Demand-Side Management Technology Workshop: Advances in Water Heating

Sponsored by
Tri-State Generation & Transmission
with Western Area Power Administration

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Westminster, CO

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Water Heating Technologies Roadmap

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with
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Topics Covered

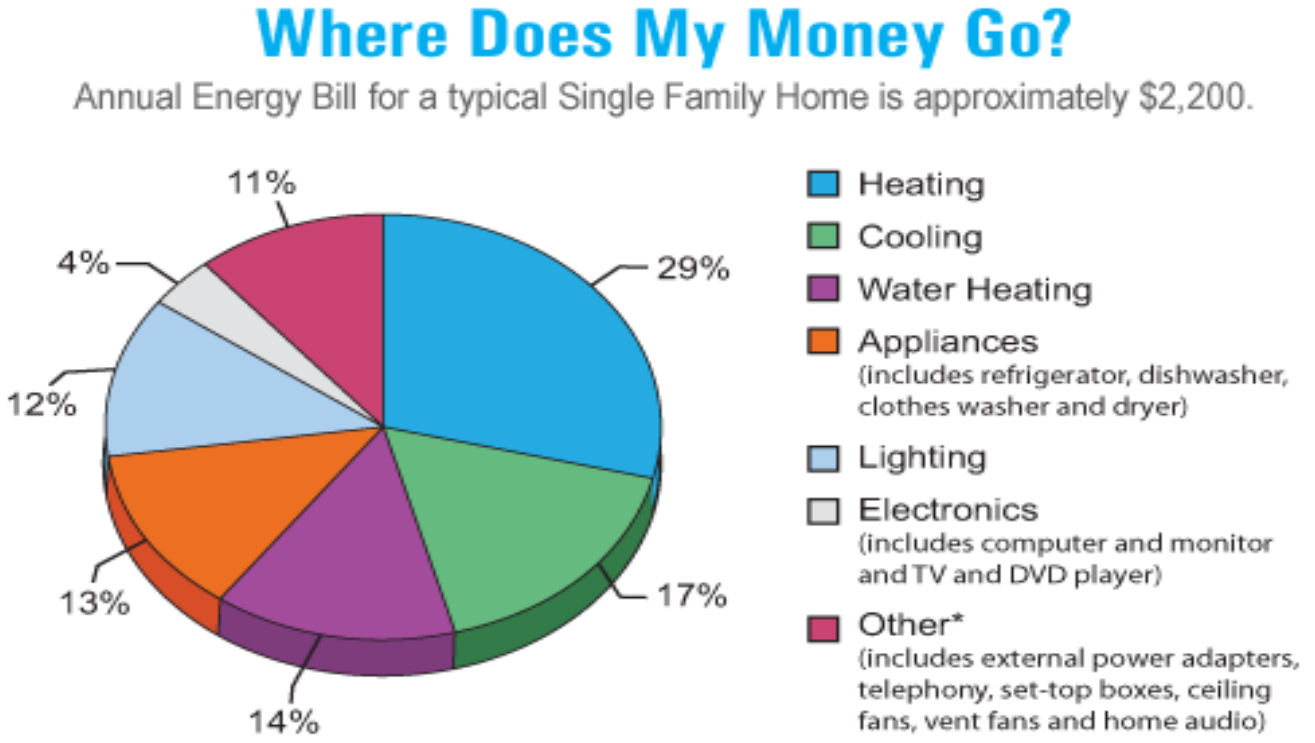
- Market Overview
- Types of Systems
- Solar Thermal vs. Photovoltaic
- International Solar Overview
- Overview of Solar Product Suppliers
- Certifications (SRCC, Etc)
- Water heating as ‘renewable energy storage’

Market Overview

- 9 Million Units Annually
- 50% Electric - 50% Gas
- 50% Retail - 50% Wholesale
- 80% Replacement - 20% New Construction
- 65% Emergency - 35% “Planned Replacements”
- Average Tank Life - 10 Years
- 10% of installed tanks replaced annually

Energy Breakdown- Water Heating

- 15-20% of Residential Energy Use
- The “Forgotten” Appliance



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Market Drivers

- Industry Consolidation
- Engineered for Replacement
- Improving Efficiency ('forced' by DOE)
- Integrated Systems
  - Geothermal Heat Pump (GHP)
  - High-Efficiency Boilers
- Safety: Flammable Vapor Ignition Resistant (FVIR)
- Emergence of Solar and other types of water heater (WH) systems

Types of Water Heater Systems

- Storage
- Tankless
  - Indirect
  - On Demand
- Heat Pump Water Heater
- Solar Water Heaters
- For more information:

www.energysavers.gov/your_home/water_heating/index.cfm/mytopic=12850

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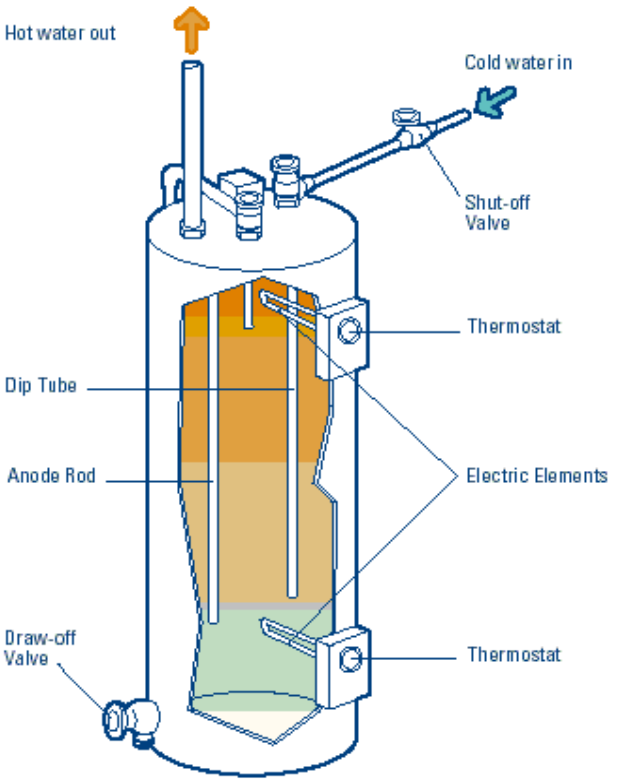
Storage Water Heaters

Conventional storage water heaters remain the most popular type of water heating system for the home.



- A single-family storage water heater offers a ready reservoir (20 to 80 gallons) of hot water. It operates by releasing hot water from the top of the tank when the hot water tap is turned on.
- To replace that hot water, cold water enters the bottom of the tank, ensuring that the tank is always full.
- Since tank water temperature is constantly maintained, energy can be wasted even when a hot water tap isn't running. This is called ***standby heat loss***.

Pros and Cons for Conventional Storage Water Heaters

Pros

- **Proven technology builders and home owners know and trust.** The straightforward system has been around for years and works well.
- **Low product cost and low installation cost.** A basic 30-gallon electric tank can be purchased for less than $300. Installation is fairly simple.
- **Inexpensive replacement cost.** If and when a water heater goes bad, the system can easily replaced with a similar unit for about $500 – $800.
- **Well-insulated models can last a long time.** Several manufacturers including Rheem and Vaughn have long-lived water heaters.

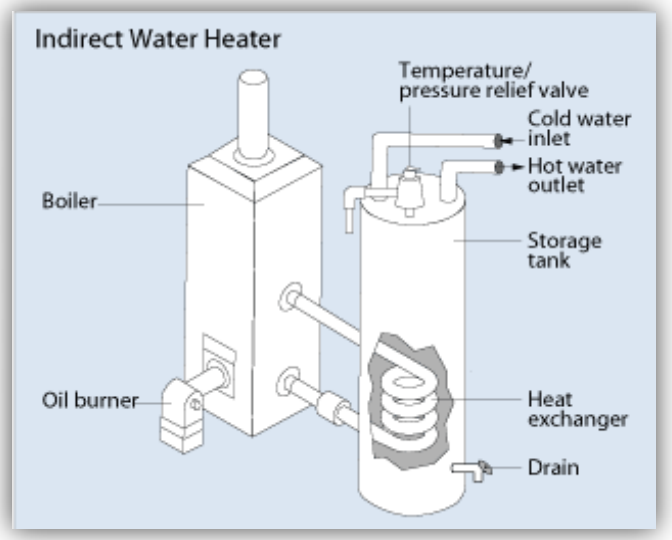
Cons

- **Conventional tanks are always on.** No matter how energy efficient it is, a storage tank cycles on a regular basis to heat and reheat water at a preset temperature, using energy to heat the water whether a homeowner needs it or not.
- **Big and bulky.** Most tanks take up space in a mechanical or laundry room, especially in smaller homes
- **May be inadequate.** Depending on the capacity and household hot water needs, a conventional storage tank may not be able to meet demand. Only about 70% of the hot water in a typical storage tank is available for use.
- **Less versatile installation.** The unit needs a fairly large space for installation and cannot be located outside the home.
- **Less durable.** Life expectancy of a conventional hot water tank is about 12 to 15 years

Source: www.builderonline.com/energy-efficiency/tankless-water-heaters-versus-conventional-storage-tanks.aspx?page=2

Indirect Water Heaters

- Requires a storage tank.
- Uses the main furnace or boiler to heat a fluid circulated through a heat exchanger in the storage tank.
- Energy stored by the water tank allows the furnace to turn off/on less often, which saves energy.



- Can use any type of fuel or energy including electric, gas, propane or solar.
- Integrated or combination water heating systems work with forced air systems, hydronic or radiant floor heating systems.
- Negative: Boiler needs to fire in summer

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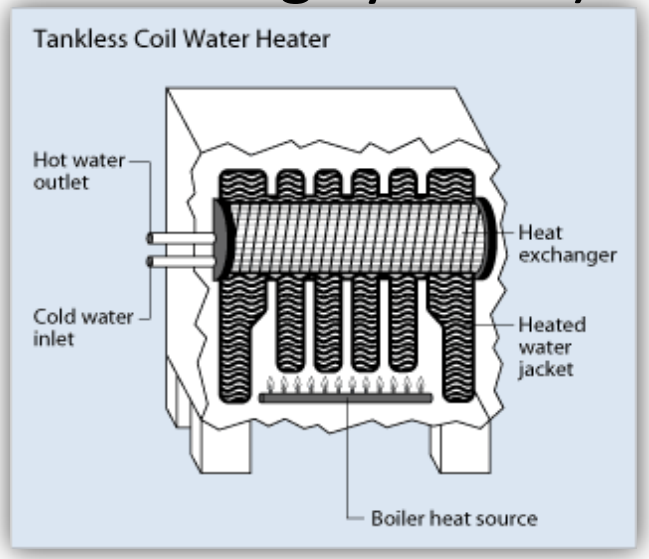
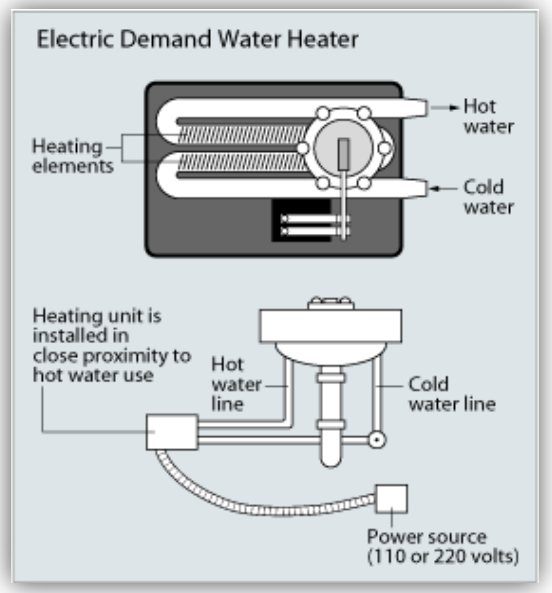
Indirect Tankless Water Heaters

- Uses a home's space heating system to heat water (integrated or combination water/space heating systems)
- Uses a heating coil (tankless coil) heater or heat exchanger installed in a main furnace or boiler. When a hot water faucet is turned on, water flows through the heat exchanger.



- Provides hot water on demand without a tank, but relies on the furnace or boiler to heat the water directly
- Tankless coil water heaters work most efficiently during cold months when the heating system is used regularly.

Demand (Tankless or Instantaneous) Water Heaters



- Demand water heaters provide hot water only as it is needed.
- When a hot water tap is turned on, cold water travels through a pipe into the unit. Either a gas burner or an electric element heats the water. As a result, demand water heaters deliver a constant supply of hot water.
- Typically, demand water heaters provide hot water at a rate of 2 – 5 gallons (7.6 – 15.2 liters) per minute.
- But even the largest model cannot supply enough hot water for simultaneous, multiple uses in large households.

Pros and Cons for Tankless Water Heaters

Pros

- Energy savings
- Unlimited hot water
- Less physical space
- Reduced risk of water damage

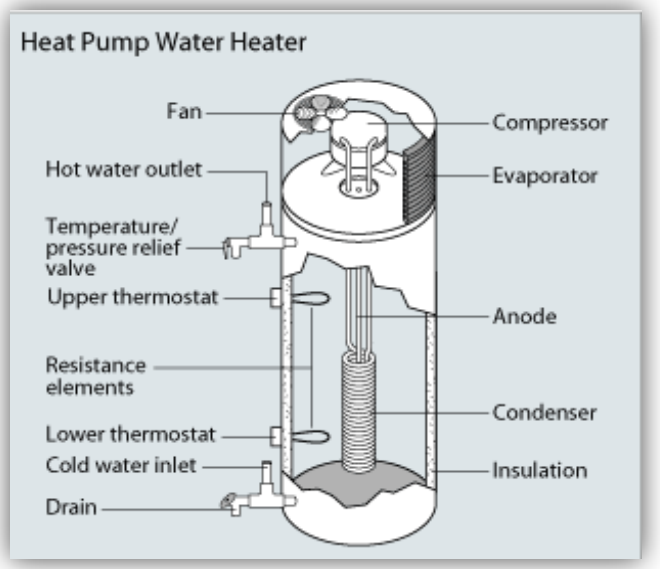
Cons

- Start-up delay
- Intermittent use
- Installation cost
- Heat source flexibility
- Recirculation systems
- Maintaining constant shower temperature
- Operation with low supply pressure
- Time-of-use metering and peak electrical loads
- Annual maintenance

Heat Pump Water Heaters

Heat source options:

- Outside air
- Air in the basement
- Air in room where unit is located.



Available with built-in water tanks (integrated systems), or as add-ons to existing electric water heaters

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Types of Heat Pump Water Heaters

Add-on Heat Pump Water Heaters:
Installed in conjunction with an existing storage water heater (wall-mounted or on top of existing tank). Converts a conventional water heater into a heat pump water heater by replacing the function of the tank's lower element. Add-on unit is intended to provide most or all of the water heating needs; standard water heater serves as a back-up heater.

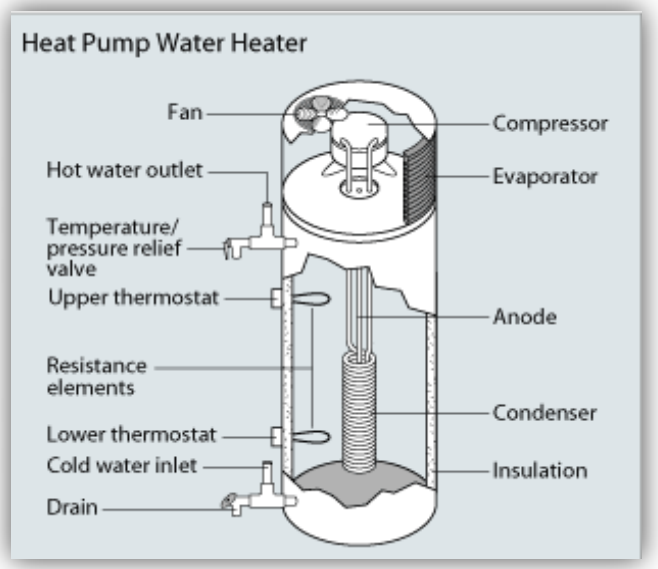
Drop-In Heat Pump Water Heaters:
In a "drop-in" or "integrated" heat pump water heater, the heat pump portion is integral to the tank, which has same footprint and connections as a conventional water heater. Installation procedures are essentially the same as a conventional water heater, except for requirement to provide for drainage of condensate.

Desuperheaters:
This is a feature on some central air conditioners and heat pumps. It is a small, auxiliary heat exchanger that uses superheated gases from the central air conditioner's compressor to heat water, providing economical supplemental water heating as a by-product of air conditioning. During the cooling season, the desuperheater actually improves the efficiency of the air conditioning system while heating water at no direct cost.

Source: Washington State University Extension Energy Program, 2008 Energy Efficiency Fact Sheet, Residential Water Heaters; www.energy.wsu.edu/documents/building/res/ht_pmp_water_htrs.pdf

Heat Pump Water Heaters

2009/2010:
Reintroduction of HPWH technology by major manufacturers due to ENERGYSTAR



1970's/1980's Negative Publicity

- Not enough hot water
- Not reliable
- Not readily available
- Too noisy
- Too Expensive

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Residential water heaters

Rheem Hybrid/Heat Pump Water Heaters

John Richards
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Rheem/Specialty Products Division

August 31, 2010

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www.rheemhpwh.com

Innovative, energy efficient.

New Heat Pump Water Heaters
GeoSpring hybrid electric heat pump

- Combination of heat pump and standard water heater
- Tank portion includes two electric heating elements, pressure relief valve, an internal porcelain-lined tank, and a replaceable anode rod.
- Compressor and evaporator are integrated into the electric water heater unit. Evaporator draws in ambient heat from surrounding air using two variable speed fans. Condenser coils wrap around outside of tank all the way to the bottom to transfer this heat into the tank and heat the water without touching the water.
- Creates the same amount of hot water as a traditional electric water heater, but can reduce water heating expenses up to 62% to save $320 per year according to DOE estimates.
- ENERGY STAR® qualified with an energy factor rating (EF) of 2.35.
- Demand response capable with four pre-programmed settings
- Adaptable to multiple communication protocols (Zigbee®, Alliance, HVI, etc.)
- Can achieve load shedding and/or load avoidance up to 3950 watts

Source:
http://products.geappliances.com/ApplProducts/Dispatcher?REQUEST=SpecPage&Sku=GEH50DNSRSA

Multiple Settings Available

GeoSpring electric heat pump water heater has an electronic back-lit LCD display and settings can be changed as needed:

- **eHeat™ mode** – Maximizes savings. In this mode, the water heater only operates the heat pump to heat the water. Most efficient mode, and allows for the greatest amount of savings.
- **Hybrid mode** – Uses less energy while still experiencing fast recovery times. Uses the heat pump to heat the water, and activates the standard electric elements a needed.
- **High Demand mode** – Operates very similar to Hybrid mode, but lets the system know in advance that it will be experiencing a larger water demand than usual.
- **Standard mode** – Shuts off the heat pump and only uses the electric elements to heat the water, just like a standard electric water heater. Standard mode allows for operation in extremely cold situations (less than 45°F)
- **Vacation setting** – System drops the temperature set point to 50°F to save energy, while also preventing the water from freezing. The unit resets it when the customer returns home.

Pros and Cons for Heat Pump Water Heaters

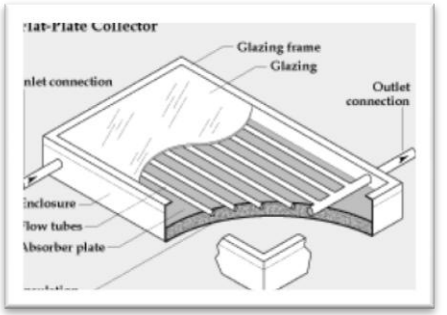
Pros

- Available with built-in water tanks
- Performs better in warm climates; may do even better
- Becoming more common
- Able to be part of a DR program
- Uses electricity to move heat from one place to another instead of generating heat directly.
- Uses about one-half as much electricity as a conventional electric resistance water heater.
- Lower operating costs that can offset higher purchase and installation prices
- Qualifies for state and federal tax credits

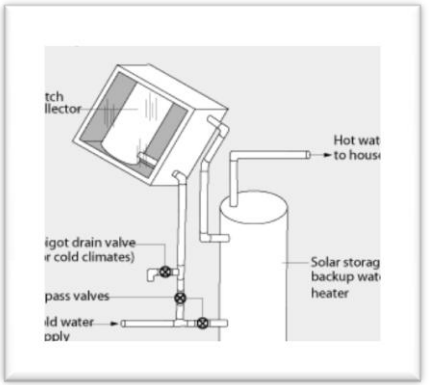
Cons

- Require installation in locations that remain in the 40°–120° F range year-round and provide at least 700 cubic feet (28.3 cu. meters) of air space around water heater
- Cool exhaust air can be exhausted to the room or outdoors; install in a space with excess heat (i.e., furnace room)
- Will not operate efficiently in a cold space.
- May have higher initial costs compared to conventional storage water heaters.

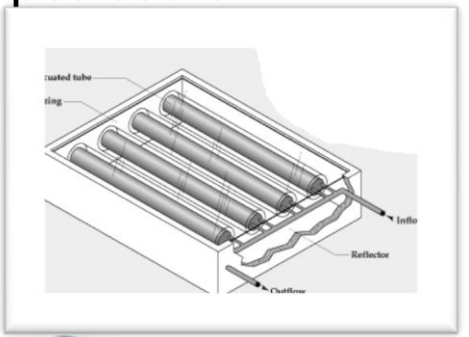
Types of Solar Collectors



Flat-plate collector: Glazed flat-plate collectors are insulated, weatherproofed boxes that contain a dark absorber plate under one or more glass or plastic covers.



Integral collector-storage systems: Also known as ICS or *batch* systems, they feature one or more black tanks or tubes in an insulated, glazed box. Cold water first passes through the solar collector, which preheats the water. The water then continues on to the conventional backup water heater, providing a reliable source of hot water. They should be installed only in mild-freeze climates because the outdoor pipes could freeze in severe, cold weather.



Evacuated-tube solar collectors: Feature parallel rows of transparent glass tubes. Each tube contains a glass outer tube and metal absorber tube attached to a fin. The fin's coating absorbs solar energy but inhibits radiative heat loss.

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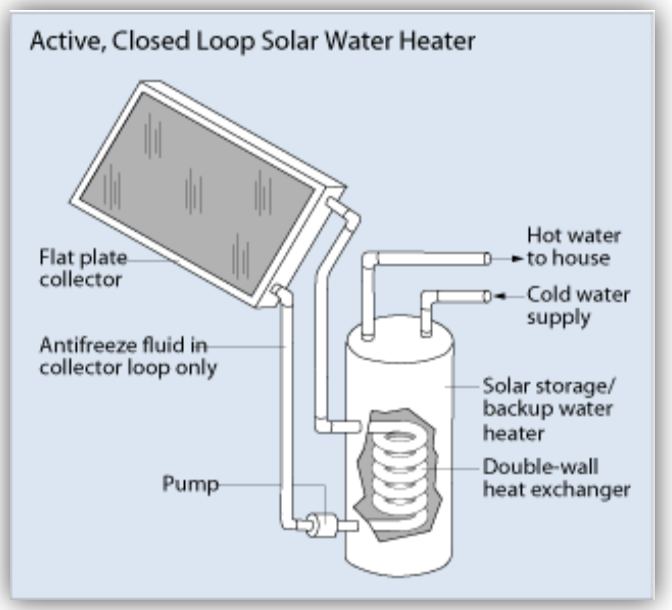
Active Solar Water Heating Systems

- **Direct circulation systems:**
  Pumps circulate household water through the collectors and into the home. They work well in climates where it rarely freezes.
- **Indirect circulation systems:**
  Pumps circulate a non-freezing, heat-transfer fluid through the collectors and a heat exchanger. This heats the water that then flows into the home. They are popular in climates prone to freezing temperatures



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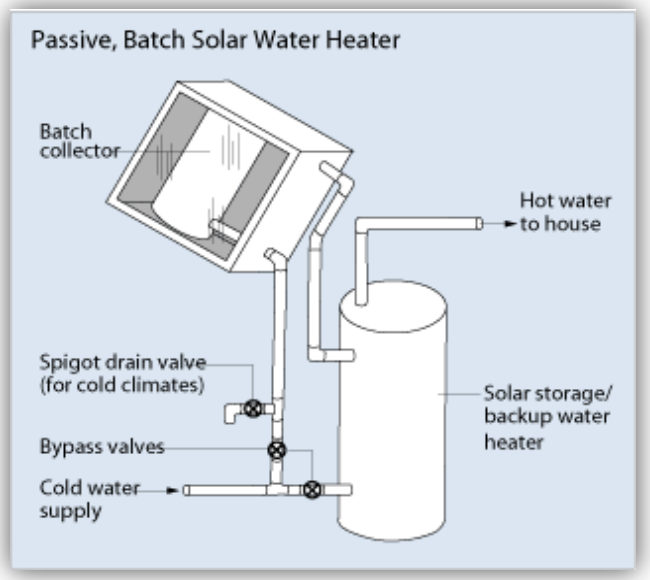
Passive Solar Water Heating Systems

- **Less expensive than active systems**
- **Less efficient, last longer than active systems**
- **Integral collector-storage passive systems:**
  - Work best in areas where temperatures rarely fall below freezing. They also work well in households with significant daytime and evening hot-water needs.



- **Thermosyphon systems:**
  - Water flows through the system when warm water rises as cooler water sinks. The collector must be installed below the storage tank so that warm water will rise into the tank; there is a concern regarding proper installation due to the weight of the water tanks.

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Pros and Cons for Solar Water Heaters

Pros

- Environmentally-friendly
- Low maintenance
- Can recover cost quickly; short payback
- Can work in almost any climate
- Rebates at state and federal levels available to reduce costs up to 30% of investment
- Utility incentives available

Cons

- Higher up-front initial cost when compared to conventional system
- Does not support a direct combination with radiators (including baseboard ones).
- Efficiency of solar powered systems depends on sunlight resources. In colder climates, where heating or electricity needs are higher, efficiency/capacity is lower.

Source: www.house-energy.com/Solar/Pros-Cons-Solar.htm

Water Heater Operating Costs Comparison

Water Heater type	Efficiency Factor (EF)	Installed Cost	Annual Energy Cost	Life Expectancy	Total Cost
Conventional gas storage	0.6	$850	$350	13	$5,394
High-efficiency gas storage	0.65	$1,025	$323	13	$5,220
Condensing gas storage	0.86	$2,000	$244	13	$5,170
Conventional oil-fired storage	0.55	$1,400	$654	8	$11,299
Minimum Efficiency electric storage	0.9	$750	$463	13	$6,769
High-efficiency electric storage	0.95	$820	$439	13	$6,528
Demand gas (no pilot)[4]	0.8	$1,600	$262	20	$5,008
Electric heat pump water heater	2.2	$1,660	$190	13	$4,125
Solar with electric back-up	1.2	$4,800	$175	20	$7,072

1. Purchase costs include our best estimates of installation labor and do not include financial incentives.
2. Operating cost based on hot water needs for typical family of four and energy costs of 9.5¢/kWh for electricity, $1.40/therm for gas, $2.40/gallon for oil.
3. Future operating costs are neither discounted nor adjusted for inflation.
4. Estimates for tankless gas water heaters are based on the federal EF rating method, which may over-estimate the efficiency of tankless water heaters in houses.

Source: ACEEE Consumer Guide to Home Energy Savings: Condensed Online Version *Water Heating* Sept. 2007
www.aceee.org/Consumerguide/waterheating.htm#lcc

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New DOE Rules for Water Heaters

Table I.1 Amended Energy Conservation Standards for Residential Water Heaters,		
Direct Heating Equipment		
Residential Water Heaters*		
Product Class		**Standard Level**
Gas-fired Storage	For tanks with a Rated Storage Volume at or below 55 gallons: EF = 0.675 – (0.0015 x Rated Storage Volume in gallons)	For tanks with a Rated Storage Volume above 55 gallons: EF = 0.8012 – (0.00078 x Rated Storage Volume in gallons)
Electric Storage	For tanks with a Rated Storage Volume at or below 55 gallons: EF = 0.960 – (0.0003 x Rated Storage Volume in gallons)	For tanks with a Rated Storage Volume above 55 gallons: EF = 2.057 – (0.00113 x Rated Storage Volume in gallons)
Oil-fired Storage	EF = 0.68 – (0.0019 x Rated Storage Volume in gallons)	
Gas-fired Instantaneous	EF = 0.82 – (0.0019 x Rated Storage Volume in gallons)	
* EF is the "energy factor," and the "Rated Storage Volume" equals the water storage capacity of a water		
heater (in gallons), as specified by the manufacturer.		
** Btu/h is "British thermal units per hour," and AFUE is "Annual Fuel Utilization Efficiency."		

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Electric Thermal Storage (ETS) Space and Water Heating

"Proven Long-Life Electric Storage"

Paul Steffes, Steffes Corporation

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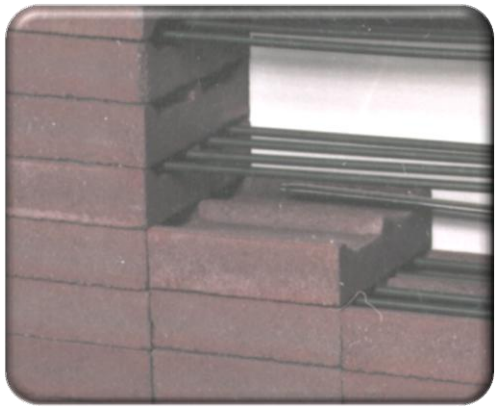
What is Electric Thermal Storage (ETS)?



Storage of Off-Peak or Renewable electricity in the form of heat for Space and Water Heating

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Family of ETS Products

Residential:

- Room Heaters, Furnaces, Hydronic
  - Up to 240kWh Storage
- Interactive Water Heater Controls
  - 100 Gallon Water Heater stores 26kWh

Commercial & Industrial:

- Furnaces and Hydronics
  - Up to 960kWh Storage

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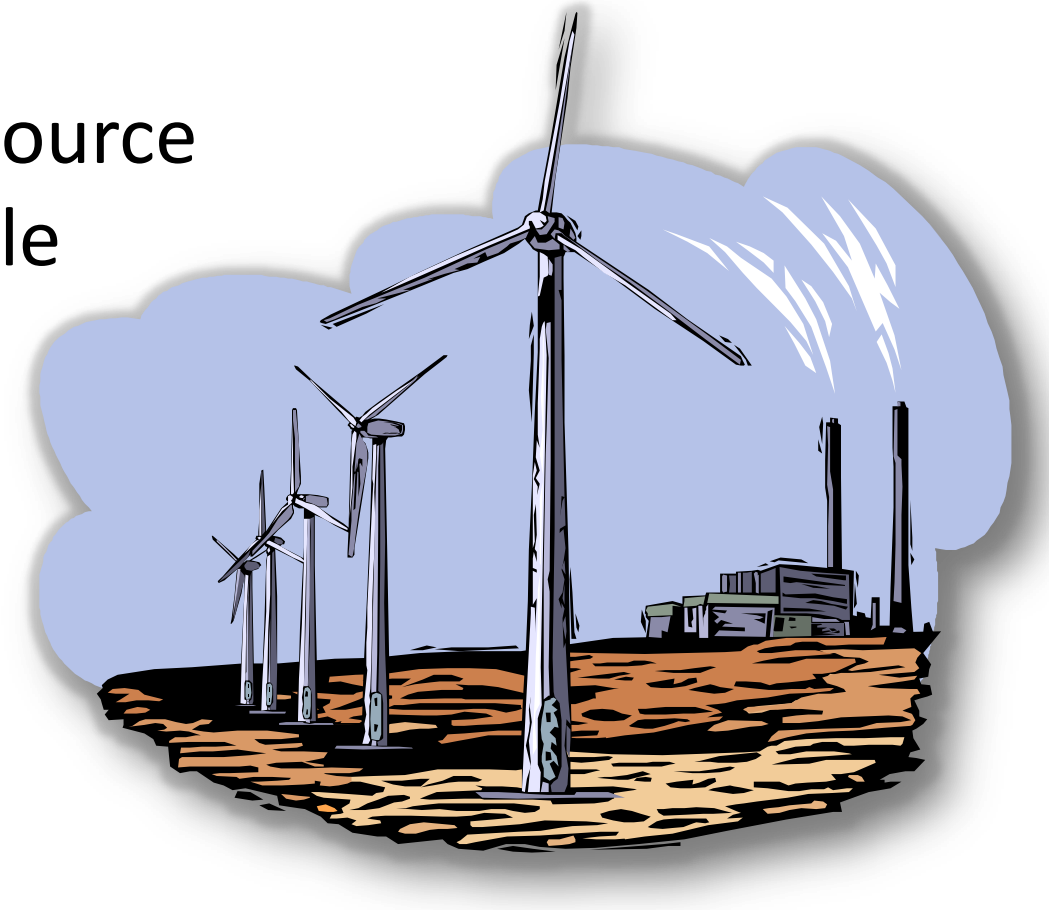
Wind Energy

- The Most Viable Renewable Energy Source
- Generation is variable and unpredictable



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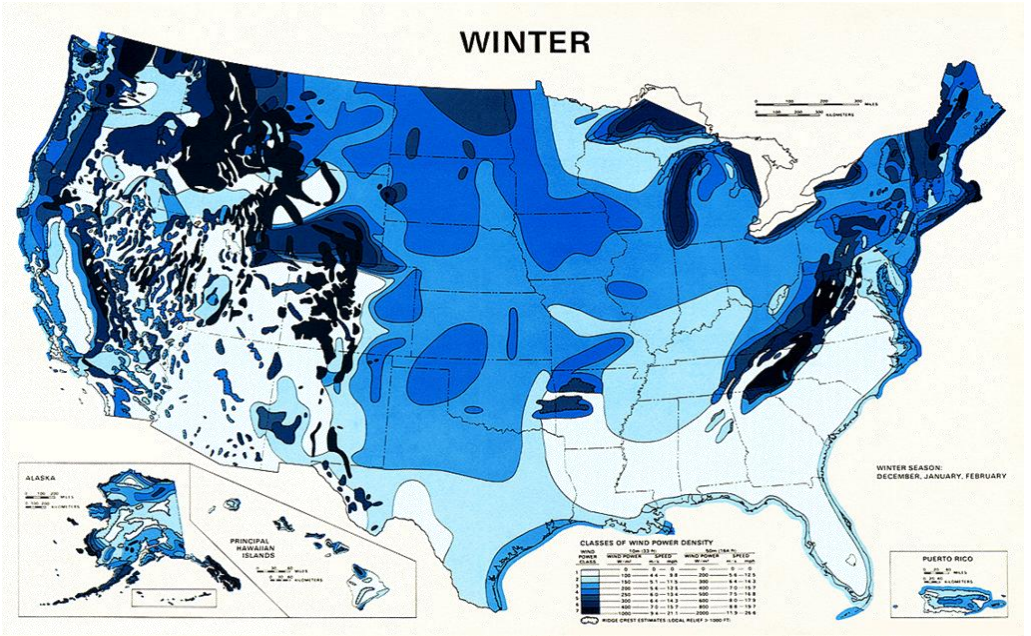

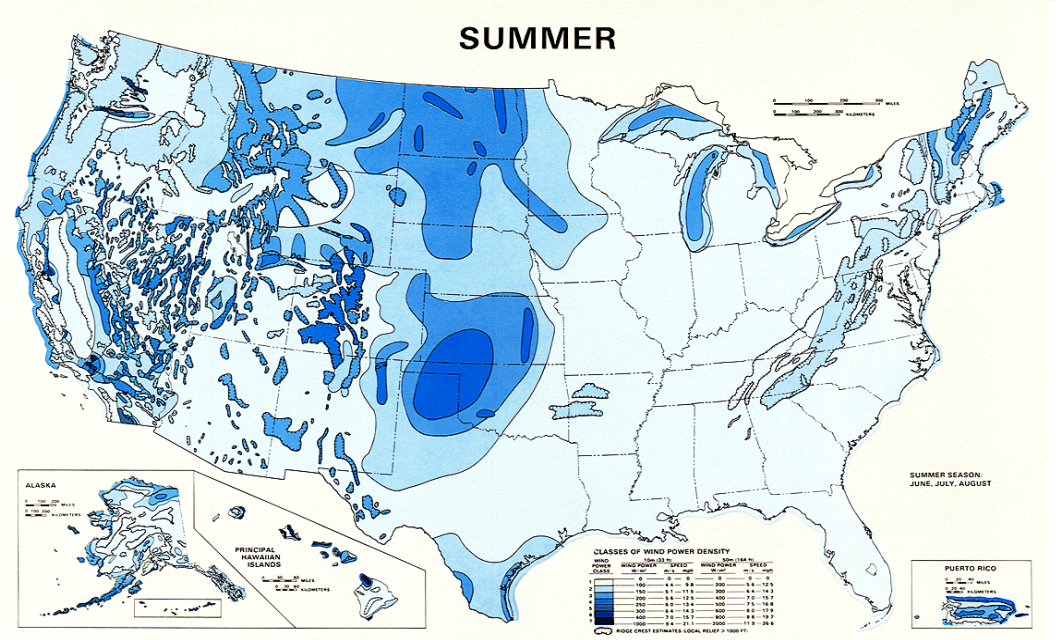

NREL Seasonal Average Wind Resource Maps

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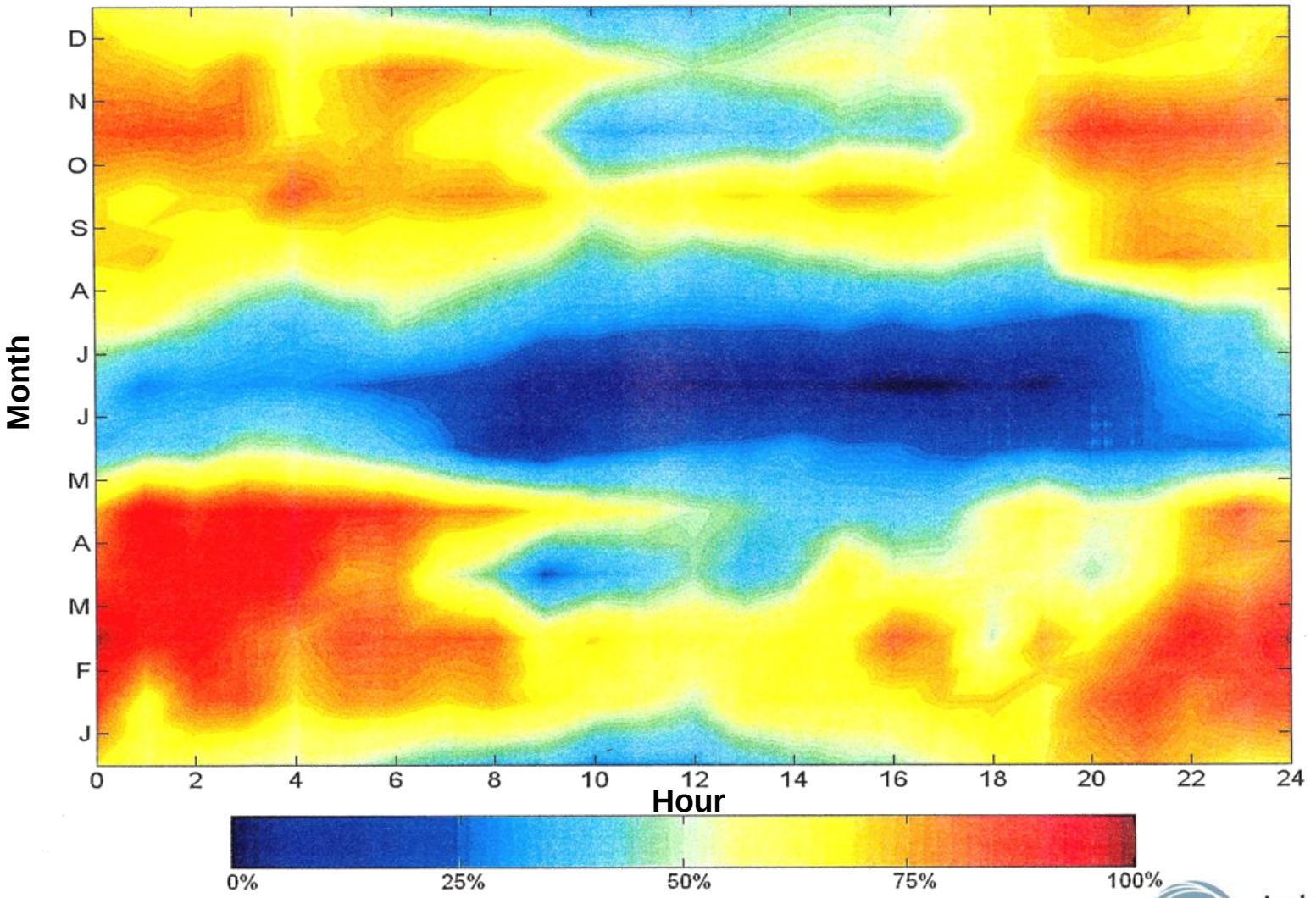
Typical Wind Farm Output Pattern

Color scale: 80MW = 100%



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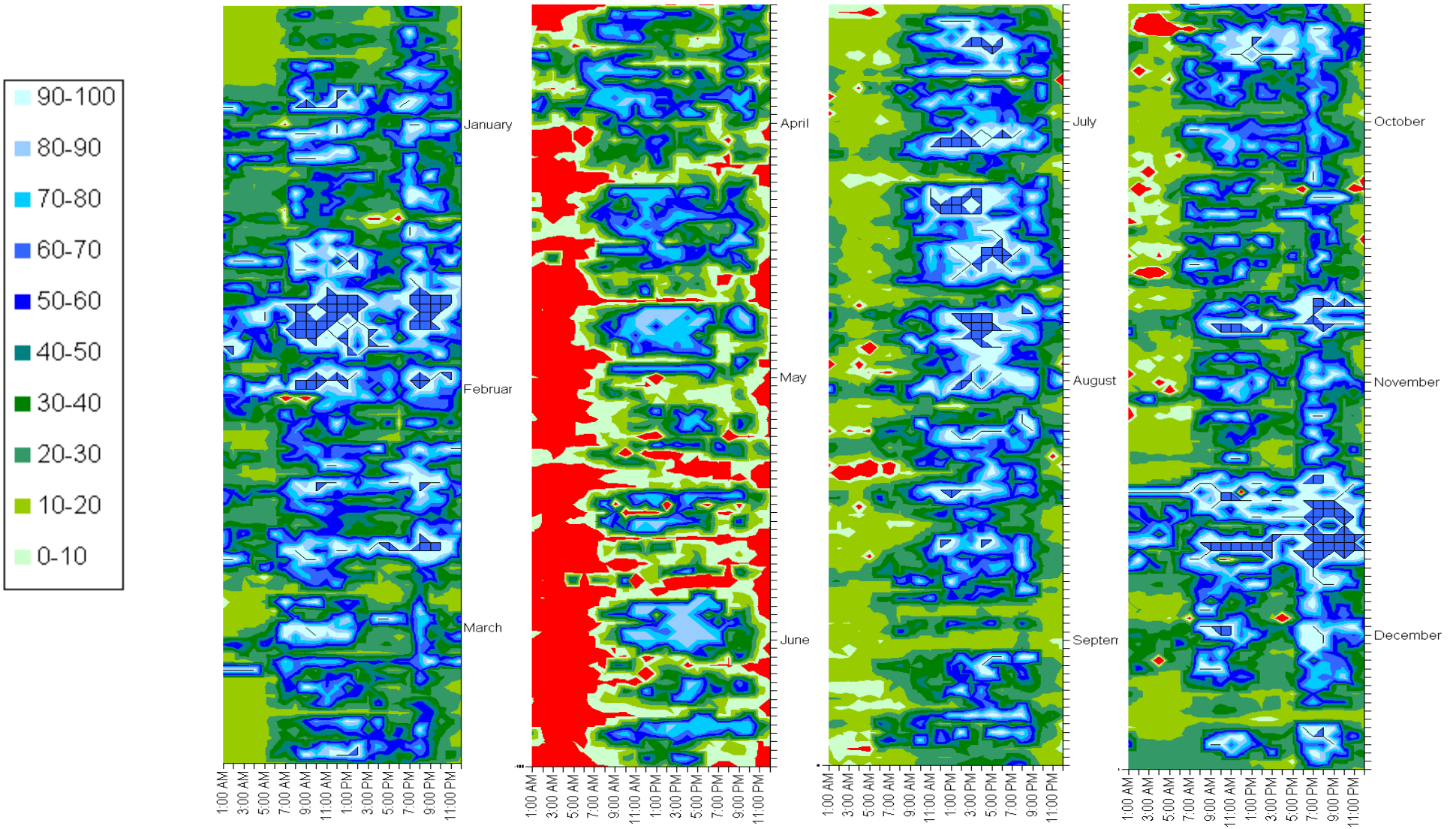
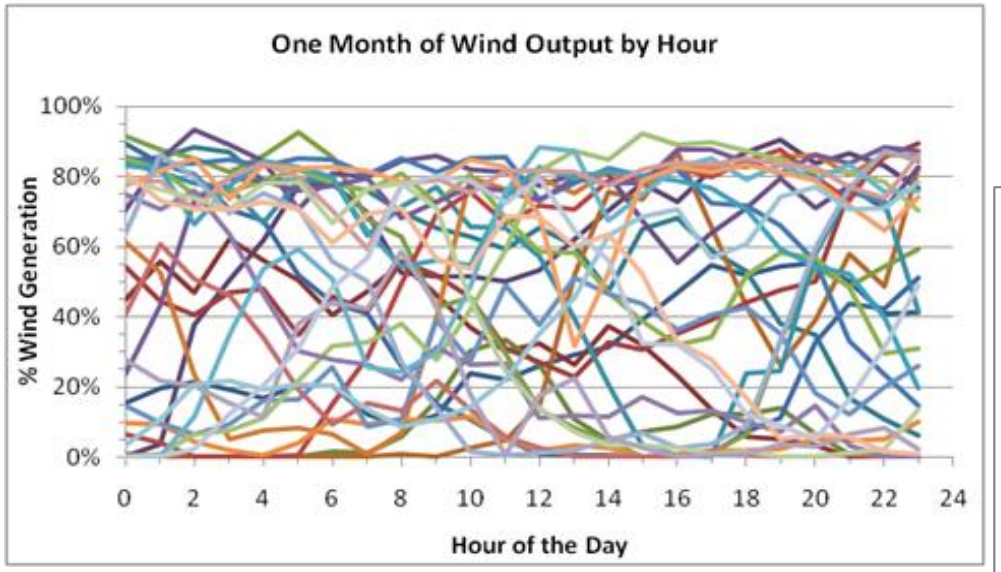
Real Time Prices-Buffalo Ridge Wind Farm

MISO NSP.Buffr Gennode LMP 2007

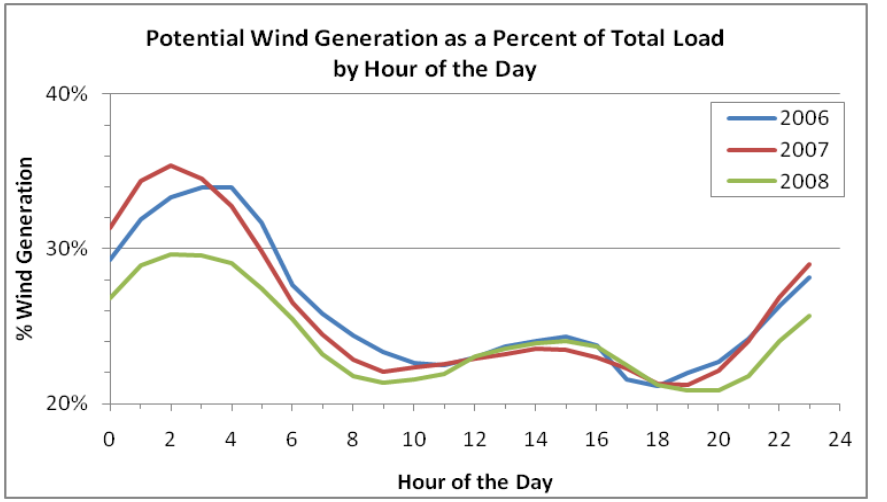


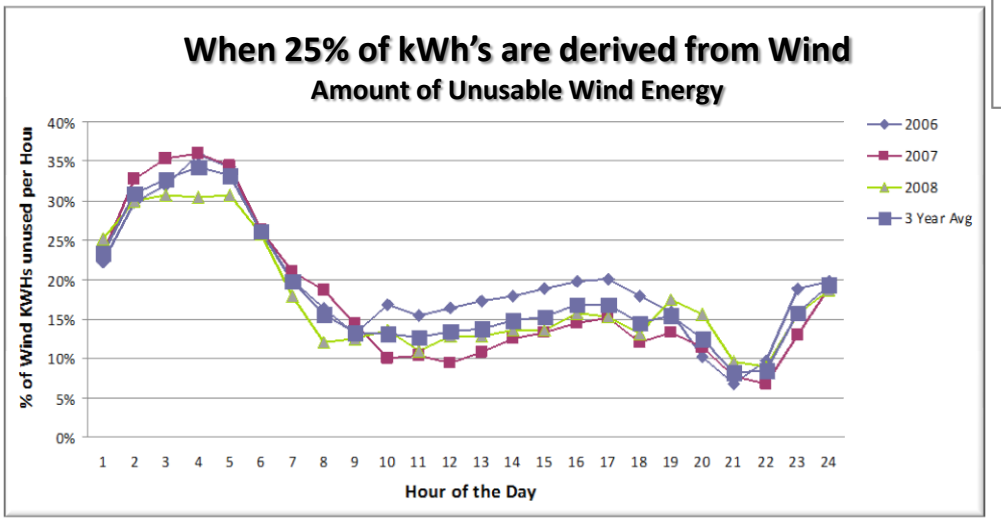
Arbitrage Value

Variability of Renewables



Stable Annual Output





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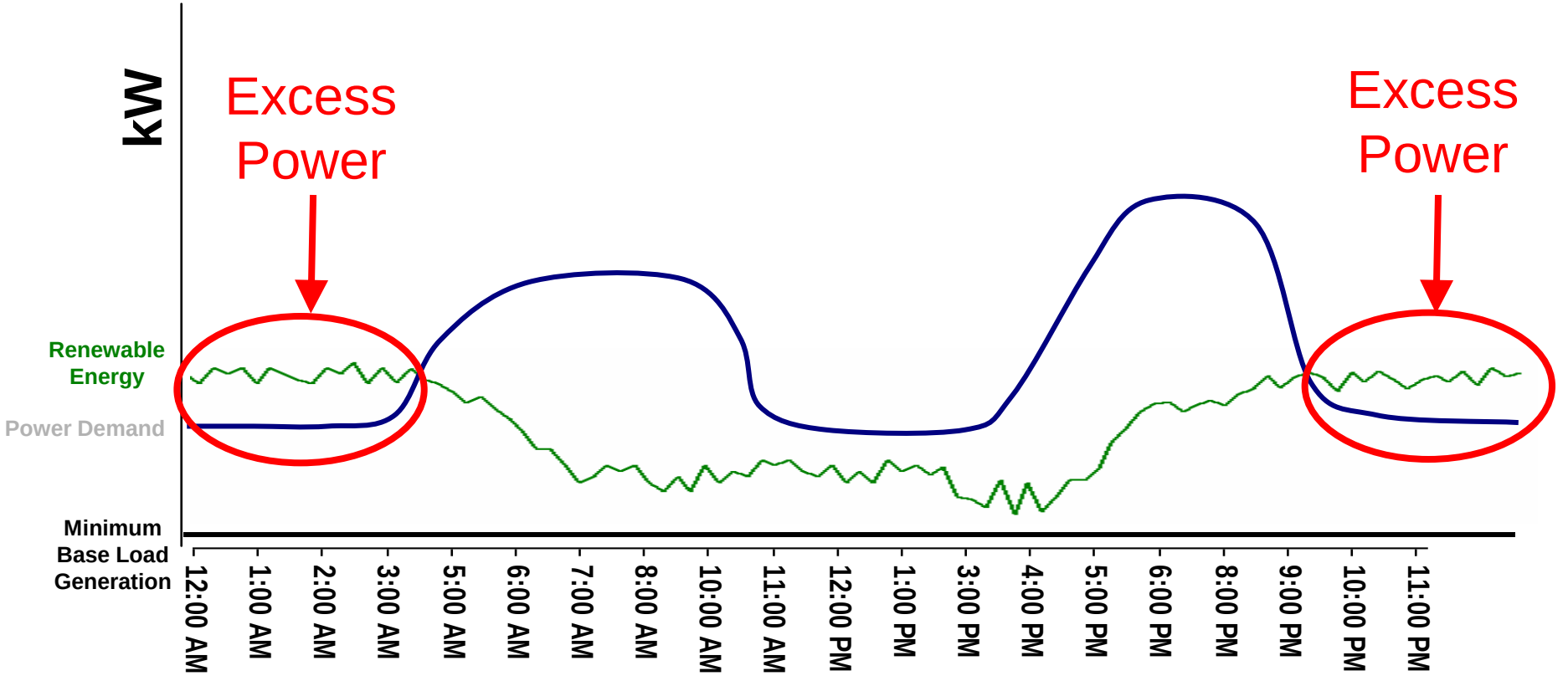
Power Generation with Renewables vs. Demand



Renewable Integration Value

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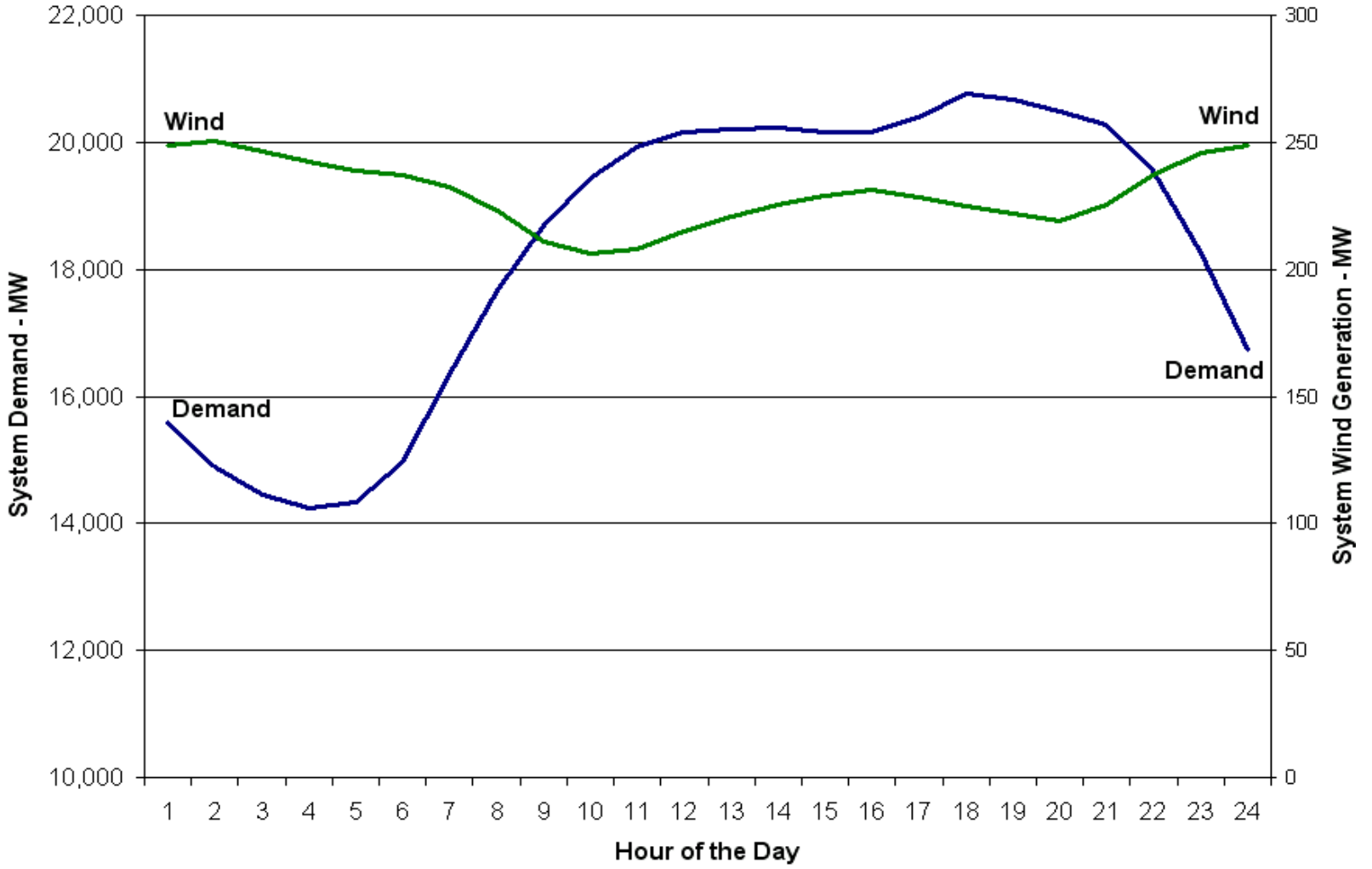
NYISO 2008 Data



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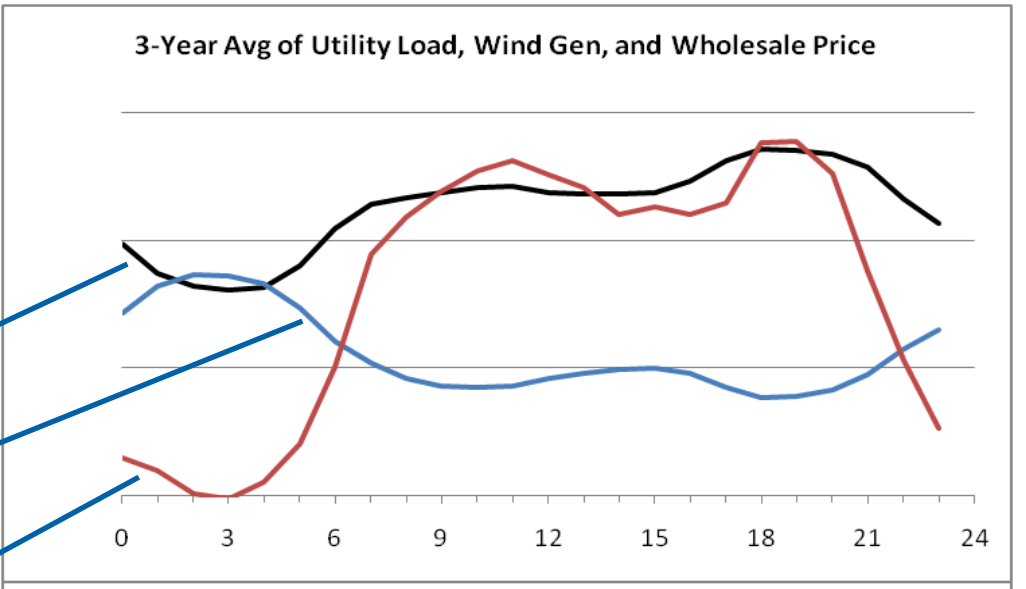
Putting it Together

Overall Utility Load

Wind Generation

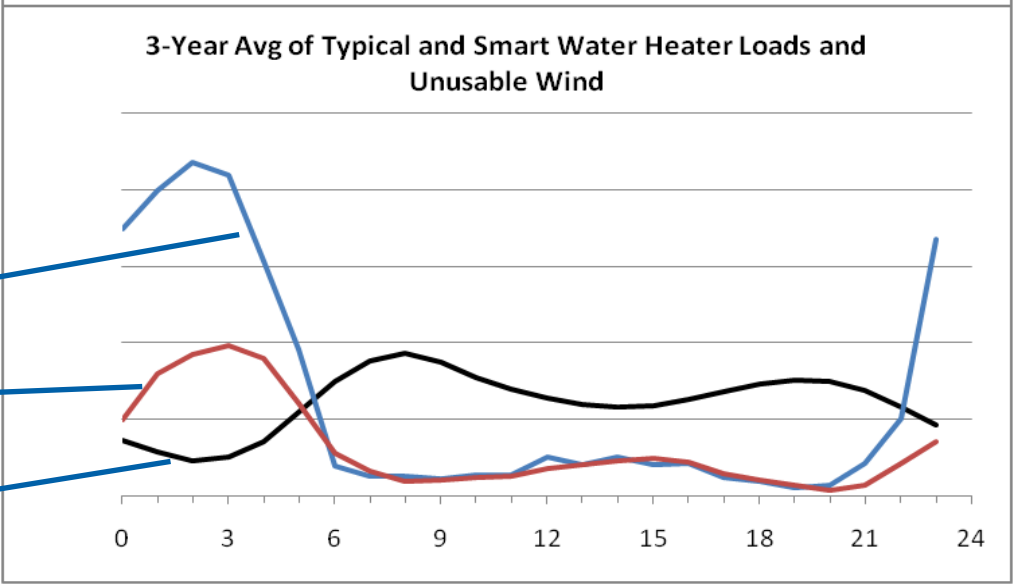
Wholesale Energy Cost



Smart Water Heater Load

Unusable Wind Generation

Typical Water Heater Load



STEFFES CORPORATION

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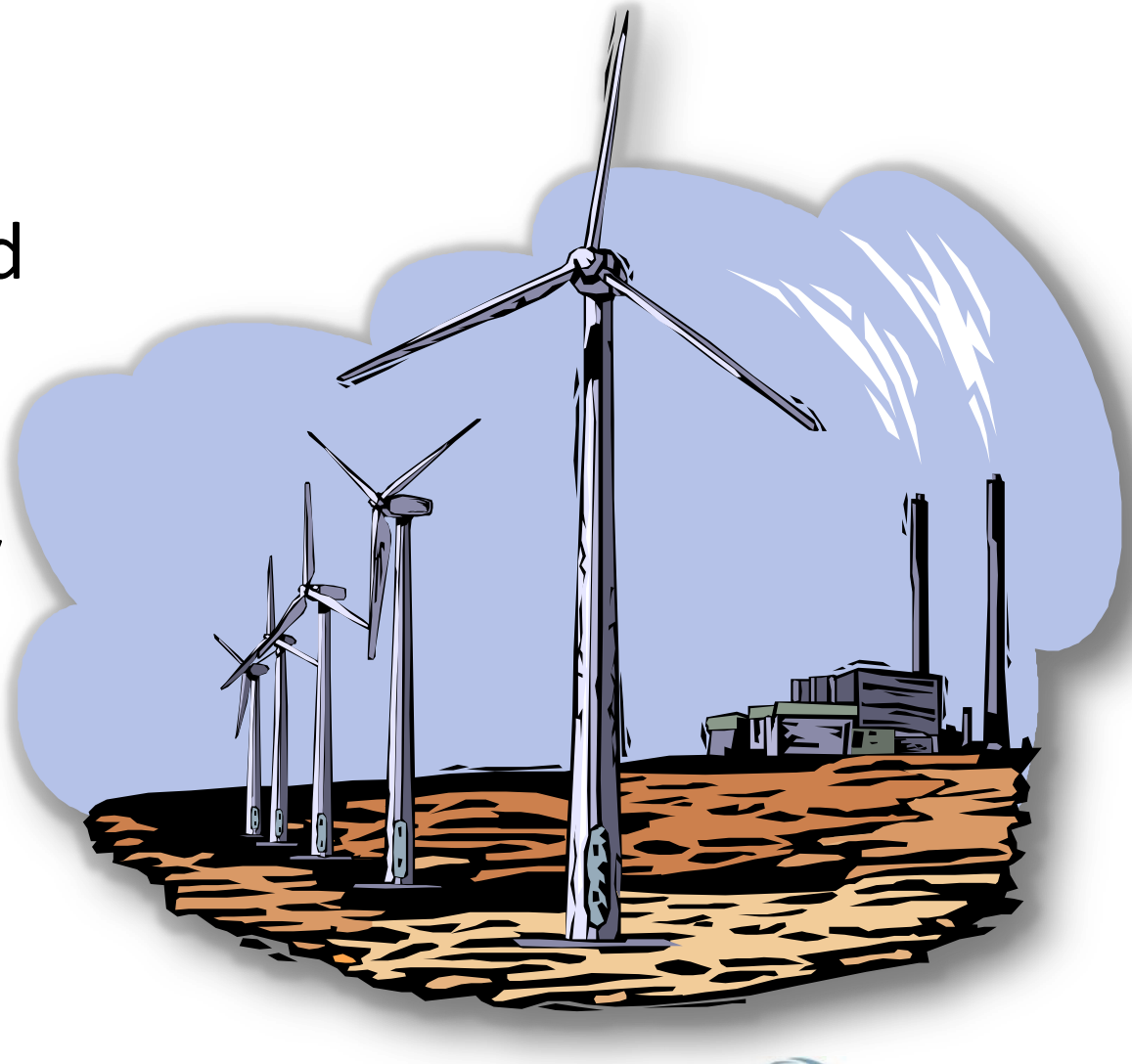
ETS… a “Thermal Battery”

Can quickly respond to changes to changes in power availability, thereby fully utilizing generation from renewable energy sources



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Interactive
Space & Water Heater Control

- Adjusts the target temperature for up or down regulation
- Adjusts the input wattage
- Provides Comfort Assurance

System Components

- Consists of 3 main components:
  - main control module
  - temperature sensor
  - water temperature regulator (mixing valve)
- No modification of the existing water heater is needed to install. The temperature sensor and mixing valve insert into the hot water outlet of the water heater and the control module mounts nearby. A small amount of plumbing and wiring is required.

Interactive Water Heater Control

Think of a 100 gallon Water Heater as a 26 kWh Battery

(nominal two day supply of hot water)

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Interactive Water Heater Control

- It connects to load control signals to store or shed electric load as an up- and down-regulation tool.
- It is ready to connect to Smart Grid signals of the future; continuously reporting its storage and shedding capabilities and responding to the very precise up- or down-regulation needs of the grid.
- This will help maximize renewable and off-peak electric resources while providing uninterrupted hot water for the consumer.

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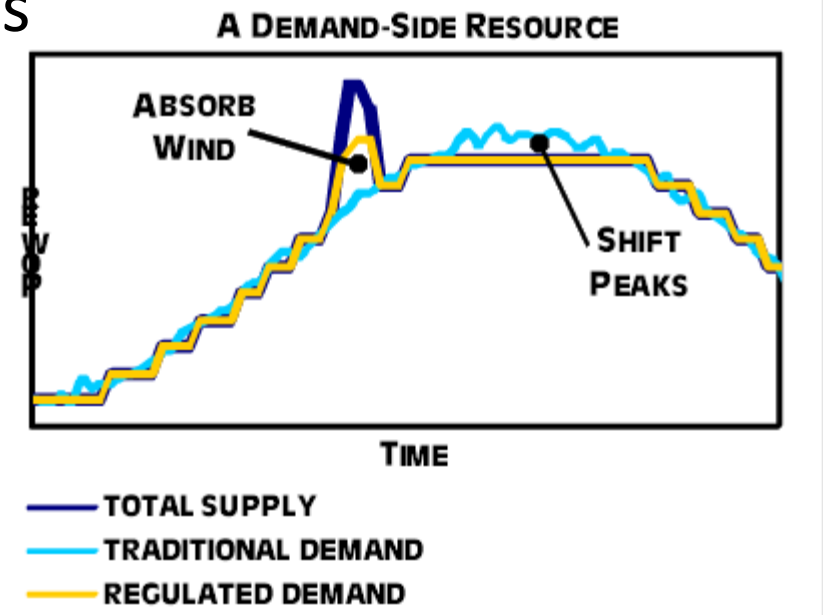
Up and Down Regulation

- Each water heater can absorb 4.5 kW of power during excess production periods such as surges in wind and solar power production.
- This same water heater can also reduce load by approximately 1 kW if desired.
- As with all Steffes heating products, you gain capacity to shift customers' loads to off-peak demand periods.



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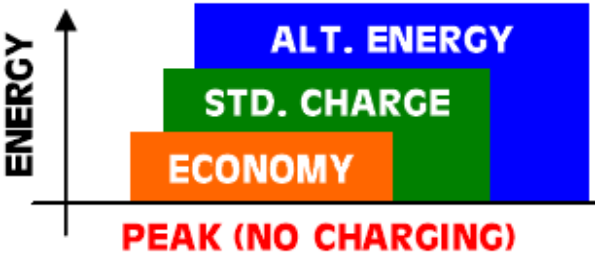
Operating Modes to Regulate Demand

- **Alternative Energy (A)** – Helps capitalize on periods of excess energy production by heating to maximum capacity. Where better to store excess renewable/off- peak energy than at the point of use?
- **Standard Charge (C)** – The Steffes interactive water heater control will charge to nominal water heater capacity.



- **Economy (E)** – Helps you reduce overall demand while maintaining your customers' comfort. The upper "bonnet" is allowed to heat to target temperature to make hot water available to your customers.
- **Peak (P)** – Helps reduce excess demand. When power is at a premium, you can divert it to those customers with great need and reduce the overall costs for those customers that don't have an immediate need.
- **Variable Control Options**– Several additional options available that provide variable control

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Low-Cost Electric Storage

Grid-interactive Renewable Space and Water Heating

Technology	Cost	
	$/kW·h	$/kW
Electric Thermal Storage†	**$30 - $60**	**$100 - $200**
CAES (above-ground)	$200 - $250	$700 - $800
ZnBr Flow Cell	$280 - $450	$425 - $1300
Pb-Acid Battery	$330 - $480	$420 - $660
NaS Battery	$350 - $400	$450 - $550
Flywheel	$1340 - $1570	$3360 - $3920

Source: EPRI 2009 energy stroage technology cost estimates

†Source: Steffes Corp., Inc.

Comparison – Cost, Energy & Carbon

This analysis uses three (3) years of actual load, wind scaled to 25% of load, LMP, and EPRI water heater data.

Energy Storage Method	Wholesale Cost ($/y)	Total Energy Used (kW·h/y)	Wind Energy Use (kW·h/y)	Nonwind Energy Use (kW·h/y)	CO_2 Reduction† (lb/y)
55-gal Uncontrolled Storage Water Heater	$251	4805	1156 24%	3649 76%	Baseline

New Dimension of Conservation and Efficiency, charging more when there is renewable energy available and storing more energy to span times without renewable energy

85-gal Grid-Interactive Storage Water Heater	**$133**	**4940**	**2726 55%**	**2214 45%**	**1436**
105-gal Grid-Interactive Storage Water Heater with Smart Signal	**$126**	**4974**	**2840 57%**	**2134 43%**	**1515**

Assumes that COP = 2 above 55°F and COP = 1 at or below 55°F

55-gal Heat Pump Water Heater (Zone 1)	$126	2407	580 24%	1828 76%	1821
55-gal Heat Pump Water Heater (Zone 3)	$153	2936	717 24%	2219 76%	1430
55-gal Heat Pump Water Heater (Zone 5)	$187	3566	880 25%	2686 75%	964
55-gal Heat Pump Water Heater (Zone 7)	$205	3899	972 25%	2928 75%	721

†Assumes 1 lb of CO_2 per kW·h of nonwind energy use.

Renewable Integration and Arbitrage Value

Smart-Grid, Distributive Energy and Load Shaping Tool

Provides precision load control for:

- **Energy arbitrage**
- **Following variable renewable generation**
- **Ancillary Services**
  - Frequency Control
  - Operating Reserves
  - Up/Down Regulation
- **Energy Independence & Conservation**

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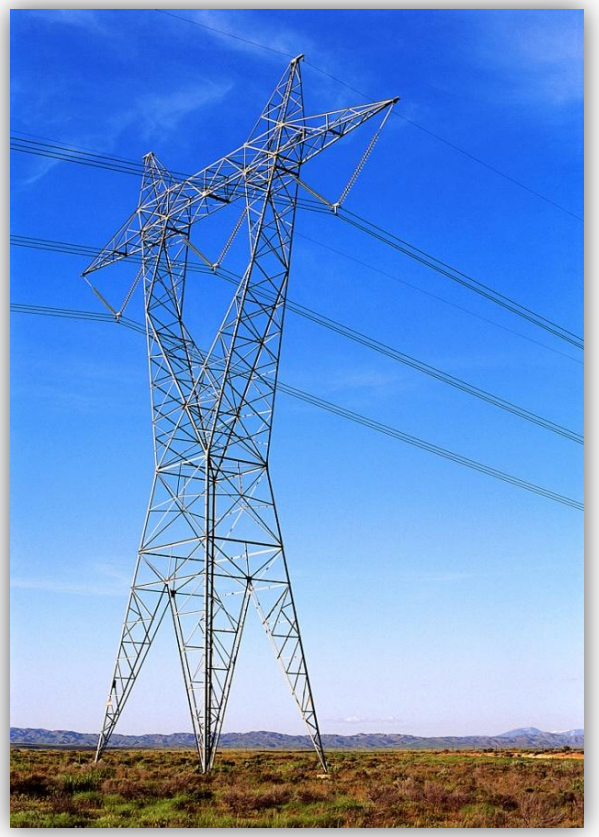
Grid-interactive Renewable Water Heating Systems are good for…

- Environment
- Consumers
- Utilities
- Conservation
- Efficiency
- The Grid



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"If we want to have a zero carbon economy, we must encourage products or technologies that have the potential of getting us there."

Questions?