CALIFORNIA PLUG LOAD RESEARCH CENTER

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Technology Roadmap

Defining a five-year strategic plan in plug load energy management

Project Proposal

Prepared for: Southern California Edison

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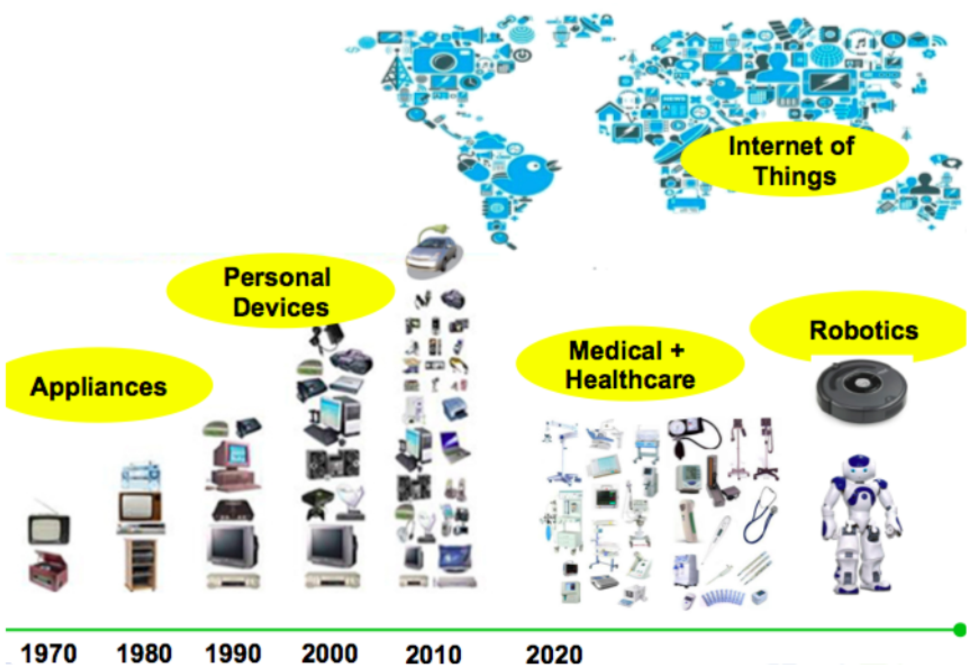
Abstract

Advancing technology in today's world is beneficial in many ways, but such changes can make it difficult to plan ahead for energy demand needs. Plug load devices in homes and commercial buildings can make planning especially challenging. For one thing, compared to building elements such as HVAC or solar panels, plug load devices are relatively inexpensive, and may be added or upgraded more frequently. In addition, individuals rather than central planners usually make decisions about buying and using plug load devices. Although any increase in plug load devices would seem to increase the overall energy demand, some emerging technologies – especially networked or "IoT" devices – may instead enable additional energy savings. The more that utilities, policy makers, and other stakeholders know about what plug load devices are being used today and can anticipate what will be used tomorrow, the better they can plan for future energy needs. To this end, we propose developing a "technology roadmap" that explores the energy consumption implications of emerging plug load devices.



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INTRODUCTION

Utilities follow the tenets of safe, reliable and affordable in delivering an efficient energy supply to meet their customers' demand. Observing the growth of electronic devices in our daily life paints a future with yet more devices. Technological advancements can improve the comfort level and convenience of our daily lives. While the sheer number of new devices suggests a greater energy demand, some advancement, such as home automation or dynamic power scaling, may provide additional energy saving opportunities. All stakeholders are now at the crossroads of determining the immediate as well as the long-term goals of energy efficiency and the various factors of influence. Significant advancements have been made via the Internet of Things (IoT). Cisco may be prescient in calling this connectedness the "Internet of Everything," as sensors and actuators, cloud computing, and data analytics are increasingly pervasive in our everyday lives. The very foundations of IoT are the utilities, as they power all the devices that make IoT possible. When products and services make energy consumption more efficient via IoT, there will be a plateau or even a decrease in energy demand. At the same time, energy supply options may expand due to continued improvements in cleaner energy and the growing use of renewable power sources such as solar, wind and water. However, unpredictable factors such as drastic climate changes (e.g., heat waves or hurricanes) make such renewable power sources unpredictable and unreliable. The difficulty in planning for energy demand is compounded by the fact that human behavior can be difficult to predict, making it challenging for policymakers and utilities to guarantee safe, reliable and affordable energy at all times. As the drought in California progresses, the energy demand structure may change further as energy is invested in supplying more reliable water sources. Now more than ever, defining a strategic roadmap in energy management and energy demands has become increasingly important.

A strategic roadmap to guide the continuing implementation of energy savings initiatives and incentives requires a better understanding of plug load appliances. As the typical home becomes more efficient in heating, a larger percentage of energy consumption will shift to plug load devices, including the ever-increasing number of smart devices, which are typically categorized under miscellaneous equipment. Going forward, plug load devices will consume almost half (Murray, 2011) of a home's energy needs. As an initial step, the relevant plug load devices need to be identified and quantified. These devices span a wide range, including items related to security, comfort, entertainment, healthcare, and personal plug-in devices. Communication between multiple devices is becoming increasingly prevalent, and should also be considered for its energy implications.

There are two major approaches to decrease the energy consumption of any given device. As technology advances, designers and manufactures can improve efficiency when the appliances are in active mode. In other words, for the same job, it requires less energy to accomplish. An example of this approach is lighting, where LED lights consume less energy than standard bulbs for the same illumination. Secondly, energy consumption can be dynamically scaled by either the workload or the user interaction—that is, put into lower-power modes when not fully active. A good example of this approach is developing products with different power modes and power management modules on board. Another example is the new generation of thermostats, which not only learn from users' temperature-setting patterns, but also include embedded motion sensors. This allows the thermostat to automatically reduce heating or air conditioning while nobody is home without users' direct intervention. A popular term often associated with this is "smart." With more and more "smart" devices entering the market, their active mode energy usage might not be highly reflective of their true energy performance.

OBJECTIVES

The main objectives of this work are to provide a vision of how plug-load devices will evolve and what the impacts of these trends will be on energy demand. The effort of identifying the devices and appliance categories should assist with the SIM Home project, where the energy savings and consumption performances of the devices are accurately measured. In turn, we can use data and observations obtained from SIM Home to build an appliance modeling kit (including device library and equipment schedules), to better estimate the energy budget of emerging technologies. In the current project, we will construct a technology library with information on a subsample of devices, to demonstrate the utility of such a database. For example, the library would allow for quickly access and comparison of data on appliances to better understand areas where incentives can be even more promising. In the future, this library can be expanded to include many other appliances.

Smart Device Energy Saving Performance

Homes and offices are increasingly filled with "smart" thermostats, security systems, lighting sensors and many other smart devices. Through cloud computing, smart devices now have the capability to collect data and analyze it for the sake of homeowners' safety, comfort and peace of mind. Knowing these "smart" devices undergo constant communication and sensing, it is critical to know whether these devices end up consuming more or less energy.

The current measurement standards for appliances, such as ENERGY STAR®, capture and characterize the active power consumption of many appliances very well. ENERGY STAR® provides a rich database and a well-recognized energy label for the general public to reference. As the consumer electronics become "smarter," the market also needs a better understanding of how features such as network connectivity, dynamic modes, and active learning affect their energy consumption. Metering and programmability can greatly assist in enhancing energy savings. Through metering, consumers are given information to make well-informed decisions that fit their needs as well as their preferences. Armed with this information, consumers can program their smart devices for optimal use, or in some cases, allow data analytics to suggest the best pattern as revealed by their past behavior.

Devices labeled "smart" often bring more convenience into our lives. But what is the cost of being "smart"? In some cases, "smart" features can end up using more energy. For example, Google Nexus phones and iPhones offer hands-free voice controls to wake up and unlock screens. This feature requires microphones to be turned on at all times to listen for and detect the "hotwords" ("Google Now" and "Hey Siri"). This convenience thus comes at a cost of battery life. On the other hand, one common tradeoff of energy efficiency improvements (e.g., low-power modes) is a reduction in system responsiveness and convenience. Again, in this project, we would evaluate the market trending of "smart" devices, related energy efficiencies, and their impacts.

Internet of Things: Networked energy saving and consumption

The emergence of IoT may have effects that go far beyond the scope of any one device. On the infrastructure level, the demand of a robust and fast network will increase the energy cost. Locally, it will require more and stronger gateways to provide the channel for devices to interconnect. The IoT may require an in-home Wi-Fi router to broadcast at a greater bandwidth to accommodate all the connected devices. An IoT framework may also come in a tree-topology format where more gateways will form a network of gateway devices. All of the local IoT infrastructures require energy to maintain IoT end nodes' connectivity. Once the computations and controls of IoT are moved to any cloud based services, globally, the demand of data centers may also increase, which requires energy to meet the increasing demands of data hosting and data transmission. For example, PlayStation is a new "cloud game service" provider. The company demands a 5 to 12 Mbps broadband Internet in order to rent and stream video game content from the Internet, instead of getting a physical disk. This would require users to subscribe to a strong Internet service and also a robust local connection from the wall to the device. At the infrastructure level, both communication channel provider and energy support will face crucial challenges. Therefore, further evaluation is required for small network equipment such as home based compact servers, set-top-boxes, routers, and other network-enabled devices.

In the future, more appliances will be equipped with sensors and communication modules. A home could have similar sensors on different appliances, meaning multiple sensors will collect the same information at the same time. Duplicated sensors waste energy; in the ideal situation, only one sensor of each type collects the information and shares it across the board. Therefore, this project should explore how devices can consume less energy over their life span within the IoT, optimizing the use of cloud computing and data combined with consumer behavior patterns.

Plug load World Energy Modeling: Library and equipment scheduling

As mentioned above, plug load devices are increasingly taking on a large share of energy consumption within both residential and commercial buildings. Since real field tests can incorporate only a few user settings and scenarios, simulation tools can help by attempting many other scenarios at a very low cost. Although field tests provide valuable results at a specific level, they are also very costly. To better anticipate and prepare for the future energy demand, a better defined, improved, and well implemented modeling tool kit will have tremendous value when estimating energy consumption. EnergyPlus is energy simulation software promoted by the U.S. Department of Energy. EnergyPlus is a very powerful tool to simulate load profiles for residential and commercial buildings. However, most plug load devices are combined under "miscellaneous loads" in EnergyPlus and given a single number to represent the total usage. In other words, the energy modeling of plug-load devices has been a black box with just one output value. This is not very descriptive of how users use their plug-load devices. We propose designing a supplemental tool kit (a component library and equipment scheduling) to model plug load devices' energy consumption associated their usage patterns. The usage patterns and actual consumption data can be imported from SIM Home results, so that the toolkit represents more realistic power consumption. In some situations, the equipment schedules are more important than their energy consumption. Equipment schedules will allow simulations to consider current surges and demand peaks.

In addition to standard plug-load devices, we will also address electric vehicles. From our previous joint studies with UC Davis, we recognized that users tend to plug in their vehicles and start recharging as soon as they arrive home, usually in the early evenings. This particular usage pattern can have a non-negligible influence on demand response. In addition, as electric vehicles gain their market share, they will become another energy-hungry device to many homes. This not only increases the power consumption for that individual home, but also brings up the peak demand of the residential level in early evenings.

We propose to implement this library and its related equipment schedules for use by utilities and policy makers while estimating the compliance of the CA title 24 zero-net-energy initiatives.

Telemedicine, Remote Healthcare and Assistive Robotics

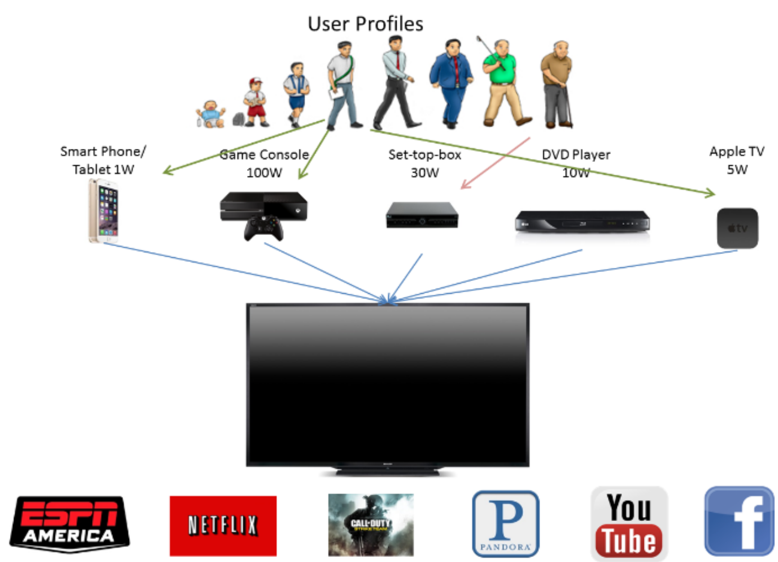
Another type of plug load device increasingly found in homes is medical and health monitoring devices. Recent technological advances have enabled the medical field to deliver care differently than in the past. As more people use wearable electronics, possibilities for remote data collection, diagnoses, and condition monitoring have expanded greatly. At the same time, patients are also taking smaller-sized medical equipment into their homes, either to treat serious medical conditions or to assist with daily activities. Common examples are respiratory machines and cardiovascular devices. Such home-use devices run for extended periods and patients can rely on these machines for a number of years. Assistive robotics may improve quality of life issues for seniors, disabled individuals, and others with special medical needs, but it is important to note that these devices can consume large amounts of energy. Moving medical care into homes will increase residential energy demand. However, it may result in either higher or lower net demand, depending on the energy efficiency of the alternatives that such care replaces (e.g., at the hospital). We would plan to address the energy demands of such devices on a regional scale.

Possible Future Extensions

Energy Negotiation

Networked devices offer the possibility of using energy negotiation between devices to increase efficiency. For example, if a user wants to watch a show on Netflix, there are multiple approaches. The user might watch on a computer, on a TV, or on some other screen, each of which vary in energy consumption as well as convenience and other preference factors. If the user watches by TV, the delivery method also affects energy consumption. For instance, the user may choose to watch from an Xbox, which is 100W, or from a set-top-box, which consumes 30W on average. Such choices matter more than most users may realize. Set-top boxes consume on average between 700 to 800 kWh per household annually, which translates to over 9 TWh of energy consumption in California. On average, Americans spend over five hours every day watching television, playing games or streaming videos, listening to music, and other network functions such as social networking and video conferencing. Users may differ not only in which devices they have available to them, but also in their personal preferences. A task that can be performed using multiple devices could be prioritized by the energy efficiency of the devices, either automatically or by the users, if they had such information readily available. Smarter delivery choices could lead to energy savings and efficiency.

Figure 1. Energy Negotiation concept representation



Entertainment Systems

An additional potential project could target home entertainment systems as a special subcategory of plug loads to demonstrate the effectiveness of energy negotiation. Up to 2008, light fixtures have been second only to HVAC in terms of energy consumption, representing approximately 35% (California Public Utilities Comissions, 2009) of the energy bill in the average home. With the influx of compact florescent bulbs and LEDs, lighting loads are reduced and home entertainment systems have become a higher relative energy burden. Currently, entertainment systems can be extremely wasteful, with many devices staying on at full power at all times even when not being used. Various solutions are emerging, which attempt to coordinate new technological options with consumer behavior and preferences to find the most optimized balance between energy savings and consumer satisfaction. How successful those solutions are, either by themselves or when combined in networked devices, remains to be seen. Scaled up energy savings at the state level will be estimated by a novel computer model.

Where are the Smart Consumers?

A better understanding of consumer behavior would allow utilities to improve grid reliability and safe delivery of energy. To this end, one proposed future project is a survey of consumers' needs and preferences for the plug load devices in their homes and workplaces. The resulting data would help to predict user engagement in efforts to improve energy savings and efficiency. Ultimately, the implementation and adoption of any program will require the cooperation of users. To design effective energy efficiency programs will require input from the end user and understanding what will motivate successful implementation of such programs. Such a study would help to guide the design of incentive programs for maximum engagement.

EXECUTIVE SUMMARY

As seen above, IoT technology and other advanced energy management systems potentially offer both advantages and challenges. A more thorough review of plug load devices is needed to develop a better measure of savings via IoT and "smart" devices. This effort will provide a better understanding of emerging technologies and their energy related performances, helping us to achieve greater efficiency. CalPlug will consider the mechanisms behind smart and especially interconnected appliances and identify ways to achieve additional savings at a lower cost overall. CalPlug plans to develop a better and more accurate modeling kit for plug load devices and to further assist with designing programs and incentives to bring a "smarter" home network to all stakeholders.

Deliverables

- (1)Interim and (2)Final roadmap report
- (3)Sample library supplementing EnergyPlus including various appliance groups.
- (4)Sample equipment schedule for appliances.

Future Works

- Design, implement and evaluate the energy negotiation framework.
- Conduct consumer study on usage patterns and feature preferences.
- Develop simulation models for larger scale applications.

Schedule

- 12 months of duration

COST ESTIMATES

Table 1. Milestones and Estimated Budget

Phases	Milestones	Hours	Budget*
1	Smart Device Energy Saving Performance	150	$17,550
2	Internet of Things – networked energy saving and consumption	300	$35,100
3	Plug Load Modeling Toolkit (library and equipment schedules)	600	$70,200
4	Telemedicine and Assistive Robotics	150	$17,550
	Total	**1,200**	**$140,400**

* Hourly rate for consultancy applied: $117/hour

Works Cited

Murray, M. (2011). Building Occupant Feedback Systems and Plug Loads. *All day symposium held at the Pacific Energy Center*. Berkeley.

California Public Utilities Comissions. (2009). Rulemaking to Examine Post-2008 Energy Efficiency Policies, Programs, Evaluation, Measurement, and Verification, and Related Issues. San Francisco.