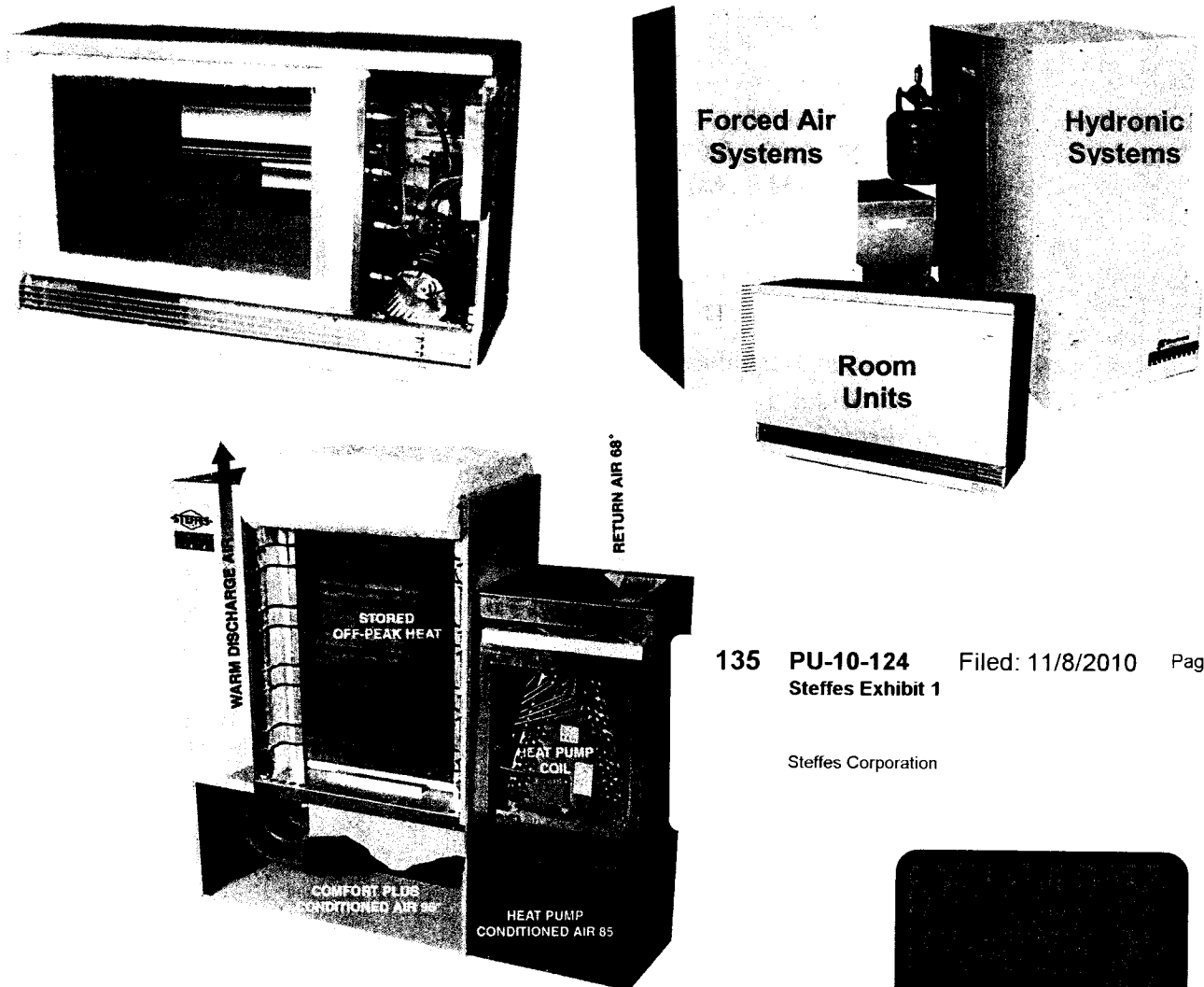


# Off-Peak Heating with Electric Thermal Storage (ETS)

Space heating and water heating are the two largest energy loads in a residence and typically account for 70% of the energy used. With off-peak electric rates, there is an opportunity to shift this energy usage to the times of the day when savings can be realized without significant lifestyle adjustments. Electric Thermal Storage (ETS) equipment helps utilize off-peak energy for a home's heating requirements.

ETS is a technology by which electricity is stored as heat during low cost times of the day. This stored heat is utilized for heating 24 hours a day. ETS equipment is available in various sizes and capacities to meet any heating requirements. ETS heat is very comfortable and reliable; and, with off-peak electric rates, it is a very low cost heating option.



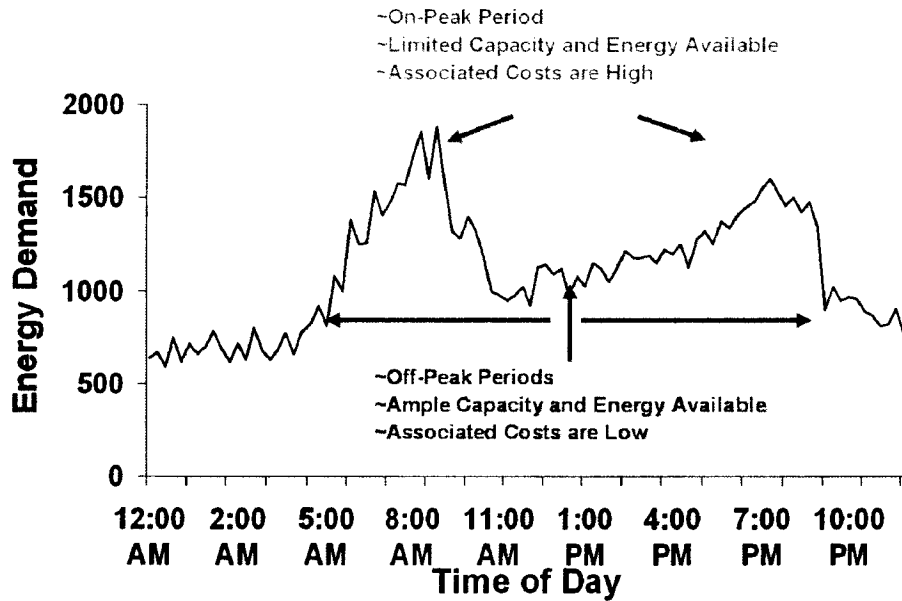
135 PU-10-124 Filed: 11/8/2010 Pages: 27  
Steffes Exhibit 1

Steffes Corporation



## Why ETS?

- Provides great benefit to Utilities and Consumers
  - Utility:
    - Load Management and Demand Response tool
    - Improves system load profile or factors. Shifts usage away from peak hours to off-peak times.
    - Improves generation, transmission and distribution efficiency
    - Defers or eliminates the need for costly upgrades to utility infrastructure (Gen, Tran, Dist – Conservation of Capacity).



- Consumer:
  - Provides significant savings on their heating bills
  - Provides a means for them to “take control” of their energy bills
  - Provides an alternative to Fossil Fuel heating

## For the future

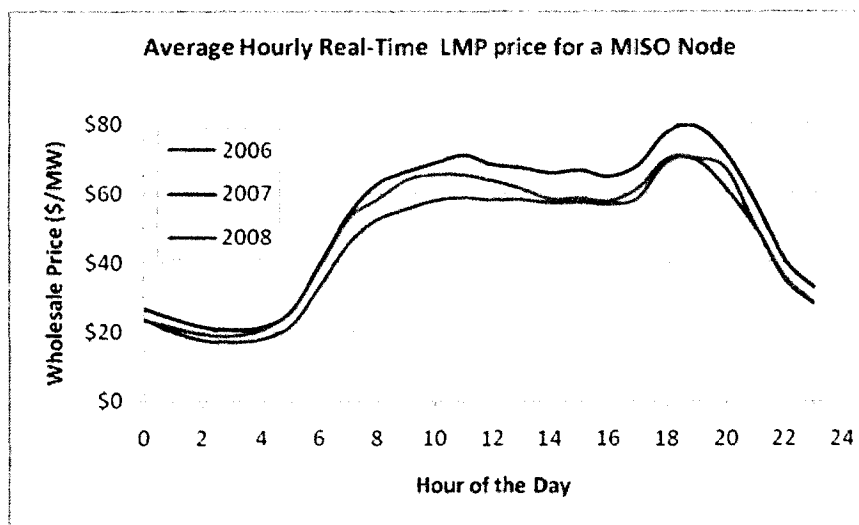
Smart Signaling/Communication and Smart Control will provide additional value to Utilities and Consumers.

- **Renewable integration**

- Wind is an Environmentally Friendly energy resource – Clean and Green
- Problem – Wind is variable and unpredictable
  - Needs to be integrated with base load generation
  - Affordable Storage is needed
  - ETS is a low-cost, proven storage technology

- **LMP following**

With smart utility communication, ETS systems can follow market prices and utilize the most economical energy



- **Ancillary Services**

- Provide up and down regulation to maintain system stability and reliability (frequency control)
- Non-Carbon emitting regulation tool.

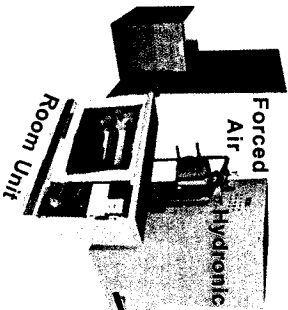
We suggest the PSC provide MDU a funding allowance to test and evaluate the consumer, utility and environmental value of smart communication and energy storage for Renewable Integration, LMP Following and Ancillary Services.

- Demonstration in a selected group of residential and commercial customers
- Can provide critical information for formation of future electric rates

**Please refer to attachments for additional information regarding the value of ETS for Consumers, Utilities and the Environment.**

# ELECTRIC THERMAL STORAGE

Electric Thermal Storage (ETS) is a technology whereby electricity is converted to heat and then used for heating homes or businesses. ETS heaters store heat in dense ceramic bricks in the heater core. Electric storage can occur during off-peak hours, during times when renewable energy is available, or during other times deemed necessary to meet the needs of the power company or grid. Heat is extracted from the brick core as needed to satisfy the comfort requirements of the consumer.



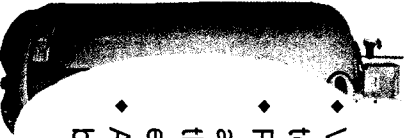
## ETS ~ Low-Cost, Long-Life "Thermal Battery"

- ◆ 13.5KWh - 480KWh storage capacity models available
- ◆ ETS is a small fraction of the cost of other electric storage options

### Interactive Water Heater Control

Transform a conventional electric water heater into an enhanced energy storage and power management device.

- ◆ Varies the target water temperature and input power
- ◆ Provides consumer comfort assurance by first charging the water heaters that need energy the most
- ◆ An 80 gallon water heater effectively becomes a 21KWh battery



# GRID OPTIMIZATION

- ◆ Better utilizes off-peak and renewable resources
- ◆ Defers substation upgrades
- ◆ Reduces transmission congestion and losses
- ◆ Improves generator efficiency
- ◆ Precision load shaping to meet system, economic, and environmental goals
- ◆ Reduces peaks and better utilizes existing generation and transmission resources
- ◆ Improves grid reliability

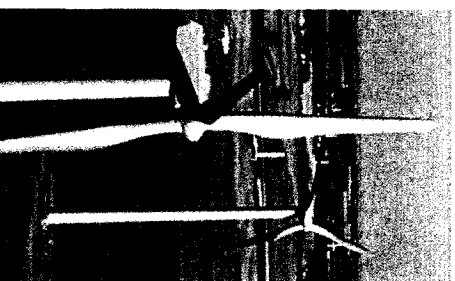
## RENEWABLE INTEGRATION

Studies have clearly documented the variability of wind generation. The wind blows more during winter than summer and as much at night as during the day. As our country's percentage of wind generation increases, the ability to store energy, especially during low demand off-peak winter hours, becomes extremely important.

Wind and solar resources ramp up and down very quickly as weather changes. ETS systems can respond just as fast to store the renewable energy. This allows a higher percentage of renewables to be utilized.

Store renewable energy when it's available and use it productively as needed.

**NOTE:** Wind Assisted Heating white paper is available upon request detailing extensive study on renewables.

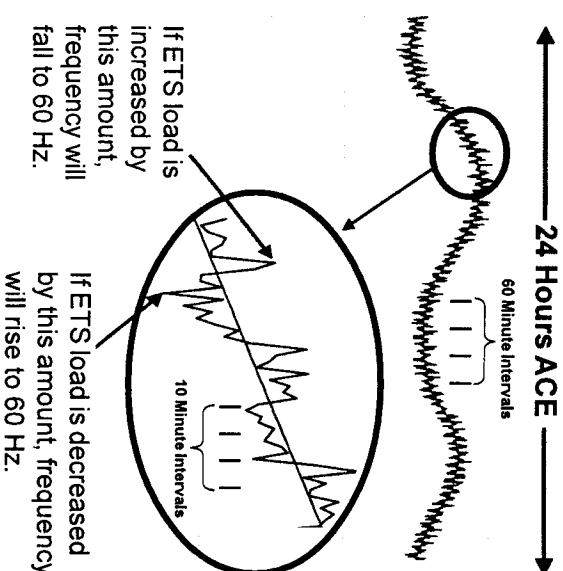


# FREQUENCY CONTROL

As more variable renewable energy is added, the need for power regulation increases.

Area Control Error (ACE) is the difference between supply and demand of electricity. This makes the frequency go high or low.

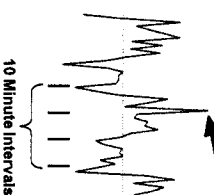
Electric Thermal Storage (ETS) space and water heaters can be used as a fast regulation tool to respond to an Automatic Generation Control (AGC) signal, thus reducing generator fuel consumption, associate emissions, improving grid reliability, yielding monetary ancillary payments or reduced cost of regulation.



### Load at the Residential, Commercial or Industrial Site

Actual ETS space or water heat storage unit charge rate varies based on AGC signal which drives the frequency to 60 Hz.

Average storage rate for space or water heat.



Fast two-way smart grid communication is needed to make frequency control work the best.

## ECONOMIC BENEFIT

- ♦ Lower power production costs
- ♦ Utilize low or negative cost wind energy during off-peak wind periods
- ♦ Reduced cost of energy purchases
- ♦ Decreased frequency control costs or receive ancillary payment
- ♦ Lower electric rates for consumers
- ♦ Improved heat pump efficiency and lower operating costs

## ENERGY INDEPENDENCE

Renewable energy and off-peak power are domestically produced electric resources which are abundantly available during many hours of the day. Electric Thermal Storage (ETS) systems provide the ability to fully utilize these beneficial energy resources for space and water heating purposes. Doing so reduces our dependence on imported oil for these purposes. In addition, our environment benefits from the lower emissions associated with these power generation sources.

### ETS Benefits:

- ♦ The Power Company
- ♦ Consumers
- ♦ Our Environment
- ♦ Our Nation

ETS systems are perfect for consumers who have availability to the following off-peak electric rates:

- ♦ Time of Use
- ♦ Smart Meter
- ♦ Real-Time Pricing
- ♦ Any Other Preferential Electric Rates

## COMMON

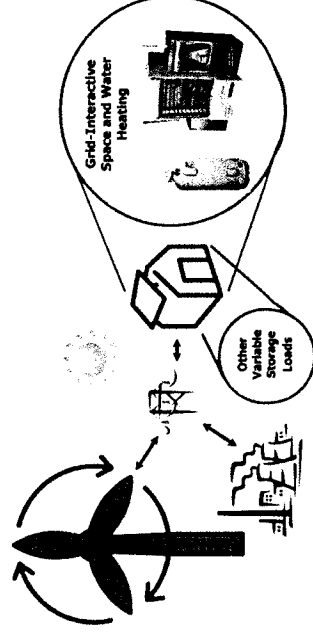
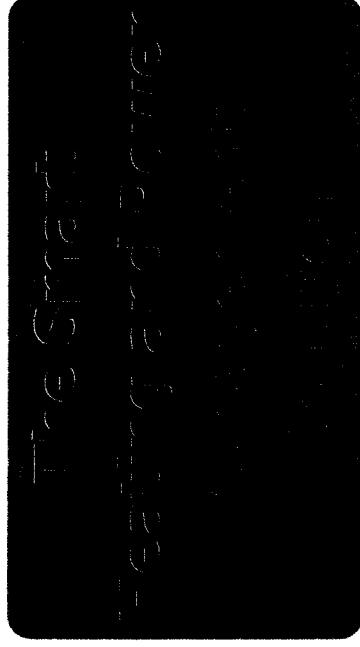
### INSTALLATIONS

- ♦ Residential
- ♦ Apartments/Condos
- ♦ Hotels/Motels
- ♦ Schools
- ♦ Courthouses
- ♦ Offices
- ♦ Warehouses
- ♦ Churches

Contact Steffes Corporation to learn more.

# Low-Cost Electric Storage

for  
**Grid Optimization,  
Renewable Integration,  
Frequency Control  
and  
Lower Electric Rates**



Manufactured in North America

Steffes Corporation • 1-888-783-3337 • [www.steffes.com](http://www.steffes.com)

# Off-Peak Heating Solutions

## Low Cost, Comfortable, Safe & Easy

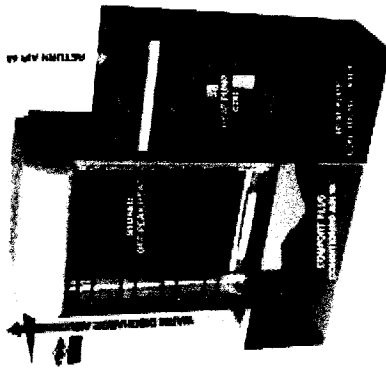
Off-peak heating systems utilize Electric Thermal Storage (ETS) technology along with your Power Company's off-peak electric rate to provide very affordable and comfortable heating. During off-peak hours when electric costs are low, ETS heating systems store electricity as heat for use in satisfying comfort requirements 24 hours per day. In most situations, **off-peak heating provides the lowest cost of operation** when compared to alternative options. In addition, **owners are enjoying the comfort and convenience** these heating systems offer. There are whole house and room unit off-peak heating systems available to meet the needs of your home or business.

↑ **No Smoke**  
 ↑ **No Fumes**  
 ↑ **No Mess**

### Comfort Plus

#### Forced Air System

The Comfort Plus forced air system is a centrally ducted product that provides a whole house heating solution. This system can be used as a stand-alone furnace or can be interfaced



with a conventional air conditioner unit for cooling. Combine the Comfort Plus unit with a heat pump for even better efficiency, lower operating costs and greater comfort for heating and cooling.

- ◆ **Clean**
- ◆ **Easy to Operate**
- ◆ **Safe & Comfortable**

### *RELAX...It's All Electric*

*Please ask us for more information on any of these products and off-peak load controls. Large residential and commercial size systems are also available. We'd be happy to visit with you about the right system for your application.*

### Room Heating Units

Room Heating Units are designed to deliver low-cost off-peak heat to a specific area or room. Many times, these systems are used in conjunction with or replacement of electric baseboard systems or wood burners. You will enjoy the quiet operation of the room heating unit in addition to exceptional comfort, convenience and low operating cost.



### Comfort Plus Hydronic System

The Comfort Plus Hydronic system adds a new dimension to heating by blending hydronic heating with Electric Thermal Storage (ETS) technology. You can now enjoy the benefits of radiant heating along with the low cost of operation off-peak heating systems provide.

Common applications of this system include in-floor heating, under floor heating and hydronic baseboards.

**Application Example**

Add the optional Steffes Air Handler and you will have the ability to receive the combination of forced air heating/cooling along with off-peak radiant hydronic heating.



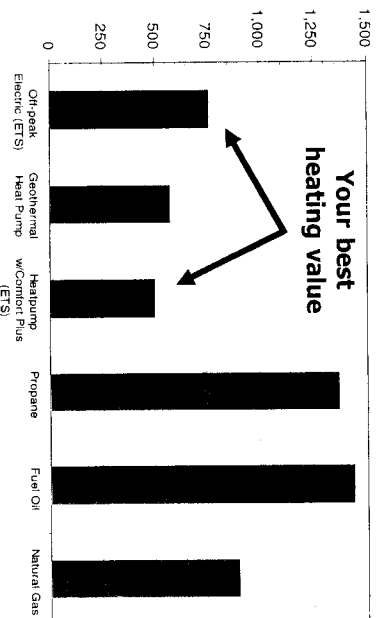
Manufactured in North America

Steffes heating equipment is backed by a 5-year limited manufacturer's warranty.

## ECONOMICS

### Typical Annual Space Heating Comparisons\*

(Based on a 45,000 BTU heat loss home)



\* Annual costs in your area will vary depending on climate, electric rates, heating fuel cost, etc. A personalized heating comparison is available.

## ADVANTAGES OF

## OFF-PEAK HEATING

- ◆ A low cost heating option
- ◆ Electric is the safest form of heating
- ◆ Electric rates are stable and predictable
- ◆ No need to worry about filling a tank
- ◆ No need to worry about carbon monoxide
- ◆ Requires no routine maintenance
- ◆ Electric heating systems are very reliable
- ◆ Electric heat is very clean
- ◆ No hassles or messes
- ◆ No smoke...no chimney

## COMMON

## INSTALLATIONS

- ◆ Residential
- ◆ Weekend Homes or Cabins
- ◆ Apartments or Condominiums
- ◆ Hotels/Motels
- ◆ Schools
- ◆ Courthouses
- ◆ Offices
- ◆ Warehouses
- ◆ Churches

Ask us about the right system for your application.

## Off-Peak Heating...

The Smart Heating Solution

# Off-Peak Heating



Ask us how Electric Thermal Storage (ETS) technology can provide you low cost heating and unsurpassed comfort.

## The Smart Heating Solution



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# Balancing Load with Grid-Interactive Renewable Water Heating

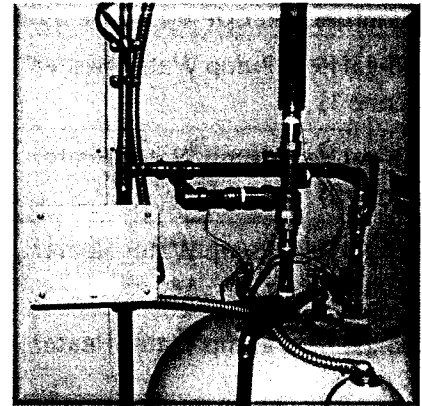
by Steffes Corporation

The Grid-interactive renewable water heater is a precisely-controllable balancing load.

As quantities of renewable-generated electricity increase, a growing amount of this variable resource is curtailed or unusable because it cannot be consumed when it is generated. The inability to integrate renewable energy into the grid can happen at any hour of the day. The ability to quickly turn a water heater charge rate up or down can provide significant value to fully-utilize renewable energy. Grid-interactive renewable water heater control provides better integration of renewable energy into the grid, brings a new dimension of system conservation and efficiency, and keeps electric rates low.

This also allows water heaters to be fast, non-fuel-consuming regulators and frequency controllers. It provides increased grid reliability and reduces power plant cycling and fuel consumed for regulation and brings significant monetary and environmental value to electric grid operators and consumers.

Grid-interactive renewable water heater controls change the electric water heater into a "thermal battery" or grid end node that can affect the system like any other electric storage technology, but at a fraction of the cost. As we move toward a low-carbon future, electricity storage is critical, and renewable water heating is a low-cost option to help achieve that goal. The grid-interactive water heater control transforms a conventional electric water heater into an enhanced energy storage and power management device. When excess renewable energy is available at attractive pricing, the controller can "super charge" the water heater to a higher temperature. A tempering mixing valve is used in this system, to ensure safety. A 105-gallon water heater, used in this application, effectively becomes a 26-kW-h thermal battery, storing up to two days-worth of an average family's energy needs. A distributed system of grid-interactive renewable water heater controls also varies the target water temperature and input power of individual water heaters to charge the water heaters that need energy the most first and at a higher rate.



## Comparative Data – Water Heaters, Energy, Renewable Integration & Carbon

Below, Table 1 provides a comparison between a conventional 55-gallon electric water heater (referred to as the baseline) and larger 85- and 105-gallon electric storage water heaters with grid-interactive renewable controllers. In addition, you will see comparative data for a heat pump water heater for the eight referenced climate zones in the U.S. For each water heater type, you will find information on the Wholesale Cost of Energy, Total Energy Used, Wind (renewable) Energy Used, Non-wind Energy Used and Carbon Reduction (CO<sub>2</sub>). A short list of definitions follows:

- Wholesale Cost: This is the cost of energy to the utility based on Locational Marginal Price (LMP) prices. Generally the utility's costs are reflected in the electric rate consumers pay.
- Total Energy Used: Energy used based on average home hot water consumption and the efficiency of the water heater.
- Wind Energy Used: This is the amount of renewable energy used by the water heater.
- Carbon Reduction: This is the amount of carbon reduction as compared to the baseline model (55-gallon conventional). The assumption used is 1 lb of CO<sub>2</sub> reduction for each non-renewable kW-h used.

**Table 1: A comparison of water heater technologies**

This analysis uses three (3) years of actual load, wind generation (scaled to 25% of load), LMP, and one (1) year of average water heater data.

Energy Storage Method	Wholesale Cost (\$/y)	Total Energy Used (kW·h/y)	Wind Energy Use (kW·h/y)	Non-wind Energy Use (kW·h/y)	CO <sub>2</sub> Reduction† (lb/y)
55-gal Uncontrolled Storage Water Heater	\$251	4805	1156 24%	3649 76%	Baseline
85-gal Grid-Interactive Storage Water Heater with Smart Signal	\$133	4940	2726 55%	2214 45%	1436
105-gal Grid-Interactive Storage Water Heater with Smart Signal	\$126	4974	2840 57%	2134 43%	1515
150-gal Grid-Interactive Storage Water Heater with Smart Signal	\$127	5082	3053 60%	2029 40%	1620
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 2)	\$140	2662	649 24%	2014 76%	1636
55-gal Heat Pump Water Heater (Zone 3)	\$153	2934	717 24%	2218 76%	1432
55-gal Heat Pump Water Heater (Zone 4)	\$176	3335	820 25%	2515 75%	1134
55-gal Heat Pump Water Heater (Zone 5)	\$187	3566	880 25%	2686 75%	964
55-gal Heat Pump Water Heater (Zone 6)	\$193	3669	911 25%	2757 75%	892
55-gal Heat Pump Water Heater (Zone 7)	\$205	3899	972 25%	2928 75%	721
55-gal Heat Pump Water Heater (Zone 8)	\$212	4074	1020 25%	3054 75%	595

†Assumes 1 lb of CO<sub>2</sub> per kW·h of non-wind energy use.

Since the evaporator of the heat pump water heater is in the conditioned space, it was assumed that below an outdoor temperature of 55 degrees F, the cooling of indoor air is undesirable and therefore, we used a COP = 2 above 55°F and COP = 1 at or below 55°F.

**Additional notes and comments:**

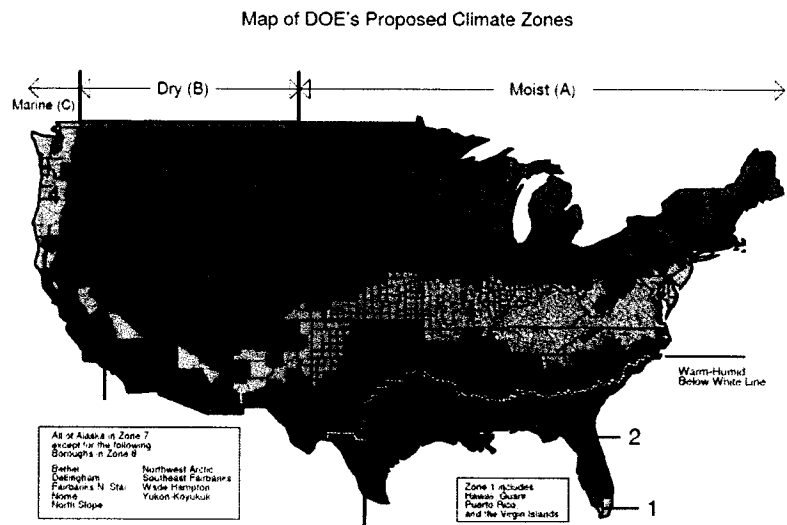
- With larger water tanks, higher percentages of wind energy can be utilized.
- As costs of photovoltaic (PV) electric generation are reduced, more variable renewable PV will be installed. Grid-interactive renewable water heaters can help balance this resource as well.
- Renewable energy is a must-take resource. As we build more nuclear generation, which is a must-run resource, there will be additional need for balancing loads with electric storage systems.

California ISO feels it will need 4,000 MW of resources like electric storage to balance the planned renewable generation.

**Findings:**

There is a significant difference in wholesale energy cost between the baseline 55-gallon water heater and the larger 85 & 105-gallon grid-interactive renewable water heater. The wholesale energy cost for the power is approximately 50% less with the grid-interactive renewable water heater, due to utilizing renewable and off-peak energy. The amount of energy consumed by the grid-interactive renewable water heater is slightly greater due to increased energy loss from the larger tanks. With the grid-interactive renewable water heater, 55% - 57% of the energy usage comes from a renewable generation source, which greatly reduces the amount of baseline generation power needed and the associated CO<sub>2</sub>.

The performance data with the heat pump water heater varies depending on where the consumer is located. The heat pump water heater takes heat out of a home and transfers it to the water. In Southern climates, when daytime outdoor temperatures are high, this is very effective. The heat pump water heater provides cooling to the home at the same time it heats water. During these times, the heat pump water heater will have a coefficient of performance of approximately 2.0. At higher latitudes, when daytime outdoor temperatures are cool (55°F or cooler), we assumed the heat pump water heater has the same efficiency as a conventional water heater since there is not excess heat in the home to use for water heating. The table shows information for eight Department of Energy climate zones. In Zone 1, which encompasses the Southern tip of Florida and Hawaii, the wholesale cost of operation is better than the baseline 55-gallon model, as predicted, and the overall energy used is lower. The percentage of renewable energy used is the same. Since there is reduced overall energy consumption, as compared to the baseline, the amount of carbon reduction is also better.



The major finding in this table is between the grid-interactive renewable water heater and the heat pump water heater. With the exception of Zone 1, which represents a very small fraction of the geographical area of North America, the grid-interactive renewable water heater has better performance in all categories. It provides the lowest wholesale cost, utilizes the greatest percentage of renewable power and offers the greatest amount of carbon reduction as compared to the alternatives. In addition, the grid-interactive renewable water heater provides the ability to do electric grid power balancing (regulation and frequency control).

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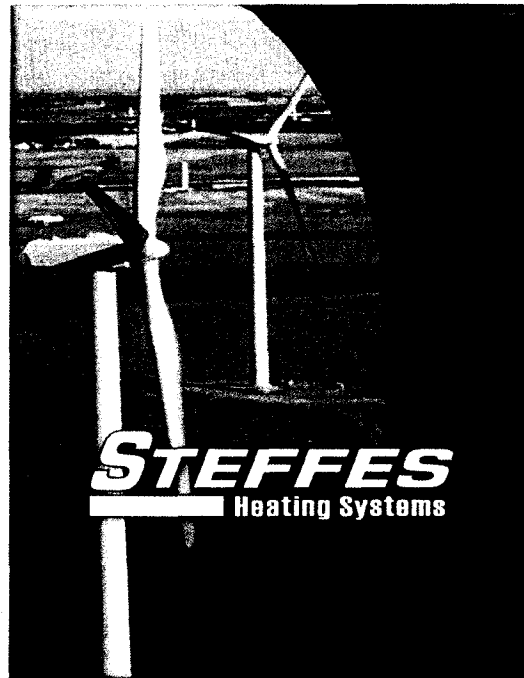
**Report on the  
Synergy of Wind and Electric Thermal Storage (ETS)**

**“Wind Assisted Heating”**

**A Distributive Electric Storage Technology that is a  
Low Cost, Long Life “Renewable Thermal Battery”**

**Prepared by:**

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**Executive Summary**

The synergy of wind energy and electric thermal storage (ETS) will help electric utilities achieve their renewable requirements today and fully utilize wind resources in the future. The synergy of wind energy and ETS can be referred to as “Wind Assisted Heating” and creates a winning situation for all parties, the wind industry, utilities, home and business owners, and the environment.

There are many challenges when trying to incorporate a large amount of wind generation into the Independent System Operator’s (ISO) transmission network. These challenges include the variability of wind, effectively utilizing the large amounts of wind available during off-peak winter hours, and maintaining a reliable and dependable electric supply. These challenges can be relieved with ETS.

**Wind Power Available for Heating**

Wind blows significantly more during heating months than it does during other times of the year as shown in the graph on the right. On average, wind blows more during off-peak than on-peak hours. The hourly and daily generation variability suggests ETS units need to be able to consume power when ample renewable energy is available.

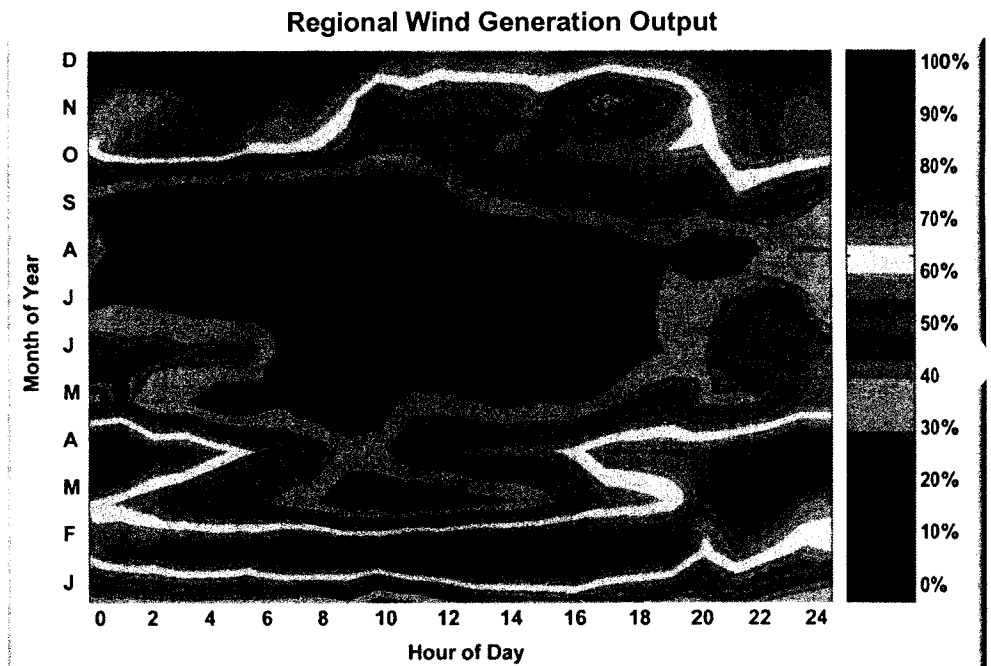
Wind generators will typically produce 33-40% of nameplate rating on an annual basis. If a State has a 20% renewable requirement, this means that 50-60% of the State’s average electric demand would need to be installed wind generation to meet the Renewable Energy Standard (RES). This assumes all renewable power would come from wind, as wind is the most economical and leading candidate at this time.

For wind utilization efficiency, having Electric Thermal Storage space heaters, Storage water heaters, and other productive uses for the power will be beneficial.

There is a mix of electric generation sources across the U.S. Most base load generators can only be turned down to a specific level, after which they must be turned off. After introducing a significant amount of renewable energy into the grid, there will start to be times on windy off-peak nights when base load generation is at a minimum and there will be extra renewable energy that will have to find a productive use. As more renewable energy is added there will be increasing periods when ETS and other electric storage technologies will help to fully use the new renewable resources.

**Heat Storage: Part of the Solution**

Electric energy storage will improve the ability to “productively use” an increasing amount of variable renewable energy. A battery, where electricity is pumped in and then taken out on demand, would have great value. Currently, the cost, efficiency, and life of electro-chemical batteries can be prohibitive. Electric Thermal Storage (ETS) equipment is an efficient, long life, and low cost “thermal battery” for the electric grid. Steffes has placed almost 100,000 units in the field over the last 20 years and has proven that ETS units can withstand continuous daily deep cycles. Since ETS units are a fraction of the cost of electro-chemical batteries, we should first fill the ETS window of opportunity and then use electro-chemical batteries later, as



needed. Electric Thermal Storage heating systems have the ability to make smart control decisions to optimize the use of renewable and off-peak energy for these purposes.

Think of ETS as a wind powered heating system. If the wind is not blowing this heating system uses another underutilized domestic resource, off-peak electricity.

### **Cost of ETS Units**

A residential or small commercial ETS heating system costs about \$30-\$60 per kWh installed compared to a recent installation of a 7MWh Sodium Sulfur (NaS) Battery which was well over \$500 per kWh. But not only is ETS a low cost Electric Storage Thermal Battery, included in the price is a heating system as well. An interesting question then can be asked, what is the value of an ETS system and who receives this value?

Thousands of ETS systems have been installed where consumers have paid \$30-\$60 per kWh simply for a low cost of operation heating system. There is extra value of Electric Storage to the Electric Utility or Electric Grid to help promote increased usage of Wind Assisted Heating systems.

### **Low Carbon Footprint AND Low Cost of Operation**

Using an air source heat pump (ASHP), along with an ETS unit, will reduce electricity used for heating by approximately 50%. Having a portion of the heating requirement filled with renewable energy, in combination with the ASHP and ETS unit, drives the carbon footprint of the home heating system smaller and smaller as more renewable energy is added. There are ways to structure electric rates to encourage renewable and off-peak electric usage which ensures a low carbon space and water heating option and keep home heating costs low. (See graphs next page)

### **Dynamic Demand Response**

In order to optimize renewable energy resources, each ETS wind assisted heating unit has the ability to respond to a Dynamic Demand Control System or the Smart Grid. The ETS control system will store electricity when any adequate renewable energy is available. This will allow other devices, such as water heaters and air conditioners, to maximize renewable energy sources and curtail electric consumption if there is a peak situation. ETS units can enhance power quality and could have the ability to do voltage and frequency control in the future.

### **Energy Independence**

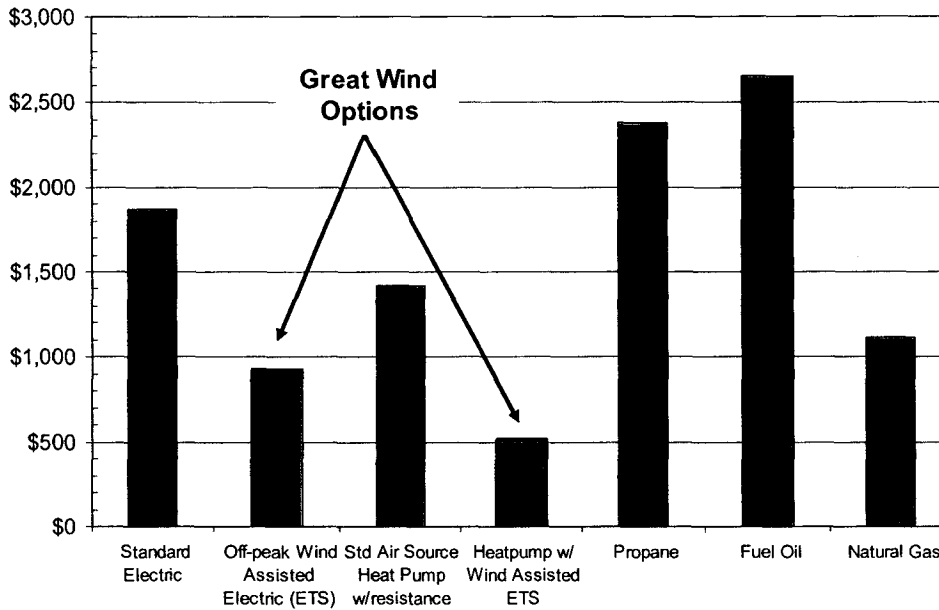
For every home using Wind Assisted Heating, we are better utilizing domestic energy resources and we can import approximately 20 fewer barrels of oil per year.

### **Conclusion**

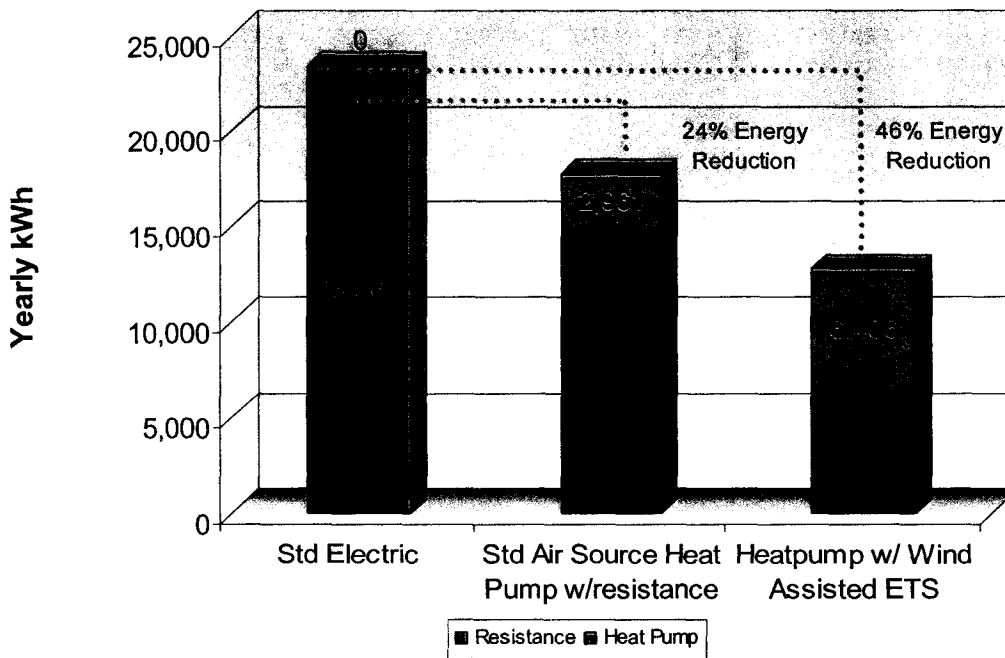
In conclusion, there is a great synergy with renewable power and ETS. Wind energy is the most cost effective renewable energy source today. On windy winter nights, wind generation will drive off-peak electric rates down, making wind assisted heating the low cost heating option. Due to the variable nature of wind, it is necessary to maintain grid reliability with some traditional baseload generation. Increased use of Electric Thermal Storage, referred to as Wind Assisted Heating, is one tool that readies the electric grid to productively use higher percentages of renewable energy. This will help ensure the new investment in wind generation is fully utilized, minimizing carbon emissions and keeping heating costs low

# Operating Cost and Energy Consumption

## End Users Estimated Annual Heating Cost Comparison



## Energy Consumption Comparison



**Notes:** Data is tabulated based on Eagle, CO temperatures applied to a home that has a heat loss rate of 45,000 btu/hr.

Std ASHP: Heat pump is locked out at temperatures below 30°. This is generally the case as it is at this temperature that the heat pump can't provide acceptable comfort.

Heatpump w/Wind Assisted ETS: Heat pump is locked out at all temperatures below 0°. The Comfort Plus has the ability to utilize the ASHP's efficiency, even at cool outdoor temperatures, and ensures great comfort at all times.

Electric rates of \$.10/kWh standard rate and \$.04/kWh off-peak rate. Fossil fuel costs of \$1.10/therm for Natural Gas, \$2.50/gallon for Propane and \$3.80/gallon for Fuel Oil. Air Source Heat Pump is a 3-ton, 14SEER.

# ***Grid-Interactive Renewable Space and Water Heating***

## **Consumer, Utility, and Environmental Benefits**

Grid-interactive renewable space and water heaters have smart controls that quickly change their charge rate and charge level, factoring in renewable generation and other critical needs of the grid; thereby significantly reducing carbon emissions and bringing a new dimension of conservation and efficiency to the electric grid. Grid-interactive controls provide utilities with an affordable and effective way to integrate renewable generation into the grid, optimize LMP power purchases, and do frequency control while providing uninterrupted home heating and hot water to the consumer.

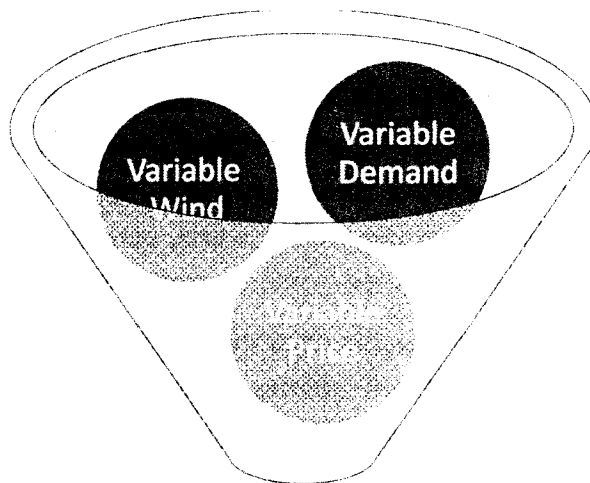
In recent years, many states have set Renewable Portfolio Standards (RPS) or Renewable energy targets to reduce the need for traditional fossil fuel-based power generation, thereby improving our environment and decreasing reliance on imported energy. Due to the variability of generation from renewable energy resources like wind and solar, it is very clear that affordable and effective electric energy storage is needed to balance – in real time – these variable power inputs and to maintain power grid stability. Domestic electric thermal storage space and water heaters are energy storage devices that can provide significant distributed renewable integration and interactive Smart Grid power management solutions.

Because most renewable energy resources are variable, there is great benefit to the utility and society if an electric space or water heater can take on additional charge or “store” more energy when renewable or off-peak low-cost electricity is available. There is also benefit, when the demand for electricity is high or when no renewable power is available, for “controlled” minimal or no charging. Utilities and consumers can integrate higher percentages of renewable energy and minimize renewable energy curtailments, reduce carbon footprints, and lower the cost of operation by varying the amount and duration of electric space and water heater charging sequences. Grid-interactive renewable space and water heater controllers are designed with flexible communication options for existing and future Smart Grid technologies. They allow for dependable, dispatchable, and verifiable symmetrical or asymmetrical up and down regulation. They integrate large amounts of renewable energy, provide fast frequency control and regulation, selectively use low-cost wholesale or retail real-time prices, and provide numerous other generation, transmission, and distribution benefits. These benefits, like regulation for frequency control, bring extra economic benefit as well as significant additional carbon reduction.

This grid-interactive control technology can fill a significant portion of our nation’s electric energy storage needs today. It can also be a valuable carbon reduction component of the Smart Grid and other clean energy initiatives in the future. It is an effective tool for integration of renewable energy resources and fast regulation of the electric grid.

# *Managing Renewables, Off-Peak Energy, and Consumer Demand*

## **Balancing Variable Generation with Control and Energy Storage**



### **Manage with Interactive Space and Water Heater Control**

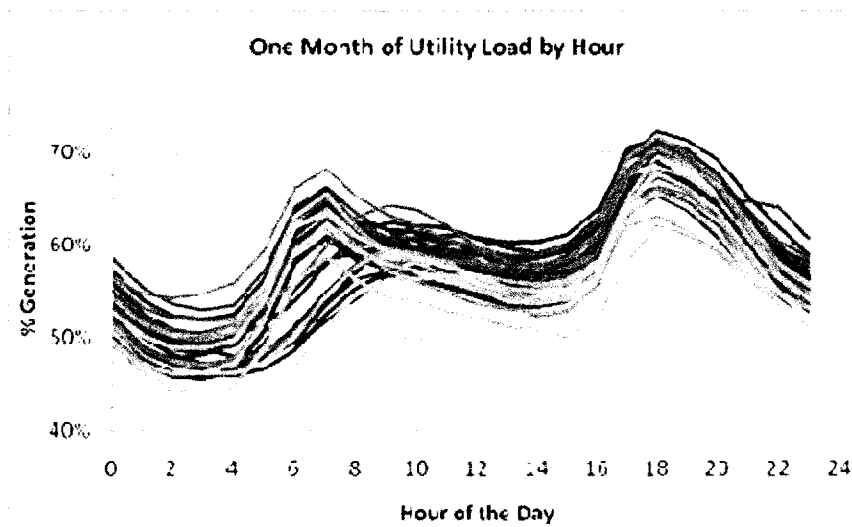
Grid-interactive renewable space and water heaters have smart controls that quickly change their charge rate and charge level, factoring in real-time renewable generation and other critical needs of the grid. This significantly reduces carbon and brings a new dimension of conservation and efficiency to the electric grid.

Renewable energy is recognized as the “green” or environmentally-friendly energy solution. Many States have adopted aggressive Renewable Portfolio Standards (RPS) or renewable targets in an attempt to shift power generation away from fossil fuel generation sources. Most of this new generation will come from wind farms. When load or other generation resources cannot change as fast as the wind, significant amounts of this carbon-free resource are wasted. This variability must also be carefully integrated with other generation sources to maintain grid stability. Grid-interactive renewable water heater loads can adjust and change as fast as wind and other renewable generation, allowing more renewable energy to be fully-integrated into the grid. This ability to track and use real-time renewable generation and other critical needs of the grid can significantly reduce the water heating carbon footprint and lower the cost of operation.

To help quantify the economic and environmental value of grid-interactive renewable space and water heating, the following information was used:

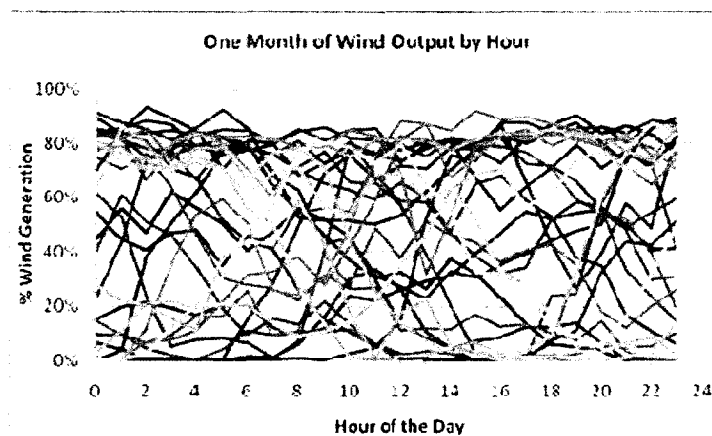
- Three years of hourly wind generation percentages for a Midwest utility
- Three years of actual hourly wind farm generation
- Three years of corresponding hourly wholesale cost of energy (LMP prices)
- Hourly average water heater load data from EPRI

## The Variable Consumer Demand:

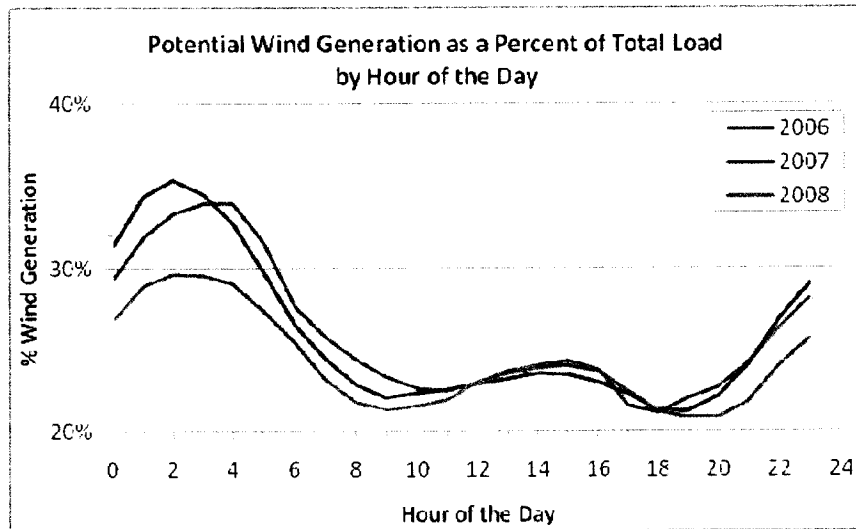


This graph represents one month of a utility's daily load curve. You will notice a definite pattern from day to day. The need to balance generation exactly with this variable load is something grid operators have done for years. When variable renewable generation is added to the variable load pattern, the need for regulation to balance the grid and maintain the 60-Hz frequency increases.

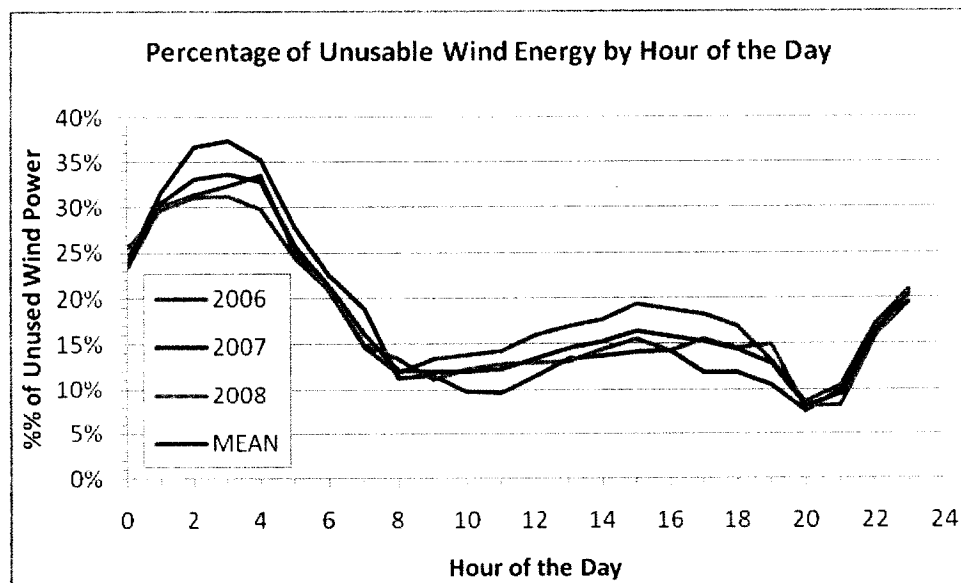
## The Variable Wind:



This graph represents one month of daily wind generation output. As you will notice, there are drastic swings in output not only from hour to hour, but from day to day. There is similar variability with solar generation. The grid-interactive renewable water heater is able to change its charge rate as fast as renewable generation to store more renewable energy when it is available and stop charging when renewable energy is not available.

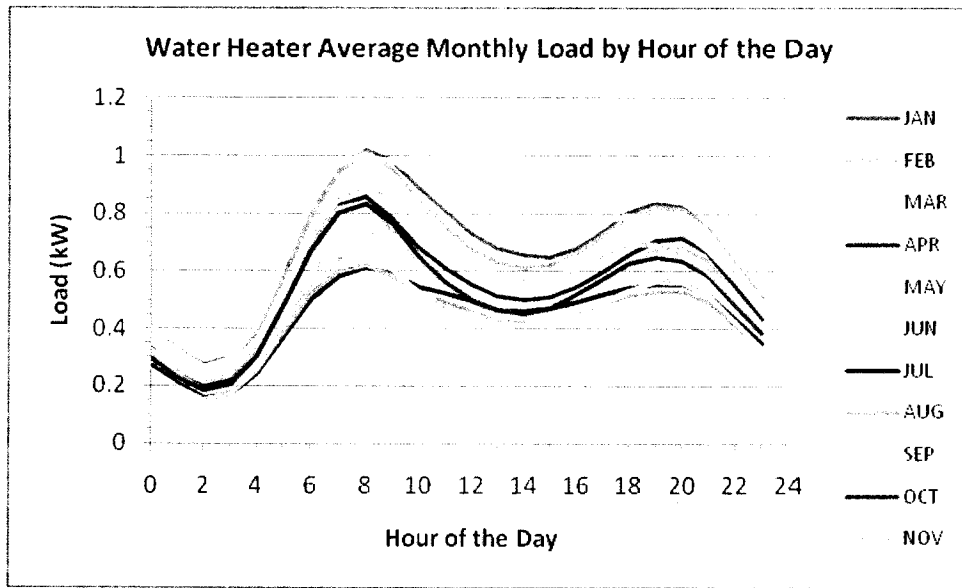


When reviewing average daily wind data over a three-year period, there is a similar pattern from year to year. On average, there is a higher percentage of renewable generation during the early and late hours of the day and a lower percentage during the hours from 8am – 6pm. It is clear that significantly more renewable energy is available, on average, during traditional off-peak hours when consumers are using less. This is also the time period when utilities may have excess wind generation, even after reducing their base load generation output to minimum levels.



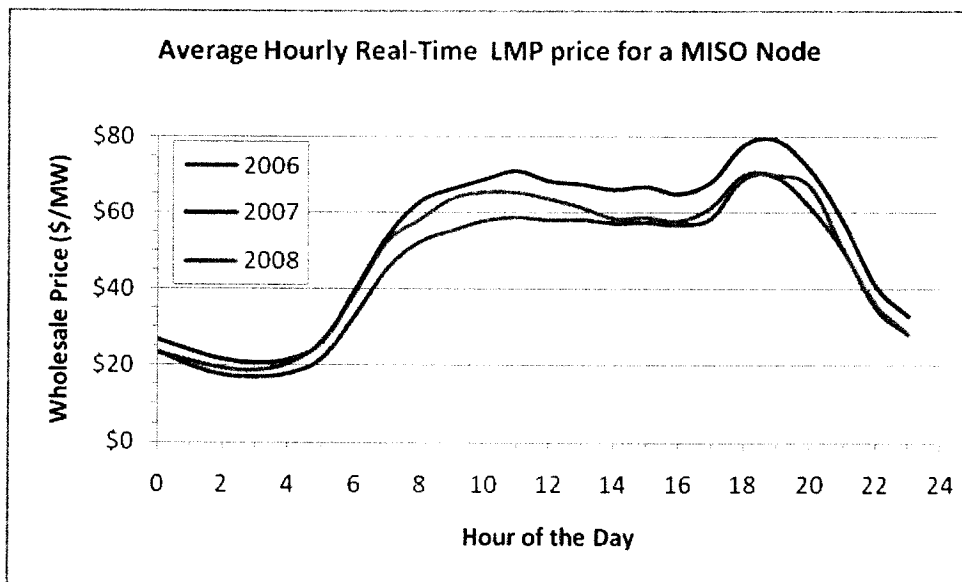
The preceding graph shows the average percentage of unusable wind generation by hour of the day. When wind energy and minimum generation levels exceed consumer demand, energy storage is needed to utilize this carbon-free resource. If this energy cannot be stored, it must be curtailed (turned off or wasted). Low-cost grid-interactive space and water heaters can use this energy which otherwise would have been curtailed. Note that most of the unusable wind is in the middle of the night, but there is also unusable wind at all hours of the day, making real-time communication essential to integrate renewables whenever they are available.

### The Variable Water Heater Load:

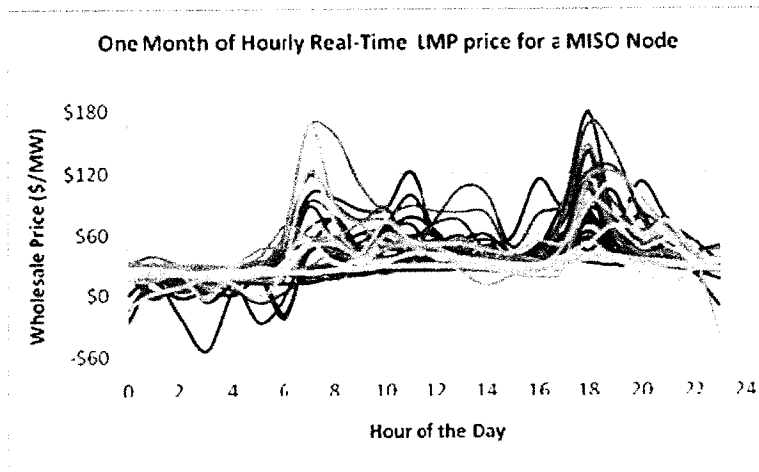


This graph represents the average hourly electric water heater load by month (based on EPRI load data from the Midwest). “Uncontrolled” electric water heaters draw little power in the middle of the night and consume the most energy when loads are typically peaking. Uncontrolled electric water heaters add to the utility’s peak load. The water heater is one of many consumer loads currently contributing to load variability, but it is a load that can quickly be controlled to meet the real-time needs of the electric grid and more-efficiently utilize existing generation, transmission, and distribution infrastructure, providing significant economic and environmental value.

### The Variable Price for Energy:

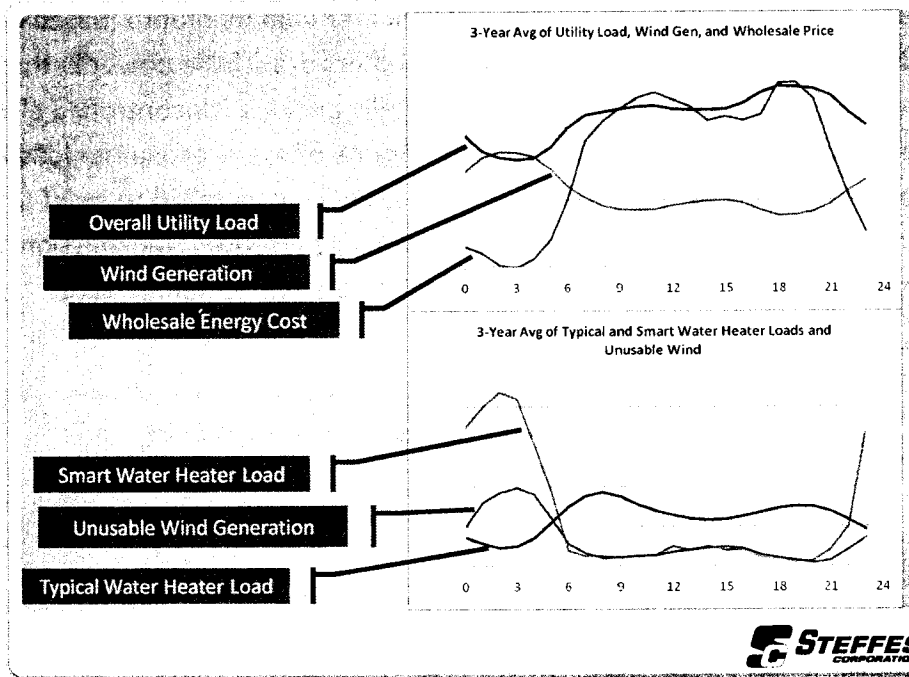


This graph compares three years of average daily energy wholesale costs, commonly referred to as the Locational Marginal Price (LMP). As you can see, the average price by hour is relatively stable year to year.



However, over a one-month period, the real-time LMP pricing varies very dramatically from \$.18 per kW-h to a negative \$.06 per kW-h. The LMP or wholesale energy price changes in most cases every 5 minutes. The LMP often goes negative when the wind blows during low-demand times.

**Putting it All Together:**



- The annual average overall utility load is low in the middle of the night.
- The average annual wind generation is almost the exact opposite of overall load, and the time with the highest percentage of wind is in the middle of the night.
- The wholesale energy price is lowest in the middle of the night.
- Most unusable wind is in the middle of the night.

Grid-interactive space and water heaters can integrate renewable energy and at the same time be a low-cost option. This load can continually change in real-time, based on the current output of renewable energy source, LMP, and other needs of the grid.

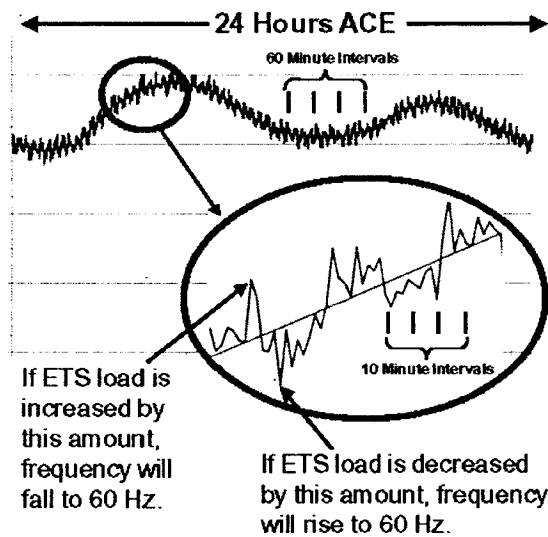
## Bonus Ancillary Economic and Environmental Value

### Frequency Control:

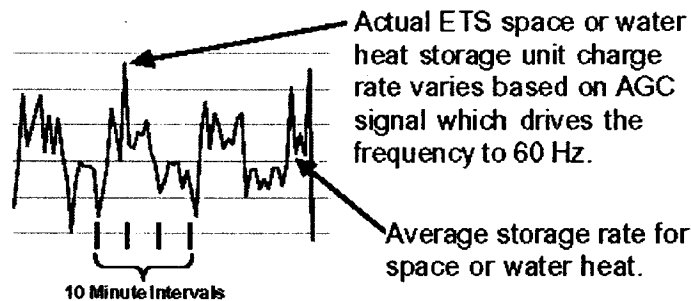
As more variable renewable energy is added to the nation’s electric grid, the need for power regulation increases.

Area Control Error (ACE) is the difference between supply and demand of electricity. This makes the frequency go high or low.

Electric Thermal Storage (ETS) space and water heaters can be used as a fast regulation tool to respond to an Automatic Generation Control (AGC) signal, thus reducing generator fuel consumption and associated emissions. In addition, grid reliability is improved. This yields monetary ancillary payments or reduced cost of regulation for utilities.



### Load at the Residential, Commercial or Industrial Site

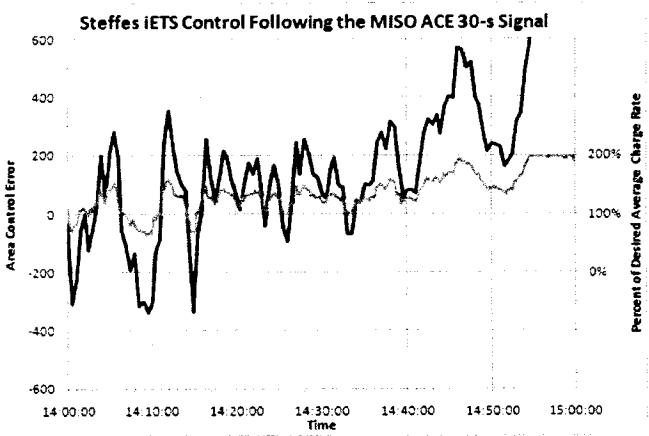
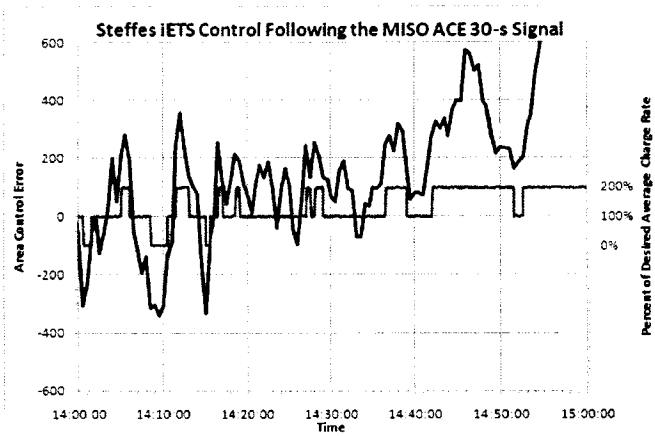


Fast two-way smart grid communication is needed to make frequency control work the best.

# Smart Signal Following

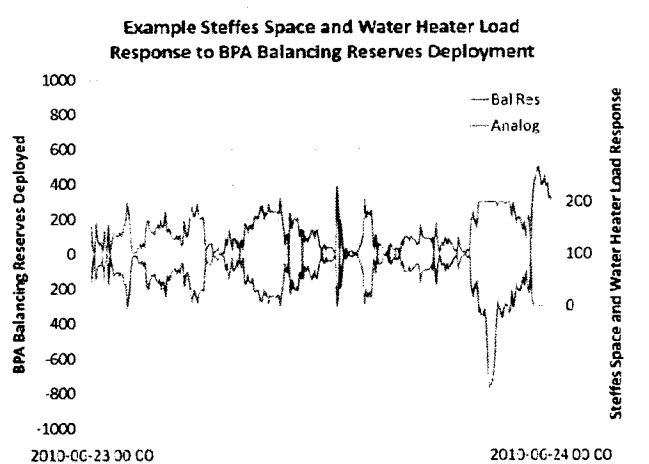
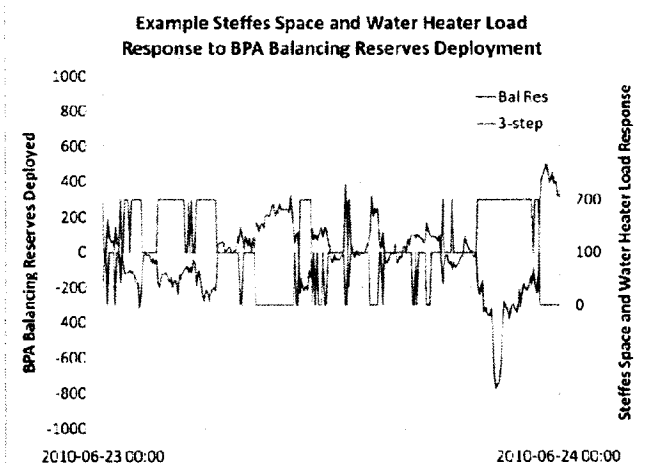
## MISO 30-s ACE or 4-s AGC Signal

The Midwest ISO (MISO) has an Area Control Error (ACE) signal that indicates the instantaneous difference between net actual and scheduled interchange. When the ACE signal is positive, it indicates that generation exceeds demand and when the ACE signal is negative, it indicates that demand exceeds generation. Grid-interactive renewable water heater controls can use this signal to add load when the signal goes high and shed load when it goes low. If the controlled load is small compared to the needed regulation capability, a 3-step charging methodology can be used to maximize the impact. If the controlled load is a significant percentage of the needed regulation capability, a much finer control strategy can be used, which tunes the charging magnitude to grid needs. The grid-interactive renewable water heater control is able to follow the 4 second Automatic Generation Control (AGC) signal in the same way.



## BPA Balancing Reserves Deployment Signal

The Bonneville Power Authority (BPA) has a Balancing Reserves Deployment signal that is used to balance renewable energy resources and demand variations with generation resources. This is the difference between predicted wind and actual wind generation in the area. When the Balancing Reserves Deployment signal is positive, it indicates that generation was increased to balance the grid and when the signal is negative, it indicates that generation was decreased to balance the grid. Grid-interactive renewable water heater controls can use this signal to shed load when the signal goes high and add load when it goes low. If the controlled load is small compared to the needed regulation capability, a 3-step charging methodology can be used to maximize the impact. If the controlled load is a significant percentage of the needed regulation capability, a much finer control strategy can be used, which tunes the charging magnitude to grid needs.



# Other Benefits of Electric Storage

(taken from the SGIIP PAP07 Scoping Study Document)

Grid-interactive storage space and water heaters provide additional benefits by helping to:

- Enhance power quality and regulate grid frequency by quickly ramping demand up and down as needed
- Support renewable integration and enhance value, enabling greater penetration and utilization of these assets, reducing the cost of integration for wind developers, and increasing the price of wind energy which at this time is negative during windy low-demand periods.
- Mitigate environmental impacts and qualify for environmental credits by enabling greater penetration and utilization of renewable energy assets
- Provide arbitrage value by enabling energy market participants to buy and store low-cost energy and sell demand reduction when energy prices are high
- Provide spinning and supplemental reserve by reducing demand during times of insufficient supply
- Defer transmission, distribution, and substation upgrades and generation capacity investments by reducing peak demand
- Extend transmission and distribution asset life and increase utilization by reducing peak demand and time-shifting load profiles
- Reduce retail energy costs to consumers by leveraging time-of-use or other variable rate structures and reducing peak demand to avoid demand charges
- Improve on-site power quality and mitigate financial losses related to power quality fluctuations by quickly ramping demand up and down as needed to offset grid conditions
- Reduce transmission and distribution loss costs

Benefit	Mechanism
Enhance Power Quality	Quickly vary load
Regulate Grid Frequency	
Support Renewable Integration and Enhance Renewables Value	
Minimize Environmental Impacts and Qualify for Environmental Credits	
Provide Arbitrage Value	
Provide Spinning Reserve	
Improve On-Site Power Quality and Mitigate Resultant Financial Losses	
Defer Transmission, Distribution, and Substation Upgrades	Time-shift load
Defer New Generation Capacity Investments	
Extend Transmission and Distribution Asset Life	
Increase Transmission and Distribution Asset Utilization	
Reduce Transmission and Distribution Loss Costs	
Reduce Retail Demand Charges	
Reduce Retail Energy Costs	

## Conclusion:

In a perfect world, there would be no fluctuation of energy consumption, generation and prices. Everything would be well-defined and very predictable. In the real world, there is much variability and uncertainty. Maintaining grid stability with the variability of renewables and consumer demand is challenging. It is clear that fast-acting electric energy storage is necessary in order to reap the full benefits of renewable energy. Grid-interactive storage space and water heaters can fill a significant portion of our nation's electric energy storage needs at a fraction of the cost of other technologies. They can also be a valuable carbon reduction component of the Smart Grid and other clean energy initiatives in the future. In order to achieve a zero-carbon economy, we must encourage the use and development of innovative products and technologies that have the potential of getting us there. Grid-interactive storage space and water heaters provide substantial benefit that can help utilities and consumers manage our energy future.

November 8, 2010

MDU rate hearing

Thank you for the opportunity to submit information for the MDU rate hearing. We strongly support MDU's effort to establish an ETS rate. We see significant benefits for consumers, MDU and the environment. This is a great first step in establishing a cost effective smart electric storage system of the future that will bring a new dimension of conservation and efficiency to the grid. In the paragraphs and pages that follow, we will provide information related to this. Additional supporting documentation is also provided and will be referenced in this document.

### **As a Demand Response and Load Management tool**

Demand response and demand side management programs have been used by utilities for many years to manage generation, transmission and distribution of power. Many utilities have been able to defer or eliminate the need for construction of new generation and other infrastructure because of the successful demand response programs they have.

Electric Thermal Storage (ETS) systems are tools utilities have used in their DSM programs for over 30 years. During off-peak hours, ETS heaters store low-cost electricity as heat and use this energy for heating homes 24-hours a day. During peaking hours, the heaters rely entirely on energy which was stored during off-peak hours. Utilities use direct load control equipment or the electric meter to signal equipment such as ETS. Power companies that include ETS systems in their DSM programs are successful in improving their load factors and system efficiency, in addition to deferring costly system upgrades. In the future, the smart grid will provide a real time link between the immediate need of the grid and each ETS system. Doing regulation with electric storage resources can reduce the carbon emission by 70% over doing regulation with fuel consuming resources. This brings a new dimension of conservation and efficiency to the grid.

### **Reduce cost for all rate payers**

Electricity sold to consumers at a lower price during off-peak hours is economically sound. On average, the wholesale cost of energy is significantly less during these hours and there is better utilization of existing transmission and distribution infrastructure. Looking at the future, significant additional economic and environmental value is on its way with smart charging, especially for renewable integration and frequency control. There are many different ways to compensate consumers, such as time of use or real-time electric rates, or a special rate that allows MDU to control the storage space or water heater as needed while providing uninterrupted comfort to the home, or MDU could own the electric storage assets and realize the real-time LMP optimization and ancillary value. Savings could then be passed on to all rate payers.

### **As a Renewable integration tool**

Most renewable energy resources have a variable generation pattern. In order to integrate renewable resources, additional “fast up and down” regulation is needed. A smart MDU signal would provide a means to aggregate distributed electric storage assets to provide this low carbon regulation service. Furthermore, low-cost smart electric storage space and water heating is a cost effective way to integrate large amounts of renewable energy. Electric Thermal Storage (ETS) is a low-cost, proven distributed energy storage resource that has been used by consumers for over 30 years. ETS systems store electricity as heat during times when renewable or off-peak low cost/low value power is available and use this stored energy as needed to satisfy consumer comfort requirements on demand. Smart signals ensure a continuous supply of hot water and space heat for the consumer and vary the charge rate and charge level of the ETS units up and down as fast as renewable generation change, and greater at ramp rates than is achievable from many traditional generation technologies. Smart signals in the home bring the possibility of low-cost terawatt hours of electric energy storage to the system. This allows for higher percentages of renewable energy on the grid at lower cost. ETS cannot provide all of our nations electric storage needs but there is a significant window of opportunity that it can fill. It makes sense to fully utilize the low-cost electric storage opportunity first and use more expensive alternative methods later as needed.

### **As Smart Appliance for the future**

Space and water heating are the two largest energy loads in homes. Smart appliances, such as Interactive ETS Space and Water Heaters, provide significant value for the advancement and management of the Grid. Operation of these systems can be regulated to meet the needs of the grid without requiring any lifestyle adjustments or sacrificing of comfort by consumers. These systems have the ability to store significant amounts of energy during hours when demand is low or extra renewable energy is available and utilizes this stored energy during peak hours or hours of limited renewable energy availability. These smart appliances provide automatic control for the storage and discharge of energy, in addition to responding to identified needs of the grid. Time of Use or other preferential electricity rates make it beneficial for consumers to use this technology in their homes or business’.

### **As a peak shaving tool with Domestic Electric Water Heaters**

Approximately 50% of homes in the U.S. have electric water heaters today which are energy storage devices that can play a very key role in increasing efficiency of the Grid. While much has been written about the potential for using electric vehicle battery charging for energy storage, it is not well known that a domestic electric water heater has approximately the same storage capability as an electric vehicle battery, and there are literally tens of millions of them already in service. Energy Storage has been identified as a critical component for managing our system of power generation, transmission and distribution while maintaining grid reliability and stability. With rapidly increasing amounts of renewable energy being added to our country’s power generation mix, the need for energy storage is becoming more essential. Smart controls were recently developed and provide utilities the ability to use electric water heaters as distributed storage devices. These controls provide the ability to do fast UP or DOWN power regulation in response to needs of the power grid, like MISO AGC signal for ancillary value as well as significant environmental value. Not only does this provide powerful and effective power management,

reducing cost and emissions, it also allows for full integration of variable renewable generation sources such as Wind and Solar.

### **As a Grid Stability and Reliability tool**

It is becoming very obvious that energy storage is needed in order to manage power generation and demand. Especially with the growing amount of renewable generation, it is becoming difficult to integrate this resource with base load power generation. Couple this variable generation with the variability of energy usage by consumers, it is very challenging to manage power supply while maintaining grid stability and reliability. While most people believe energy storage is a key component for a stable and reliable Grid, conventional energy storage options available today are very costly and not economical. Examples of these storage options are CAES, Flow Cells, NaS Batteries and Flywheels. These have a cost range of \$200 - \$1,500 per kWh of storage capacity.

Electric Thermal Storage (ETS) is an energy storage technology that has been used in U.S. for the past 40-years. It is a distributive energy storage technology that stores electricity as heat during preferential times of the day or night. This energy is used for heating homes and commercial & industrial applications. ETS systems are proven, long life, low-cost energy storage devices. The installed cost of ETS systems ranges from \$40 to \$70 per kWh of storage capacity. Historically, utilities have used ETS products for demand response and load management purposes. Today and for the future, these fast response storage systems can provide additional value such as Grid Optimization, Renewable Integration and Frequency Control. Consumers benefit from lower heating bills (and electric rates) and our country benefits from a reduction of imported oil.

### **Closing comments**

In the past, power generation has followed load, which varies with the instantaneous needs of consumers. As our country's dependency on variable renewable wind and solar generation increases, there will be a greater need to have the load follow instantaneous generation. Renewable energy is a "must take" resource. If we are going to have a high percentage of these variable and "must take" resources run our nation and the economy, smart energy storage is needed. To better use existing utility infrastructure and improve reliability and bring a new dimension of conservation and efficiency to the system, smart energy storage is needed.

Smart control is an enabling key, benefiting consumers, the utility and the environment. A cost effective way to bring load and generation into balance is to use the Smart communication with low-cost distributive energy storage in real-time. This allows extra generation to be stored when necessary and allows consumers to consume energy as needed. MDU's time of use Electric Thermal Storage rate 13 is a great first set for significantly more economic and environmental benefits in the future.

We strongly support MDU's effort to establish a ETS rate and would also recommend consideration of a pilot smart control demonstration to evaluate the additional benefits ETS can bring to MDU and rate payers.

Thanks again for the opportunity to provide input at this rate hearing. We welcome you to contact us to visit more. You can reach us at 701-483-5400 or [offpeak@steffes.com](mailto:offpeak@steffes.com). You may also view more information on this technology at [www.steffes.com/offpeak](http://www.steffes.com/offpeak) or [www.steffes.com/off-peak-heating/smart-grid.html](http://www.steffes.com/off-peak-heating/smart-grid.html)

Steffes Corporation