American Council for an Energy-Efficient Economy

Intelligent Efficiency Conference

Track A: Integrating Distributed Resources

1A Enabling the Virtual Power Plant

Marc Collins, DNV GL

Opening Remarks

American Council for an Energy-Efficient Economy

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Andrew Machado, Cadmus

Supporting the Virtual Power Plant

Agenda

Background

Technology & Infrastructure Review

Regulation Overview & Impacts

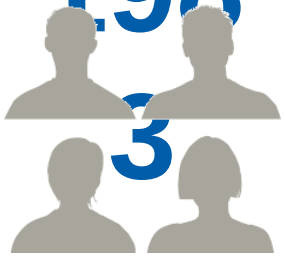
Key Take-Aways

CADMUS

Since 1983

Energy and environmental consulting firm with over 520 employees

33 years serving Utilities, Commercial & Industrial Customers, Government



Leaders in EM&V approach and methods: DOE's UMP, IPMVP

$ % Experts on DSM policy and planning, cost-effectiveness, and market effects analysis

Specialize in Energy Systems Engineering, Emerging Technology, EM&V

Understand regulatory environment underlying power planning methods

IoT, Smart Grid, HEMS

- **Internet of Things (IOT)** – network connectivity for objects (and not just people)
- **Advanced Metering Infrastructure (AMI)** – utility meter with two way communications
- **Open Systems Interconnection (OSI) model** – framework for communication over a network
- **Home Energy Management System (HEMS)**
- **Home Area Network (HAN)**

Source: http://gargasz.info/how_internet_works_i_think.pdf

Networking & Data

Protocol - set of rules for communication between two devices (e.g., Bluetooth)

Standard - adopted guidelines for communication (which often reference specific protocols, e.g., 802.11n)

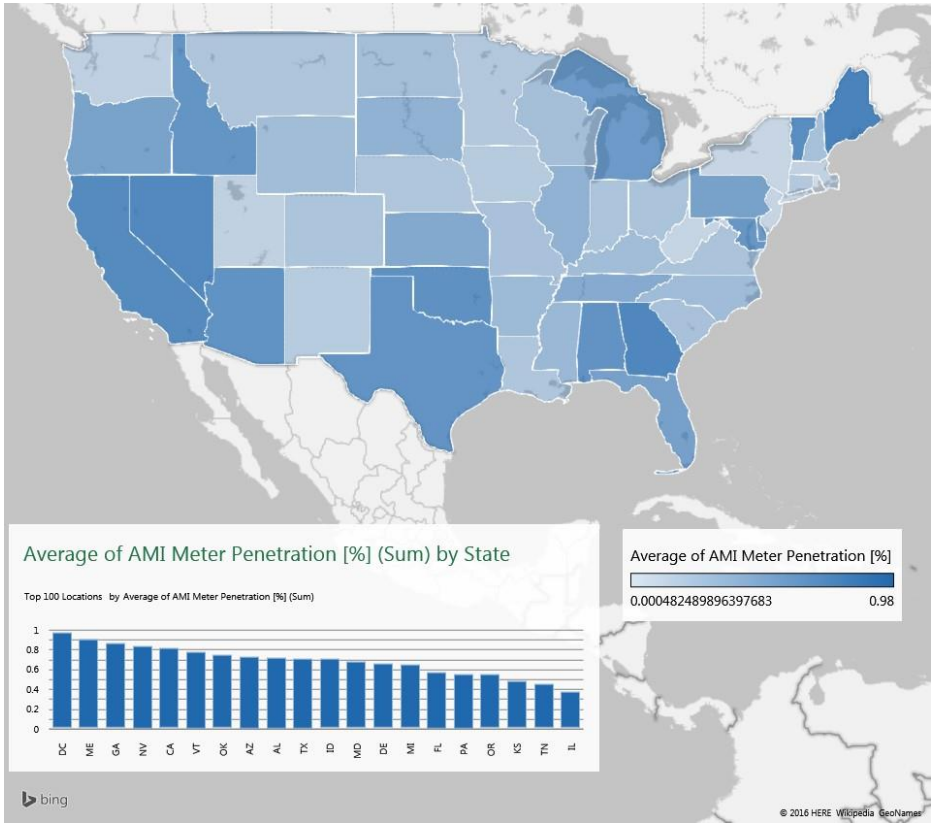
Green Button – DOE initiative for customer energy data access

Latency – network transit time

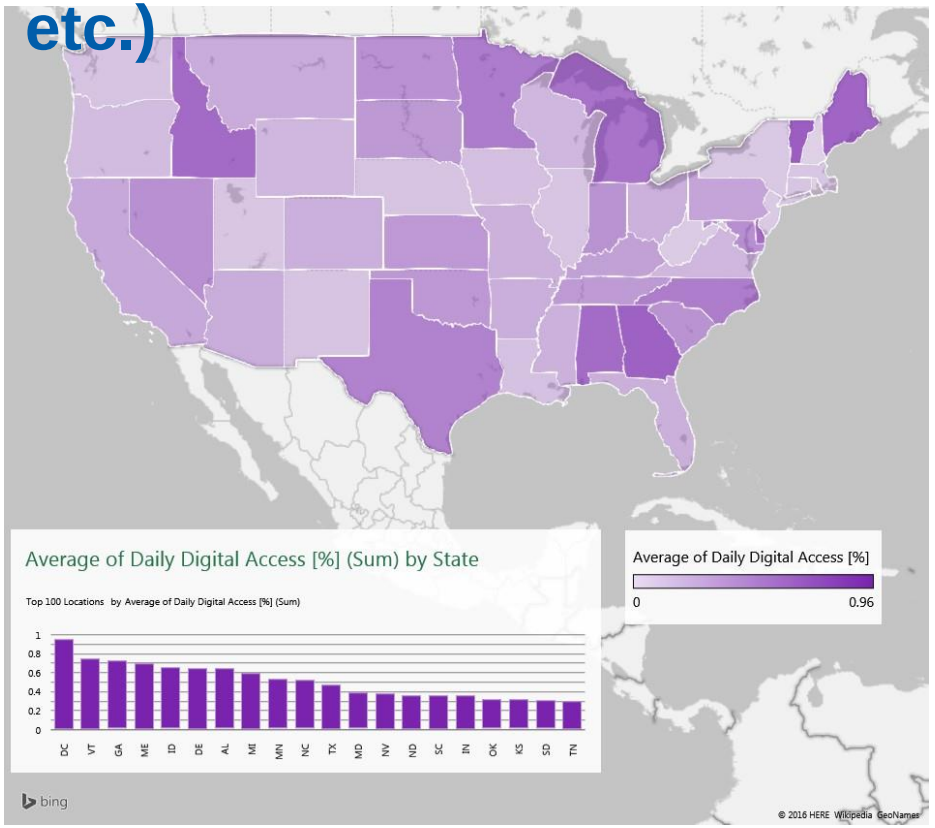
Cellular (GSM, CDMA)

2015 Smart Meters & Energy Data

AMI Meter



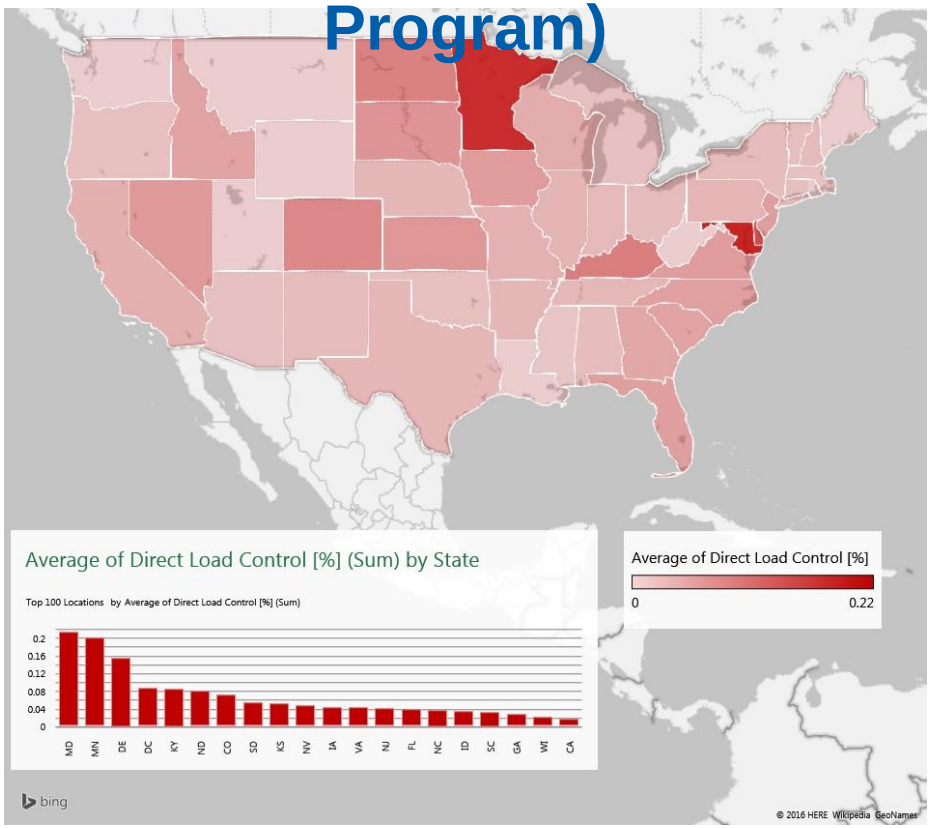
Daily Digital Access (portal, etc.)



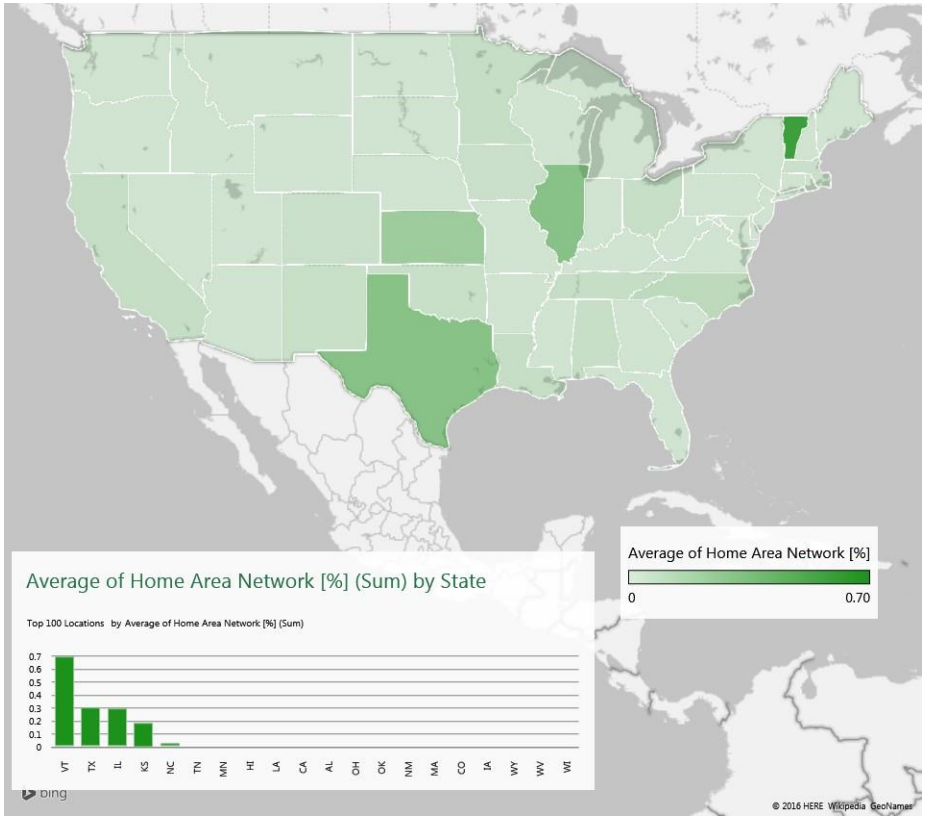
Source: U.S. Energy Information Administration (EIA)

2015 Load Control & Local Network

Load Control (by Utility Program)

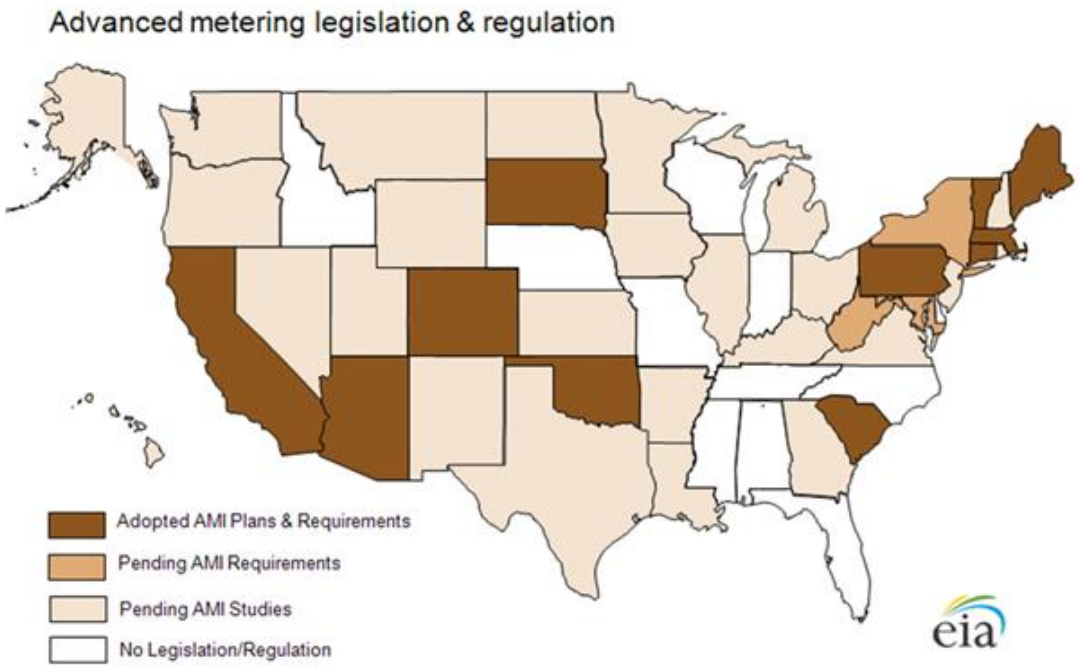


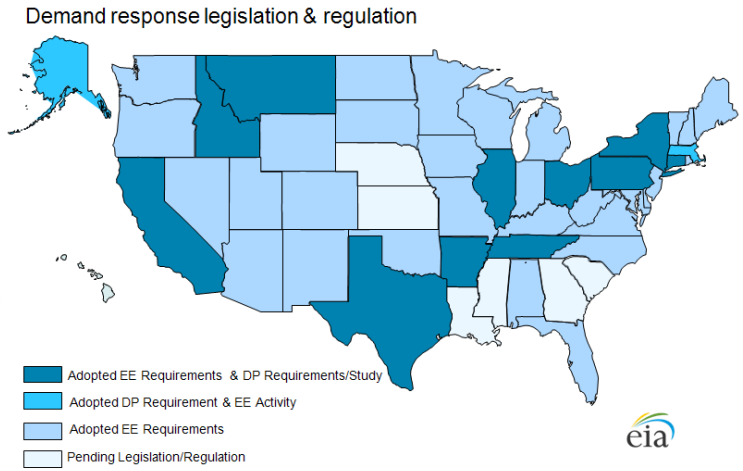
HAN Gateway Enabled

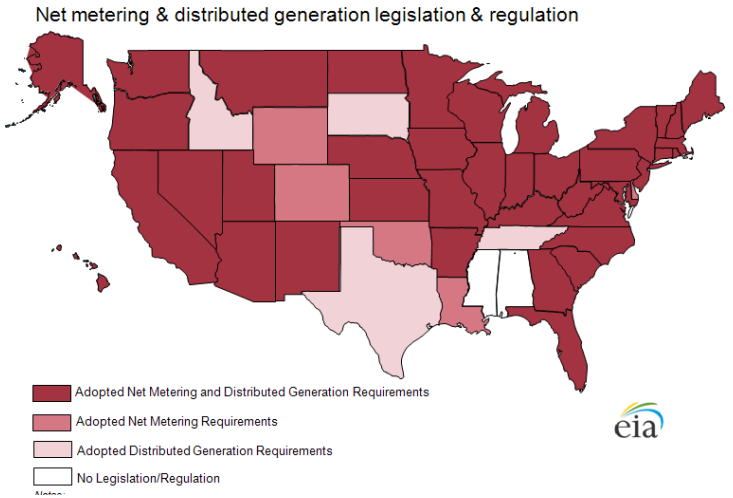


Source: U.S. Energy Information Administration (EIA)

Regulation Overview







Source: U.S. Energy Information Administration (EIA)

Regulation Impacts

British Columbia, Canada (100% AMI)

- 1.9 million smart meters, 100% IPv6
- BC Energy Plan and Clean Energy Act mandated 100% AMI by 2012
- Vision for Multiservice Grid Network

Maine (91% AMI)

- 820,000 customers statewide
- $96 million in Smart Grid Investment Grants (American Recovery & Reinvestment Act)

California (82% AMI)

- 12.5 million AMI meters statewide out of 15.2 million total meters
- San Diego Gas & Electric awarded $28 million in SGIG / ARRA funds; Sacramento Municipal Utility District awarded $127 million
- Widespread implementation of Green Button initiatives
- Commission funded Pacific Gas & Electric HAN pilot in 2013, ~5000 customers

Illinois (38% AMI)

- Largest relative increase (>20%) in AMI penetration from 2014-2015
- Energy Infrastructure Modernization Act (EIMA) of 2011
- Ameren Illinois investing in IoT infrastructure & testing
- Offering HAN integration, vetting technology

Wisconsin (24% AMI)

- Heterogeneous mix (>90 utilities)
- Madison Gas & Electric awarded $5 million in SGIG / ARRA funds
- No major regulation regarding AMI / IoT

Indiana (17% AMI)

- 5 large utilities, greatest AMI penetration is 7%
- No major regulation regarding AMI / IoT

Massachusetts (3 %) vs. Rhode Island (0% AMI)

- One electric utility operates in RI
- Same utility operates in MA - AMI & data access available

Key Take-Aways

1. IoT energy technology is dynamic ecosystem – signs of convergence are appearing
2. IoT energy infrastructure is spreading at varied rates
3. Regulation is helping to drive adoption and growth; lack of regulation *may be* hindering adoption & growth
4. Demand Side Management & Energy Efficiency professionals must plan for future, mitigate risks

Supporting the Virtual Power Plant

CADMUS

Andrew T. Machado, PE, CEM, LEED AP

Senior Associate, Energy Services

Office (617) 673-7110

Andrew.Machado@cadmusgroup.com

Facebook.com/CadmusGroup

@CadmusGroup

Linkedin.com/company/the-cadmus-group

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Track A: Integrating Distributed Resources

1A Enabling the Virtual Power Plant

Conrad Eustis, Portland General Electric Co.

Barriers to Alonetic Appliances

Portland General Electric

855,000 customers, 52 cities served

Service territory population 1.9 million, 43% of state's population

4,000-square-mile service area

2,650 employees

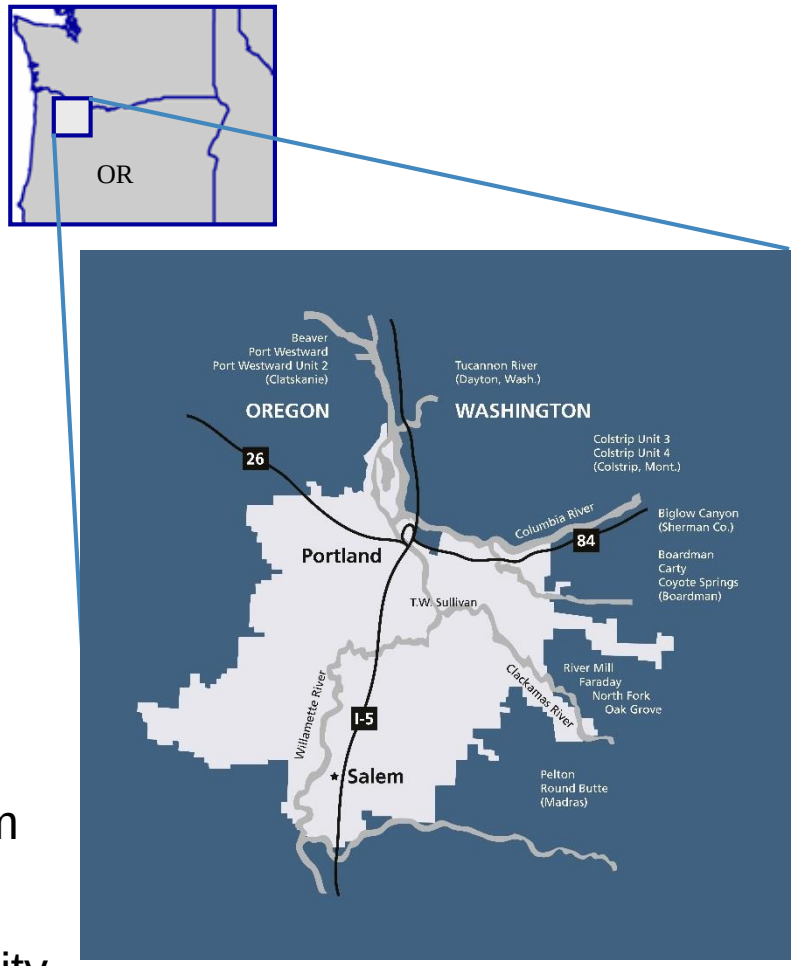
Summer peak 3,950 MW (2009)

Winter peak 4,073 MW (1998)

Number #1 in US by NREL in Renewable energy sales and customers

First multi-MW Li-Ion battery-inverter system placed in operation by a utility

21% of owned-generation nameplate capacity is wind generation; 36% is renewable.



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Word for Emerging Concept

- In 2040 we want most loads and distributed generation to be ***alonetic***

- Word created in 2014
- <u>Opposite</u> of alonetic is ***egonetic*** which is the behavior of today's devices

Alonetic, adjective

ăl • ō • nĕt' • ĭk

- **alo-** from 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

Portland General Electric

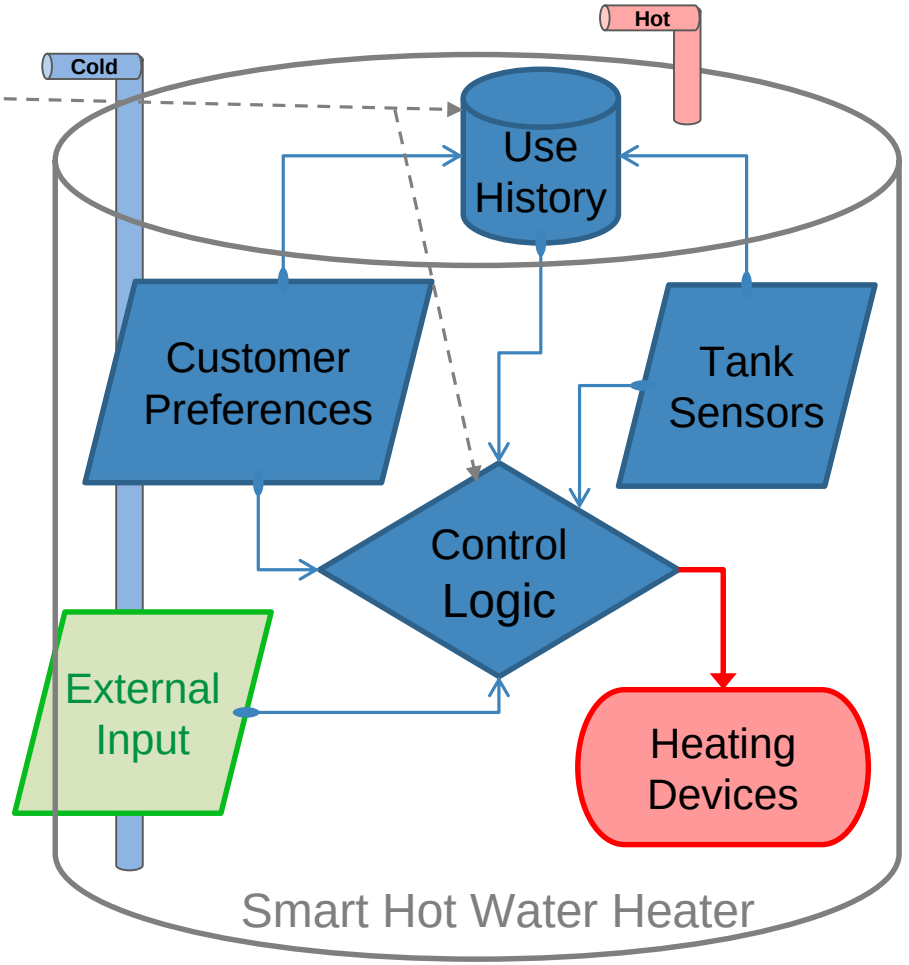
Definition/details of smart water heater

Moore's law comes to load behavior here

1. A water storage tank where heating devices are controlled by logic in an electronic circuit.
   (I.e. not bimetallic switches)

2. A water heater designed to accept external signals as an input to the control logic

E.g. Hourly Price Forecast OR Direct control for load shifting



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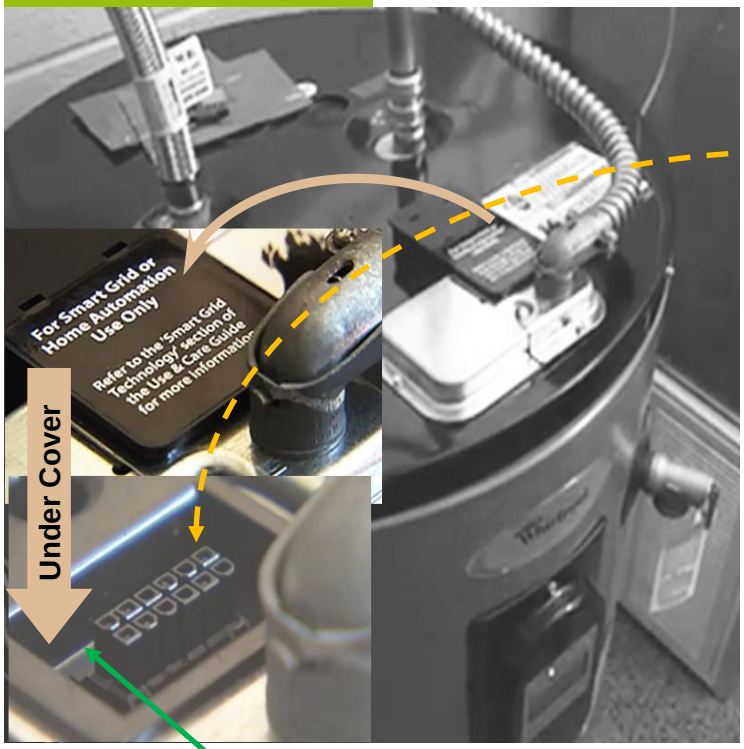
Current PGE Pilot: Customer installs communication



ANSI/CTA-2045“plug” on communication device

Early communication device from e-Radio

- This E-Radio device hears control commands **broadcast on FM** radio and returns water heater status via Wi-Fi if enabled by Customer.
- **This option can work in 99+% of US**, (including rural areas) today

GOAL:

ANSI/CTA-2045 socket on tank.

(This one proprietary)

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Advantages of a standard socket

- Enables any WAN, or LAN, or wired communication method
- Compared to embedded communication, doesn't use energy or hardware cost until customer enrolls
- Security issues solved in communication device not in appliance
- Standard creates high volume consequently lower cost for communication device
- Communication device can have a "library" of device-specific "drivers"
  - Command protocols can come and go, without ever affecting the functionality of an appliance with a 20-year life

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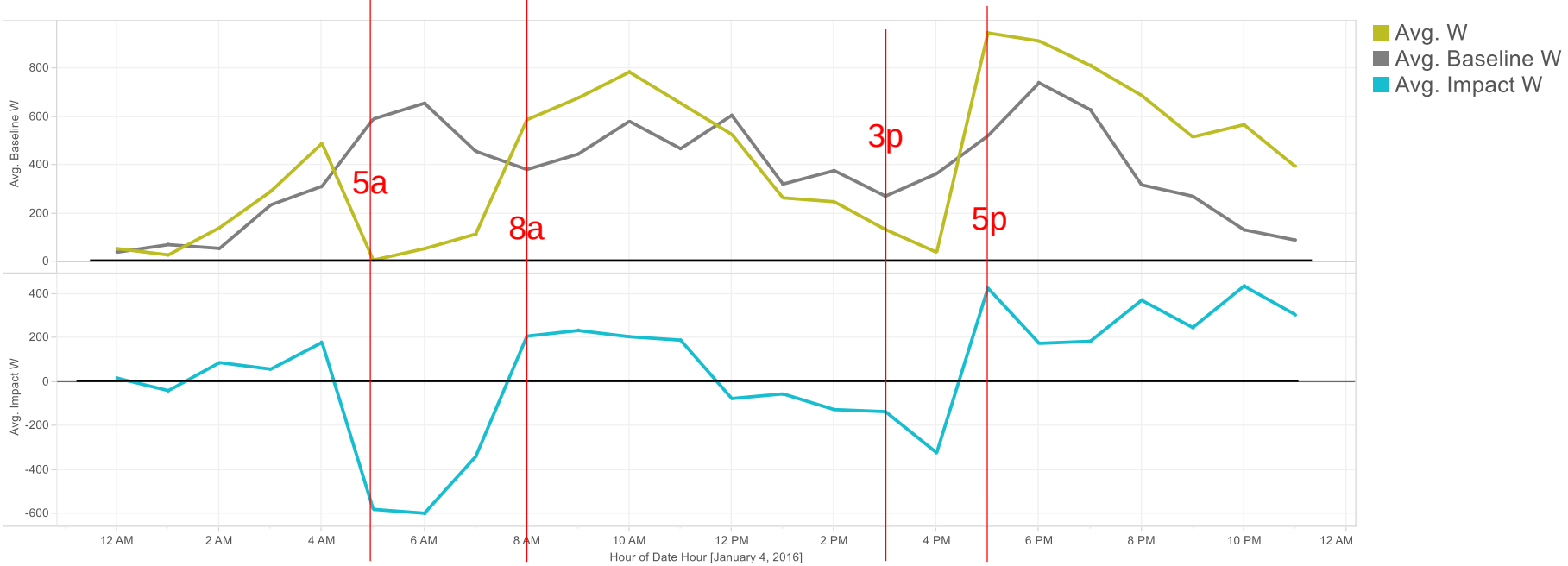
Peak Shaving Benefit

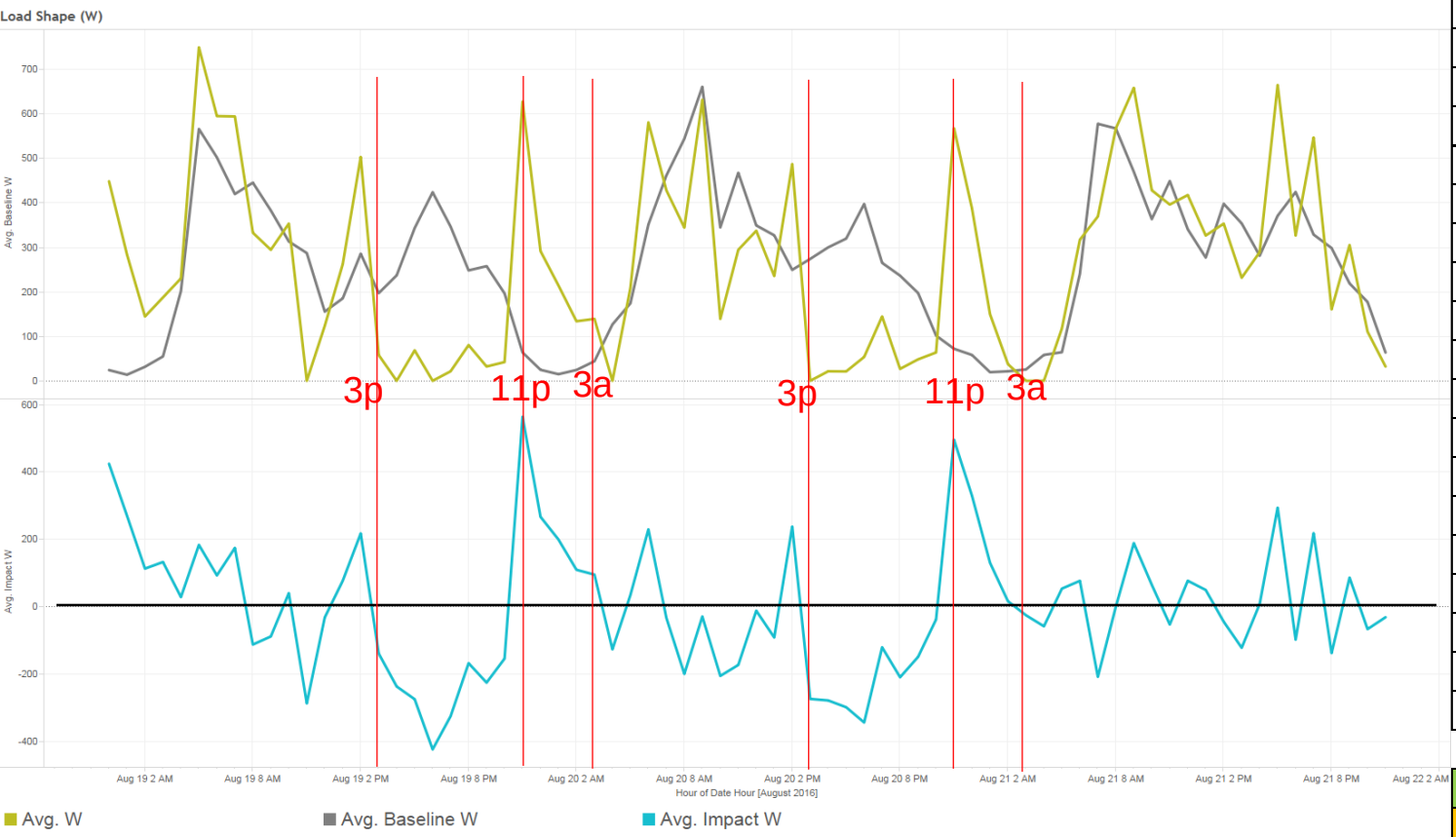
- Traditional demand response tested in winter and summer
- Peak demand impacts around ~0.3 kW in both seasons

Summer			
Duration	**Time**	**Peak Days**	**Avg W Impact**
4 hour	3pm-7pm	1	-291
6 hour	2pm-8pm	2	-266
8 hour	3pm-11pm	1	-244
Winter			
Duration	**Time**	**Peak Days**	**Avg W Impact**
6 hour	5am-9am, 3pm-5pm	1	-297
6 hour	5am-8am, 3pm-6pm	1	-391
4 hour	3pm-7pm	1	-297



Energy Shifting Benefit

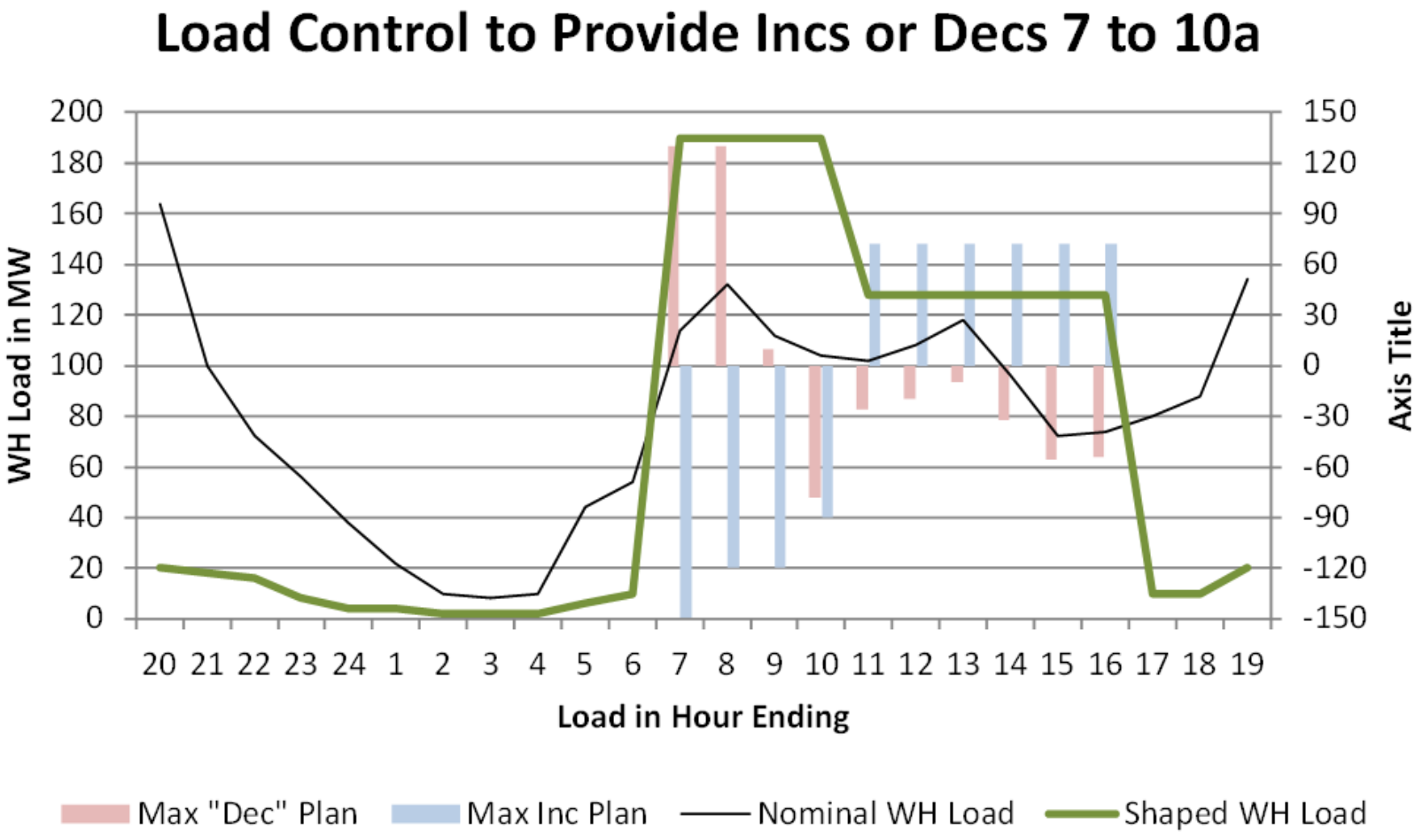
- Example Days: 8/19-8/21
  - Control strategy: load up for 15 minutes, then shed from 3pm to 11pm, then duty cycle for 4 hours



Hour	W Impact
0	340
1	200
2	80
3	68
4	-52
5	91
6	133
7	-22
8	-104
9	24
10	-34
11	-171
12	11
13	12
14	137
15	-179
16	-169
17	-93
18	-289
19	-76
20	-172
21	-96
22	-86
23	343
Average	-4

Total Charge	1167
Total Discharge	-1160

One Use Case: Real-time “Inc” & “Dec”



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Standardization Creates Major Benefits

- Less cost and simple means **more customers** will try it
- With market transformation all 50 million existing electric water heaters (including heat pump water heaters) could be economically controlled; potential means:
  - **25,000 MW of demand response capacity**
    - (i.e. ability to avoid 100 large peaking plants = $20 billion)
    - Daily ability to provide 25 GW in Incs and Decs
    - 120 million MWh of discretionary load to absorb excess renewables
  - Annually displace 25 million tons CO_2 (= elimination 7 million cars)
  - Annual reduction in revenue requirement of $5 billion

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Barriers to Alonetic Devices

- "Smart" appliances today all have proprietary interfaces
  - **Irony: IoT** is about every**T**hing interoperating; but we have more than a dozen mega-companies pushing their proprietary approach to ensure upside for their business
- Communication interface must be designed and implemented at factory.
- Customers (that buy appliances) not seeking grid responsive capability; thus in commodity appliance market, manufacturers incur cost and have no way to recovery cost; since benefits are in electricity industry
- No major player to create market standard: 30+ major "appliance" manufacturers; 100+ major utilities
- Without every water heater equipped with socket, incremental cost to connect existing smart water heaters is $250, not $20

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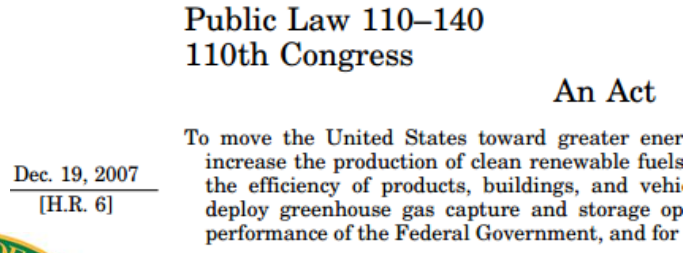
Approaches to market transformation

1. Seek legislative mandate
   (insufficient consensus)
2. Ask DOE to identify consensus standard
   (Wyden/Cantwell letter; DOE didn't try hard enough)
3. Now trying, legislation for large, national demonstration
4. Market transformation led by Pacific NW (In progress now, strategy: "I'll have what she's having")
5. PGE will lead by example



Public Law 110–140
110th Congress

An Act

Dec. 19, 2007
[H.R. 6]

To move the United States toward greater ener
increase the production of clean renewable fuels
the efficiency of products, buildings, and vehi
deploy greenhouse gas capture and storage op
performance of the Federal Government, and for

Portland General Electric

Thanks

Conrad Eustis

503-464-7016

Conrad.eustis@pgn.com

Portland General Electric

American Council for an Energy-Efficient Economy

Intelligent Efficiency Conference

Track A: Integrating Distributed Resources

1A Enabling the Virtual Power Plant

Matthew Bye, Trane (Ingersoll Rand)

Enabling Buildings as a Grid Resource

Buildings Offer Enormous Grid Services Potential…

There are more than 5 million commercial, industrial and institutional buildings across the United States

Lodging	Healthcare	Office Space	Warehouse	Education	Other
158,000	157,000	1,012,000	796,000	389,000	3,806,000

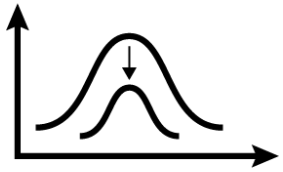
Source: FERC, GAO-14-73 Electricity Markets

Opportunities in Buildings: From the Grid's Point of View

TRANE BUILDING ADVANTAGE

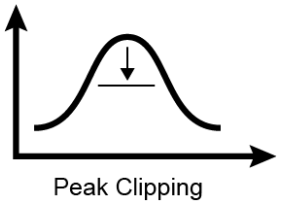
Version 1.0 Energy Efficiency

- Use less energy over time
- Unscheduled
- One-time incentives
- Not controllable



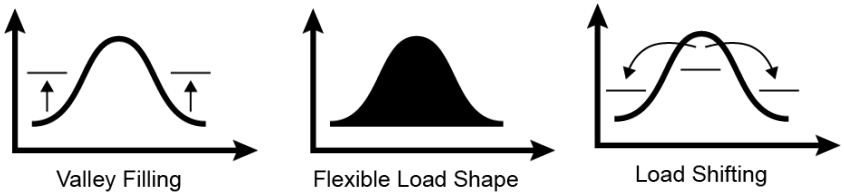
Version 2.0 Demand Response

- Sacrifice-type curtailment
- Few times per year
- On/off



Version 3.0 Grid Resource

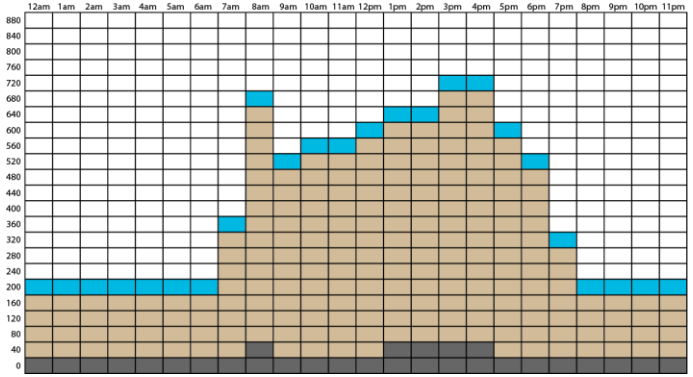
- Non-sacrifice
- Utility dispatched ("hand to throttle")
- Frequent/daily



Activating Buildings as Grid Resources

Unaffected Load

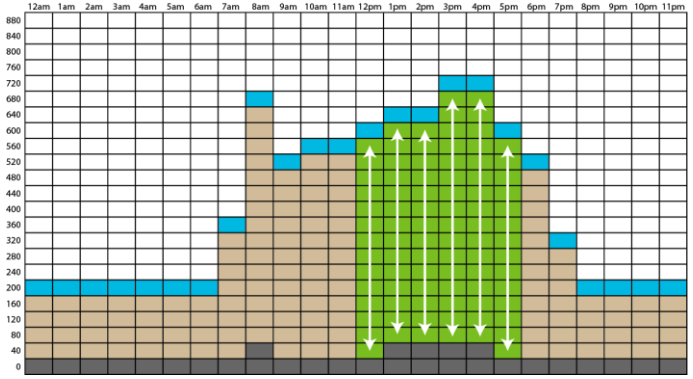
- Core building equipment
- Storage and advanced controls
- Response algorithms
- Replicated over a portfolio of buildings



Unaffected load profile of a building

Grid Services Enabled

- Capacity
- Energy
- Ancillary Services



Building delivering capacity to the grid

Questions?

Matt Bye, LEED AP
Trane Commercial Energy Services & Controls
Grid Services Product Manager

matthew.bye@trane.com

Thank you!

Marc Collins
Senior Principal Consultant, DNV GL
416-522-3064
Marc.Collins@dnvgl.com

Raymond Kaiser
Director Energy Management Systems, Amzur Technologies
941.320.9866
Raymond.Kaiser@amzur.com

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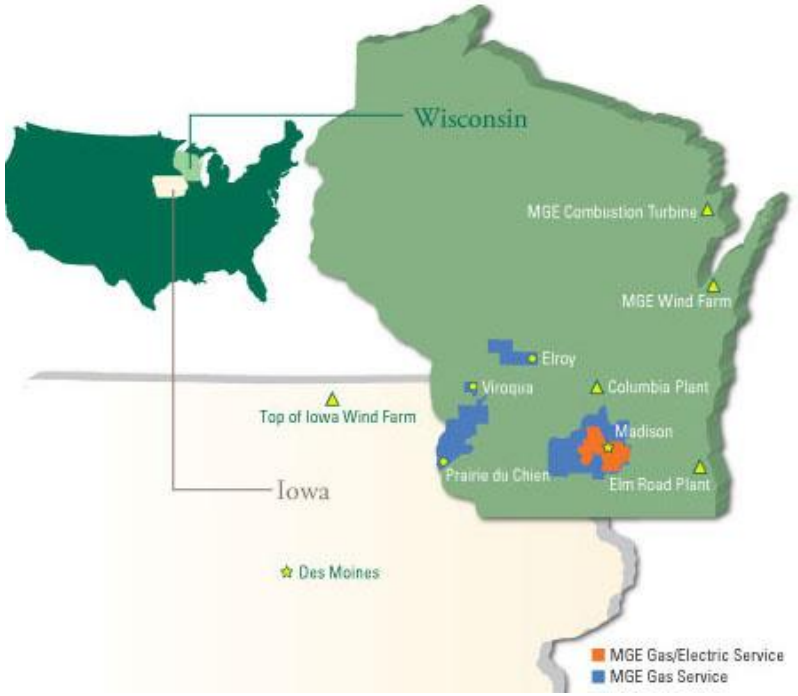
Deep Dive - Wisconsin

Madison Gas & Electric (MG&E)

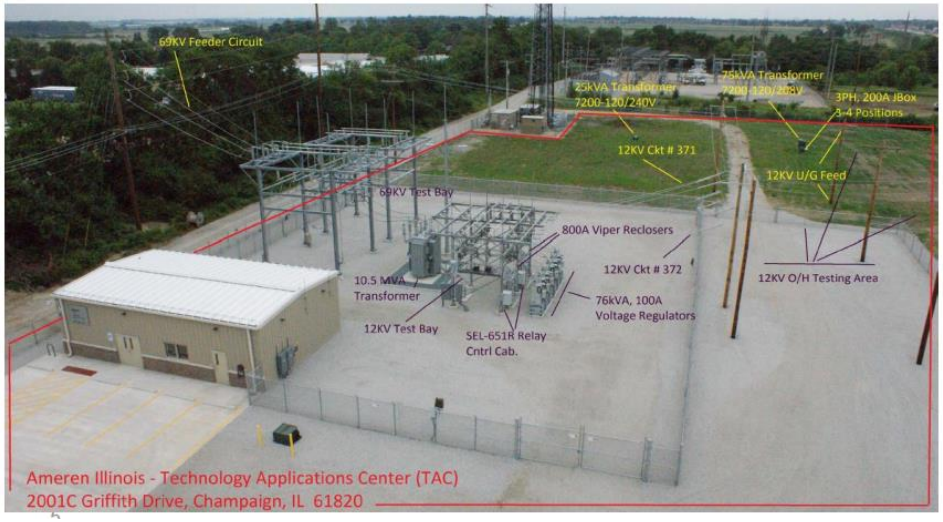
- ~148,000 electric customers
- ~7,000 AMI meters replaced this year due to AT&T sunset of 2G network



Images: http://madison365.com/wp-content/uploads/2015/11/MGE.jpg ; https://www.mge.com/images/embed_servicearea_2010.jpg

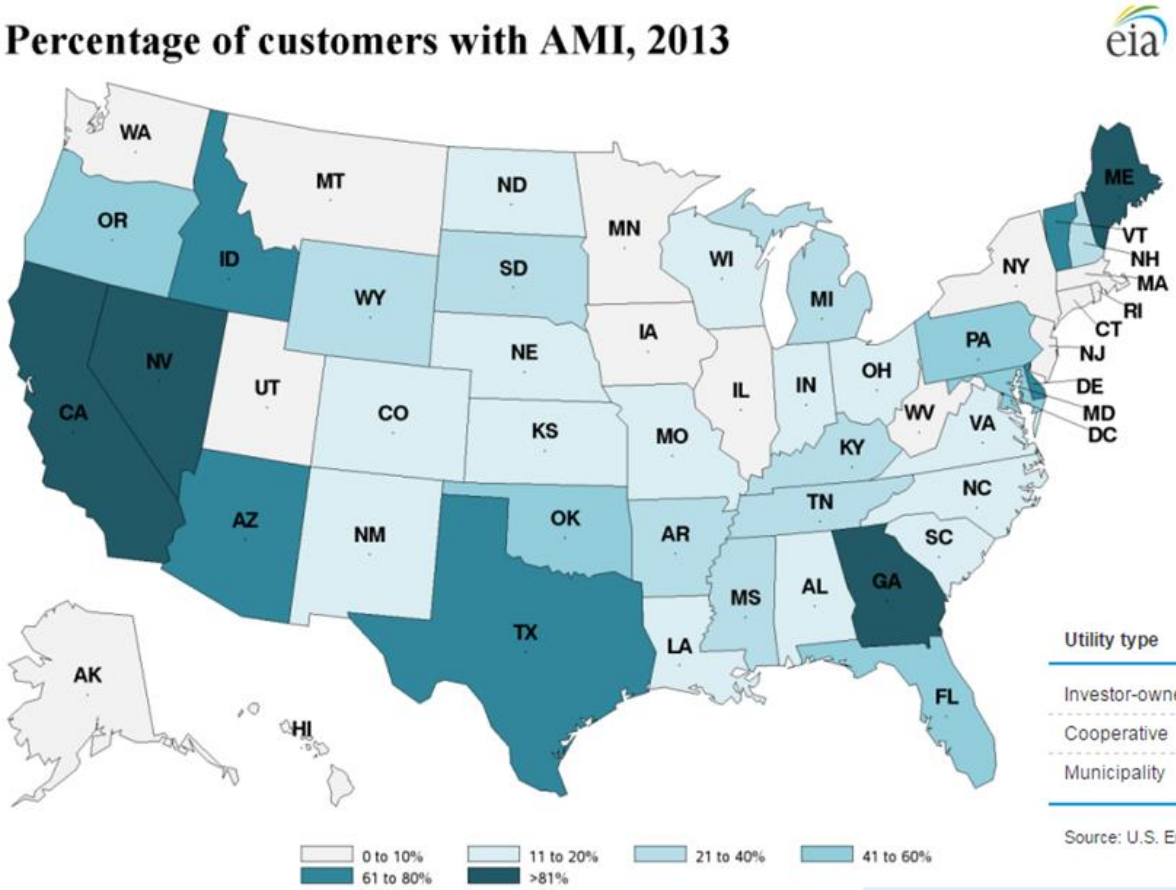
Deep Dive - Illinois

- Energy Infrastructure Modernization Act (EIMA) of 2011
- Planned 780,000 new AMI meter installs by 2022.
- Commission order to support customer home area network (HAN) device integration.
  - $3.3 million testing facility opened in August 2013



Images: https://tcipg.org/sites/default/files/slides/iw2014_borries_don.pdf

2013 AMI Meter Penetration



Utility type	Total customers	AMI meters	AMR meters	AMI penetration rate (%)	AMR penetration rate (%)
Investor-owned	106,477,972	38,856,749	34,517,067	36.5	32.4
Cooperative	18,881,923	8,564,797	7,774,317	45.4	41.2
Municipality	16,180,915	2,638,935	5,253,854	16.3	32.5

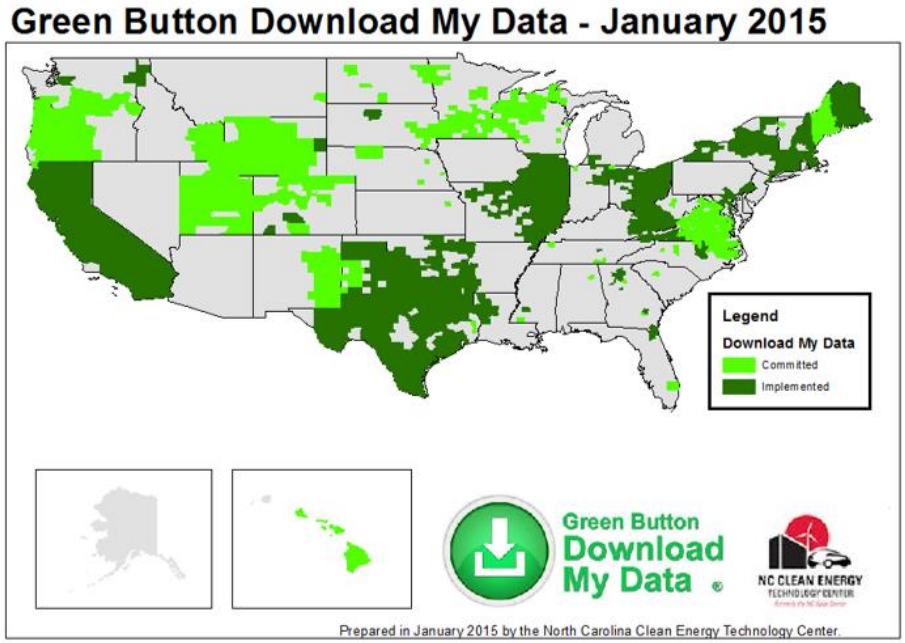
Source: U.S. Energy Information Administration, Annual Electric Power Industry Report (Form EIA-861)

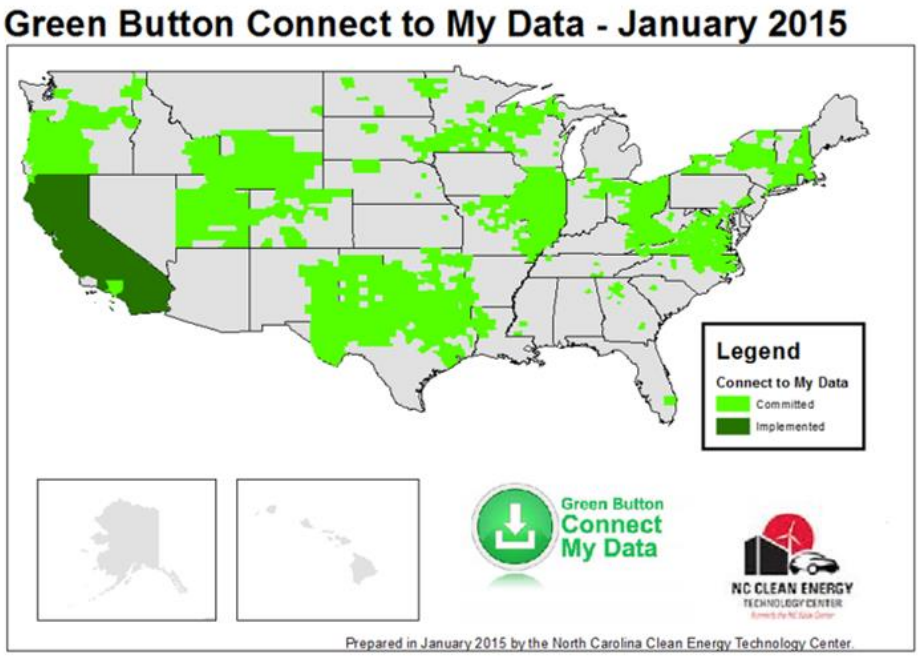
Number of AMI installations by sector, 2014

Residential	Commercial	Industrial	Transportation	Total
51,710,725	6,563,614	270,683	916	58,545,938

Source: U.S. Energy Information Administration (EIA)

2015 Cloud Data Access

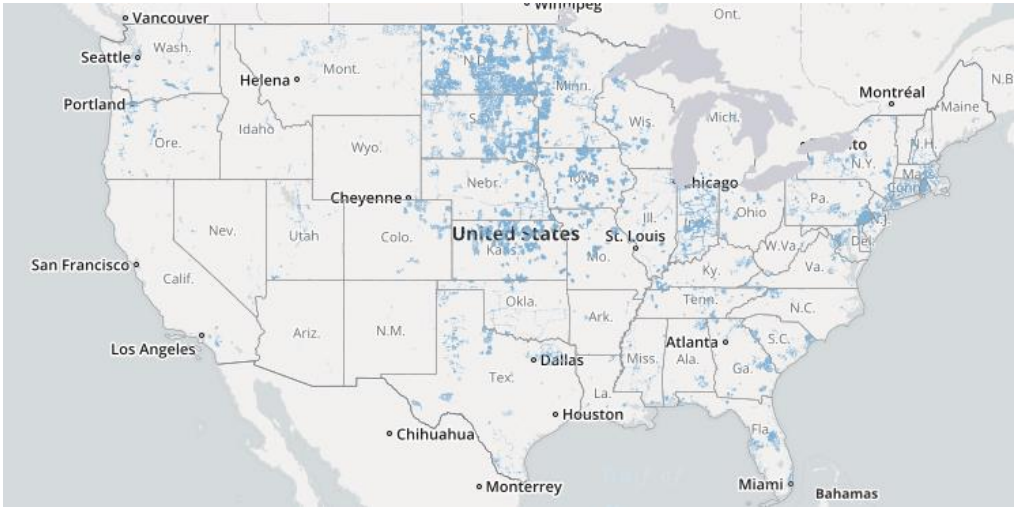




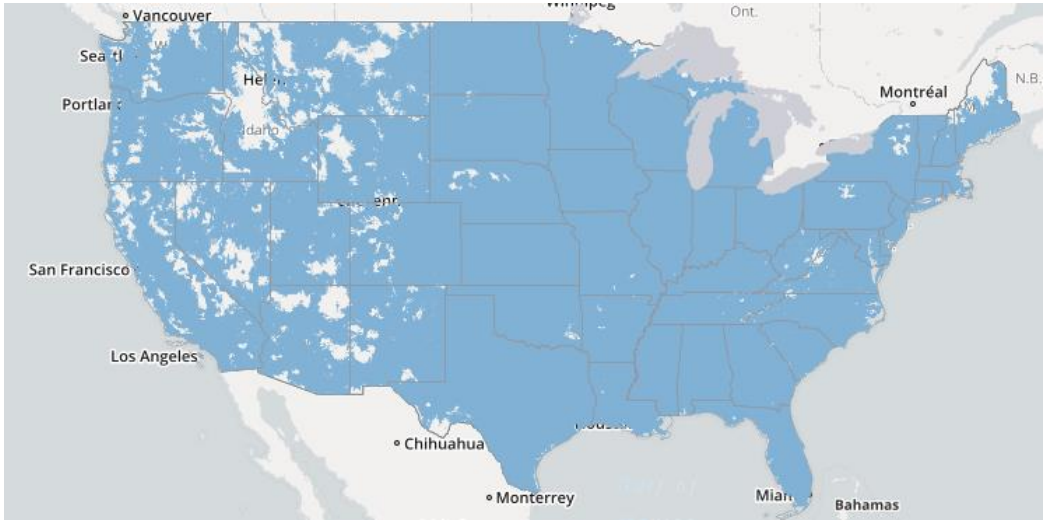
Source: http://www.dsireusa.org/resources/detailed-summary-maps/green-button-map/

Nationwide Broadband

Fiber to the End User



Terrestrial Mobile Wireless

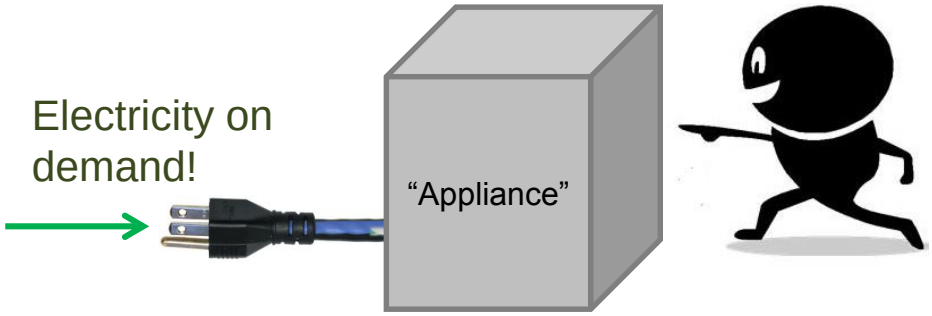


Source: National Broadband Map, http://www.broadbandmap.gov/technology ; data as of 6/3014

More on Alonetic

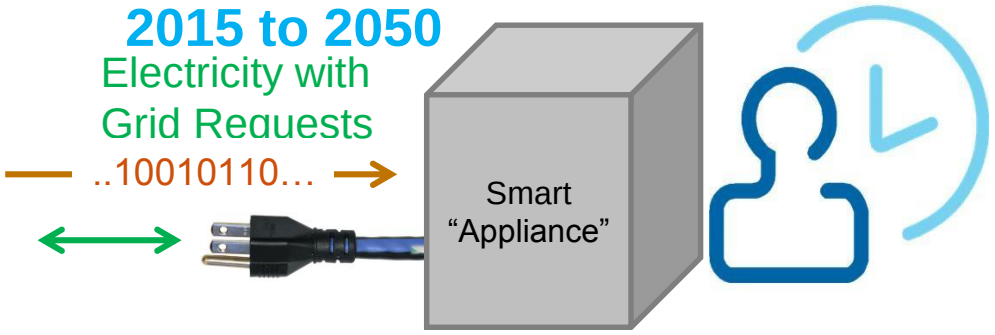
- **For first 120 years**
  - Energy flows one way to customer
  - Customer loads and generation serve best interests of customer
- By 2008, renewables at scale everyone talks about storage
- By 2010, Idea: many loads can respond to price and control signals to help integrate renewable generation.
- **Alonetic is word to describe concept**

Then: 1890 to 2010



Customer commands; device giveth

2015 to 2050

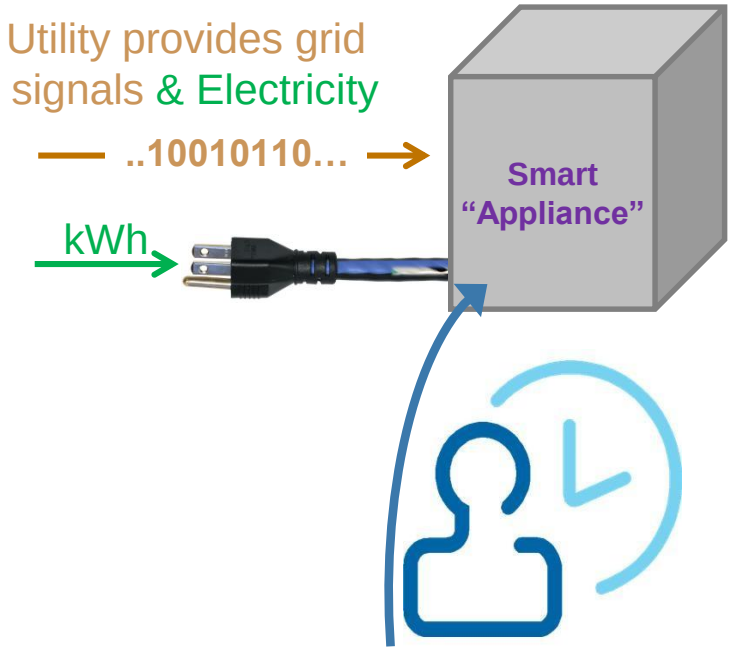


Customer inputs flexibility→ device serves customer & grid!

Portland General Electric

Why Alonetic Devices Create Win-Win

- In a nutshell: Customers benefit because they don't pay full cost of the new technology
- Utility provides "rebates" in return for control permitted by the customer
- Secret sauce in each **smart** device
  - Manufacturer provides simple way for **customer** to define **flexibility**
  - Device receives **utility signals via standard** communication
  - Control logic in device **maximizes grid benefit,** but **ensures customer needs met**



Customer inputs flexibility, then device serves customer & grid!

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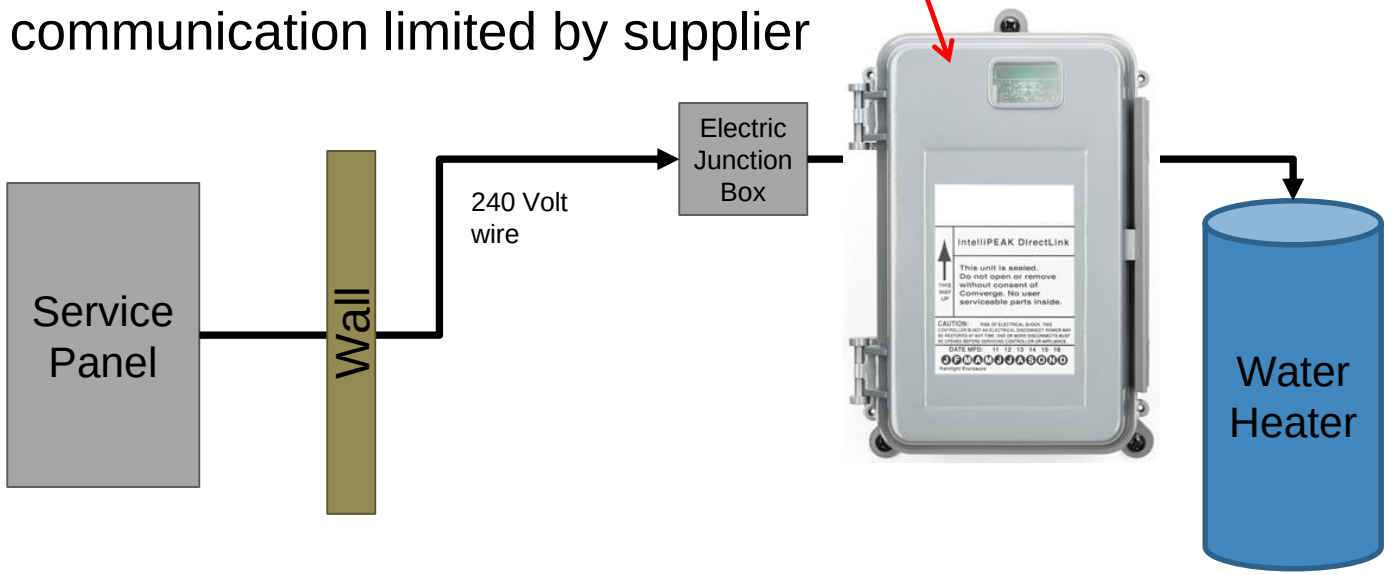
Easy Targets for Alonetic Devices

Electric Device	Egonetic Design	Alonetic Design
PV System	Customer with Net Metering	Customer's Smart PV Inverter provides voltage support
Whole House Battery Backup	Expensive asset used 0.02% of time	Battery serves: customer in outage, utility to reduce peak
Water Pumping	Tanks maintained between low/high set points	Variable speed pumps vary output ∝ renewable output
Com' HVAC: Fans/Chillers	Temp maintained between low/high set points	Variable speed compressors/ fans vary output ∝ renewable output
PEVs	Charge after evening commute	Charge rate ∝ renewable output
Heat Pumps	Temp maintained between low/high set points	Variable speed compressors vary output ∝ renewable output
Commercial Refrigeration	Temp maintained between low/high set points	Pre-cooling before peak causes reduced load during peak
Water Heater	Reheat after each cold water draw	Always has hot water in top-third; bottom reheat to serve grid

Portland General Electric

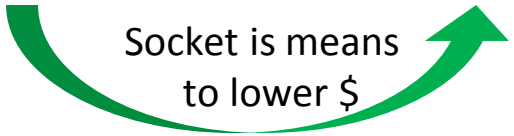
Existing Process for Water heater DR via load control box

- Licensed electrician
- Often a city permit
- Customer at home
- Water heater loses all power
- Choice of communication limited by supplier

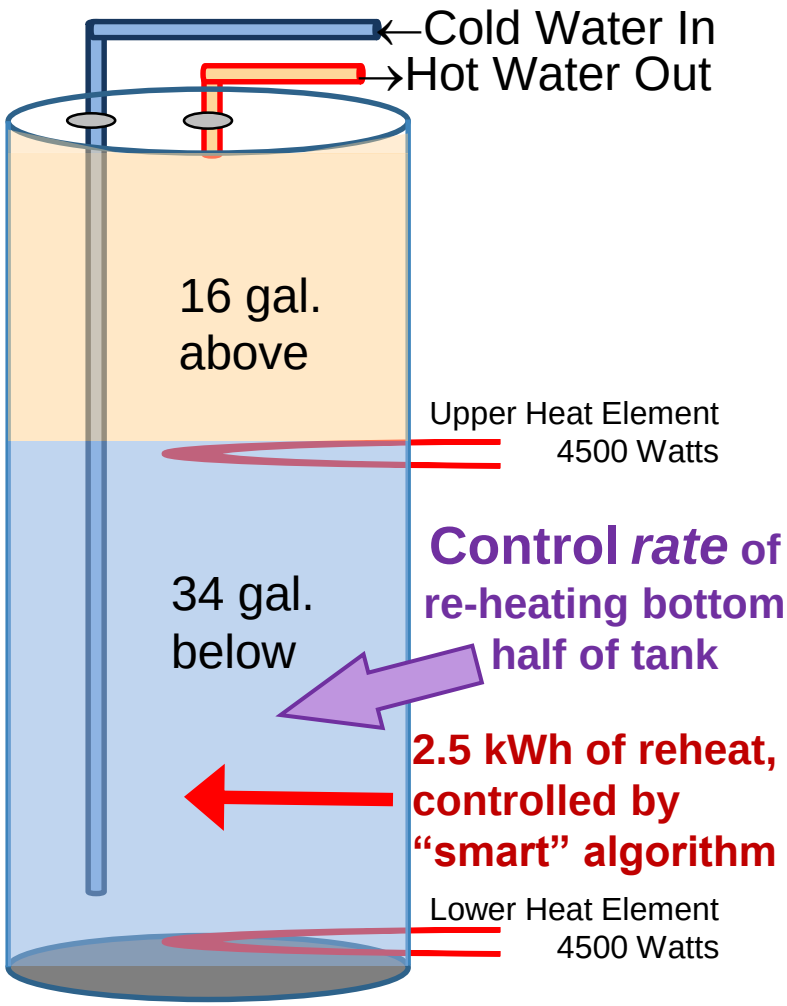


The Box Install is Too Expensive

Control Method => Install Component	Control Box	Standard Socket on Tank
Factory tank modification	none	$15 (in volume; only $1 for heat pump WH)
Control box	$100	none (uses tank controls)
Communication device	included above	$50 -> $10 (in volume)
Installation & materials	$175 ($25 (average) for aborted starts)	$0 (customer-installed)
Join program incentive	$50 (to leave work to meet installer)	$0
Reserve to remove unit	$50	$0
Marketing	$M	50%*$M
Permit	$15	$0
Total	**$390 +$M**	**$65 -> $10 + 0.5*$M**



EXAMPLE: Smart Water Heater Control Creates Capacity & Energy Savings



- **"Smart" tank always keep top third of tank hot**
- Service provider controls re-heating on bottom element to enable to these daily benefits (based on 200,000 water heaters)

1. For Wind integration over 20 hours:
   - Establish 500 watt *average* by cycling "on" 7 mins in each hour, but in…….
   - In real-time control load between 0 & 1.0 kW
   - Total flex-load range is 0 to 100 MW
   - 500 MWh of load sink for renewables
2. For load shift, reduce system peak by ~100MW

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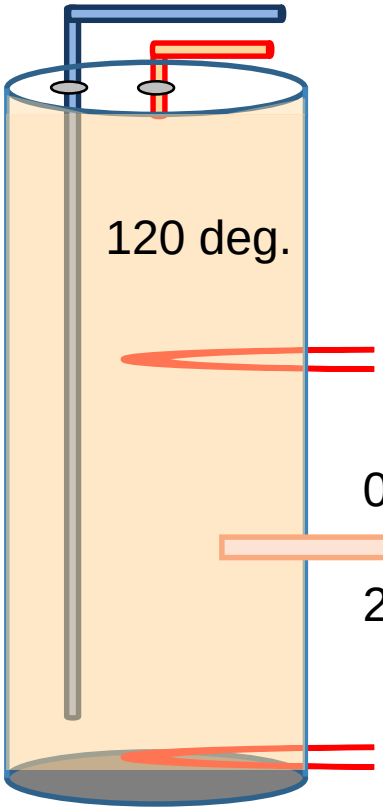
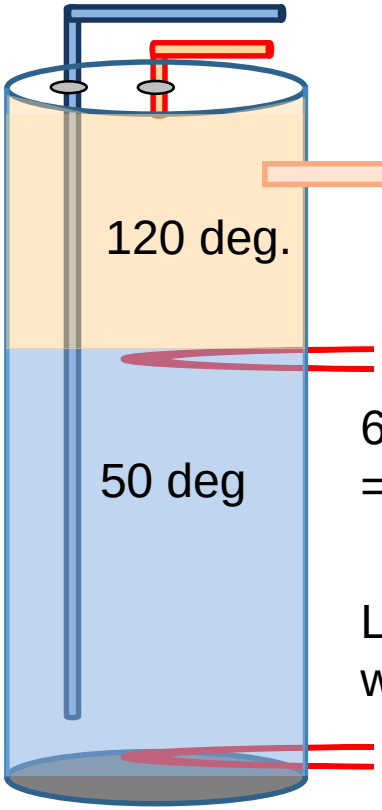
First Way to Save Energy

1. Conventional- lower standing losses ~52 kWh/yr
   a. 0.5 mmBtu at plant



Room at 65 degrees

0.95 EF tank Losses 225 kWh



0.95 Losses

75 kWh

65% of time (2/3)*225 = ~90 kWh

Losses 0 kWh when cold

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3 Ways to Save Energy by Choosing When to Reheat Cold Water: Alonetic Water Heater

Using 5.5 kWh storage 344 days/yr

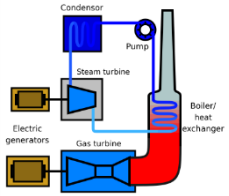
1. Daily arbitrage: 230 days
   Save = 2.5 mmBtu/yr

2. Firming winding 2,450 hrs/yr
   Save = 2.3 mmBtu/yr

3. Sink for excess wind 5 days/yr
   Save = 0.3 mmBtu/yr

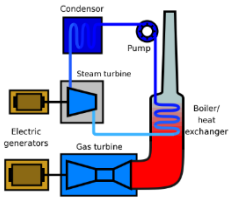
Total = 5.5 mmBtu/yr
- Equivalent 640 kWh at meter

Day Heat Rate 8,700

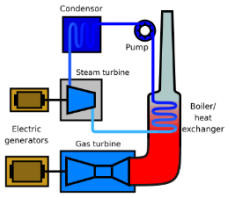


VS.

Night Heat Rate 7,100

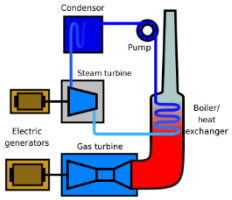


Peaker Heat Rate 8,750

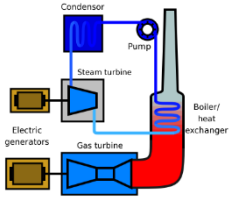


VS.

Baseload Heat Rate 6,826



Night Heat Rate 7,100



VS.

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Notes for Inc./Dec. Slide

- The black line is water heater load without any shaping, but we show a 24-hour period beginning hour ending 2000 on Aug 13
- The green line is the firm load we would create with 18 hour advance notice prior to hour ending 7a on Aug 14.
- The red bars show how the green shape would change if the real time desk requested a dec for the hour ending 7a; in other words we could increase WH load from 180 MW to 310 MW. Note that the total dec capability is limited to 270 MWh (can be shaped via the real time request)
- The blue bars show how the green shape would be changed if an inc is requested for the same time period. That is the 180 MW load could be decreased to about 30 MW in the first hour and to 60 MW in the second hour, etc.
- The green shape was designed quickly to create roughly equal decrement in power for incs and decs.
- An alternative design could create equal MWh for incs or decs or a preference to have either more inc or more dec capability, or capability for an early or later start time.

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More on CTA-2045

- Remaining slides explain more about what CTA-2045 is, and isn't.
- Key take way should be that requiring CTA-2045 adoption is the key to
  1. Enabling **any** physical communication method, Wi-Fi, ZigBee, CDMA, Ethernet, PLC, etc.
  2. Enables **any** command language used by the appliance, including proprietary commands
  3. Enables future proofing! i.e. the ability for an 20-year old appliance to interact with new communication methods, not even know today, by simply adding a translation device at the communication device plugged into the CTA-2045 socket on the appliance

This EPRI video might complement your understanding : https://www.youtube.com/watch?v=BHMssq6_R94

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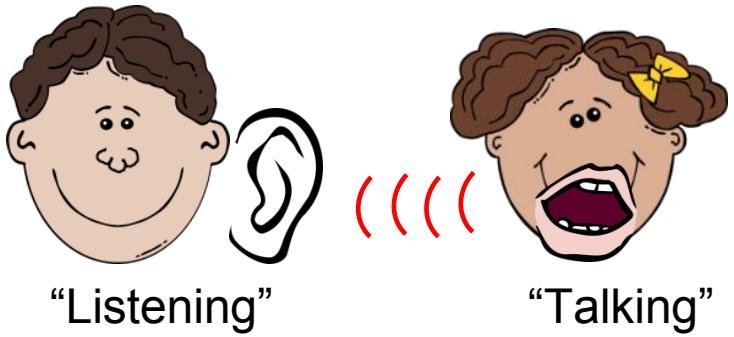
What is CTA-2045, really?

- Digital communications are complex and break
- A single, end-to-end communication (including human communication) requires multiple standards
- Before the CTA-2045 question, let's review the analogy of human-to-human communication.

HTTP, JPG, XML, WSP, TCP, IP, Ethernet, Sonet, GSM, DSL, IEEE802.11, USB, RS-232



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Human Communication Requires Use of 3 standards

1. Use the same physical communication method
   - E.g. ears and vocal cords connected by brain
   - We take this for granted but how would you talk to a dolphin or alien?
2. Use the same rules to exchange information
   - E.g. wait to talk until the current conversation finishes
3. Use the same language
   - E.g.: Latin

Quod erat demonstrandum!

Lo entiendes? 你明白吗？ Erhalten sie es?

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#1 The Physical Standard

- This is about physical ability to perceive a communication signal
  - You have the right sensor and signal processor
  - Humans use light, sound, and touch

- Most of us have vocal cords and ears with brains to create/process sound waves
  - Most humans have the same physical standard, even if they use different languages
  - Hearing-impaired people example of difficulty and cost of not having a working hearing sensor
  - *Spoiler Alert: CTA-2045 is like putting ears and vocal cords on all appliances, or a USB socket on all computers*

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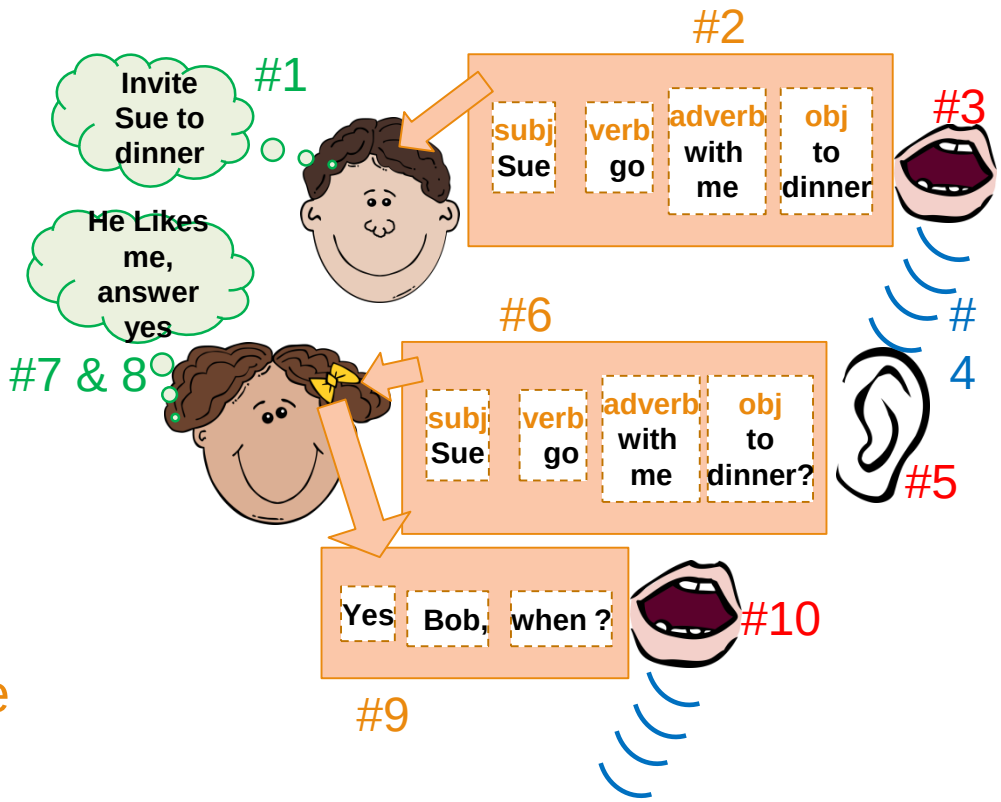
Information Flows Through "Layers", each Requires a Standards

1. LS: Bob conceives msg.
2. DLL: construct msg.
3. PL: create msg.
4. ➔ physical conveyance
5. PL: Sue Hears msg.
6. DLL: Deconstruct msg
7. LS: processes msg.
8. LS: conceives response
9. DLL: constructs response
10. PL: creates response



Language Standard
Exchange Standard
Physical Standard

Info at physical layer can travel distance

Language Standard
Exchange Standard
Physical Standard

= (LS)

= Data Link Layer (DLL)

= Physical Layer (PL)

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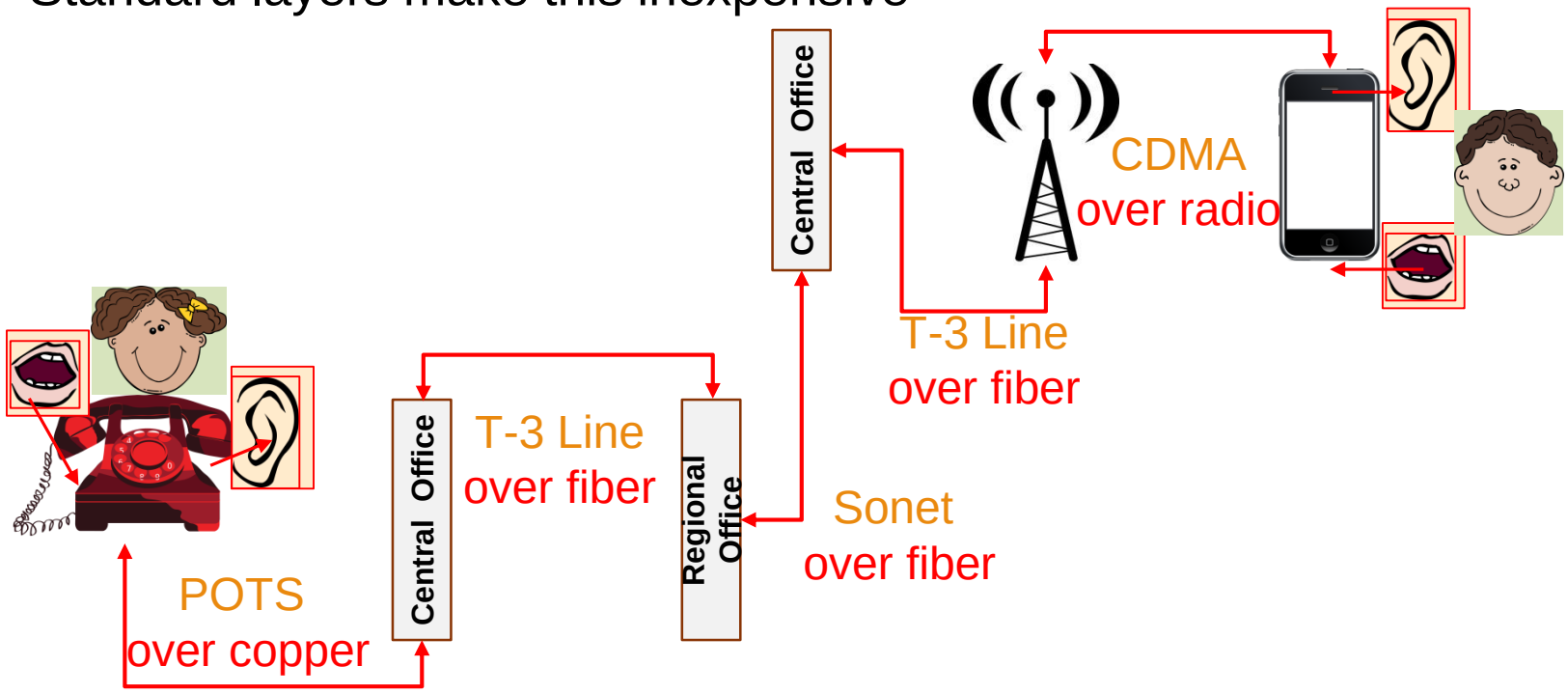
Digital Communication More Complex

- Assets that enable long distance communication are expensive so increasing data speed, and # of users a constant goal
- Standards for digital communication layers make this possible
- Communication often traverses <u>many</u> physical media
- Standard layers make this inexpensive



ANSI/CTA-2045

- Physical layer

  - Standard form factor
  - Standard physical process (RS-485 or SPI)
  - Provides standard power supply
- Data link layer (Exchange rules: “i” before “e” except after “c”)
  - Negotiates language to speak
    - SEP, OpenADR, BACnet, **Proprietary**, CTA-2045
    - TCP/IP pass through
  - Data format
  - ACK, NAK
- Optional application layer (except)
  - Shed & return-to-normal required

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Standard communication interface

Need to reduce cost: Choices

Credits: Creative Commons

- Wired
  - E.g. RS-485, Ethernet, BACnet
  - Secure, but hassle
- Wireless
  - PLC (e.g. Home Plug), Wi-Fi, CDMA, Z-wave, Bluetooth
  - Always-on energy use, even if never connected
  - Opens vector for hackers
    - Many appliances can not upgrade software

- Socket *(socket allows all of above standards)*
  - USB, ANSI/CTA-2045
    - USB, prone to noise, does not support PLC
    - ANSI/CTA-2045
    - Today, to address issues in red, smart appliances have proprietary sockets

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Telegram: First "modern" real-time, long-distance communication

- Humans, physically, can only communicate about 100 yards with sound, about a mile using a flashing light
- 1836, Samuel Morse, Joseph Henry, and Alfred Vail invent Telegraph system

Application standard

First standard was for English with composition rules to create brevity

Rules to write a Telegram

- A telegram must always be written in capitals.
- No columns in the telegram form should be left unfilled.
- Different ideas conveyed in a telegram should be clearly shown with full stop(.) or the word 'STOP' should be written between them.
- Words used should be clear, precise, direct and specific.
- As every word costs, selection of appropriate words to give the complete 'sense' must be made.
- All linking words, articles, prepositions and unnecessary details are generally avoided.
- Salutations are avoided.

Credit: LearnNext™: Telegram-Writing-Rules

Exchange standard DDL

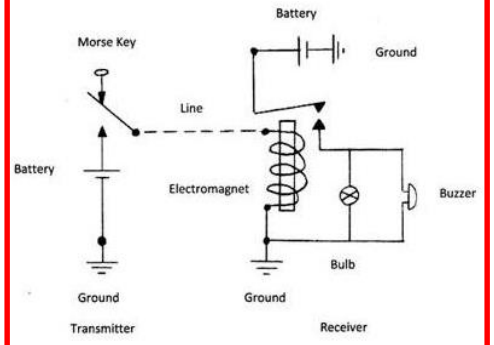
Letters and punctuation encoded to dots and dashes (**Morse Code standard**)

Special codes controlled use of network, e.g. end of message, clear to start, error, wait, msg understood

One message would complete before next begins

Physical standard

Dots and Dashs (current pulse) over a single wire



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Digital Communication More Complex

- Asset that enables long distance communication are expensive
- Increasing data speed and # of users on a given asset a constant goal
- So today, more than just 3 layers
- What I've been calling the exchange standard is now known as the Data Link Layer (DLL)
- Communication today often traverses on <u>many</u> physical media