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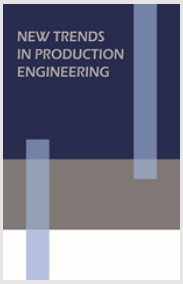

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Addressing Energy Efficiency by Periodical Energy Audits

Wes Grebski
The Pennsylvania State University, USA
Michalene Grebski
Northampton Community College, Monroe Campus, USA
Agnieszka Czerwińska-Lubszczyk
University of Technology and Humanities in Bielsko-Biała, Poland
Dominika Jagoda-Sobalak
Opole University of Technology, Poland

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INTRODUCTION

Energy is indispensable to human existence, and its need is on the increase daily due to technological advancement. Buildings require cost-effective and sustainable solutions (Adewale et al., 2018). The transition of householders towards optimal energy use in the residential sector has proved to be challenging. There are various techniques like for example: energy performance certificates, prompts, norm appeals, commitments, economic incentives and disincentives, feedbacks, community-based initiatives, benchmarking, goal setting and gamification, energy labels and energy auditing (Iweka et al., 2019). Energy auditing is a process for accessing energy usage by individual energy-consuming devices on a residential or commercial scale. An energy audit is a method for determining the most cost-effective measures that improve energy efficiency (von Knorring, 2019). After the energy audit is completed, a diagram can be created which defines the energy consumption by individual energy consuming devices, e.g. refrigerator, washer, dryer, television, heating system, hot-water heater, etc. An energy savings plan follows the energy auditing process (Grebski & Cai, 2010a). First it focuses on *low hanging fruits*, e.g. installation of high efficiency lightbulbs, high efficiency appliances, etc. Insulating the building and changing windows/doors is usually very costly…*high hanging fruits.* They are addressed as secondary measures due to a longer payback time.

ENERGY AUDIT

The energy auditing process can be conducted by a professional energy auditor or by the residents/owners of the property. Hiring an energy auditor can be costly, so many people are willing to conduct the energy audit themselves. The basic equipment used in an energy audit is a power monitor. The power monitor

Contact address: aczerwinska@ath.bielsko.pl

can be purchased for approximately $100 or borrowed from a local municipality or power company. The power monitor is plugged into an electrical outlet. It measures the amount of energy transferred from that electrical outlet to the appliance. This method measures the energy consumption by the individual appliances which are plugged directly to the receptables. It is necessary to make a detailed list of the electrical appliances and devices/gadgets, such as air conditioners, computers, etc. (Grebski & Cai, 2010b). The collected data from the power monitor needs to be recorded in the table. Table 1 contains real data for an energy audit conducted by one of the publication's authors.

Table 1 Energy Used by Existing Appliances

Device	Energy Usage/Hour (kilowatt x hour) kWh	Energy Usage/Month (kilowatt x hour) kWh
Electric Washer	2.25	67.5
Electric Dryer	3	90
Air Conditioner	1.1	264
Refrigerator	.17	122
Microwave	1	12
Computer	.05	18
Stove	2	120
Dishwasher	1.4	42
Toaster	.9	3.5
Electric Water Heater	5	400
Small Appliances (iron, toaster oven, etc.)	.5	10
Lights	2	360

Total Energy Usage/Month: 1509 kWh

The data is from that author's primary residence. The energy usage per hour was measured by using a power monitor.

The exception to this was lights and the water heater because those devices are wired directly (no receptacles). The power consumption for those devices was calculated by multiplying power capacity (printed on the device) by the approximate time of usage per day. There is a need to especially inspect the energy usage by older appliances.

Monthly energy usage was calculated using this equation.

Energy Usage/Month = Energy Usage/Hour x Hours of Usage/Month

An energy audit for lights was conducted as follows:

- Count the number of lightbulbs in each room and determine their power (e.g. 60 W, 100 W, etc.).
- Determine and record the total power (in watts) for each room in the building. Use the following formula.

  (number of bulbs per room in the building) x (watts per bulb) =
  (Total watts per room in your residence)
- Convert watts to kilowatts according to the following formula.

  (Total watts) x .001 = (Total kilowatts)

- Calculate the energy used by the lights in each room according to the following formula.

  (Total kilowatts (KW) per room in your residence) x (Hours per day used) = (Total Kilowatt hours (KWh) per day per room in your residence)
- Calculate the energy used by the lights in the entire building/residence by adding the energy used by the lights in the individual rooms.

Other things to consider during your residential (home) lighting audit as follows:

On the day of the audit, were any lights turned on in unoccupied rooms? Yes
Are light levels too bright, adequate, or too dim in any spaces? No
Were any other lights, such as desk lamps, used in any rooms? No
Are there movement sensors in any rooms? No
Are lights fixtures clean to provide the best light? Yes
Is light available from windows not exposed to direct sun? Yes

ENERGY USED BY MODERN ENERGY-EFFICIENT APPLIANCES

Energy labels are seals or energy efficiency rankings usually found on white goods and appliances. These labels attract the attention of consumers to the energy information of the product and helps the consumers to make better choices when acquiring appliances. (Iweka et al., 2019) Modern energy-efficient appliances have an energy-efficient sticker as shown in Fig. 1.

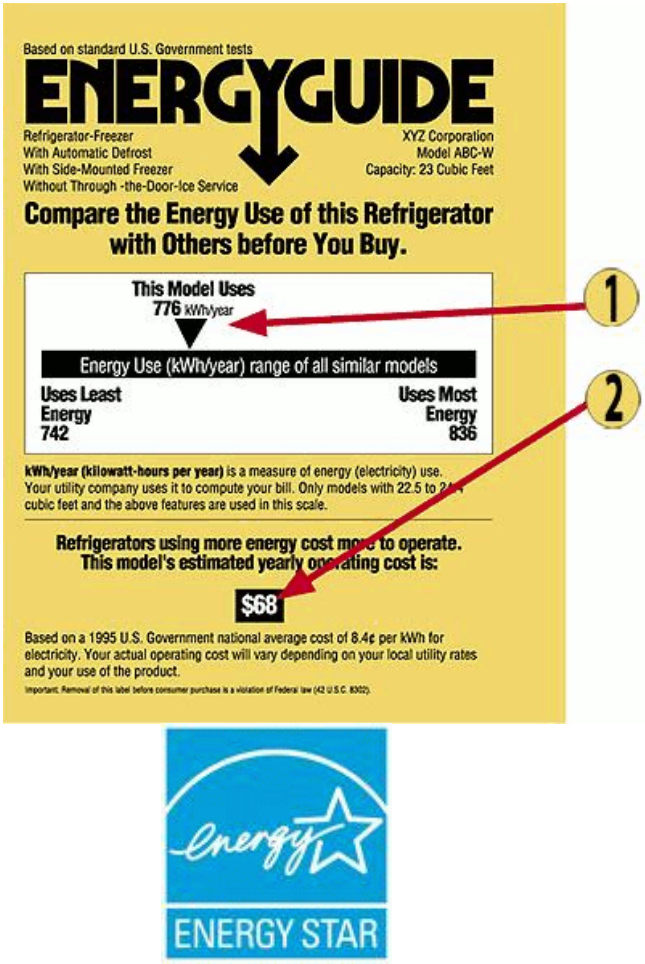

Fig. 1 Modern appliances energy-efficiency sticker used in United states of America

Table 2 contains the energy usage by modern appliances. The yearly energy usage was taken from the energy-efficiency stickers. The cost of the appliances includes the price, sales tax and delivery. This data was collected from an appliance distributor.

Table 2 Energy usage by modern appliances

Appliance	Energy Used Yearly (kWh)	Energy Used Monthly (kWh)	Cost to Purchase
Electric Washer	109	9.1	$600
Air Conditioner (wall unit)	890	74.2	$350
Refrigerator	505	42.1	$1400
Dishwasher	194	16.2	$650
Electric Water Heater	4700	391.7	$350
Freezer	357	29.8	$600

Appliances have energy efficiency stickers. The yearly energy usage was taken from the energy efficiency sticker.
The cost of the appliance includes the price with sales tax and delivery.

ENERGY SAVINGS

Due to today's rising energy prices, the efficient use of energy consumed by facilities is possible with the energy savings that can be made by updating the technology, optimizing and constant controlling. (Hadra et al., 2019). To calculate the expected energy savings, it is necessary to compare the present energy use of existing appliances with the energy use of modern energy-efficient appliances (Grebski & Dudeck, 2013). This comparison of energy use and energy savings is shown in Table 3. The total energy use of the present appliances is 1509 kWh. The total energy saving per month is 646.4 kWh

Table 3 Comparison of energy use and energy savings

Appliance	Age	Energy Consumption (kWh)	Modern Consumption (kWh)	Modern Cost	Excess (kWh)
Electric Washer	15	67.5	9.1	600	58.4
Electric Dryer	15	90	80	500	10
Air Conditioner	10	264	74	350	190
Refrigerator	20	122	42	1400	80
Microwave	12	12	10	200	2
Computer	1	18	18	800	0
Stove	15	120	120	600	0
Dishwasher	20	42	16	650	26
Toaster	5	3.5	3.5	40	0
Electric Water Heater	5	400	380	350	20
Small Appliances	10	10	10	200	0
Lights	10	360	100	50	260
Total	**-**	**1509**	**862.6**	**-**	**646.4**

Comparing the use of energy by the existing appliances with the energy used by newer energy- efficient appliances, it is easy to see where the potential

for energy savings exists. In this sample energy audit, the energy savings for individual appliances have been calculated. (Dudeck & Grebski, 2011).
If all appliance in the house (lightbulbs, air conditioners, refrigerator, washer, dishwasher) were replaced with energy efficient appliances, energy consumption would decrease from 1509 kW/h to 862.6 kW/h. The energy use reduction would be 42%.

Payback Time

The payback time was defined as the time needed to generate energy saving to pay for new appliances. The payback time was calculated as follows:
Calculating the payback time for the replacement incandescent light bulbs with energy efficient light bulbs is as follows:

Lights: Replacement Wattage: 100
Number of Light bulbs: 20

$$\text{Cost} = \frac{(\#\text{ of bulbs}) \times (\text{price per bulb})}{}$$

$$\text{Cost} = 20 \times \$2.50$$

$$\text{Cost} = \$50.00$$

Monthly cost of energy by incandescent light bulbs is 360 kWh x 0.1 $/kWh = $36.00
Monthly cost of energy used by energy efficient light bulbs is 100 kWh x 0.1$/kWh = $10.00

Monthly Energy Savings = Cost of energy for old bulbs –
Cost of energy for new bulbs

Monthly Energy Savings = $36.00 - $10.00

Monthly Energy Savings = $26.00

Payback Time = Cost of light bulb replacement/Monthly Energy Saving

Payback Time = $50/$26

Payback Time = 1.9 months

Appliances: Total Replacement Cost = Appliance Cost
(including sales tax and delivery)

Amount of Energy Currently Used = Monthly Energy Consumption
(Present Appliance/Measure by Power Monitor)

Amount of Energy Used by Modern Appliance = Monthly Energy Consumption
(Energy Star Appliance/Energy Guide Sticker)

Excess energy is calculated using the following:

Excess Energy = (amount of energy currently used) –
(amount used by modern appliances)

Time endured until money is saved (for one appliance at a time) is calculated using the following:

(cost of new appliance)/(former monthly cost) – (new monthly cost) =
# of months

Look at the column with the energy excess use. Compare the use of energy by the existing appliances with the energy used by newer energy efficient appliances. It is easy to see where the potential for energy savings exists (Grebski, et al., 2014). In this sample energy audit, the energy savings for air

conditioners, refrigerator, washer and dishwasher have been calculated. The payback time has also been calculated for those four appliances.

Air Conditioner Payback Time

- Cost of the energy used by the old air conditioner:

  264 kWh x 0.1 $/kWh = $26.40

- Cost of energy used by new energy efficient air conditioner:

  74 kWh x 0.1 $/kWh = $7.40

- Payback time = Cost of New Energy-Efficient Air Conditioner/Monthly Saving of Energy:

  Payback time = 350/($26.40-$7.40) = 18 months

Refrigerator Payback Time

- Cost of the energy used by the old refrigerator:

  122 kWh x 0.1 $/kWh = $12.20

- Cost of energy used by new energy efficient refrigerator:

  42 kWh x 0.1 $/kWh = $4.20

- Payback time = Cost of New Energy-Efficient Refrigerator/Monthly Saving of Energy:

  Payback time = 1400/($12.20 - $4.20) = 175 months (14.5 years)

Washer Payback Time

- Cost of the energy used by the old washer:

  67.6 kWh x 0.1 $/kWh = $6.70

- Cost of energy used by new energy efficient washer

  9.1 kWh x 0.1 $/kWh = $0.91

- Payback time = Cost of New Energy Efficient washer/Monthly Saving of Energy:

  Payback time = $600/($6.70 - $0.91) = 103 months (8.6 years)

Dishwasher Payback Time

- Cost of the energy used by the old dishwasher:

  42 kWh x 0.1 $/kWh = $4.20

- Cost of energy used by new energy efficient dishwasher:

  16 kWh x 0.1 $/kWh = $1.60

- Payback time = Cost of New Energy-Efficient dishwasher/Monthly Saving of Energy:

  Payback time = $650/($4.20 - $1.60) = 250 months (20.8 years)

Environmental benefits

Energy audits are very important for protect environment (Wu, 2019). It could be prepared for very energy-intensive buildings like hospital (Hwang et al., 2019), sports facilities (Kamahina et al., 2019), hotels (Nocera et al., 2019), shipping companies (Knorring, 2019), historic buildings (Mazzola et al., 2019), construction project (Zhang & Zhang, 2019) and also for our houses with operate

24 hours, 365 days a year. The environmental impact based on the energy saved can be calculated by using an *environmental impact calculator* which can be accessed through the following website. http://www.epa.gov/cleanenergy/energy-resources/calculator.html.

CONCLUSIONS

The energy-auditing process can be a very effective method of promoting an energy-saving culture (Grebski, Cai & Anwar, 2010). The understanding of the energy-consumption process by individual appliances in the household is helping in planing a more efficient use of those appliances. Replacing the existing and often outdated appliances can lead to a significant saving of almost 50% of the present energy consumption. A decrease in the energy use is making an important and significant progress in protecting the environment and reducing smog. Energy saving does not normally decrease the quality of life of the residents. Energy efficiency is the most cost-effective method of lowering energy use and protecting the environment. Alternative and sustainable forms of energy should be considered after the energy efficiency is already addressed.

Energy audit, with used “do-it-yourself” procedure are focus on environmentally, economically and socially effective, which contributes to the implementation of the concept of sustainable development.

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Abstract.
The publication focuses on assessing the energy efficiency in residential and to some extent commercial applications. An energy audit is always the first step in addressing energy efficiency. The purpose of the publication is to present the benefits of using an energy audit. It explains a "do-it-yourself" procedure for an energy audit. The publication also focuses on calculating the potential energy saving by updating low-efficiency electric appliances with high-efficient alternatives. The environmental benefits of addressing the energy efficiency of households is also being discussed. An energy audit using a "do-it-yourself" procedure focuses on the economic, ecological and social impact to environment. The energy audit contributes to the implementation of the concept of sustainable development in our day by day life.

Keywords: Energy audit, energy efficiency, energy saving