Technology Sector
Plug Load

Product Category
Advanced Power Strip with Motion Sensors

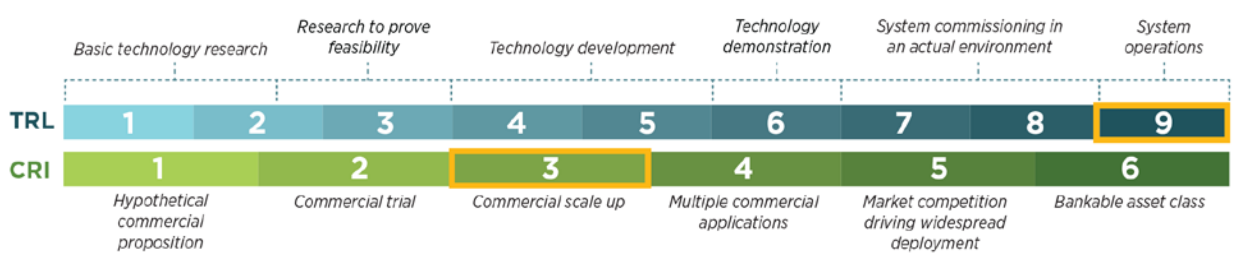
Last Updated
11/20/2018

*Figure 1: Picture of advanced power strip that can turn on if motion is detected* [1].

## Product Category Overview

A Tier 2 advanced power strip (APS) is equipped with a highly sensitive passive infrared (PIR) motion sensor that controls outlets based on occupancy sensing. APS also features master/switch electrical current sensing and schedule/timer controls. A Tier 1 APS has the master/switch electrical current sensing function but is not equipped with PIR motion sensing. For simplicity, APS is used hereafter to refer to a Tier 2 APS. If the system detects no movement within a specified period of time, it removes power from the switched outlets and shuts off plug-in devices to reduce the amount of standby electricity office electronics consume. Master/switch functionality recognizes if there is an electrical current through the strip's control outlet. If there is no electrical current, the "switched" outlets will be turned off. The scheduling and timer feature allows users to set a specific time to turn off any device plugged into the smart plug. Key functionalities include: (1) motion detection to remove the power supply when unoccupied for a specific period, (2) master/switch functionality, (3) schedule and timer controls, and (4) fireproof surge protection.

## Characterization at a Glance



# Product Category Characterization

## Energy Benefits

Electricity savings are achieved when the APS turns off office equipment plugged into it but not in use, eliminating standby power draw. Devices that use electricity during standby mode are known as standby power draw or phantom loads. Some such devices are coffee makers, personal computers, monitors, space heaters, commercial printers, etc. There are three methods with which the APS recognizes the need to turn off the office equipment: (1) PIR motion detection, (2) electrical current sensing of the control switch, and (3) schedules set by the operator.

The first method (IR motion detection) turns off devices when no motion is detected within a specific timeframe set by the user. When individuals forget to turn off the power strip, the APS will detect no motion and turn off the devices after the timer times out.

The second method via electrical current sensing is the feature that recognizes active usage of the device plugged into the control outlet. The devices typically plugged into the control outlet are used most frequently—typically a monitor or computer dock. When the APS senses no active electrical current flowing through the control outlet, it turns off the other devices plugged into the switched outlets. These devices are used less frequently, such as a personal printer, copier, scanner, or lamp.

The third method (scheduling) designates specific days and times that the equipment should be turned on/off. The scheduling feature works best for equipment with large phantom loads like commercial printers. Typical schedules would be on during 7AM-6PM for weekdays and shut down over the weekend.

## Non-Energy Benefits

Some non-energy benefits include data collection of equipment usage and increased fire safety and equipment life. The real-time, daily, and monthly electric power consumption data gives the user insight into when the device is using electricity but not being actively used. With this new information, the user can set the schedule so that the device turns off at the most appropriate time without compromising daily activities. This flexibility and control gives the user a variety of options that suit his or her working schedule. Traditional surge protectors use metal oxide varsitor (MOV) components; APS MOVs are encased with ceramics and can dissipate heat faster than traditional MOVs. The ceramic casing is also fireproof and capable of preventing fire during abnormal surge conditions.

## Product Category Differentiation

This product differentiates itself from other smart plug devices because it creates efficiencies by using motion detection to control the amount of energy other devices use. Compared to a traditional power strip outlet with no controls, an APS is an incremental improvement because it enables the power strip to turn off other devices via the PIR motion detection and electrical current sensing of the controlled outlet. Traditional power strips don’t have the functionality of motion detection or current sensing of the master outlet. Tier 1 APS have the master/switch electrical current sensing function but are not equipped with IR motion sensing. Tier 2 APS have both the master/switch electrical current sensing function and the IR motion sensing capabilities.

## Installation Pathway and Dependencies

The installation pathway of this product category is plug-in, and the only installation dependency is the type of voltage the device runs on, which can only be for 120V devices not 240V.

## List of Products

Table 1: Summary of manufacturers and products for the product category.

| Manufacturer | Model | Type | Differentiating Feature |
|---|---|---|---|
| TrickleStar | TAA3701 | 120-volt | Has sensor system that is able to turn off/ on a network of APS. |
| Embertec | Emberstrip 8AV+ (Bluetooth) | 120-volt | Has Bluetooth connectivity to control one or more APS devices from iOS or Android application. |

## Quantification of Performance

A literature search was conducted and a sample of published study results are summarized in Table 2.

Table 2: Summary of results from literature review

| Location | Application | Results | Reference |
|---|---|---|---|
| Minnesota, USA | Field measurement of eight office buildings that have more than 40 workstations per building over a three-month period.<br>Baseline is the existing condition consisting of 312 workstations, 312 computers, and several individual larger plug loads.<br>Measurements include APS with foot pedal, APS with occupancy sensor, behavior campaign + user chosen APS.<br>The behavior campaign development comprised of applying design thinking methodologies for education around employee APS use during the study. | All energy savings are in units of kWh per workstation.<br>Baseline of workstations: 332 kWh/yr.<br>APS with foot pedal savings: 42 kWh (19% ± 12.6%).<br>APS with occupancy sensor savings: 67 kWh (21.7% ± 14.0%).<br>Behavior campaign with foot pedal APS savings: 70 kWh (22.4% ± 13.2%). | [2] [1] |
| Delaware, Pennsylvania, West Virginia, New Jersey, Maryland; USA | Field measurement of eight buildings over a 3-month period from General Services Administration where plug loads averaged 21% in total building electricity consumption. In each building, baseline technology was 12 standard power strips with no control capability.<br>Each power strip was replaced with APSs which monitored and provided power to an array of devices.<br>Three types of plug load strategies demonstrated: 1) schedule timer 2) load-sensing using an advanced power strip and 3) a combination of the two above.<br>Note that the reported savings were exclusively using schedule timer control. Savings from current sensing were not included due to technical issues in the project. | 26% plug load reduction (energy savings) at workstations on top of the computer power management that was already in place.<br>Average energy savings by device type: Printer = 35%; Laptop = 21%; Monitor = 7%; Under-cabinet light = 14%; Misc. equipment = 51%<br>Kitchen equipment = 46%<br>The largest savings were due to constant loads such as printers that were not being turned off or kitchen/workstation equipment not being de-energized. | [3] |

## References

[1] "Tricklestar," Tricklestar, 11 May 2018. [Online]. Available: https://www.tricklestar.com/products/motion-sensor.html. [Accessed 20 Novemeber 2018].

[2] S. Hackel, C. Plum, M. Colburn, G. Marsicek, T. Rozenbergs, N. Kessler, R. Carter and L. Kieffaber, "Impacts of Office Plug Load Reduction Strategies," Minnesota Department of Commerce, Division of Energy Resources, Minnesota , 2016.

[3] I. Metzger, D. Cutler and M. Sheppy, "Plug-Load Control and Behavioral," National Renewable Energy Laboratory, San Francisco, 2012.

**Product Characterization Report**
**California Energy Product Evaluation (Cal-EPE) Hub**

Technology Sector
Plug Load

Product Category
Enterprise Servers with Integrated Power Management

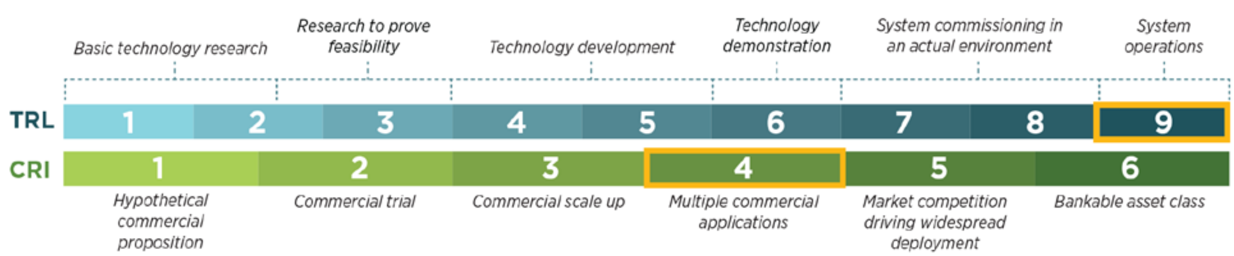
Last Updated
12/18/2018

*Figure 1: Picture of enterprise server* [1]

## Product Category Overview

An enterprise server is a computer server that runs the essential functions of a business, such as virtualized server hosting platforms (cloud hosting), email servers, hosting company websites, managing databases, etc. Key functionalities include: (1) integrated power management features, (2) efficient power supplies and (3) the capability to measure real-time power use, processor utilization, and inlet air temperature. Comprised of hardware and software, these servers are generally fault tolerant with low failure rates to optimize server operations like consolidated connections, choice of broadcast, TCP/IP or multicast, as well as user-defined tools for conflation and hibernation. These factors improve network and desktop performance for the requirements of an enterprise business rather than for an individual user, unit, or specific application.

## Characterization at a Glance




## Product Category Characterization

### Energy Benefits

Electricity savings are achieved through three key features: integrated power management, performance data measurements, and efficient power supplies. Integrated power management includes pre-installed supervisory software systems that have power management enabled and have the functionality to reduce power consumption through dynamic voltage, frequency scaling during low utilization or reduced power states, and low idle power draw. These capabilities enable the server to operate more efficiently with less maintenance from IT staff.

Performance data measurements include readings of power consumption (watts), inlet air temperature, and average processor utilization at specific minimum accuracy and frequencies. These readings all contribute to the improved manageability and lower total cost of ownership.

When deployed in a data center, which typically houses thousands of enterprise servers, efficient power supplies combined with real-time data measurements reduce the need for excess air conditioning in the server room or data center facility where they are housed.

## Non-Energy Benefits

More efficient servers and reduced waste heat result in significantly less water used for cooling systems. There is high potential for water savings in large data centers.

## Product Category Differentiation

This product differentiates itself from other enterprise servers because these servers have integrated power management design which enables efficient processing and less manual IT support.

## Installation Pathway and Dependencies

The installation pathway of this product category is equipment replacement and plug-in. Installation dependencies require IT installation and support for upkeep and maintenance of the servers in the data center.

## List of Products

Table 1: Summary of manufacturers and products for the product category.

| Manufacturer | Model | Type | Differentiating Feature |
|---|---|---|---|
| Lenovo | ThinkSystem ST250 | Tower/ Pedestal | 1-socket tower server that can also be rack mounted as a 4U rack server. |
| Super Micro Computer, Inc. | 2029TP-HC0R series | Multi-node | Dual socket P (LGA 3647) supports Intel® Xeon® Scalable Processors |
| Super Micro Computer, Inc. | 5019P-WTR series | Rack-mount | Single socket P (LGAsupports Intel® Xeon® Scalable Processors |

## Quantification of Performance

A literature search was conducted and a sample of published study results are summarized in Table 2.

Table 2: Summary of results from literature review

| **Location** | **Application** | **Results** | **Reference** |
|---|---|---|---|
| Durham, North Carolina, USA | A power analyzer was used to determine power usage (in watts) for two servers during performance testing at one-second intervals over a 2-minute period.<br>Both servers had integrated power management applications: "Dell OpenManage Power Center" and "HP Insight Control" which features an approach to setting power limits.<br>Two conditions of the servers were tested: when the intended power limit was set to 80% of their total power and no power limit.<br>Performance testing included a real-world database workload test with significant input/output activity. | These results feature the power usage and performance testing of both servers utilizing only one aspect of power management, setting the power limit.<br>Dell:<br>-80% limit: 304 watts<br>-Actual power usage: 302 watts<br>-Difference between intended power usage and actual power limit: 2%.<br>-Performance decrease: 1%<br>HP:<br>-80% limit: 342 watts<br>-Actual power usage: 312 watts<br>-Difference between intended power usage and actual power limit: 10%<br>-Performance decrease: 35.2% | [2] |
| USA | The Cloud Energy and Emissions Research (CLEER) Model is an open-access model for assessing the net energy and emissions implications of cloud services.<br>The CLEER Model was used to assess the technical potential of cloud-based business software for reducing energy use and greenhouse gas emissions in the U.S.<br>Three common business applications were assessed: email, productivity software, and customer relationship management (CRM) software. | All energy savings discussed are technical potential savings that could be realized under maximum adoption of cloud-based solutions.<br>Present day systems for business email, productivity, and CRM software require 268, 98, and 7 Petajoules (PJ) of primary energy each year, with a total present day primary energy footprint of 373 PJ/year.<br>If all present day-systems shifted to the cloud, the energy footprint could be reduced to around 47 PJ/ year and potential savings of 326 PJ/year or 23 billion kWh of electricity. | [3] |

## References

[1] "Super Micro, Inc.," Super Micro, Inc. , [Online]. Available: https://www.supermicro.com/products/system/2U/2029/SYS-2029TP-HC0R.cfm. [Accessed 16 December 2018].

[2] P. Technologies, "Server Power Management Comparison: Dell OpenManage Power Center and HP Insight Control," Principled Technologies, Durham, 2012.

[3] E. Masanet, A. Shehabi, L. Ramakrishnan, J. Liang, X. M. Ma, B. Walker, V. Hendrix and P. Mantha, "The Energy Efficiency Potential of Cloud-based Software," Lawrence Berkeley National Lab, Berkeley, 2013.

[4] A. Shehabi, S. Smith, D. A. Sartor, R. E. Brown, M. Herrlin, J. G. Koomey, E. R. Masanet, N. Horner, I. L. Azevedo and W. Lintner, "United States Data Center Energy Usage Report," Lawrence Berkeley National Laboratory, Berkeley, 2016.

[5] "SERT Suite," Standard Performance Evaluation Corporation, [Online]. Available: https://www.spec.org/sert/. [Accessed 18 December 2018].

Technology Sector
Plug load

Product Category
Networked EV Charging Management Services with Grid Integration

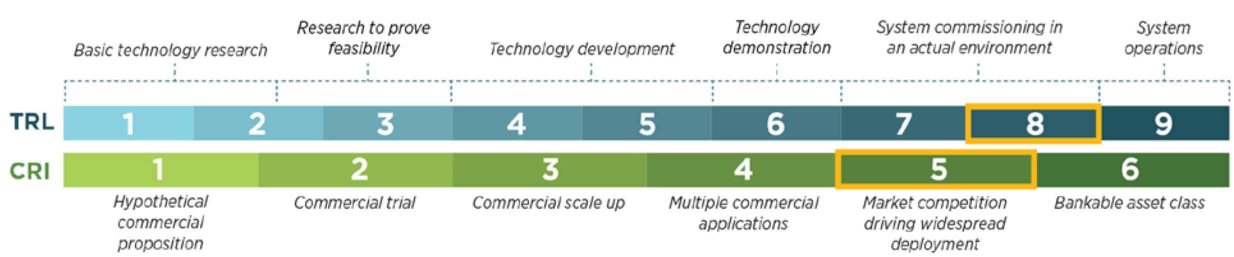
Last Updated
10/23/2018

*Figure 1: Charging end point (charging station) of a networked EV charging service.* **[1]**

## Product Category Overview

This product is a network of electric vehicle chargers also referred to as electric vehicle supply equipment (EVSE) with network communication capability that are used to intelligently control charging processes in fleets of commercial electric vehicles. The "vehicle-to-grid" (V2G) solutions are transforming the way plug-in electric vehicles (EVs) interact with the grid, enabling drivers to sell electricity and allowing utilities to modulate how quickly they charge based on the real-time grid system demand. Key functionalities include: scheduled charging, demand response, restriction to certain users, remote software updates, integration with multiple software providers for customer flexibility, and load balancing.

## Characterization at a Glance




## Product Category Characterization

### Energy Benefits

This prodcut category achieves electricity savings though the network communication compatibility which supports demand response and peak shaving. Demand response (DR) capabilites allow the charging operator to send control signals to throttle the peak charging capacities for various stations in response to DR signals issued by the grid operator. These control signals and variable capacities give flexibility to the driver and the control operator to use electricity when it is the cheapest instead of using it during peak times, which strains the grid. Peak shaving is a feature which allows charging operators to set a maximum capacity for their charging stations during specific time frames, or even time frames that match available grid situations which can prevent peak usage to avoid high demand charges. Also, as an alternative mode of transportation, EVSE reduces petroleum usage as an electricity source.

## Non-Energy Benefits

Non-energy benefits for this product category include monetary savings via demand response programs, priority load balancing, and environmental benefits such as greenhouse gas reduction and improved air quality. If consumers decide to enroll in demand response programs they can earn monetrary incentives to move their electricity demand off peak. Some programs are offered in smartphone applications that compute ideal time to charge a vehicle while taking into account the driver's schedule and the availability of electricity in the grid. The EVSE connected functionality to the internet is a priority because this feature allows the station to send push notifications to drivers reminding them to charge during specified periods to receive their monetrary incentives.

Priority load balancing helps minimize "range axiety," which is the fear that a vehicle will have insufficient range to reach its next destination; range anxiety is one of the major barriers to wide-scale adoption of EVs. By distributing the electrical capacity in proportion to all the charging stations in use, EVSE ensures a fleet of EVs optimal charging within the limits of available power. Figure 2 is an example of load balancing benefitting a consumer by assessing the charging status of the cars already charging, queing the car that consumed the most, and allowing the 5th car to start charging.


*Figure 2: Priority load balancing.* [2]

## Product Category Differentiation

The cloud platform uses algorithms to predict the power and energy needs of the grid, the range needs of the vehicle owner, and the environmental factors that impact both. The platform then modulates the time and rate of EV charging to optimize grid needs. EVSE offers different network capability than basic charging infrastructure offers by managing increased loads, providing more flexible and reliable power distribution for all EVs, and giving the operator and consumer access via the internet to control certain EVSE funtionalities.

## Installation Pathway and Dependencies

The most effective installation pathways are new construction and major renovation. Both pathways share a similar process of finding a location site and selecting the EVSE that fits within that site. Installation dependencies include availability of power, constructability, and environmental protection. Availability of power and constructability factor in which how difficult it is to place equipment; for example, if the service equipment is located near a power source there would be less trenching needed for conduit runs. The best installations would be through softer features such as grass, rather than sidewalks, asphalt, or extensive landscapes. Environmental protection, in this case, refers to the equipment's exposure to the elements, so places to avoid are areas prone to flooding or standing water. Workplace and commercial locations have additional siting factors such as parking capacity, proximity to destination, and modal connections. Priority locations for EVSE include areas with concentrations of retail, recreation, and public services such as employee parking areas, parking lots, shopping centers, and high-volume roadway access points. All these locations depend on the property ownership and type of land use.

## List of Products

Table 1: Summary of manufacturers and products for the product category.

| Manufacturer | Model | Type | Differentiating Feature |
|---|---|---|---|
| eMotorWerks | JuiceBox Pro 32C/40C/75C | Level 1 and Level 2 charger | Juice Green Net software that monitors and reacts to instantaneous energy market in specific geo-locality.<br>LED indicator lights to provide status on power, Wi-Fi connectivity, and charging.<br>Energy Star certified. |
| SemaConnect | Series 6 | Level 1 and Level 2 charger | Integration with smart cards to give access to specific drivers.<br>LED indicator lights to provide status on power, Wi-Fi connectivity, and charging. |
| ChargePoint | CT400 | Level 1 and Level 2 charger | Integration with smart cards to give access to specific drivers.<br>Supports Waitlist to notify drivers when charging becomes available and completed.<br>Customizable LCD screen for custom graphic/ video content.<br>Charges two cars simultaneously.<br>Energy Star certified. |
| EVBox | Business Line | Level 1 and Level 2 charger | Integration with smart cards to give access to specific drivers.<br>Charges two cars simultaneously.<br>Energy Star certified. |

### Quantification of Performance

There was no information identified, but there will be more investigation for study results.

## References

[1] "EVBOX," EVBOX, 9 October 2017. [Online]. Available: https://business.evbox.com/product?utm_expid=.6mdL9ga7SK2qvtMlHDFUgw.1&utm_referrer=https%3A%2F%2Fwww.evbox.com%2Fproducts. [Accessed 15 October 2018].

[2] "EVBOX," EVBOX, 9 October 2017. [Online]. Available: https://www.evbox.com/learn/faq/difference-priority-load-balancing. [Accessed 15 October 2018].

Technology Sector
Plug Load

Product Category
Networked Power Receptacle Controls

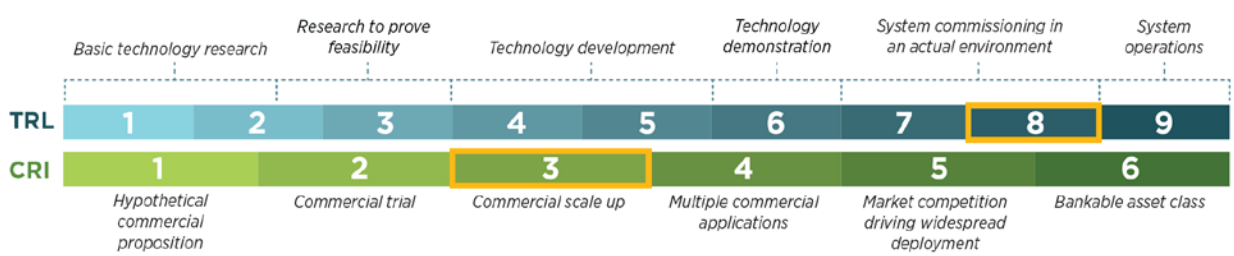
Last Updated
11/13/2018


*Figure 1: Picture of smart plug that reports energy usage data* [1].

## Product Category Overview

Networked power receptacle controls (NPRC) are systems comprised of a smart plug that can report energy data on the device plugged into it and a cloud-based platform that can manage multiple plugged in devices. The smart plug sits between the device and the wall socket and serves as the local energy meter. All devices work together by forming a mesh network to send energy data to the gateway, which then sends data to the cloud. The NPRC provides a cloud-based reporting and control dashboard which has advanced data visualization, scheduling, and configuration capabilities, real-time control over all the sockets, ability to recognize if certain equipment is on when it should not be, and ability to time-shift energy usage to specific times to utilize off-peak rates.

## Characterization at a Glance




## Product Category Characterization

### Energy Benefits

NPRC saves electricity by providing the operator both data demnstrating how devices are being used and dynamic control to apply those insights to save electricity, extend device life, and manage building energy use. The operator can set a predetermined schedule to shut equipment such as space heaters, fans, and computers down when spaces are unoccupied.

## Non-Energy Benefits

NPRC provides non-energy benefits including monetary savings and device health monitoring. NPRC can save money both by alerting the operator when devices should be on or off but are not and by using the time shifting feature to enable the operator to charge equipment during off-peak rates. The system will automatically send power to the equipment that needs charging at a specified time, to ensure a full charge by morning. NPRC can monitor device health by detecting erratic or excessive energy use whith typically precedes device failure. The operator can use this ifnormation to make minor repairs or replace equipment before it malfunctions. Also, the ability to monitor and collect data on real-time usage can be used for sustainability programs to encourage low usage of certain equipment. The system will recognize whether or not certain equipment was used, thus giving insight on who was participating in the program for rewards or incentives. These sustainability programs can be used in locations like offices, hotels, and schools.

## Product Category Differentiation

NPRC's communication between the smart plug and the cloud differentiates it from non-connected smart plugs because the system can control multiple loads, set dynamic schedules, monitor energy usage for more than one outlet, and time-shift energy usage to specific times set by the operator. In contrast, a smart plug alone can control only one outlet and can't communicate with other smart plugs. The system provides the operator flexibility to set dynamic schedules by department, location, type of device, or even individual devices. A smart plug alone would be able to set the schedule for only the equipment plugged into its own outlet.

## Installation Pathway and Dependencies

The installation pathway of this product category is plug-in, and the only installation dependency is the type of voltage the equipment runs on; the voltage can be either 120V or 240V and each requires a different type of smart plug.

The support dependency for this system is an operator or building energy manager that is educated on user behavior. This facility champion can select which devices will be monitored and set the dynamic schedules accordingly. Another support dependency is access to enterprise IT infrastructure for internet access to communicate with the cloud.

## List of Products

Table 1: Summary of manufacturers and products for the product category.

| Manufacturer | Model | Type | Differentiating Feature |
|---|---|---|---|
| BOSS | BOSS 120 Smart Plug<br>BOSS 220 Smart Plug<br>BOSS Atmospheres | BOSS 120 and BOSS 220 are physical smart plugs that monitor and control 120Vand 220V devices, respectively.<br><br>BOSS Atmospheres is a cloud-based platform that can be accessed through mobile devices, tablets, and other devices. | NPRC smart plugs can be grouped and controlled, whereas ordinary smart plugs cannot be grouped, and if they can be grouped they would need some type of gateway to connect to the network for grouping. The BOSS smart plugs have integrated the connection to Wi-Fi directly into the plug itself. |

| Manufacturer | Model | Type | Differentiating Feature |
|---|---|---|---|
| IBIS Networks | InteliSocket™<br>InteliGateway™<br>InteliNetwork™ | The InteliSocket™ is the physical smart plug that has three versions: single outlet for 120V, a duel outlet for 120V, and a single outlet for 240V.<br><br>The InteliGateway™ is another physical device used to connect the plug with the network.<br><br>The InteliNetwork™ is the cloud-based reporting and control dashboard that can be accessed through mobile devices, tablets, and other devices. | The plug reports energy usage data on devices every 15 seconds, the gateway collects all reports and sends them to the cloud-based network in real time. Also, the gateway is able to send information about device health and internal state, and can aggregate and cache plug load data in case of connectivity problems for up to 30 minutes. |

## Quantification of Performance

A literature search was conducted and a sample of published study results are summarized in Table 2.

Table 2: Summary of results from literature review

| Location | Application | Results | Reference |
|---|---|---|---|
| Longmont, Colorado, USA | Department of Energy, General Services Administration Green Proving Grounds and lab staff coordinate technology reviews, site selection, M&V plans, and dissemination of results for piloting IBIS Networks in a medium to large commercial building for the following partners: PetSmart, Costco, and Luxottica (eyewear).<br><br>Field test<br><br>The baseline is a standard plug outlet that does not collect and relay real-time energy data.<br><br>Certain plug load devices were connected to the IBIS plugs to monitor and control energy usage. | The results report has not been published yet by either Better Buildings or Green Proving Grounds. There will need to be more research into whether the results have been published or not. | [2] |

References

[1] "InteliSocket Page," Ibis Networks, 27 08 2009. [Online]. Available: http://ibisnetworks.com/. [Accessed 27 November 2018].

[2] M. Deru and R. Langner, "2017 Building Technologies Office Peer Review," 3 March 2017. [Online]. Available: 2018. [Accessed 23 November 2017].

**Product Characterization Report**
**California Energy Product Evaluation (Cal-EPE) Hub**

Technology Sector
Plug Load

Product Category
Smart Plugs

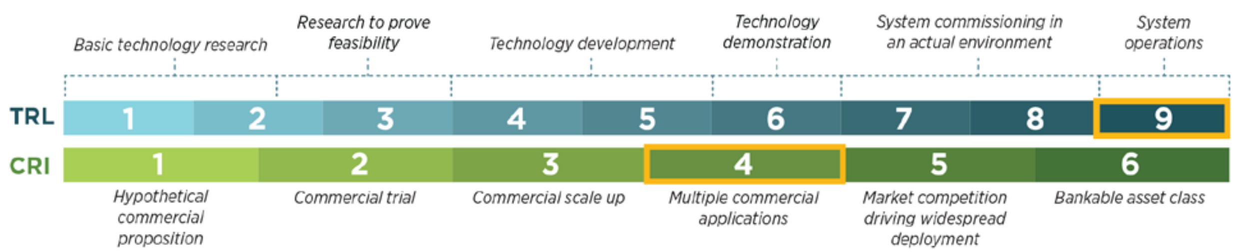
Last Updated
12/10/18


*Figure 1: Picture of smart plug that can connect to WiFi and home ecosystem technology* [1].

## Product Category Overview

A smart plug can monitor power consumption, set schedules and timers, and remotely turn on/off any device plugged into it. It can be controlled via a smartphone application after connecting to Wi-Fi. A mobile application on iOS and Android serves as the user interface to manage all the connected smart plugs if there is more than one in a building. Key functionalities include: (1) turn on/off power to the devices from anywhere over a Wi-Fi network, (2) set schedules to fit daily needs, (3) real-time, daily and monthly energy monitoring on an iOS or Android smartphone application, and (4) the ability to create personalized settings to control multiple devices.

## Characterization at a Glance




## Product Category Characterization

### Energy Benefits

Electricity savings are achieved by enabling users to set schedules and timers to turn off office electronics and appliances that continue to use electricity in standby mode, also known as phantom loads. Some examples of office equipment that have phantom loads are coffee makers, personal computers, monitors, commercial printers, etc. The scheduling and timer feature allows users to set a specific time to turn off any device plugged into the smart plug. When the device is turned off, the phantom load is gone and there is no electricity consumption from the device. Integrating timer controls with a mix of daytime and overnight schedules can cut the consumption of the phantom loads. Since smart plug load controls only impact phantom loads, the phantom load profile of the equipment needs to be high to achieve higher savings.

## Non-Energy Benefits

A non-energy benefit is the increased operational efficiency and personalization enabled by real-time, daily, and monthly electric power consumption data. This insight gives the user information on when the device is using electricity but not being actively used. With this new information, the user can set a flexible schedule so that the device turns off at the most appropriate time without compromising daily activities and working schedule.

## Product Category Differentiation

This product differentiates itself from other smart plug devices because it can integrate easily with either a smartphone or a smart home management hub, rather than being a standalone system with a separate gateway which communicates to a cloud application. Compared to a traditional outlet with no controls, a smart plug provides incremental improvements by enabling control over a network of plugged devices and measuring real-time plug load electricity consumption. Traditional plug outlets have no control and cannot measure the electricity consumption of the devices plugged in.

## Installation Pathway and Dependencies

The installation pathway of this product category is plug-in, and the only installation dependency is the type of voltage the equipment runs on which can be either 120V or 240V which require two different plug types.

## List of Products

Table 1: Summary of manufacturers and products for the product category.

| Manufacturer | Model | Type | Differentiating Feature |
|---|---|---|---|
| Koogeek | P1 Plug<br>KLWP3 Plug<br>KLWP1 Plug<br>KLWP2 Plug | All plugs are physical smart plugs that monitor and control 120-volt devices. | Integrates easily with smart home management hubs and smartphones, rather than having a gateway which communicates to a cloud application. |
| Belkin | Wemo Insight Smart Plug | All plugs are physical smart plugs that monitor and control 120-volt devices. | Pairs with smart thermostat to sync devices with Home/Away Mode. |

## Quantification of Performance

A literature search was conducted and a sample of published study results are summarized in Table 2. The literature search did not yield any results that directly document potential savings of smart plugs. However, we identified two studies. One study by Stanford University measured electricity being drawn from all pieces of equipment plugged into an outlet on campus. While not reporting direct savings, the study provided insights into the savings potential in each plug load category that can be realized by smart plugs. The second study utilizes an advanced power strip’s schedule/timer feature, which functions the same way as a smart plug to reduce the phantom loads of appliances. An advanced power strip (APS) has multiple outlets equipment could be plugged into; whereas, a smart plug has only one outlet it can control. This study is used as a proxy since no relevant smart plug literature was found.

Table 2: Summary of results from literature review

| Location | Application | Results | Reference |
|---|---|---|---|
| Palo Alto, California, USA | Field measurement of 220 buildings on Stanford University's campus.<br><br>Within the buildings, 110,529 pieces of plug load equipment were recorded and used to evaluate plug load energy consumption by equipment type and building type. | In total, the plug load consumption from these buildings consume nearly 500 million kWh per year and comprise 32% of the electricity consumption of the buildings surveyed.<br><br>Total energy consumption by equipment type:<br>Lab Equipment = 50%<br>Computers and monitors = 36%<br>Kitchen and Breakroom = 5%<br>Office Occupant Comfort = 3%<br>Printers and Scanners = 2%<br>Audio/ Video = 1%<br>Gym and Training Equipment = 1%<br>Laundry Equipment = 0% | [2] |
| Delaware, Pennsylvania, West Virginia, Southern New Jersey, Maryland, USA | Field measurement of eight buildings over a three-month period from General Services Administration where plug loads averaged 21% in total building electricity consumption.<br><br>In each building, the baseline technology was 12 standard power strips with no control capability. Each of these power strips were replaced with APSs which monitored and provided power to an array of devices.<br><br>Three types of plug load strategies were tested, 1) scheduled timer 2) load-sensing using an advanced power strip and 3) a combination of the two above. | The results underscored the effectiveness of schedule-based functionality, which reduced plug loads at workstations by 26%, despite computer power management in place.<br><br>Average energy savings by device type:<br>Printer = 35%<br>Laptop = 21%<br>Monitor = 7%<br>Under-cabinet light = 14%<br>Miscellaneous equipment = 51%<br>Kitchen equipment = 46%<br><br>Scheduled timer controls reduced most electricity, more than load-sensing and combined controls. There were some difficulties in implementing load-sensing controls; whereas, the scheduled timer control was simple to operate.<br><br>The largest portions of savings were due to constant loads such as printers that were not being turned off or kitchen/ workstation equipment not being de-energized. | [3] |

## References

[1] "Koogeek," Koogeek, 21 August 2017. [Online]. Available: https://www.koogeek.com. [Accessed 20 November 2018].

[2] M. Hafer, "Inventorying Plug Load Equipment and Assessing Plug Load Reduction Solutions on a University Campus," October 2015. [Online]. Available: http://sustainable.stanford.edu/sites/default/files/resource-attachments/Plug%20Load%20White%20Paper%20FINAL.pdf. [Accessed 20 November 2018].

[3] I. Metzger, D. Cutler and M. Sheppy, "Plug-Load Control and Behavioral," October 2012. [Online]. Available: https://www.nrel.gov/docs/fy13osti/55780.pdf. [Accessed 20 November 2018].