A Look Ahead – Future State of Plug Loads and Energy Saving Opportunities

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Overview of the Project

1.1 Project Overview

The consumer electronics market continues to grow exponentially, driven by increasing technological advances and sharp reductions in per-unit costs. However, this rapid expansion threatens to impose novel strains on the global energy supply that will directly and indirectly affect not only consumers and utilities but also our environments. Addressing these concerns begins with a systematic review of technology trends, understanding consumer needs and preferences, and identifying energy saving opportunities that can also preserve grid reliability and resiliency. Key points to consider include:

- types of technological improvements manufacturers can make themselves to devices,
- incentives and information that can be given to consumers to make behavioral changes towards energy efficiency, and
- concerns about the energy and infrastructure challenges of increased connectivity.

This "Look Ahead" project consists of a compilation of recently published studies as well as other available materials describing various energy-saving opportunities and provides a summation of the reviewed references, information, and literature towards a stronger plug load advocacy program. Covered topics are as follows:

- The future state of plug load devices – technology trends and energy needs
- Microprocessor-based plug-in appliances vs. standard plug-In appliances (or smart appliances vs. standard appliances)
- Impact on data center and demand response: Whether tomorrow's anticipated demand of energy test and stress the reliability of energy production of the existing network infrastructure
- A better understanding of plug-load information delivery to the consumer
- Plug-in energy baseline review for residential building energy simulation results

1.2 Findings

Current trends identified in this report include general energy-saving opportunies as well as specific areas of interest; both may lead to the development of strategic energy-efficient incentives and possibly of next-generation codes and standards.

As the world enters the Internet of Things (IoT), both home and residential environments will see an exponential rise in the incorporation of emerging "smart" technologies. The resultant data might prove a powferful aid in energy-efficiency improvement, to various stakeholders, from homeowners to public utilities. In the process; however, it is critical that these IoT technologies develop in conjunction with sound methadologies for addressing a host of related concerns, such as security, privacy, ease of use, and cost effectiveness.

The value of a a “smartened” world lies primarily not in the hardware but in the massive volume of data that the hardware compiles, With properly collected and analyzed data, energy savings and efficiency decisions can be better understood and subsequently managed. However, the challenges are many, for large data sets requires many layers of predefined rulesets or machine intellegence to process the data to fuel decision making and develop predictive intelligence engines. The largest challenge is the uniqueness of individuals and their varying choices or preferences. Even in one single household, the adults within the family may have opposing preferences and/or needs compared to other members of the family. Human behavior, therefore, is an uncertainty to the final overcome. However, as creatures of habit, it would be best to have no-disruptive lifestyle technologies that can seamlessly be implemented for energy savings and efficiency to achieve mass adoption in any plug-in device, including IoT.

There are also many challenges with IoT for smart energy controls: the “smart” home may not be smart with respect to energy efficiency as the devices collecting home user and environmental data may likely be required IoT devices to be always “on” and “on alert” states. Devices on a duty cycle, in order to save energy, may be too late to response to an incident that requires immediate attention. Components of smart devices have become increasingly energy efficient; however, the growth of the number of varied plug-in devices may offset the energy that have been saved by other measures and continue to demand more. The aging of our grid infrastructure continues to be stressed, and with the plateau of renewable generation incentives, challenges remain as to how will energy demands be met.

This report also examines trends in the energy demands of the infrastructure supporting these smart devices, such as the telecommunications network, processor design, and data center evolution. Of particular interest are the challenges related to the multiple simultaneous levels of optimization required to achieve an optimized energy efficiency solution.

1.3 Challenges

Consumer electronics is ever-evolving rapidly with new products entering the market daily. Plug load appliances form an even broader category, where norms are ephemeral and constantly re-invented. Thus, any analysis of the industry, market, and consumers must maintain a broad scope, covering seemingly disparate topics that subtly weave together upon careful examination of their technological and/or energy-saviing properties. In this report, we attempted to divide the scope into sections to view the future landscape of consumer technology and products, examining the current good practicies and further application opportunities, investigating the furture demand with respect to the infrastructure, exploring the human factors and also reviewing potential codes and standards opportunities. The many topics in plug-loads have increased exponentially, therefore, for purposes of this general report we mainly focus the influencial emerging technologies and products.

1.4 Recommendations for Further Investigations

This report attempts to cover a broad topic area, including plug load devices traditionally labeled as miscellaneous devices and emerging markets of the newest appliances in the next five to ten years. The plug load device landscape is massive and complex, with multiple degrees of uncertainty. We identify these challenges as unknown characteristics of the field either due to the limited data sets available, partial maturity of the technology, and/or opportunities to improve upon the existing technologies to extend their energy saving capabilities, and recommend further investigations and possible lab testing. These areas are in:

- Wireless charging
- 3D printing
- Micro datacenter (for home or small businesses)
- Co-location server utilization
- Behavioral study leading to consumer education for energy saving behavioral change

Technologies with great potentials and/or abilities to bring energy savings to the next level:

- Home automation
- Telemedicine and robotic assistive living
- Occupancy sensing
- Exploration of future marking for energy efficient appliances

1.5 Summary

It is an era of unprecedented growth for both home and industry electronic devices. The explosion of smart devices and IoT (connected people and things) has added various forms of value to consumers, but along with it a corresponding additional burden on the energy supply. The potential functional benefits of smart devices will drive market acceptance; however, the energy demand of these devices requires addressing more energy saving solutions and/or codes and standards. We also evaluate the benefits and costs of various microprocessor-based energy management control systems, and other novel hardware systems that quietly serve as the backbone of the Internet of Things. Also addressed are technologies and devices that can potentially improve both efficiency and throughput of all of the above. Finally, any energy savings will not be achievable without proper communication among consumers, vendors, and utilities program managers to encourage an understanding of the grand challenges of the future for energy; to this end, we specifically focus on methods to best provide relevant and actionable information for assisting consumers with their home improvement projects and new purchases.

Study Results

Task 1 The Future State of Plug Load Devices: Technology Trends and Energy Needs

The Internet of Things (IoT), smart machines, mobility, and telecommunications form a set of interrelated disciplines soon to be of significant importance to business. Opportunities in this sector are expected to drive large-scale changes in energy demand and response.

1.1 Computing Landscape Change

In 2015, several defined megatrends (large, slowly evolving social, economic, political, environmental, or technological shifts) drove changes in the technology world [1]. Listed are the top five megatrends identified by a 2015 Gartner report [1], and illustrated in Figure 1-1, are:

- Megatrend 1: Digital business moves towards inflated expectations without the necessary security and privacy protections as well as the essential infrastructure to support the data and analytical needs of digital business.
- Megatrend 2: IoT, the mobility, and smart machines rapidly approach the hype peak.
- Megatrend 3: Digital marketing and digital workplace quickly gaining more attention and business opportunities.
- Megatrend 4: Analytics as a tool for mapping unique and individual user behaviors into massive data collections for producing actionable intelligence
- Megatrend 5: Big data and cloud descend into the trough of disillusionment. In fact, information and cloud technologies, services and disciplines remain critically important; however, as they become ingrained in the fabric of business and IT, clients begin to see through the market hype into the limited realities of the technology.

In summary, IoT-enabled devices, from personal electronics to smartened sensors used in industrial settings, are still growing rapidly, and are quickly becoming an essential element of human productivity and quality of life. Behind the scenes, cloud computing retains a fundamental role as the digital backbone behind any emerging smart hardware.

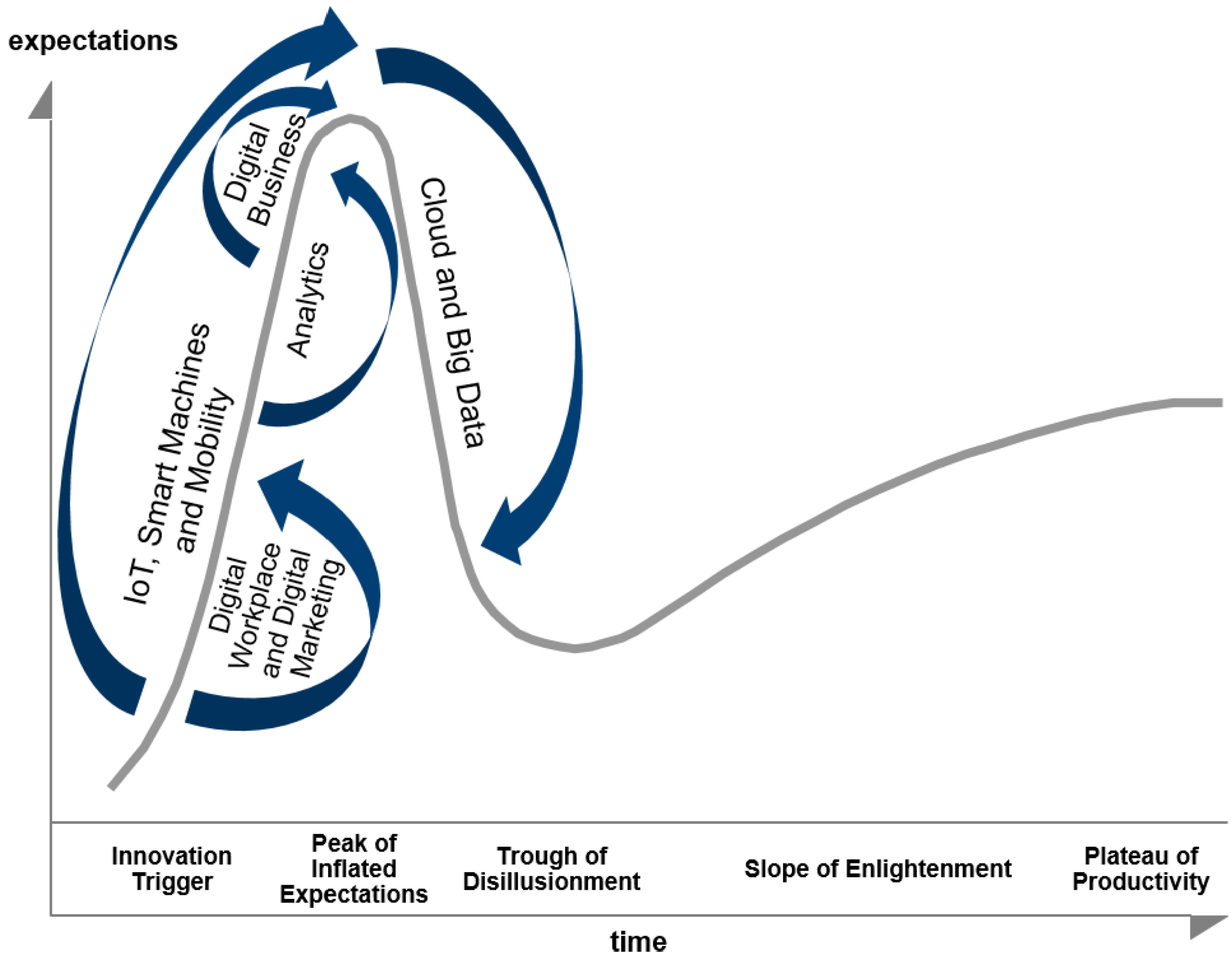


Figure 1-1 Megatrends Driving Significant Profile Shifts from Gartner, 2015 [1]

1.2 Smart Home, Smart Objects, and Smart business

A smart object (SO) is an autonomous, physical digital object augmented with sensing/actuating, processing, storing and networking capabilities [2]. As the electronic and telecommunications technologies behind smart objects become commoditized over the next few years, the cost of IoT-enabling devices will approach a plateau. As such, owning five hundred smart objects will no longer be surprising but expected in some communities. In fact, forecasts suggest that a family will own over 500 smart devices by 2022 [3]; Figure 1-2 shows breakdown of domestic smart objects by categories:

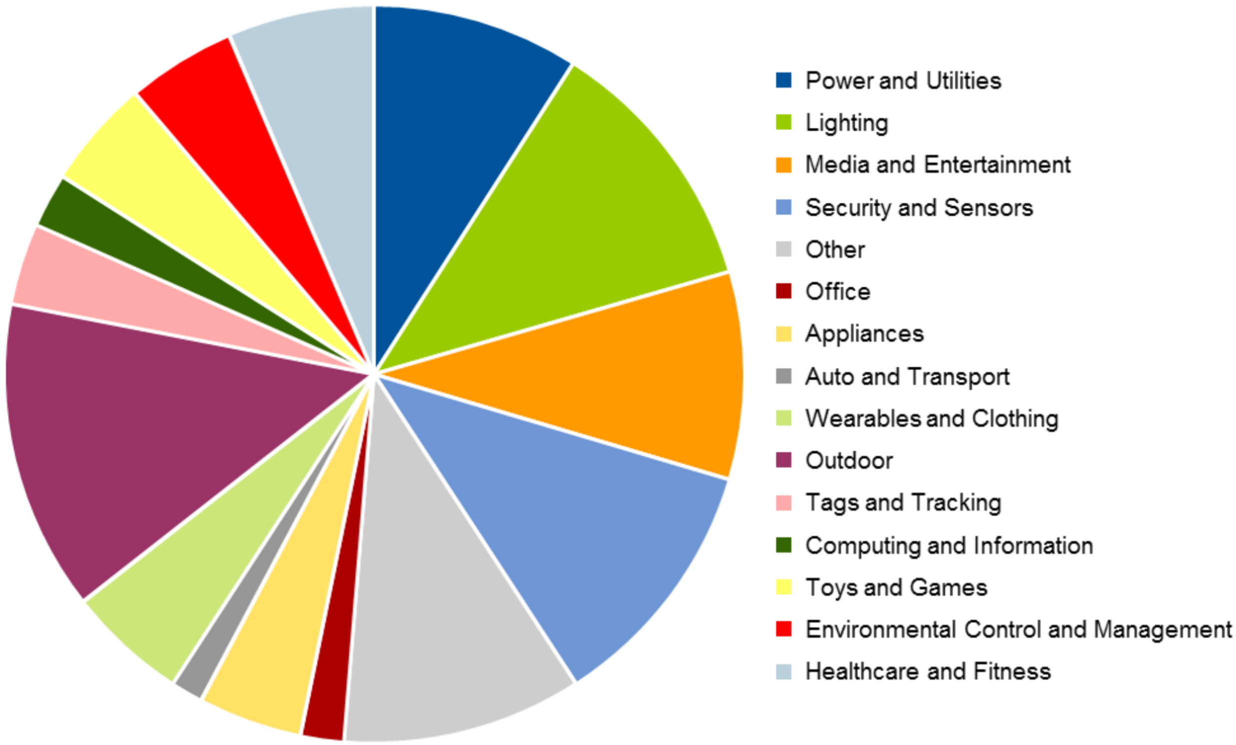


Figure 1-2 Relative Proportions of Domestic Smart Objects [3]

Note: The pie chart represents 100% of the smart objects in a home; the size of each segment represents the percentage of items in that category.

There will be additional edge devices (network-enabled devices that connect to an internal local area network with an external wide area network or the Internet) connected to the network directly or indirectly via one another. In addition to the network upgrade requirement, this will also add a burden to the electric grid. With each smart device, a small amount of vampire load (also known as stand-by power or phantom load) is introduced. The vampire load will aggregate at both the household and national levels. We expect to see these devices communicating on different network protocols, which in turn call for a number of different network gateways and routers.

Considering the various lifespan of electronic devices, the “five hundred” smart devices are expected to include amongst themselves “legacy” appliances, devices unsupported by the new hubs and gateways used to integrate the supermajority of the connected devices; these older devices may require separate gateways by themselves as they would not be compatible with new smart devices or objects. All these smart objects are the edge devices of the IoT world and require a considerable amount of energy just to power up and support their intelligence and communication capabilities. Further investigation is needed so as to develop a better understanding of the landscape of IoT appliances with regards to their functionalities, network protocols, energy consumption, and other parameters, and identify ways to work seamlessly among legacy and new devices

1.2.1 Wearable Electronics

Wearable electronics is a diverse and rapidly growing consumer market, and includes everything from augmented reality glasses to smart textiles. In this discussion we will highlight the energy impact of this class of devices using one of the elder statesmen of wearable electronics, the fitness tracker device.

Fitbit, for example, singlehandedly controls a 68% market share of the wearable fitness solutions market [4], having sold a total of 10.9 million devices, with 6.7 million users actively subscribed to their services [5], and shown in Figure 1-3. Since the device can still function without an annual subscription, the actual number of active product users should be somewhere between the two figures mentioned above. Given the physical size of the battery, the approximate battery capacity is 180 mAh according to aftermarket replacement battery suppliers. As the typical full charge lasts up to five days, Fitbit use alone creates an energy demand of approximately 88 MWH of electricity annually, an estimate that increases upon factoring in charger inefficiency and vampire load. Moving forward, Fitbits represent but a fraction of the total market: similar devices are manufactured by Apple, LG, and other consumer electronics brands, and smart watches made by Apple and Samsung in particular are notoriously power-hungry. In general, these devices require charging every day despite carrying batteries larger than the one used by Fitbit.

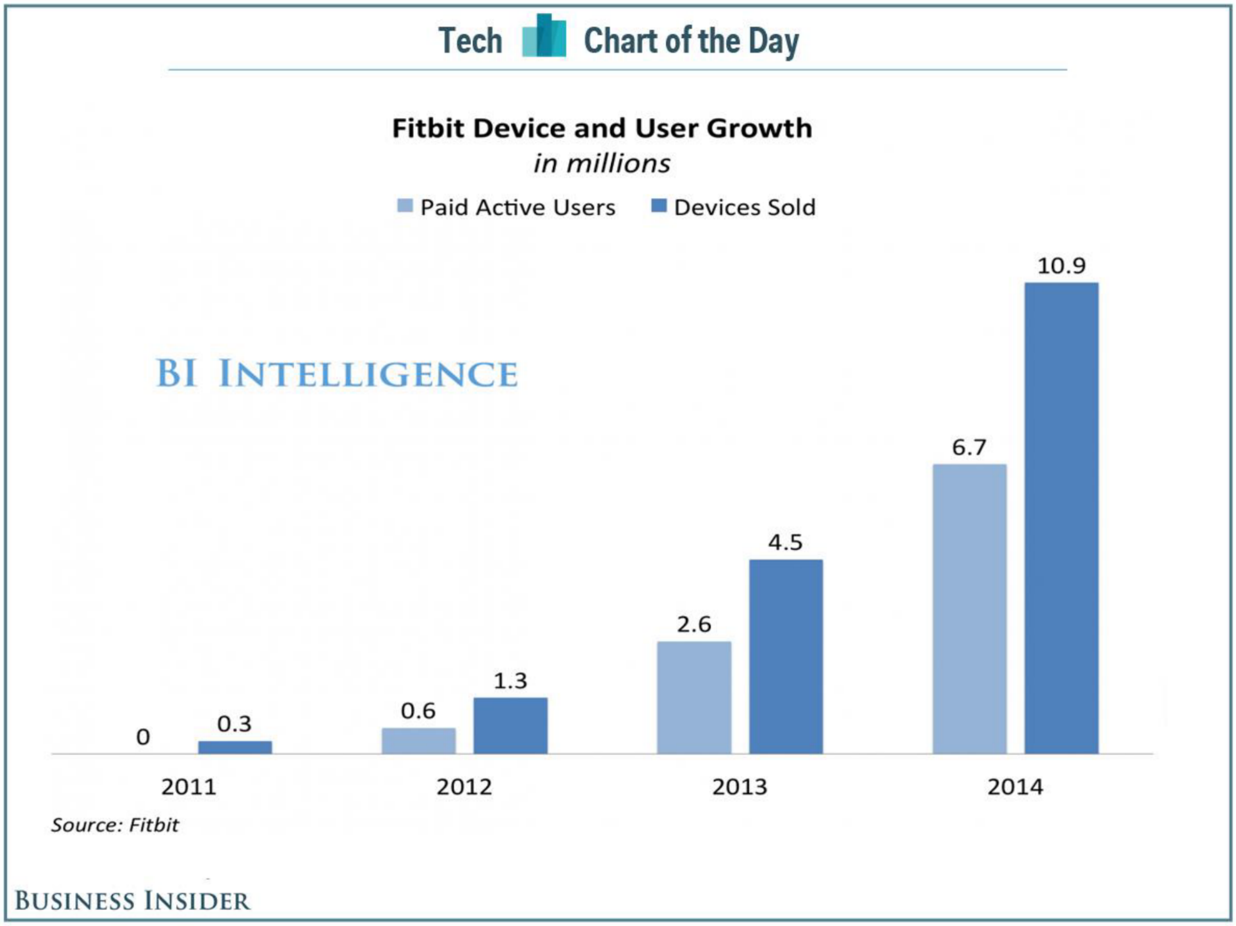


Figure 1-3 Business Insider Fitbit Device and User Growth Chart by year [5]

1.2.2 Home Automation

Apple's current partnerships , for example, with home automation companies such as Lutron and Insteon promise to provide convenience and energy savings by bringing device control and operational feedback to the wrists of customers using Apple's wearable Apple Watch. Omnipresent feedback regarding energy usage can assist energy savings related choices, and bringing control to the wrists of users is a natural extension of the market's standardized use of cell phone app interfaces for controlling and scheduling appliance duties. Wearables provide users with a more direct feedback from the energy management system reminding or suggesting to them to take an action such as turning off unused lights or turning down the temperature on the thermostat. By bypassing the relatively cumbersome phone interface, a wrist-mounted controller can provide a more convenient user experience; it can also simply serve as a complementary device option within a user's electronic toolbox. Ease of interaction and well-timed suggestions significantly reduce the effort of active energy saving, subtly encouraging behavior-based energy savings. Furthermore, this feature would allow gateways to accurately acquire the location of the users such that devices within an automated network can respond correctly and accurately to user behavior, further optimizing the behavior-modifying effects of the device.

1.2.3 Smart Thermostats and Demand Response

Smart thermostat technologies are being adopted for utility applications. For example, Illinois aims to replace one million conventional programmable thermostats with smart upgrades over the next few years [6]. As part of the renovation, they are incentivizing customers to buy and install a Nest of ecobee3 thermostats, although the programmable thermostats are often put in “hold” mode and do not run on a schedule that would save energy and money. At the same time, Nest is working with utilities on demand response. Furthermore, Nest is working on the new Weave protocol to enroll more IoT devices into the mesh network. Nest is also concentrating on making instantaneous responding devices with latency less than 100 milliseconds to ensure user retention rate by reducing user frustration from activation delays.

1.2.4 Wireless Charging

As the number of smart edge devices grows in use at home or office, it is also envisioned that instead of traditional plug-in charging with AC/DC adaptors, wireless charging methods provides more convenient ways for consumers to charge their devices. However, the current efficiency of the wireless charging methods continues to lag behind that of traditional plug-in chargers. Additional technology advancement to improve efficiency and new regulations in wireless charging is needed for a rapidly growing consumer market.

1.3 Virtual and Augmented Reality and Gaming

Augmented reality (AR) and virtual reality (VR) technologies both provide stereo 3D high definition video and audio, with VR featuring closed and fully immersive, while AR being open and partly immersive, i.e. one can see through and around it. Where VR puts users inside virtual worlds, immersing them, AR puts virtual things into users’ real worlds, augmenting them. AR and VR could hit $150 billion in revenue by 2020 (AR at $120 billion and VR at $30 billion) [7]. The gaming industry is very interested in using VR to provide a next-level gaming experience to the consumer. Although they approach the technology from a user experience enhancement perspective, this move has an added side effect of reducing the energy footprint of game consoles. Instead of displaying gameplay on a high resolution TV screen, the graphic user interface display can be reduced in physical size when moving to a VR system such as headset gear. Additional savings are gained from the elimination of traditional audio: VR often eschew a large sound system, and instead feed audio directly into the users’ ears. In this scenario, the energy footprint of a stereo system is downsized to a headset without sacrificing the quality of sound effects. Even the most energy efficient TV in the 35-50 inch category consumes 29.1W [8], whereas a VR headset can operate around the same energy consumption level as a cell phone. With limited access to VR headset power consumption datasets, one hobbyist has taken the time and effort to investigate the power consumption of an Oculus Rift Development Kit 2 [9]. With their test setup, Oculus operates at 600mA with an USB power adapter. Therefore, the entire VR headset operates at less than 3 W. However, we do not know whether AR or VR will replace TV as the center appliance in a living room setting, but will become an addition to the existing crowd of entertainment devices. While VR or AR has much smaller energy footprint than the current game console/TV/stereo combined for entertainment system, more AR or VR devices will be used and could lead to additional demand of energy consumption.

1.4 Additive Manufacturing and Prototyping (3D printing)

Additive manufacturing (AM), also known as additive fabrication, additive processes, additive techniques, additive layer manufacturing, layer manufacturing and freeform fabrication [10], is, as defined by ASTM F2792-12 [11] with a reference to ISO 1033-1:1994 Industrial automation systems and integration, a process of joining materials to build objects from 3D model data, usually layer upon layer, as opposed to more wasteful subtractive manufacturing methodologies, which remove material in a stepwise manner from a bulk starting substrate. The primary applications of additive fabrication are design and modeling, fit and function prototyping, and direct part production. A popular form of additive fabrication for individual users, business or hobbyists is 3D printing. Technological advancements have even resulted in developments of body parts/organ “printing” (produced with additive methods) on demand.

AM provides certain advantages and disadvantages relative to injection molding over well-established method for polymers manufacturing. The AM method provides a fast turnaround at an extremely low cost compared to injection molding and other traditionally available prototyping methods. As a result, many AM service providers and manufacturers are looking into ways of applying this technology towards larger scale of productions. By 2017, nearly 20% of durable goods "e-tailers" (electronic retailers) will use 3D printing to create personalized products, with each “e-tailer” owning on average 5.4 3D printers and by 2020, the additive manufacture (including 3D printing) market is expected to be worth $10.8 billion [12] after factoring for machines, materials, and the relevant services.

This will continue to grow strong and demand more energy [13]. In general, most 3D print jobs require more than two hours, with but some extending overnight. For example, a Makerbot Replicator 2 consumes 150W (221W by original Makerbot Replicator [14]). Printing one product/part can consume 0.3kWhr to 1.8 kWhr (12 hours of printing) using one printer only. Comparing to office imaging equipment (copier and printer), an ENERGY STAR® copier (at 40 pages per minute printing speed) uses 183 kWhr (equivalent to 0.5 kWhr per day) and 136 kWhr (0.37 kWhr per day), evaluated with

50% duty cycle of 84 hours standby and 84 hours sleeping [15]. The energy demand of an actively working 3D printing has surpassed the energy demand of shared copiers by 3.6 to almost 5 times. However, as mentioned above, there will be multiple 3D printers coexisting in an “e-tailer”, which will further increase the energy demand. While the 3D printer is actively working, the energy consumption is mainly caused by the heat dissipation of the plate and extrusion nozzle. Users not conscious about energy savings may unintentionally waste large amounts of energy by leaving the printer heated over a long period of time.

In 2015, the two major market leaders are Stratasys Ltd. (Brand Names: MakerBot) shares 30.8% of the market, earning $151.9 million in revenue. Comparing itself to the year before, their revenue was $74.7 million. This increase in revenue is over 100% in a year [16].

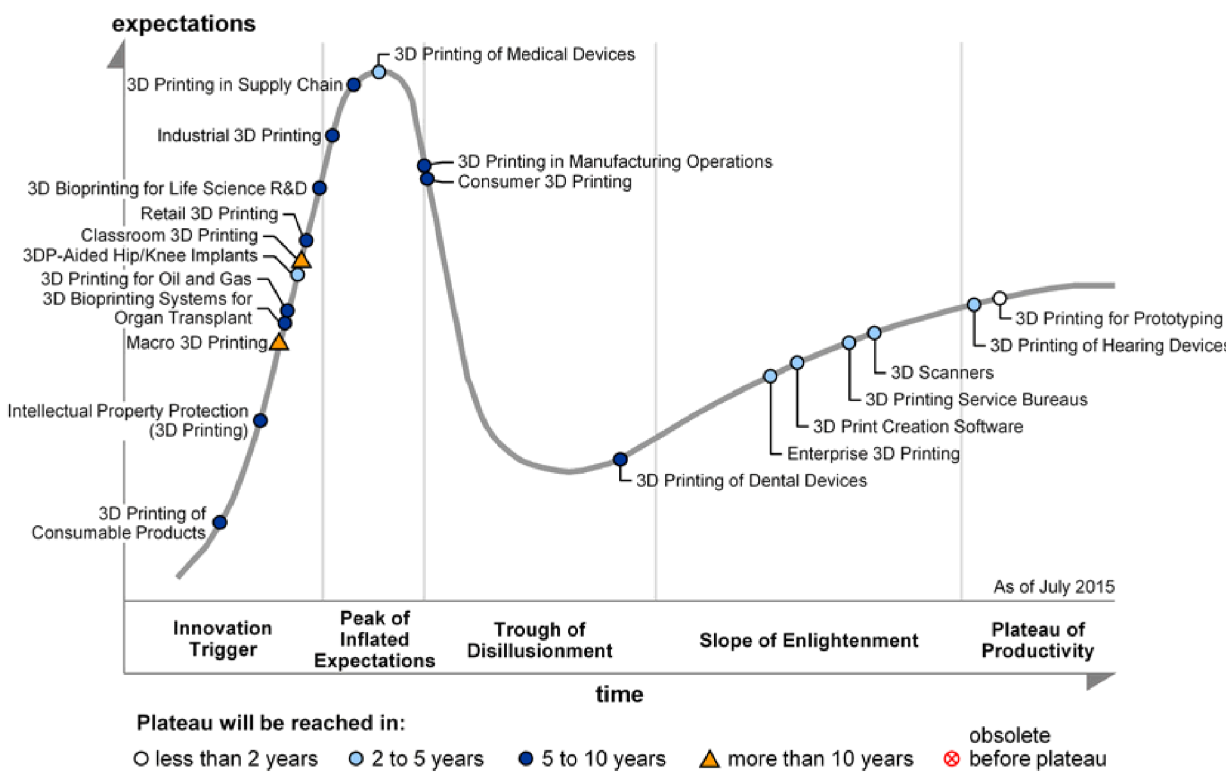


Figure 1-4 Hype Cycle for 3D Printing, 2015 [17]

As the initial hype about 3D printing settles, the 3D printing industry will begin exploring less traditional applications. 3D printing for research and development is plateauing. Medical related 3D printing technologies takes five seats on the uprising curve shown in In 2015, several defined megatrends (large, slowly evolving social, economic, political, environmental, or technological shifts) drove changes in the technology world. Listed are the top five megatrends identified by a 2015 Gartner report, and illustrated in

Figure 1-4, while industrial related 3D printing occupied three seats. Industries that may take advantage of 3D printing technologies include, but are not limited to [18]:

- Medical Device Manufacturing
- Car & Automobile Manufacturing
- Aircraft, Engine & Parts Manufacturing
- Architects
- Specialist Doctors
- Food production

AM-related industries will create additional energy demands. However, AM in general and 3D printing in particular is expected to provide a net reduction in energy consumption by improving energy efficiency in transportation via small quantity production. When a design/model is transferred over the network, the end user can directly print the product design/model locally or even on-site. Shortening aspects of the supply chain reduces shipping and handling costs, losses related to damaged products, and wait-times on both the consumer and manufacturing end. AM also reduces the cost of overproduction by producing customized products on demand, and may further lower demand in niche production fields [19]. The National Institute of Standards and Technology (NIST) report [19] concluded that AM is a cost-effective method for small batch production with continued centralized manufacturing. Given that materials are the most costly aspect of the production of AM, NIST also indicated that technological advancements in the near future can reduce the raw material cost, which may in turn reduce the overall cost of AM systems.

1.5 Water and Energy

The current California drought, which has plagued the state since 2012, has additionally affected energy generation and consumption. Both surface and underground aquifer water levels have dropped accordingly. Energy is required for water sourcing and conveyancing, treatment and distribution, end use and water treatment. On average, water conveyance requires more than 50 times the energy for Southern California, than it does for Northern California. This is also five times the national average [20]. The problem is compounded by a decrease in the snowpack at higher elevations, reducing the amount of water available to be converted into hydroelectric energy. In 2013, hydroelectric supplied approximately 24,102,160 MWh, equivalent to 12.09% [21] of California total in-state generation, while in 2014, this number dropped to 8.33% at approximately 16,469,573 MWh [22]. Burning natural gas and energy importing from out of state make up the deficit occurred in hydroelectric generation. Another large consideration is that significant energy is used to sanitize water sources, ground water pumping, transportation, and recycling. Currently, household water use accounts for approximately 64% of total urban water consumption [23]. The state of California is currently calling for innovative technologies to help resolve this issue as well as incentivize water and energy efficient appliances.

1.6 Telecommunications

Despite its maturity, telecommunications is still a growing sector demanding more energy to transmit greater amount of data packets through many advanced communication protocols. As the ever-expanding backbone of the Information Age, the world's telecommunications infrastructure is expected to demand a corresponding increase in energy for foreseeable future. As an example of the infrastructure's current rate of evolution, nearly five years after debut their groundbreaking LTE technology, Verizon has announced their preparation plans for a 5G network field test, a network that, once fully implemented, promises to provide fifty times more throughput than the current 4G LTE technology.

To address concerns about the power demands of such high-performance networks, a startup company called Ingenu is providing discounted network access, at the cost of reduced speed, on the premise that not all devices require a high-speed network connection. To lower their cost, they rely on the 2.4G wireless (Wi-Fi) band, eliminating the cost of securing a frequency band regulated by the Federal Communications Commission. Ingenu is deploying towers to serve an approximately 300 mile radius (resulting in up to ten times fewer tower constructions), with download speeds of 2 kB for mobile units to operate with less overhead.

Additionally, cable service providers have observed that customers are increasingly eschewing cable television subscriptions, while favoring broadband Internet [24]. Digital subscriber line (DSL) was a popular technology bringing higher speed (than dial-up) Internet to homes and small business over ordinary copper telephone landlines in the past. Coaxial cable can allow 20-30 channels on the same coaxial cable with data rates of 1 to 5 Mbps [25] , while coaxial cable by itself can carry high-speed internet access, TV services and phone services all together. Comcast, the nation's leading cable provider, reported that as of the first quarter of 2015, it had more broadband subscribers than it did cable subscribers. Paralleling cable television is the landline telephone and Internet services: AT&T and Verizon report that landline telephone service is in decline as customers prefer wireless-only phone services in households, and industry observers have suggested large landline carriers will continue to shrink dramatically in terms of residential phone customers.

As phone and cable companies suddenly find themselves competing with one another (or merging in the case of AT&T and DirecTV) in the providing the so-called triple play phone-television-Internet package to customers, the competition is distilling down to a battle between coaxial cable and twisted pair wires. , and cable companies added more than 800,000 broadband subscribers in the U.S. during the third quarter of 2015, with Comcast and Time Warner Cable leading growth by adding a combined 552,000 new subscribers. Simultaneously, telecommunication companies reported declines in DSL and slower growth in fiber subscriptions recently, with AT&T losing 106,000 subscribers and Verizon adding only 2,000. Strategy Analytics [26] anticipated that cable operators will continue to increase US broadband market share as they roll out DOCSIS 3.1, a gigabit-enabling technology that offers even higher speeds. Although combining services into triple play packages may provide better data handling from the provider side, the users' demands continue to increase, which in turn may demand greater amount of energy to transport data packets.

At the same time, voice over Internet protocol (VoIP) has gained popularity. While the traditional telephone system dedicates a single line to each phone call, the packet switching technology used by the VoIP can send small pieces of many calls along one line, reassembling them at the end. The great bandwidth conservation has brought up the energy efficiency with this VoIP technology by sharing the same resource to transmit multiple data sources. Analysts expect the VoIP system to grow and attract huge investments and new equipment [27].

1.7 Telemedicine and Robotic Assistive Living

A subset of wearables focused on health and wellness segues elegantly into telemedicine by collecting patient "health" data that can be assembled into sophisticated intelligence reports via IoT. Supporting these analytic features are energy-demanding arrays of back end data gathering and computing hardware; the only uncertainty is the precise amount of energy needed to execute these IoT features.

In contrast to discussions regarding novel IoT-related challenges is the stubborn traditional shortage of healthcare, especially in light of the United States' aging population, one expected to further strain the healthcare system to unsustainable levels [28]. Compounding this difficulty is the reality that the once uninsured population is now using a medical care through the Patient Protection and Affordable Care Act (commonly known as the "Obamacare"). While a paper in the Health Services Research (HSR) journal [28] also indicated that the economic burden of aging in 2030 should be no greater than raising the baby boomer children in 1960s, it would be beneficial to develop an improved payment and insurance system over the existing one by taking advantage of advances in medicine and behavioral health, and expanding the benefits of preventative care. Aside from various proposed policy changes and infrastructure upgrades, many researchers and industry partners have invested in researching and developing assistive robots for caring aging population to:

- Provide preventative care remotely
- Monitor health conditions and symptoms regularly and remotely
- Reduce the number of hospital visits, which may require family members' companionship
- Reduce hospital readmissions
- Making health care more affordable in the long run
- Improve senior citizens' life quality for independence and more

Robotics can be one of many solutions that technology can provide. Once they are designed and trained properly, robots can reduce the human care provider labor cost of the health care system. As shown below, among the applications listed, assistive living has shown to be the strongest growth.

Table 1-1 The 10 Fastest Growing Robot Applications, Compound Annual Growth Rate (CAGR %) 2013-2018 [29]

Applications	CAGR % 2013-2018
Assistive living	12.0
Logistical support	11.3
Cleaning and inspection	11.3
Construction and demolition	10.5
Couriers and guides	9.6
Surveillance	9.2
Bomb and land mine disposal	9.2
Military space	9.1
Home security	9.1
Research and development	9.1
Average for all 26 applications	5.6

In addition to healthcare, logistical support, cleaning, inspections, and surveillance and home security are all promising household "robot" applications with a strong forecast for the next 10 to 20 years. In North America alone, the value of robotics used for assistive living can reach $83 million with a compound annual growth rate (CAGR) of 4.7%, $20 million with CAGR of 10.8% in cleaning and inspection robots, and $50 million in home security [29]. All these robots will be connected to the grid as well as becoming the edge nodes of IoT.

A DARPA robotics competition from June 2015, (winner shown in Figure 1-5), in which robots built by international teams competed under a set of rules and extreme circumstances, provided the world with a dramatic demonstration of the promise of robotics. The robot had to demonstrate human behavior, drive a utility vehicle, use power tools, and even make decisions with limited outside communication, which are all designed to simulate real life disaster situations faced by human rescue teams.

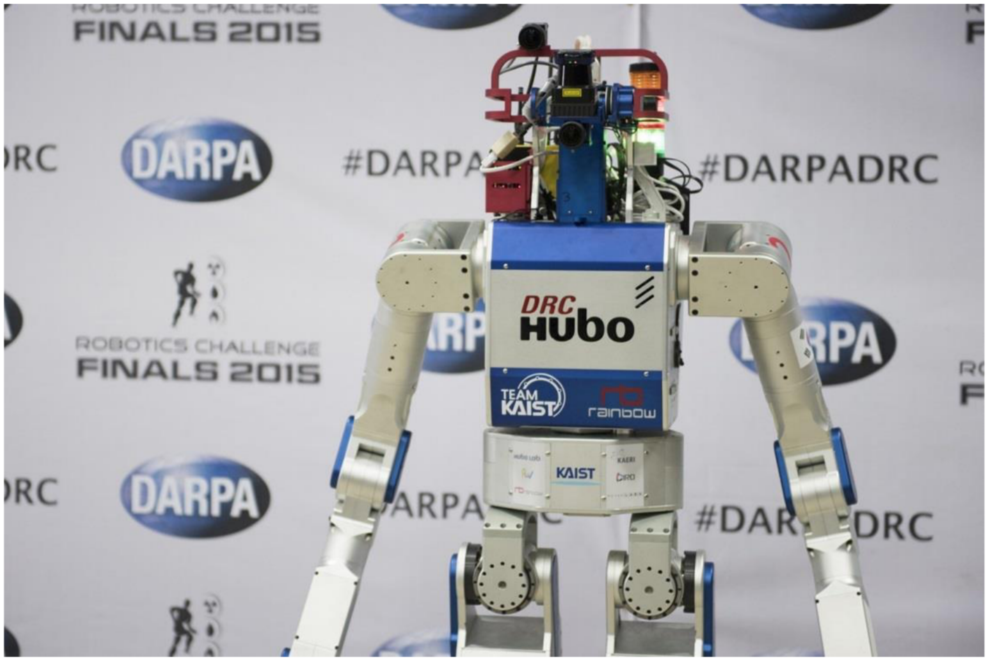


Figure 1-5 The DRC-Hubo humanoid robot from South Korea's Team KAIST won the DARPA Robotics Challenge Finals with a winning time of 44 minutes, 28 seconds to win the $2 million grand prize.

The competition was very successful in demonstrating the technology’s state-of-the-art and yielded a number of takeaway lessons. However, our expectations of robotics are beyond the current capabilities of the robotic industry as we expect robots to comparably perform or outperform human beings in a variety of tasks.

State of the art robots can currently perform specific tasks and routines, but are unable to perform any complex series of actions. In other words, robots can currently assist humans in many ways, but only by working in groups, with each specialized robot compensating for the others’ inabilities, in order to complete one complex task. The 2015 DARPA competition focused on disaster response, but the technology is currently being adapted towards assistive living.

Although the robots showcased the most advanced technologies, they did so also by pushing the upper boundaries of their battery capacities. For example, the updated version of the ATLAS robot (from the 2014 competition) is designed with 3.7 kWhr lithium-ion battery pack, to perform one hour of “mixed mission”. A standard small car battery holds approximately 0.57 kWhr (commonly rated for 45 AH at 12.6 V), which is equivalent to about 15% of this robot’s battery pack. Therefore, deploying robots may create a greater energy concern until better energy management systems or battery technologies are developed.

With the growing number of sensors and specialized edge devices, preventative medicine and medical devices may very well become the primary line of defense in healthcare, while already-ill patients can expect an improved quality of living through remote monitoring and telemedicine. Additionally, wearable sensors can double the inputs for household robotics providing vital information of the care receiver to complement robots on-board sensors. Finally, robots can provide specialized assistance and companionship as well. Given the tremendous growth expected in this sector, the energy demands of these devices will play a significant role in the preparation of future electric grids.

Codes and Standards Opportunities	Recommendation for Future Study
Wireless Charging	Wireless Charging
3D printing	3D printing
	Home Automation
	Telemedicine and Robotic Assistive Living
	AR/VR

Task 2 Microprocessor-based Plug-in Appliances vs. Standard Plug-in Appliances (i.e., Smart Appliances vs. Standard Appliances)

2.1 Major Household Appliances (white goods appliances)

From our 2015 study (CEC PODR05-V20 and PODR05-21 publication pending) completed with UC Davis, in which we modeled energy use in a 2200 ft^2 house built in various configurations, pre-cooling strategies reduce the peak hour demand of energy consumption more efficiently than any other practice. In a real household, if the thermostat could communicate with the plug-in fans to start pre-cooling prior to AC activation, this intelligence will help reduce the peak demand greatly. The IoT concept is the backbone to this coordination with lower level of microprocessor-based plug-in fans. For further improvements, a battery bank can be added and controlled by a microprocessor to condition the space smoothly while reducing the peak demand: the purple curve, as shown in Figure 2-1, illustrates this point. In the second graph to the right, if a microprocessor based control algorithm is in place, the battery storage can even further help to reduce the peak demand, instead of simply rapidly discharging itself.

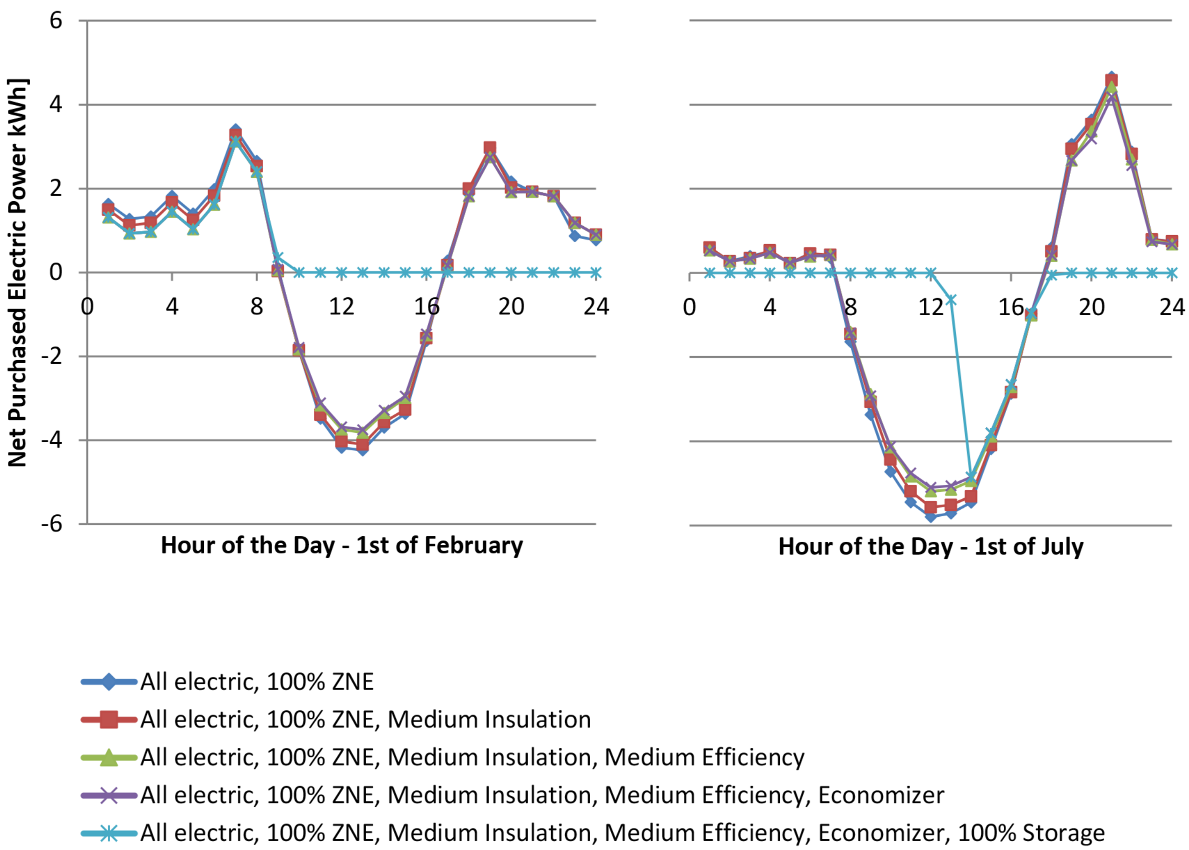


Figure 2-1 Simulation result from project Smart Power for the Smart Home project (joint with UCD)

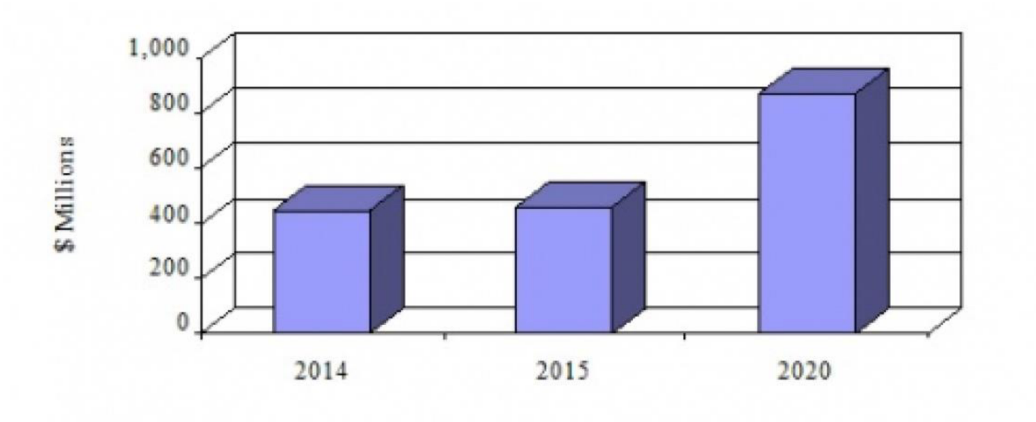
Clothes dryers are another example of a technology that can benefit from a microcontroller-based energy management system utilizing their sensor data. Commonly, users choose a timed drying cycle based on an estimate of moisture content in wet clothes, often overestimating in the process, therefore, wasting energy during the excess operational runtime. An average electric dryer uses approximately 3.3 kWhr of electricity during a 45-minute load. Dryers equipped with moisture sensors are useful for ensuring that the drying cycle will not enter into any unnecessary extended cycles.

Another common sensor on modern dryers is the load capacity sensor, which can further assist in shortening the drying-cycle time and minimizing energy waste. These sensors are useful in theory; however, users' reviews demonstrate how poorly they translate to the real world. According to users' reviews, the sensors are cumbersome and prone to premature failure due to a combination of user error and poor maintenance. Therefore, to optimize the effectiveness of the sensor based technologies, it often requires some basic consumer acceptance and awareness of the technology and the intelligence. Under proper use, the temperature sensors attached at exhaust can auto terminate a drying session to reduce or eliminate energy waste comparing to timer based dryer. Manufactures indicated to Department of Energy (DOE) that temperature sensing can provide 10% real-world energy savings, whereas moisture sensors yield 15% savings [30].

2.2 Home Appliance Mesh Network and Energy Management Information Systems (EMIS)

Energy Management Information systems (EMIS) are enabling tools that support users' efforts in improving the energy efficiency of their facilities by providing better access to energy usage and system data and by applying analytics to collected data [31] . EMIS are optimally designed for correcting operational issues/errors in large buildings, but this technology can also apply to individual houses, by allowing homeowners to remotely control over their appliances. Automated monitoring and controlling systems can also collectively present the usage data while providing unsupervised power management; the cognition of such EMIS is thus a promising method for energy savings.

U.S. RESIDENTIAL ENERGY MANAGEMENT INFORMATION SYSTEMS MARKET, 2014-2020
($ MILLIONS)



LEGEND
($ MILLIONS)

Segment	2014	2015	2020
Residential EMIS sales	449.3	460.1	872.4

Source: BCC Research

Figure 2-2 BCC Research EMIS market analysis [32]

From 2015 to 2020, the residential EMIS market is projected to increase by 89.6%, as shown in Figure 2-2. These EMISs will be organized as a home network, normally with one or more gateway devices to relay and store historical data. EMIS functionality is not limited to data presentation either, as they may also provide additional actionable information for the users.

While the advantages of microprocessor-based plug-in appliances are most obvious in larger loads, such as the washer, dryer and water pump for swimming pool, the technology can be extended to all home plug loads as well. A natural development of this logic is the creation of a meshed network for all appliances in the house: instead of "smartening" individual devices, many manufacturers start to make hubs and/or gateways for communicating across all network enabled devices, providing a centralized intelligence and a hub for interfacing all users.

The current batch of state-of-the-art IoT microprocessor-based devices are fragmented by their design and protocol. However, Google I/O 2015 saw the announcement of the Brillo, a stripped down version of Android for IoT devices, as well as Weave, a standardized language for IoT devices. While Google is not the first or only company to push for a communication standard (Weave, and operating system Brillo), might very well be instant frontrunners, given their simplicity, as well as the market share and developer community of Android OS.

2.3 Occupancy Sensing

A recently published research [33] showed occupancy based HVAC systems saved 37% energy without sacrificing indoor climate control. The occupancy data is represented by binary numbers instead of the occupancy-count. Even with a two-state input and a simple control microcontroller system, the system showed significant energy savings from day-to-day and zone-to-zone.

2.4 Control algorithm

We have entered the era of network-based energy saving for devices that are connected and rely on the network capable of broadcasting (e.g., routers, RF hubs, and etc.). With IoT here to stay, machine to machine (M2M) communications is on the rise, which subsequently can affect plug loads with increasing complexity of correlated sensing and energy based decision making. Any successful energy saving IOT based solution requires both an applicable ruleset for the target space, and a proper setup, at the very minimal. We are enjoying the connectivity without giving proper attention to the energy saving potentials on network interfaces. The need for a well-defined energy management policy has led researchers to continuously work on several strategies for different scenarios. For example, Luiz et al. [34] proposed a time-based network management system to minimize both power consumption and the performance penalty when the internet interface is turned off. The work presented a sound argument in favor of a flexible timeout for Internet interfaces and also applicable strategies for other microprocessor based appliances. However, more work needs to be accomplished in this area to fully capture as much energy savings as possible by have M2M communications improved while not interrupting consumers' energy needs and preferences. Complex algorithms and better understanding of behavior will need to be achieved for optimal energy efficiency.

2.5 Example Application: Small Electric Table-top Water Heater

Tabletop water/coffee heaters (also known as “electric thermo pots”), ubiquitous to many residential kitchen and workplace break rooms, are an example of a widely-used class of device that might benefit dramatically under the automation provided by microprocessor-based control.

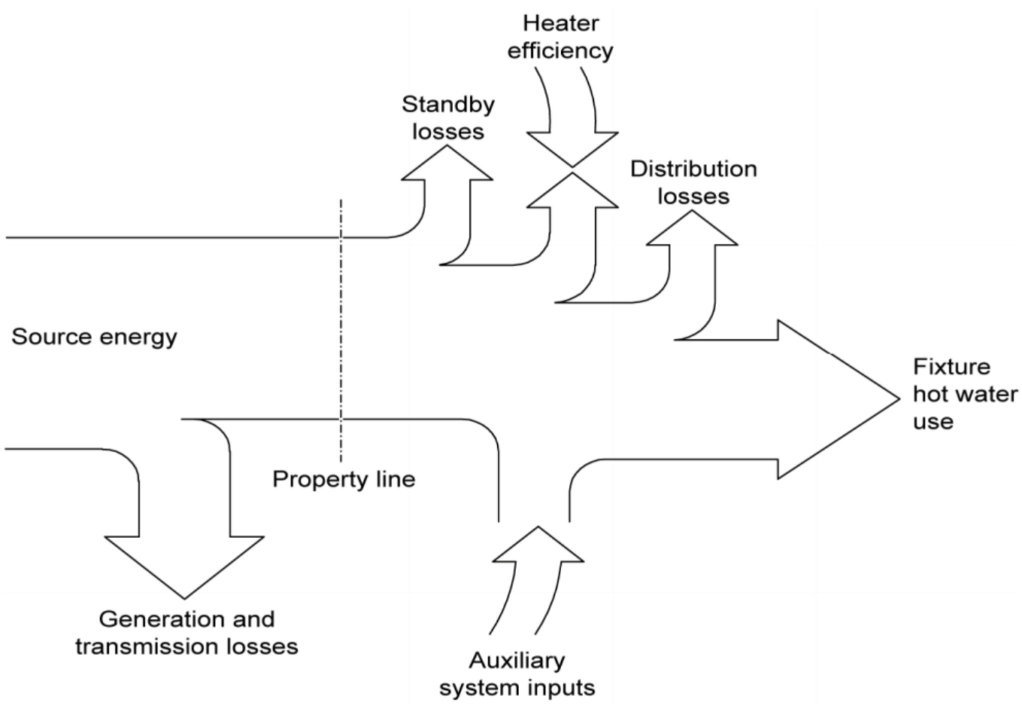


Figure 2-3 Energy Flow of Water Heating. Source: CEC-400-2008-016

Small coffee warmers prepare hot water at the point-of-use, thus bypassing the distribution losses characteristic of larger centralized heaters as shown on Figure 2-3 however, due to commonly used features such as keep-warm options, standby losses become significant.

The popular Panasonic NC-EH30PC electric thermo pot provides an illuminating example of both technology progress and opportunity for improvement. According to its technical data sheet, the device draws 750W over a period of 27 minutes to bring 3 liters of water from a room temperature (68 ºF nominal) to boiling. The unit includes an energy-saving measure in the form of a keep-warm option in which it will maintain the water temperature at 140ºF, 180ºF, 190ºF, or 208ºF over a six-hour period at a cost of, on average, 21 , 31, 39, and 45 watts, respectively. This provides the user with several convenient options of maintaining a constant supply of water compared to time-inefficient alternative of waiting for a fresh serving of cold water to boil with every use. Unfortunately, it is noteworthy that such power management options are often neglected by end-users, many of whom are completely unaware of their devices' energy-efficiency features and do not enable them at all [35]:

Additionally, like most small water heaters, this device does not include the more sophisticated power management, such as vacation modes and clock-based energy throttles. Such options might seem trivial for lightly-used at-home devices, but in larger communal devices, the energy savings can become significant. A specific example is the workplace water cold/hot water dispenser, whose heating element runs constantly at around 100 W to maintain an immediately available supply of near-boiling water. This might be necessary during peak usage, such as the morning and mid-afternoon coffee periods, but a waste of energy during lulls in the day and at night, and could benefit from the implementation of a timing or occupancy sensing mechanism. Indeed, given the large number of uses, i.e. data points, per day, a dispenser employing energy control technology might very well is able to log usage and autonomously fine tune its heating element schedule to simultaneously optimize both energy consumption and user wait times.

The water cooler is unique in that it can earn an ENERGY STAR® certification if the entire machine, including both the heater and the cooler, operates at less than 36.25 watts. Current interest in energy-efficiency of home devices suggests that now is an ideal time for drawing up similar guidelines for thermo pots [36]. Small water heaters are regulated by federal standards (specified in Title 10 Chapter II Subchapter D CFR §430) under instantaneous electric water heaters.

Finally, from strictly a materials and engineering design point-of-view, due to their packaging and form factor, small heaters include relatively light thermal insulation compared to their larger centralized water heaters, resulting in another mechanism for thermal loss. Improved insulation can significantly reduce the thermal loss while maintaining the water temperature.

2.6 Further Grid Benefits

Microprocessor-based plug-in appliances can even further enhance grid stability. "Smart grid" generally refers to a class of technology people are using to bring utility electricity delivery systems into the 21st century, using computer-based remote control and automation. These systems are made possible by two-way communication technology and computer processing that has been used for decades in other industries [37]. With the microprocessor-based energy management system, the devices form a network either in the home Wi-Fi or within their own network. The device level or house level intelligence allows the utility to communicate with the end users directly during outraging high demand periods to avoid over consumption resulting blackouts and overstressing the grid. According to an article recently published in an IEEE journal [38], in such a network, a programmable logic controller can run the “Distributed Algorithm of Appliances Scheduling” for homes, which schedules the appliances to run on different schedules in a realistic manner based on the price of the energy, where energy unit pricing is used as a representation of supply level. The energy management system is used as an input as well as an actuator.

Codes and Standards Opportunities	Recommendation for Future Study
Thermo Pot	Occupancy sensing
	Smart appliances in home Automation

Task 3 Impact on data center and demand response: whether tomorrow's anticipated demands of energy test and stress the reliability of energy production of the existing network infrastructure.

Information technology (IT) remains a fast growing industry in offering high performance processors ever decreasing cost. "Moore's law" stated the observation that the number of transistor in a dense integrated circuit doubles approximately every two years. The technical advancements make cost of high performance processors to drop continuously as the newer technology appears in the market with increased computation power. Almost every large IT company either hosts server farms as a service to others, or hosts their own, and even smaller companies maintain one or a few servers of their own as the server cost goes down. Servers have even entered the residential market, where are used primarily to store and share home media. By 2020, the market for home media servers is projected to reach approximately $200 billion [39]. This growth places a distinct strain on the electric grid due to the fact that servers, by design, operate constantly, thus adding a perpetual load to the home energy usage baseline. In this section, we will review the infrastructure needs and shifts, and potential solutions to accommodate the demands within the existing infrastructures while raising the needs of more technical advancements.

3.1 The Aging Infrastructure and Ongoing Upgrades

IoT edge devices have created asynchronous Internet traffic over the years. For example, the increased image quality and clarity in online streaming videos call for larger data packets. The Internet in general has expanded beyond projections from twenty to thirty years ago, from simple text data exchange to video streaming. However, current infrastructure was never designed to carry even the ever-growing data packet sizes of today, much less the internet of the near future. With heavier data demands, data centers have outgrown the energy supply levels that local utilities have projected or planned for. They are currently strategically located adjacent to energy sources such as water dams or wind farms to power their datacenters with renewable energy [40]. Ultimately, this "large scale server farm" business model still will not completely resolve the end node data triggered power consumptions, where data transmission and data relay still needs energy to host distributed servers at multiple layers.

Compared to most other data types, video transmission requires the use of a significant amount of bandwidth over a small amount of time, especially during "live" broadcasts, and has prompted the search for novel routes of data transfer. This past July, AT&T announced the acquisition of DirecTV, a merger that may allow AT&T to, in addition to significantly expanding their high-speed Internet service to millions of new households permit them to split some of the Internet traffic, especially media-related contents, to the satellite service, effectively combining the bandwidth of both coaxial cable and fiber optics, to ensure uninterrupted services.

3.2 Server management strategies

Data centers experience occasional periods of high demand during which existing infrastructure cannot accommodate all users' requests. IT industry leaders face the same problem as they run the server farms to provide the content hosting services. In this report, we examined different approached to the problem from both hardware and software point of views.

Microsoft released a white paper on "Accelerating Deep Convolutional Neural Network (CNN) Using Specialized Hardware" [41]. In this white paper, they explored the utilization of neural network machine learning technique to reduce the dimension of the dataset, as illustrated in Figure 3-1. Each time the neural network is applied to the dataset, in this case, the image RGB values, the dataset is represented by a smaller set, using convolution of data where the correlation is reflected by the neural network.

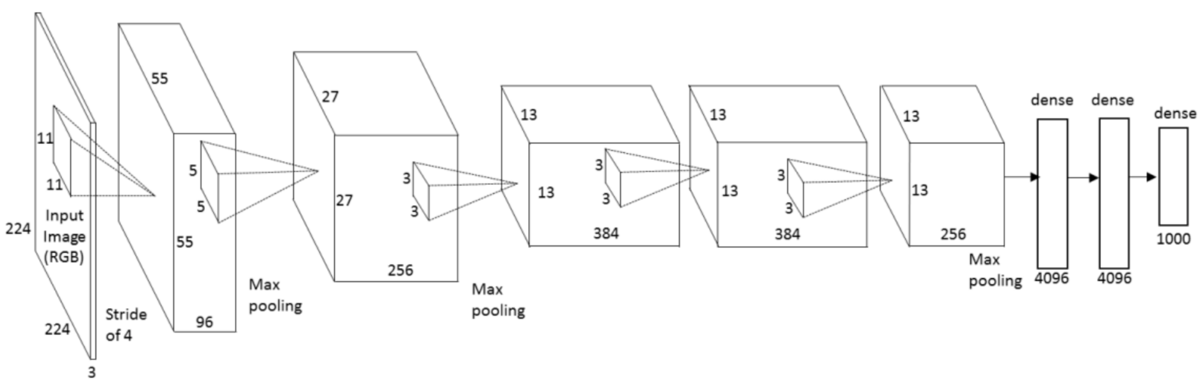


Figure 3-1 Microsoft CNN FPGA algorithmic illustration

Microsoft has also recently also revealed their Catapult project, in which researchers developed the CNN FPGA (field programmable gate arrays) accelerator to advance their back end servers. Using this propagation structure, Microsoft's team improved the throughput of the data center by allowing it to be more dynamically configurable even at run-time, which dynamically improved the scalability of the data center on both performance and energy savings. This architecture also minimizes off-chip traffic by leveraging chip memories, i.e. it reduces energy consumption as well as heat dissipation during data transfer between different processing units. The system is designed with spatially distributed arrays of processing elements (PEs) that can be easily scaled up to thousands of units. With this improved throughput system, a Catapult Server can process 2318 images/s in CIFAR-10 dataset using 25 Watt of max power.

Earlier this year, at their Open Compute Project, Facebook announced Yosemite [42].Yosemite is a system on chip (SoC) compute server, which is superior to traditional data center servers in terms of performance-per-watt. This Open Compute server supports heavily parallelizable workloads. Most SoCs consume around 30 W and Yosemite has a 65 W thermal design power (TDP) but can operate up to 95 W. The throughput of the SoC from an energy perspective is very efficient comparing to traditional servers. Worthwhile noticing, the Open Compute server design is open source. However, the current version of SoC design as servers could only offer a subset of many features from a traditional server. Yosemite is just one example of IT working in conjunction with hardware engineers towards a more energy-efficient world. As a general rule of thumb, IT corporations are increasingly working with the integrated circuit (IC) design industry to optimize the design for their unique situation and utilizations. Chip engineers are asked deviate from the traditional route of prioritizing performance above all else, and to design with an eye for energy efficiency as well.

Colocation, a form of data center that hosts servers from multiple organizations and individuals, is gaining popularity for a few reasons. Relatively small businesses cannot afford to run their own servers with dedicated capital and human resources. Colocation data centers are less transparent to the users regarding their power usage efficiency (PUE), the ratio of total facility energy over IT equipment energy. Total facility energy is measured inclusively of the energy dissipated by the building as a whole, but mainly consumed by power delivery systems, cooling and ventilation units, and the IT equipment. IT equipment energy describes the energy used by the computation processes, data storage and network equipment. While colocation service providers usually do not oversee energy efficiency of IT operation from customers, they do assist their customers with infrastructure energy efficient practices. In addition, the providers can promote practices to improve IT energy efficiency, such as incentivize customers to free up resources when they are not needed, to further reduce the energy demand of their servers, or providing virtual systems. A newer colocation facility can aim for PUE of 1.1 to 1.4, but older facilities will not be able to achieve this level of efficiency. Same as any server rooms, colocation energy budget consists primarily of two parts: cooling and power distributions to the servers. Colocations can take similar steps as normal data centers when it comes to the cooling strategies, utilizing as much as natural ventilation as possible to reduce the demand for additional cooling.

Advanced server energy monitoring/management tools attack the problem from a system wide approach. Often these energy monitor/management tools create profiles of usage for a server/ server rack/ site. The profile may include information of usage patterns, power consumption patterns, artificial intelligence, and other features; the profile can then be analyzed by the management tools to check for time-dependent variables or others for an optimal use of energy or optimal performance. Scholars like Vijayaraghavan and Dornfeld argued good monitoring system must have the following features [43]:

- Be capable of concurrent monitoring of energy use and technical process parameters.
- Adhere to data standards.
- Features a scalable architecture to handle future increases in data volume.
- Feature modular architecture to support analysis across different manufacturing scales.

There are also rule based energy statistical methods for analyzing energy profiles. Another scholar Seem [44] described such a system that aggregates daily statistical patterns based upon monitored parameters, such as average power, peak power, and etc. With these parameters, any drift in system energy parameters can be easily noticed, and preset actions can be carried out to resolve the system drift. This architecture is more beneficial for server sites, when additional sub-metering devices are deployed. The sub-metering devices allow the system to have sub-profiles, instead of having an overall management for different zones in the server farm.

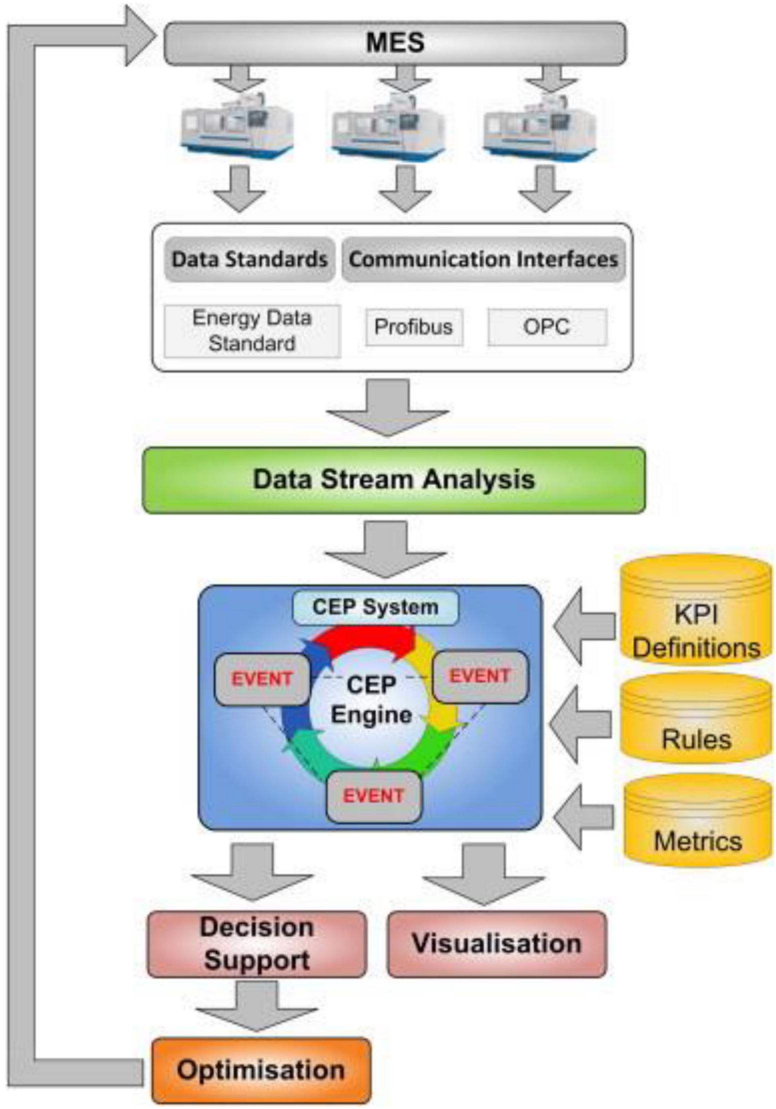


Figure 3-2 Proposed energy management framework by Vikhorev et. al. [45]

This proposed framework, as shown in Figure 3-2, advances industrial energy management by continuously obtaining energy-related information from any location of interest, combining it with corporate-wide information to optimize efficiency. The framework is intended to support different communication protocols. The system also has features that are beyond the state-of-art practice to help management to monitor and identify machine failures from energy analysis. Instead of using raw data, the series of data is collected to identify events for problem diagnosis. An event-driven software tool based on predefined logical rules is applied here to suggest an action. The system also calculates the real-time energy performance, which is in turn integrated for real-time visualization and presented to the IT managers for further decisions. The server management system's primary advantage is the elimination of identification of server site activities from the power signature. Instead, a server site can directly acquire the actual computing activities and idling time. This allows a dynamic power scaling for all servers if idling is identified as one of the events. This group also evaluated the complex event processing (CEP) in a manner comparable to the analysis of stock trades. In order to avoid a time gap between event identification and suggested actions, they also recommended distributed CEP computation to sub-section management levels as well, where one server is tasked with monitoring and reporting on the entire rack of servers.

3.3 Emerging ARM Processor Appearance in Data Centers

While Intel currently dominates the server chipset market (over 95% market share in server chipset) with its high precision and fast computation processors, its current position primarily meets the higher end of the computation demands. Today, the Intel x86 architecture is being greatly challenged by the ARM processors, with enhanced cost effectiveness and low power requirements.

Many development and evaluation efforts with ARM architecture servers are simultaneously underway. Much has been reported on the development side but little was disclosed on the field evaluation side. Morgan Stanley has been testing ARM servers in its data centers in an effort to reduce its reliance on the dominant vendor: Bert Shen, Morgan Stanley's Vice President of Technology Business Development, reported a "5x performance improvement per rack compared to an Intel Haswell EP solution" at ARM TechCon. PayPal also has adopted ARM servers and is satisfied with its performance [46].

3.4 Virtual Machine Management

A recent trend for mobile devices is to use cloud services by initiating a virtual machine (VM), which has enabled more possibilities and convenience of archiving, retrieving, and exchanging various types of data. However, mobile devices join and leave the cloud services more frequently than traditional devices. During no operation or stalling, the VM should free up memory spaces as well as any interactions with hardware devices to transition into a low-power state. However, the low-power state creates a delay during the next visit of the VM from the user. The research group from Korea introduced the prediction-based energy policy to address this challenge [47]. They were able to show approximately a 20% savings in energy.

3.5 Data Center Power and Cooling Technologies

In a typical data center with moderately efficient cooling system, IT equipment loads can account for over half of the entire facility's energy use. In addition to improving IT equipment energy efficiency, cooling system may present energy saving opportunities [48]. Data centers' power and cooling systems demand extremely large capital investments and are designed to last for a decade or more in a relatively unchanged state. To make the data centers more efficient and effective, the cooling and power technologies must be improved and renovated to some degree [49].

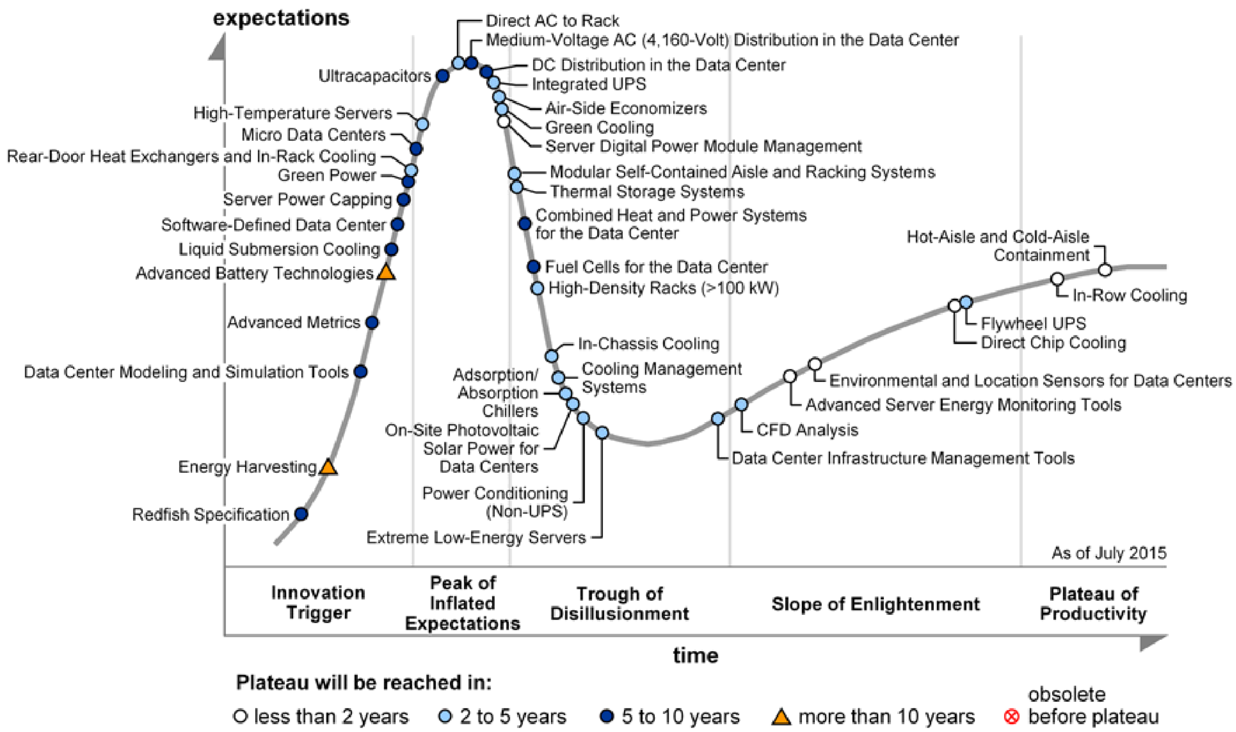


Figure 3-3 Hype Cycle for Data Center Power and Cooling Technologies, 2015, Gartner [49]

Of the 39 technologies listed in Figure 3-3, Gartner's analysis indicated that 45% can at least moderately improve energy efficiency. Additionally, various technologies expected to come of age over the next five to ten years are already in the pipeline, positioning themselves to replace today's most effective energy practices. These technologies are assessed with data center infrastructure management (DCIM) tools with strong predictive analytics capabilities for better power and cooling management effectiveness.

Table 3-1 Priority Matrix for Data Center Power and Cooling Technologies, 2015

benefit	years to mainstream adoption: less than 2 years	2 to 5 years	5 to 10 years	more than 10 years
transformational		Data Center Infrastructure Management Tools	Micro Data Centers	
high	Advanced Server Energy Monitoring Tools Environmental and Location Sensors for Data Centers Hot-Aisle and Cold-Aisle Containment In-Row Cooling	Air-Side Economizers CFD Analysis Cooling Management Systems High-Density Racks (>100 kW) High-Temperature Servers Modular Self-Contained Aisle and Racking Systems Rear-Door Heat Exchangers and In-Rack Cooling	Data Center Modeling and Simulation Tools Medium-Voltage AC (4,160-Volt) Distribution in the Data Center Software-Defined Data Center	Advanced Battery Technologies Energy Harvesting
moderate	Server Digital Power Module Management	Adsorption/Absorption Chillers Extreme Low-Energy Servers Flywheel UPS Green Cooling In-Chassis Cooling On-Site Photovoltaic Solar Power for Data Centers Power Conditioning (Non-UPS) Thermal Storage Systems	Advanced Metrics Combined Heat and Power Systems for the Data Center Fuel Cells for the Data Center Liquid Submersion Cooling Redfish Specification Server Power Capping Ultracapacitors	
low	Direct Chip Cooling	Direct AC to Rack Integrated UPS	DC Distribution in the Data Center Green Power	

As of July 2015

Table 3-1 suggests that hot-aisle and cold-aisle containment, a method for preventing the partial short-circuit of hot and cold air in a server farm, is promising energy-conservation tactic. In this technique, servers must be mounted face-to-face and back-to-back, as air distribution determines the hot-aisle and cold-aisle. The aligned outlets, therefore, will push hot air to the cold-aisle and the return inlets are facing the hot aisle. The separation of hot-aisles and cold-aisles will also increase the cooling efficiency. In addition, temperature differences of the supplied cold air and return air will also increase the cooling efficiency. The system implementation is illustrated in Figure 3-4.

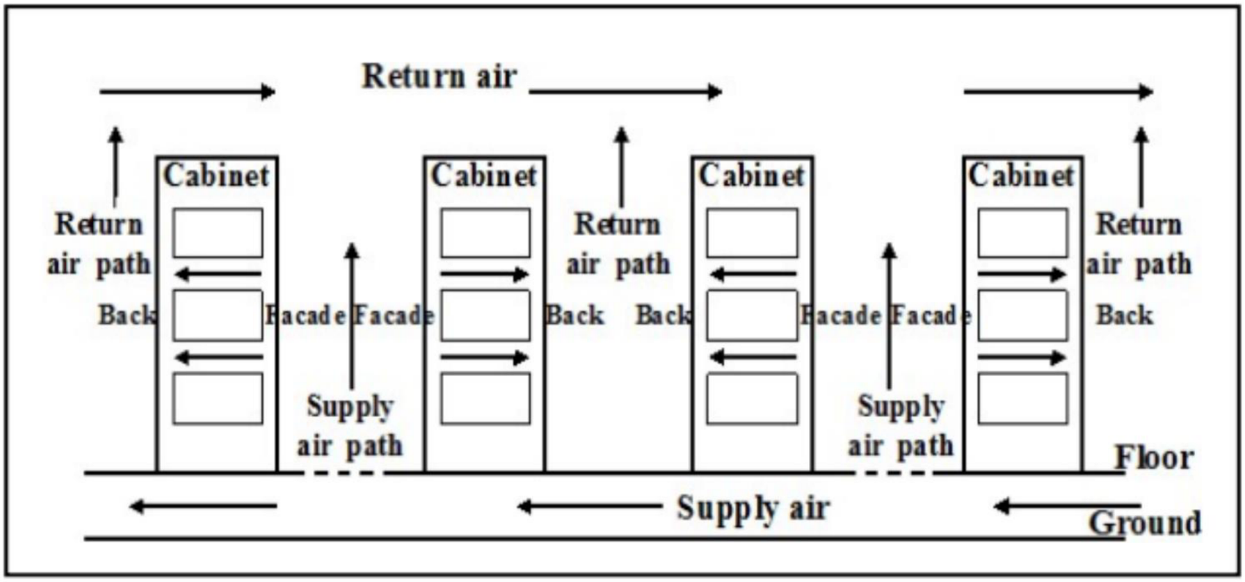


Figure 3-4 The distribution of cold and hot aisle in a typical data center

This setup does not prevent air mixing over the top of the racks. To better isolate the hot and cold aisle, the following setup is proposed, shown in Figure 3-5:

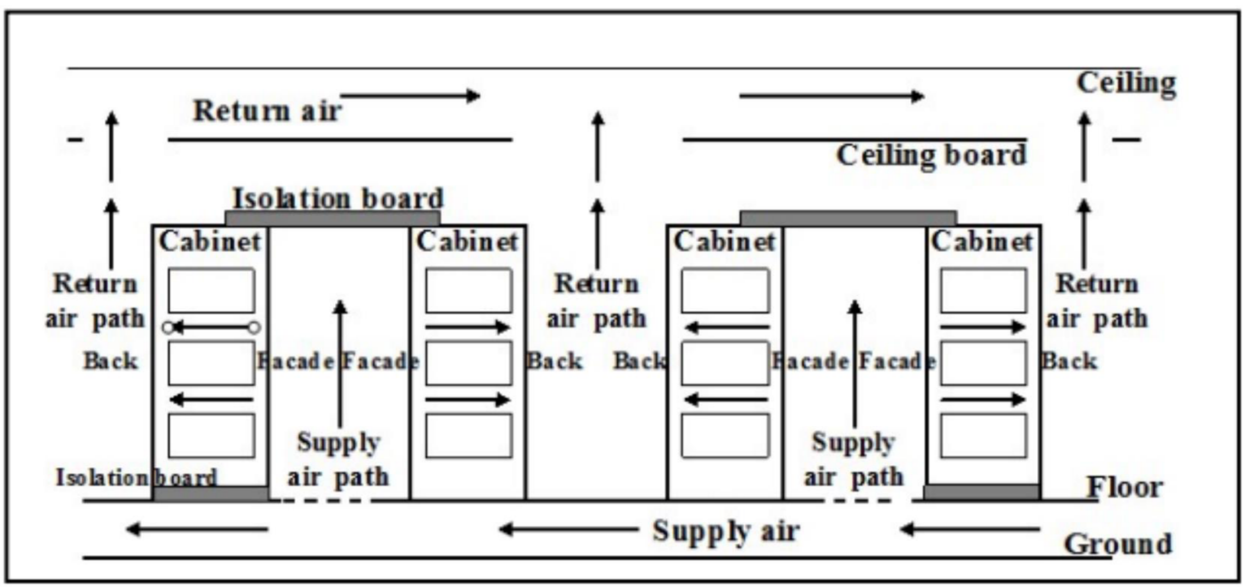


Figure 3-5 Cold aisle containment with isolation

This setup traps the cold air in the aisle without mixing with the hot return air on top. It also prevents awful air-mixing phenomenon, where the temperature of the entire space is controlled resulting “an ideal cooling environment for devices”. This small adjustment will significantly improve the cooling efficiency [50].

When a new data center is designed and a row cooling method is considered as a primary cooling method, there are significant benefits of going purely row cooling instead of hybrid cooling [51]. For an ideal setup, most of the servers are mounted on the racks and limit the need of non-racked equipment. Row cooling can also be set up to provide cold air to the non-racked equipment. The non-racked equipment is expected to work at a higher temperature decoupled from racked equipment.

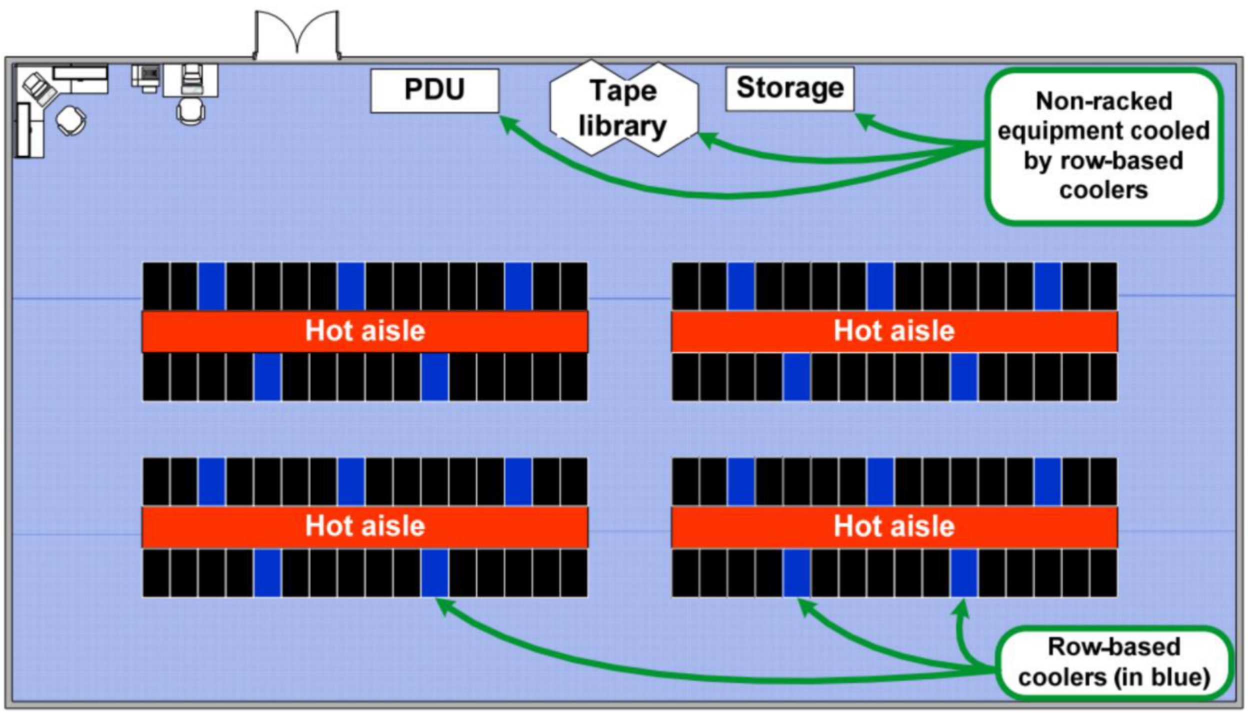


Figure 3-6 Sample data center layout with row cooling and ancillary IT equipment [51]

As Figure 3-6 illustrated how the row-based coolers are inserted between server racks. Instead of relying on traditional ground cooling, row-based cooling can efficiently reduce the temperature of the devices on the rack, and only the devices while maintaining hot aisles.

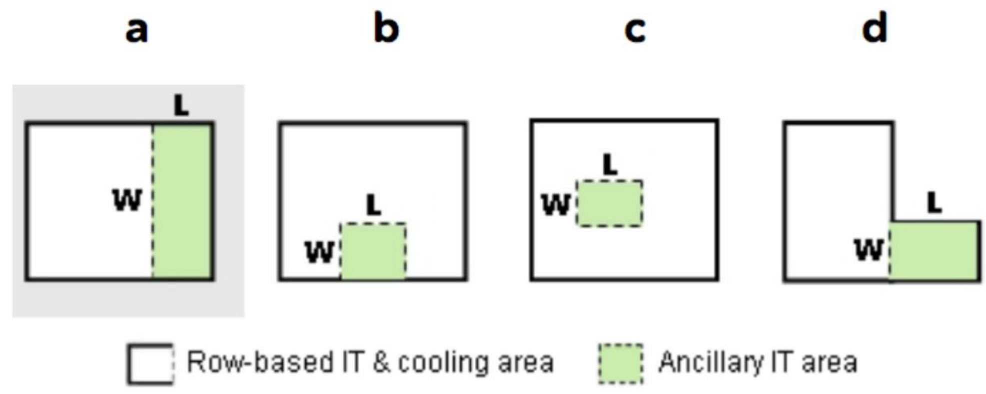


Figure 3-7 Placements of ancillary equipment in the data center [51]

However, the non-racked (ancillary) devices placements can also affect the cooling effectiveness of the in-row cooling. An 'L' shape placement, as shown in Figure 3-7, is the most promising cooling effectiveness among other placements. When non-racked devices are present in the longer tail of the 'L' shaped server room, they appear to have the least thermal coupling effect on other racked servers in the room, as illustrated as the D configuration in the figure above. At the same time, width and length ratio has great impact on the row cooling effectiveness. As the width-and-length ratio increases, the thermal coupling effect increases as greater air contact area for heat exchange. Strategically placing the ancillary devices in the green shaded region with a designated row cooler will avoid any compromise of the overall network devices cooling strategies.

Furthermore, row cooling can reduce cooler redundancy to achieve better energy saving for perimeter units.

3.6 Micro Data Center (mDC)

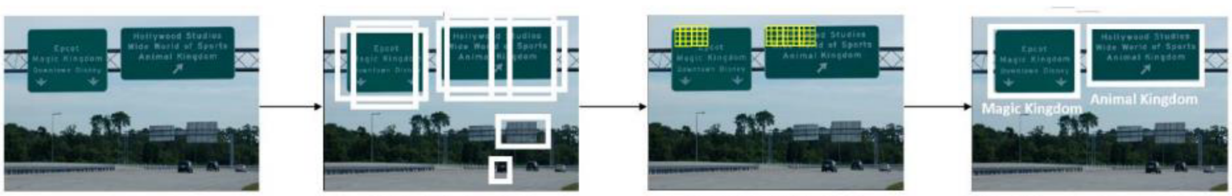
Large-scale data centers are a proven technology that will continue to serve as the backbone of many emerging technologies. However, construction of large-scale data centers is often constrained by many factors. For example, builders must consider the center's location relative to the renewable energy sources needed for its operation [40]. Additionally, for cases in which users wish to transfer large volumes of data over short times, the center's location relative to users becomes important. These and other considerations can limit the practicality of a traditional data center; however, going forward, micro data centers (mDCs) may be a practical solution to some of these concerns [52]. mDCs:

- Enable the rapid deployment of a fully functional cost, space, and energy – efficient data center, including in new market locations

- Feature affordable, scalable infrastructure that allows data center operators to automatically micromanage power consumption, cooling delivery and temperature set points
- Accelerate technology transfer of enterprise computing to the small- to medium-business market place
- Can be scaled to meet changing business needs with "pay-as-you-go" infrastructure
- Can deliver highly granular, vendor-specific, and optimized server, network, storage, and telecommunications environments
- Typically enable 50% savings in operating costs compared to traditional data center design and build
- Require a smaller, higher density 300-800 W/ft2 footprint vs. legacy 150-200 W/ft2 data center

A recent Microsoft study [53] demonstrates some of the potential benefits of mDCs:

recognition: server versus mobile



road sign recognition[1]

stage	Mobile (Samsung Galaxy Nexus)	server (i7, 3.6GHz, 4-core)	Spedup (server:mobile)
detection	2353 +/- 242.4 ms	110 +/- 32.1 ms	~15-16X
feature extraction	1327.7 +/- 102.4 ms	69 +/- 15.2 ms	~18X
recognition[2]	162.1 +/- 73.2 ms	11 +/- 1.6 ms	~14X
Energy used	11.32 Joules	0.54 Joules	~21X

[1]convolution neural networks
[2]classifying 1000 objects with 4096 features using a linear SVM

Microsoft

Figure 3-8 Delay and Power Consumption Comparison between Mobile and Server End [53]

The Microsoft study illustrates some of the benefits of servers for reducing delays in computation-intense activities such as image detection and recognition. As shown in Figure 3-8, although the computation power of a mobile device can currently run a support vector machine (SVM, machine learning algorithm) and perform essential recognitions, it is not necessarily the optimal method for doing so with a confined battery size; indeed, more complex image recognition algorithms are expected to demand ever more computation power from a processor, and may soon completely outgrow this methodology. Additionally, from a Big Data perspective, if the recognition is based on machine learning, a lone mobile device may not be able to classify images using the accumulated knowledge or a prior well-trained model.

The use of servers and cloud computing rectifies these drawbacks; however, despite the rise of 4G-LTE, latency remains a concern, and a primary obstacle to user retention of cloud-based technologies. Indeed, the transmission delay may very well become the largest delay in the entire transaction, bringing with it a corresponding increase in the cost of data transmission management.

A more distributed and localized server system may bring benefits to both the cloud service providers and the user end. More and more mDCs will be created in the next few years to address similar issues like delay in data traffic [54] and forming a $6.3 billion market by 2020 [55]. The mDCs will also expand the network coverage area, in which a network of servers can transfer the data and computation jobs to neighboring servers. Also, the current network system does not have network package control and routing control when a packet is sent from a mobile device to the backend, tasks Microsoft claims mDCs can perform. Microsoft Research also claims that hyper-scale data centers are not sufficient to meet the user demands all over the globe. Instead, an extensive infrastructure of mDCs (1-10s of servers with several TBs of storage, $20k-$200K/mDC) will bring the cloud closer to the users while remaining affordable.

To enhance the battery saving on mobile devices, the mDCs can reduce the LTE active time by one second. For a 20-network-transfer-per-hour scenario (notifications, email, etc.), total energy saving can be optimized to 6624J per 24-hour time period [53].

Codes and Standards Opportunities	Recommendation for Future Study
	Micro Data Centers
	Colocation data service

Task 4 What Information of Plug Load Devices Do Consumers Need and Want and How Should It Be Delivered?

Rapid advancement in capability and variety of many consumer plug load devices along with a cultural hype of owning the latest and greatest lead to rapid device turnover [56] [57] [58]. In addition to device turnover, the total number of consumer devices is continuing to rise [59] [60], especially on mobile devices. There are two major factors to consider for changing human behavior to affect the energy use: 1) efficiency (the one shot purchasing of an energy efficient device) and 2) curtailment (repetitive behavior to reduce energy use) [61]. For manufacturers, curtailment can be difficult to address as it is reliant upon individual behavior. Many studies have shown that a message for energy savings or environmentalism for an individual must be actionable, clear, and direct [62] [63]. Yet in a societal context, the diffusion of "green" beliefs as the societal norm is the ultimate goal [64] [65] of reaching behavioral change. Routine energy consumption may be controlled in large part by cultural and societal norms and economic factors [66]. Message reinforcement and feedback may aid decision making processes of considering 'green' and economic factors for individuals [62].

4.1 Knowledge to behavioral change

Federal Trade Commission (FTC) mandated labels such as the "Lighting Facts" have been used with success for informing consumers of product energy requirements for many forms of consumer purchased lighting [67]. This sign provides typical energy use information and data about the color and light output for the labeled bulb. These product labels use a standard format of information presentation that is similar to popular Food and Drug Administration (FDA) "Nutritional Facts" labels on food and drink [68] and the "Drug Facts" labels on over the counter medication sold in the USA [69]. The use of the "Nutrition Facts" was mandated per the 1990 Nutrition and Labeling Education Act [70]. Use of this label has improved customer decisions and has shown it highlighted customer attention to the negative aspects of nutrition (such as fat or sodium) [70]. Successful adoption of the "Nutrition Facts" label lead to the development of the similar "Drug Facts" label in 1999. The continued use of the "Nutrition Facts" label in a new form highlights the success of using a simple tabular infographic for conveying customer information [71].

Similar summary labeling approaches with recognizable, synergistic, and familiar formatting can be used on other plug-load devices in addition to lighting. Currently the FTC EnergyGuide labels are present on many appliances, we suggest this approach be used to augment, not replace, the EnergyGuide labels presently used on many large appliances. We also suggest that this label be made present ubiquitously across numerous consumer plug load devices sold and not primarily reserved for larger appliances as the FTC EnergyGuide label typically is [72].

Infographic food labeling has been shown to disproportionately influence “highly motivated” and “less-knowledgeable” individuals [70]. Continuation of this logic can provide these types of consumers with additional information for energy use information. The inclusion of a mobile phone scannable QR-code or a packaging UPC code can be linked via an application to a database where additional information is presented for typical energy use and options for energy efficiency. The development of a mobile energy tracking application can provide more meaningful information based on sensed and analyzed user behavior, and present how the scanned device would contribute to a user’s energy footprint. Mobile applications can also provide information about the energy usage of his/her post purchase of devices.

AR products have used image recognition for identification and logging. Image recognition products such as “Google Goggles” have demonstrated the ability to extract information from images of devices and device labels and interpret this information to provide identification of imaged objects. Applying AR, it is possible to produce a solution that can be used to image products and labels and use this information to produce energy footprint information. Integration with a “Smart Home” IoT system and a ‘smart meter’ for real-time pricing can provide more granular information as to plug load usage to refine footprint estimation. The gathered knowledge can be used by an informed customer to make greener choices when replacing or adding devices in the home.

One key feature to enable this technology in a mobile platform is accurate location services. Location along is one of the most valuable pieces of information for enabling many customer engagement opportunities. To better inform consumers about energy related information, engaging consumers will be a very critical future requirement, allowing marketing teams and customer engagement strategists to tailor the information to the customer based on the interface (phone call, browser and app) and the location information. With the current technology, developers can develop apps using sensors on the phone. Apps can detect 0.25-meter zones in accuracy as an op-in feature for customers [73]. GPS and Wi-Fi helps to isolate the location to an accuracy of 1 meter. With Bluetooth LE and NFC technology, the 0.25-meter resolution is very achievable at a low cost.

Location technology combined with previously described mobile applications can allow correlation of smart meter or IoT measured energy usage data with behavior to help improve energy use patterns. Expansion of the role of mobile solutions can additionally provide more meaningful information for wasteful behavior patterns for IoT connected devices and assist users with devices that may be accidentally left on.

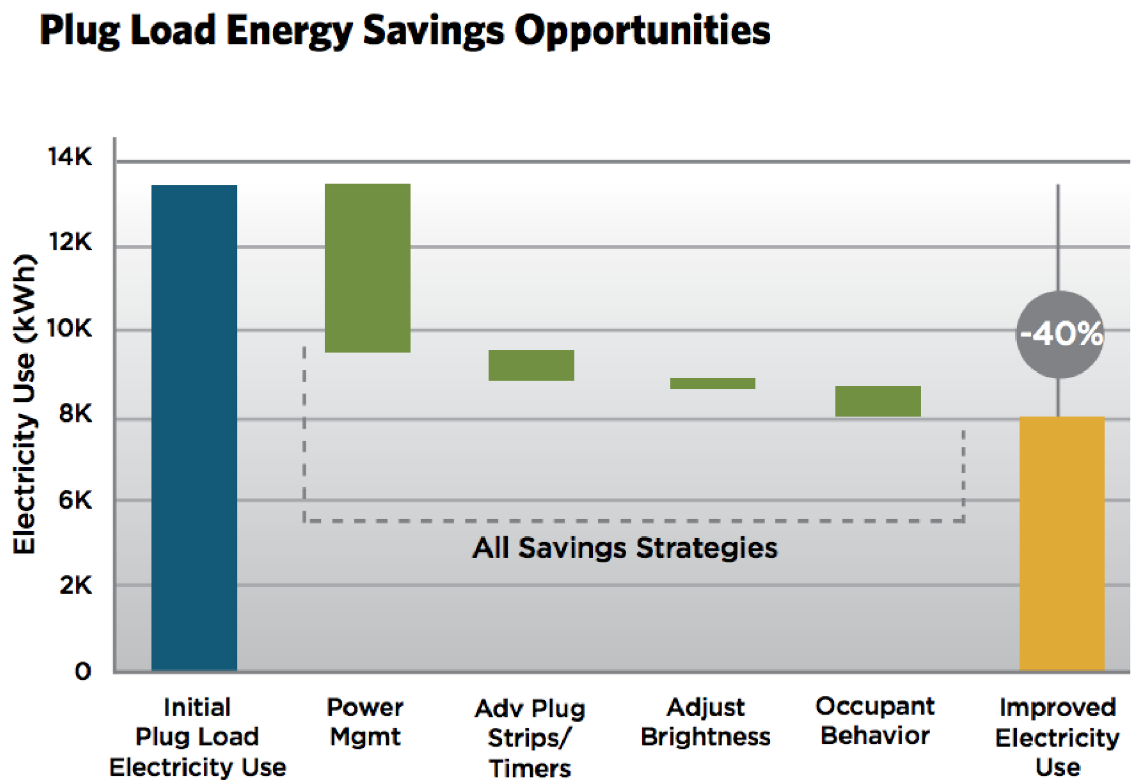


Figure 4-1 Different power energy saving strategies and potentials. In a small office in California, low- and no-cost energy-saving measures reduced plug load energy use by 40%.

New Buildings Institute (NBI) has examined various methods for energy saving potentials and identified that the power management shows the greatest potential, as shown in Figure 4-1. The figure illustrated methods of reducing plug load electric energy use without improving the device efficiency itself. The combination of power management, advanced plug strips/ timers, brightness adjustments and occupant behaviors can achieve 40% of energy saving. Among the methods listed above, occupant behavior change does not require any infrastructure upgrades or retrofitting [74]. Energy saving may be achieved by removing unnecessary loads, replacing old electronics with better and more efficient devices, reducing energy wasted by enabling power management settings for plug load devices.

A major contributing factor to the acceptance of "green" approaches is broader social acceptance, which takes time. Something as conventional today as recycling was a fringe activity practiced by a motivated few 30 years ago [75]. Reduction to barriers to entry (e.g., ease of participating) and informing the personal and societal benefits to potential participants work hand in hand in promoting and creating similar movements.

Barriers to entry are typically outside the consumer's choice. If energy saving appliances are not readily available to a customer, only very motivated and informed customers will seek such devices out via unconventional means. Similarly, if the price point for the energy saving alternative is too high, this external factor can increase the barriers to entry via this same mechanism. Incentives and external mandates can provide the customer with reduced barriers to entry, and in more extreme cases, mandated phase-outs of energy inefficient technologies such as incandescent light bulbs [76] could reduce the barriers as well.

Incentives are designed to reward energy awareness in purchasing decisions. There are upstream and downstream rebates respectively incentivize manufacturers and consumers. Often, positioning a device in a retail location can influences the purchasing decisions of individual consumers more effectively compared to upstream and downstream programs [77]. Focused and targeted a midstream incentive [78] will also help to get the devices to consumers faster and easier. Retailers are the direct interface between manufacturers and consumers. The effort in labeling energy efficient products and making them accessible can significantly increase the sale of energy efficient devices. In this case, the retailers can even use their sales techniques for energy efficient products in addition to the existing midstream incentive programs. It is worthwhile mentioning that SCE currently has already had midstream incentive programs in place with many retailers [79]. The current system of upstream and midstream rebates is the most efficient and effective method for widely installing most forms of energy efficient equipment into the building stock.

Various levels of information in the purchasing population are critical for wide adoption of energy saving devices as well. A national survey based study [80], found that 80 percent of the consumers are broadly aware of energy efficiency and its benefits. Over 80 percent of the consumers are also aware of energy-efficient appliances options and in home retrofitting options. Energy efficiency was stated as the second greatest product characteristic after price for making the purchasing decisions. But, this finding is contradicted in reality. Consumers are not well informed enough of the impacts and beneficial gains of energy efficient choices. In fact, according to a McKinsey study [81], and shown in Figure 4-2, some consumers even tend to overestimate the energy efficiency of their devices. The study noted that many consumers simply lacked the extra push of incentives and awareness to drive them to alter their consumer patterns and behavior. Small changes that have little to no impact on the consumer's lifestyle can lead to energy savings as high as 20%. The McKinsey study suggested that marketers must utilize more emotional motivation and attitudinal drivers to encourage energy efficient behavior in additions to the use of rebates and incentives. With proper product labeling of the beneficial impacts that certain purchase decisions would bring, consumers should be self-motivated to make certain purchase decisions more easily knowing the benefits to their own lifestyle (i.e., costs) and the environment (i.e., lowering carbon footprint). Encouraging energy efficiency is not one way street for only marketers to work and to strive for; it takes an active role of consumers to want to be energy efficient as well through better awareness. However, bridging the gap between energy efficient awareness and actual consumer purchasing actions still remains a challenge. The McKinsey study showed with the presence of an elementary-school child in a household, there is a 10 to 20 percent increase in interest in home energy improvement. Women are more likely (6 to 10 percent) than men to engage in energy saving behaviors. This study also suggested combining attitude, behavioral and demographic indicators while designing incentives as well as communicating to the consumers to optimize the sales of energy efficient products. It was concluded that emotional appealing messages have a greater resonance to majority of consumers. It was stated, "Messaging that highlights the home-improvement potential of an energy-efficiency initiative or product is likely to have greater resonance and appeal for the home-focused selective-energy-savers segment than simply stating its cost-saving potential."

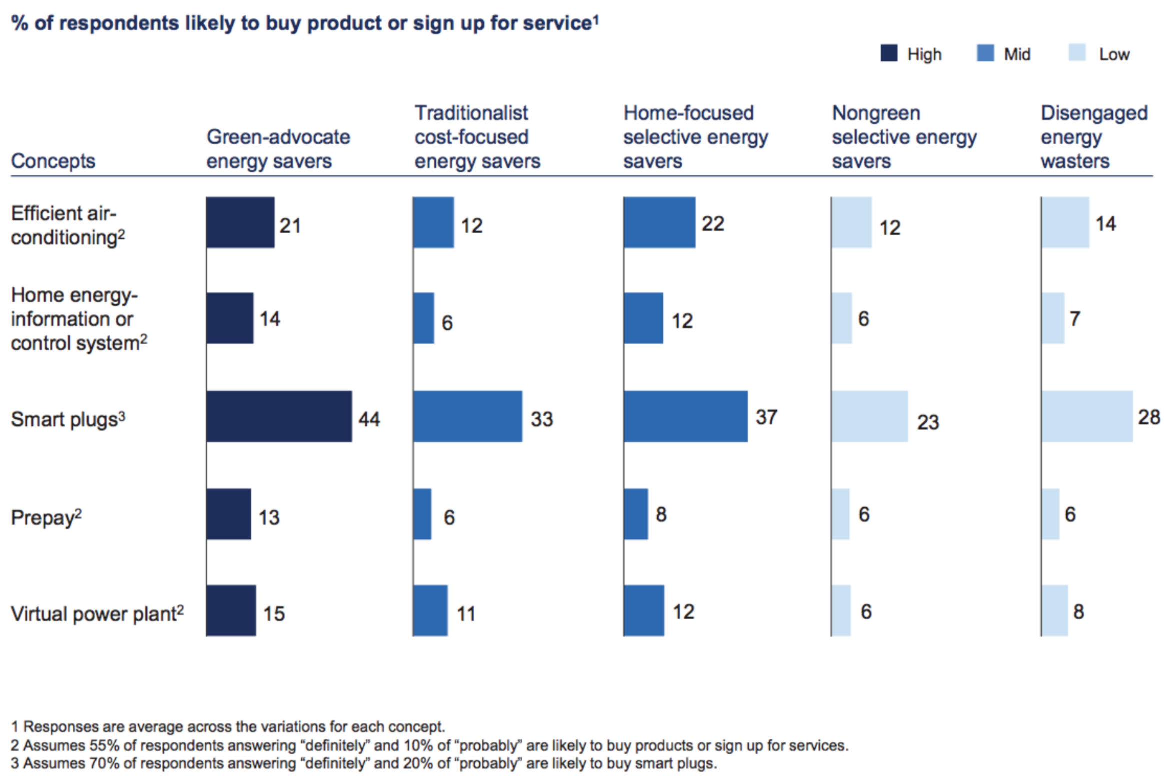


Figure 4-2 Segments vary in their response to concepts, McKinsey report 2013 [80]

Energy efficiency continues to remains as one of the biggest challenges that government face in encouraging consumers to practice energy efficient habits and make smart consumer purchases. Although consumers in the United States are familiar with some of the basic practices and benefits, their perceptions on energy efficiency is commonly misinformed. As shown in a business school study [82], consumers are commonly overloaded when making purchase decisions. The study revealed that many brands lead consumers on confusing purchasing paths on whether the product is energy efficient or not. The study suggests that in order to resolve this issue, the number of information paths for consumers need to be minimized. From this study, it can be concluded that brands need to better communicate and market their energy saving products with more direct messages. Better labeling may be part of the solution.

Consumers are better tailored to make smart purchase decisions if they are more informed about as to how the purchase decision will directly impact their lifestyles positively or negatively. With this said, both marketers and consumers need to work together to understand the fine line between the wants and needs of customers when making purchase decisions. Some suggested tactics that are already being implemented are energy labeling on the product. Additionally, consumers should be informed about the amount of energy that goes into manufacturing the product (i.e., carbon footprint) and how it impacts the environment in overall as well. The labeling that goes on a product should give more than an idea of how it would benefit the consumer if they purchased the product, but it could include the “price” it took deliver the product prior to purchase. As noted earlier, consumers require a detailed exchange of the costs and benefits of the product before making their decision.

4.2 Digital customer engagement

More and more digital appliances have entered our lives. Especially for those who invest in energy technologies, such as photovoltaic (PV) panels, electrical vehicles and etc., the need for the digital customer engagement increases. However, the utility industry in general, lags behind other industries in customer engagement, especially in digital channels, such as mobile and social. Utility customers are expecting this change, as they are migrating from phone calls to online tools and mobile apps for paying bills, solving problems and getting answers. Utilities should satisfy core customer service requirements across multiple digital channels that also bring more energy savings. For example, smart meters with appropriate information feedback, selected by individual customers, can bring 5 to 20 percent reduction in energy usage [62].

Ratepayers are no longer simply passive. Ratepayers also produce energy and this new shift makes them to be the new producers/consumers (pro-sumers). As the consumers are becoming prosumers, their need for digitized information about their energy consumption and production increases [83].

Codes and Standards Opportunities	Recommendation for Future Study
	Behavioral study leading to consumer education for holistic energy saving behavioral change
	Exploration of future marketing for energy efficient appliances

Task 5 Plug-in energy baseline review for residential building energy simulation tools

California Investor Owned Utilities (CA IOUs) submitted a codes-and-standards-enhancement (CASE) report in support of California Energy Commission's (CEC's) effort on adding the rulesets (or methodology) for modeling the annual energy usage by miscellaneous electric loads (MELs) [84]. Historically, California Building Energy Efficiency Standards (Title 24) has not included code requirements that aim to reduce energy use by MELs; the only exception to this is lighting loads. Traditionally, Title 24 captured internal heat gains from MELs, not necessary for estimating household energy use by MELs. The focus has been changed when California introduced a visionary and strategic goal of reaching zero-net-energy (ZNE) homes by 2020. In order to evaluate a new home, whether it meets the ZNE or not, there is a need for estimating and allocating MELs' annual energy consumptions per home size. When all energy needs are properly identified, after implementing energy efficiency requirements per Title 24, builders can properly size on-site renewable generation to achieve ZNE.

The CASE report outlines new rulesets for estimating annual energy consumptions for the following loads: refrigerators and freezers, dishwashers, clothes washers and dryers, cooktops and ovens, televisions, set-top boxes, computers, notebooks and monitors, lighting, and other MELS.

CalPlug team has peer-reviewed and commented the report. The overall methodology as documented on the CASE report appears to be reasonable and accurate. However, there were areas where CA IOUs could make improvements. CalPlug, therefore, has provided inputs to consider the boundary conditions for each type of annual energy consumption calculation. Currently, the report is under the review by the CEC.

Additional Considerations

1.1 Legal Marijuana Production and Energy

New changes in the political and social landscapes for several US states have brought about new markets with new energy demands. The partial legalization of marijuana (also known as cannabis) and its growing market may have a significant impact on energy usage. Legalized marijuana farming is the fastest growing industry in the USA [85], with upwards of 69,000 tons of cannabis are produced annually for medicinal and recreational use [86]. Fueling this is a $3.5 billion USA cannabis market that continues to grow without any form of energy efficiency regulation or oversight [87]: In fact, over $6 billion of energy was consumed in cannabis farming operations in 2012 [88], a quantity exacerbated by the fact that double quantity yields can be produced under hydroponic growing operations utilizing 24-hour lighting conditions [89].. Aside from electrical power consumption, the greenhouse gas emissions from legalized marijuana cultivation in the 23 states is almost equal to those of every car, home and business in New Hampshire [87].

In conventional indoor cannabis cultivation, full spectrum high intensity lights with water and air handling are required [89]. Light quantity is the major governing factor for cannabis growth in indoor grow operations. With light quality playing a subordinate role [90] [91], sufficient light output is the key for high yields. For example, common household incandescent light bulbs have a superior spectrum for plant growth, but lack of sufficient light output and are not commonly used for growth operations [92]. LED bulbs, on the other hand, do have the capability of offering tunable light output for spectral and intensity qualities. The use of LED and high pressure sodium (HPS) lighting is a proven energy effective alternative to traditional high intensity discharge metal halide (HID) growth lighting, but at the cost of a higher initial capital investment [91]. LED lighting can generate similar light output compared to HID lighting with 1/5 of the energy input [92]. HPS lighting with double ended bulb bases can be as electrically efficient as LED lighting, yet at a 5 to 10 times lower economic cost based on current technology [91]. In addition to bulb and fixture efficiency, other factors must be taken into consideration. The heat generated by fixtures must be vented accordingly, leading to increased power requirements by HVAC systems responsible for temperature and humidity control. Also, lighting requirements are strongly determined by grow-room setup: an inefficient setup with poor lighting on plants can require more lights for a given production output [92].

Many misconceptions are present in the grow community about lighting types and the effect on yield [92]. Unfortunately, the emergence of the industry from the shadows of illegality has not heralded any inter-industry communication. Fostering dialog among lighting manufacturers and consumer electronics efficiency organizations may help bring energy efficiency conversations into the world of cannabis cultivation. Continued studies on the efficacy of high efficiency lighting and the continued reduction in LED lighting costs may help drive the industry toward more efficient growth operations. With sales of product nationally averaging approximately $300 per ounce [93], maximizing the growth quantity of cannabis is essential considering traditionally high business expenses. Continued instability in the growth and distribution of the cannabis industry challenges long term capital investment [94]. With a ‘shoot and scoot’ mindset developed from days of underground operations, energy efficiency does not factor high on the list of business concerns with this mentality [90]. High turnover of grow operations favors quick and dirty growth setups where low cost, inefficient setup and equipment are used. Maturity and legitimacy of the industry will likely cause growers to consider the positive economic impacts of long-term operational economic factors, thereby taking energy efficiency into consideration.

1.2 Electrical Vehicle Smart Charger

Consumers have expressed interest in electric vehicle options, as shown in a survey asking about their most preferred technology for 2020. Indeed, plug-in hybrids rank the highest as the most preferred choice of electrical technology since 2013 survey. The third most popular technology is fuel cell electrical vehicles, with the highest incremental of 10% from 2013. Although there are many other factors affecting the actual market adoption rate of electric vehicles (EVs) or hybrid technologies, the consumers have shown strong interests [95], and shown in Figure 6-1. The adoption rate will naturally go up once the pricing point is acceptable for consumers.

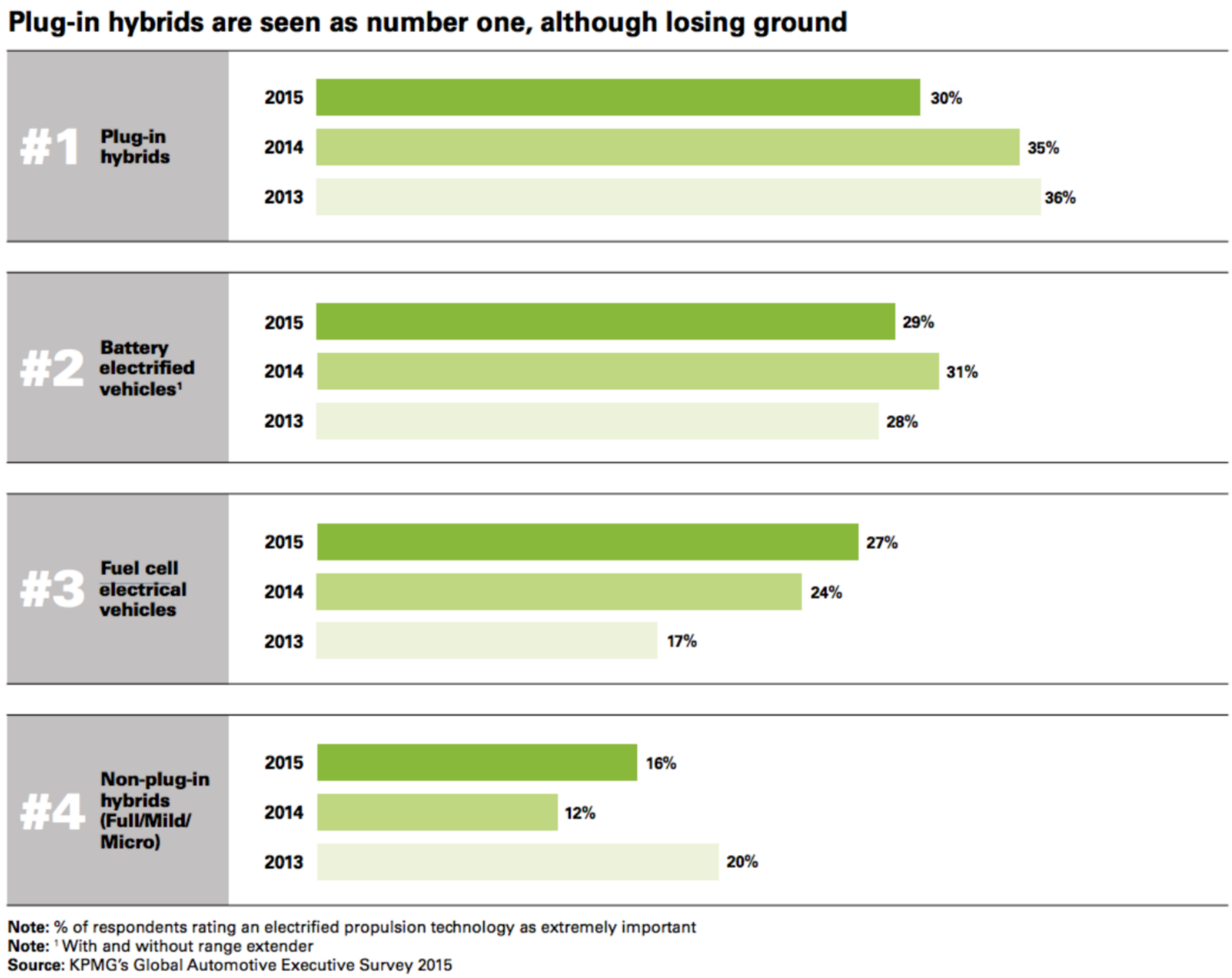


Figure 6-1 2013-2015 Survey Result of Most Popular Electric Vehicle Technology in 2020 - Ranking by Consumers [95]

Unprecedented energy demands may arise as more and more electric vehicle owners start to plug in their chargers (or supply equipment) directly to the grid. There are a few sources of energy waste:

- Battery energy conversion between chemical energy and electrical energy
- Battery charging circuits conversion inefficiency
- Battery leakage
- Battery overcharging

Research and development of new battery technology are expected to occur in the next few years as shown in Figure 6-2 below. The common home use EV supply equipment (EVSE) is standardized as level 1 and level 2 types. The actual charger for these type of connections is present within the vehicle itself, the external interface unit is designated as supply equipment in these cases. Alternatively, and external DC quick charger can supply DC directly to the onboard cells, bypassing internal AC/DC conversion.

Heavy research efforts are focused on power density and longevity of the vehicle battery cells. Currently, maintaining a healthy capacity of any battery remains the most practical method for extending the lifetime of a battery in any vehicle. Also, improving on battery leakage and overcharging both require an understanding of the real time state-of-charge in the battery. Most existing work uses regression based on a time-variant circuit model, which may be hard to converge and often does not apply to different chemistry classes of batteries [96]. On the other hand, battery state-of-health has not yet been as rigorously studied as state-of-charge. State-of-health is a critical step before having an accurate measurement/estimate of state-of-charge, instead of leading to error in state-of-charge estimation errors. The relationship between open circuit voltage (OCV) and state-of-charge has been well established and verified all along [97]. However, a comprehensive analysis of battery health and real time state of traditionally requires cell-network disassembly to take direct measurements as the OCV fluctuates at different charging state. Developing and applying advanced algorithm may help to estimate the battery charging status. Moving forward, an accurate measurement of battery charging status can help avoid overcharging and provide accurate estimates for completing the charging cycle or even prolonging the battery life.

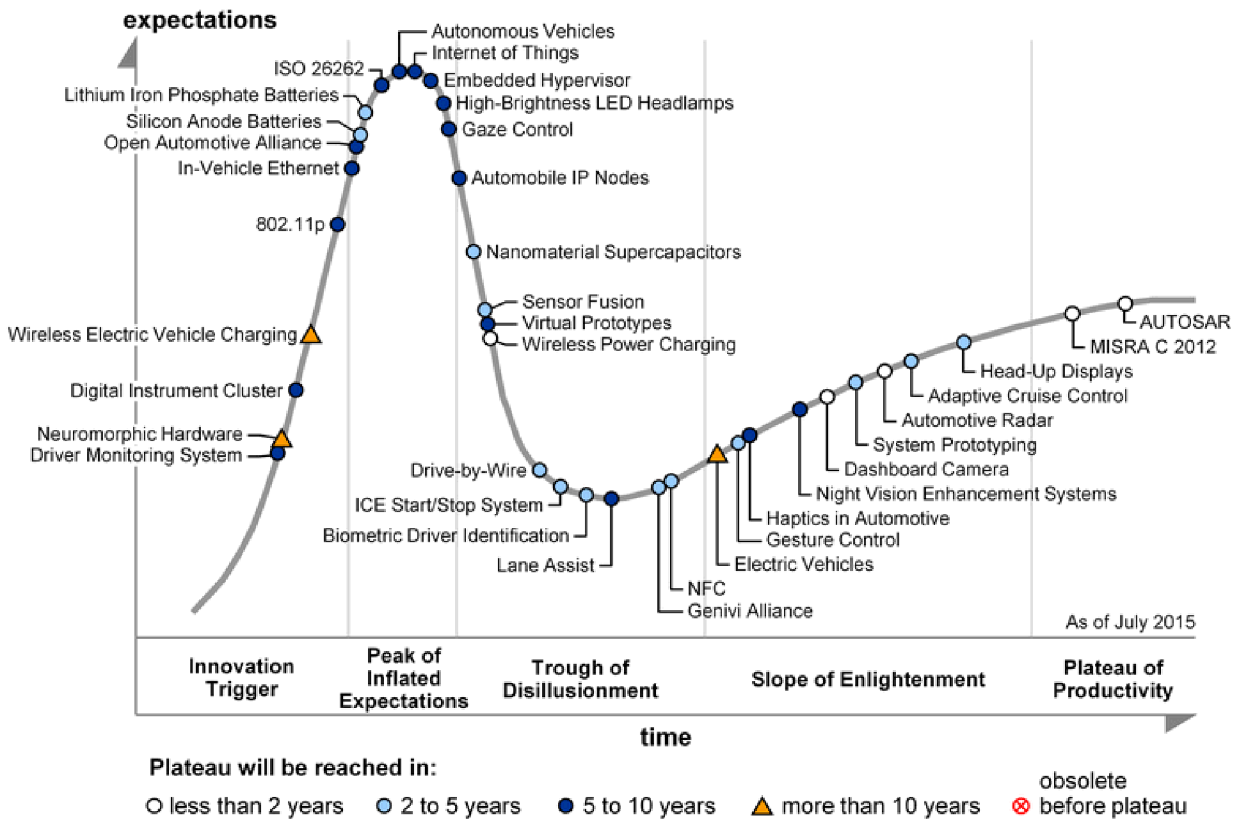


Figure 6-2 Hype Cycle for Automotive Electronics, 2015 [98]

Along with the ongoing research efforts addressing these questions, the aggregated demand for EVs is of a significance importance to the grid. With some of the smaller EVs requiring 12 kWhr for a full charge (as is the case for the 2011-2012 Chevrolet Volt), EVs can outcompete many conventional energy hogs in American households. Majority of consumers choose either level 1 or level 2 EVSE based on the car configuration or the home electrical panel setup. The Level 1 is a 120 V service, while level 2 is a split single phase (J1772 type 1) or a three-phase (62169-2 type 2) 240V service. A 240 V connection permits higher energy transfer for a given time. At 7.4 kW, a range of approximately 60 miles is possible within a three to four-hour charging time. DC charging station, however, has the quickest charging speed providing a 40-mile driving range for a 10 min of "quick" charging. The Tesla Supercharger (a DC charging solution), for example, can even provide a 170-mile of driving for a 30-minute charging [99]. Repeated deep and rapid charges or discharges, however, likely degrade the cell capacity and overall health of the battery. Furthermore, due to the high cost of DC quick chargers, the most uses will not install them on their homes. Such chargers will likely be relegated to shared-use roles in common locations.

Vermont Energy Investment Corporation has conducted a study [100] in comparison of level 1 and level 2 chargers. The assessment has included over 1000 charging cycles involving a total of 17 vehicles. The study also evaluated the influence of weather conditions. The results are presented in the tables below.

Table 6-1 Summary of Level 1 vs Level 2 charge efficiency

Charge event dataset	Average Level 2 Charge Efficiency	Average Level 1 Charge Efficiency	Efficiency gain of Level 2 charging
Total combined	86.4%	83.7%	**2.7%**
High energy only (>2 kWh charge)	86.5%	84.2%	**2.3%**
Low energy only (<2 kWh charge)	83.5%	70.7%	**12.8%**

Table 6-2 Summary of Level 1 vs. Level 2 charge efficiency with climatic variation

Charge event dataset	Average Level 2 Charge Efficiency	Average Level 1 Charge Efficiency	Efficiency gain of Level 2 charging
High energy only (>2kWh charge) between 53^0 F and 70^0 F	87.8%	85.8%	**2.1%**
High energy only (>2kWh charge) and less than 53^0F ambient temperature	87.3%	84.0%	**~3.4%**
High energy only (>2kWh) and greater than 70^0 F ambient temperature	85.3%	82.2%	**~3.2%**

The two tables above have shown that level 2 charging, the faster of the two methods, can charge a vehicle with less energy loss, whether at more extreme weather conditions or low energy draw.

This presents the opportunity for smart charger development where a charger can be equipped with sensors detecting factors that deteriorate efficiency. An ideal design should have minimized energy loss when converting AC to DC. At the same time, the future chargers should also have the intelligence to carry out more efficient algorithms for charging cycles that adapt to battery conditions. Also, future chargers should be able to perform demand response and schedule charging accordingly. EVSE units should minimize cable heat loss and have low phantom power requirements.

For example, if a charger can respond to exterior temperature or know the weather conditions ahead of time, the charger can charge the vehicle at ambient temperature, which is beneficial for both charger energy efficiency as well as the battery. This reduces the load on internal battery cooling systems (if present) during charge, saving additional energy. This can be easily integrated with the smart thermostat if they are preinstalled in the house, or even have a standalone network connection to gain the information on weather conditions during seasons where dramatic temperature drop occurs at night.

At the same time, plug-in hybrid cars have smaller batteries compared to full electric vehicles, and charging cycles for these vehicles may be completed within two to four hours if only a small portion of the charge is consumed. However, owners may still plug in the vehicles habitually upon returning home, around peak hours in the mid-late afternoon. When no intelligence is present, the charger will immediately initiates the charging cycle, although the owner may not drive it until the next morning. If a grid-connected intelligence can schedule the charge after peak hours, owners may benefit a lower energy unit pricing, while the vehicle is charged seamlessly. Strategic use of the onboard microprocessors capabilities in EVSE units or installing additional microcontroller/microprocessor can both accomplish this goal.

Although EVs are usually in their own category of plug load, the charging method, state of charge, and state of battery health still require further research as the charging cycles of these batteries alone can create larger energy demand than the household. Further research and development can further help to improve the charging efficiency as well as demand responses.

1.3 Localized Energy Generation Storage

Localized energy generation is seeing comparable increases as well. California is ahead of schedule for meeting the renewable portfolio standard (RPS) requirements: the California Energy Commission estimated that nearly 25 percent of electricity retail sales in 2014 were served by renewable energy generated from resources such as wind, solar, geothermal, biomass and small hydroelectric [101]. Senate Bill 350 signed into law October 7, 2015, increased the RPS target from 33 percent by 2020 to 50 percent by 2030 [102]. Also, General Electric announced its 30-MW battery energy storage system, by far the largest in Southern California, for providing a potent buffer against energy demand peaks as we move forward with clean energy generation and storage. GE has claimed this to be the “game changer.” At the same time, SCE also has made progress of ease peak demand, as 320,000 customers have agreed to join demand response programs [103].

The effectiveness of such localized energy storage should be further evaluated to better serve for the demand response purpose.

Codes and Standards Opportunities	Recommendation for Future Study
Legal Marijuana Plantation, Production Energy	Legal Marijuana Plantation, Production Energy
Electrical Vehicle Smart Charging	Electrical Vehicle Smart Charging
Localized Energy Generation Storage	Localized Energy Generation Storage

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