Overview of CalPlug Research

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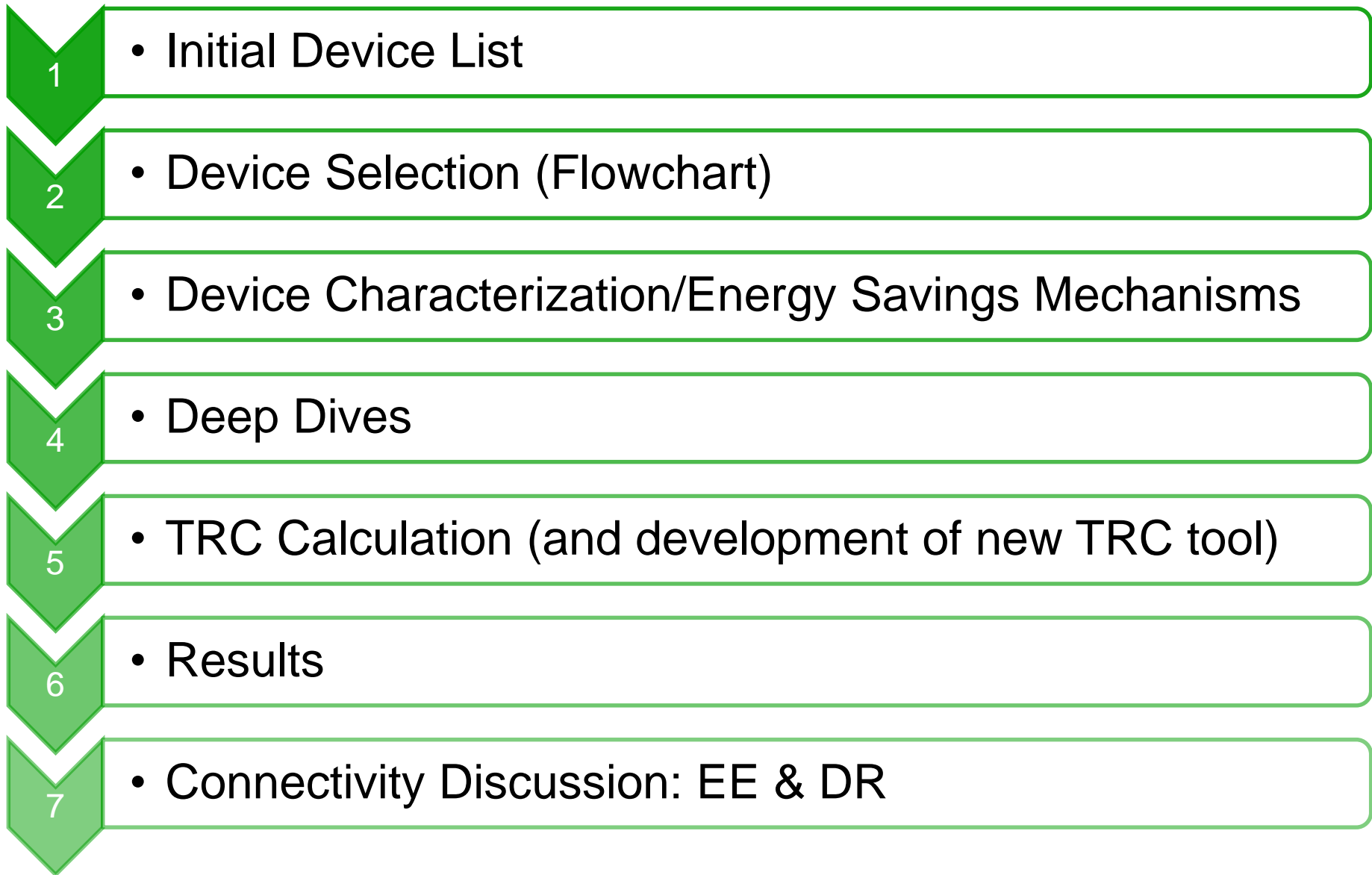
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EE and DR Program Opportunities in Connected Plug Load Devices (SDG&E)

Project Goals:

➢ **Provide insight into under-researched connected devices**

➢ **Assess potential energy savings for connectivity in residential plug loads**

➢ **Make relevant EE and DR program recommendations**

Global Smart Home Market, 2016-2022 (USD Billion)

Source: Zion Research Analysis 2017

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Approach

1. • Initial Device List
2. • Device Selection (Flowchart)
3. • Device Characterization/Energy Savings Mechanisms
4. • Deep Dives
5. • TRC Calculation (and development of new TRC tool)
6. • Results
7. • Connectivity Discussion: EE & DR

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Significant Residential Plug Loads → **Device OR System** → **Evaluation for:**
1. Connectivity
2. Market Trends
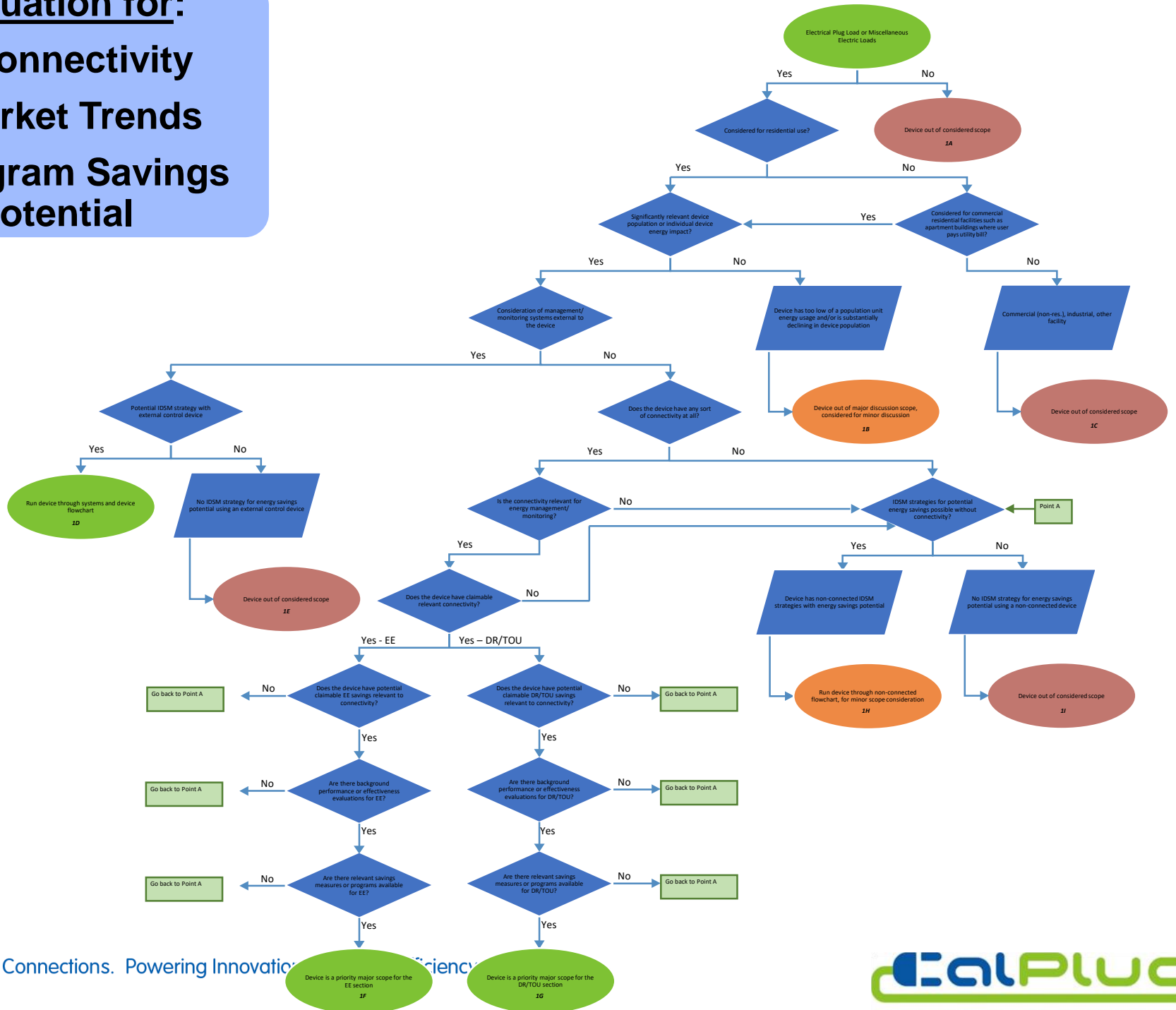3. Program Savings Potential

Controlled Outlets
TV
Game Console
DVD Player
Audio Receiver
Tuner
Speakers

Always-on Outlets
Cable Modem
DVR

APS with controlled devices

Device with onboard energy management

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Evaluation for:
1. Connectivity
2. Market Trends
3. Program Savings Potential

Electrical Plug Load or Miscellaneous Electric Loads

Yes → Considered for residential use?
No → Device out of considered scope — 1A

Considered for residential use?
- Yes → Significantly relevant device population or individual device energy impact?
- No → Considered for commercial residential facilities such as apartment buildings where user pays utility bill?

Considered for commercial residential facilities such as apartment buildings where user pays utility bill?
- Yes → Significantly relevant device population or individual device energy impact?
- No → Commercial (non-res.), industrial, other facility → Device out of considered scope — 1C

Significantly relevant device population or individual device energy impact?
- Yes → Consideration of management/monitoring systems external to the device
- No → Device has too low of a population unit energy usage and/or is substantially declining in device population → Device out of major discussion scope, considered for minor discussion — 1B

Consideration of management/monitoring systems external to the device
- Yes → Potential IDSM strategy with external control device
- No → Does the device have any sort of connectivity at all?

Potential IDSM strategy with external control device
- Yes → Run device through systems and device flowchart — 1D
- No → No IDSM strategy for energy savings potential using an external control device → Device out of considered scope — 1E

Does the device have any sort of connectivity at all?
- Yes → Is the connectivity relevant for energy management/monitoring?
- No → IDSM strategies for potential energy savings possible without connectivity?

Is the connectivity relevant for energy management/monitoring?
- Yes → Does the device have claimable relevant connectivity?
- No → IDSM strategies for potential energy savings possible without connectivity?

Point A → IDSM strategies for potential energy savings possible without connectivity?
- Yes → Device has non-connected IDSM strategies with energy savings potential → Run device through non-connected flowchart, for minor scope consideration — 1H
- No → No IDSM strategy for energy savings potential using a non-connected device → Device out of considered scope — 1I

Does the device have claimable relevant connectivity?
- Yes - EE → Does the device have potential claimable EE savings relevant to connectivity?
- Yes – DR/TOU → Does the device have potential claimable DR/TOU savings relevant to connectivity?

Does the device have potential claimable EE savings relevant to connectivity?
- No → Go back to Point A
- Yes → Are there background performance or effectiveness evaluations for EE?

Are there background performance or effectiveness evaluations for EE?
- No → Go back to Point A
- Yes → Are there relevant savings measures or programs available for EE?

Are there relevant savings measures or programs available for EE?
- No → Go back to Point A
- Yes → Device is a priority major scope for the EE section — 1F

Does the device have potential claimable DR/TOU savings relevant to connectivity?
- No → Go back to Point A
- Yes → Are there background performance or effectiveness evaluations for DR/TOU?

Are there background performance or effectiveness evaluations for DR/TOU?
- No → Go back to Point A
- Yes → Are there relevant savings measures or programs available for DR/TOU?

Are there relevant savings measures or programs available for DR/TOU?
- No → Go back to Point A
- Yes → Device is a priority major scope for the DR/TOU section — 1G

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CalPlug Connectivity Classification

Connectivity Class	Class Identification	Class Description
0	Non-Connected (Null Case)	Power management w/out connectivity
1	Reporting Only	Energy usage reporting; manual DR notifications
2	Real Time Monitoring w/Control	Connectivity class 1 + ability to adjust settings remotely
3	Demand Response (Automated)	Remote triggering for DR actions
4	Network-Based Device Management	Remote/cloud capability to control or fine tune device operation
5	Network-Based Management w/ Edge Computing Control	Connectivity class 4 + capability of local (edge) processing

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Assessing Cost Effectiveness

➢ **TRC = Total Resource Cost**

➢ **Problem: Insufficient data**

➢ **Solution: We created a new assessment tool for modified TRC calculation**

  ➢ Simplifies and streamlines the variables

  ➢ Allows a range of inputs to reflect uncertain data

  ➢ Produces reasonable program performance bounds to assess cost-effectiveness

Simplified TRC Calculation

Equation: $$TRC = \frac{Benefit}{Cost} = \frac{UAC_t + TC_t}{PRC_t + PCN + UIC_t}$$

Cost Effectiveness = TRC > 1

	Variables	Definition of Variables
Benefits	UACt	*Utility* avoided supply costs in year t (Energy savings)
	TCt	Tax credits in year t
Costs	PRCt	Program Administrator program costs in year t
	PCN	Net Participant Costs
	UICt	Utility increased supply costs in year t

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Results: Devices/Systems (EE)

Device/System	CA Work Paper	Energy Star Specific Product Category	Modeled lifetime (yr)	Model Max TRC
Connected Refrigerator (v. non-connected) Class 1,2,3,4	✔	✔	14	0.05
Connected Washing Machine (v. non-connected) Class 1,2,3,4	✘	✘	11-15	0.62
Variable Speed Pool Pump (v. 2-speed) Class 1,2,3	✘	✔	9-11	(5.71)
Smart Plug with Window AC Unit (v. without smart plug) Class 1,2,3	✘	✘	3-5	(1.6)
Smart Plug with Hot Water Dispenser (v. without smart plug) Class 1,2,3	✘	✘	3-5	0.97
Tier 2 APS with AV/Entertainment (v. without APS) Class 1	✔	✘	3-5	(1.6)

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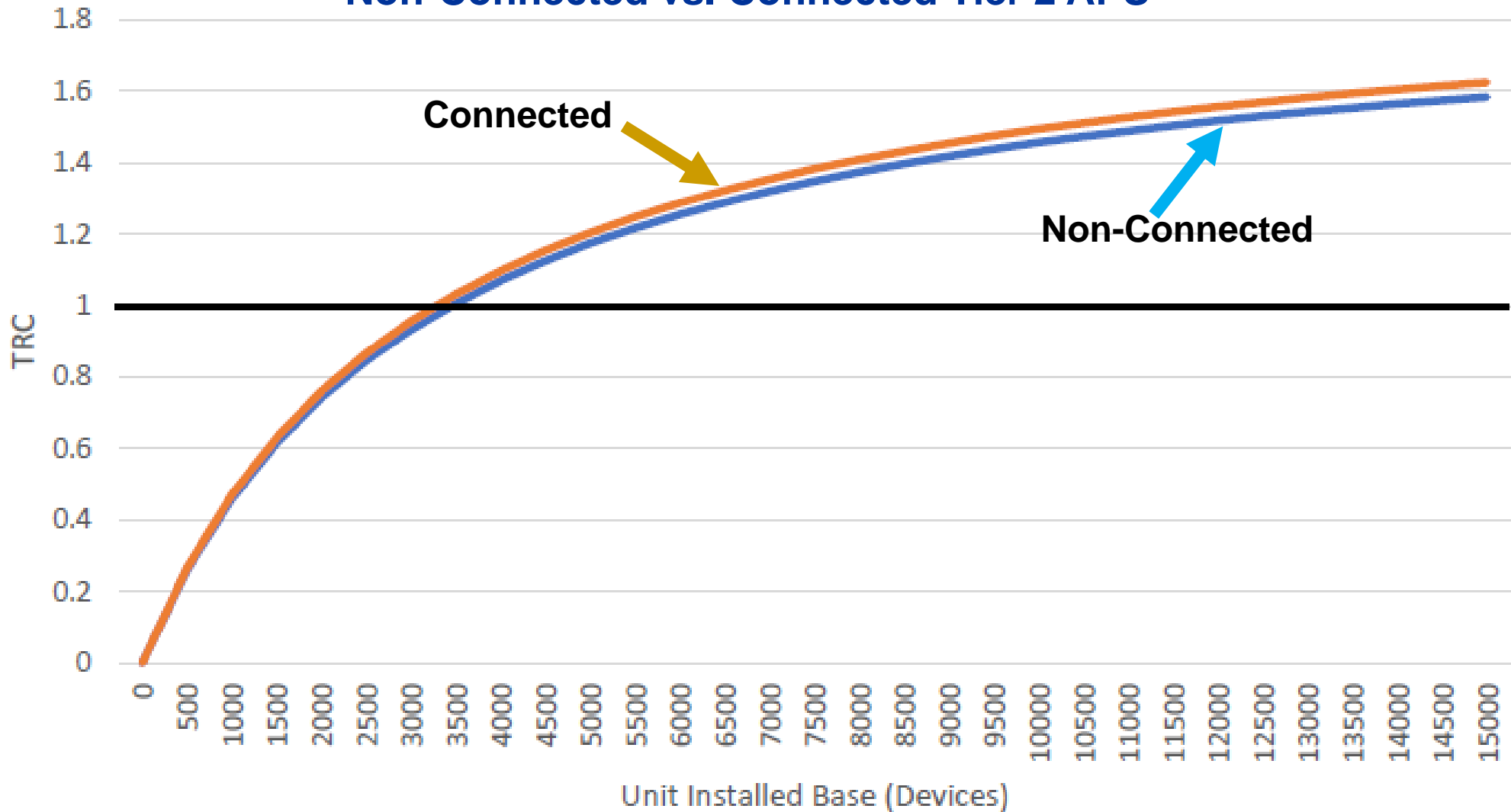
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So Does Connectivity Save Energy?

➢ **Comparison between connected and non-connected Tier 2 APS shows almost identical hardware, software, and functionality**

  ➢ Connectivity adds user monitoring features, but no real extended EE

  ➢ Connectivity features lead to only about 6 kWh/year additional savings per field trial results

➢ **Similar findings for other devices:**

  ➢ Washing machines

  ➢ Refrigerators

  ➢ VSD pool pumps

  ➢ Smart plugs

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Role of Connectivity and Decision Space
Assessing value, accuracy, and actionability

Human in the loop (HIL) control
Summarized user feedback in a convenient user interface improves both usage efficiency and reduction of wasteful use estimated at 2-6% savings <u>in many cases.</u>
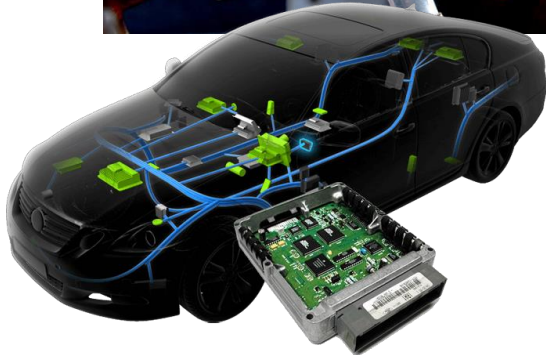
Automatic and Coordinated Control
More parameters and potentially more stable decision space. **Often logical rules: What added benefit can coordination, AI, or connectivity add?**

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Energy Efficiency and Connectivity: Discussion

- **Current status of EE with Connectivity**
  - **Limited CA work completed to current date**
    - Need further device field tests

  - **Limited EE connectivity opportunities for plug load appliances**
    - Role of user interfaces and device interaction, expanding actionability and decision space
    - Connectivity enabling operation towards
    Human-in-the-Loop/User behavior

- **Extended considerations**
  - **Costs/overhead of connectivity**
  - **Integration into IoT systems/SHEMS**

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Connectivity and DR: Results

Device	Shift period duration (ENERGY STAR)	Shift savings (261 periods/yr) kWh/yr	Shed period duration (ENERGY STAR)	Shed savings (261 periods/yr) kWh/yr
Connected Refrigerator	4 hr	15.97 kWh/yr	10 min	1.53 kWh/yr
Connected Washing Machine	4 hr	15.40 kWh/yr (at 100%)	10 min	1.55 kWh/yr (at 100%)
VSD Pool Pump	4 hr	63.20 kWh/yr	20 min	8.10 kWh/yr

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Connectivity and DR: Discussion

- **ENERGY STAR Smart Connected Devices category largely is focused on DR action.**

- **AutoDR relies on connectivity for control**

- **Load shift/shed limited for plug load devices**
  - **User experience**

- **DR solutions better suited to major appliances than smaller plug loads**
  - **Larger peak loads to shed**
  - **Physical control limits**

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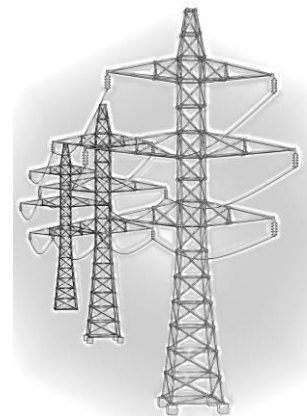
Summary

- ➤ **Connectivity offers limited EE savings in plug load devices**
  - ➤ **IoT systems in future may address this challenge**

- ➤ **Connectivity offers limited DR savings in plug loads**
  - ➤ **Potential for Human-in-the-Loop**

- ➤ **Recommendation: Continued collaboration between utilities, DOE/ ENERGY STAR program, and manufacturers to improve EE standards and DR protocols for plug loads**

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Questions?

Thank you!

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