Efficient and ZNE-Ready Plug Loads
CPR Meeting

CEC EPC-15-024; LBNL 104713

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Lawrence Berkeley National Laboratory

Project Participants

- LBNL
- UC Berkeley*
- Belkin*
- Power Integrations
- Delta Products
- EPA/ENERGYSTAR

* Subcontractors

Project Goals and Objectives

The goal of this research is to reduce energy used by plug loads in buildings by demonstrating more efficient technologies that use less energy, are powered in different ways and provide additional features that consumers find attractive.

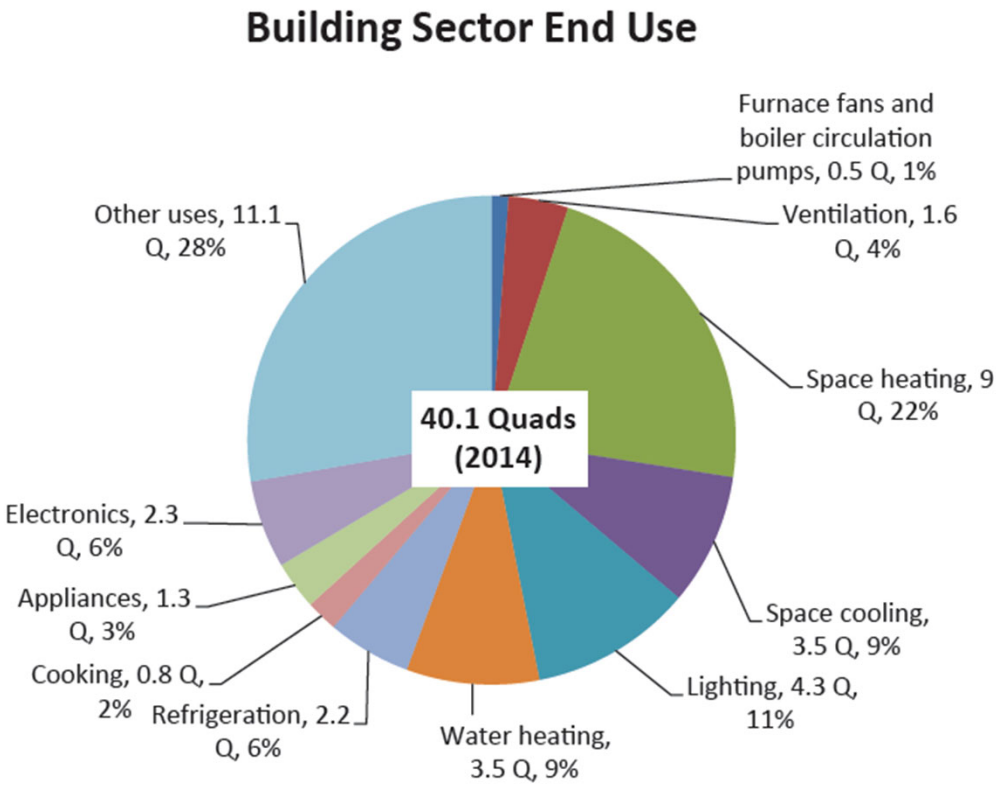
Objectives:

- Develop prototypes of devices that have lower energy consumption, including a power supply with energy harvesting and storage capabilities, DC-powered devices, and energy-saving solutions for safety, security, and medical devices;
- Collect information about plug loads in buildings; and
- Convey to market new technical solutions to reducing plug load energy use.

Background: Types of Plug Loads

- **High usage, but infrequent**
  - Well pumps, aquariums, hot tubs
- **Extensions of traditional end use devices**
  - Local space & water heating
  - Kitchen extensions: rice cookers, kettles, toaster ovens, tortilla makers
  - Some lights
- **Electronics and information technology infrastructure**
  - TVs, gaming consoles, displays, printers, set-top boxes, modems, routers
- **Health, safety, security**
  - "builder-installed" loads, sensors, alarms, mechanical ventilation
  - "Japanese" toilets, exercise machines, oxygen machines
- **Networked products ("Son of standby")**
  - Many of the above
  - Many new white goods
  - Lights
  - Lots of little stuff

The Evidence

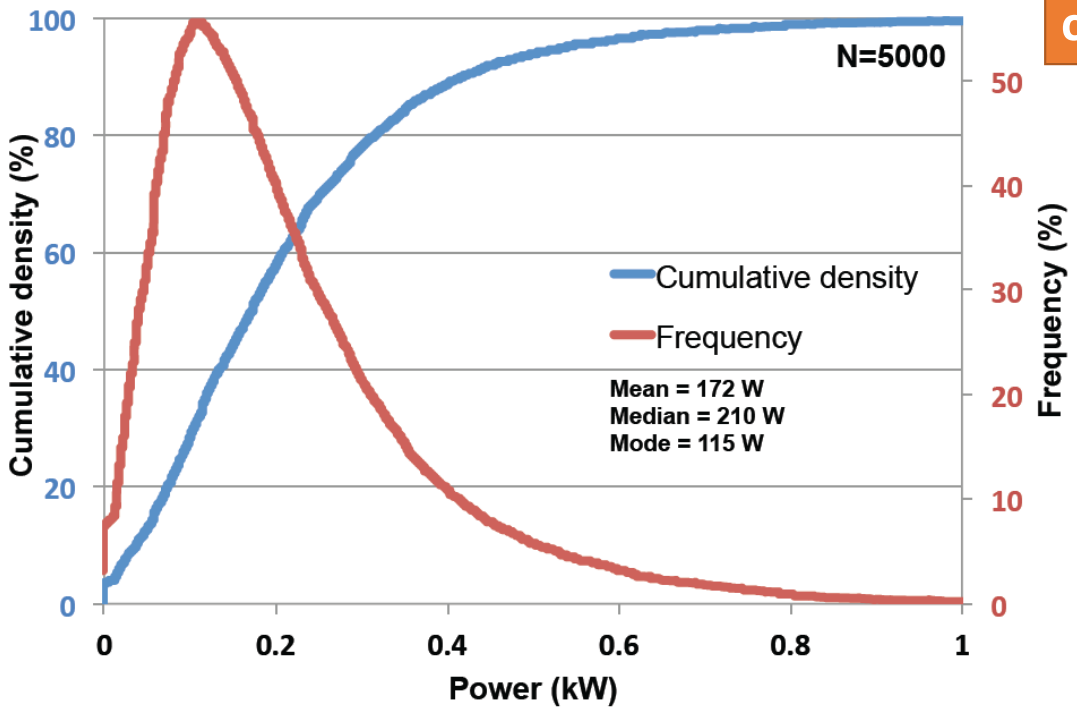


Source: QTR 2015

- Many more electrical devices in homes & buildings
  - >50 devices/home
- Minimum power consumption (homes and commercial buildings)

Minimum Power Consumption in 5000 Existing California Homes

Lowest observed power consumption during one year from smart meters

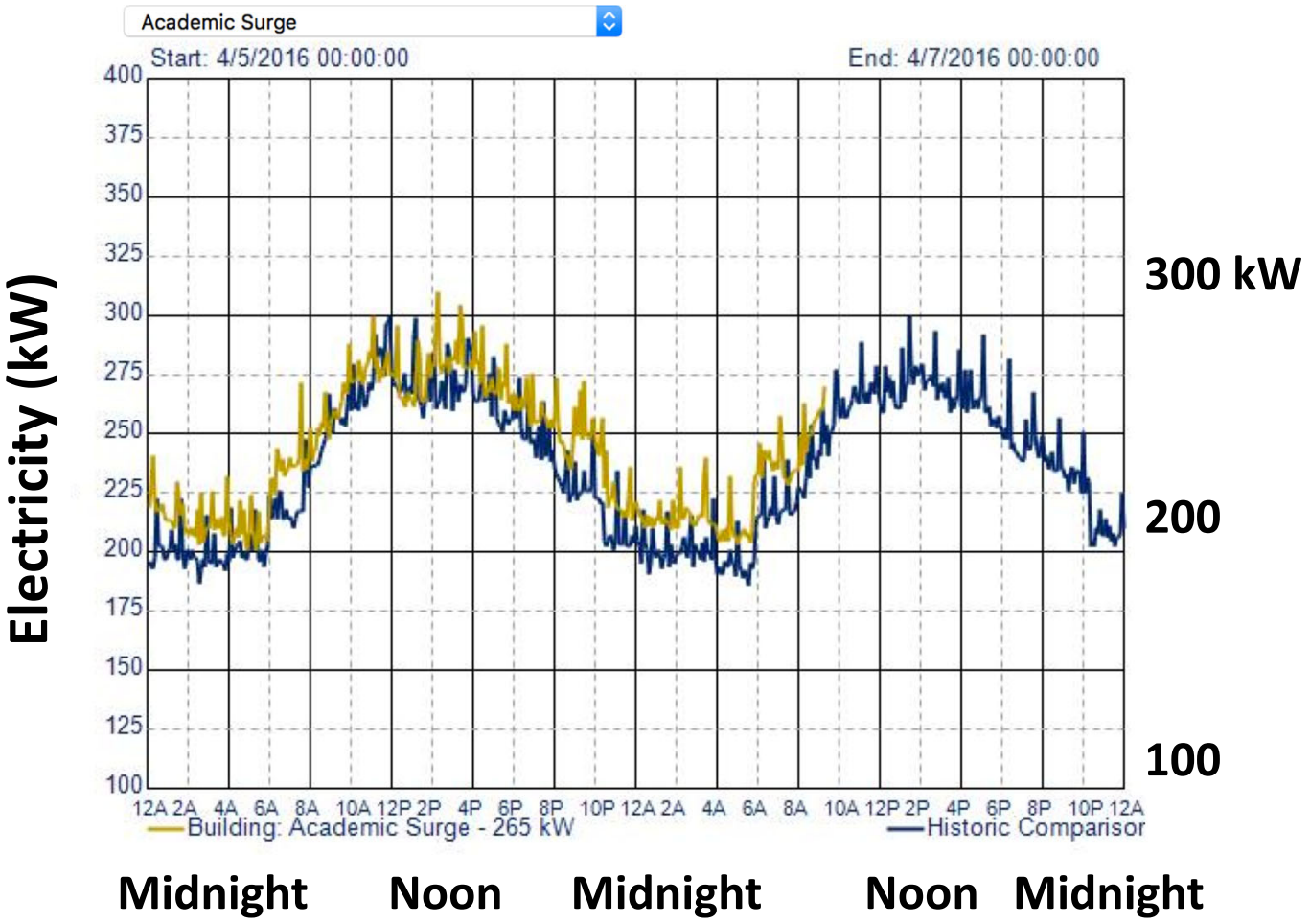


8760 hr x 0.17 = ~20% of annual consumption

No electric water heat, AC, space heat, etc.

What is this?

Power Consumption in one UC Davis Class/Office Building



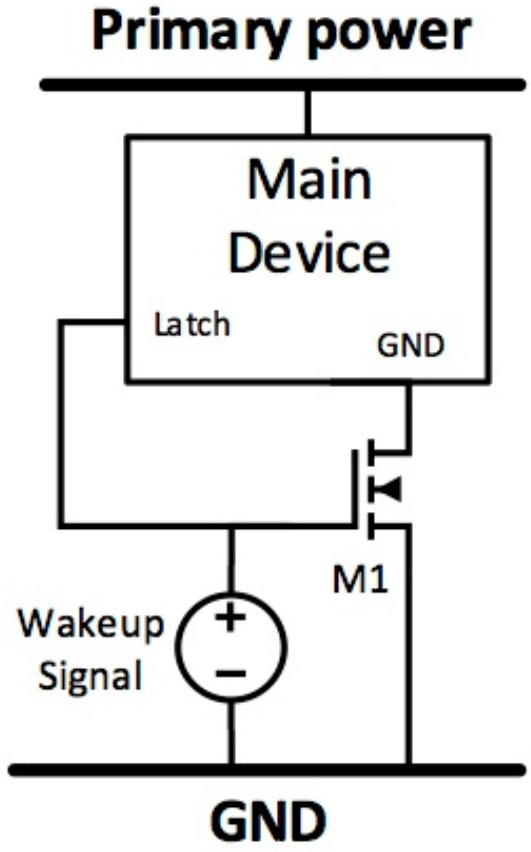
We Don’t Even Know What to Call It

- “Other” (Meier, 1987)
- “Miscellaneous” (Meier, 1992)
- The subset of standby:
  - “vampire loads” (anon. ~1999)
  - “wall warts” (anon. ~1998)
  - “lopomo” - LOw POwer Mode—energy use (CEC & Meier ~2004)
- Plug Loads
- “MELs”
  - “Miscellaneous Electrical Loads” (NREL, ~2010)
  - “Miscellaneous & Electronic Loads” (Nordman, ~2011)
- Residual or not otherwise categorized
- Minor
- “Stuff” (Meier, 2016)

Project Task 2
Zero-Standby Technology Power Supplies and Devices

- Create prototype hardware devices that demonstrate extended periods of “zero-standby” time by incorporating energy harvesting, internal energy storage, and mechanisms to reduce low-power mode energy use
  - Standzero is a new metric of performance: the duration of time a product can operate without mains power
- Initial plan: reduce low-power mode energy use
- Proposed standzero solution: use a footer switch to disconnect power
  - IR harvesting strategy, based on Yamawaki et. al
  - Proposal for universal RF wakeup radio strategy

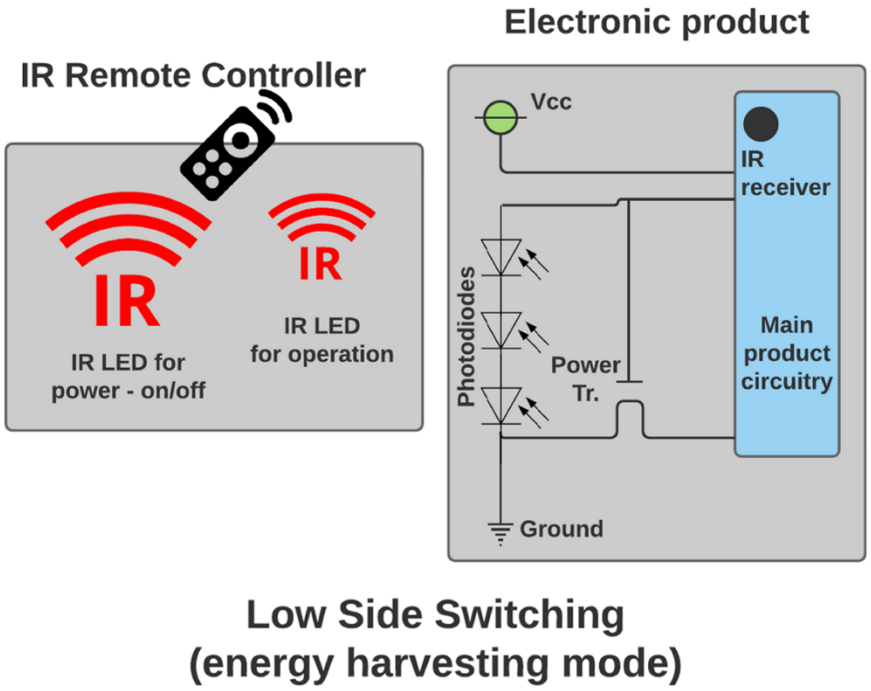
Footer switch to disconnect device from primary power



Footer switch: NMOS switch that connects main device GND to power supply GND

- Best way to reduce standby power: disconnect main device
- Wakeup signal triggers footer switch M1 to connect main device to GND
- When powered, main device latches footer switch
- Main device can put itself to sleep by unlatching footer switch

A remote control's IR signal to switch on a TV's power supply using energy harvesting

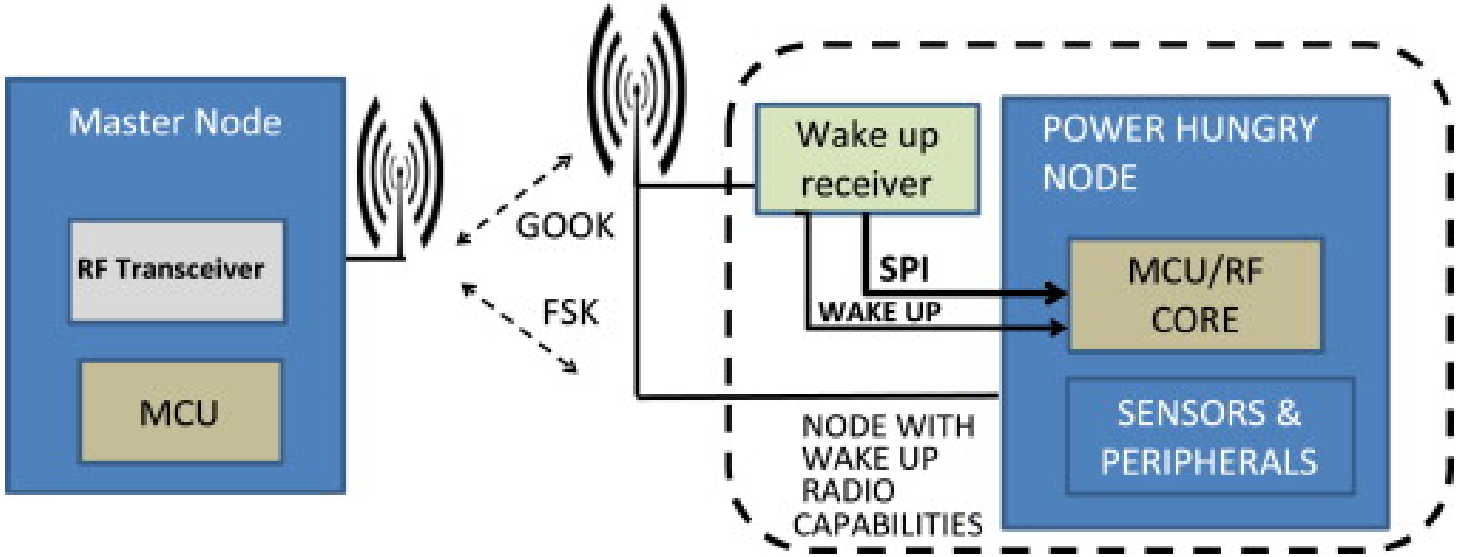


Energy harvesting of the energy in the remote control's IR signal is used to switch on primary power to a TV's power supply.

Design proposed by Yamawaki and Serikawa, 2015

This solution applies to all products with remote controls. Standzero time = ∞

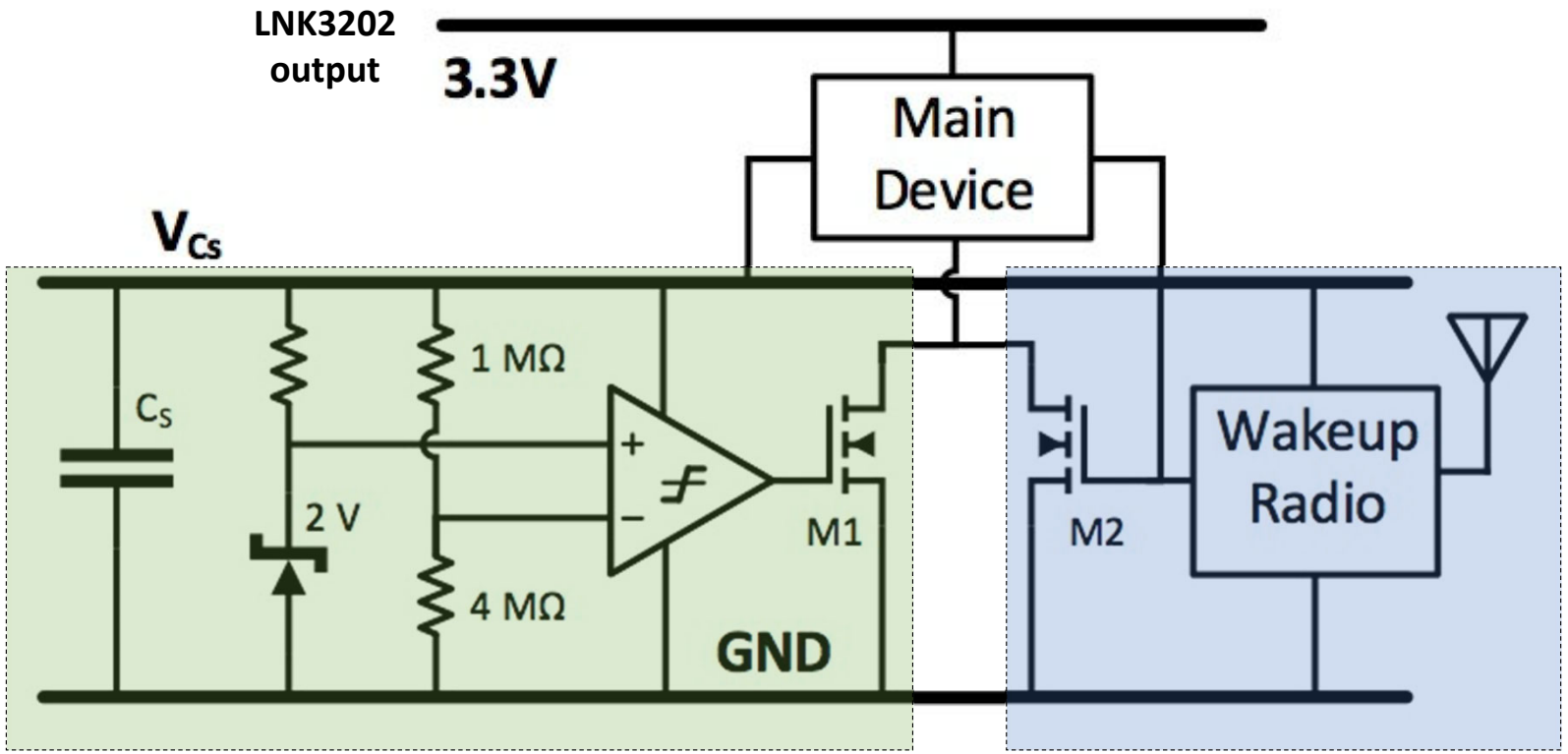
Wakeup Radio for IOT Connected Plug Loads



Source: Microelectronics Journal

- Wake-up radio: a low power secondary receiver whose sole purpose is to take the main device out of standby
- Can often be configured with a unique signaling address to differentiate devices

Wakeup Radio Standzero Strategy



- Power supply for wakeup radio
- Footer M1 ensures that Vcs is always greater than 2.5 V

- Wakeup radio circuit
- AS3930 chip allows for unique addressing to wake up the correct device

Next Steps

- Develop prototype of wakeup radio solution
- Develop standby power simulation tool to investigate inclusion of energy harvesting and storage
- Categorize many various plug-load devices and determine the best zero-standby solutions for each one

Task 3: Builder Installed Electric Loads (BIELs)

"Electricity use of components installed by contractors during construction or remodeling required by health and safety codes or expected by occupants"

Examples →

1. Definition
2. Test Procedure
3. Measurements

HVAC control	**Crankcase heater**	**Electronic air cleaner**	**Hydronic zone valve control**
ERV / HRV	**Continuous exhaust fan**	**Attic exhaust fan**	**Ceiling fan control**
Fireplace control	**Water heater control**	**DHW circulation pump**	**Instantaneous water dispenser**
Oven / Range	**Built-in Microwave**	**Dishwasher**	**Swimming pool / Spa control**
Fountain Pump	**Irrigation control**	**Garage door opener**	**Central vacuum**
Water softener	**Intercom / video**	**Audio server**	**Cable box**
Router	**Video recorder / cameras**	**Cable amplifier**	**Smart home hub**
USB outlet	**PV Inverter**	**Bell transformer**	**PoE Injector**
GFCI	**AFCI**	**Smoke detector**	**CO detector**
Security / Alarm	**Illuminated light switches**	**Street address light**	**Doorbell light**
Landscape lighting control	**Photocell**	**Occupancy sensor**	

Ambiguity in Definition of BIELs

Tankless Water Heater

vs.

Instant Hot Water Dispenser

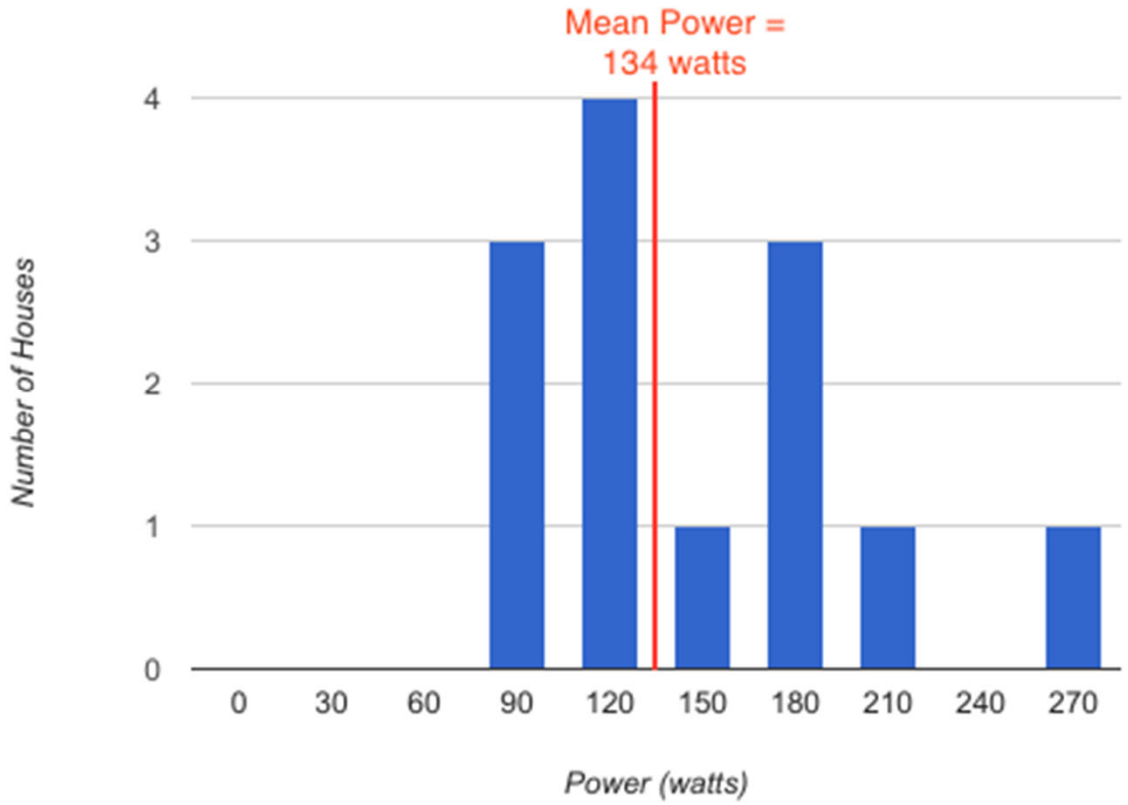
- Builder installed
- Gas heat – DHW end use
- Electronic controls - ~3 watts standby

- Builder installed
- Electric heat – miscellaneous end use
- Standby heater power ~20 watts
- No standby control power

Test Method

1. Identify home after construction is complete and prior to occupancy
2. Take a census of all electrical equipment
3. Configure power state of all BIELs
4. Disconnect any non-BIELs
5. Record meter power reading three times over a period of two minutes

Field Measurements in 15 Homes



Note:
134 W >1000 kWh/year

Task 4: Efficient, Direct DC Devices

- Develop designs for devices in can be directly powered from DC
- Create efficient devices that save energy by using DC power directly
- Reduce standby and active losses by eliminating AC/DC power supplies
- Work with Belkin on direct-DC versions of their products
- Coordinate with Energy Star

What We Did

1. Select 3-5 device types that natively use DC
2. Develop design alternatives for direct DC powering using "standard DC:" USB-PD or Power over Ethernet (PoE)
3. Prototype three or more devices powered directly from DC
4. Evaluate performance vs. AC baseline

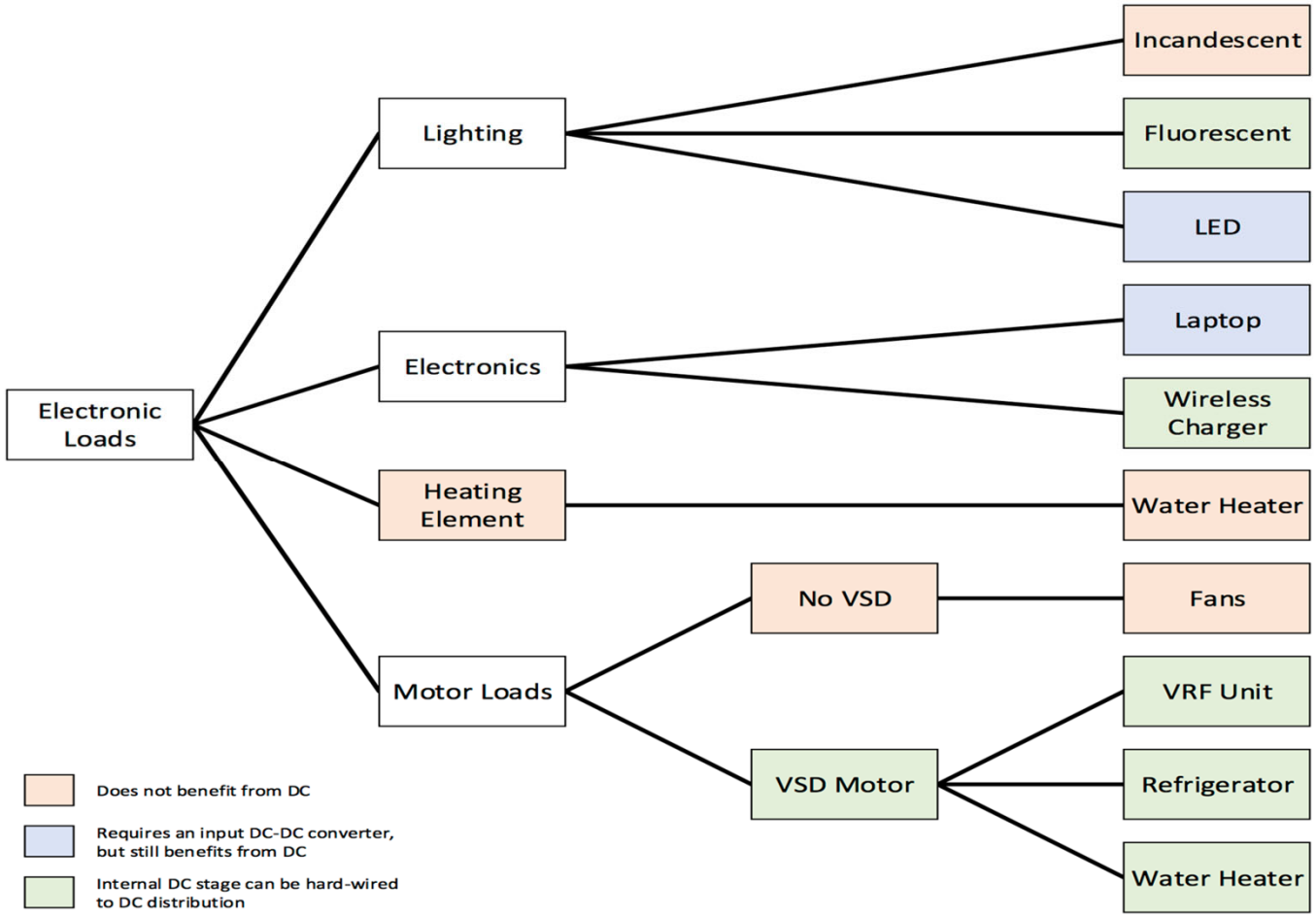
Electronics: WiFi router*

Motor-driven: Air conditioner or refrigerator

Lighting: LED portable lamp

Ventilation: DELTA bathroom fan*

Interaction of DC with Plug Load Functions



Preliminary Target Product Categories

- Electronics: WiFi router*
- Motor-driven: Air conditioner or refrigerator
- Lighting: LED portable lamp
- Ventilation: DELTA bathroom fan*

* Project partners

Task 5: Plug Loads in a ZNE Commercial Building

- Investigate plug loads in a ZNE Commercial building
- Clarify relationship to Title 24 simulation and compliance

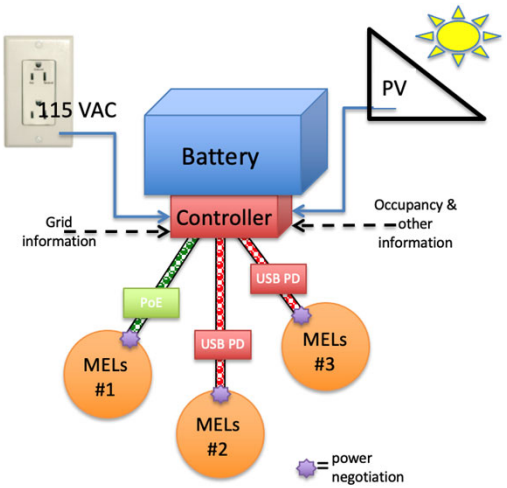
Delta North America Headquarters
Fremont CA

Type	Office (76%), Warehouse (22%), Multi-purpose (2%)
Floor Area	172,405 ft^2 (16,017 m^2)
Completion	October 2015
Others	LEED NC Platinum, Planned NZE
【 Major Energy Facilities 】 Photovoltaics, Battery, Geothermal Air Conditioning System, LED Lighting	

A few successes but no home runs

- Identification of problem areas:
  - Achieving zero-standby
  - Builder-installed loads
  - High MELs in commercial buildings
- Technical progress
  - DC power applications, Power Delivery
  - Device communication, especially energy information
  - DOE approach on core functionalities within MELs
- Overlooked:
  - 120V appliances: stoves, water heaters, clothes dryers
  - Rapid rise of batteries
  - Panel upgrade implications
  - Dynamic electricity pricing

Home Energy Router (HERo)



FoxConn killed it