Energy Center of Wisconsin
Electrical Energy Auditing B4 2013
DRAFT

Typical Electrical Energy Usage by Appliance

Load or Device	Typical (not max) Operating Watts	Typical Standby Watts	Typical KWH/yr	Notes
Kitchen Appliances				
Refrigerator	725		1,000	
Range	1,500		300	Includes microwave
Microwave oven	1,000			
Dishwasher (depends on dryer cycle, water heating) Stds in kWh/yr, for standard size (8 place settings)	1,200		200	
Toaster	1,000		32	
Countertop oven	1,150	0.0	47	
Coffee maker	1,000	1.6	160	
HVAC				
Furnace (blower) for heating and central AC operation	440	20	1,025	
Central AC (excluding furnace blower)	2,500		750	
Room AC	570	<1	150	
Baseboard electric space heating (entire house)			17,000	
Ventilation fan running for 62.2 compliance (conventional fan)			140	
Dehumidifier (based on 50 pint/day capacity)	450	3.2	477	
Air Cleaner (51-100 CADR)			596 (?)	
Electric space heater	1300	<1	315	
Water Heating				
Electric	4500		3,200	
Gas Power Vent			85	
Gas Tankless			25 to 60	
Hot tub			2,500	
Laundry				
Washer	425		55	Savings come from drying
Electric Dryer	3,400		900	

Load or Device	Typical Full Load Watts	Typical Standby Watts	Typ KWH/yr	Notes
Lighting				
Bath(s) (8.9 lamps)	418		242	
Bedroom(s) (8.2 lamps)	385		222	
Kitchen (6.4 lamps)	256		215	
Outdoor (4.1 lamps)	221		214	
Lighting – total (51.4 lamps)	2,364		1,560	
Entertainment				
TV	40 – 325	3	144	3.2 per home
Cable, satellite boxes	25	<1	200	
Compact Stereo	32	4	64	
Radio	4	1.6	9	
Computer & Office				
Tower computer CPU	70	2.4	262	
CRT (old style) monitor	43	1.2	52	
Modern flat screen monitor				
Laptop computer	30	<1	113	
Chargers				
Cordless phone base	1.9	<1	12	
Phone & camera chargers	2.0		11	
Tool & flashlight chargers	13	4	38	
Misc				
Vacuum cleaner	540	0.0	55	
Aquarium equipment	24	0.0	153	
Treadmill	307	6	57	
Well pump	750			
Sump pump	600			

Basic Power & Energy Formulas

Energy

Energy = Power x Time
KWH = KW x Hours = W/1000 x Hours

Power

Power in Watts = V x A x PF
V = Voltage
A = Current (Amps)
PF = Power Factor (1.0 for heating loads, less for motors, compressors, and most power supplies)

ROUGH rules of thumb:

If a load is always on:
kWh/yr = W/1000 x 8,760 Hours = W x 8.76 OR (*roughly*) kWh/yr = W x 10

If a load is always on, and electricity costs $0.12/kWh:
$/yr = kWh/yr x 0.12 = W/1000 x 8,760 x 0.12 = W x 1.05 OR (*roughly*) $/yr = W x 1

If you know the kWh (for any time period):
$ = kWh x 0.12 OR (*roughly*) $ = kWh/10

Energy Consumption Trends (Association of Home Appliance Manufacturers)

Year	Refrigerator kWh/yr	Freezer kWh/yr	Dishwasher kWh/cycle	Clothes Washer kWh/cycle	Room AC EER BTU/hr W
1972	1,726	1,460	4.17	3.81	5.98
1978 or 79	1,453	985	3.23	2.80	6.72
1980 or 81	1,278	883	2.87	2.59	7.02
1985	1058	787	2.72	2.58	7.70
1990	916	600	2.67	2.67	8.73
1995	649	465	2.07	2.22	8.97
2000	704	476	2.00	2.20	9.30
2005	490	442	1.67	1.13	9.95
2010	462	547	1.37	0.66	10.18

Note that increased energy use over time may be due to increased size.

Typical Total Electrical Energy Use in Residences[1]

- Average electrical energy use in U.S. homes about 11,300 kWh/yr
- Average in WI homes is 8,500 kWh/yr (includes multifamily), costing about $1,070 ($0.123/kWh average)
- Highest users - Louisiana and Tennessee, both around 13,000 kWh/yr
- Lowest users - Maine, at 6,300 kWh/yr, followed by Vermont, California, and Hawaii

Appliance specifics

Refrigerator

- Efficiency (based on approx. 19 cu ft auto defrost, top freezer, no other frills)
    - NAECA (Federal) 481 kWh/yr
    - EnergyStar 385 kWh/yr
    - CEE Tier 2 25% less than Federal standard
- Monitoring: measure energy use for 1 or 2 days to get good data
- How to save:
    - Get rid of extra refrigerators if not needed. Remember, the "extra" 'fridge may well be an old, inefficient model, and might use 1,000 + kWh/yr
    - Energy Guide labels and EStar ratings are by type, not across all refrigerators
    - "Energy Saver" switches that control perimeter heaters – careful – ON can mean "Savings ON", or "Heater ON", which have opposite meanings. Turn OFF when not needed (generally needed only during most humid summer weather, if at all).
    - Clean coils periodically

Freezer

- Efficiency (based on 12 cu ft upright, auto defrost)
    - NAECA (Federal) max 475 kWh/yr
    - EnergyStar max 428 kWh/yr
- How to save:
    - Defrost when needed (manual defrost units)

Dishwasher

- Efficiency
    - Pre-2000 estimate 430 kWh/yr, 7.0 gal/cycle (680 kWh/yr total)
    - Federal (May 2013) 307 kWh/yr, 5.0 gal/cycle (485 kWh/yr total)
    - EnergyStar 295 kWh/yr, 4.25 gal/cycle (445 kWh/yr total)
- Ratings assume 215 cycles/yr
- How to save:
    - Run only full loads
    - Use normal wash; high-soil wash probably uses an additional fill
    - Turn off heated drying (est 40 kWh/yr)

[1] 2010 values from U.S. Energy Information Administration

Gas Furnace, including blower power for AC

- Energy use in heating & cooling typically 1,025 kWh/yr for blowers using permanent split capacitor (PSC) motors and 555 for blowers with ECMs. Continuous fan operation adds 3,700 kWh for PSC, 740 for ECM.
- Hours of operation: heating typically 1,000 hr/yr, cooling 300 hr/yr. Continuous fan adds 7,500 hrs/yr.
- ECMs are more generally called Brushless Direct Current or Brushless Permanent Magnet motors. Several variations are appearing on the market.
- Standby power (control circuitry) typically 8 W for furnaces with PSC motors, and 12 W for those with ECMs, adding about 60 to 90 kWh of energy consumption per year.
- How to save:
    - Select ECM when replacing furnace (and might be possible to retrofit)
    - Use continuous fan operation only if there's a compelling reason, and make sure fan speed is as low as practical. Note that HVAC dealers & installers are increasingly promoting full-time fan operation.
    - Replacement furnace with ECM or

Central AC

- Air handler blower power is included in gas furnace, not AC
- ECW study indicates typical central AC run time in Wisconsin is 310 hrs/yr (but with significant differences from northern to southwestern WI)
    - This is about 30% less than would occur if people just set the thermostat and left it all season, because we in the north use AC with some discretion. About 20% of air conditioners are still off when the outdoor temp is 90 F.
- Efficiency
    - Federal standard SEER 13.0, EER 11.0
    - EnergyStar SEER 14.5, EER 12.0
    - Incremental cost for SEER 15 compared to Fed minimum $238/ton
- Savings - Measures
    - Shell energy improvements – insulation & air sealing
    - Seal & insulate ductwork in unconditioned space
    - Purchase high efficiency unit when replaced
- Savings – Behavioral & maintenance
    - Discretionary use, programmable thermostats
    - Reduce loads – close blinds & curtains
    - Close off ducts to basement
    - Night cooling – open windows and ventilate when it gets below 60 F at night
    - Thermostat setting
    - Ceiling fan use
    - Make sure airflow through condenser (outdoor unit) is unrestricted
    - Tuneups (refrigerant charge and airflow adjustment) might save 5% on average, but of more value in some systems
    - Cleaning dirty condenser coils can save a few percent, at no cost

Room AC

- 780 kWh/yr (Energy & Housing in WI)
- Efficiency (based on 9,000 BTU/hr unit, with louvered sides, intended for window mounting)
    - Federal standard 9.8 EER (
    - EnergyStar 10.8 EER
    - CEE Tier 1 11.3
    - Incremental cost for moving from Federal standard to EnergyStar is $40, for CEE Tier 1 is $80
- Energy use: (per IL TRM) 220 hr/yr typ operation in Rockford. See TRM footnote for more detail.
    - Estimate: (9,000 BTU/hr / 9.8 EER BTU/hr W) x 220 hr/yr = 202 kWh/yr
- How to save:
    - Discretionary use

Dehumidifier

- Efficiency (based on 50 pint/day size)
    - Typical 1.14 liters/kWh
    - DOE min 1.60 liters/kWh
    - EnergyStar min 1.85 liters/kWh
- Is there an opportunity?
    - Is it being used through the winter? Necessary to do so?
        - Check ratings of liters/kwh. Higher better,
- How to save:
    - Set humidistat higher (try around 60%)
    - Use seasonally as needed (usually summer and early fall)
    - Keep filter clean

Ceiling Fan

- How to save:
    - Use in summer, not in winter (moving air feels cooler)
    - Savings come from reducing air conditioner use

Water Heater

Electric

- Typical energy use: 3,200 kWh = [(45 gal/day) x (70 F) x (8.33 BTU/gal F) x (365 day/yr)] / [(0.88 efficiency) x (3413 BTU/kWh)]
- Savings opportunities:
    - Use less hot water (low flow showerheads, cold water for laundry)
    - Turn temperature down to about 125 F (will save on laundry, but not for bathing)
    - Tank & pipe insulation
    - Fuel switching to gas

- Pipe insulation savings per IL TRM estimated 123 kWh/yr for R-5 wrap on 5 ft of exposed pipe.
- Tank insulation: Add R-8 insulation to R-8 existing, 200 kWh/yr.
- Low flow showerhead savings example in IL TRM, based on replacing 2.67 gpm w/ 1.5 gpm showerhead, 8.2 min showers, 1.92 showers per day is 468 kWh/yr.

Heat Pump Water Heater

- Note that if EF of conventional electric storage tank water heater is 0.90, that a HPWH with an EF of 1.8 is exactly twice as efficient
- EF should be able to approach 2.0 or a bit higher, but performance in service depends on how much backup resistance heat is used
- Savings ~half, or typ 1,600 kWh/yr
- (IL TRM) The incremental capital cost for this measure is $1,000, for a HPWH with an energy factor of 2.0. The full cost, applicable in a retrofit, is $1,575. For a HPWH with an energy factor of 2.35, these costs are $1,134 and $1,703 respectively
- Problem: Heat pumps steal heat from the basement, nobody knows how much this affects space heating

Clothes Washers

- About 80% of clothes washing energy goes to dryer, 15% to water heating, 5-6% to washer power. High spin speed is the key difference in more efficient washers.
- Efficiency: Modified Energy Factor includes energy use for washer, water heating, and clothes drying. MEF = cu ft / (kWh / cycle)
    - Federal standard MEF at least 1.26
    - EnergyStar MEF at least 2.0
    - Best 2.6 kWh/load
    - Estimated total laundry energy use (washer, hot water, and dryer) for typical existing system 1,160 kWh/yr. Washer only: 0.20 KWH/cycle Full system: Old 4.5 kWh/load
- Typical use 260 cycles/yr
- Savings available for replacing typical existing washer with CEE Tier 1-3 washers is 30 – 42%
- How to save:
    - Replace washer with higher MEF unit (also look for LOWER Water Factor)
    - Use highest available spin speed
    - Use cold water wash
    - Fuel switch dryer to gas

Clothes Dryers

- Usage 2.1 – 3.7 KWH/cycle
- How to save:
    - Use sensors to control drying
    - Consider gas for replacement dryer

- Keep vent clean. Fires in clothes dryer vents cause 2,900 fires, 5 deaths, 100 injuries, and $35M per year on average in the U.S.

Lighting

- Average residential light operates 1.8 hr/day (660 hr/yr), a bit higher in kitchens and outdoors.
- About 60% of residential lamps are incandescent, 25% CFL, 10% linear fluorescent
- Lamps now labeled by lumens in addition to Watts. Lumens/Watt is the "efficacy" (efficiency) of the lamp.
- Technologies
  - Incandescent 12 - 18 lumens/Watt
  - Halogen 16 - 29 lumens/Watt
  - CFLs 60 - 70 lumens/Watt
  - Linear fluorescent 80 - 100 lumens/Watt
  - LED 60 – 70 lumens/Watt
- Options
  - Replace incandescent lamps used more than a couple hours a day with CFLs or LEDs
  - Reduce lighting hours, e.g. outdoor lighting. Replace timers or always-on lighting with motion detector controls.

Television

- Wattage when operating (typical)
  - 36 inch LCD 50 W
  - 29 inch CRT 130 W
  - 42 inch plasma 200 W
- Power varies with brightness (plasma) and backlighting (LCD)
- Typical operation assumed 5 hrs/day for primary set
- How to save:
  - Turn off when not watching (do dogs really like TV?)
  - Unplug old sets with high standby power

Computers

- Power management (sleep or hibernation mode set for both monitor and CPU) - ECW found average savings opportunity of 185 kWh/yr

Behavior change options for reducing electrical energy consumption
[add rules for estimating savings where available]

- Give up the second refrigerator
- Thermostat settings
- Turn off lights
- Use dehumidifier for fewer months, and turn to higher humidity setting
- Don't run furnace blower full time

- Don't leave entertainment devices on
- Well pumps
- Sump pumps
- Attic fans
- Run pool pumps for a limited number of hours each day
- Electric heat
- [Don't grow marijuana]

Purchase options for reducing electrical energy consumption

- Buy new, higher efficiency appliances
- Fuel switching
    - Water heater
    - Dryer
- Electric dryer
    - Automatic moisture sensor controls

Audit & Analysis Methods

Methods

Objective is to estimate kWh/yr for Existing Condition, and for New Condition after improvements are made

- Utility bill graph
- Interview
- Use "typical" kWh as starting point
- Apply historic averages (e.g. AHAM)
- Use Energy Guide labels
- Online information (e.g. CA Energy Commission)
- Inspect appliance labels
- Modeling (primarily heating and cooling loads)
- Monitor operating hours
- Monitor kWh usage

Procedures

1. Start w/ utility bills
    a. Graph usage for a full year
    b. Find approximate average for "low" months (spring & fall)
    c. Additional usage in summer months is a rough estimate of cooling energy
    d. Additional usage in winter months is some combination of space heating (including blower), lighting, water heating, etc., and doesn't tell us a lot

2. Walk-through
    a. Extra refrigerators or freezers?
    b. Dehumidifiers?
    c. Lighting types?
    d. Electric water heater?
    e. Electric dryer?
    f. Energy Guide labels?
    g. Read appliance labels, date of manufacture, ratings (liters/kWh on dehumidifiers)
3. Interview
    a. Laundry: # of loads, hot water use
    b. Dishwasher: use, cycles
    c. Lighting: long on-times, outdoor lights
    d. Air conditioner: controlling gains, thermostat
    e. Dehumidifier: seasonal use, humidity setting
    f. Furnace blower: always on?

- Energy Guide labels
    - Informative – provide estimated kWh/yr for most electric appliances, plus assumptions about number of cycles, etc.
    - Not always helpful, don't e.g. provide MEF for clothes washers
- Candidates for monitoring
    - Refrigerator (especially older) – how much on time?
    - Television (especially older) – how much on time, how many Watts?
- Sleuthing for high standby loads
    - All sorts of miscellaneous loads might have standby power consumption that can add up to real numbers (maybe 100 W)
    - Warmth is evidence of standby loss, also, perhaps, an audible 60 Hz hum.
    - Poking around *safely* with a clamp-on ammeter can be instructive
- Estimate kWh/yr for end use under existing conditions
    - Start with assumed energy use for existing appliances
    - Guesstimates based on age of appliance
    - Modify per Energy Guide label if available, usage reported by occupants, and any other fa

Tools

- Clamp on ammeter
- Run-time loggers (current switch + state logger, or light-activated logger)
- kWh meters
- Split extension cords used with ammeter and current switch

Measurement of Electrical Energy

Basic, handheld meters

- DMM
- Ammeter
- Power analyzer

Monitoring

- WattsUp meters
- Hobo energy monitors
- Continental Controls WattNodes

Calculations

Based on efficiency (can be applied to appliances where the load is assumed to be fixed, and you can get a handle on the approximate efficiency of the old unit and the replacement unit)

Basic principle: Delivered energy = Input Energy x Efficiency

Input Energy new = Input Energy old x (Efficiency old / Efficiency new)

References & Resources

- Energy Center of Wisconsin Plug Load Study
- Energy Center of Wisconsin Dehumidifier Study
- Florida Solar Energy Center Research Highlights from a Large Scale Residential Monitoring Study in a Hot Climate, Danny Parker, Florida Solar Energy Center, 2002
- Florida Solar Energy Center Updated MEL and Appliance Energy Usage Profiles … Bldg America, 2010
- IL Technical Reference Manual

  State of Illinois, Energy Efficiency Technical Reference Manual
  Final Technical Version as of August 20th, 2012
  Illinois Energy Efficiency Stakeholder Advisory Group (SAG), VEIC primary authors
  (Note the TRM is not a primary resource, but is based on compilations and interpretations of research and engineering work from a wide variety of sources.)

Consortium for Energy Efficiency
http://www.cee1.org/
Lists of appliances meeting CEE energy standards, including clothes washers, room air conditioners, refrigerators, and dishwashers

Association of Home Appliance Manufacturers (AHAM)
http://www.aham.org
Fact sheets on a wide variety of topics related to home appliances

California Appliance Efficiency Database
http://www.appliances.energy.ca.gov/

Database allows lookup of rated energy use of several appliance types by make and model number. Includes 7,500 refrigerator models going back to 1998.

Data loggers

Onset Computer
www.**onset**comp.com/
Hobo data loggers (state loggers, light loggers)

Electronic Educational Devices
wattsupmeters.com/
WattsUp energy loggers