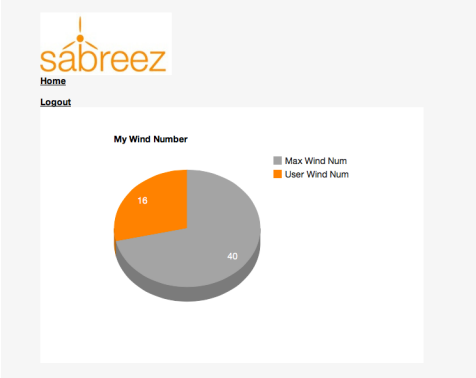
Residential Demand Response using a Single Variable Information System- The Wind Number

ABSTRACT



Renewable energy has become cost-competitive with natural gas and coal-fired power plants as a source of electricity. However, intermittency and reliability remain a deterrent to adoption. Fossil fuel power plants are still required as backup. It would be helpful if people used power at certain times of the day when renewable energy is abundant, and now consumers can control when they use electric power like never before.

Smart home technologies like wi-fi enabled appliances, electric vehicles, whole-house battery systems, and solar are being adopted by consumers for a range of reasons. People value clean energy, and are starting to realize that these technologies save money and represent a great investment. Utilities are interested in developing a two-way communication with residential customers through Demand Response Programs enabled by Smart Meters. Time-variant pricing will be used to balance demand with generation. The Wind Number is a Residential Demand Response Program that offers energy consumers a compelling value proposition; Clean Energy Costs Less.

Sabreez has defined the Wind Number as the ratio of power coming from wind divided by the power coming from fossil fuel sources, multiplied by 100. It's an energy-use game on Facebook that uses the Green Button feature to combine hourly energy usage data with hourly power generation data to present a pie chart. The results verify initial modeling that indicates an increase in a household's Wind Number with the implementation of additional Smart Home technologies. Households that have done little in terms of energy improvements have low Wind Numbers; Households that have installed solar or charge an electric vehicle have higher Wind Numbers. Messaging on time of use rates, hourly availability of clean energy, energy saving technologies, and results of the monthly winners all contribute to positive reinforcement of clean energy consumption. The platform for the pilot program can be viewed at www.facebook.com/windnumber.

The Wind Number is a metaphor for a household's clean energy consumption. Furthermore, it increases when intermittent wind is strong and decreases when natural-gas turbines are required to meet peak demand. It is a form of normative reporting based on a single variable; when a household uses electricity. It's independent of home size, occupancy, age, and other variables that are difficult to account for with current normative reporting programs. Since Wind Numbers increase with the purchase of additional smart home technologies, it should find sponsorship from a range of stake holders. Beginning next Spring, the Facebook platform should be expanded across multiple media to reinforce the brand. Shortly thereafter, the program should be implemented on a much larger scale and in additional markets, like Texas and the Plains States.

Introduction

Until recently, there have been two major problems with renewable energy, cost and integration of electrical generation with demand. Cost is now less of an issue. Costs of solar and wind are now competitive with the most efficient fossil-fuel-powered plants. Still, renewable energy is created on Mother Nature's schedule, which does not necessarily coincide with when people are using electricity. Energy storage remains an issue and adds integration costs to renewables in the absence of fossil fuel generating plants. While solar and wind reduce fuel consumption, natural gas power plants are still required to meet demand when it's not sunny or windy.

There are a number of new technologies available to consumers which reduce demand for electricity. These include solar, LED lighting, new appliances, and home automation systems. Electric vehicles allow consumers to power their cars at night when rates are low at a fraction of the cost of fossil fuels. Now whole house batteries are available as well, allowing consumers to charge the battery system when rates are low and use that power when rates are high.

Utilities are offering time of use electric rates that are determined by demand, which is highly variable. Rates are lowest at night and higher during the daytime. In the Summer, rates are higher due to air conditioning demand. For the remainder of the year, rates are higher in the morning when people awaken and during the late afternoon. Time of use rates are becoming mandatory in California in a couple of years, and residential customers are ill-prepared to understand them or recognize the savings opportunities they offer.

In a world powered by renewable energy, wind power is less predictable than solar; it can be windy any hour of the day, but generally dies down in the middle of the day. Conversely, solar is known to be productive only during daylight hours, so while the number of

hours of solar power production is less, it's more predictable. Solar power is generally strongest in the middle of the day when wind power is waining.

There is a relationship between solar, wind, and natural gas powered plants. In the absence of sun and wind, power supply is typically balanced by natural gas fired power plants. With increasing renewable energy production, the capacity factor of fossil fuel powered plants is decreasing, making them more expensive to operate in terms of fixed costs per Megawatt-hour (MWh). This cost is getting carried through to the consumer, who can opt for a time of use electric rate to reduce their bill. Therefore, the more renewable energy a consumer uses, the more money they save. Since solar is strongest during the day when demand is higher, and wind is strongest at night, the more power consumers use at night when demand is low, the more money they save. Conversely, using less electricity when fossil-fuel powered plants are cranking up for just a couple of hours each day saves money.

Using more wind power and less fossil fuels saves money. Essentially, clean energy costs less. Sabreez has defined a variable that is proportional to the ratio of a User's power that comes from wind versus fossil-fuel-powered plants; The Wind Number. The Wind Number is defined as the ratio of a consumer's electricity that comes from wind vs fossil fuels, multiplied by 100. If a consumer receives power in equal amounts from wind as from fossil fuels during any hour, the Wind Number would thus be 100. The Wind Number is a measure of clean energy consumption. The Wind Number is presented relative to the maximum for the period as a pie chart. This metaphor can be marketed to consumers because it's based on consumption. This is a stark contrast to most energy-saving programs, which offer consumers less of something they depend on daily. Clean energy costs less. Fossil fuels cost more. Moreover, solar, electric vehicle charging at night, and shifting appliance usage to the nighttime hours all increase a consumer's Wind Number. This single variable

known as the Wind Number is a smart meter game where people that use more clean energy and less fossil fuels win, and spend less for energy. Research over the past few years indicates that this basic relationship solves many of the problems associated with renewables integration, reducing the cost of addressing climate change.

The Wind Number

Hourly energy generation data from the California Independent System Operator (CAISO) is used to create an hourly database of Wind Numbers. This database can then be matched to the hourly consumption data of an energy consumer using the Green Button feature developed by the utility industry and U. S. Department of Energy. Over any period of time, a consumer's Wind Number is defined as the ratio of power that comes from wind power vs fossil fuels, multiplied by 100. For example, to determine a consumer's Wind Number over a month, the hourly products of the Wind Number and a User's hourly consumption are summed up over a month, then divided by the total hourly consumption.

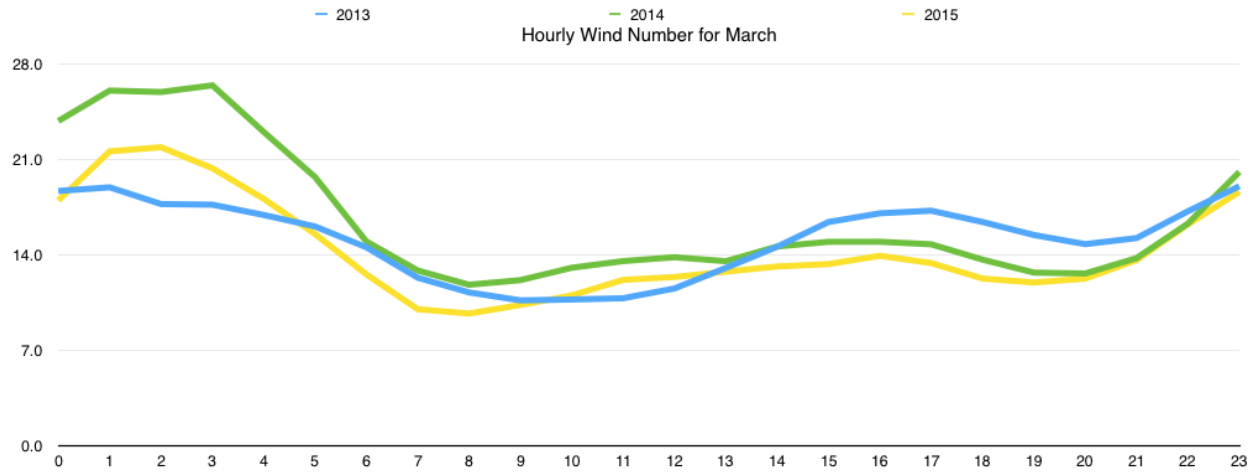
As will be demonstrated, Wind Numbers are highest during the early morning hours and lowest during the mid-day hours. This is most pronounced during the Spring and Summer months, particularly during months when overall electrical demand is highest.

The Wind Number is the subject of U.S. Provisional Patent Application Serial No. 61/904,573, filed November 15, 2013, for METHODS FOR ANALYZING ENERGY CONSUMPTION TO REDUCE COST AND DEVICES THEREOF and U.S. Patent Application Serial No. 14/540,589, filed November 13, 2014 for METHODS FOR OPTIMIZING AN ANALYSIS OF ENERGY CONSUMPTION TO REDUCE COST AND DEVICES THEREOF.

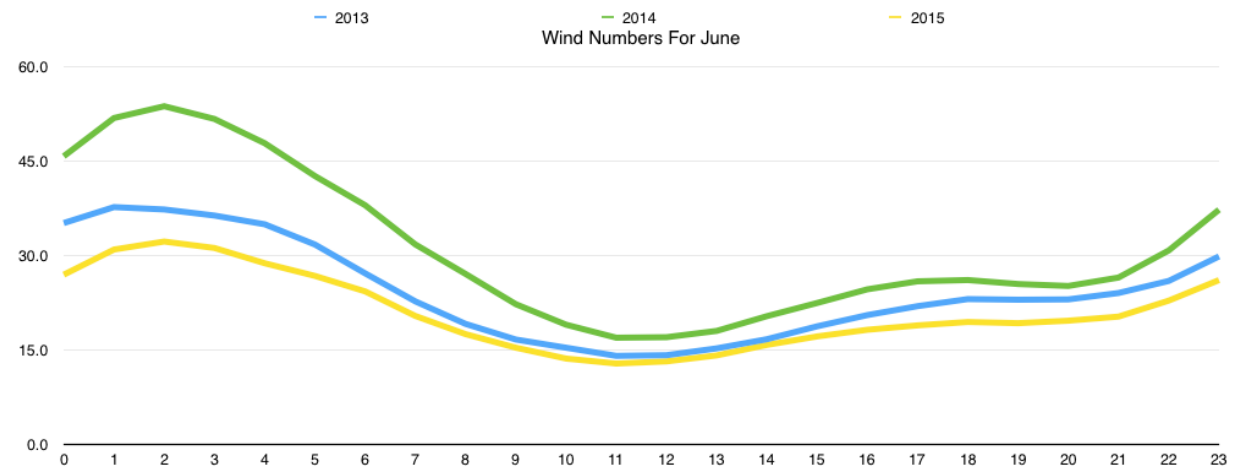
Seasonal Factors

Wind power generation in California starts building seasonally in the Spring. Charts of the Wind Number from the last three years for the months of March, June, August and January are presented below.

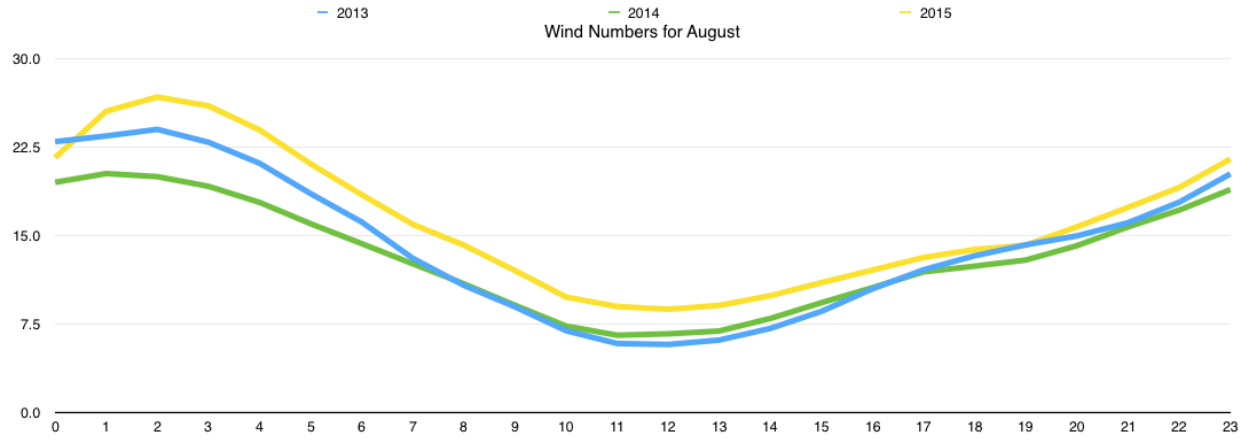
March



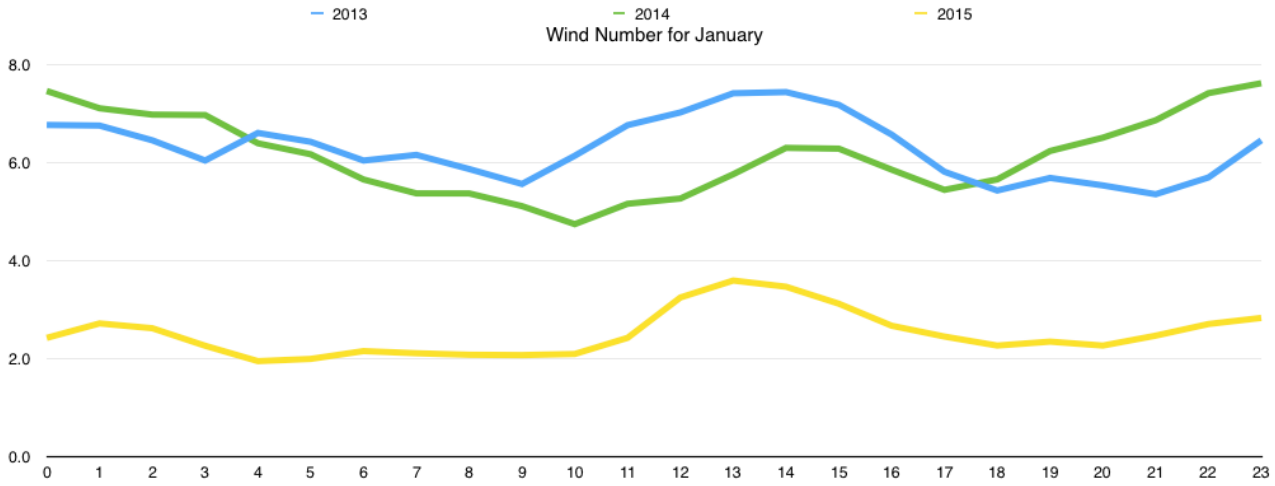
June



August



January



Analysis of seasonal Wind Numbers indicates that Wind Numbers are highest during the month of June, which is when wind is strongest and Summer heat is increasing mid-day demand. Wind Numbers increase between March and June, and start to wain in July. The chart for January Wind Numbers reflects a general decrease in wind, and less of an inverse correlation with demand. Wind Numbers are highest when demand is low and wind power is up, between the hours of 11 pm and 5 am.

System-Wide Demand

Demand for electricity in the State of California is highly variable, but the following general observations can be made;

1. Overall demand is highest in the Summer resulting from air conditioning use,
2. Summer mid-day demand can exceed 40 Gigawatts (GW), but typically ranges between 30 and 40 GW,
3. Solar can currently produce up to 6 GW of electric power during the middle of the day and is growing rapidly each year,
4. Year-round demand is lowest during the period from 11 pm to 5 am,
5. The demand curve is changing with solar deployments, with a morning small peak and a late afternoon spike in demand. The afternoon spike is currently about 10 GW over less than two hours, but expected to grow,
6. Fossil-fuel power plants generally supply power to meet almost all of the afternoon spike in demand, which lasts for less than 3 hours,
7. As more renewables are brought online, net peak demand will be increasingly pushed towards the morning peak and even more to the afternoon peak, with higher time-variant pricing associated with those times, and
8. Wholesale and Retail electricity prices are lowest when Wind Numbers are highest and Demand is lowest.

Energy Consumption Factors

The Wind Number is a scalable method of decreasing energy costs for consumers. When a User shifts their energy consumption pattern to the early morning hours, they increase their Wind Number and save money by using a cleaner energy mix. Wind Numbers were evaluated for the March, June, August, and January Periods.

Using the data from a California home, the following Wind Numbers were obtained;

	March	June	August	January
Wind Number	15.5	23.3	11.5	5.2

Energy Modeling

The following technologies were applied to the household's energy consumption to evaluate the effect on the household Wind Number;

Appliance/Pool Pump Load Shifting

The model was run to evaluate how adjusting just 1 kWh per day from the daytime hours to the early morning hours when Wind Number are highest. This could be achieved by using the delay button on a dishwasher or clothes washer, or running an electric dryer once every four or five days.

Wind Number	March	June	August	January
Base	15.5	23.3	11.5	5.2
With Adjustment	15.9	23.8	11.8	5.2

As illustrated in the table, Wind Numbers increase for the Spring and Summer periods, but remained the same for the January (Winter) period. Additional modeling indicates that the increases would be greater for pool pumps, or any other additional load shifting, including air conditioning usage to some degree. With the adoption of smart appliances, Users will be able to increase their Wind Number using web-based consumer interfaces.

Electric Vehicle Charging

To evaluate the effect of vehicle charging on the household's Wind Number, 300 kWh of vehicle charging were added to consumption between the hours of Midnight and 5 am. Based on three miles per kWh, this corresponds to 900 miles per month.

Wind Number	March	June	August	January
Base	15.5	23.3	11.5	5.2
With Adjustment	17	26.1	13.9	5.3

Similar to the increases observed with shifting appliance run times, Wind Numbers increase for the Spring and Summer periods, but remained the same for the January (Winter) period. The magnitude of the increase is greater for each period due to the volume of electricity consumed.

Rooftop Solar

To evaluate the effect of solar on the household's Wind Number, the output of a 4 kW solar array was modeled with the following outputs per month.

	March	June	August	January
Solar kWh	343.12	610.42	567.23	216.94

The resulting Wind Numbers compared to the base household Wind Number for each period were as follows:

Wind Number	March	June	August	January
Base	15.5	23.3	11.5	5.2
With Adjustment	17.6	29.3	16.2	5.1

A similar pattern of increasing Wind Numbers is noted for each period. Whereas electric vehicle charging increased the Wind Number by increasing consumption when Wind

Power was relatively high, the Wind Number increase associated with Solar is achieved by decreasing overall consumption when overall system-wide demand is high.

Combined Load Shifting, Electric Vehicle, and Solar

Combining the three previous examples into one model, the following patterns emerge.

Wind Number	March	June	August	January
Base	15.5	23.3	11.5	5.2
Load Shifting 1kWh/day	15.9	23.8	11.8	5.2
Electric Vehicle	17	26.1	13.9	5.3
Solar	17.6	29.3	16.2	5.1
Combined Effect	19.3	32.7	19	5.2

As illustrated in the table above, Wind Numbers increase with each of the levels of smart technologies adopted by the household during the Spring and Summer seasons when demand is highest. The Wind Number is a scalable residential demand response program that benefits a range of stakeholders in the smart grid ecosystem.

Summary

Climate change is a massive problem, but the technology to reduce green house gas emissions is available; it just has to be developed and integrated into consumer energy demand.

The cost of electricity from Wind and Solar power has dropped to the point where they are cost competitive with fossil fuels. The problem is that electricity from these resources is generated intermittently on Mother Nature's schedule and not necessarily coincident with demand. However, consumers are gaining increasing levels of control over when they consume power, through wi-fi connectivity and batteries which power vehicles and new whole-house batteries.

Electrical generation data is available to evaluate the natural patterns of seasonal production of solar and wind power resources. Solar power production is only available during the daylight hours. Wind power is potentially available at any hour of the day, but usually strongest at night. Currently, natural gas power plants balance renewable energy production with demand, and as observed in California, the ramp-up to meet demand can be extreme in the late afternoon as solar power wains.

California is changing to mandatory time of use electric rates. There is a strong correlation between low cost electricity and wind power production. There is also a strong correlation between fossil fuel power plant utilization and peak rates, since many of these plants are only needed for a few hours per day, on average. Although there will be increasing amounts of energy storage being developed, the primary source of dispatchable electricity is anticipated to remain natural gas turbine power plants.

With hourly energy consumption data now available through smart meters, it is possible to illustrate to consumers where their electricity comes from and their impact on the environment. This could be conveyed in terms of carbon, but reporting a negative value will only appeal to a small segment of the overall population, and it's not a message they're likely to monitor. People are consumers, and are being told to consume more throughout the day for a range of products, so for many, the message of consuming less that utilities have traditionally offered is of questionable value. Alternative energy is a cost-saving alternative to fossil fuels, it's just a matter of educating the consumer about how to use it given the new technology.

By showing the consumer the ratio of their electricity that comes from wind versus fossil fuels (the "Wind Number"), a residential demand response program has been fashioned that offers a compelling value proposition to energy consumers. Analysis of this variable

over the last three years indicates there is a strong correlation between the “Wind Number” and time of use electric rates. Consumers that use less power coming from fossil fuel plants will have lower Wind Numbers over a billing period, whereas people that use more power after midnight will save more and have higher Wind Numbers.

Modeling of Wind Numbers for various smart home technologies indicates that Wind Numbers and savings increase for all technologies. Using the delay button on appliances to run them after midnight rather than in the afternoon increases Wind Numbers. With the advent of smart appliances, consumers should be able to increase their Wind Number simply by hitting a button. Running a pool pump after midnight also increases the Wind Number. Consumers that have rooftop solar have higher Wind Numbers, since the home is not drawing power from the grid in the middle of the day when Wind Numbers are lowest. Charging a vehicle battery at night significantly increases a User’s Wind Number, and should soon be integrated with vehicle Apps to discourage daytime charging.

The Wind Number is a form of normative reporting based on a single variable; when electricity is consumed. Thus it does not vary based on house age, size, or number of occupants. Users that consume more energy when wind power is strong and less energy when natural gas fired power plants are required to meet demand will have higher Wind Numbers. As California further develops Wind and Solar resources, Wind Numbers will increase, and so will the importance of increasing consumer awareness of pricing signals. The Wind Number is a positive message as opposed to a warning message. While critical peak pricing messages will continue, and probably become more frequent, the Wind Number platform is a message that offers consumers a valuable solution, allowing retention of energy consumers in demand response programs.

The Wind Number was introduced on Facebook in 2014 as a social game. Messages typically focused on times of the day when wind power was abundant, technologies that saved money and increased Wind Numbers, contest announcements (winning strategies), Smart Day events, and to a lesser degree environmental messages. Advertising was focused on the San Francisco Bay Area. Prizes were awarded each Summer month to the Users with the highest Wind Number. Winners were awarded a box LEDs, which in California should save them more than $1,000 over their multi-year lifetime.

Having completed two years of marketing trials, the off-season will be spent developing a comprehensive marketing program to take the residential demand response program state-wide in 2016.

Prepared November 11, 2015

Prepared by:

W. Scott Hoppe
Managing Partner
Sabreez, llc
www.sabreez.com
www.windnumber.com
www.facebook.com/windnumber
scott@sabreez.com