 years ago to $140/ton today, a 25-fold increase--because >175 new reactors under way board around world. And because other fuels also are rising;
- **Other:** http://www.mnforsustain.org/erickson_dell_minnesotas_energy_future_part_V.htm#Minnesota%20Energy%20Sources,%20Uses,%20and%20Needs

Energy cost increases: Crude oil has nearly tripled from $55 to $145/bbl in just a few years;
Heating oil has jumped from $1.95/gal. to $3.40 in Mpls, i.e. a home annual heating oil bill may have soared from ~$2,000 to a forecasted $8,000 for 2009;
Natural gas has quadrupled from ~3.25 to 13 $/MBtu and may be headed for $20;
Gasoline has nearly tripled from ~1.50 to 4.13 $/gal.

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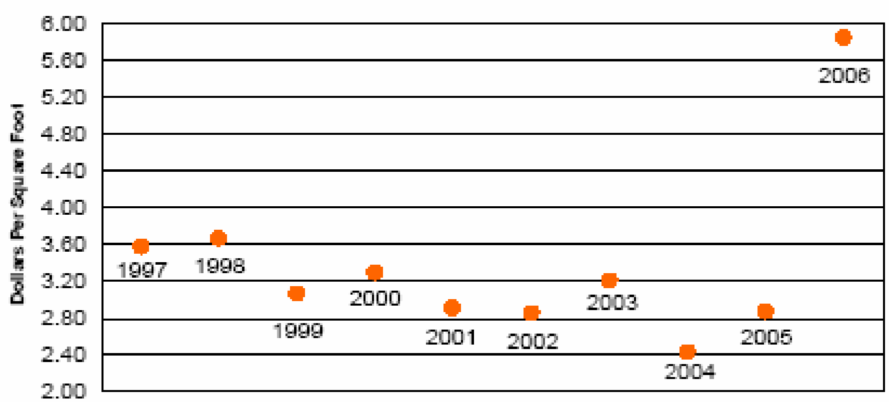
2. Solar Photo-Voltaic (PV)*

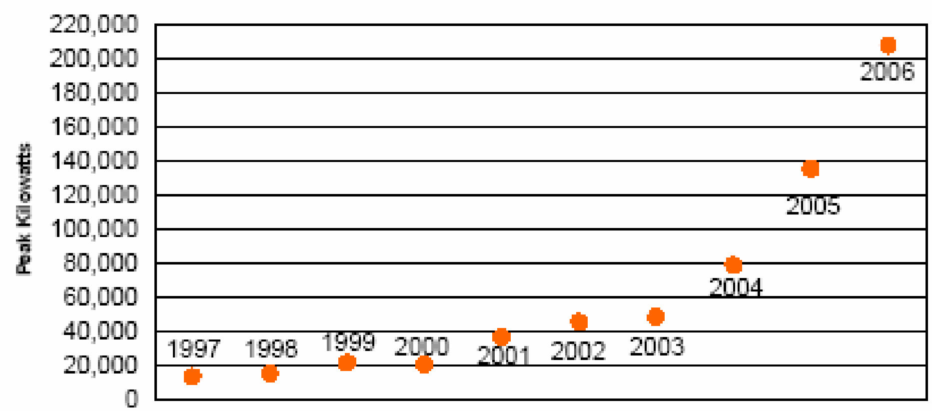
- Capacity factor (MN average) ~ 19%; effective ’06 cost: 18.4 $/avg-W
- Prices of PV 2005-6. Cells: 2.17-2.03; Modules: 3.19-3.50 $/peak-kW
- Total US exports 2006: 131 peak-MW; of these 81 MW to Germany
- Total US imports 2006: 174 peak-MW
- Total US domestic 2006: 206 peak-MW; 54% higher than in 2005

Figure 2.4 Solar Thermal Collector Average Price, 1997-2006



Source: Energy Information Administration, Form EIA-63A, "Solar Thermal Collector Manufacturers Survey."

Figure 2.5 Photovoltaic Domestic Shipments, 1997-2006



Source: Energy Information Administration, Form EIA-63B, "Annual Photovoltaic Module/Cell Manufacturers Survey."

Conclusion: Solar-PV still needs subsidy to grow for ~10y

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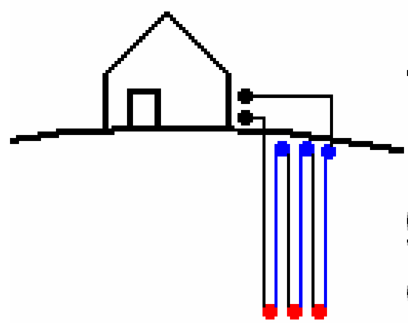
* http://www.eia.doe.gov/cneaf/solar.renewables/page/solarreport/solar.pdf

2. Geothermal Energy

Geothermal gradient is the rate of change of temperature vs. depth.
How can we use that source of heat?
The geothermal gradient varies depending on location.
Average: 75°F/mile up to ~150°F/mile in volcanically active areas.



Thermopile for leveraging Earth's thermal gradient for htg. & Earth's cool for cooling.

Applications

Heat-Pump: Ground-coil 4 -10 ft under the surface to function as
heat exchanger = evaporator for winter heating
= condenser for summer cooling
while observing regulations to avoid ground water contamination

Thermo-Electric

Conclusion: Other than for heat pumps, geothermal energy needs more research on cost-effectiveness for MN

DOE: http://www.newton.dep.anl.gov/askasci/env99/env205.htm

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2. The Nuclear Option (Preliminary)

Status in terms of availability (reserves), "feedstock cost" and total electricity "product" cost in $/kWh (which we can compare with other energy costs) w/o subsidies if any; yes regulations and approved op. licenses. What we can learn from France. $4.5B for More Hanford Plutonium Waste Cleanup

Pros: Long life of feedstock; no CO2, Hg or SO2 emissions; potential for high capacity, especially if reprocessing of spent uranium and breeder reactors can be acceptably deployed
Cons: High costs of capital (10-12$/W), feedstock-processing, storage, decommissioning (4$/W) & hazards. Is France's high nuclear contribution to electricity causing any problems?

CONCLUSIONS: Minn. should vigorously study expansion of nuclear energy (see France's example). It may be one of many elements of a comprehensive energy solution.

Shipping radio-active waste materials in vitrified caskets, in France.

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2. The Nuclear Fission Option* (Prelim.)

So it's not surprising that worldwide in 2006 ...

- New nuclear capacity was smaller than solar PV additions, or 1/10th of windpower additions
- Nuclear retirements exceeded additions, so *net* nuclear capacity fell by 0.5 GW while micropower added >30 net GW
- Micropower passed nuclear power in total annual electricity production (16% of total)
- Distributed renewables got $56b of private risk capital; ~~nuclear, as always, got zero~~
- And in China, distributed renewables had 49 GW—7× nuclear capacity—and added 7× more per year

Conclusion: Need to balance nuclear pros and cons

* **Amory B. Lovins, *23 February 2008***

The Case for Fast Breeder Reactors

1. Fast reactors can convert U-238 into fissile material at rates faster than it is consumed making it economically feasible to utilize ores with very low uranium concentrations and potentially even uranium found in the oceans.
2. Fast reactors in conjunction with fuel recycling can diminish the cost and duration of storing and managing reactor waste with an offsetting increase in the fuel cycle cost due to reprocessing and fuel refabrication.
3. Virtually all long-lived heavy elements are eliminated during fast reactor operation, leaving a small amount of fission product waste that requires assured isolation from the environment for less than 500 years.
4. Although fast reactors do not eliminate the need for international proliferation safeguards, they make the task easier by segregating and consuming the plutonium as it is created..
5. The combination of fast reactors and reprocessing is a promising option for reasons of safety, resource utilization, and proliferation resistance.

Fast Reactor Technology: A Path to Long-Term Energy Sustainability ***Position Statement 74***
November 2005 AMERICAN NUCLEAR SOCIETY www.ans.org

Two Major Fusion Projects

Two fusion projects are underway in the U.S. and France (ITER).

The U.S. project Is ongoing in several sites throughout the U.S. each addressing a different technological requirement of fusion. The main site is at the National Ignition Facility in Livermore, CA. The project is called the Fusion Ignition Research Experiment (FIRE).

The ITER project is an International Project that is underway in France. It is designed to demonstrate the feasibility of a commercial fusion Power Plant. Research and development is ongoing in several countries.

Brian Toren

FIRE Schedule

There are five stages to FIRE:

1. Configurization Optimization Concept development	Completion in 2031
2. Burning Plasma demonstration	Completion in 2035
3. Materials Development and Testing	Completion in 2036
4. Component Testing	Completion in 2042
5. Demonstration of plant	Demo in 2047
6. Commercially Viable Plant	Estimated in 2060

Estimated Cost - Billions(?)

http://www.ofes.fusion.doe.gov/more_html/NASDavies.pdf.

Brian Toren

ITER Schedule

There are several stages to the ITER poject:

ITER Construction	Complete in 2015
Development Operations/Test	Complete in 2025
Operational Phase	Complete in2036
Demo Power Plant Construction	Complete in 2032
Demo Power Plant Grid Connect	Complete in 2040
Materials Testing	Ongoing
Demo Power Plant Completion	Complete in 2049

Estimated Cost – 13+ Billion Euros

http://www.iter.org/a/index_nav_1.htm Click on Timeline

Brian Toren

2. Carbon Sequestration

With Earth crust density of d ~ 2.7 g/cm3, a pressure of p=2500 psi is balanced by the hydrostatic pressure at a depth of p*10/14.5/d = 638 m or 2,095 ft

With water density of d ~ 1 g/cm3, a pressure of p=2500 psi is balanced by the hydrostatic pressure at a depth of p*10/14.5/d = 1724 m or 5,657 ft

CO2 has a higher density than water at p > 2500 ? psi and therefore would sink to the ocean's bottom and form CO2 hydrates. However, the rate of dissolution is not zero (500 years?[1])

Convert CO2 to torpedo-shaped solid at -78.5°C and drop into ocean sediment, for conversion to clathrate, according to C.N.Murray et al, *Energy Convers. Mgmt* 37(6-8), 1067 (1996)

Calculations show that, CO2 may replace and release CH4 from S-I clathrates. Consider this if there are methane clathrates present where CO2 sequestration is to be attempted[3].

[1] US Pat. 5,397,553 (EPRI, 1995) method to form CO2-in-water clathrates of density > 1.1 g/cm3 of sea water, approximately CO2·8H2O. Recheck suggested "alignment" of CO2 molec.
[2] US Pat. 5,700,311 (Dwain F.Spencer, 23 Dec.1997) method to extract CO2 from gas mix into water to form clathrates. H2 does not form clathrates

Conclusion: Carbon sequestration remains elusive and is not ready for commercialization

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3. Summary of MNF Conclusions. Voted

	Yes	No
1. **Securing supplies of "sustainable energy" is public affairs priority #1;** Gov. interven. is needed.	~18	vs 0.
2. **Wind is economical today for Minnesota & Dakotas**, w/capacity factors of 35-45%	~18	vs 0.
3. **Subsidize renewable/efficient energy equipment ($/W) and output ($/kWh), consistent with 3x E.M.***	~15	vs 3.
4. **Solar needs to be & should be subsidized** (See $0.35-0.52/kWh subsidy in Germany, dropping 5-6%/y)**	~15	vs 3.
5. **Support community/coop-based network of small energy sources (solar-PV & -thermal, wind, biomass, H2-energy storage, H2-economy.**	~15	vs 3.

* EM = Economic Multiplier

** K.Bauer, Director Renewable Energy, DENA, 25 June 2008

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3. The Pros and Cons of Subsidies

Cons
Why to Avoid All BioFuel Production Subsidies

- Past subsidies have supported ethanol-from-grain production, which we now agree is unsustainable; therefore subsidies should not be used at all.
- Grain-to-ethanol has competed with food production and raised food prices
- Ethanol additions cause mileage to decrease
- Agriculture orgs. continue to lobby for corn-ethanol subsidies

Pros
Counterpoint

- Ethanol production is shifting from grain to cellulosic feedstock, & fills need for non-toxic oxyg'd, anti-knock additive
- Other factors have been blamed as well: Higher fuel costs and population growth
- Was this decrease worse than w/ MTBE?
- Agreed that subsidies should include a "sunset" clause

Conclusion:

- Energy Production subsidies are bad and should be stopped

- What other ways might help to achieve the development to meet the speed of change in the markets, w/o the listed pitfalls and w/o having to wait for the "market forces"?
Would we have seat belts and safety bags w/o government intervention?

How about subsidies with built-in technical performance milestones and a "sunset clause"?

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4. Proposed Suggestions

Voted
Yes No

- Short Term (< 2 years): • Conservation:
  - Reduce highway speed limit to 55 mph
  - Promote better home insulation, green bldgs & public transp.
  - Wind is presently best new energy value, w/free “feedstock” & compl. to food. Area of 86 acres for peak-100 MW at ~ 30% avg. load. Incentivise business to double present MN wind capacity for ~$1.4B, $341M new revenue and ~4-year payback
  - Develop electrolysis to generate H2 for energy storage, and
  - Dev. fuel cells for car power to reduce gasoline consumption — **16 2**
- Medium Term (< 5 years): • Solar-PV may become competitive after its price drops by 10x in ~12 years. Land area cannot be cultivated – therefore better for rooftops. Review subsidy rate.
  - Cellulose & coal conversion is practiced by large plants; but small, mass-produced biomass plants may too be econ. viable.
  - Finance via coop organization
  - Use electrolysis to generate H2 for energy storage, and
  - Use fuel cells for car power to reduce gasoline consumption — **15 3**
- Long Term (>=10 years): • Solar-PV, wind, mod. biomass plnts
  - Solar-Photo-Catalytic

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4. Proposed Suggestions(Cont'd.)

- **As in Europe, we should insure that biofuel targets meet strong sustainability criteria** (as per review by W.Bank study, & Prof.Ed Gallagher, head UK's Renew.Fuels Agency , commissioned by, Brit.Transport Secr. Ruth Kelly in Feb.'08)
- **Achieve World zero pop. growth via Total Fertility Rate ~ 2 kids/woman.** http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/P/Populations.html

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Collaboration and Innovation

"IBM is re-inventing the way it innovates. At one time the tech giant was a true believer on go-it-alone R&D. The feeling was that if a technology wasn't invented by IBMers, it wasn't as good. Now the computer pioneer realizes that no matter how big an organization is, more smart people are going to work outside its walls than inside. So it courts R&D partners aggressively. **'We are the most innovative when we collaborate,'** declares Chief Executive Samuel J.Palmisano".

THANK YOU !
ANY QUESTIONS?

p.18 of the Innovation Insert of
Business Week issue of Sept.10, 2007

Comparison of Fuel from Biomass, Solar-PV &Wind

	SHORT COMPARISON OF LARGE AND SMALL PLANTS									
	Inputs	Large	Large	Small	Small	Small	Small	Sol PV	Sol PV	Wind
3	Capacity in ethanol gal/h ="22kW"	3750	3750	25	25	"556"	"556"	"556"	"556"	"556"
4	Up-Time in h/year	6000	6000	6000	6000	6000	6000	1653	1653	2453
5	Ref. Plant size in million gal/y	30	30	30	30	30	30			
6	Ref. Plant cost in $/(gal eth/y)	3	3	3	3	3	6	10.1	5	5.1
8	Total number of plants produced	1	1	150	2,000	2,000	2,000	2,000	2,000	2,000
9	Fcty assembly saving factor	1	1	2.7	2.7	2.7	2.7	1	1	1
10	Years to pay loan in years	8	8	8	8	8	8	20	20	20
11	Interest on loan in %/y	8	8	12	12	12	12	12	12	12
12	Profit in % of fuel sales	20	20	10	10	10	10	10	10	10
13	Economy of plant scale, power	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
14	Learning curve in %/doublg.	83	83	83	83	83	83	83	83	83
15	BM feedst.cost in $/ton	30	30	0	0	30	50	0	0	0
16	Include BM transp.cost: 0=N,1=Y	1	1	1	1	1	1	0	0	0
17	Plant op.labor cost in $/h/shift	50	50	30	30	30	30	1	1	1
18	BM harvest in tons/acre	3.5	3.5	3.5	3.5	3.5	3.5	0	0	0
19	Distribution in % of mfct. cost	80	64	20	20	20	20	5	5	5
20	Cost of BioMax-25 kW BTE, k$	250	250	65	32.4	32.4	32.4			
	Outputs									
1	Last plant cost in Million $	90	90	1.17	0.582	0.58	1.16			
2	Plant capacity cost in $/(gal-eth/y)	3	3	5.84	2.911	2.91	5.82	16	8	8
3	Fuel retail price in $/gal ethanol	3.29	3.00	2.99	1.955	2.42	3.76	8.0	4.3	2.6
4	Fuel retail price in $/gal gasoline	5.19	4.73	4.73	3.09	3.82	5.94	12.7	6.8	4.1
	BioMax electricity cost in ¢/kWh	26.3	26.3	6.14	3.4	3.4	3.4			
						A\TL-07-PI-Bus-Mod, 25-JUN-08				

MinneFuel, LLC

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