Carbon-Free and Nuclear-Free Energy System: New England Workshop

PREPARED FOR CITIZENS AWARENESS NETWORK,

BY IEER AND GIVEN AT MANCHESTER, VERMONT, 1 FEBRUARY 2014

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Workshop overview

1. What are our energy system goals?
2. Current energy system impacts
3. Energy basics and the current energy system
4. Carbon-Free, Nuclear-Free Basics: technical (Efficiency, Renewable resources, Demand response, Storage)
5. Carbon-Free, Nuclear-Free Economics
6. Impacts of the transition
7. Overview of the big opportunities and obstacles
8. Equity, democratizing the energy system, and creating a path to an emissions-free future within 30 years

Energy system goals

Sustainable: low to no carbon emissions, low air pollution, low water use and pollution; including an emissions-free **energy sector** (**not only electricity**) by 2050 at the latest

Reliable supply (light comes on when you flip the switch)

Affordable bills (so electricity and fuel supply can be maintained and the businesses can stay solvent) -- obviously related to income

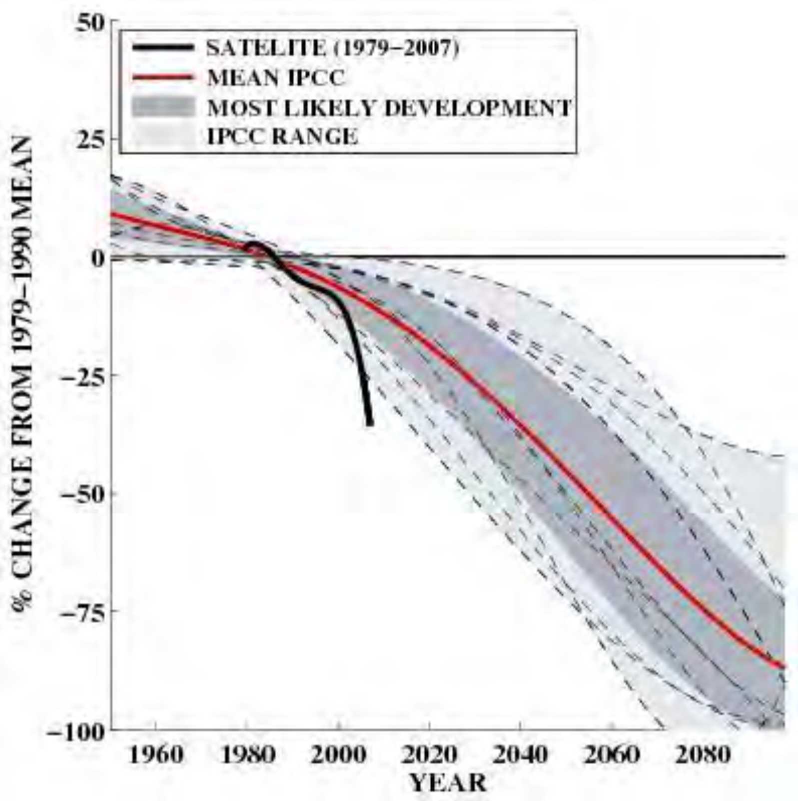
Economically just: active inclusion of low-income people in the benefits – and ensuring costs are not increased, and preferably reduced, for low-income groups

Amenable to control and participation by individuals, families, and communities (democratizing the energy system)

Just transition: ensure that communities that are deeply dependent on the existing fossil fuel system (like coal mining, oil and gas, etc.) have a just transition – training, jobs, etc.

Current energy system impacts

Great Arctic Ice Melt of 2007



Dramatic change in worst case scenario

Previously 2070

Now 2010 or 2015 (Louis Fortier, Scientific Director, ArcticNet, Canada)

(Chart courtesy of Dr. A. Sorteberg, Bjerknes Centre for Climate Research, University of Bergen, Norway)

Cooling systems for thermal power (Maryland depends on Susquehanna River water)

SUSQUEHANNA NUCLEAR POWER PLANT

(Credit: U.S. Nuclear Regulatory Commission / PPL Susquehanna)

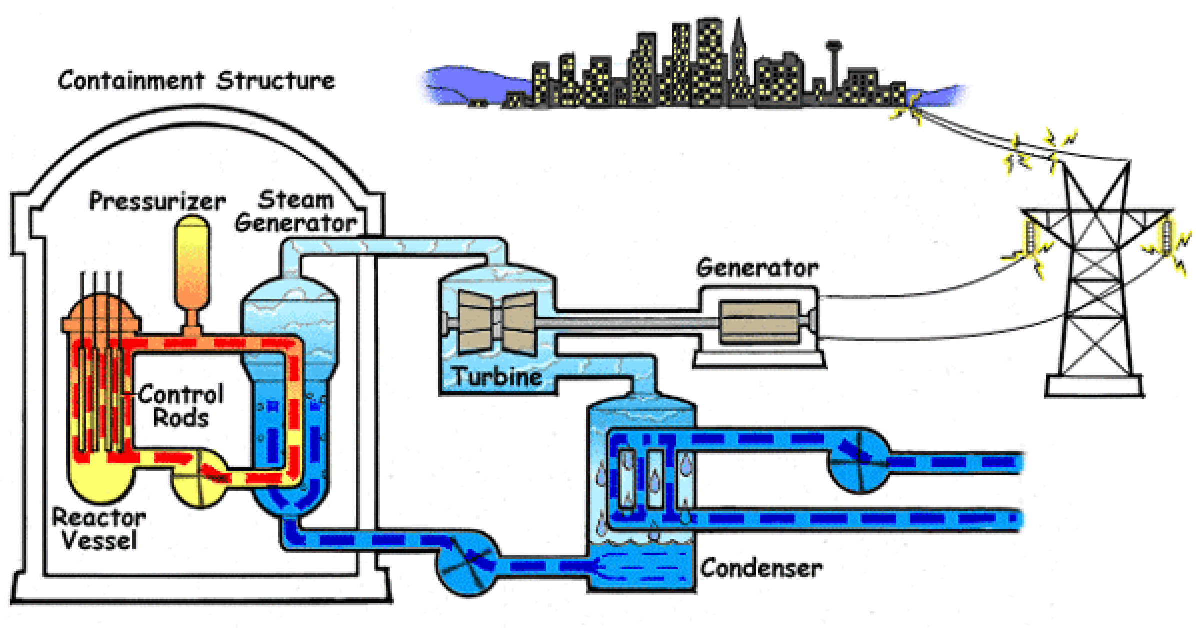
BRANDON SHORES AND HERBERT A. WAGNER COAL-FIRED PLANTS (BALTIMORE)

(Credit: Doc Searls, via PD Tilman at http://commons.wikimedia.org/wiki/File:Herbert_A._Wagner_Generating_Station_aerial.jpg. See http://www.flickr.com/photos/docsearls/6888207436/ and http://creativecommons.org/licenses/by/2.0/deed.en)

Credit: U.S. Nuclear Regulatory Commission

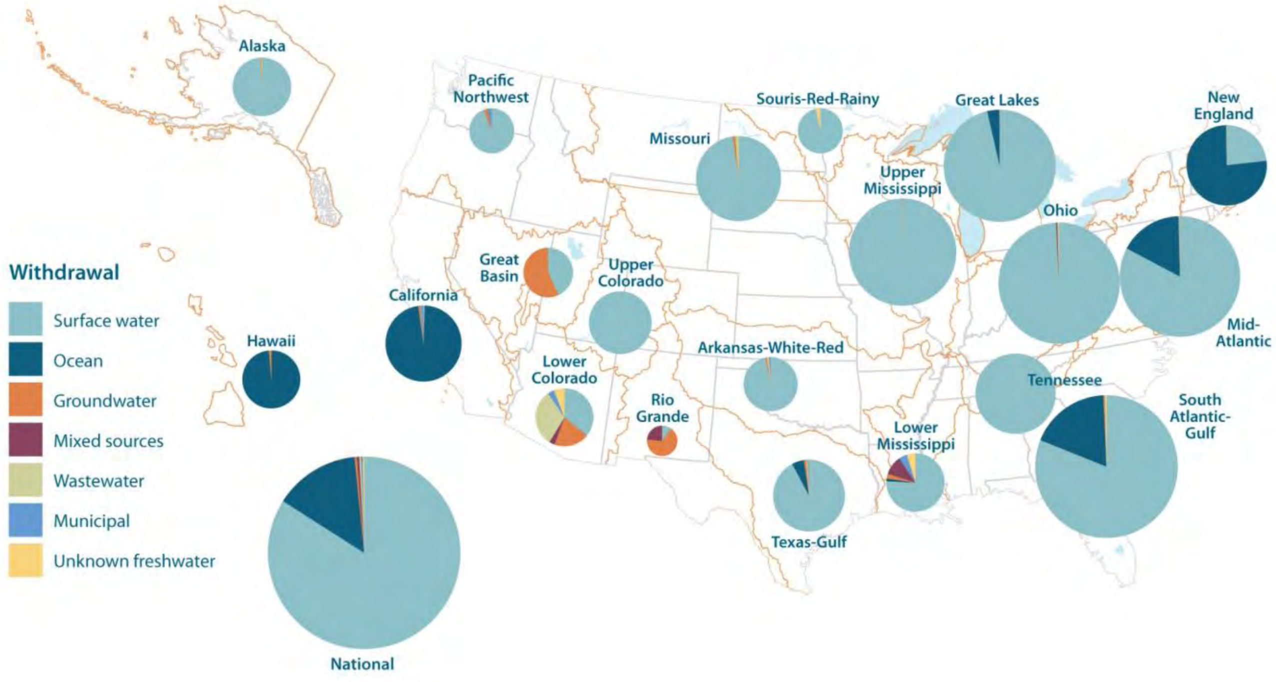
Thermal power generation

Note condenser: two thirds of the energy input is discharged into cooling water at this point



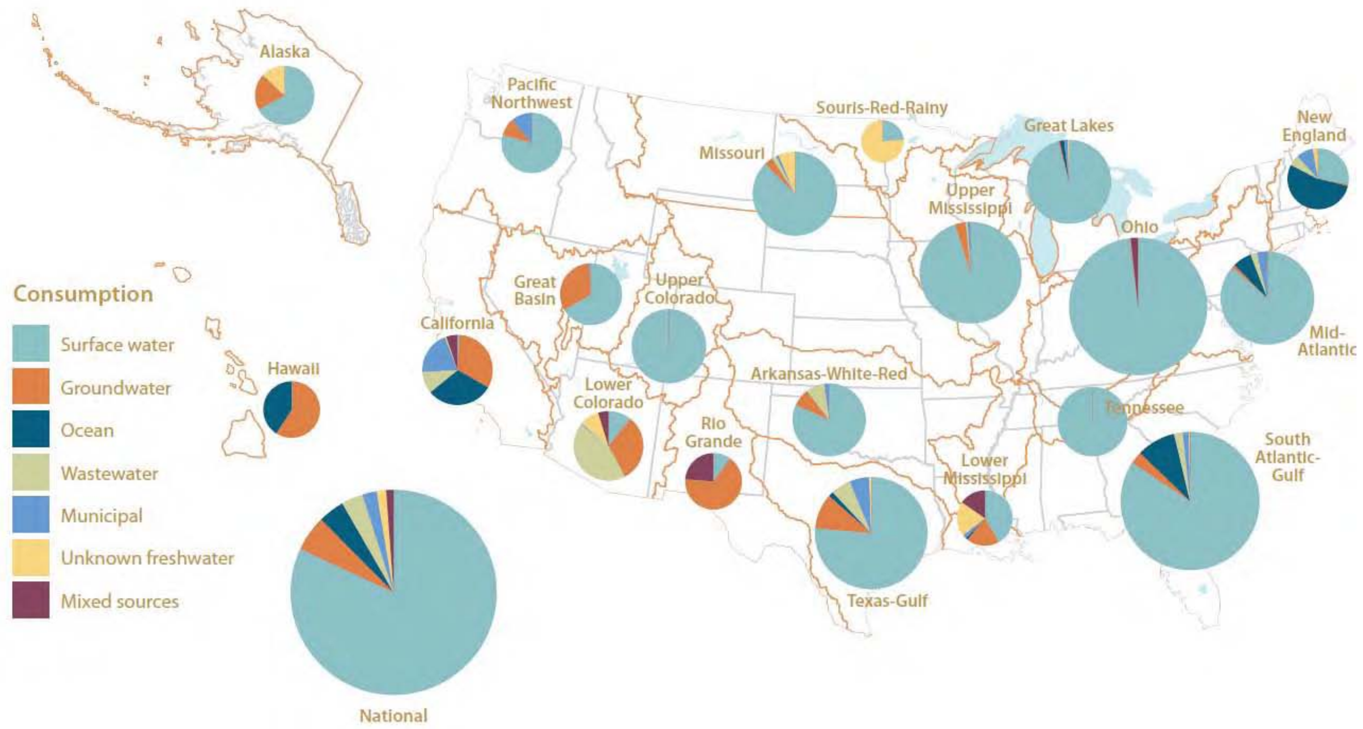
(Credit: U.S. Nuclear Regulatory Commission)

Power plant withdrawals: Most vulnerable – Mississippi basin, mid-Atlantic, Southeastern U.S., Texas



(Credit: Averyt et al. 2011 (www.ucsusa.org/electricity-water-use) Figure 5)

Power plant consumption: Most vulnerable – Mississippi basin, mid-Atlantic, Southeastern U.S., Texas



(Credit: Averyt et al. 2011 (www.ucsusa.org/electricity-water-use) Figure 5)

More environmental impacts

Most air pollution

Indoor air pollution

Respiratory and cardiovascular diseases

Cancer

Much water pollution

Huge amounts of water use for thermal generation

Land devastation – such as mountain top removal, open pit mining, mining wastes and wastelands

Radioactive and toxic wastes, dumps, and discharges with long-term damage to livability

Billions of tons of CO2 emissions per year and severe climate disruption

Aesthetic devastation

Ecological system disruption in many dimensions from ocean acidification to species damage and extinction

Indoor carbon monoxide details: a potential significant issue for health and environmental justice

Carbon monoxide is a natural trace gas produced by the body and regulates neural, muscular, and blood-system functions – very low level: 0.5% of hemoglobin oxygen capacity.

Produced by natural gas cooking, wood stoves, fireplaces, and present in secondhand smoke.

No threshold established for harm.

Levels that are many times the EPA limit of 9 ppm have been measured in homes that were studied for CO presence.

Heart attacks, strokes, and possible effects on learning, and possible adverse pregnancy outcomes, among other things.

Epidemiological data are lacking but sufficient data exists to indicate that this is a problem, notably, but not only, in low-income homes.

May be exacerbated by reducing leaks and air infiltration.

Nitric oxide pollution may also be problem.

Economic, security, and social impacts

Boom and bust cycles and unstable communities – especially primary production

The riches of the land as a cause of the poverty of the people (Paraphrase from Eduardo Galeano: Open Veins of Latin America)

Environmental injustices

Wars for oil

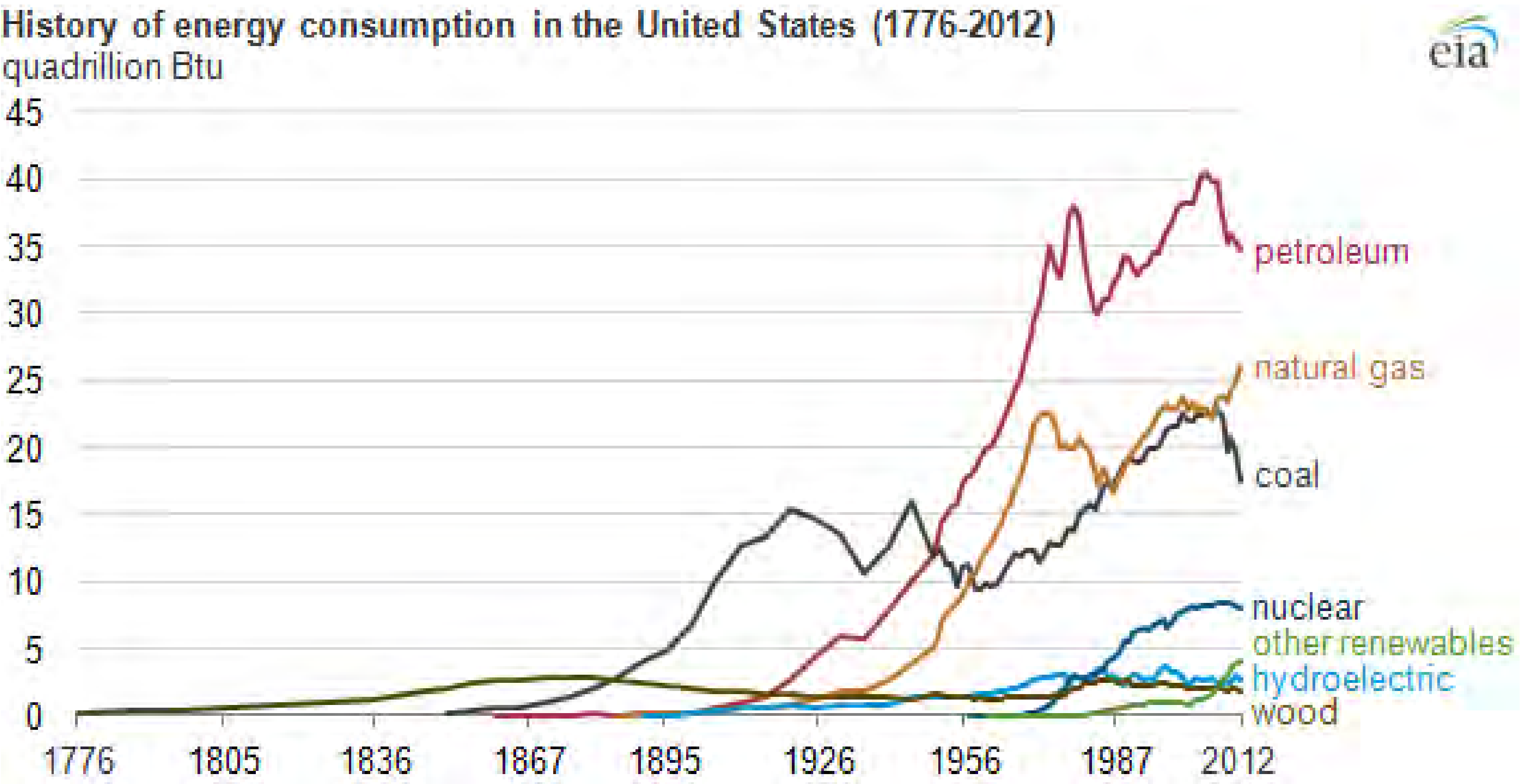
Nuclear proliferation

Nuclear energy: The “Faustian bargain” Alvin Weinberg (especially breeder reactors)

Loss of democracy

Energy basics

Energy consumption history by fuel – United States

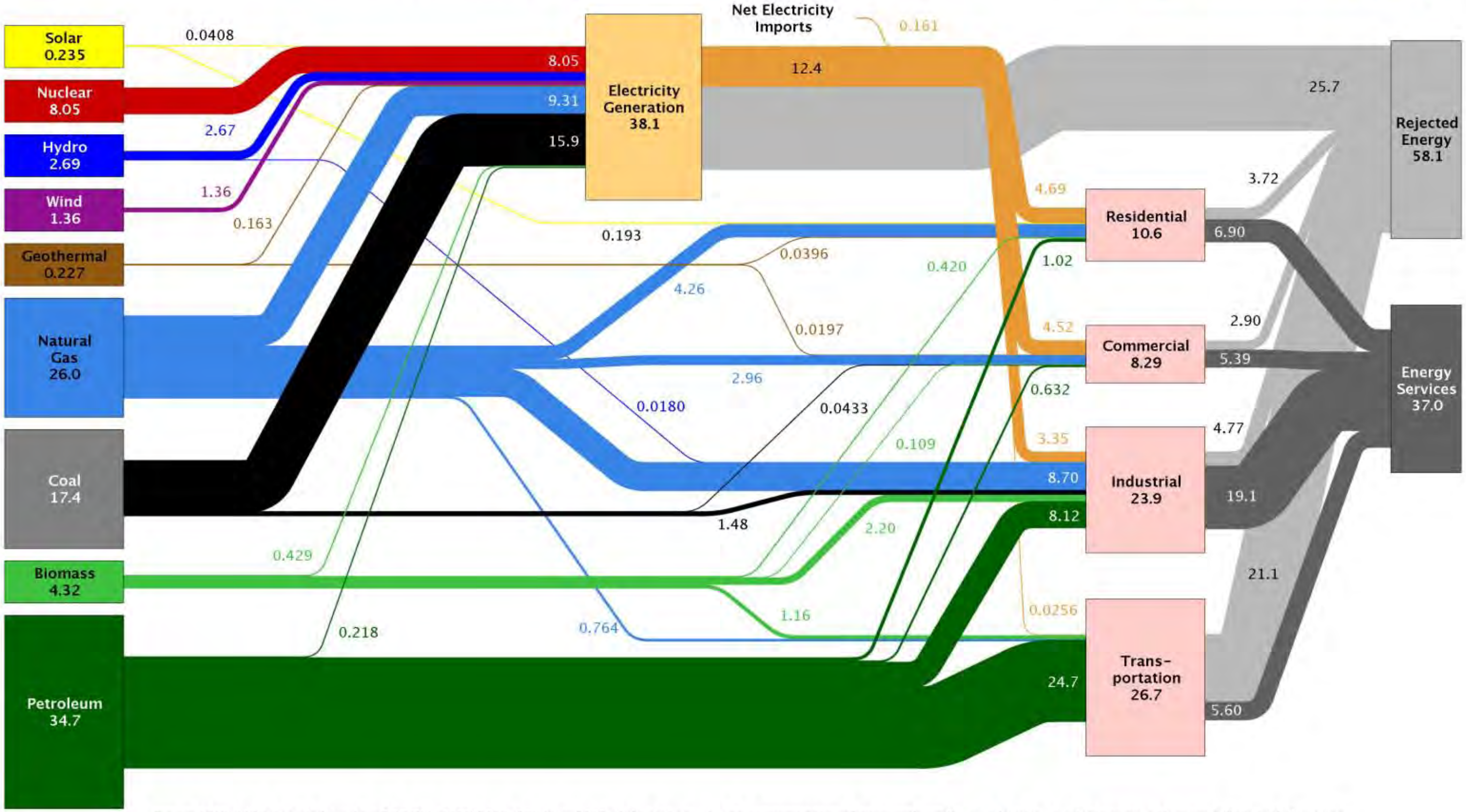


(Source: http://www.eia.gov/todayinenergy/detail.cfm?id=11951&src=Total-b2)

National energy overview (“Sankey” diagram)

Estimated U.S. Energy Use in 2012: ~95.1 Quads

Lawrence Livermore National Laboratory



Source: LLNL 2013. Data is based on DOE/EIA-0035(2013-05), May, 2013. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports consumption of renewable resources (i.e., hydro, wind, geothermal and solar) for electricity in BTU-equivalent values by assuming a typical fossil fuel plant "heat rate." The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 65% for the residential and commercial sectors 80% for the industrial sector, and 21% for the transportation sector. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527

Source: LLNL 2013 (https://www.llnl.gov/news/newsreleases/2013/Jul/images/28228_flowcharthighres.png). Credit: Lawrence Livermore National Laboratory and the Department of Energy)

Efficiency notes

1. The LLNL Sankey diagram shows 57 quads of waste and 42 quads of useful energy – for an efficiency of only 43 percent. **Half the waste is thermal losses at power plants.**

2. But waste is greater. Transportation efficiency shown as 30 percent, BUT most of the "useful" energy is in moving the steel and plastic not the people. Example -- passenger vehicle: Payload = 200 pounds; vehicle weight = 3000 pounds; so efficiency = 30 percent times (200/3200), which is a little less than 2 percent! Average gasoline car = 25 mpg. Electric can be bike equivalent of ~1000 mpg. But need safer infrastructure for it to be more widely used.

3. Residential efficiency is shown as 80 percent, but it is far lower. For instance, building envelopes are leaky. Best building practices can reduce heating and cooling energy footprint by 50 to 80 percent.

4. Natural gas leaks not shown. May be a big climate impact.

5. Incandescent lamps: 3 percent of electricity into light. CFLs, 12 percent. Best LEDs, 20 percent. This does not take into account thermal losses in electricity generation. Only the fraction of electric energy converted to visible light.

6. Overall, efficiency measured by utility and the second law of thermodynamics and taking inefficient and uneconomical equipment into account is much lower than the 43 percent indicated by the Livermore Sankey diagram.

Carbon-Free, Nuclear-Free basics

Areas of inquiry

1. How much energy do we need: efficiency, conservation, economic structure.
2. Is there enough renewable energy?
3. The electricity system: what happens when the sun does not shine and the wind does not blow (or at least enough)? What happens when there is power available is more than the load?
4. Transportation.
5. What about direct fuel use – like natural gas and oil for heating and water heating? This is connected to efficiency, fracking, etc. How to transform these sectors?
6. Economic Justice.
7. Impacts from renewables.

Efficiency

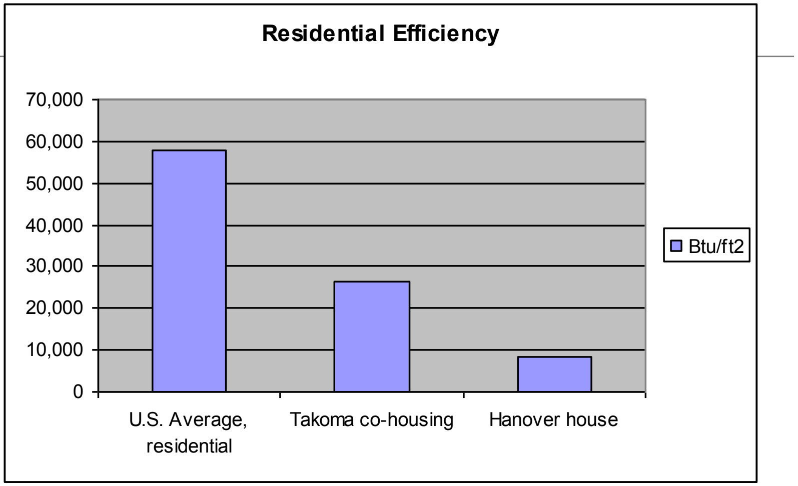
Residential and Commercial Efficiency Examples

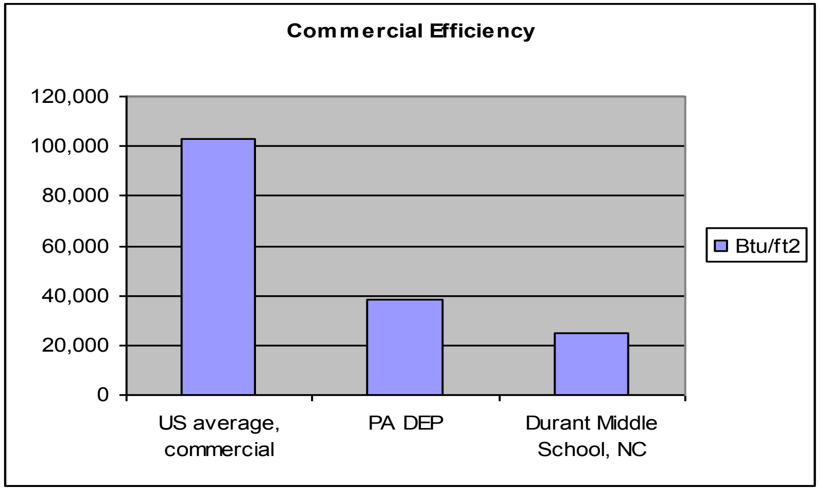
Efficiency improvement of 3 to 7 times is possible per square foot

Existing homes more costly to backfit but much is still economical

Standards at the local and state level are needed

Zero net CO2 new buildings and communities by 2025 can be mandated

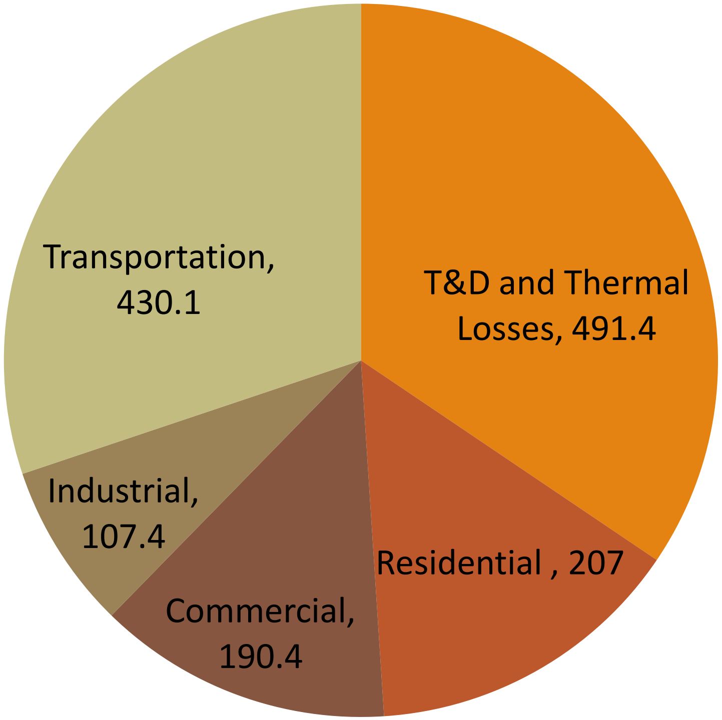




Source of graphs: IEER: Carbon-Free and Nuclear-Free

Maryland energy overview as an example: Thermal losses at power plants are important

2011 Maryland Energy Consumption, by sector (trillion Btu)



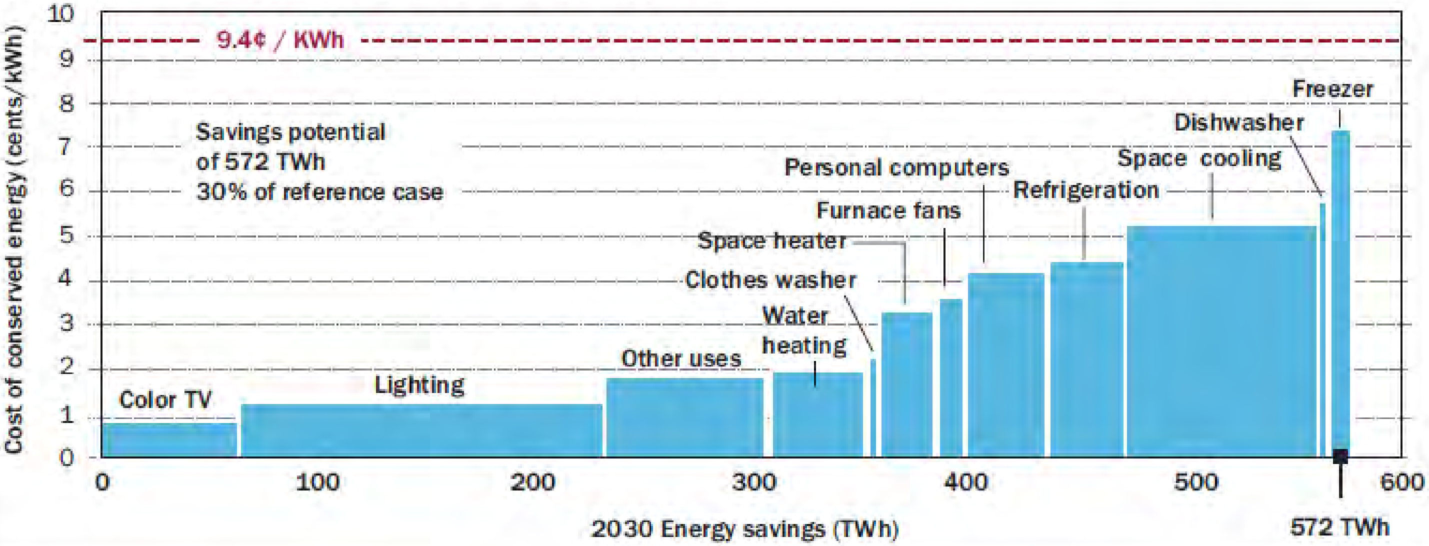
(Source: IEER)

Source: Cost of efficiency measure (Source APS 2008)

Figure 25

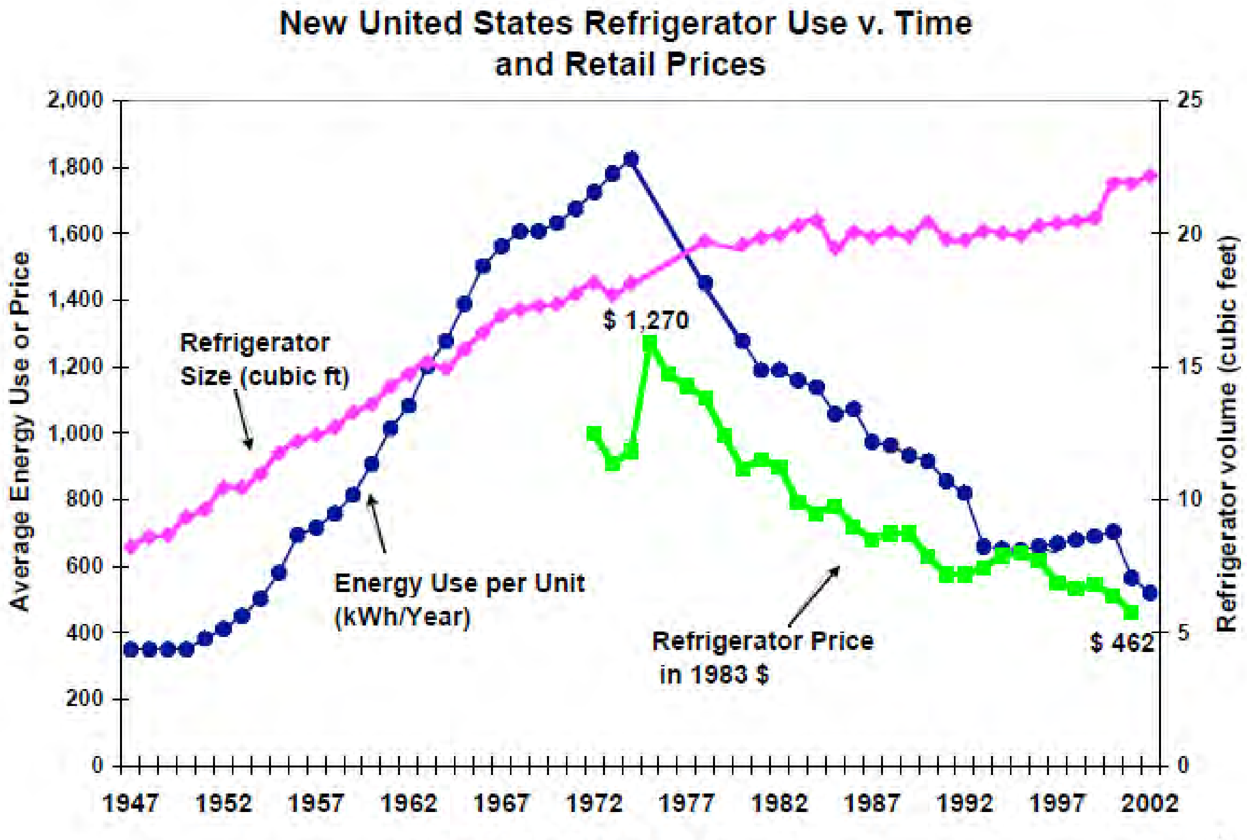
Residential electric savings potential for year 2030

Conservation supply curve for electric energy-efficiency improvements in the residential sector. For each measure considered, (the energy savings is achieved at a cost per kWh less than the average residential retail price of 9.4 cents/kWh, shown as the horizontal red dashed line.



(Used with permission from the American Physical Society's report: *"Energy Future, Think Efficiency"* (2008).)

Refrigerator standards and cost



Source: David Goldstein

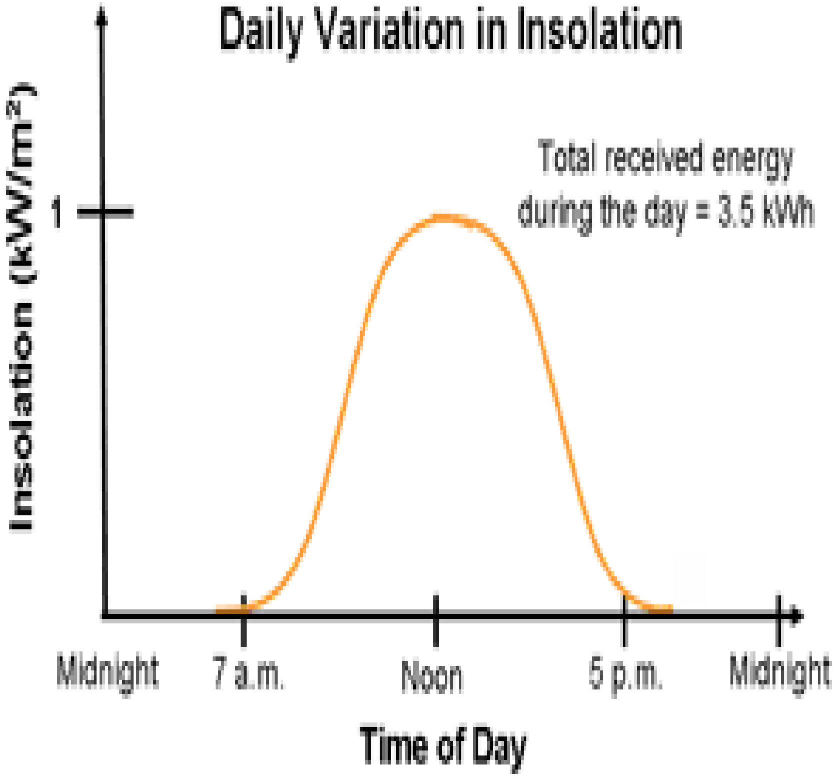
(Source: Rosenfeld 2008, Slide 8 at http://www.energy.ca.gov/2008publications/CEC-999-2008-017/CEC-999-2008-017.PDF)

750 kW US Navy San Diego Parking Lot

(Credit: DOE/NREL (NREL-12373). Credit: SunPower Corporation)

Grid reliability

Bright day, looming clouds



(Credit: www.mpoweruk.com)

(Credit: Avesun | Dreamstime.com)

Dealing with intermittency

Smart grid: consuming devices talk to producing devices; storage devices, smart meters, mediate conversation

Store heat while the sun shines

Store cold while the wind blows

Solar and wind integration

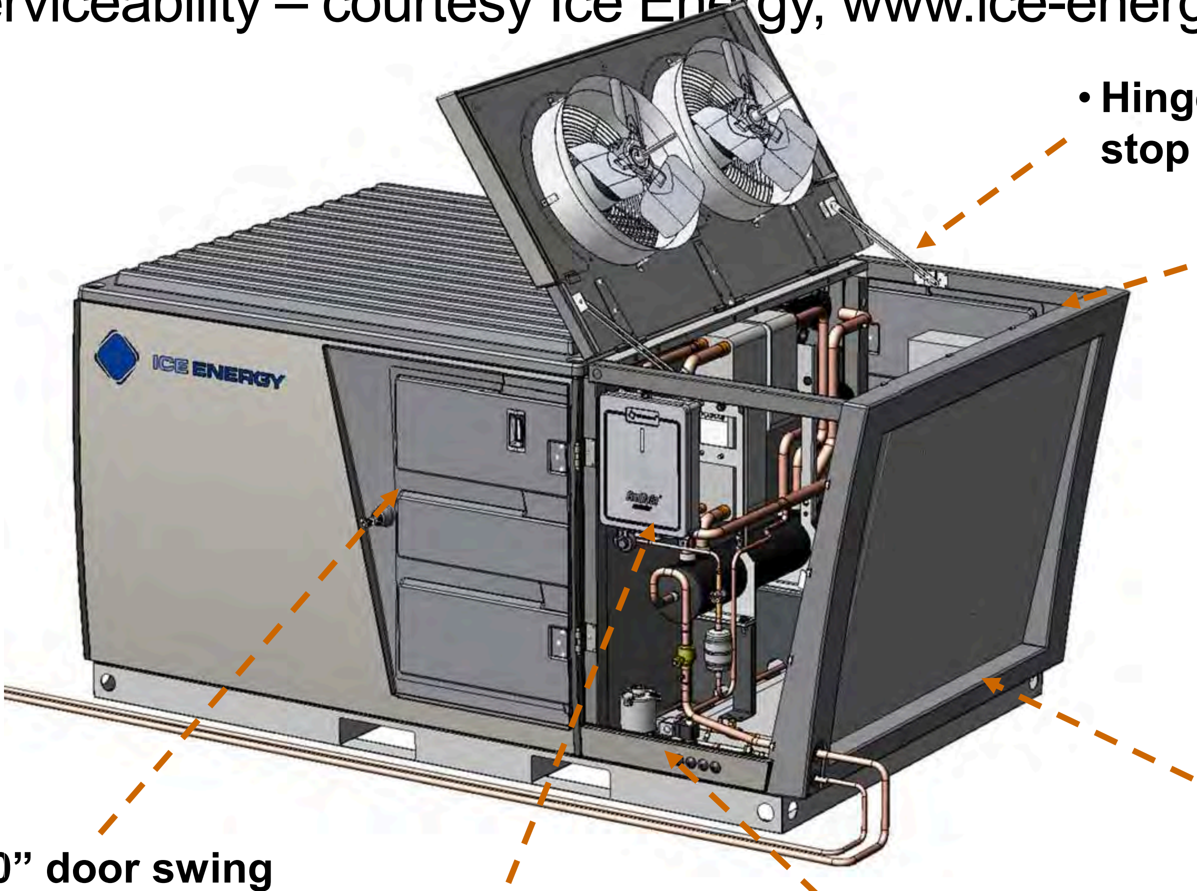
Existing hydro backup

Existing natural gas standby (U.S. has enormous surplus capacity), long-term: replace fuel with biogas (use aquatic plants, such as microalgae, as feedstock)

IGCC solid biomass (e.g., algae), geothermal, CHP

Other storage elements, medium- to long-term (compressed air, including, vehicle-to-grid, dispatchable wind – produce compressed air instead of electricity at the turbine and generate electricity when needed, e.g., General Compression http://www.generalcompression.com

The Ice Bear - Designed for building controls, reliability and serviceability – courtesy Ice Energy, www.ice-energy.com

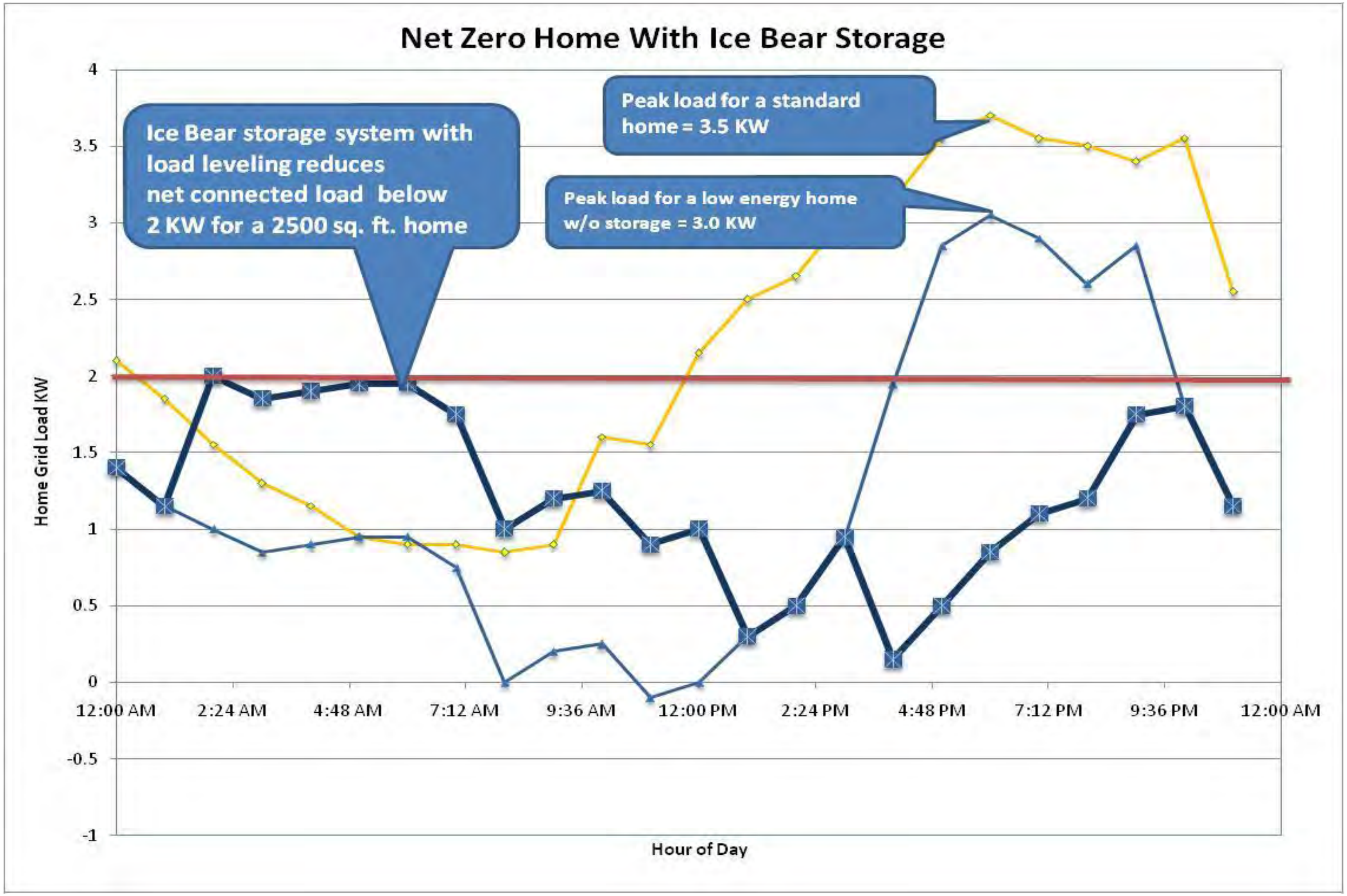


- Hinge with positive stop and "latch"
- Door on opposite side for access to compressor and water pump
- Compressor location
- 30" door swing
- magnetic "catch" in open position
- CoolData Controller™
- Refrigerant pump uses 100 W on peak

CoolData™ Controller is designed to monitor and control up to 200 building data points, serve as FDD and communicate with Ethernet

Courtesy of Ice Energy

SMUD ZEH with Energy Storage – courtesy Ice Energy



ZEH w/ Ice Bear 70% peak reduction

(Courtesy of Ice Energy)

Electric car: Phoenix Motorcars Pickup - this type of battery useful for vehicle to grid

All electric: Range 130 miles, about one-third kWh per mile

Altairnano batteries can be:

Charged in 10 minutes with special equipment

Retain 85% capacity after over 10,000 charging and discharging cycles

Suitable for vehicle to grid applications

There are other similar lithium-ion batteries from other manufacturers now coming on the market

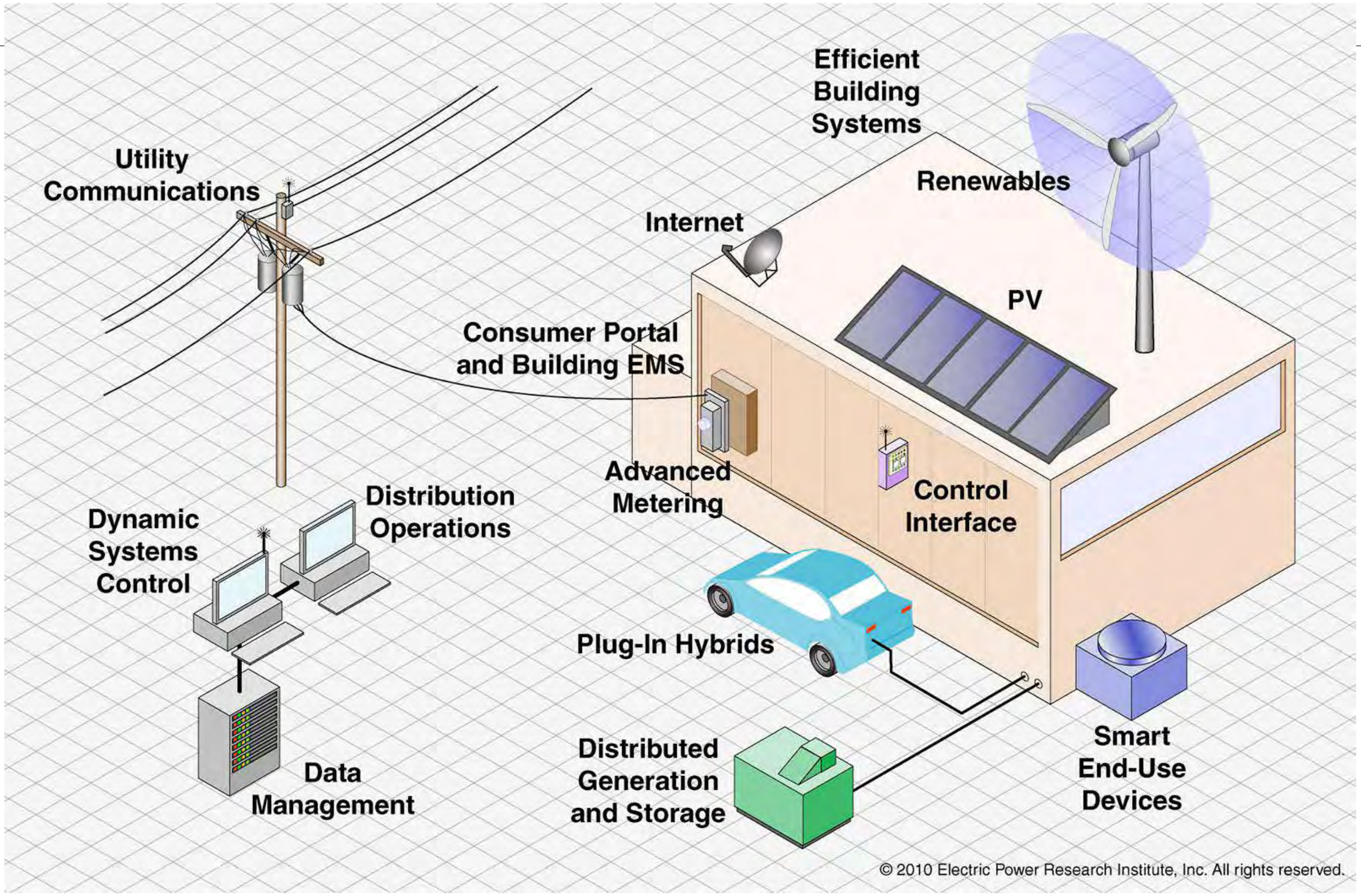
Cost reduction needed – appears to be occurring rapidly

(Image courtesy of Phoenix Motorcars)

Tesla: 0 to 60 in 4 secs. (goal); 200 mile range, 0.2 kWh/mile, off-the-shelf lithium-ion batteries combined in special battery pack

(Courtesy of Tesla Motors)

Smart Grid Network



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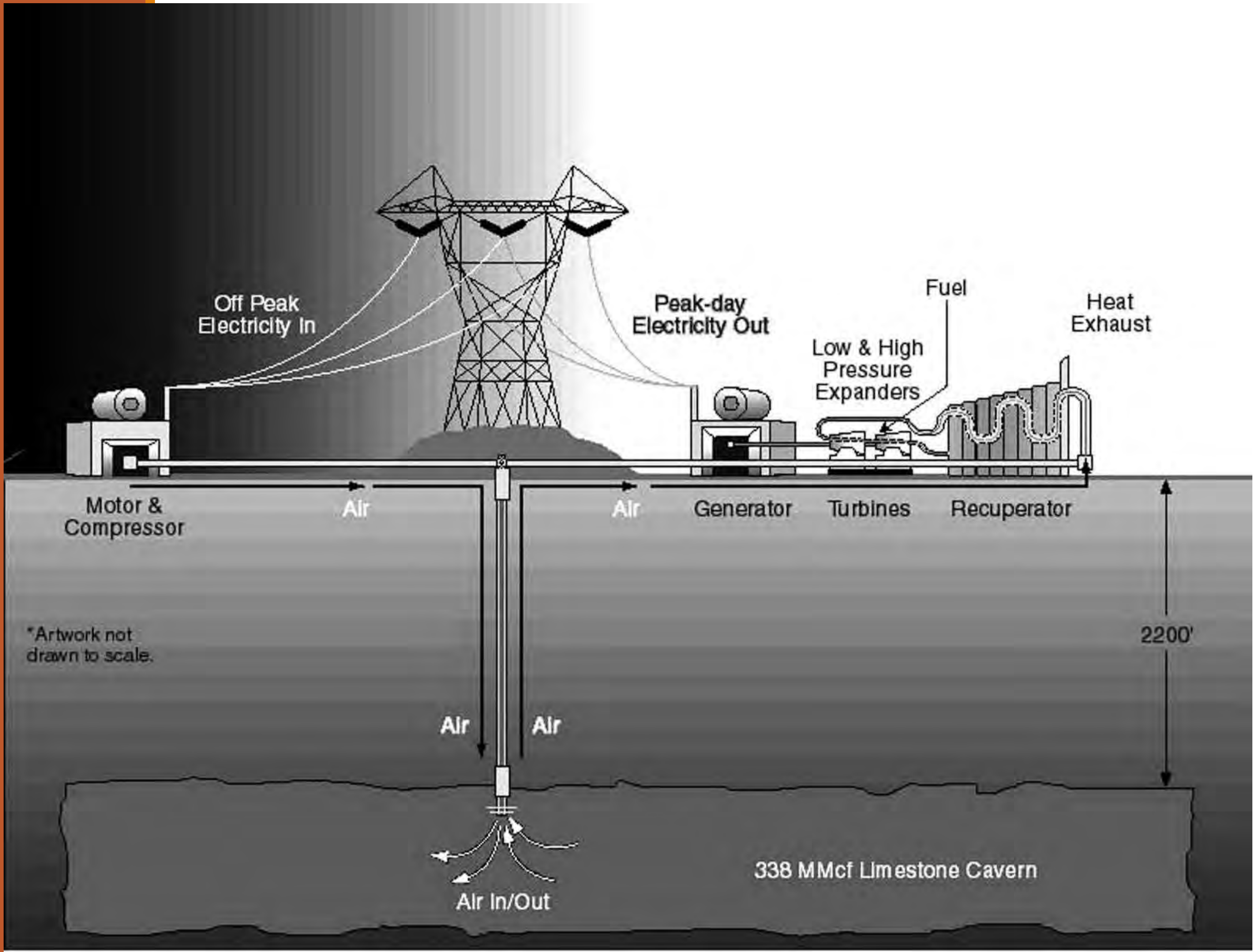
Sodium sulfur batteries with wind power in Japan

(Courtesy of NGK Insulators)

Compressed Air Energy Storage

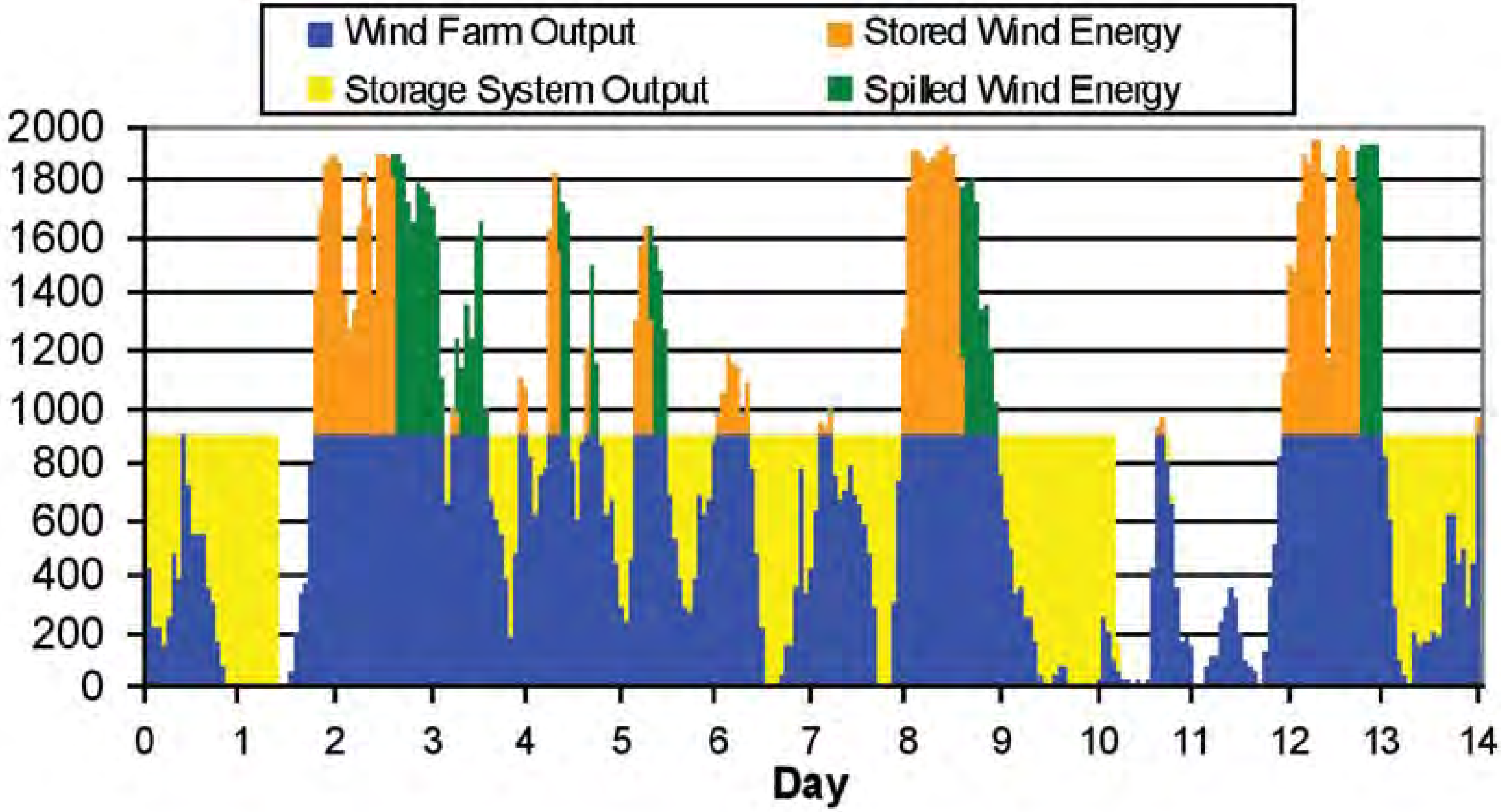
Currently most promising in a wide variety of settings. Like compressed natural gas storage.

Geology requirements have to be met.



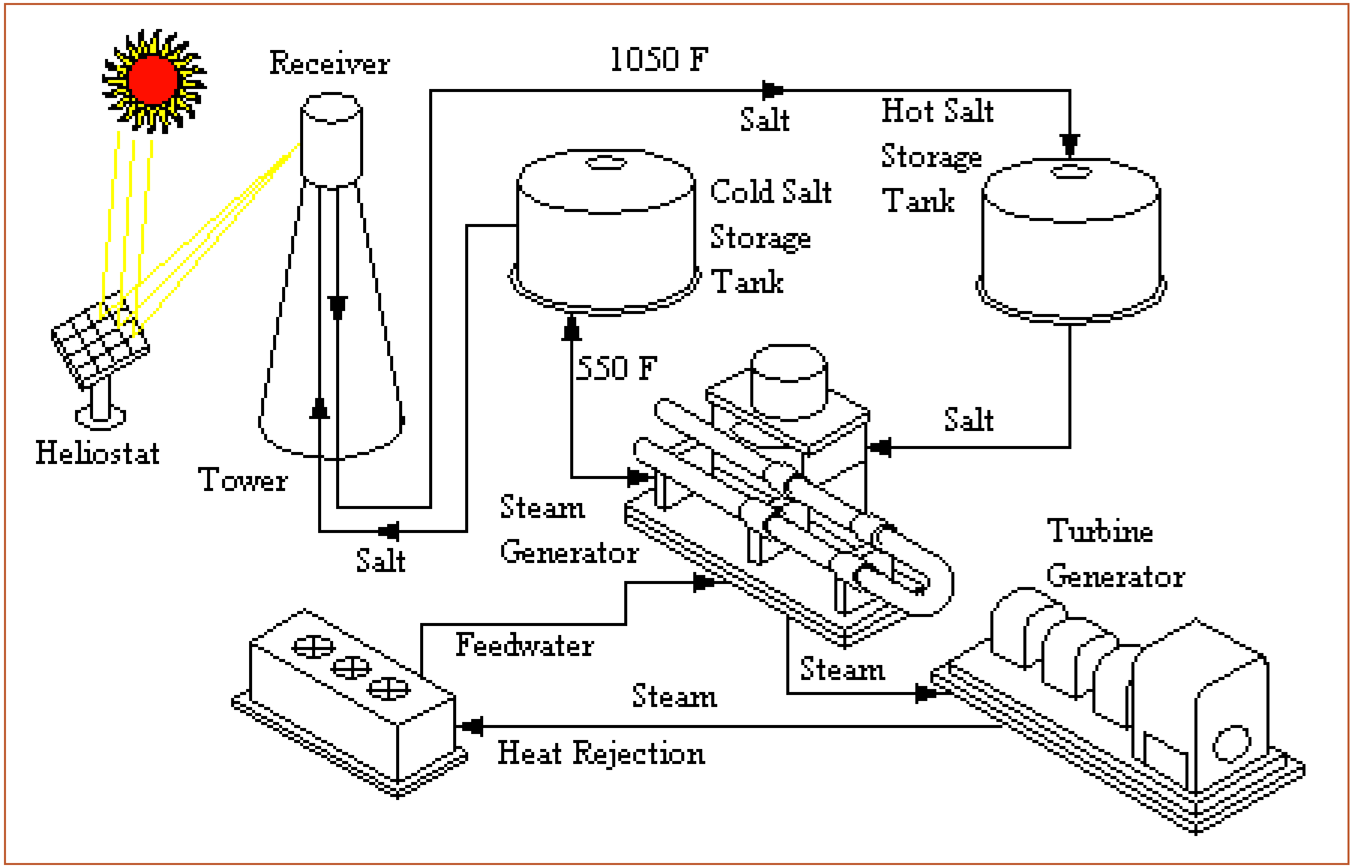
(Source: http://www.sandia.gov/media/NewsRel/NR2001/norton.htm)

NREL model for baseload wind



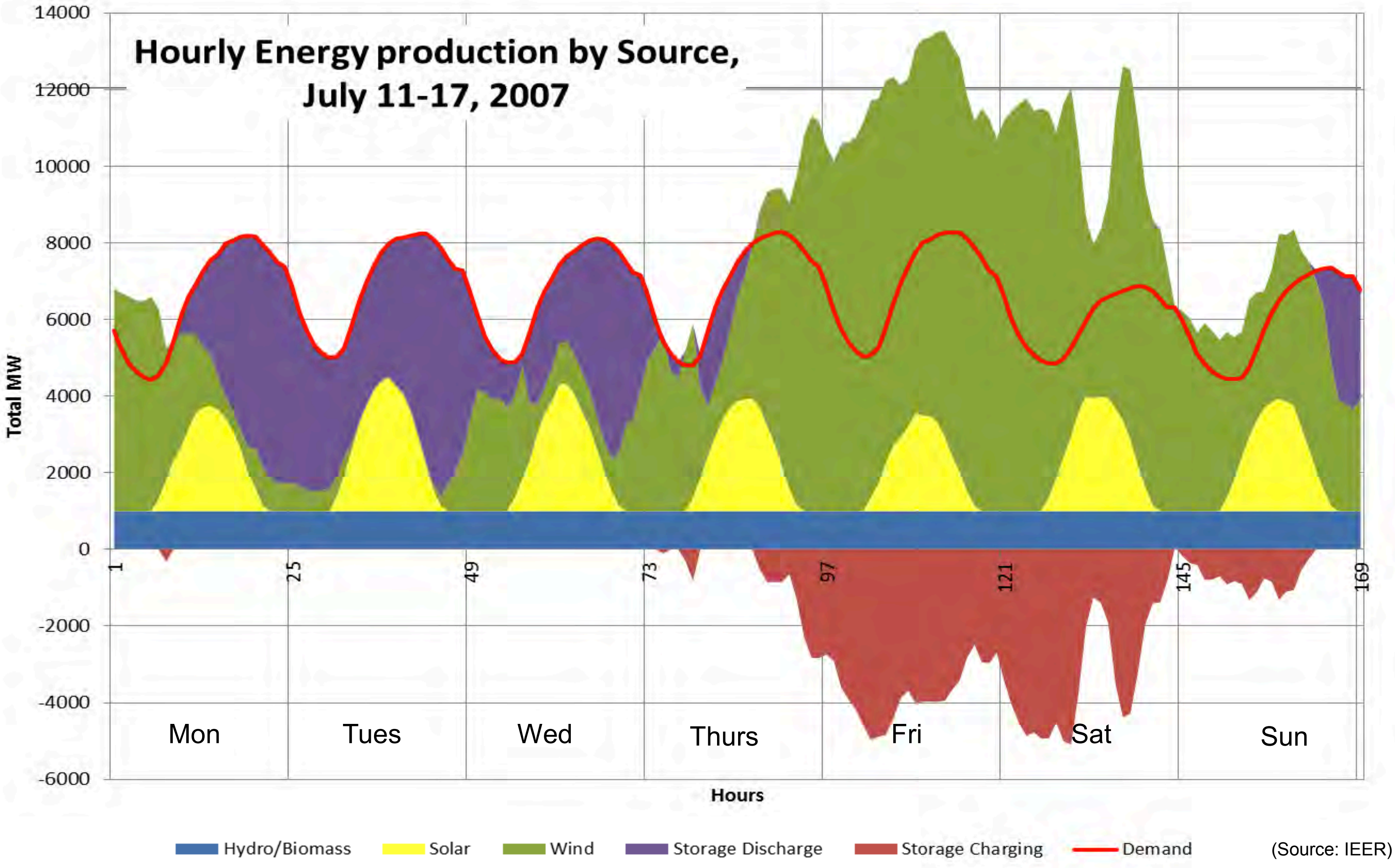
This figure was developed by the National Renewable Energy Laboratory for the U.S. Department of Energy.
(Source: http://pbadupws.nrc.gov/docs/ML1036/ML103620008.pdf)

Storing heat – solar power at night (but not suitable for the Eastern United States, see NREL study, 2012)



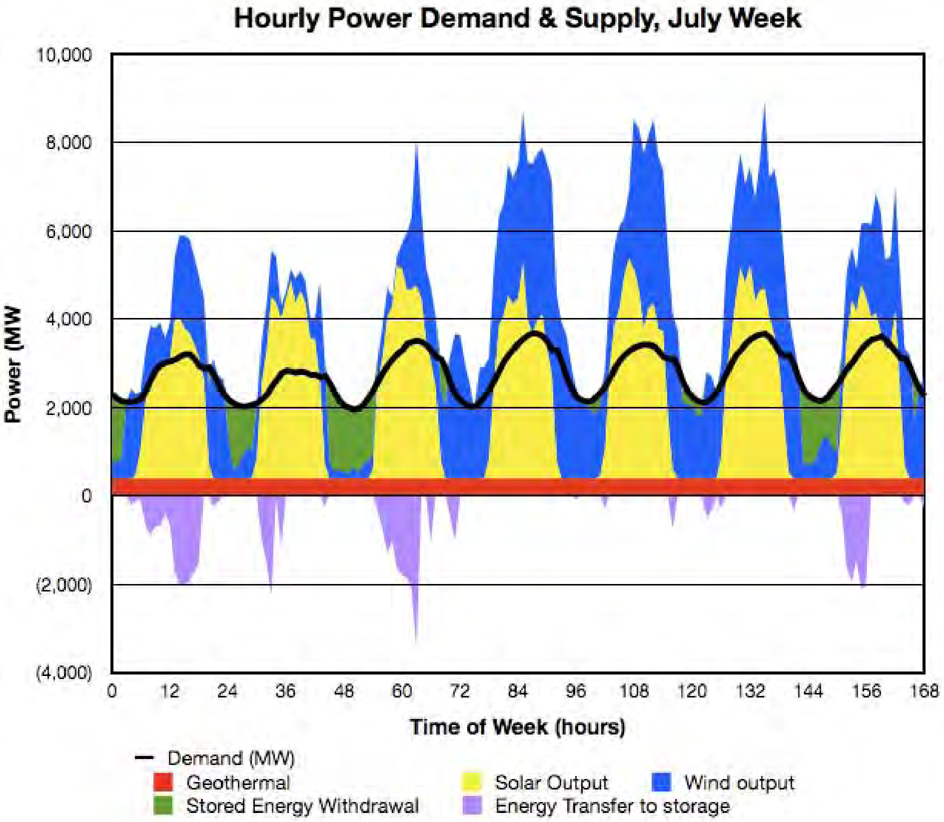
Credit: Sandia National Laboratories (http://www.sandia.gov/Renewable_Energy/solarthermal/NSTTF/salt.htm)

Modeling 100% Renewable MN



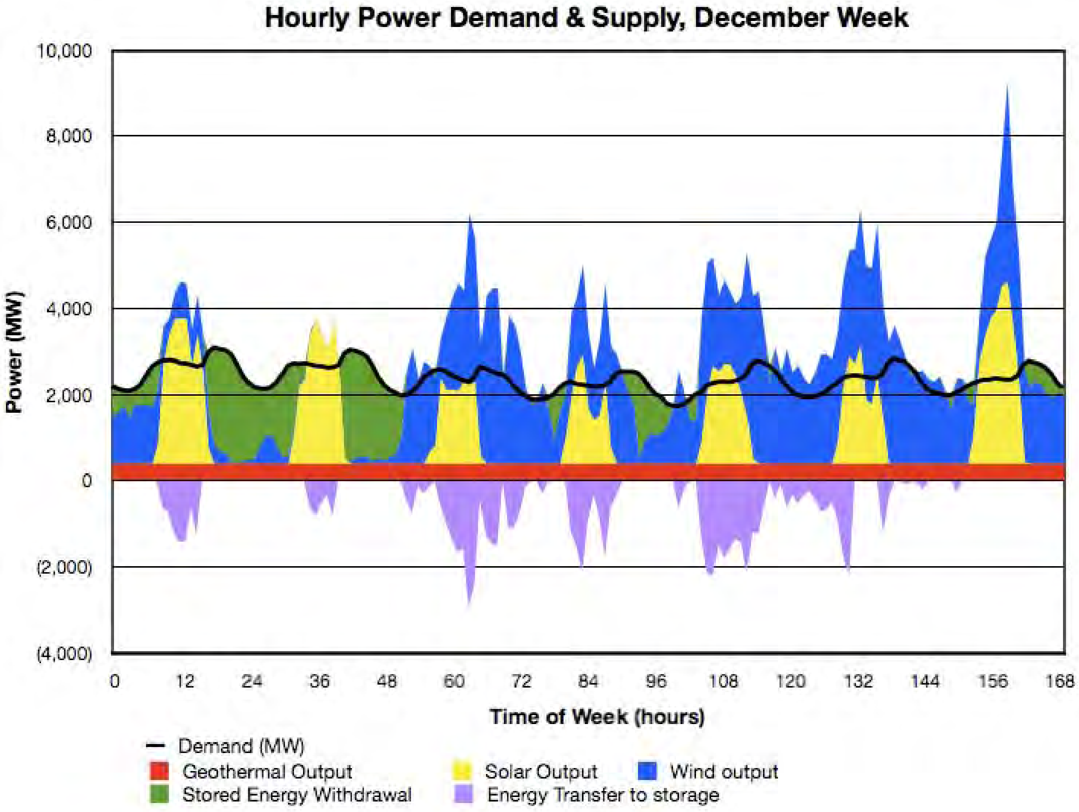
(Source: IEER)

Utah: Hourly demand, renewable supply and storage, summer week, fully renewable scenario. Note large amount of "spilled energy"



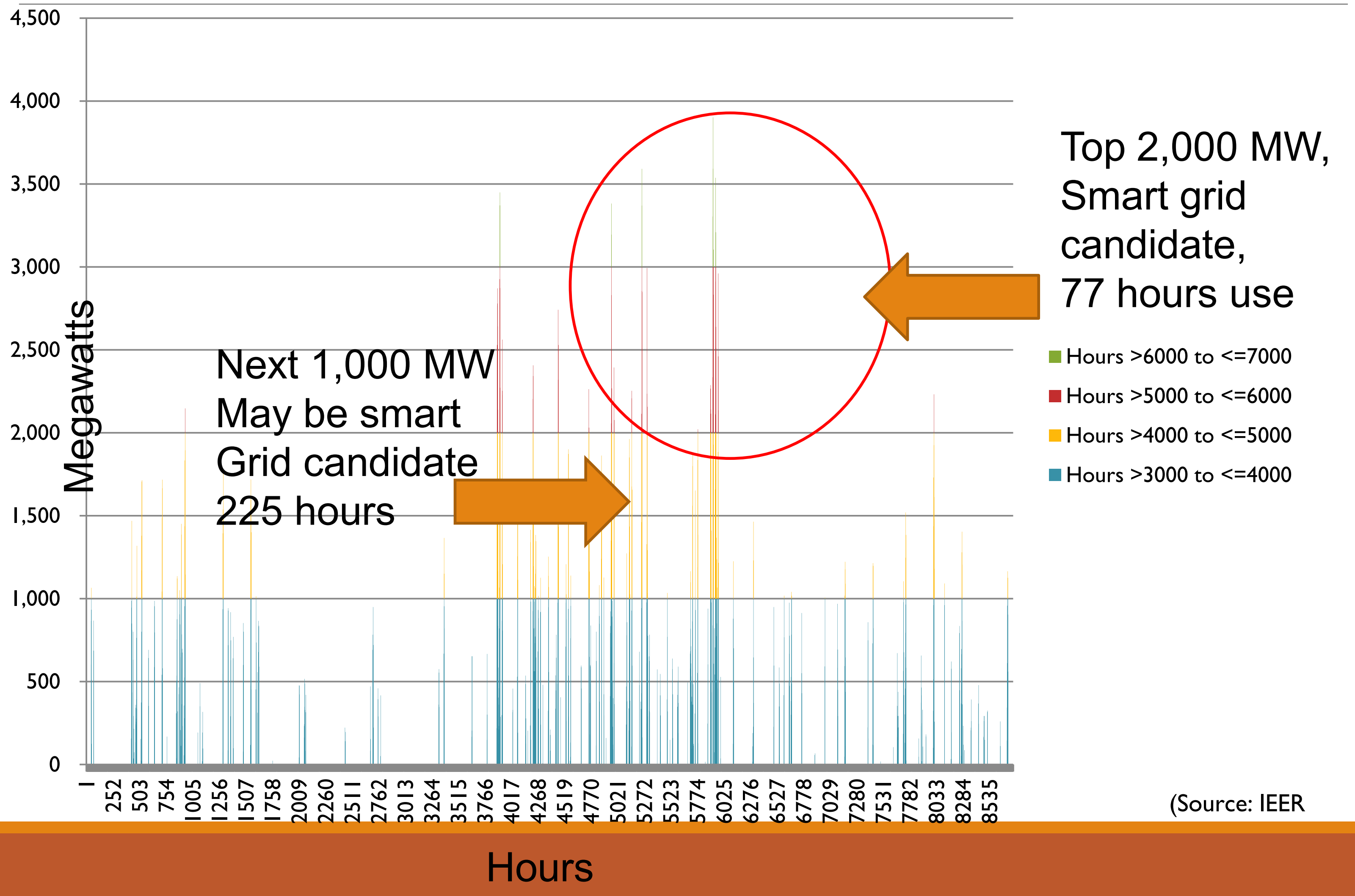
(Source: IEER, at http://ieer.org/resource/climate-change/eutah-renewable-energy-roadmap/)

Utah hourly demand, renewable supply and storage, winter week, fully renewable scenario. Much less “spilled energy”



(Source: IEER, at http://ieer.org/resource/climate-change/eutah-renewable-energy-roadmap/)

Further savings are possible: Top 2,000 MW generation from storage only used 77 hours a year!
What is needed? Smart grid.



Top 2,000 MW,
Smart grid
candidate,
77 hours use

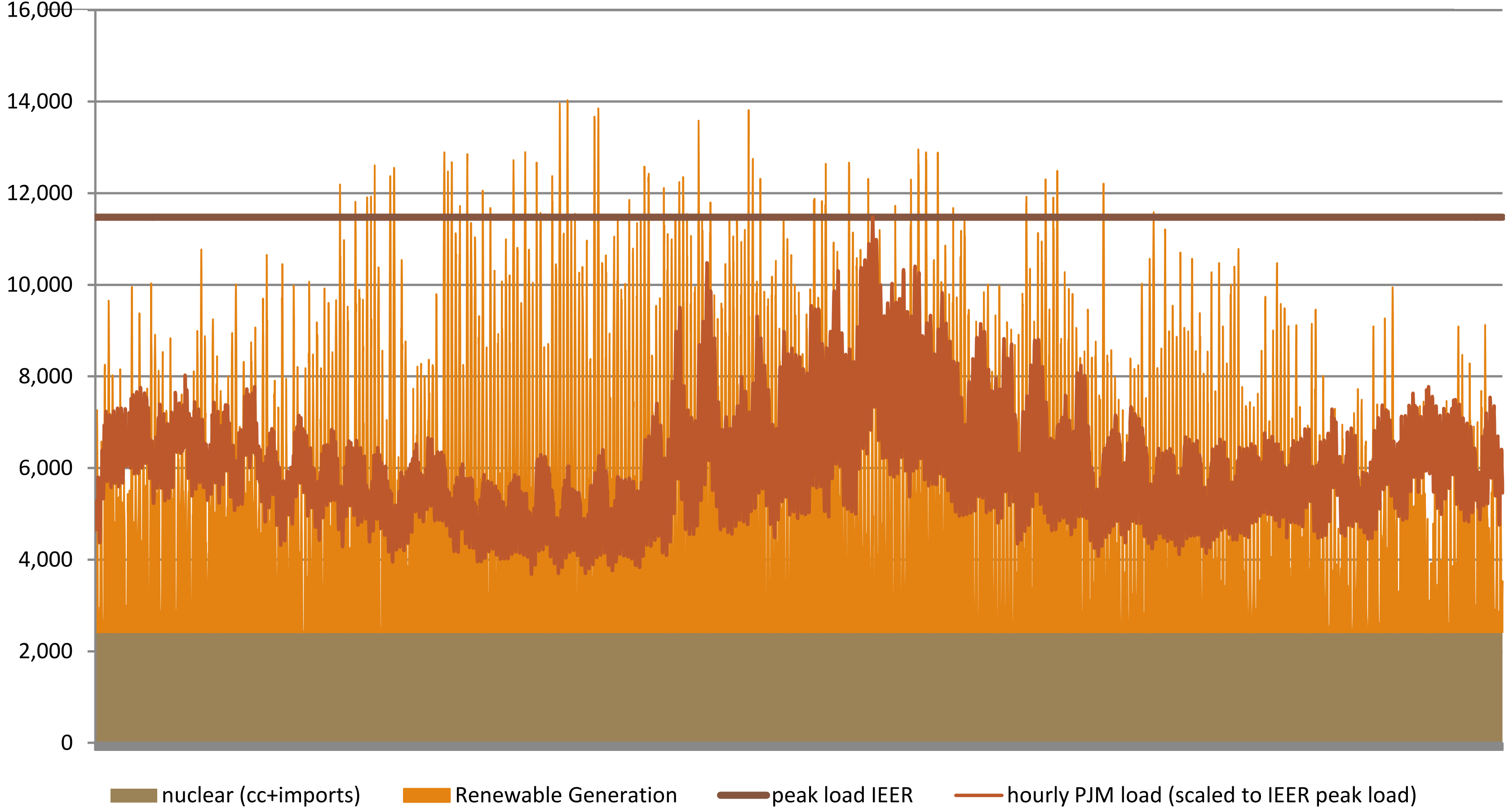
Next 1,000 MW
May be smart
Grid candidate
225 hours

(Source: IEER

Last 2,000 MW of generation from storage – few hours, very high cost – shows need for smart grid, highlighted rows. Scenario is CAES plus 1,000 MW baseload (hydro/biomass)

	hours tranche used	average tranche generation, MW	Total tranche generation, MWh	expander capital cost $/MWh
0 to 1000	3,686	886	3,264,721	8
1000 to 2000	2,835	824	2,335,363	11
2000 to 3000	1,801	712	1,282,590	20
3000 to 4000	828	592	490,181	52
4000 to 5000	225	559	125,860	202
5000 to 6000	65	526	34,167	745
6000 to 7000	12	417	5,001	5,092

Nuclear plus high renewable penetration: a poor match, needing frequent curtailment of renewables: generation > load for over 3,000 hours in the year (36 percent of the time). Heuristic calculation for Maryland 50% RPS using PJM data, preliminary



Transportation

Most land transport can be electrified – possibly all. Electric vehicles can provide critical support to a grid with large amounts of solar and wind.

Main technical issue for fossil fuel in transportation is aircraft fuel.

Possibilities: biofuels (land impact issues, and air pollution issues as well)

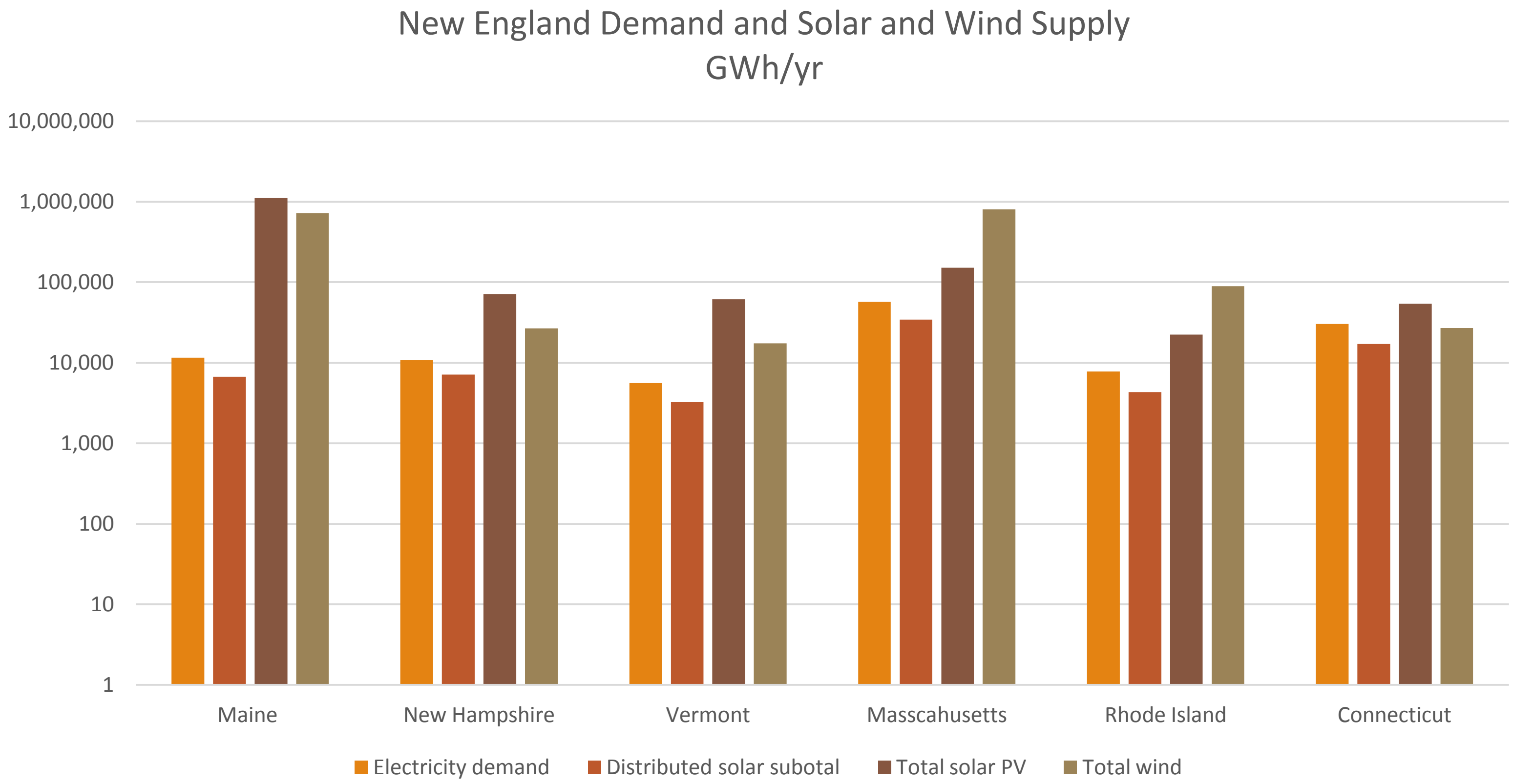
Renewable hydrogen from wind and solar – hydrogen has been used to fly aircraft, including a converted passenger jet. Some greenhouse gas issues if flown in the stratosphere (35,000 to 40,000 feet) – water vapor there is a greenhouse gas. Major R&D effort is needed.

Electric aircraft (including fuel cells) – currently small aircraft have been developed.

Solar aircraft (beyond Wright brothers stage at present, but still experimental aircraft – have flown at night)

Renewable energy potential: wind and solar

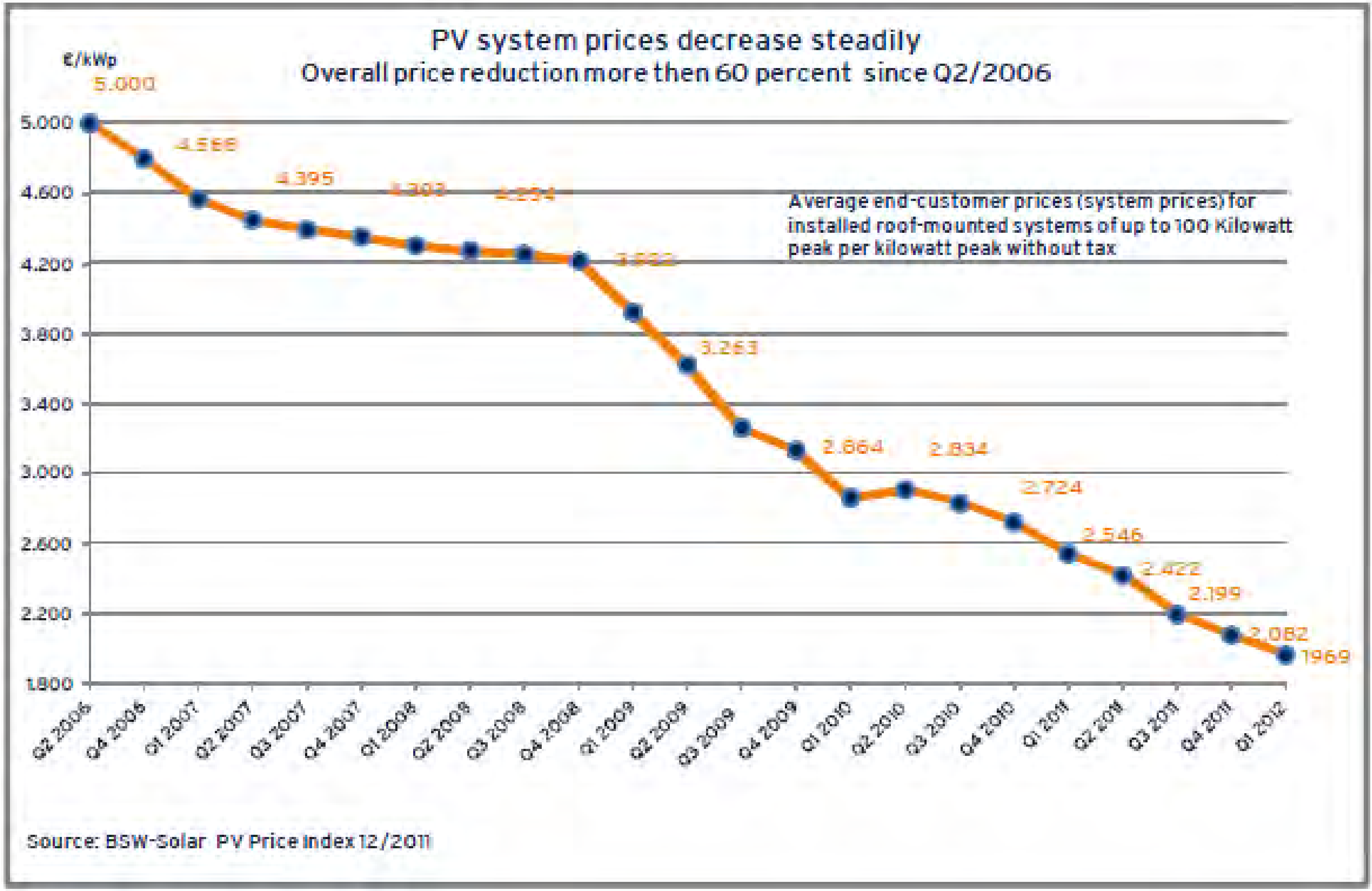
New England renewable energy potential (note logarithmic scale)



Brandon
shores

Cost

German small-medium system PV prices



Source: BSW-Solar PV Price Index 12/2011

Source: BSW-Solar 2012

San Antonio TX and northern California rates and bills

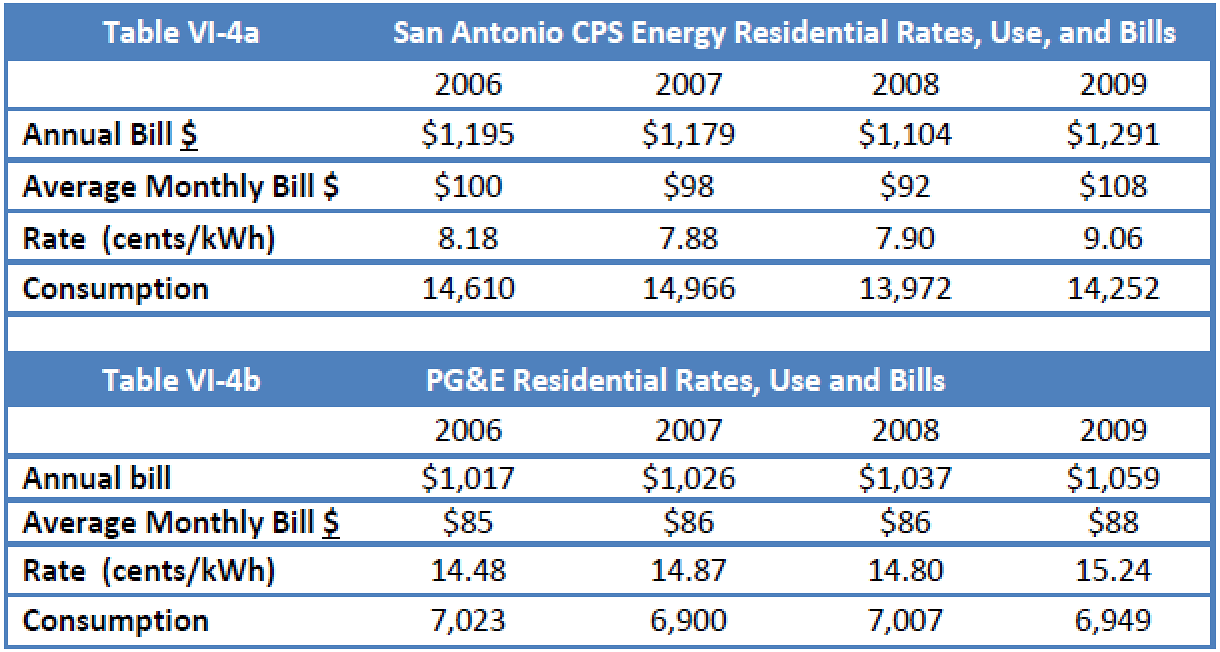


Table VI-4a	San Antonio CPS Energy Residential Rates, Use, and Bills			
	2006	2007	2008	2009
Annual Bill $	$1,195	$1,179	$1,104	$1,291
Average Monthly Bill $	$100	$98	$92	$108
Rate (cents/kWh)	8.18	7.88	7.90	9.06
Consumption	14,610	14,966	13,972	14,252

Table VI-4b	PG&E Residential Rates, Use and Bills			
	2006	2007	2008	2009
Annual bill	$1,017	$1,026	$1,037	$1,059
Average Monthly Bill $	$85	$86	$86	$88
Rate (cents/kWh)	14.48	14.87	14.80	15.24
Consumption	7,023	6,900	7,007	6,949

(Source: IEER, at ieer.org/wp/wp-content/uploads/2012/03/renewableminnesota.pdf)

Energy justice

Energy cost burden by income group – national data

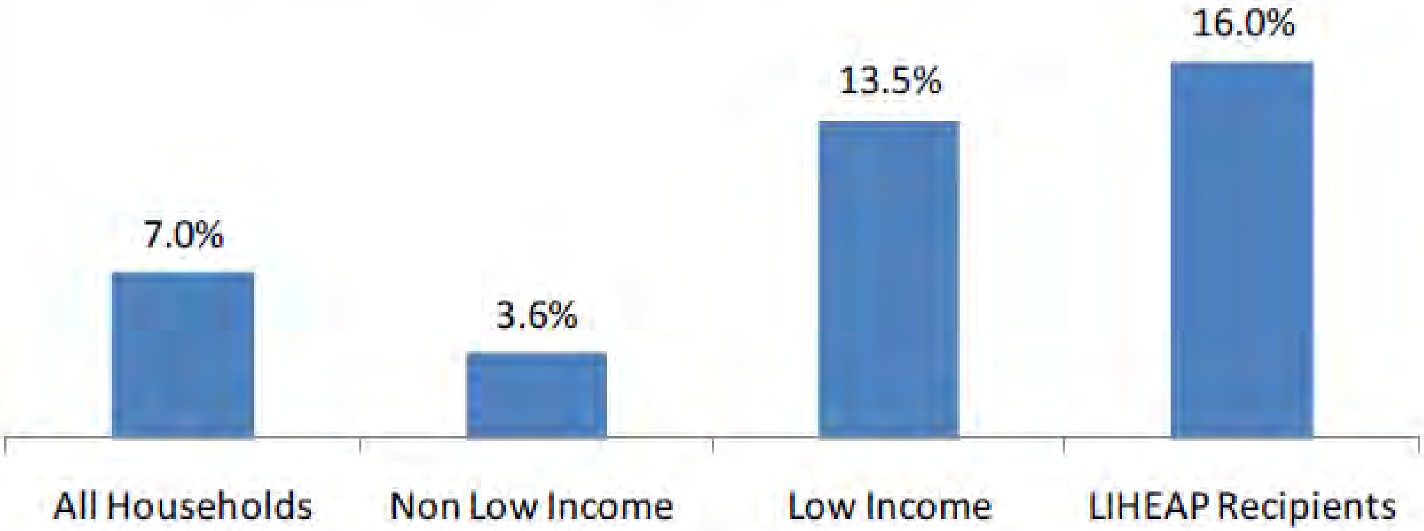


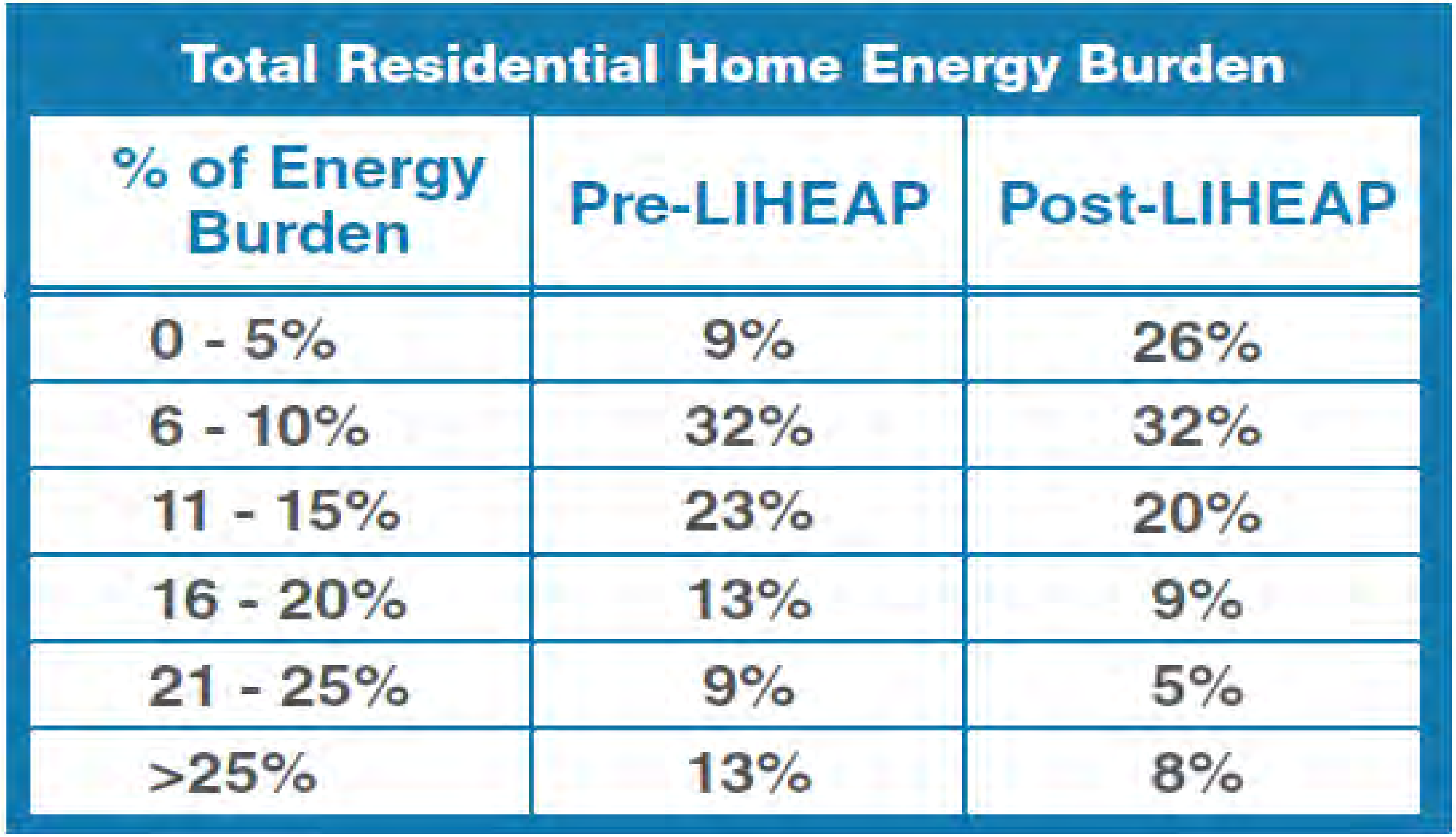
Figure 1.

Low Income Households Carry Heavy Home Energy Burden

Source: U.S. Department of Health and Human Services, Administration for Children and Families, Office of Community Services, Division of Energy Assistance. *LIHEAP Home Energy Notebook for FY 2007* (Washington, DC: USDHHS, 2009).

Note: **LIHEAP: Low Income Home Energy Assistance Program** (Source: AARP 2010, at http://assets.aarp.org/rgcenter/ppi/cons-prot/2010-05-energy.pdf , from data at http://www.acf.hhs.gov/sites/default/files/ocs/FY07 LIHEAP HomeEnergyNotebook.pdf)

Energy cost burden among those receiving assistance: typical assistance amount ~$400/year



Total Residential Home Energy Burden

% of Energy Burden	Pre-LIHEAP	Post-LIHEAP
0 - 5%	9%	26%
6 - 10%	32%	32%
11 - 15%	23%	20%
16 - 20%	13%	9%
21 - 25%	9%	5%
>25%	13%	8%

Source: National Energy Assistance Directors' Association 2011 at http://neada.org/wp-content/uploads/2013/05/NEA_Survey_Nov11.pdf)

Community Solar

Critical for allowing ALL to participate in a democratized energy system

Credit on electricity bill via virtual net-metering encourages even more efficiency

Utility ownership allows new revenue streams

Success connected to determining the value of solar to the grid (because customer load is not actually reduced)

Financing (leasing or ownership) of solar by lower-income groups (less than median income) and increasing rental home efficiency are keys to success on equity, democracy, and GHG goals.

Community choice aggregation is another tool.

Economic Equity

One metric of success should be affordability for all income groups as a fraction of income. This looks different in different economic groups

Ripple effect of reducing energy costs potentially significant (lower public support demands, or greater reach with public dollars, more income kept in hands of low-income persons, etc.)

A goal statement for equity could be: Ensuring energy security with dignity for all with a zero or very low emissions energy sector.

Renewable energy impacts

1. Visual

2. Manufacturing (Wind: cement, steel, on-site. Solar: use of chemicals in silicon manufacture, thin film: rare materials plus chemicals in manufacture. Silicon is generally to be preferred since very low raw material impact – sand is the raw material)

3. Land (for wind and utility solar)

4. Noise (for wind only)

5. Transmission lines (for wind and utility solar)

6. Birds (wind only). Much less than buildings and cats; should not ignore; can be reduced

7. Offshore construction impacts?

Detailed Responses

All energy supply has an impact. Best to minimize energy use and materials throughput, and recycle what cannot be reused.

Efficiency is best for what we do use. In a really advanced energy system, current economic output could be had with well under 20 percent of present US energy use.

As far as possible, we must restrict impacts to the generation benefiting, allowing reversibility choices for future generations to do better

For example, we find negative visual impacts of wind. They are for the generation that benefits. Best locations produce the lowest prices.

Distributed solar has the least impact. Sprawl is a poor image to describe rooftop installations. Sprawl is a problem, but it is really housing suburban sprawl that is the issue. Putting solar on the rooftop doesn't change that.

Solar panel materials can be recycled.

In maybe ten or fifteen years, building integrated solar may eliminate visual issues. Available today but not as efficient as solar cells made of silicon.

Bird mortality is much larger for buildings and cats – and climate disruption will have a huge impact on flora and fauna too.   Indeed, in some areas it is already having a major impact.

That said, it is important minimize impact and focus more on distributed solar and offshore wind. Bat mortality can be reduced in areas where that is a concern by modifying wind turbine operation. Useful publication: Proceedings of the Wind Energy and Birds/Bats Workshop: Understanding and Resolving Bird and Bat Impacts Washington, DC, May 18-19, 2004; Co-Sponsored by The American Wind Energy Association and The American Bird Conservancy.

My personal opinion: Audible noise is really not a significant issue with modern wind turbines. A wind turbine is less audible at the foot of the turbine than a typical heat pump in a hotel room.

Response to critics of the CFNF concept – energy choices

1. Freeze in the dark

2. Burn fossil fuels with air and water pollution, massive land use (when mining is included), climate disruption, ecosystem damage that is often irreversible, severe health impacts, etc. And a huge negative economic impact, which is unfolding at present.

3. Kick plutonium and radioactive waste down the road to our children for uncounted generations, spend a lot of money doing it, economic risks, severe accident risks with vast long term land and water impacts (including the oceans), proliferation risks (30 bombs worth of plutonium per 1000 megawatt reactor per year).

4. Look at the view (there are other impacts from solar and wind)

Choice 4. is not perfect but much better than the others. It can also be done technically at reasonable cost.

End note

Slides are primarily a summary of *Carbon-Free and Nuclear-Free: A Road Map for U.S. Energy Policy* by Arjun Makhijani

Find the source citations in the downloadable version of the book, available at no cost, on the Web at http://www.ieer.org/carbonfree/CarbonFreeNuclearFree.pdf or contact Institute for Energy and Environmental Research.

The book can be purchased in hard copy at www.ieer.org.

Graphics also from: *Renewable Minnesota* (2012) at http://www.ieer.org/reports/renewableminnesota, and *eUtah, a Renewable Energy Roadmap* (2010) at http://www.ieer.org/reports/eUtah2010.pdf.