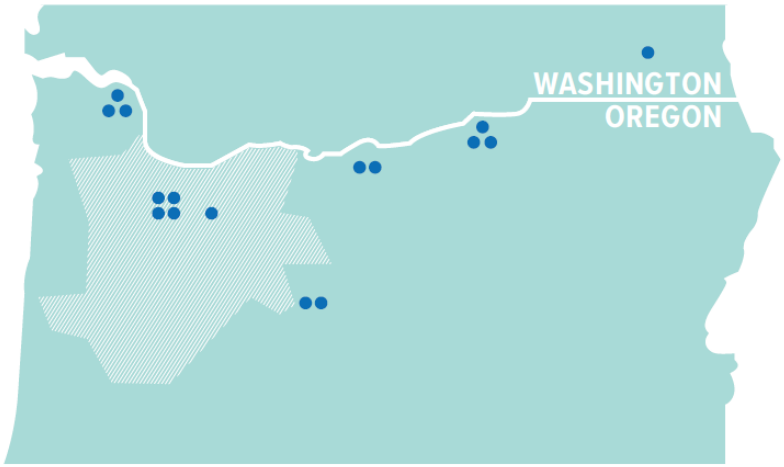
600 curtailment events in 220 days.

What's next?

Conrad Eustis
March 12, 2019

Presented at:
ACEEE Hot Water Forum

Portland General Electric is a fully integrated energy company based in Portland, Oregon serving approximately 885,000 residential, commercial and industrial customers in 51 cities.



Diverse generation mix

16 major generation plants providing a cleaner energy future

Quick facts about PGE

- 2,950 employees
- 47% of state's population
- 19.1 million MWh delivered
- Peak load: Dec. 21, 1998 4,073 MW
- Summer Peak 2017 3,972 MW
- No. 1 renewable power program in the nation with 200K participating customers
- Top ranking in JD Power 2017 Electric Utility Business Customer Satisfaction Study
- First multi-MW Li-ion battery-inverter system placed in operation by a US utility
- 2018 national award from EPRI for leadership and support in sustainability planning

Addressing peak system demand

Peak system demand is that one hour, over several years, when simultaneous demand of commercial, residential and industrial loads reaches a maximum.

Peak is often hundreds of megawatts higher than a typical day.

Demand response value proposition

- Conventional solution generation: the lowest cost power plant costs $800/kW.
- 200 MW plant to meet peak demand costs ~$160 million
- Tough to justify for something that's runs only a few hours per year.
- Choices:
  - Build plant
  - Short term solution in wholesale market?
  - Meet peak with demand response

Why hot water heaters for DR?

- The cheapest demand response resource is usually from large industrial or commercial customers, if they're willing to be curtailed.
- But water heaters are make sizable contributions to both morning and afternoon peak loads—but economic?
- The Pacific NW study, and business case, creates a realistic solution to an economic, large resource
- The economic benefit in OR and WA has NPV of $230.
- Resource size is 300 MW at 26% enrollment level
- U.S. potential is about 15 times this

3.6 million water heaters in the PNW—most will get replaced over 15 years. A 1,400 MW/ 2,500 MWh resource opportunity.

except……..

Challenge

Existing DR technology is obsolete and not cost-effective. I call it crow-bar technology because it's requires a lot of dirty work and it is customer-unfriendly.

Barriers to residential DR at scale

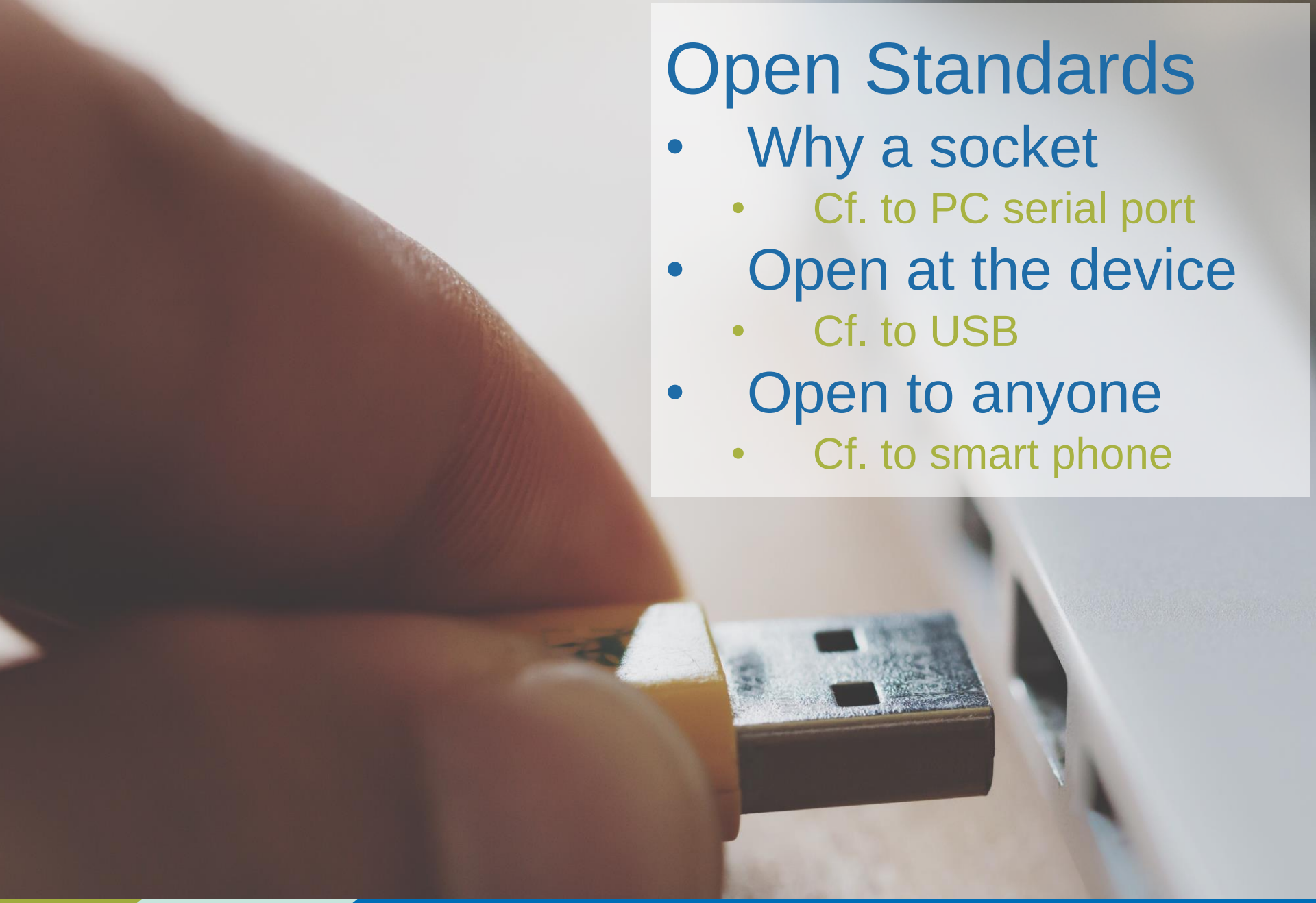
Customer perspective

1. Difficult customer experience
2. Concern about insufficient hot water
3. Small participation incentive

Utility perspective

4. Too costly to connect one device

How do we get past the barriers?



Open Standards

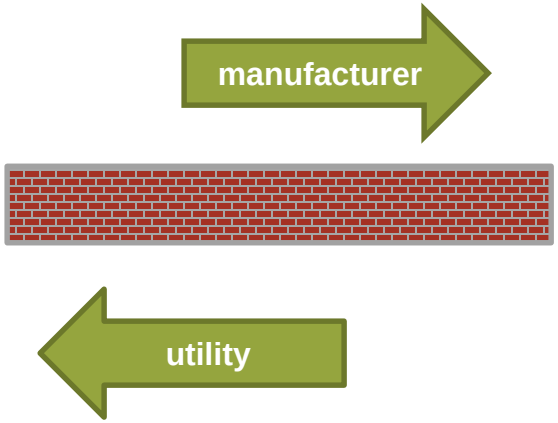
- Why a socket
  - Cf. to PC serial port
- Open at the device
  - Cf. to USB
- Open to anyone
  - Cf. to smart phone

ANSI/CTA-2045 to the rescue

- CTA-2045 is gaining momentum.
- Creates a consistent customer experience.
- Enables simple implementation for the provider.
- A standard creates volume for hardware.
  - Volume creates low cost.
- Solves three-out-of-four barriers.

Catch-22

- Water heater manufactures sell into a national market for customers, not utilities.
- Customers are not asking for “DR-enabled water heaters
- Utilities have sufficient benefit to cover the cost of implementing CTA-2045 on water heaters.
- However, one utility’s market share is too small to affect a manufacturer’s product plan.



PGE has tried these approaches:

- Sought a legislative mandate
- Asked the DOE to identify a consensus standard
- S.1874 proposes a large, national demonstration
- Market transformation led by PNW

In progress

www.bpa.gov/goto/smartwaterheaterreport

NW regional pilot objective: Demonstrate market transformation is cost-effective

Vision:

What does a transformed market look like?

- **ALL** electric water heaters (standard electric and heat pump) over 40 gallons shipped to the PNW have an open-source communication interface (CTA-2045).
- Enroll customers by sending communication device in mail.
- ENERGY STAR and the DOE recognize and promote ANSI/CTA-2045.
- Utilities and aggregators leverage DR capabilities of CTA-2045.
- New IoT models emerge in home.

Participants

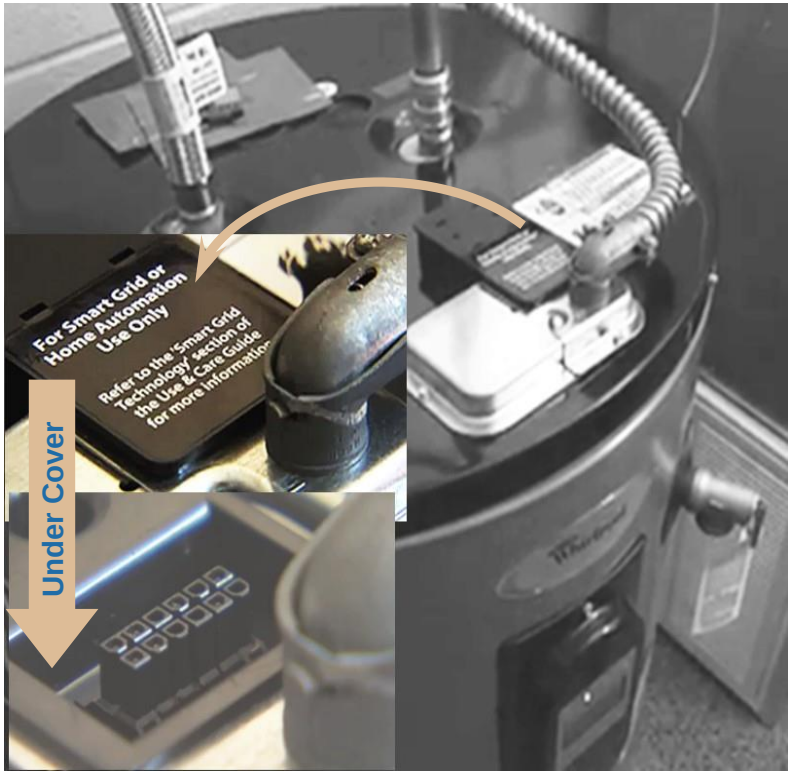
- **Project funding:** $1 million BPA TI 336 (BPA labor & cost share not included)
- **Project leads:** Tony Koch, BPA and Conrad Eustis, PGE
- **Suppliers:** A.O. Smith, General Electric, e-Radio Inc.
- **Major support organizations:** NEEA (Geoff Wickes) and PNNL (Cheryn Metzger)

Utility Participants:

Portland General Electric, Tacoma Power, Puget Sound Energy, Clark Public Utilities, Emerald PUD, Snohomish PUD, Springfield Utility Board, Franklin PUD

Objectives

- 175 heat pump water heaters.
- 90 resistance water heaters
- 24x7 Control, 365 days/year
- Quantify
  - ❖peak load mitigation
  - ❖energy shifting
- Customer acceptance
- Regional education
- Market transformation plan
- Business case to justify market transformation plan



Project uses smart water heaters

"Smart"

- Electronic control
- Standard control language
- OEM enables DR response
- DR commands ignored to maintain sufficient hot water

Low Cost only if:

- Standard Physical Socket (e.g. CTA-2045, USB, etc.)
- Standard format for data packets
- Standard initial exchange of information
- Does NOT depend on DR language

"Smart" Status:

- Only 5 to 10% of tanks sold
- All have proprietary interfaces
- Ready; but need adapter

Photo Credits: General Electric and A.O. Smith

Customer satisfaction

- 190 Participants completed survey
  10 Elec Resistance and 180 HPWH

- Ran out of hot water last year?
  - *40% never*
  - *50% couple times*

- How satisfied were you with the Pilot?
  - *83% Very*
  - *15% Somewhat*

- Likely to participate in DR Program in the future?
  - *72% very likely*
  - *24% Somewhat likely*

- Primary Motivation to joining the study:
  - *38% Amount of incentive*
  - *46% knowing that I'm helping to avoid a new power plant*
  - *43% knowing that I could influence more clean renewable energy on the grid*
  - *26% Getting an annual report that quantify my contribution to the CO2 reduction*

Peak demand reduction results

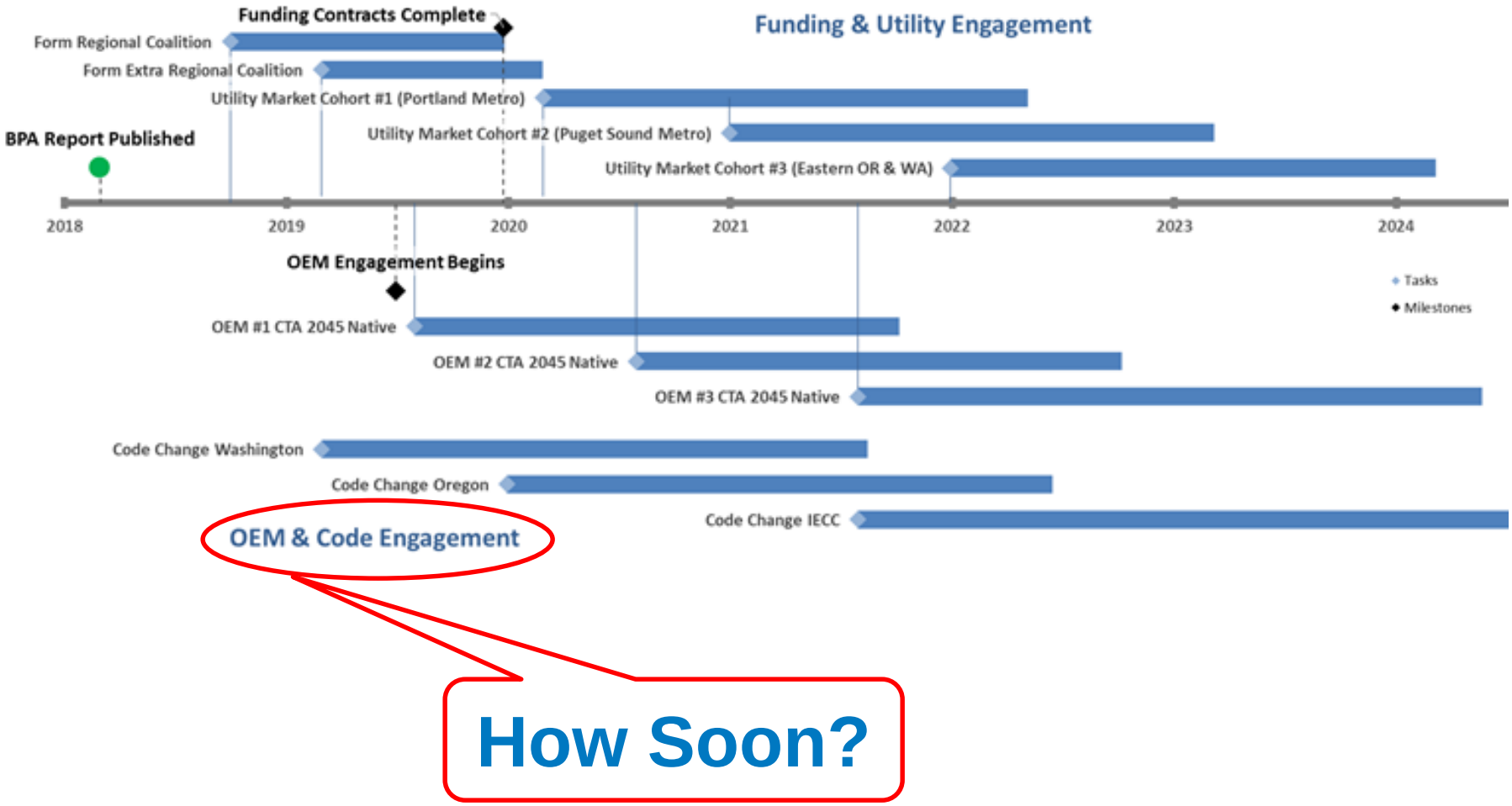
Winter Peak Results	3-Hour Shed Watts Reduction	95% CI
Heat Pump Water Heaters		
A.M. peak	223	±27
P.M. peak	165	±31
Resistive Water Heaters		
A.M. peak	374	±65
P.M. peak	321	±74

Summer Peak Results	4-Hour Shed Watt Reduction	95% CI
Heat Pump Water Heaters		
P.M. peak	85	±10
Resistive Water Heaters		
P.M. peak	347	±29

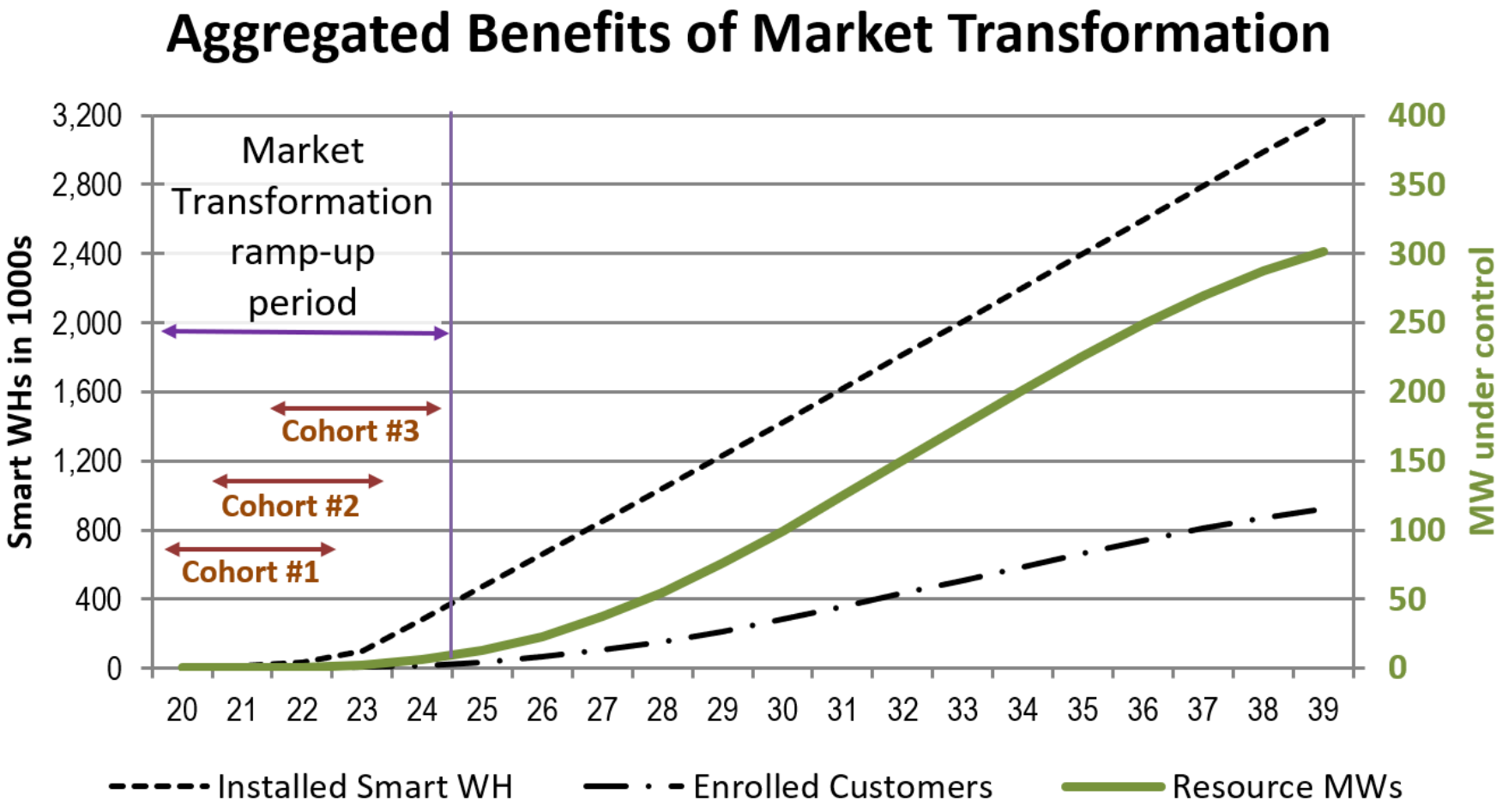
Grid emergency results

Time	Winter/Spring Grid Emergency Watt Reduction	95% CI	Summer Grid Emergency Watt Reduction	95% CI
Heat Pump Water Heaters				
A.M. period	244	±32	122	±20
P.M. period	167	±43	96	±11
Resistive Water Heaters				
A.M. period	562	±69	393	±50
P.M. period	563	±105	389	±39

Market transformation plan



301 MW by 2039 (@ 26.5% adoption)



Business case results

Public Share 33%
IOU Share 67%

Mix of Public and IOU

B/C Ratio in 2054 2.59

26.5% **Regional Adoption**

301 PV Benefits of Peaker	**MW** PV Cost of WH DR	**Savings as NPV in 2019 $**	PV of all Expense	Recurring Program Expense	Utility Total PV Cost	Total MT PV Cost
$374	$144	**$230**	$144	$70	$46	$29

$ in millions

All Public

Discount Factor **4.2%**

B/C Ratio in 2054 2.77

301 PV Benefits of Peaker	**MW** PV Cost of WH DR	**Savings as NPV in 2019 $**	PV of all Expense	Recurring Program Expense	Utility Total PV Cost	Total MT PV Cost
$506	$183	**$323**	$183	$94	$57	$32

All IOU

Discount Factor **7.2%**

B/C Ratio in 2054 2.47

301 PV Benefits of Peaker	**MW** PV Cost of WH DR	**NPV in 2019 $**	PV of all Expense	Recurring Program Expense	Utility Total PV Cost	Total MT PV Cost
$309	$125	**$184**	$125	$58	$41	$27

Not included: Soft benefits

- Use of thermal storage in tanks to shift load to greener generation reduces CO_2. At $50 per ton, it's worth about $6 million/yr (900,000 water heaters @ 26.5% adoption.)
- Locational value
- Ancillary services: frequency regulation, load following, black start, spinning reserve, etc.
- Economic dispatch: A least-cost means to sink excess wind and solar generation


What’s Next

Solution……?

- Sell plan to utilities in 2019
- When sufficient commitment achieved, launch transformation with manufacturers
- Work to get state codes requirements, then national
- Actively seeking interested utilities

Questions?

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Advantages of a standard socket

- Enables any WAN, or LAN, or wired connection method
- Compared to embedded communication, doesn't incur energy or hardware cost until customer elects connected-operation… maybe never.
- Security issues solved in the communication device, not the appliance
- Volume lowers the cost of the communication device
- Cheap memory means communication device can have a "library" of device-specific knowledge
- [Remote] communication protocols can come and go, without ever affecting the functionality of an appliance with a 20-year life

New concept

- **For first 120 years**
  - Energy flows one way to customer
  - Generation built with “obligation to serve”
- **Renewables at scale everyone talks about battery storage, but flexible loads are cheaper!**
- **Need a better, richer word!**

Alonetic, adjective

ăl • ō • nĕt • ĭk

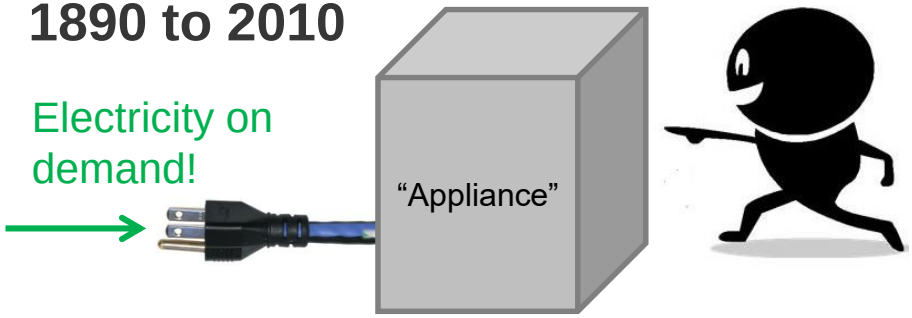
alo- from the Latin “to support”

net as in the electric grid **net**work

-ic of, or **pertaining to**

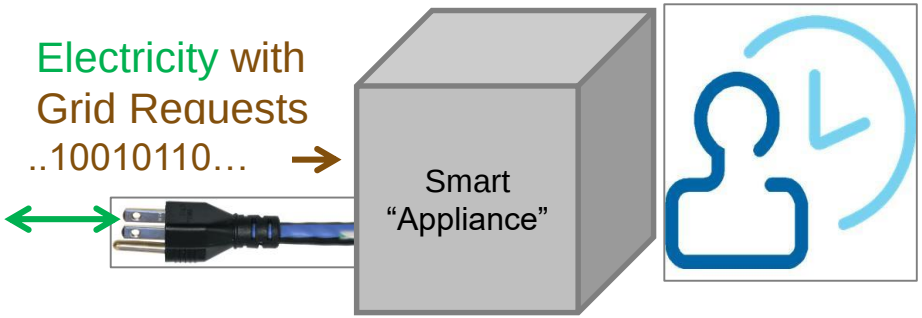
Definition: The ability of an electric device to beneficially support operation of the electric grid. Antonym: egonetic

1890 to 2010



Customer commands; device gives

2020 to 2140



Customer inputs flexibility to device; device serves **customer 1st**, then grid!

Water heater benefits as Flex Powerplant

- Expected peak demand benefits
  - HPWH
    - 0.18 kW load reduction;
    - 1.5 kWh as storage (twice a day)
  - Resistance
    - 0.35 kW load reduction;
    - 3 kWh as storage (twice a day)
- 24x7 ops reduces natural gas use at powerplants
  - ~ 2.9 million Btu per water heater/year used as flex resource

Daily control saves system energy

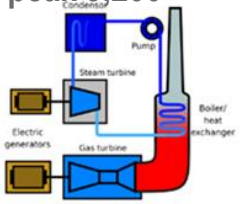
In 21st century, system energy savings more important than device efficiency

Assume 3 kWh stored per tank on 344 days per year

1. Daily Economic Dispatch on 180 days yields 1.1 mmBtu/year saved
2. Wind firming on 114 days yields 0.8 mmBtu saved
3. Sink excess renewables on 50 day yields 1.0 mmBtu saved

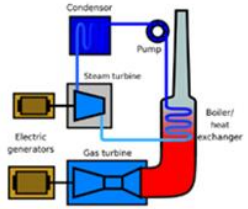
2.9 mmBtu saved can generate >390 kWh at the meter

Heat Rate during avg. daily peak 9,200

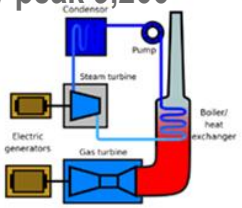


VS.

Night Heat Rate 7,100



Heat Rate during avg. daily peak 9,200



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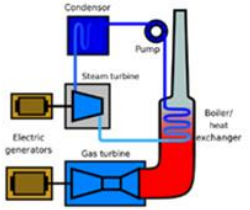
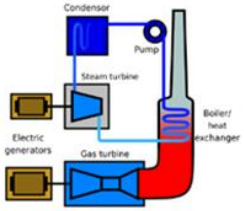
VS.

Baseload Heat Rate 6,826



Night Heat Rate 7,100



VS.

Northwest potential

Credit: http://www.publicdomainpictures.net/view-image.php?image=145778&picture=business-success

- Market:
  - 3.5 million WH
- Likely benefits (adoption at 50%)
  - After fifteen years (0.3 kW per tank)
    - 500 MW resource ~ $500 million
- Cost (customer adoption at 50%)
  - $15 per tank + $1 mil in engineering per manufacturer
  - $60 per enrolled tank (comm device and recruitment)
  - Accumulated cost after 15 years = $150 million (B/C = 3.0+)
- Daily storage benefit
  - ~ 2 kWh without mixing valve
  - 3,500 MWh at $300/kWh = $1.0 billion in value cf. to battery

Open-in-cloud vs. open-at-device

- Open-in-the-cloud means home run to the device maker to interact with any 3rd party
- 3rd party needs legal agreements with every device maker to simplify customer experience.
- Open-at-device means customer is charge, and any architecture is possible

Photo credit EPRI

Vendor Vision

Consumer or Automation Vision

Design affects customer experience

Open-at-device; modular interface

- Supports grid control without using internet
- Supports participation without needing customers internet or passwords
- Supports easy use of 3rd party HEMS
- Future proof against 5G IoT architectures and business models
- Security fixes never involve device

Open-in-cloud

- Requires 3rd parties, like DR aggregators of utilities, to have agreements with 50+ device makers
- In major disaster, loss of Internet means loss of in-home energy management
- More revenue opportunities for device maker