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A Living Laboratory Product Function Assessment
Residential Energy Display Devices

The Energy Detective TED-1000

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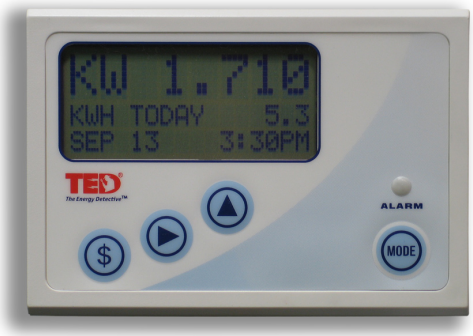

Introduction

Consumers typically have little idea of how their household activities and appliance use affect energy consumption, and its cost and environmental impact. Providing households with information that allows them to better understand when and how they use electricity may induce desirable changes in the level and profile of electricity consumption.

If this is the case, understanding the cost/benefit of investments in information delivery processes and devices is necessary. The alternatives are diverse, ranging from more detailed billing data, to installing and operating technologies that provide consumers with instantaneous and detailed feedback through in-home displays.

For the 2007 Energy Efficiency Initiative, the EPRI Living Laboratory undertook a first step in conducting research on display devices: identifying available products and testing their functional performance. These tests do not address customer behavior in response to the displayed information; the goal is to develop information that can be used for field tests and deployments of such devices in multiple utility territories.

Varieties of devices are commercially available; the EPRI Living Laboratory identified sixteen as of late 2007. Some take power measurements independently of the utility meter while others read power data directly from the meter. Commonly displayed information includes power consumption, energy usage, cost per hour, and a predicted electricity bill. Retail prices vary from about $100 to several hundred dollars.

This assessment is of a display device called The Energy Detective, from Energy, Inc.

Summary of Functions

Collectively, real-time energy display devices are intended to provide functions which may include the following:

- Provides status on electricity consumption (and presumably increased customer awareness of electricity use)
- Provides cost of operating electrical appliances (and presumably increased awareness on by customers on what appliances cost the most to operate)

Objectives

The intent of assessing residential energy display devices is to evaluate the functionality of these devices, and map their functionalities to industry needs as it relates to the

Energy Efficiency Initiative. The main objectives for evaluating residential display devices include the following:

- Physical specifications (Product Overview section)
- Metering interface and measurement options (System Architecture section)
- Installation details (System Architecture section)
- Electricity rates and tariff options (Functionality section)
- Accuracy of readings and measurements (Performance section)

Product Overview

Energy, Inc., a Charleston, South Carolina company, makes a residential energy display device called The Energy Detective (model TED-1000). EPRI purchased one TED-1000 in July 2007 for testing in the Living Laboratory. General product information is provided in Table 1.

Table 1. Product Information

Manufacturer	Energy, Inc.
Company web link	www.theenergydetective.com
Product Name and Model	The Energy Detective, TED-1000
Product Category	Residential energy display device
Product Status and Availability	Available, in production; patented
Retail price for one unit	$140
Warranty	1 year limited

The Energy Detective, like other display devices with similar functions, is designed to help people understand how changes in their behavior affect energy use and their monthly bill. In addition to providing a snapshot of a home's current energy consumption and cost, The Energy Detective projects monthly bills, logs historical data, and provides alarms to alert occupants of high energy use and cost. The physical specifications of The Energy Detective are provided in Table 2.

Table 2. Physical Specifications

Display screen type	LCD (black on grey)
Display backlight	No
Character height range	0.25 to 0.5 inches
Mounting	Wall and/or desktop stand
Operating environment	Indoor
Device power source	120 V AC
Approximate battery life	No batteries required
Data retention during power outage	Yes

Test Environment

The Energy Detective is connected to the main power source that powers EPRI's Living Laboratory in Knoxville, Tennessee. The Living Laboratory is powered by a 240 V split-phase residential transformer rated for 200 A service. All residential display devices, including The Energy Detective, are monitoring electrical loads connected to the Living Laboratory, including:

- 8 incandescent lamps
- 2 fluorescent fixtures
- 5 compact fluorescent down lights
- 0.75 hp fan motor
- 5,000 Btu air conditioner
- Several plug loads (network switch, computer, gateway equipment, etc.)

The display devices brought into the Living Laboratory are verified for operation according to the manufacturer's specifications. Furthermore, accuracy of each display device is compared to a revenue-grade power quality meter (Square D ION 7300). The accuracy measurements are taken at varying load points that account for both resistive and inductive (motor) loads. These measurements are provided in the Performance section.

System Architecture

The Energy Detective calculates power and energy from current and voltage measurements. A functional diagram is shown in Figure 1 to illustrate where and how the power measurements are taken. Each current transformer (CT) may be clipped around any selected wires within the circuit breaker panel, allowing monitoring for an entire house or individual circuits. The voltage measurement is taken from the wall outlet. The display device calculates cost from a predefined rate structure, entered by the user or installer. (The TED-1000 measures true root means squared (RMS) power, accounts for power factor, and is listed by the manufacturer as having ±2 percent accuracy.)

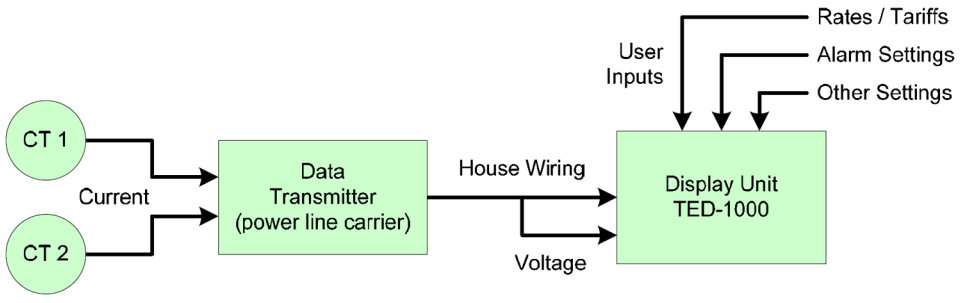

Figure 1. The Energy Detective Functional Diagram

Metering Interface and Measurement Options

The Energy Detective does not interact with the utility meter in any way. For power and energy measurements, the TED-1000 relies exclusively on its own sensors for measuring at the circuit panel for its specified accuracy. A summary of metering and measurement specifications is provided in Table 3.

Table 3. Metering and Measurement Specifications

Utility meter interface options	None
Measurement source	Circuit breaker panel/indoor house wiring
Measurement sensors	2 current transformers; 1 line voltage (from wall outlet plug)
Data transmission method	Power line carrier
Interference with other devices/systems*	No interference with other home automation products
Energy measurement accuracy*	±2%
True RMS measurement	Yes
Accounts for power factor	Yes
Reaction time/update speed*	2 sec

** Data according to manufacturer's specifications*

Installation Details

The currently available model, TED-1000, must be connected to a home's circuit panel in order to measure whole-house energy consumption. The TED-1000 comes with two CT's that are intended to clip onto the main power lines feeding the circuit breaker panel. Alternatively, these CT's may be clipped onto branch circuit wires for circuit-specific measurements. Because the main circuit panel cover must be removed, Energy, Inc. recommends that an electrician or well-qualified homeowner install the device.

Energy, Inc. includes the data transmitter with the TED-1000 package and refers to it as the "measuring transmitting unit." As shown in Figure 2, the data transmitter collects current measurements from the CT and transmits this data into the circuit panel using powerline carrier. The data transmitter requires one unused/spare 15 A or 20 A circuit breaker to be used to connect the transmitter. The current data is distributed throughout the house, allowing The Energy Detective to be plugged into any outlet to receive a complete set of measurements. As of March 2008 , EPRI had not determined if the display unit and data transmitter would communicate across different phases within the same household.

An initial setup is required for proper operation of The Energy Detective. The installer must program a three-digit code into the device in order for it to communicate with the data transmitter. Additionally, the electricity rates/tariffs must be programmed for cost estimates that mimic the customer's electric bill.

Functionality

The primary objective of the display device's functionality is to provide an accurate and user-friendly interface for displaying household electricity usage and associated costs. Since the pricing information is manually entered by the user or installer, that person must know what rate structures and tariff options

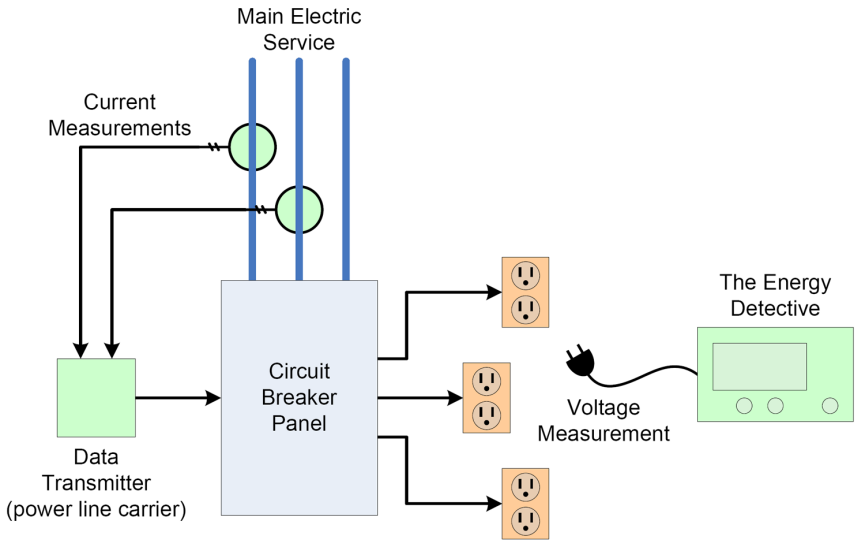

Figure 2. The Energy Detective Installation

the device will support. EPRI also evaluated other functionalities: alert options and displayable output options.

Electricity Rates and Tariff Options

The Energy Detective supports many manually programmed tariff structures:

- Flat or fixed rate
- Tiered rate (up to 5 tiers based on monthly energy use)
- Time-of-use rate (two unique peak rates for morning/evening times)
- Seasonal rates (summer and winter)
- Demand charge (penalty for exceeding a maximum power level)

More complex rate structures may also be defined by combining the above tariffs. For example, a user can program a tiered rate that includes both peak and off-peak charges for both summer and winter seasons. Other charges that may be programmed into the device are the following:

- Energy surcharge (a percentage added to energy charge)
- Sales tax (a percentage added to entire bill)
- Fixed monthly charge (for recurring monthly costs)
- Minimum monthly charge

The TED-1000 does not support net metering, meaning that it will not be able to monitor power that is delivered to the grid from the customer, such as with photovoltaic cell installations.

Alert Options

Another functionality of The Energy Detective is its ability to alert the user with visual and audible alarms for six different conditions. Each alert condition is pre-programmed by the user or installer and includes alarms for the following:

- Exceeding a cost per hour ($/hr) limit
- Exceeding a power (kW) limit
- Exceeding a monthly cost ($/month) limit
- Exceeding a monthly energy (kWh/month) limit
- Exceeding a high voltage limit
- Falling below a low voltage limit

Displayable Outputs

The Energy Detective displays a variety of options for viewing electrical and cost data. While the screen can display only three lines of information, the user may select several screens to view other usage data. The viewable data sets include real time or instantaneous data, daily data, and monthly data (per billing cycle). The entire list of displayable output options are shown in Table 4.

Communication Protocols

The TED-1000 supports only a proprietary communication link between the data transmitter and the display device. According to the manufacturer, the communication link (power line carrier) will not interfere with other home automation systems that also transmit data across household wiring, such as X-10 systems.

Standards

According to the manufacturer, the current model of The Energy Detective does not support any industry-wide standards. The device operates independently of the utility meter and is an entirely self-contained system.

Performance

The Energy Detective performed as specified by the manufacturer in terms of general operations. The device, after it was installed according to the manufacturer's directions, worked properly for all functionalities identified in the Functionality section. The accuracy measurements shown in this section are relative measurements compared to measurements from a digital revenue-grade power quality meter (Square D ION 7300). Thus, the display device's absolute accuracy is not represented by the values shown.

Table 4. Display Output Options

Instantaneous data (limited by reaction time):	
Power consumption (kW)	Yes
Energy cost per hour ($/hr)	Yes
Line current (A)	No
Line voltage (V)	Yes
Energy rate currently in effect ($/kWh)	Yes
Carbon emissions per hour (kg/hr or tons/year)	No
Daily data:	
Energy consumed today (kWh)	Yes
Energy cost today ($)	Yes
Monthly data (per billing cycle):	
Energy consumed this month (kWh)	Yes
Energy cost this month ($)	Yes
Peak electrical demand this month (kW)	Yes
Peak cost per hour this month ($/hr)	Yes
Minimum/maximum line voltage this month (V)	Yes
Projected energy use for end of month (kWh)	Yes
Projected energy cost for end of month ($)	Yes
Days remaining in current billing cycle	Yes
Other items displayed:	
Alarm visual indicator	Yes
Alarm audible indicator	Yes
Historical data retention (days or months)	Yes, 2 months viewable
Date and time	Yes
Temperature	No
Humidity	No
Countdown timer	Yes

Accuracy Measurements - Energy

The values charted in Figure 3 represent energy measurement accuracy testing in the Living Laboratory over many days of continuous power consumption. The energy measurement test spanned two weeks where the average power consumption of the Living Laboratory was kept above 1.0 kW. The exact loading during this two-week trial varied from less than 0.1 kW to over 4.0 kW, and the average power factor was above 0.95.

Two horizontal lines are shown in Figure 3 that represent ±5% accuracy relative to a revenue-grade meter. The Energy Detective maintained 1% accuracy or better for energy measurements throughout the entire trial.

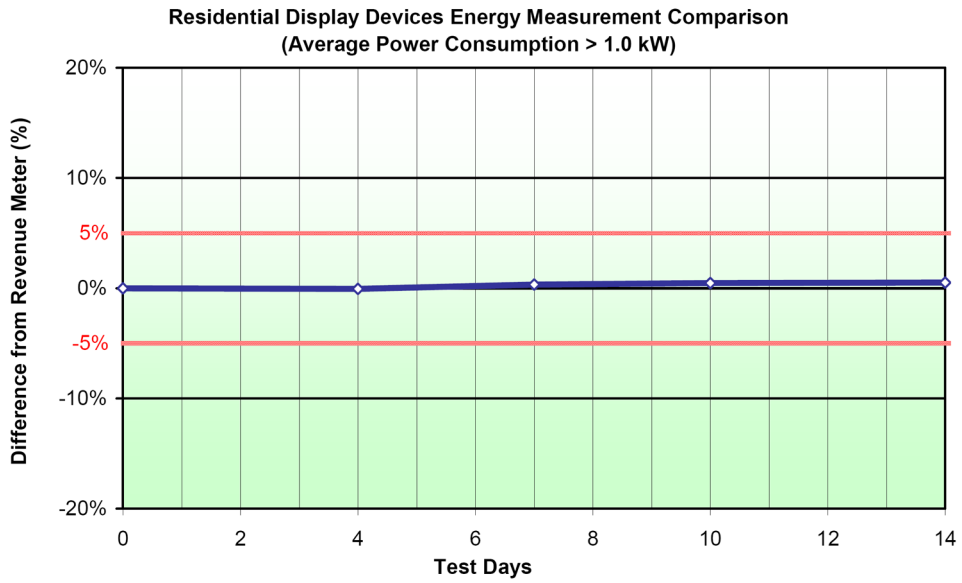

Figure 3. Energy measurement comparison

Accuracy Measurements - Power

Power measurements were taken for The Energy Detective under two controlled tests, of which both were administered independently of the energy measurement test. The first power measurement test involved adjusting the electric power loading in the Living Laboratory from 30 W to 3,000 W with a power factor greater than 0.9. These power levels were obtained primarily by adjusting the lighting loads. The fan and air conditioner were turned on only at the highest power levels. Fifteen data points were taken in this range, and each sample is graphed in Figure 4.

The Energy Detective, like other display devices that measure power directly (by using CTs) exhibited significant error – up to 67% difference from the revenue meter – at power levels less than 200 W. Such extreme measurement error is to be expected at low power levels because the magnetic coupling of the CTs is poor at low currents. The CTs included with most display devices are rated for 100A, and accurate readings when the current is below 1 or 2 A (or below 100-200 W) should not be expected.

The second power measurement test mimicked the first power measurement test except that the power factor was kept below 0.8. This was accomplished by powering the fan motor, air conditioner, and computer; and by eliminating all lighting loads. Twelve data points each were taken in this range, and each sample is recorded in Figure 5.

By powering large inductive or non-linear loads, the power factor will decrease and could contribute to the error in a display device's power reading. Common household loads that would decrease the power factor include air conditioner compressors, washing machine motors, refrigerator compressors, and personal electronics that are not power-factor corrected.

The Energy Detective maintained better than 5% accuracy for power measurements above 200 W in both power measurement tests. It should be noted that The Energy Detective is more accurate at report-

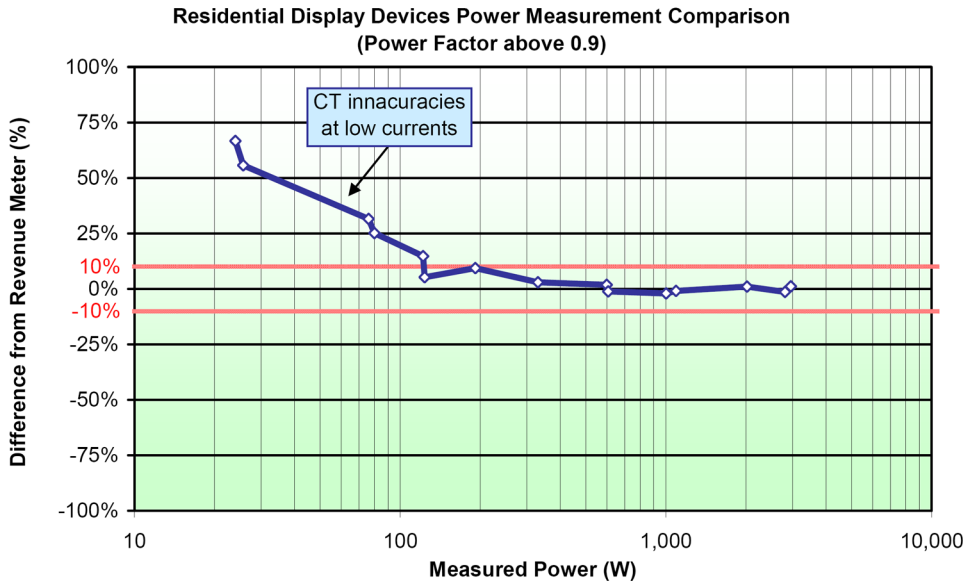

Figure 4. Power Measurement Comparison, Power Factor > 0.9

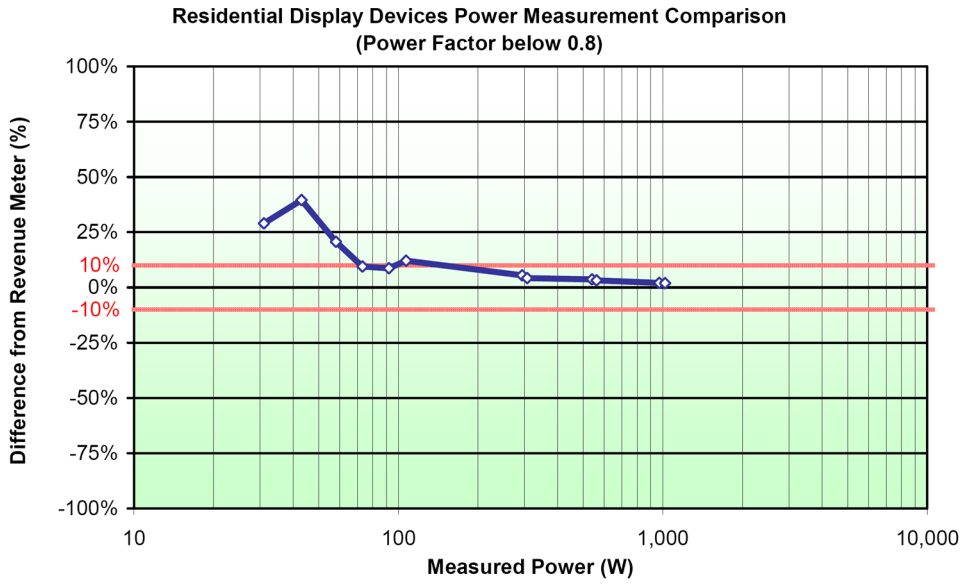

Figure 5. Power Measurement Comparison, Power Factor < 0.8

ing energy values than power values. Power measurements are taken as an instantaneous reading. Thus, the displayed power values will vary each time the display device updates the screen. Energy values, on the other hand, are not displayed as instantaneous readings because energy measurements must be taken over a given time period and accumulate "slowly" relative to power readings.

Vendor Support

EPRI purchased the TED-1000 from Energy, Inc. and encountered no lead-time for this single purchase, as the TED-1000 was available immediately for processing and delivery. Energy Inc. offers a one-year limited warranty on the TED-1000 and all other TED branded products. This warranty is only for products sold in the United States and Canada. As of March 2008, EPRI had not determined if Energy, Inc. offers additional technical support to utilities (or homeowners) that buy The Energy Detective

Energy Inc. reported in March 2008 that it plans to introduce upgraded models and related products in the near future. Three Energy Inc. products will be included in the Energy Efficiency Initiative product database: TED-1000 (available now), TED-1001 and TED-5000 (available in 2008). The TED-1001 will be an upgraded model that adds open-architecture computer connectivity and branch circuit monitoring capabilities. The TED-5000 will be a home energy management system that allows the homeowner and/or utility company to communicate remotely to the system (includes control for HVAC and other electrical devices). As of March 2008, Energy Inc. had not released information on the specific communication protocols or standards that the TED-5000 may support.

Issues

EPRI has identified two issues with the TED-1000. First, the LCD display does not have a backlight, resulting in a display that can be difficult to read in low-light conditions. Second, the display device and the data transmitter should be connected to the same phase wiring. The manufacturer states that the data transmitter could transmit data through the secondary side of a utility transformer across to the second phase, but the device is not designed to operate in this way. EPRI has not yet determined if the device will work when the display unit and data transmitter are connected to different phases within the same household.

Conclusions

Under the Energy Efficiency Initiative, EPRI has verified that The Energy Detective (TED-1000) functions as stated by the manufacturer.

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