

## Chapter 5

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# Energy Efficiency

A couple of years ago, a friend of mine told me his electric utility company had sent him an email saying the electrical consumption in a vacant home he had for sale was out of line compared to other homes in the neighborhood. I am not sure what algorithm they use to make this determination, but it sounded convincing. He decided to wait for the following month's update. It showed the same thing, a significant variation compared to other homes in the neighborhood.

My friend retrieved electric bills from the prior year when the home was occupied, and found the current electrical consumption was significantly higher than the prior year. In financial terms, the current electric bills were running a few hundred dollars per month more than when the home was occupied. Something in the home must be running. We went to the home and checked every room, the basement, garage, and attic. Some appliances and electronic items can be using electricity even when they are turned off. We unplugged them all. We checked the thermostats to make sure the home was not unnecessarily being heated or cooled. He then waited for the following month's bill.

Once again, the kilowatt hours of electrical power consumed was significantly higher than for the same month of the prior year. Something had to be running my friend was not aware of. I called another friend who is quite knowledgeable about all aspects of utilities for homes. His first question was about where is the source of water for the home. The water source was a well on the property. He suggested calling a well specialist. An inspection by the well specialist revealed the well pump was clogged with iron rust and unable to deliver the required water pressure. As a result, the well control kept the well pump on continuously. The new pump and related labor was expensive, but not nearly as much as continuing to run the pump 24x7 indefinitely.

Americans have had a major dependency on electricity in the home for more than 75 years. When electrical power to the home is lost, we can face major inconveniences. When we are using electricity unnecessarily, we may not notice it until we get the bill. In this chapter, I will discuss how a smart home can give us feedback on our energy usage.

### **Monitoring Energy Usage**

The American Housing Survey (AHS) is sponsored by the Department of Housing and Urban Development (HUD) and conducted by the U.S. Census Bureau. The survey is the most comprehensive national housing survey in the United States. I extracted a subset of the data, excluding the very high and very low incomes. The data show housing cost is approximately \$1,400 per month or 36% of income.<sup>70</sup> Nearly \$300,

more than 20% of income, is spent on home energy usage, split roughly equally on electricity and oil or gas. An expenditure of nearly \$4,000 per year, and much more for many, suggests monitoring the usage of home energy can be quite important and easily justified.

### **Electricity**

When I was at IBM, some of the product laboratories would loan me new equipment they had developed. I had been the Vice President of Marketing for the IBM PC Company when we launched the IBM ThinkPad in 1994, and I evangelized about the product in many speeches and blog postings. The other labs knew I would do the same with their products. Some of the products loaned to me were better suited for small businesses, rather than for home use, but I was happy to have them and use them.

One of the products was an IBM equipment rack about as big as a medium-sized refrigerator. It fit nicely in my basement. Inside of the rack, I had a server and a large array of computer storage, which I loaded up with music. In effect, I had an early version of my own cloud computing infrastructure and streaming music service. The installation was overkill for a consumer, but fun to learn about, write about, talk about, and use. I had it all tied in with the home automation system. I could select music tracks from keypads around the home. This was before Amazon Web Services, the iPhone and iTunes, and other music services.

One day I was showing the equipment rack to a friend. He put his hand on the top and noted the rack was quite warm. This was not surprising, given the industrial scale equipment inside. Then it dawned on me, I wonder how much electricity I am using. I looked around for ways to monitor this, and discovered P3 International, a New York based company, which had developed a product called the Kill A Watt® EZ.<sup>71</sup> The innovative product has a user-friendly power meter which enables people to calculate the cost to use their home appliances. See figure 5.

The company says, “Now you can cut your energy costs and find out what appliances are actually worth keeping plugged in.” I was intrigued. The Kill A Watt® EZ is incredibly easy to use. You simply plug it into a receptacle, and then plug the appliance you want to evaluate into the Kill O Watt. You enter the cost per kilowatt you pay to your electricity provider. The large LCD display will measure the consumption by the kilowatt-hour, the same as your local utility, and then show the operating cost of your appliance or, in my case, an equipment rack full of IBM equipment. The display calculates the immediate cost and forecasts what it will be by the week, month, and year.

When I plugged the IBM equipment rack into the Kill A Watt® EZ, the numbers stunned me. The projected cost of operating the rack exceeded \$100 per month. Today, you can buy a lot of streaming music and cloud services for much less than half of that. Since the equipment was all fully depreciated and of no further interest to IBM, I sold the equipment on eBay for a modest amount. Reducing the amount of energy can not only save money, but also save the environment. I donated the eBay proceeds to Carbonfund.org to help offset my carbon footprint.<sup>72</sup>



Figure 5. Kill A Watt® EZ. By P3 International.

The Kill A Watt® EZ only measures the energy used by devices plugged directly into the meter. There is also good reason to monitor the total amount of energy used for everything in the home. This could enable you to see the collective effect of using home automation to turn unnecessary lights off and removing or replacing inefficient appliances.

Aeon Labs, was founded in 2006 and is based in Silicon Valley, California. The company designs, develops, and manufactures products for home automation. The company describes its technology as, “Designed to improve the pleasure we derive from the home and office spaces in which we spend most of our time, and to save energy.”<sup>73</sup>

An example of the latter goal is the Aeotec Home Energy Meter. When connected to your home electrical panel, the device will monitor the total consumption of electricity used by your home. See figure 6 for a picture of the Home Energy Meter. The device reports your energy use to your home automation hub real-time, so you can see how much total electricity you use and when you use it.

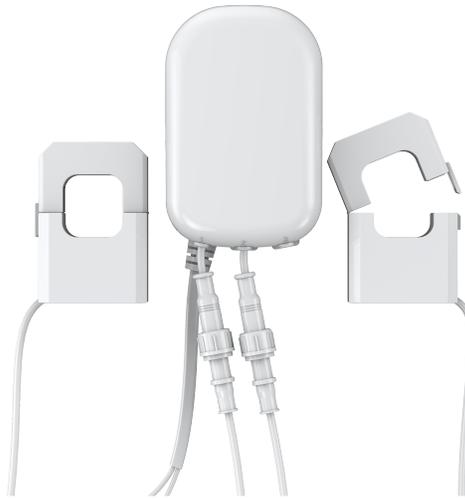


Figure 6. Aeotec Home Energy Meter. By Aeon Labs.

The Home Energy Meter must be wired into your electrical panel. This should only be done by a professional electrician to ensure a safe installation. The electrical usage data is transmitted to your hub up to 300 feet away via wireless communication. Once you have the data, there is a lot you can do with it. You may want to see a daily, weekly, or monthly email showing the usage. You can compare your monthly usage with what your electricity provider charges you. Most importantly, you can see the effect of your efforts to use energy efficiently and save as much money as possible.

Cambridge, MA based Sense has developed a home electricity monitoring system which can identify how much energy each individual home device is consuming. The Sense Home Energy Monitor can be installed into your electrical panel like the Aeotec product. It monitors electricity consumed by home appliances, and can identify them uniquely based on algorithms it has developed.<sup>74</sup> See figure 7. The company provides a specially designed mobile application to allow consumers to see appliances which may be defective or using electricity excessively. At a cost of \$299 for the device plus professional electrician installation cost, the Sense monitor may take some time to pay for itself through saved electricity.



Figure 7. Sense Home Energy Monitor. By Sense

### **Backup Generator**

The family vacation cottage in the mountains of Pennsylvania endures a lot of power outages. It is in a remote area with above ground power lines which are vulnerable to wind and storms. In 2007, I decided to invest in a propane powered backup generator. Founded in 1959, Generac was the first to develop affordable home standby generators, and they claim to be the #1 manufacturer. I found a local contractor who was able to install the generator on a concrete slab under an elevated storage shed in my side yard.

The generator I selected only covers critical areas of the home: refrigerator, heating system, the most important lighting and outlets, security system, cable modem and router, and the home automation system. One nice feature of the generator is an automatic weekly test cycle. On the day and time you select, the generator runs for 15 minutes and then shuts down. The weekly exercise of the engine prevents its oil seal from drying out and damaging the generator. It also provides some charging of the starter battery.

The weekly engine exercise works well, assuming the battery can start the engine. If I am not at the cottage, I have no way of knowing if the weekly exercise occurred. I have had several occasions over the past five years where the exercise did not occur because the battery was dead. A power failure occurred, and the generator did not do its job. I got a freeze warning message from my home automation system and, fortunately, my neighbor was at home. He checked the home and found the power had been restored. A contractor came later and replaced the worn-out battery.

Although I have avoided catastrophes, I concluded there must be a way to monitor the generator and be sure it was able to make its weekly run. Generac offers a \$279 Mobile Link™ Remote Monitoring feature which allows you to monitor the status of your generator from anywhere using a smartphone, tablet, or desktop app. It is a well-designed feature, but it is expensive and it is not available for any generators older than 2008 (mine is 2007). Replacing the generator would be very difficult and expensive.

There must be a way some home attitude could be applied to the problem. I tried several experiments with the home automation system and developed a solution. I purchased an inexpensive wireless vibration sensor and used Velcro® to attach it to the top lid of the generator. When the generator runs on Saturday morning, the sensor detects the vibration and sends a wireless signal to my home automation hub in the smart home. The signal causes a trigger which, in turn, starts an action which sends me an email saying, “The generator just started”. I created a variable in the hub called Generator Ran and set the value to “No”. When the generator runs, the hub sets the variable to “Yes”. An hour after the generator was supposed to run, the hub checks the variable. If it is still “No”, I get an email saying, “The generator did not run”. I can then take appropriate action.

### **Fuel Oil**

The level of oil in a fuel oil tank has historically been measured with wooden or metal dipsticks, tank clocks, dial gauges, or floats inside the oil tank. Innovation is long overdue, but Stutensee, Germany based Inno-Tec GmbH has filled the gap with an innovative product called the Proteus EcoMeter.<sup>75</sup> The EcoMeter uses ultrasonic technology to measure the level of fuel in an oil tank. The company says the ultrasonic technology provides measurements up to 10 times more accurately than comparable mechanical or electronic measuring devices. Fuel oil suppliers can monitor the filling level in the tank accurately without having to open the tank, thereby avoiding spills.

Ultrasound refers to sound waves with frequencies much higher than what humans can hear. The concept behind ultrasound is quite simple. The sound waves are emitted and they travel until they hit something and bounce back. By measuring the time of the round trip, it is possible to measure the distance. It is used in many applications. The Tesla Model S was the first car to use ultrasound for long range sensing. Elon Musk, South African-born Canadian-American business magnate, investor, engineer, and inventor, said the Tesla ultrasound system is, “long-range, offers 360-degree coverage, and establishes a protective cocoon around the car. It can see anything: a small child, a dog. And, it can operate at any speed.”<sup>76</sup>

The Proteus EcoMeter consists of a long life, battery-operated, ultrasonic sensor which can detect the level of fuel in a tank. It has a digital radio receiver which is equipped with an easy-to-read LCD display. The transmitter can send the tank level nearly 500 feet to the display. See figure 8 for a picture of the LCD display. The EcoMeter is nicely designed for the consumer. There are no mechanical parts needed to be installed inside the tank and there is no wiring required. The company has sold more than one million EcoMeters in Europe. The cost is approximately \$150.

The EcoMeter can enable you to conveniently monitor your fuel oil level anywhere in the home, and it can be tied in to a home automation system. Adding the home attitude factor enables you to have schedules to check the fuel level at predetermined times. Actions can send you text messages when the fuel is low or when a delivery is made. In the winter, you can combine the fuel oil level with your morning home audio Good Morning greeting.

The EcoMeter monitoring provides more than simply the fuel level. It shows the remaining amount and percentage of fuel in a graphical display, plus it displays the

average consumption per day, week, month, and year. The system provides cold weather warnings, a battery status alarm, and a heating cost overview. An additional feature is the monitoring of CO<sub>2</sub> emissions.



Figure 8. EcoMeter for Fuel Oil. By Proteus.

### **Propane**

Propane and natural gas expenditures, on average, are 36% less than for fuel oil.<sup>77</sup> Nevertheless, it could be useful to monitor the usage to see the effect of changing thermostats or other energy saving strategies, rather than wait for the bill. Natural gas supply is theoretically infinite, but with a propane tank, it would be good to know when it is running low and when a delivery has been made.

Monitoring of natural gas and propane gas can be done technically, but there are barriers to putting the necessary equipment in place. Companies which make monitoring equipment focus on businesses who have multiple locations and tanks. Their equipment and services are not affordable or justifiable for most consumers. Connecting sensors to tanks or gauges requires some form of electrical connection, and using the words gas and electricity in the same sentence raises significant legal liability issues. In the case of natural gas, it is usually provided by a city or township, and they specifically prohibit the attachment of anything to their gas lines, even inside your home.

Eventually, propane tanks and natural gas meters will probably include a Wi-Fi connected sensor which provides continuous monitoring. However, because of the legal

liabilities and utility company restrictions, there are few if any licensed electricians or plumbers looking for monitoring installation business. Until monitoring becomes a standard feature for propane and natural gas, the only way to install a home attitude for energy monitoring is the do-it-yourself approach.

Joe Thomas, a senior software developer at Bloomberg in New York, had been looking for a solution to remotely monitor the level of propane gas in outside tanks at a family vacation home in upstate New York for years. In 2015, he gave up waiting, and decided to create a monitoring solution himself. He developed an approach which has worked reliably for more than two years. Joe can see the percentage full of his propane tank on his smartphone. He also gets text alerts when the level passes thresholds he chooses, such as below 25% or 10%. He gets a text message when the propane company refills the tank so he can prepare to pay the impending bill. More importantly, he gains the comfort to know he can go to his vacation home in the winter and not worry about encountering an empty propane tank.

Joe's solution is not for the faint-hearted. It involves installation of two special hardware items and some expertise with a soldering gun and test equipment. The electronic parts cost approximately \$150. Joe is quick to note he is not an electrician or plumber, and he cautions do-it-yourselfers to implement at their own risk. See <http://www.rochestergauges.com/pages/locations.html> for technical details on the equipment Joe used to develop his elegant solution to detect the level of gas in the propane tank.

At my home, I have two propane tanks buried underground in the backyard. The tanks provide energy for the outdoor grill, kitchen stove, ovens, clothes dryer, hot water, fireplaces, radiant heat in the floors, and a 25,000-watt backup generator. Being so dependent on propane is the reason for two tanks. I had the Viessmann furnace inspected after 15 years, and the service technician told me it was, "Clean as a whistle". Although, over those years, propane may have been slightly more expensive than fuel oil, the total cost, including servicing, has likely been less.

The propane provider, the home automation contractor, and I designed some home attitude into the propane installation. The tanks share a monitoring sensor like what Joe Thomas used. It was installed professionally. The sensor is connected to a small control panel in my basement via an underground cable. The panel is wired into the home automation hub. I can monitor the level of propane on home keypads or remotely via iPhone and iPad.

I can get alerts if the level runs low, but I don't have to worry because the propane provider is monitoring the tanks also. Between two and three AM every morning, a small telephone panel, which is connected to the control panel, places a call to the provider and reports the propane level. When the level gets low, the provider dispatches a truck to deliver propane. This provides benefits to both the propane provider and to me. I like it because it minimizes the number of times the truck ties up my driveway, and the driver must drag a substantial hose through a garden gate and across the lawn. I also get fewer bills to pay than otherwise. The provider likes it because fewer propane deliveries adds efficiency to his operation.

## Natural Gas

Because of the restrictions imposed by city or township, which specifically prohibit the attachment of anything to their gas lines, natural gas monitoring is more challenging than propane monitoring. Poul-Henning Kamp, a Danish computer software developer, decided to take on the challenge. He lives in Slagelse, Denmark and is known for his work on various global software initiatives. He has contributed to many open source projects which have improved the quality and security of the Internet. Poul-Henning is a highly accomplished technical expert in many areas. Unfortunately, at this stage, it takes such talent to figure out how to monitor natural gas usage in the home.

Paul-Henning discovered the gauge on his natural gas line incorporated some technology inside which could be used to monitor the usage, but the utility forbids anyone from tinkering with it. Upon closer examination, he noticed the rightmost zero on the gauge was metallic and colored, and he got the idea to find an optical sensor which could recognize the zero. He then designed some electronic circuitry to pick up the signal from the sensor and transfer it to his computer using a modified printer cable. Poul-Henning implemented his innovation in 1996 and has used it to gather a lot of data.<sup>78</sup>

I asked Poul-Henning if he was optimistic about some mainstream monitoring technologies to emerge soon. He said, “Not really. Something new will have to be devised.”<sup>79</sup> He sees a solution like what Joe Thomas devised as a possibility for monitoring in the future.

Although Poul-Henning is not optimistic about the near-term availability of inexpensive, easy to use, accurate, and meaningful monitoring technology, he does see monitoring as potentially quite helpful. “If you want to reduce natural gas usage, you have to monitor it.” He said, “Natural experiments all over the world have shown up to 10-15% reduced usage, if meters are visible as part of your daily routine, as opposed to being hidden away somewhere.”<sup>80</sup> Getting a continuous stream of data from monitoring is theoretically useful, but in practice the data can be hard to interpret correctly.

Poul-Henning believes monitoring data can be useful as a corollary to weather data. For example, by combining the data with wind direction data, it can help plan for where more insulation of your home may be effective in reducing heating needs. See figure 9 for an image of a two-year time-exposure taken by measuring how much sunlight hits various parts of his roof solar panels. It shows which trees shade the panels, and thereby limit the efficiency of his solar heat.

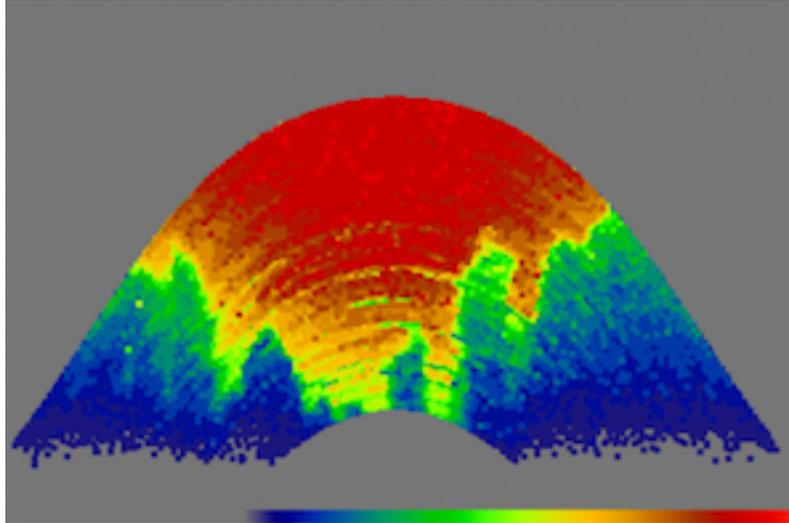


Figure 9. Time Exposure Image. By Solar Panels

Poul-Henning Kamp is a true believer in monitoring everything he can. He has thermocouples to measure the temperature under his home foundation, the heating unit, ventilation system, and at his solar electrical panel. He also has electrical meters on all appliances, and sensors on water, electricity, heating, solar panels, and other things. He enjoys being creative with monitoring and then enjoying the study of his data. He has clearly demonstrated a home attitude, and has set the bar quite high for the rest of us.

### **Water**

The koi pond in our back yard is in open space. There are no trees in the area tall enough to prevent the sun from beating down on the pond and causing algae to thrive, it also causes water to evaporate. The pond has a small waterfall powered by a submersible pump. If the water level gets too low, the pump will gasp and eventually burn out.

There are numerous types of water level sensors which could enable me to monitor the water level, but I decided to take a different approach. I had a plumber but a PVC water line from our basement, under the ground, and into the pond. He put a solenoid valve in the water line in the basement, and I connected the wire cable from the valve to the home automation hub. Rather than automatically sensing the water level of the pond and having the hub turn on the water, we setup a daily schedule. For example, every day at 3 PM, the water would turn on for 10 minutes. We got to know the right time and amount from experience, and the system worked just fine.

However, we started to notice there was not enough water in the pond. We upped the time limit to add more water, but the level continued to be too low. We summoned the pond contractor, and he discovered there was a leak in the rubber mat which lines the bottom of the pond. The water was running into the ground. As it turned out, I am glad we did not have a water level sensor and automatic filling. We may not have noticed the problem and wasted an excessive amount of water. The excess may also have worn out the well pump, while wasting a lot of electricity in the meantime.

Saving water can be good for your budget and a good thing for the environment. Lake Wylie, South Carolina based FortrezZ, has a product called the Flow meter.<sup>81</sup> It connects to your water intake plumbing and sends data to your home automation hub to help you manage water consumption and detect water leaks in your home. Flow Meter tracks water usage and reports gallons used. You can track household water usage and see where your peak consumption is. Flow meter checks the temperature nearby, for example in your basement, to detect freezing conditions and sends temperature alerts. Flow meter tells you if water is flowing or if it's off. It knows if the flow is small, like a running toilet, or if it's large, like a garden hose left on. You can create triggers in your home automation hub to provide alerts. For example, you can create an action in your hub to automatically turn off water if too much water is flowing, or automatically turn water off if it has been running for too long. You can also set limits to turn water off when a set number of gallons have been used for the day.

### **Summary**

In this chapter, I discussed several aspects of home utilities, including electricity, propane, natural gas, fuel oil, water, and backup power generation. I also described techniques for monitoring these critical resources. Not only can monitoring give you piece of mind from knowing what is going on in your home, it can also help you save as much money as possible as a result. Something else to monitor is the weather.