Cooling a Fevered Planet - Technology
Worksheet by Gar W. Lipow and Jonathan Rynn

This spreadsheet contains bottom up scenarios. It takes specific technologies, the known cost of implementing them, and various scenarios for responses to such implementation and technical improvements (including no technical improvement!) and add up costs and benefits. This is intended to be an open source model.

Main	This worksheet
Efficiency	Summary tables for very aggressive and moderately aggressive efficiency scenarios
Renew	Summary tables for renenwable energy costs with no technical improvements
TechImprove	Efficiency scenarios with technical improvements
Renewtech	Renewable scenarios with techncial improvements
costs	Combining various technical and renewable improvements to get costs for various scenarios
Scenarios	Compares the costs of varous levels of investment and responses. It concludes that we had better pursue efficiency aggressviely and NOT FAIL. Low efficiency responses are expensive.
Residential Assumptions	These worksheets contain narratives about assumptions as to the cost and means of efficiency improvements, electricifcation and use of solar thermal in various sectors.
Commercial Assumptions	
Transport Assumptions	
Industry Assumptions	
Renewable Assumptions	Narrative explaining reasoning behind renewable scenarios
CyberTran	Discusses CyberTran and conventional light rail. CyberTran is not considered in scenarios, but is nonetheless something we should develop.
Sgrid	Discusses the potential of the smart grid, and why it reduces, but does not elimiante the need for dispatchable electricity
Rgrid	Shows costs of renewable grid, detail on why interconnection can give reliable power, and how combining sun and wind can produce more stable grid than either alone
Transport Safey	Paybacks from reductions in accidents by switching to trains or buses - does not substantially change scenarios, but important payback in CyberTran Sheet
Paybacks	Estimated payback costs for various scenarios
Totals	Total to show fossil fuel an biofuel use

Aggressive efficiency

Category	Cost billions U.S. Dollars			
heavy rail	450	January 2008 Estimate from oil drum (electricfy a portion and greatly increase capacity)		http://www.theoildru
		Sanity Check 1 - Railroad Study of cost to maintain existing frreight share 148 bllion		http://www.aar.org/Pu
		Sanity Check 2 -Rail advocacy group study of cost of slight increase $225 billion		http://www.go21.org/
Transit funding	500	Mixed rail and electrified buses		
electric cars	500	Assumes 5,000 added cost for first 100 million sold, cost difference between electric and convetional drops to zero thereafter		
Electric short haul trucks	50	Assumes 50 billion towards transition until electric short haul trucks catch up in cost with conentional		
Air travel		Air travel falls by half, costing GDP recovered as GDP switched to other uises		
Marine improvements	100	SkySails, engine overhauls, long rund new ships with better hulls, better propellors switch to natural gas		
Residential insulation, solar, heat pumps and appliances	2,000	Based on $20,000 average per residence of efficiency measures, solar, and heat pumps -		
		much cheaper in multi-unit than single unit, much cheaper in new than exisitng		
Commercial savings	1,295	Ratio of energy use, plus denser use so less costly saving		
Industrial	2,000	Higher percent, but still denser use, plus multiple processe opportunities for synergy plus effects of mater		See supplementary det
Additional Savings: - substituting renewables for coal and gas electricity reduces primary conversion losses				
Total	*6,895*	*Total efficiency means plus solar climate control and modest wind use in shipping*		

quad consumption 2005	100	quad
These measure could save between 40% and 80% per unit of GDP		
High Response	20	quad
Medium Response	40	quad
Low Response	60	quad

High response in kWh (low consumption)	5.86E+12
Medium Response (medium consumption)	1.172E+13
Low Response (high consumption)	1.758E+13

Why per unit of GDP? Because regardless of efficiency scenario, we need low emission sources. Given that there is very limited potential for biofuels, that mostly means electricity
But solar and wind resources are many times any forseeable consumption in this century. So. Assuming sun and wind remain more expensive than fossil fuels the practical limit to our ability to
subsitute them for fossil fuels is limited only by our ability to use them efficiently enough to make up for the extra cost. If we can produce twice as much from a kWh of electricity, we can afford to
to buy solar electrcity for double what we currently pay for coal.

Moderate Efficiency

Category	Cost billions U.S. Dollars			
heavy rail	400	January 2008 Estimate from oil drum (electricfy a portion and greatly increase capacity)		
		Sanity Check 1 - Railroad Study of cost to maintain existing frreight share 148 bllion		http://www.theoildru
		Sanity Check 2 -Rail advocacy group study of cost of slight increase $225 billion		http://www.aar.org/Pu
light rail	500	Rail and Electrified Bus transit		http://www.go21.org/
electric cars	500	Assumes 5,000 added cost for first 100 million sold, cost difference between electric and convetional drops to zero thereafter		
Electric short haul trucks and trolley buses	50	Assumes 50 billion trollely lines for buses plus 50 billion for added cost for trucks & buses		
Air travel		Air travel falls by half, costing GDP recovered as GDP switched to other uises		
Marine improvement	100	SkySails, improved engine - very long term better hulls, propellers and switch to natural gas		
Residential insulation, appliance upgrades, shared heat pumps or solar	1,200	Very few heat pumps. Little active solar heat		
		much cheaper in multi-unit than single unit, much cheaper in new than exisitng		
Commercial savings	1,295			
Industrial	900		40	See supplementary det
Additional Savings: - substituting renewables for coal and gas electricity reduces primary conversion losses				
Total	*4,945*	*Total efficiency means plus solar climate control and modest wind use in shipping*		

quad consumption 2005	100	quad
These measure could save between 30% and 60%		
High Response	40	quad
Medium Response	55	quad
Low Response	70	quad

High response in kWh (low consumption)	1.172E+13
Medium Response (medium consumption)	1.6115E+13
Low Response (high consumption)	2.051E+13

Why per unit of GDP? Because regardless of efficiency scenario, we need low emission sources. Given that there is very limited potential for biofuels, that mostly means electricity
But solar and wind resources are many times any forseeable consumption in this century. So. Assuming sun and wind remain more expensive than fossil fuels the practical limit to our ability to
subsitute them for fossil fuels is limited only by our ability to use them efficiently enough to make up for the extra cost. If we can produce twice as much from a kWh of electricity, we can afford to
to buy solar electrcity for double what we currently pay for coal.

	kWh	
Net Electricity Generation 2006	4,064,702,000,000	http://www.eia.doe.gov/cneaf/electricity/epa/epates.html
kWh per quad	293,000,000,000	
Quads current electricity	13.8727030716724	

Cost to generate this renewably without technical breakthroughs

Cost per kW for Wind Generator	$1,300-$1,700	http://www.bpa.gov/Energy/N/projects/post2006conservation/doc/Windpower_Cost_Review.doc
Midpoint	1,500	
Wind power capacity compared to nameplate	30.50%	http://www.awea.org/newsroom/releases/Wind_Power_Capacity_012307.html
1 KW at 30.5% capacity	2,672	kwh per year
To produce 100% of demand	1,521,334,681	KW nameplate capacity
To compensate for 10% transmission losses	1,673,468,149	KW nameplate capacity
To compensate for 30% loss of 2/3rds of power due to storage losses (2/3rds of 30% of delivered not generated. Stoarge is close to delivery points for cost and stablility reasons.)	1,825,601,617	KW nameplate capacity
Cost of Wind	2,738	billion dollars
3 hours storage (compared to nameplate)	1,597	billion dollars
Transmissions & Smart Grid	450	http://www1.eere.energy.gov/windandhydro/pdfs/4_transmission_integration_smith.pdf
		60 billion for 20% so 300 billion for 100%
		does not have to scale linearly because large amounts of storage handle transient demand spikes
backup NG at $800 pe KW	730	billion dollars
total	5,516	billion dollars
cost per KW	$3,625.79	
Existing hydro and geothermal provide another .5% bring total from renewables to 99%		
Cost per kwh per year	$1.3571	

Solar costs	40% utiliization	http://www.ethree.com/GHG/19%20Solar%20Thermal%20Assumptions%20v4.doc
Cost per KW	3,389	Overnight costs including six hours storage for 340 meg plant
kWh per KW (40%)	3,504	
KW to meet demand	1,160,017,694	
10% for transmisison	1,276,019,463	
7% of two third for storage losses	1,335,567,038	
Generation Costs	4,526	
10% increase to cover low water version	4,979	
Tramission lines	300	
Another 18 hours storage at $40/kWh	92	
backup NG at $800 pe KW	534	billion dollars
Total Cost	5,905	
Cost per KW	$5,090.41	
cost per kWh per year	$1.4527	
Cost around 35% solar/ 65% wind	7,574	
Cost of 30% redundancy to cover all seasonal variation and most annual varietion	9,846	
Capital cost per annual kWh generation	$2.4224	

Aggressive efficiency

Category	Cost billions U.S. Dollars		
heavy rail	450	January 2008 Estimate from oil drum (electricfy a portion	
		Sanity Check 1 - Railroad Study of cos	http://www.theoildrun
		Sanity Check 2 -Rail advocacy group s	http://www.aar.org/Pu
light rail & electric buses	500	see supporting Detail sheet	http://www.go21.org/
electric cars	100	Cheaper batteries means electric cars cost about $1,000 more	
Electric short haul trucks	35	Assumes faster improvement in electric trucks	
Air travel		Air travel falls by half, costing GDP recovered as GDP switche	
Ships converted to hybrid engines running on natura	100	Cost upgrading ships to natural gas driven hybrids, supplemen	
Residential insulation, solar, heat pumps and applia	2,000	Based on $20,000 average per residence of efficiency measur	
		much cheaper in multi-unit than single unit, much cheaper in	
Commercial savings	1,295	Ratio of energy use, plus denser use so less costly saving	
Industrial	2,000	Higher percent, but still denser use, pl	See supplementary det
Additional Savings: - substituting renewables for coal and gas electricity reduces primary conversion losses			
Total	*6,480*	*Total efficiency means plus solar climate control and modest v*	

quad consumption 2005	100	quad
These measure could save between 40% and 80% per unit of GDP		
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Moderate Efficiency

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		Sanity Check 1 - Railroad Study of cos	http://www.theoildrun
		Sanity Check 2 -Rail advocacy group s	http://www.aar.org/Pu
light rail + electrify buses	500	see supporting Detail sheet	http://www.go21.org/
electric cars	100	Assumes 6,000 added cost per car with 100 million cars made	
Electric short haul trucks	50		
Air travel		Air travel falls by half, costing GDP recovered as GDP switche	
Ships converted to hybrid engines running on natura	100	Cost upgrading ships to natural gas driven hybrids, supplemen	
Residential insulation, appliance upgrades, shared l	1,200	heat pumps under streets or shared solar heating panels	
		much cheaper in multi-unit than single unit, much cheaper in	
Commercial savings	1,295		
Industrial	900	40	See supplementary det
Additional Savings: - substituting renewables for coal and gas electricity reduces primary conversion losses			
Total	*4,595*	*Total efficiency means plus solar climate control and modest v*	

quad consumption 2005	100	quad
These measure could save between 30% and 60%		
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Medium Response (medium consumption)	1.6115E+13
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	kWh	
Net Electricity Generation 2006	4,064,702,000,000	http://www.eia.doe.gov/cneaf/electricity/epa/epates.html
kWh per quad	293,000,000,000	
Quads current electricity	13.87	

Capital Cost to generate this renewably with moderate tech breakthroughs

Cost per kW for Wind Generator				
Multiple turbines per tiliting tower lower cost	900	http://www.popsci.com/scitech/article/2008-05/ten-times-turbine		
Wind power capacity compared to nameplate. (Lower perecent of maximum capacity but extensive use of offshore still raises net capacity)	35%	Wind shadow reduces percent capacity		
1 KW at 35% capacity	2,453	kwh per year		
To produce 100% of demand	1,657,168,134	KW nameplate capacity		
To compensate for 10% transmission losses	1,822,884,948	KW nameplate capacity		
To compensate for 30% loss of 2/3rds of power due to storage losses	2,154,318,575	KW nameplate capacity		
Cost of 100% wind	1,939	billion dollars		
3 hours storage (compared to nameplate) at lowered ($300 per kWh) cost	1,491	billion dollars		
Transmission lines	300	http://www1.eere.energy.gov/windandhydro/pdfs/4_transmission_integration_smith.pdf		
		60 billion for 20% so 300 billion for 100%		
		does not have to scale linearly because large amounts of storage handle transient demand spikes		
backup NG at $800 pe KW	862	billion dollars		
total	4,592	billion dollars		
cost per KW	$2,771.03			
(Note: we also have existing hydro, geothermal to some extent as added stabilizer)				
Solar costs	40% utiliization	http://www.ethree.com/GHG/19%20Solar%20Thermal%20Assumptions%20v4.doc	also	http://www.l
Cost per KW (mass production, use of waste heatf or desal)	1,695	Overnight costs including six hours storage for 340 meg plant		
kWh per KW (40%)	3,504			
KW to meet demand	1,160,017,694			
10% for transmisison	1,276,019,463			
7% of two third for storage losses	1,335,566,443			
Generation Costs	2,263			
10% increase to cover low water version	2,489			
Tramission lines	300			
Another 18 hours storage at $15/kWh (near term breakthrough)	34			
backup NG at $800 pe KW	534	billion dollars		
Total Cost	3,358			
Cost per KW	$2,894.88			
Cost of ~65% wind and 35% sun	4,162			
Increase by 30% to cover most seasonal and some annual variation	5,411			
Capital cost per annual kwh	$1.33			

Capital Cost to generate this renewably with aggressive tech breakthroughs

Cost per kW for Wind Generator		
Multiple turbines per tiliting tower - pure guess on cost	1,500	http://www.skywindpower.com/ww/index.htm
Wind power capacity compared to nameplate	60%	Flying energy generators at 15,000 + feet gain higher capacity
1 KW at 55% capacity (FEG)	4,818	kwh per year
To produce 100% of demand	843,649,232	KW nameplate capacity
To compensate for 10% transmission losses	928,014,155	KW nameplate capacity
To compensate fo 20% loss of half of power due to storage losses	1,012,379,078	KW nameplate capacity
Cost of 100% wind	1,519	billion dollars
2 hours storage (compared to nameplate) ($250 per kwh storage costs)	422	billion dollars
Transmission & Smart Grid	450	http://www1.eere.energy.gov/windandhydro/pdfs/4_transmission_integration_smith.pdf
		60 billion for 20% so 300 billion for 100%
		does not have to scale linearly because large amounts of storage handle transient demand spikes
backup NG at $800 pe KW	`	billion dollars
total	2,390	billion dollars
cost per KW	$2,833.40	
(Note: we also have existing hydro, geothermal to some extent as added stabilizer)		
Solar costs	40% utiliization	http://www.ethree.com/GHG/19%20Solar%20Thermal%20Assumptions%20v4.doc
Cost per KW larges scale mass production, computer controlled flat mirrors or inflate	600	Overnight costs including six hours storage for 340 meg plant
kWh per KW (40%)	3,504	
KW to meet demand	1,160,017,694	
10% for transmisison	1,276,019,463	
7% of two third for storage losses	1,335,566,443	
Generation Costs	801	
10% increase to cover low water version	881	
Tramission lines	300	
Another 18 hours storage at $10/kWh (aggressive breakthrough)	23	
backup NG at $800 pe KW	534	billion dollars
Total Cost	1,739	
Cost per KW	$1,498.83	
cost of ~65% wind and ~35% sun	2,163	
Cost to increase by 30% to cover all seasonal and some annual variation	2,812	
Capital cost per annual kwh	$0.69	

No Technical Improvement Scenarios

Aggressive Efficiency Scenarios

Aggressive investment/strong efficiency response	kWh needed
Cost of aggressive scenario (billions)	6,895
High response in kWh (low consumption)	5.86E+12
Medium Response (medium consumption)	1.172E+13
Low Response (high consumption)	1.758E+13
Capital cost per annual kWh of renewalbes	$2.4224

Aggressive investment/strong efficiency response	
Efficiency Costs	6,895
Renewable costs	14,195
Total	21,091

Aggressive investment/moderate efficiency response	
Efficiency Costs	6,895
Renewable costs	28,391
Total	35,286

Aggressive investment/low efficiency response	
Efficiency Costs	6,895
Renewable costs	42,586
Total	49,481

Moderate Efficiency Scenarios

High response in kWh (low consumption)	1.172E+13
Medium Response (medium consumption)	1.6115E+13
Low Response (high consumption)	2.051E+13

Moderate investment/strong efficiency response	
Efficiency Costs	4,945
Renewable costs	28,391
Total	33,336

Moderate investment/moderate efficiency response	
Efficiency Costs	4,945
Renewable costs	39,037
Total	43,982

Moderate investment/low efficiency response	
Efficiency Costs	4,945
Renewable costs	49,684
Total	54,629

Moderate Technical Improvement Scenarios

Cost per annual kWh	$1.33

Aggressive Efficiency Scenarios

Aggressive investment/strong efficiency response	
Efficiency Costs	6,480
Renewable Costs	7,801
Total	14,281

Aggressive investment/moderate efficiency response	
Efficiency Costs	6,480
Renewable Costs	15,601
Total	22,081

Aggressive investment/low efficiency response	
Efficiency Costs	6,480
Renewable Costs	23,402
Total	29,882

Moderate Efficiency Scenarios

Moderate Effciency Cost	4,595
High response moderate renewable improve	
High response in kWh (low consumption)	1.172E+13
Medium Response (medium consumption)	1.6115E+13
Low Response (high consumption)	2.051E+13

Moderate investment/strong efficiency response	
Efficiency Costs	4,595
Renewable costs	15,601
Total	20,196

Moderate investment/moderate efficiency response	
Efficiency Costs	4,595
Renewable costs	21,452
Total	26,047

Moderate investment/low efficiency response	
Efficiency Costs	4,595
Renewable costs	27,302
Total	31,897

Aggressive Technical Improvement Scenarios

Aggressive Efficiency Scenarios

Aggressive investment/strong efficiency response	
Efficiency Costs	6,480
Renewable costs	4,054
Total	10,535

Aggressive investment/moderate efficiency response	
Efficiency Costs	6,480
Renewable costs	8,109
Total	14,589

Aggressive investment/low efficiency response	
Efficiency Costs	6,480
Renewable costs	12,163
Total	18,644

Moderate Efficiency Scenarios

Moderate investment/strong efficiency response	
Efficiency Costs	4,595
Renewable costs	8,109
Total	12,704

Moderate investment/moderate efficiency response	
Efficiency Costs	4,595
Renewable costs	11,150
Total	15,745

Moderate investment/low efficiency response	
Efficiency Costs	4,595
Renewable costs	14,191
Total	18,786

2.93E+13	kwh in 100 quads	O&M & Fossil Fuel	293.00				

No Technical Improvement

Scenario	Cost/Billions	30 year payback payback billions 5% interest	Payback needed Including O&M	30 YR Net	20 year payback needed billions 5% interest	Payback needed Including O&M	20 Year Net
Aggressive 80% savings	21,091	(1,371.98)	$1,664.98	($656.19)	(1,692.37)	$1,985.37	($335.80)
Moderate 60% Savings	33,336	(2,168.54)	$2,461.54	$140.37	(2,674.95)	$2,967.95	$646.78
Aggressive 60% savings	35,286	(2,295.41)	$2,588.41	$267.24	(2,831.44)	$3,124.44	$803.27
Moderate 45% Savings	43,982	(2,861.11)	$3,154.11	$832.95	(3,529.26)	$3,822.26	$1,501.09
Aggressive 40% savings	49,481	(3,218.84)	$3,511.84	$1,190.67	(3,970.52)	$4,263.52	$1,942.35
Moderate 30% Savings	54,629	(3,553.69)	$3,846.69	$1,525.52	(4,383.56)	$4,676.56	$2,355.40

Moderate Technical Improvement

Scenario	Cost/Billions	30 year payback payback billions 5% interest	Payback needed Including O&M	30 YR Net	20 year payback needed billions 5% interest	Payback needed Including O&M	20 Year Net
Aggressive 80% savings	14,281	(928.99)	$1,221.99	($1,099.18)	(1,145.93)	$1,438.93	($882.24)
Moderate 60% savings	20,196	(1,313.79)	$1,606.79	($714.38)	(1,620.59)	$1,913.59	($407.58)
Aggressive 60% Savings	22,081	(1,436.43)	$1,729.43	($591.74)	(1,771.87)	$2,064.87	($256.30)
Moderate 45% savings	26,047	(1,694.37)	$1,987.37	($333.80)	(2,090.04)	$2,383.04	$61.88
Aggressive 40% Savinge	29,882	(1,943.86)	$2,236.86	($84.30)	(2,397.80)	$2,690.80	$369.64
Moderate 30% savings	31,897	(2,074.95)	$2,367.95	$46.78	(2,559.50)	$2,852.50	$531.33

Aggressive Technical Improvement

		30 year payback payback billions 5% interest	Payback needed Including O&M	30 YR Net	20 year payback needed billions 5% interest	Payback needed Including O&M	20 Year Net
Aggressive 80%	10,535	(685.30)	$978.30	($1,342.87)	(845.33)	$1,138.33	($1,182.84)
Moderate 60%	12,704	(826.41)	$1,119.41	($1,201.76)	(1,019.39)	$1,312.39	($1,008.77)
Aggressive 60%	14,589	(949.04)	$1,242.04	($1,079.12)	(1,170.67)	$1,463.67	($857.50)
Moderate 45%	15,745	(1,024.22)	$1,317.22	($1,003.95)	(1,263.40)	$1,556.40	($764.77)
Aggressive 40% Savinge	18,644	(1,212.79)	$1,505.79	($815.38)	(1,496.01)	$1,789.01	($532.16)
Moderate 30%	18,786	(1,222.03)	$1,515.03	($806.14)	(1,507.40)	$1,800.40	($520.77)

Efficiency upgrades for existing homes

The assumption here is that extremely aggressive expenditures can reduce consumption in existing homes by 80% and that moderately aggressive expenditures could reduce consumption by 60%. http://www.nohairshirts.com/chap17.php

Install full floor and attic insulation, attic to R50 (or more depending on climate), floor to R30 or more depending on climate. Install maximum weather-sealing consistent with avoiding indoor air pollution. Retrofit energy recovery ventilators in 5% or 10% of cases where such retrofits will pay for themselves. Insulate and seal frames of non-operable windows, and apply normal weather sealing to operable windows. Provide insulating curtains for all windows, except where the window is due for replacement: then upgrade the replacement from standard to high efficiency windows. (In some cases you may still use insulating curtains, in others they are redundant.)

Install sink aerators high efficiency showerheads, and thoroughly check any plumbing for leaks, repairing any that are found. Install heat recovery systems that use hot water from hot water going down the drain to pre-heat water entering the water heater. Replace other water appliances with high efficiency versions - hot water heaters (replaced with demand water heaters, or highly insulated storage water heaters), washing machines, and dishwashing machines. Replace oldest first to so that they are as amortized as possible before replacements. (If funded by a tax credit or rebate program for example, apply the credit or rebate to appliances over ten years old.)

Replace all incandescent or halogen lights with CFL (except where they won't fit, or where lack of ventilation makes them dangerous or where exposure to excess humidity and extreme temperatures shorten their lifespan). Replace refrigerators over ten years old with high efficiency models: any incentive program must include a requirement to dispose of old refrigerator.

Computers and electronic appliances generally consume more energy during manufacture than they do in their lifetime. The object therefore for electronics and small appliances is to provide incentives to make sure they are in use as long as possible before disposal, and that when they are replaced that the replacements are high efficiency in both manufacture and operation.

All of the above applies to both moderate and aggressive efficiency programs. In aggressive versions I would add:

1) Ground source heat pumps where practical. One trick used in some Scandinavian countries might both lower the cost of ground source heat pumps, and increase the potential for using them in all homes without exhausting stored ground heat: take advantage for road resurfacing to bury shared grounds source systems under roads as well as under the land dedicated to the buildings themselves. That would lower the costs of burying the pipes deeper, and also improve the ratio of land available for the systems to building square footage to be conditioned.
2) Modern air source heat pumps: although in temperatures above zero they can match ground source heat pumps for efficiency, as temperatures approach zero they turn into resistance heaters, and usually have simple resistance elements built in for just that reason. So overall, air source heat pumps will produce an average of 2 to 2.5 units of heat for every unit input - 3 or 4 units when temperatures are above zero, and .95 when temperatures are below zero.
3) In sunny cold climates solar space heaters combined with reasonably efficiency air conditioners for hot weather may be practical. (In some climates you can omit the air conditioner.) To the extent that ground neither ground source heat pumps nor solar were practical, air source heat pumps in have now been improved to the point where they are reasonably efficient, though this lowers overall efficiency since they turn into resistance heaters once temperatures hit zero.
4) Even in cloudy cold Seattle solar hot water heaters may be practical much of the time. There is some sun in every month, and since you need hot water summer and winter you can amortize your capital investment as fully as available sunlight allows.

For the extremely aggressive version costs could be around $20,000 or more for a single family home, but more like $15,000 or less per unit for multi-unit homes because of smaller square footage and shared walls and economies of scale. Modular homes/mobile homes/trailers would be in between - smaller square footage, but no shared walls. Instead of attic insulation, trailers with flat roofs could have foam roofs installed.

For the less aggressive version, I'm assuming $6,000 to $12,000 per residence.

In new residences the cost of 90% rather than 80% efficiency improvements can range from 5% of construction costs to negative. (The latter sometimes happens due to savings in the size of climate control equipment, and using forms of insulation that double as weather sealing and structural material.)

Jürgen Schnieders, *CEPHEUS - Measurement Results from More Than 100 Dwelling Units in Passive Houses*. May 2003. *Passive House Institute*, 23/Dec/2003 <http://www.passiv.de/07_eng/news/CEPHEUS_ECEEE.pdf>.

(Note: he documented an 80% reduction compared to German standards. But Germans use about half the energy per capita as the U.S.

States Census Bureau, "Section 19 - Energy and Utilities," *Statistical Abstract of the United States 2002*. December 2002. *United States Census Bureau* <http://www.census.gov/prod/2003pubs/02statab/energy.pdf>.p847
Table No. 1350. Energy Consumption and Production by Country: 1990 and 2000

So this is a 90% savings, compared to U.S. standards. Actually it is a bit more, because the 80% savings compares to tougher requirements for new German homes, not average use.

[214]U.S. Department of Energy - Energy Information Administration, "2001 Consumption and Expenditures Tables - Space-Heating Expenditures Tables," A Look at Residential Energy Consumption in 2001. 23/October 2003, 23/Dec/2003 <ftp://ftp.eia.doe.gov/pub/cons

Table CE2-9e. Space-Heating Energy Expenditures in U.S. Households by Northeast Census Region, 2001 - Preliminary Data

Table CE2-12e. Space-Heating Energy Expenditures in U.S. Households by West Census Region, 2001 - Preliminary Data

U.S. Department of Energy - Energy Information Administration, "2001 Consumption and Expenditures Tables - Electric Air-Conditioning Expenditures Tables," *A Look at Residential Energy Consumption in 2001*. 23/October 2003, 23/Dec/2003 <ftp://ftp.eia.doe.gov/pub/consumption/residential

Table CE3-9e. Electric Air-Conditioning Energy Expenditures in U.S. Households by Northeast Census Region, 2001 - Preliminary Data

Table CE3-12e. Electric Air-Conditioning Energy Expenditures in U.S. Households by West Census Region, 2001 - Preliminary Data

[215]Joe Wiehagen and Craig Drumhelle, Strategies for Energy Efficient Remodeling | Seer 2003 [Case Study Report, 2004). 30/Mar 2004. National Renewable Energy Laboratory, 1/Oct/2005 <http://www.toolbase.org/docs/MainNav/Remodeling/4564_SEERCaseStudyF

[216] Agence France-Presse, *Thai Architect Hits on Blueprint for Sustainable Living in the Tropics*. 28/September 2003, Terra Daily, 06/Jul/2005 <http://www.terradaily.com/2003/030928033742.6azaxajn.html>.

Maria Cheng and Julian Gearing, "Green Seeds,". *Asia Week* 27-18 11/May 2001, Asia Week, 05/Jul/2005 <http://www.asiaweek.com/asiaweek/magazine/nations/0,8782,108626,00.html>.

[217]And according to Amory Lovins this was larger than he needed.
Paul Hawken, Amory Lovins, and L.Hunter Lovins, *Natural Capitalism: Creating the Next Industrial Revolution* (Boston: Little, Brown and Company/Back Bay, 2000).
Chapter 5:Building Blocks. p103.

[218]U.S. Department of Energy - Energy Information Administration, "2001 Consumption and Expenditures Tables - Total Energy Consumption," A Look at Residential Energy Consumption in 2001. 23/October 2003, 23/Dec/2003 <ftp://ftp.eia.doe.gov/pub/consumption/

Table CE1-9c. Total Energy Consumption in U.S. Households by Northeast Census Region, 2001 - Preliminary Data

U.S. Department of Energy - Energy Information Administration, "2001 Consumption and Expenditures Tables - Water-Heating Consumption Tables," *A Look at Residential Energy Consumption in 2001*. 23/October 2003, 23/Dec/2003 <ftp://ftp.eia.doe.gov/pub/consumption/residential/2001ce_ta

Table CE4-9c. Water-Heating Energy Consumption in U.S. Households by Northeast Census Region, 2001 - Preliminary

[219]U.S. Department of Energy - Energy Information Administration, "2001 Consumption and Expenditures Tables - Water-Heating Expenditures," A Look at Residential Energy Consumption in 2001. 23/October 2003, 23/Dec/2003 <ftp://ftp.eia.doe.gov/pub/consumptior

Table CE4-9e. Water-Heating Energy Expenditures in U.S. Households by Northeast Census Region, 2001 - Preliminary Data

Table CE4-10e. Water-Heating Energy Expenditures in U.S. Households by Midwest Census Region, 2001 - Preliminary Data

[220]U.S. Department of Labor Bureau of Labor Statistics, "Table 8. Region of Residence: Average Annual Expenditures and Characteristics," *Consumer Expenditure Survey 2002*. 13/Nov 2003. *U.S. Department of Labor Bureau of Labor Statistics*, 06/Jul/2005 < http://www.bls.gov/cex/2002/Stanc

Table 8. Region of residence: Average annual expenditures and characteristics, Consumer Expenditure Survey, 2002

[221]Whedon 0.5 GPM Ultra SaverAerator - US$3.50
Energy Federation Incorporated, *EFI Internet Division Residential Catalogue | Bath Faucet Aerators*. July 2005, Energy Federation Incorporated, 13/Jul/2005 <http://www.energyfederation.org/consumer/default.php/cPath/27_52>.

similar product to above for $2.15
Conserv-A-Store, *Conserv-A-Store :: Recycling Supplies, Solar Lighting, Electrical, Plumbing & Water Conservation Products-Economical & Eco-Friendly! Part Number: 01-0104*. July 2005, Conserv-A-Store, 13/Jul/2005 <http://www.conservastore.com/productdetail.php?p=23>.

[222]Conserv-A-Store, Conserv-A-Store :: Recycling Supplies, Solar Lighting, Electrical, Plumbing & Water Conservation Products-Economical & Eco-Friendly!. July 2005, Conserv-A-Store, 13/Jul/2005 <http://www.conservastore.com/index_plumbing.htm>.

[223]According to the Handyman Club the Stepflow Kick Pedal should be discounted to $129
Tom Sweeney, *Handyman Club of America - Hands Free - Pedal Valve Makes Sink Faucets Convenient and Clean*. February 1999, Handyman Club of America (Publishers of Handy Magazine), 13/Jul/2005 <http://www.handymanclub.com/document.asp?cID=57&dID=777>.

And here it is on-line for $120.00 with shipping and such probably around $129 .
Professional Piercing Information Systems, *Products: Step-Flow Operated Sink Valve*. 16/June 2005, Professional Piercing Information Systems, 13/Jul/2005 <http://www.propiercing.com/products.html>.

[224]Priced at $27.00 without shipping at sustainable village. Assuming six bucks in shipping charges total of $60. Since sustainable village ships this only to developing nations, I've given the URL of manufacturer who should be able to tell where we in the U.S. can actua

Sustainable Village, *Sustainable Village - Products - Aqua Helix*. 2005, Sustainable Village, 13/Jul/2005 <http://www.thesustainablevillage.com/servlet/display/product/detail/22602>.

Jet Blast Industrial Services, *Aqua Helix Home*. 18/Feb 1999, Jet Blast Industrial Services, 13/Jul/2005 <http://www.jetblast.net/ahhome.html>.

[225]Microphor LF-210 $539.00
Dean Petrich, *Toilet Prices*. 16/July 2005, Ultra-Low Water-Flush toilets, Aqua Alternatives, 20/Jul/2005 <http://www.enviroalternatives.com/toiletprices.html#ULTRA-LOW%20WATER-FLUSH>.

[226]WaterFilm Energy Inc., GFX 40% Off. GFX Heat Exchanger, 25/May 2005, WaterFilm Energy Inc., 20/Jul/2005 < http://www.gfxtechnology.com/sale.html>.

Carmine Dr. Vasile, *International Data on Successfully Demonstrated Energy Efficiency Projects - Residential Waste Water Heat-Recovery System: GFX*. April 2000, Centre for the Analysis and Dissemination of Demonstrated Energy Technologies, 20/Jul/2005 <http://gfxtechnology.com/CADD

Note where showers are not the main hot water consumer in the household storage recovery systems are available in the same price range:

National Association of Home Builders Research Center, *Drainwater Heat Recovery*. 2004, National Association of Home Builders Research Center, 08/Aug/2005 <http://www.toolbase.org/tertiaryT.asp?DocumentID=2134&CategoryID=1402>.

[227]EnergyStar Dishwasher product rating - in this case 85% better than average new model (so divide by 185).
(Note: this does not quite double efficiency of what is currently for sale, which means it is probably double or better that currently in use - but we will use EnergyStar rating as conservative estimate of savings)

Energy Star Program of the EPA and DOE, *Energy Star Qualified Dishwashers*, List of Energy Star Dishwashers with Efficiency Ratings. 14/June 2004, Energy Start Program of the EPA and DOE, 10/Jul/2005 <http://www.energystar.gov/ia/products/prod_lists/dishwash_prod_list.pdf>.p1

[228]Average Energystar & regular appliance prices 2000

The NPD Group, Inc., *NPD INTELECT REPORTS SIGNIFICANT GROWTH FOR ENERGY-EFFICIENT APPLIANCES*. Average Appliance Prices: Energystar Vs. Non-Energystar, 18/October 2000, The NPD Group, Inc., 10/Jul/2005 < http://www.npd.com/press/releases/press_001018.htm>.

(Note: A market survey is a legitimate source for pricing information).

[229]ASKO, D3350. 204. ASKO, 05/Jul/2005 <http://www.asko.se/ASKO/brandsite/main.cfm?moduleID=10&productID=2814#>.

[230]Universal Appliance and Kitchen Center, 24" ASKO Dishwasher, D3121. Quote July 10 for Asko D3121, July 2005, Universal Appliance and Kitchen Center, 10/Jul/2005 <http://store.universal-akb.net/24asdid3.html>. (Note this was for a particular day – the key is

[231]Liz Madison, Kitchen Tools, Kitchen Electrics, Cookware, Tableware - LizMadison.Com -GWL11. GWL11 Clothes Washer, July 2005, Liz Madison, 10/Ju <http://www.lizmadison.com/housewares/Product.asp_X_SKU_Y_GWL11_Z_REF_Y_SHLIZ>.

No doubt the particular page will have expired by the time you read this. The main point is that you can get a washing machine that saves nearly 80% of the energy a non-Energy Star model would use for about $220 more.

[232]Energy Star Program of the EPA and DOE, ENERGY STAR® Qualified Clothes Washers, ENERGY STAR® Qualified Clothes Washers with Effiiciencies and Projected Yearly KWh Consumption. 21/June 2004. Energy Star Program of the EPA and DOE, 11/Jul/20

(Again this rates against average new available, so efficiency compared to installed home clothes washers is probably slightly better.)

[233]Mark Hutchinson, Trickle Irrigation: Using and Conserving Water in the Home Garden - University of Maine Cooperative Extension Bulletin #2280. April 2005, University of Maine Cooperative Extension, 13/Jul/2005 < http://www.umext.maine.edu/onlinepubs/htmpub

[234]William B. DeOreo, David M. Lewis, and Peter W. Mayer, Seattle Home Water Conservation Study: The Impacts of High Efficiency Plumbing Fixture Retrofits in Single-Family Homes. December 2000. Aquacraft, Inc. Water Engineering and Management, 08/Aug/20

[235]Madison Gas & Electric Company, Water Heaters. Feb/25 2005. Madison Gas and Electric Company, Madison Gas and Electric Company, 08/Aug/2005 <http://www.mge.com/images/PDF/Brochures/Residential/WaterHeaters.pdf>.p3.

[236]Low Energy Systems, Inc, Infinion with Battery Spark Ignition. August 2005. Low Energy Systems, Inc, 08/Aug/2005 <http://www.tanklesswaterheaters.com/infinion2.html>.

[237] U.S. Department of Energy Office of Energy Efficiency and Renewable Energy, "Energy Savers: Compact Fluorescent Lamps," Energy Savers: A Consumer Guide to Renewable Energy and Energy Efficiency, 21/June 2004, 19/Aug/2005 <http://www.eere.energy.g

[238]Fisher & Paykel, Washers. August 2005, Fisher & Paykel, 19/Aug/2005 <http://usa.fisherpaykel.com/laundry/washers/washers.cfm>.

[239]Secondary (end use) consumption is 4 kWh per load for the electric dryer, plus .23 kWh per load plus .22 therms per load for the gas dryer. If you convert therms to kWh at 100% efficiency this comes out the gas dryer actually using 67% more energy than an electr

Energy Star Program of the EPA and DOE, "About the HES Appliance Module," *The Home Energy Saver*, Table 3: Other Appliances and Miscellaneous Energy Usages, 06/June 2001, Energy Star Program of the EPA and DOE, 20/Aug/2005 < http://homeenergysaver.lbl.gov/hes/aboutapps.html

However, on average heat driven power plants convert only 36.47% of heat energy into electricity.

International Energy Agency, *Electricity Information 2002 Edition*, Electricity Information, vol. 2002 Edition, no. ISBN 9264197931 (Paris: OECD - Organisation for Economic Co-operation and Development, 2002).p.II.706
Part II Table 9 United State Electricity Production From Combustible Fuels in Electricity Plants"

So dividing the electricity consumption in both gas and electric dryers by 36.47, and then converting both to therms or both to kWh as you please, you end up with a 35.47% savings.

[240]California Energy Commission, "Dryers," Consumer Energy Center - Inside Your Home, August 2005, California Energy Commission, 20/Aug/2005 <http://www.consumerenergycenter.org/homeandwork/homes/inside/appliances/dryers.html>.

Efficiency upgrades for commercial buildings

http://www.nohairshirts.com/chap18.php

In commercial buildings well known techniques (not including heat pumps or solar) can save an average 70% of total energy consumption in existing buildings during a full rehab, and of course in new buildings as well. Again, because of urgency, we probably should not wait the full 20-25 years until existing buildings need such rehabs, but we can do older ones first, and ensure that buildings have at least ten years amortization from their creation or last rehab before doing such work.

Commercial buildings have high enough demand and sufficient roof space that it may be profitable to put up solar heaters and chillers and then add ground source heat pumps for back up besides. At any rate we can do at least one. So ground source heat pumps or solar providing heat, air conditioning and hot water or a combination of both will be in addition to such rehabs. Because of economies of scale, including the fact that some technology used for commercial buildings is not even available on a small enough scale for most residential use, the cost of commercial savings are a lot lower than in residential upgrades.

Examples

In cold dark Amsterdam, NDB (now ING) bank built an integrated, light, airy, lovely, sunlit, plant-filled building. It uses around 35,246 BTU per month[246], compared to a U.S. average consumption of 119,500 BTU per commercial square foot in 2002[247] Energy reductions alone saved the bank around $2.4 million U.S. dollars annually. The $700,000 additional investment the building cost over an average building its size in the Netherlands repaid costs within four months. When NDB first moved into the building they saw absenteeism drop by ten percent as an additional bonus.	69% saving
Anglia Polytechnic University (APU) Learning Resources Centre, 'The Queen's Building', 41,842 BTU per square foot[248]. Net capital saving of £240,750 – before the first savings in operation.	63% saving
Leeds City Office Park 39,306 BTU per square foot[249]: £437,000 capital investment provides energy cost reductions of £72,603 per year	66% saving
Enschede tax office (Netherlands) 35,185 BTU per square foot - at an additional capital cost of 421,972 NLG[250]: annual saving 67,097 NLG.	69|% saving
Sukkertoppen office building, owned by Employees Capital Pension Fund, retrofit, rented commercially to small computer companies and educational organizations[251]. 30,114 BTU per square foot; cost data proprietary, but successful commercial venture.	74% saving
Ridgehaven Office building renovation City of San Diego Environmental Services Department. 27,296 BTU per square foot; simple payback rate of 30%.[252].	76% saving
[253]Bloomington, Illinois Amtrak passenger station, insulation, outdoor shading, passive solar heating, - 2.4- kilowatt rooftop solar array, efficient lighting. Simple five year payback of about $100,000 in costs	75% saving
The Pennsylvania Department of Environmental Protection's Cambria Office less than 40,000 BTU per square foot[254]. Capital savings in climate control equipment paid for all or most of efficiency measures[255]. Costs/ft^2 within normal range for area[256]	65% saving
National Resources Defense council office on two floors of the already efficient American Association for the Advancement of Science in Washington D.C. - already included efficient air conditioning system, and low-e windows operable windows that saved more than half of climate control energy. Buildout combined daylighting with low energy electric lighting systems, to save 75% of normal lighting bills[257]. A stairway between the two floors reduces elevator use; energy star office equipment saves computer costs. Green materials were used in construction as well. "Green premium" on order of $10 per square foot; energy savings combined with productivity increases should yield a four year payback or less.	70% saving

Again this is data mining; the examples are well executed new buildings and rehab projects with large secondary energy savings, and good economic rates of return. This would be meaningless in

We have demonstrated we can save between two-thirds and three-quarters of the energy in both existing and new commercial buildings (compared to the current average) with a simple payback ra

Therefore, it is a conservative assumption that average payback will be five years or less if productivity gains are included, probably a pessimistic one. Similarly, a seventy- percent or more saving

Given a 70% energy savings, a productivity gain at least equal in value to that savings, and a five year simple payback, and a 6.5% discount rate, this means we can pay ~2.84 times current cost fo

End Notes

[241]Amory B. Lovins and William D. Browning, Negawatts for Buildings, Jul/1992). 15/Nov 2000. Urban Land Institute, 21/Jan/2004 <http://www.rmi.org/images/other/GDS-Negawatts4Bldgs.pdf>.pp4-5

[242] Sarah Goorskey, Andy Smith, and Katherine Wang, Home Energy Briefs #7 - Electronics, 2004). 3/Dec 2004. Rocky Mountain Institute, 20/Aug/2005 <http://www.rmi.org/images/other/Energy/E04-17_HEB7E

[243]Mark Palmer and Alicia Mariscal, Green Buildings and Worker Productivity: A Review of the Literature, Aug 2001). Aug 2001. San Francisco Department of the Environment, 22/Aug/2005 <http://www.sfenviro

[244]Gregory H. Kats, Green Building Costs and Financial Benefits. October 2003. Massachusetts Technology Collaborative State Development Agency for Renewable Energy and the Innovation Economy., 23/Ja

[245]Gregory H. Kats et al., The Costs and Financial Benefits of Green Buildings: A Report to California's Sustainable Building Task Force, Oct 2003). Oct 2003. California Sustainable Building Task Force, 29/Jan/

[246]William Browning, NMB Bank Headquarters: The Impressive Performance of a Green Building, June 1992). 24/Feb 2003. The Urban Land Institute, Rocky Mountain Institute, 22/Aug/2005 <http://www.rmi.org/

[247]U.S. Department of Energy Office of Energy Efficiency and Renewable Energy, 2004 Buildings Energy Databook, Jan 2005). Jan 2005. U.S. Department of Energy Office of Energy Efficiency and Renewable
Table 1.3.4 - Commercial Delivered and Primary Energy Consumption Intensities, by Year

[248] http://erg.ucd.ie/EC2000/EC2000_PDFs/dossier_1011.pdf
Commission of the European Communities, *Energy Consumption and Cost Effectiveness of EC2000 Buildings*, Jan 2000). *Energy Comfort 2000*, European Commission Thermie Project to Reduce Energy and Improve Comfort and Env

[249]
Ibid 248 pp2-3.

[250]Ibid 248 pp3-4.

[251]Energy Research Group - University College, Case Study Module C - Sukkertoppen - Copenhagen DK. Mid Career Education: Solar Energy in European Office Buildings. Nov 1997. Energy Research Group -

[252] Joseph J. Romm, Cool Companies: How the Best Businesses Boost Profits and Productivity by Cutting Greenhouse Gas Emissions (Washington D.C. & Covelo CA: Island Press, 1999).p51.
Chapter 3: Buildings.

[253] Joseph J. Romm, Cool Companies: Proven Results - Cool Buildings. 2005, Romm,Joseph J., 22/Aug/2005 <http://www.cool-companies.com/proven/buildings.cfm>.

[254]Green Building Council, USGBC - LEED Case Study - Energy - DEP Cambria. 2003, Green Building Council, 22/Aug/2005 <http://leedcasestudies.usgbc.org/energy.cfm?ProjectID=47>.

[255]Green Building Council, USGBC - LEED Case Study - Finance - DEP Cambria. 2003, Green Building Council, 22/Aug/2005 <http://leedcasestudies.usgbc.org/finance.cfm?ProjectID=47>.

[256]U.S. Department of Energy Office of Energy Efficiency and Renewable Energy, Department of Environmental Protection, Cambria Office Building, Ebensberg Pennsylvania - Highlighting High Performance, N

[257]Buy Recycled Business Alliance, Natural Resources Defense Council, 2004). 17/Sep 2004. Buy Recycled Business Alliance, 22/Aug/2005 <http://www.brba-epp.org/brba-epp.org/pdfs/Natural%20Resou%E2%

Transportation

For ground transportation, the main savings is via electrification of cars, increased mass transit, and switching from trucks to freight trains, plus electrification of freight trains on the most heavily used routes.

http://www.nohairshirts.com/chap16.php

				kWh/mile
Automobiles				
Solectria Sunrise	Energy Conversion Devices, Inc., Energy Conversion Devices, Inc. 1997 Letter to Stockholders -Commercializing Technologies That Enable the Information and Energy Industries. Dec 1997, Energy Conversion Devices, Inc., 26/Sep/2005 <http://www.ovonic.com/PDFs/LtrstoShldrs/ecd97ltr.pdf>.p3.	320	MPG(e)	0.11
210 miles on 80% of 240 mile = 210 miles on 23 kWh	http://www.ovonic.com/PDFs/LtrstoShldrs/ecd97ltr.pdf			
Think City -105 mile range 28.3 kWh 2 seats	http://www.think.no/think/content/view/full/384	129.8587	MPG (e)	0.36
$25,000 price pioint	http://www.autobloggreen.com/2008/04/21/vc-firms-bet-on-th-nk/			
TRIAC 2 seater	http://www.greenvehicles.com/			
$20,000 100 mile range	http://gadgets.elliottback.com/2008/05/14/green-vehicles-triac-available-for-preorder/			
144 vol 160 amp hours 23 kwh 100 mile range	http://www.greenvehicles.com/specs/triac.html	152	MPG (e)	0.23
Tesla Motors 2 Seater Sports car 220 miles on charge	http://www.teslamotors.com/efficiency/charging_and_batteries.php			
$110,000	http://www.teslamotors.com/buy/resyourcar.php			
53 kWh	http://www.teslamotors.com/blog4/?p=64	132	MPG(e)	0.40

Conventional light rail

http://www.lightrailnow.org/myths.htm
ttp://www.lightrailnow.org/facts.htm
ttp://www.lightrailnow.org/features.htm

CyberTran

http://www.CyberTran.com
http://www.vtpi.org/tca/tca0501.pdf
http://www.antiochpress.com/article.cfm?articleID=2079
A greener alternative to eBART by Madan Sheina - 3/15/2007
The Antioch Press
See Cybertran Tab for discussion of both conventional and Cybertran Light rail

Freight Rail

Alan Drake of the Oil Drum has made some interesting estimates of what it could cost to completrely upgrade our rail system. His point is that we could electrify about 65,000 miles of our 178,000 miles sytem, and add some other improvements - and end up moving freight fast enough to compete with most long distance trucking, because the key miles he electrified and some of the additional track he proposes and other improvements he suggest would speeed up most of the routes over which freight would move. He estimates a total cost of 400 billion dollars. Freight uses 1/8th the energy of trucks (on average) to move freight. Electrification would at least double this efficiency, where locomotives ran off wires rather than hybrid diesel engines. Incidentally, electrifying more than one third of rail tract would electricfy more than 80% of freight tons.

http://www.theoildrum.com/node/3836/329791

Modal Efficiency

Stacey C. Davis and Susan W. Diegel, TRANSPORTATION ENERGY DATA BOOK: - Edition 22, ORNL-6967 (Edition 22 of ORNL-5198). Sep 2002. Center for Transportation Analysis Science and Technology Division of the Oak Ridge National Laboratory for the U.S. DOE, 23/Sep/2005 < www-cta.ornl.gov/cta/Publications/Reports/ORNL-6967.pdf >.
p2-19. Table 2.14 - Intercity Freight Movement and Energy in the United States, 2000
www-cta.ornl.gov/cta/Publications/Reports/ORNL-6967.pdf

Electrification Affect on Freight Train Effficiency

At least double - 17 to 1 to 21 to 1 compared to trucks
http://hopeforthefuture.info/articles/erail.html

A couple of studies on more modest improvements: these serve as sanity checks; their cost estimates for smaller changes support Drake's estimates for bigger ones.

http://www.aar.org/PubCommon/Documents/natl_freight_capacity_study.pdf
http://www.go21.org/PolicyIssueContent/BottomLineReport.aspx

Water Transport

Oil and Coal account for about half of ton-miles shipped by water (Domestic)

Transporation Energy Data Book (Above)
p12-6 Table 12.5 - Breakdown of Domestic Marine Cargo by Commodity Class, 2000

Oil comparable internationally

Oil alone accounts for almost 61% of tons shipped internationally in 1998, though less of ton miles With coal shipments, the total ton miles will be at least comparable to U.S. water shipping. In addition, as oil prices rise, and as a carbon price is instituted, we will see fewer of other low value commodities shipped as far as well. To some extent more will be made domestically in every nation, less imported. Where that can't be done, or is too costly, imports will tend to be from nearer markets. Shipping costs will make nearer suppliers cheaper than distant ones, even when there are significant diffferences in manufacturing costs.

Marine Policy: Shipping and Ports
Hauke L. Kite-Powell, Marine Policy Center, Woods Hole Oceanographic Institution, Mail Stop #41, Woods Hole, Massachusetts 02543 USA
citation: J. Steele et al., eds., Encyclopedia of Marine Science, Academic Press, 2001, pp. 2768-76.
Table 1: World seaborne dry cargo and tanker trade volume, million tons, 1950-1998.
http://www.whoi.edu/science/MPC/dept/meetings/Luce_presentations/shipping%20and%20ports.pdf

Sky sails and other high sails could proivde between 10% and 35% of sjhipping energy

http://skysails.info/index.php?L=1

In new ships - better hulls, propellors and engines can double fuel efficiency. Also running engines on natural gas can reduce greenhouse emission. Retrofitting existing ships or prematurely retiring them would require a combination of continuing high oil or carbon prices, and no drop in demand for shipping.

For flying, while there are some efficiency improvements we can make around the edges, basically I'm assuming we will be doing a lot less of it. Oil prices may lead to this result regardless of what actions we take.

We are eliminating most oil and gas pipeline transport due to drastic reductions in fossil fuel used. There are also tricks to increase the effiiciency of what remains

In industry I'm assuming efficiency improvements and electrification. A lot of industrial energy efficiency improvements will be life cycle improvements - making things last longer, making them out of less energy intensive materials, even rethinking the purposes of goods and services and finding alternative ways to perform the same functions. There will also have to be rethinking of processes, alternative ways to produce goods that require a lot fewer delivered BTUS. Also as we will have to look for ways that electric processes can substitute for fuel based processes without compromising either energy efficiency or quality - for example electric arc furnaces for processing scrap metal compared to the BOF furnaces that were common decades ago. (There is even some work that now allows an electric arc furnace with a bit of carbon added in the form of coal or charcoal to be used in processing raw ore.) And of course we won't forget various ways of recycling industrial energy - combined heat and power, but also using waste heat from one industrial process to run another.

58,497,(

1,348,84
674,247

Renewables

I concentrate mainly on solar and wind, because worldwide, that is where most renewable potential that can be developed with currently commercial technology is. Most of the hydro that can be developed worldwide already has been. Most of what is left is in environmentally sensitive areas, and also are home to people whose way of life will be destroyed by new dams. Geothermal has huge potential with very minor breakthroughs, but with today's technology you can't get more than a tiny percent of our energy demand, more like a silver coating on a silver bb than an entire silver bb.

Note that a single wind plant or a single solar plant is a fuel saver rather than a provider of base or load following power. (A single solar power plant can be a peak power provider, because hot climates where solar resources are greatest consume peak power, logically enough, when the sun is hottest and brightest. This even applies in some colder climates that have high air conditioning loads during summer. In New York City for example, enough PV could cut peak demand, because in spite of coldness of NY winters, summer air conditioning drives New York's peak demand.) But a grid that mixes multiple wind farms in multiple major climate zones with solar electricity from can apply between 33% and 40% percent of the electricity it produces to base needs - even without storage, just because the wind will pick up one place when it dies somewhere else most of the time. (Such a grid requires a lot of HVDC and other grid improvements; based on estimates from the electric industry I'm assuming about 300 billion worth.)

Nationwide, times without much wind everywhere will mostly tend to be short. Three hours of storage compared to a wind based grid's nameplate capacity will let wind power meet 95% or more of needs (This is really nine to ten hours of average production.) A solar powered grid needs 16-24 hours storage to meet the same goal. But mixed wind and solar grid, with about 30% redundancy and an approximately 2 to 1 ratio of wind to solar can provide a 99% or better renewable grid with the remaining 1% based on natural gas. Though I assume that 99% of energy is provided by natural gas, I factor in very high capacity - equal to about half of solar and wind capacity, for rare short occasions when combined sun fall below needs long enough to exhaust shortage - rather than trying to provide 100% solar.

Wind is going to mostly be large wind farms, because small wind power from small wind farms or single turbines is more expensive per kWh. Small turbines are more expensive per KW of peak power. They are even more expensive per kWh since often these smaller turbines use lower percentages of their capacity. Also large wind farms have maintenance advantages, because they have enough machines to justify full time maintenance staffs. Wind is the least expensive form of renewable electricity. If you get it from multiple sources in multiple major climate zones connected by High Voltage D.C. lines, less than 3 hours storage (compared to peak capacity) can let it provide up 95% of your power.

Solar electricity is going to be mostly concentrating solar power (CSP) because you can store heat more cheaply than electricity. Small heat engines are generally maintenance nightmares, especially Stirling engines, so CSP will probably mostly be large solar plants driving large (or at least medium) steam engines. CSP has two disadvantages compared to wind. It is more expensive per kWh to produce, and since most of it is produced during the peak five daily hours of sunlight, it needs 16-24 hours of storage rather than three hours of storage wind needs to provide base power. However it has the advantage that this storage costs much less per kWh than wind - $40 per kWh for solar compared to $150-$350 per kWh to store electricity.

During normal years, solar, wind, hydro and geothermal plus storage provide nearly 100% of electricity (with a 30% surplus discarded or sold at rates close to zero to anyone willing to make use of intermittent surplus electricity). Natural gas will provide a little over a tenth of a percent during such years. During years with volcanic activity and wind drought, natural gas will supply a higher percent of total electricity. So over the long run we assume natural gas supplying about 1% of electricity.

Although I include zero technical improvement scenarios, I also consider highly probable and somewhat probable breakthroughs.

Obvious breakthroughs are more deployment of offshore wind with higher capacity, and also systems with multiple turbines per tower. This lowers capacity utilization, because the turbines provide wind shadow to one another, so a lower percent of the wind hitting all turbines combined is utilized. However, this reduction is only a few percent, whereas capital costs per kW can be reduced 40%. Also this is most useful in offshore applications, where capacity utilization is higher than on land anyway.

A more extreme possibility are flying energy generators - which actually fly turbines thousands of feet up on using what amounts to more stable less mobile helicopters or balloons. This would let wind utilize its generating capacity at rates comparable to coal (60% or 70%) or even at 90% (in very limited geographical locations). This could lower wind cost to 2 cents per kWh or less, and greatly reduce the need for storage as well.

In solar there are more much greater potential for reductions. The most obvious is storage, where so far every expert who has looked at it thinks we can reduce storage costs from the current $40 per kWh thermal equivalent to $10-$15 per kWh thermal equivalent. In terms of concentrating mirrors, our own Sunflower's point about small concentrating mirrors being cheaper than larger ones, because of not requiring steel frames has now been validated by MIT. On another path, it has been demonstrated that you can get 95% of the concentration the best parabolic mirrors provided by using computer controlled thin straight mirrors - aluminum mirrors on wooden frames. There is also CoolEarth who is working inflatable parabolic mirrors - which could supply solar with capital costs cheaper than natural gas (and no fuel). There are even more potential breakthroughs in photovoltaic solar cells, but no comparable potential in electricity storage (except in the remote case that EESTOR proves more than vaporware). (We simply are not likely to see the electricity storage in the $10-$15 per kWh in the near future - though we could see a drop to $200 or $300 for 10,000+ cycle batteries, which would be a major breakthrough for electric cars.

Also some of the flow batteries most suitable for utility storage tend to return only 70% of the electricity that is input to them. There is a real chance in the near future we will see $250 per kWh flow batteries with 10,000 cycle life spans that can return 80% or

CyberTran and UltraLight Rail

Ultralight rail, something has never been fully tested in the real world has major potential as a breakthrough for mass transit.

One of the reasons transit has trouble competing with cars is that is gets you there more slowly, and it does a poor job of delivering many of its supposed compensating advantages.

A second argument is lower stress. Well the jam packing I mentioned puts back a lot of that stress to begin with. But there is also a multiplication of stress points. If you leave five minutes late for work in a car odds are we will be five minutes late. (OK you may hit unexpected traffic and roadwork, but that is probably already included in the definition of leaving on time.) Just miss your bus or train by five minutes, if you are lucky another one will be along in ten or fifteen minutes. On most routes at most times, that delay will be more like twenty to forty minutes. (And is some systems it can be an hour or an hour and a half.) But even once you are in transit this particular type of stress is not over. Most transit trips involve transfers. So regardless of whether you are on time, you have to worry about whether you make your transfer point on time. Miss that by five minutes and you have another possible long delay. Between being packed like sardines, and problems with transfers, it is no wonder recent studies show transit riders suffer more stress than drivers.

This is why I really want automated ultralight rail to work. Not only is it cheaper than many other light rail options, if it works it delivers the full benefits mass transit has always promise. Here is how in it works:

Most of the cost of commuter rail is track, guideways and stations. If you can cut each 80 passenger train car into four twenty passenger train cars or eight ten passenger cars (following one after the other) you reduce the weight your track has to bear, and the peak voltage your lines need to carry. The increased costs of cars is trivial compared to the savings, especially since various savings in making smaller cars ensure you don't increase vehicle cost per seat much if at all. However this kind of car shrinkage multiplies your operating cost, the number of drivers by four to eight times, and more than makes up for these capital savings.

The idea behind ultralight rail therefore is to automate these small light trains, make them driverless and computer driven. That preserves the capital savings while also providing operation savings too. And of course the lighter cars also give you increased energy efficiency.

But once you are using automated driverless light trains, there is no longer a reason to use fixed routes and schedules (except on heavily traveled lines during peak use). Instead let them run 24 hours a day, scheduling them as people buy tickets. Since vehicle costs are a small part of capital you can maintain enough slack in the number of cars available to make sure nobody ever has to wait more than five minutes from time of ticket purchase, and also make sure nobody ever has to stand. With small light cars you can have all stations offline, and with automated scheduling you can optimize routes on the fly - fairly direct travel, few or no transfers. (And on the rare occasions there are transfers, you can make sure there is neither any danger of missing the transfer or of having to wait long for the connecting route.)

In short, the time difference between auto and transit travel is less than with conventional transit, you really can (always) read the paper or play computer games, or nap or whatever on your trip, and transfers are rare and worry-free. You really can compensate for slightly longer travel time with much lower stress! At the extreme this can be a Personal Rapid Transit system - essentially automated cars on rail. Most proposals are still mass transit (like the CyberTran system that typically has about 14 seats per car) - shared but automated and optimized light rail.

What I'd really like is to see a CyberTran system replace most automobile traffic in the U.S. or at least replace it for the half of the population currently within a quarter mile of a bus stop. And it would pay for itself too, if it really cut automobile ownership, not just miles drastically - say by two thirds for so. That might happen. Manhattan which has the best mass transit system in the U.S., has an automobile ownership rate about 1/3rd of the U.S. average. (In fact the greater NY Metro area bus system is a prime candidate for having major routes replaced by CyberTran.) But CyberTran is actually more expensive per seat than automobiles until you count things like parking spaces. So you have to actually reduce auto ownership not just use for it to pay for itself.

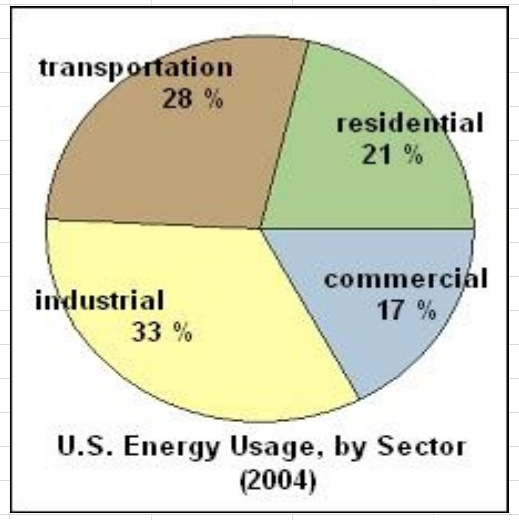
And if we provide decent electric cars in areas with a lot less density than Manhattan we might not get that drastic a reduction. Though I think in the long run we want light rail most places bus systems currently run, for the next twenty years we need to find the 500 or so best candidates for light rail, and install it there - CyberTran+A3 or conventional depending on what turns out to work best. (CyberTran sounds good, and has passed all sorts of both simulated and prototype tests, but has never been run commercially in the real world. We should fund real world tests for various forms of ultralight rail, while continuing with conventional light rail plans. If ultralight rail proves itself, then we can modify the plans and deploy it instead of conventional. If not we won't be behind in deploying conventional light rail.

Cybertran costs to replace all bus routes			
cost per mile	15,000,000	http://advancedtransit.org/doc.aspx?id=1061	
2004 U.S. bus route miles	215,252	http://www.bts.gov/publications/state_transportation_statistics/state_transportation_statistics_2006/	
total	3,228,784,500,000		
About half U.S. population has access to mass transit		http://www.apta.com/government_affairs/aptatest/testimony070725.cfm	
Transit costs figures	http://www.vtpi.org/tca/tca0501.pdf		
	Transportation Cost and Benefit analysis		
	Victoria Transportation Institute		
Annual returns needed for 20 year payback at 5%	($259,086,021,761.20)		
Annual returns needed for 30 year payback at 5%	($210,037,065,289.95)		
Annual returns needed for 50 year payback (since it can last that long)	($176,862,274,496.95)		
National Transportation Statistics 2008			
U.S. Department of Transportation			
Research and Innovative Technology			
Administration			
Bureau of Transportation Statistics			
Page 220 (PDF reader dependent)			
Table 3-13: Personal Consumption Expenditures on Transportation by Subcategory (Current $ millions)			
2006 New & Used Cars	165,100,000,000		
2006 New & Used Trucks & RVS	209,300,000,000		
Tires, tubes, accessories, and parts	59,800,000,000		
Repair & Rental	208,400,000,000		
NTS total	*642,600,000,000*		
Add parking costs	*374,000,000,000*	http://seattlepi.nwsource.com/national/216997_parking22.html	he High Co
Reduction in accident costs with a swich to light rail	*238,835,517,940*	Transport Safety Sheet	
total	**1,255,435,517,940**		
About 49% of U.S. population lives within a quarter mile of a public (non-school) bus stop			
Mahattan with best public transit in U.S. and one of worst enviroments for car ownerhips has 1/3rd U.S. rate of automobile ownership'			
So absolute best case CyberTran replacing every bus coul save 2/3rds of 49% of auto owneship costs	410,108,935,860		
If CyberTran could reduce car ownershiip by half for 49% of population	307,581,701,895		
Breakeven point with 35% reduction and 30 year payback	215,307,191,327		
Breakeven with 29% reductiona and 50 year paybakc	178,397,387,099		

Given that really awful bus systems still reduce auto use by 8% (remember tranit carries 4% of passenger miles but is only accessible to half the population) it seem likely that a really first rate transit system could reduce auto use by at least 1/3rd. Again in extreme cases we see reductions in auto traffic of two thirds.

Bottom line: Massive investment in Cybertran in addition to everything would pay off handsomely, if it was utilized
If it did not cut automobile use heavily, you come out behind - on a 3.2 trillion investment
Conclusion, deploy only in fairly dense urban and suburban areas where a substantial number of people are likely to WANT to give up cars
I'm guessing 50,000 miles properly deployed would safely pay for itself, by 80/20 rule compared to 250,000 miles bus toutes. -so total cost 750,000,000,000
However, to be conservative I'm suggesting only deploying 450 billion for light rail, and another 50 billion for electrifying buses either via wires or batteries
Also I'm not suggesting CyberTran deployment be funding on any large scale. I would suggest spending 250 million to deploy is a densly populated small town as an experiment
It should be funded as a full small town transit system - covering all major routes so that it is a true test. Based on those results further deployment should then be considered or not.

Note that these are over-optimisitc estimates of potential for the smart grid. They assume implementaition of maximum phyically possible potential without considering feasiblity. These are maximums, upper limits and NOT real achievable potential.



	Percent sector	Percent total		
Residentail Space Heating	32.00%	6.72%	32.55%	0.1311
Residential Water Heating	13.00%	2.73%		
Residential Air conditioning	11.00%	2.31%		
			0.2298507	
Commerical Space Heating	13.00%	2.21%		
Commerical Air conditions	11.00%	1.87%	1.090425	
Industrial				
Process heat and power	70.00%			
Low temp process heat (part of the above 70% figure)	15.00%		Energy Economics Vol 29 Issue 4 July 2007 pp 889-912 Dolf Gielen & Michael Taylor	page 893

but rough estimates suggest that 15% is used as feedstock, 20% for
process energy at temperatures above 400 °C, 15% for motor drive systems, 15% for steam at 100
to 400 °C, 15% for low-temperature heat and 20% for other uses, such as lighting and transport

Total U.S. electrical consumptionin 2006		4,064,702,000,000	
total Low temp uses that can be time shifted in smart grid			
Residential climate control and hot water		11.76%	
commercial climate control and hot water		4.08%	
Industrial low temp process		4.95%	
		20.79%	
Add in refrigerationa and compressed air		1.00%	
Total vehicle miles traveled in cars & light trucks 2005	2,749,555,000,000		Table 1-32: U.S. Vehicle-Miles (Millions) - National Transportation Statistics 2008 U.S. Department of Transportation http://www.l
kWh at 0.33 kWh per mile	907,353,150,000	kWh per year	
kWh as percent total electrical consumption (including new electrical demand for electric vehicles)	22.32%		
Total pecent of electricity consumption shiftable in smart grid (assuming no increase in electrical consumption). Note that this is a maximum.. Because this is a percentage efficiency improvements don't change things. Plus, there is as much or more potential for efficiency improvments in low temperature heat as anywhere. Plus there is the potential for solar to reduce demand for low temperature heat. So even as a maximum, this is optimistic. Effciency improvements may REDUCE smartgird potential.	34.27%		

For example lets take a strong efficiency scenario	
75% reduciton in industrial consumption, with 80% of remainder switched to grid	
Low temp heat reduced by 80%, with remaining 20% switched to grid	
Compared to current energy consumption:	
one quarter of 33% of energy that is U.S industrial, 80% electrical	6.60%
Indiviudal electric vheicles	3.13%
Residential at 20% of current	4.20%
Commercial at 20% of present	3.40%
Total electrical demand -higher than current grid, with a lot fewer low temp applications for demand shifting	17.33%

So in th is high efficiency scenario a smart grid supplies less flexibiltiy than it does in a low effciency one.

We are NOT going to substitute demand shifting for baseload or load following. A smart grid can reduce the need for dispatchable electricity, but not eliminate it, And that need is NOT just emergency backup
It is routine and daily.

Remember, time switching is not the same storage capacity: being able to reduce shift 1/3rd of demand is won't let you shit 100% of demand for an eight hour period, whereas eight hours storage will let you supply 100% of demand for a period of time (more or less than eight hours depending upon when needed).

Nine hours storage of wind system used at 30.5% capacity is ~27 hours, say 3 to be safe

http://www.udel.edu/V2G/docs/KemptonDhanju06-V2G-Wind.pdf

According to Archer-Jacobson data used in this study, low power events over nine hours were as follows

Hours	# Events	No backup needed coverd by 9 hours wind storage	
1	150	150	205.2
2	56	112	
3	45	135	
4	33	132	
5	12	60	
6	10	60	
7	6	42	
8	5	40	
9	2	18	
	Total	749	
% hours in year		8.55%	Nine hours or fewer - fulfilled by time shifting - from avail overages of ne

Even we commit to 20% of nameplate with 30.5% actually reached then we have less than that available only 10% of time (excluding long outages or less than 13% of time including long outages.) We have a third of production not committed that can be time shifted to meet the shorter outages, leaving onl 4.2% to be supplied by backup. If storage was cheap enough we could supply 100% and have capacity left over. Most the these outages are 3 hours or left, so some of our nine hours can be used to timeshift production even now for load following and peaking.

Hours	# Events	Hours needing backup
10	9	90
11	3	33
12	3	36
13	3	39
14	1	14
15	1	15
16	1	16
17		
18		
19	1	17
20		
21		
22	1	18
23		
24	0	0
Total		278
	342	
hours in a year		8760
% hours not covered		3.17%
In addition, even during low wind there is some wind 90% of the time		2.38%

Solar: Deserts typically have 25 cloudy or rainy days. We can assume that perhaps 1 or 2 of these days will be isolated covered by 24 hour storage.

24 cloud days lasting longer than 24 hours

6.58% of hours require backup.

6.58%

Percent of hours not covered for 65% wind		1.55%	
Percent Hours not coverd by 35% solar		2.29%	
total		3.84%	
Mix of sun & wind plus 30% redundancy should eliminate 80% of these		0.77%	
Geothermal and Hydro		0.64%	
Net after Geothermal and Hydro		0.13%	
Combined Cycle Turbines at 58% plus 10% lossses = 52.2% efficiency so gas consumption		0.25%	
So in normal year grid is		99.75%	emissions free
One year in five		99.00%	emission free
In case of major volcanic eruptions that drop solar output drastically assume	2 yrs in 17	95.00%	emission free
So total output even averaging in bad years less than 1% from natural gas		99.06%	emissions free

	Quads	Quads NG for electricity if 95% of energy is electricity	NG+biomass remaining for transport & feedstock	
EIA Reference Case - Quad consumption 2030	118.01	1.01	6.99	
80% savings	23.60	0.20	7.80	
60% Savings	47.20	0.40	7.60	
30% Savings	82.608614	0.71	7.29	

Approximately 65% wind and 35% olar minimizes seasonal variation

With that mixture it looks like a 30% margin will cover most seasonal & annual varietion

For 100% grid	
Wind	65.16%
Sun	34.84%
For 130% grid	
Wind	84.70%
Sun	45.30%

Transit Safety and Security Statistics and Analysis
Annual Report (Formerly SAMIS)
http://transit-safety.volpe.dot.gov/Data/samis/default.asp?ReportID=2
Transit Fatalities

	2006		Fatalities Per 100 Million Passenger miles	% of auto
Commuter Rail	85	9,102,553,926	0.93	66.23%
Heavy Rail	23	4,681,146,806	0.49	34.85%
Light Rail	17	1,806,248,516	0.94	66.75%
Motor Bus	94	17,654,709,436	0.53	37.76%

http://transit-safety.volpe.dot.gov/Data/samis/default.asp?ReportID=11
For Passenger Miles

Auto and Light truck deaths
http://www.nhtsa.gov/portal/nhtsa_static_file_downloader.jsp?file=/staticfiles/DOT/NHTSA/NCSA/Content/TSF/TSF2006FE.pdf
2006 NATIONAL STATISTICS

Fatalities per 100 Million Vehicle Miles Traveled 1.41		1.41	
Economic Cost of Traffic Crashes (2000)			
(estimate for reported and unreported crashes) . . . . $230.6 billion		230.6	billion
Fatalities 2000		41,945	
Fatalities 2005		43,443	
Increase		1.03571343425915	
damage 2005		238.8	billion

Cost for tranist - LRT and Bus — http://www.lightrailnow.org/myths/m_mythlog001.htm

	capital cost per annual passenger mile	Lives saved per 100 million miles	Average
· Bus	$0.88	0.88	
· LRT	$0.74	0.47	0.522557830179
		100s of millions of passnger miles	annual lives saved
Capital budgets for transit	500,000,000,000		
Assume half to electified buses	250,000,000,000	2,841	
half or LRT	250,000,000,000	3,378	
autos, SUV, light trucks		27,496	
percent of miles shifted to transit		22.62%	
applying percemt actual % social costs		11.82%	
So payback in saved accidents for transit		$ 28.23	Billion
If economic costs of avoided deaths are valued at 7 million each		43,535,012,285	

Energy Cost 2008 (low projection)		1,266,410,000,000	http://www.eia.doe.gov/oiaf/aeo/excel/aeolmtab Annual Energy Outlook 2008 DOE/EIA-0383(2008) Low Economic Growth Table 3. Energy Pric State Energy Price and Expenditure Estimates 1970 Through 2005
			http://www.bea.gov/bea/dn/nipaweb/TableView.asp?Selecte ational Income and Product Accoun Table 1026. **Retail Sales--New Passenger Cars: 1990 to 2005** Table 7.2.6B. Real Motor Vehicle Output, Chained Dollars Final sales of motor vehicles to
half of 2004 HWY capital & maintenance (2000 dollars)		53,300,000,000	http://www.fhwa.dot.gov/policy/2006cpr/es06h.htm **Status of the Nation's Highways, Bridges, and Transit: 2006 Conditions and Performance** 106.6 billion construction 96.036036
Heavy Truck Purchases		50,000,000,000	Very rough (and low) estimate based on GDP
Increased labor productivity		520,000,000,000	4% improvement in productivity - see detail 1% of 2006 GDP is 130 billion http://www.bea.gov/industry/xls/GDPbyInd_VA_NAICS_1998-2007.xls
Water pollution reduction		14,500,000,000	http://www.vtpi.org/tca/tca0515.pdf The **Economic Impact of Motor Vehicle Crashes**, 2000
Ecomomic values of lives saved by switch to transit		43,535,012,285	
Transit reductions of accident costs (excluding lives saved)		28,230,039,912	See Transport Safety Worksheet
Air Pollution reduction		345,192,500,000	See Air Pollution Table below Measuring the damages of air pollution in the United States Nicholas Z. Mullera and Robert Mendelsohn Journal of Environmental Economics and Management Volume 54, Issue 1, July 2007, Pages 1-14 midrange va
		2,321,167,552,197	http://www.forbes.com/opinions/2007/11/12/flint-trucks-toyota-oped-cx_jf_1113flint.html
	billions	$2,321.17	

==

Air Pollution Table

SUMMARY OF THE NONMONETARY EXTERNALITIES OF MOTOR-VEHICLE USE http://www.its.ucdavis.edu/publications/2004/UCD-ITS-RR-96-03(09)_rev1.pdf
Report #9 in the series: The Annualized Social Cost of Motor-Vehicle Use in the United States, based on 1990-1991 Data
UCD-ITS-RR-96-3 (9) rev. 1
Mark A. Delucchi
Institute of Transportation Studies
University of California
Davis, California 95616
TABLE 9-9. SUMMARY OF COST ESTIMATES
A. THE NONMONETARY EXTERNAL COSTS OF MOTOR-VEHICLE USE, 1990-91 (109 1991$)

			Mid Range values	
Health costs directly from vehicle tailpipe emissions			141,750,000,000	
Agricultural crop losses			2,000,000,000	
Visibiltiy			25,000,000,000	
damage to buildings			10,400,000,000	
Subtotal from vehicles			179,150,000,000	
95% reduction thus equls		95%	170,192,500,000	
Savings from reducing power plant pollution by 95%		human health from coal	175,000,000,000	http://www.catf.us/publications/reports/Dirty_Air_Dirty_Power.pdf
Grand total air pollution			345,192,500,000	

Payback in reduced Traffic Fatalities				
	Rail	Truck	Rail as percentage of Truck	
Freight fatalities per billion ton miles	0.61	1.45	42.07%	http://www.aar.org/pubcommon/documents/govt/brown.pdf Page 7 - Exhibit 1 The Value of Rail Intermodal to the U.S. Economy Thomas R. Brown, Anthony B. Hatch
Incidents and Injuires per billion ton miles	12.4	36.4	34.07%	

Paybacks

Lastly there is the question of paybacks. The first payback is the most obvious - energy. Since I assume 2008 projected EIA energy costs, this part is obviously somewhat of an underestimate even for 2008, and a large underestimate for the future. Some of my other paybacks are going to raise more eyebrows though I think they are actually quite solid.

The biggest single payback for phasing out fossil fuels is increased productivity. That is a surprising conclusion, one we had better take a bit at a time.

The average value of productivity increases in green buildings is slightly over 10% for combined lighting, ventilation and thermal control.

Kats, Greg,State of California, Sustainable Building Task Force, October 3, 2003, *The Costs and Financial Benefits of Green Buildings*, 61. http://www.usgbc.org/Docs/News/News477.pdf, 12/17/2008.

Finance, insurance, real estate, rental, and leasing, professional and business services, private educational services, private health care, private social assistance, and government combined represent about 53% of total GDP value added. The majority of these services are provided in commercial office buildings. It is true that a large minority are provided in other setting. But a large percent of the cost in manufacturing, mining, construction, transportation and so forth consists of administrative and support services. In general it is a fair estimate that half of GDP either is produced by office work, or is produced by other types of work done inside offices.

So greening buildings alone increases productivity by around 5.3%.

Current Industry Analysis Division, Bureau of Economic Analysis (BEA), U.S. Department of Commerce, *GDPbyInd_VA_NAICS: Value Added by Industry, Gross Output by Industry, Intermediate Inputs by Industry, the Components of Value Added by Industry, and Employment by Industry*,
http://www.bea.gov/industry/xls/GDPbyInd_VA_NAICS_1998-2007.xls, 12/17/2008

Given the value of GDP this easily translates into over 530 billion.

Energy savings in transportation also increases productivity. Freight trains have always been much more productive per ton-mile moved than trucks. It takes fewer drivers, and fewer loaders and unloaders to move goods by train than truck. If we move high value freight from trucks to trains then freight transport productivity will quadruple for those goods.

Similarly, emissions savings in industry depend in part on making goods last longer, reducing scrap. Much of the payback for industrial savings is in the form of reduced maintenance, and of fewer emergency shutdowns. So we can expect productivity gains in the industrial sector as well.

Lipow, Gar. *No Hair Shirt Solutions to Global Warming*. (Web published, 2007), 9-65. No Hair Shirts, http://www.nohairshirts.com/chap1.doc, 12/17/2008.

Assuming we use 5 quads of fossil fuels (almost all natural gas) + 3 quads of truly sustainable biofuels			
http://www.nohairshirts.com/chap16.php			Quads
Quads for electricity			0.94%
Rail: currently 1.89% of transport	0.5481	Quad	
We reduce coal coal by 95%	0.339822		
We double the efficiency of 85% of it	0.2266394		
We multiply use by 2.5	0.5665984		
Rail total			0.5665984
Trucking			
Trucks use 17.65% of 29%	5.1185		
Switch 85% of that to rail	0.767775		
Double efficiency of remaining trucking	0.3838875		
Trucking total			0.3838875
Reducitons in Material Intenstiy Save half of industrial energy	16.5		
We save another 30% through efficiency improvements	11.55		
We convert 80% of this to electriicity	2.31	2.31	
We use 2 quads of feed stocks		2	
total industry			
Assume 95% of auto, light truck, motor cycle and transit are electrified: that leaves			1
Intercity - unchanged (already efficient)			0.07
School bus (increased efficiency)			0.058
Constuction and Agricultture	1.155		
Can be improved in efficiency, some electrified			0.5775
Commuter and Transit rail electrify completely			
Water Freight 4.43% of 33 (In 20 years we can replace half of it with more efficient ships)	1.4619		
20% skysails plus 50% replacement with 50% more efficient ships (assume lifespand 30-50 years so 20 yrs halfway through replacement of 40 percent average			0.87714
Water recreationg	0.462		
Cut in half - recreational boaters and cruise ships can use more sails, solar replace boats with more efficient ones			0.231
Pipelines - reduce by 90%+			0.054945
Total			382.85%
That leaves for air travel			4.1715461
Current air travel	between 3-4 quad		
But of course current air travel puts out about 3X the emissions its fuel use would suggest Can cut in half by			
flying low, but still brings total above 5%. In short air travel reamins one of the areas we have to cut for emissions sake			
Oil prices may drive prices up enough to do this anyway.			
IF we can get more than three quads of biofuels sustainably with 95% or better net reductions in greenhouse gas emissions, then we have a huge margin			
Note that this can even be low net energy, if the energy input is low carbon variable wind electricity, and the output is fuel.			
Note that thereafter:			
We can finish electrifying freight.			
We can improve batteries to the point where cars and light trucks are 100% electric, maybe even to the point where short haul heavy trucks are 100% electric.			
We can completely electriy all construction and agriculatural equipment			
At the end of 20 years, we can have replaced half of marine freight. By then SkySails may be improved to where they proivde have the power for new and existing ships			
Hydrogene technology may advance to the point where it can be used in industry or ships, if it it is still not suitable for cars.			
If we get cheap electricty where we can afford large thermodynamic losses, hdyrogen may even become a reasonable way to store elecriity.			
We can't completely electrify the automobile in 20 years because:			
1) the autombile has a life cycle of 20 years			
2) It will take 7 years to develop mature economcial 200 mile range full BEVS and have factories fully in place			
But: by the time a car reachs 13 years of age it is driven about ten percent of the average fleet.			
So if all cars from 2017 forward are either full BEV or PHEV , then by 2030 90% of auto miles will be driven on those carss			
So in basically in addition to what is already estimate about 10% to 15% emissions from todays fleet will continue			
So in 2030 add	2.3142	quad	
These will all be thirteen year old cars. They will be goned by 2040 and if that is not soon enough we can offer			
a buyback program to retire them sooner - if oil prices don't drive them out of existence or lower use much more			
than I've estimated in any case.			