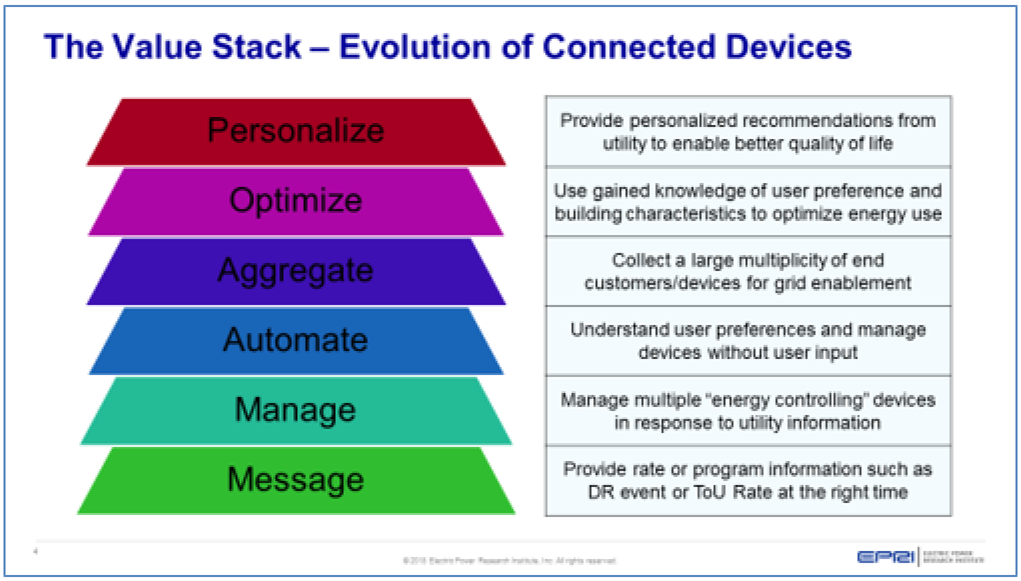
Technical and Market Characterization of the Connected Home

ET Project Number: ET17PGE7201



Project Manager: **Kari Binley**
Pacific Gas and Electric Company

Prepared By: **Ben Clarin, Ram Narayanamurthy and Penn Zhao**
Electric Power Research Institute
3420 Hillview Ave.
Palo Alto, CA 94304

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ABBREVIATIONS AND ACRONYMS

AI	Artificial Intelligence
AMI	Advanced Metering Infrastructure
API	Application Protocol Interfaces
BEMS	Battery Energy Management Systems
BGE	Baltimore Gas and Electric
BYOD	Bring Your Own Device
CAGR	Compound Annual Growth Rate
CEE	Consortium for Energy Efficiency
CIS	Customer Information Systems
ConEd	Consolidated Edison
CPP	Critical Peak Pricing
DER	Distributed Energy Resource
DIY	Do-it-Yourself
DR	Demand Response
DRMS	Demand Response Management System
DSM	Demand-Side-Management
DSO	Distribution System Operator
EE	Energy Efficiency
EPRI	Electric Power Research Institute
EVSE	Electric Vehicle Service Equipment
FD&D	Fault Detection and Diagnostics
FFVIP	Far-Field Voice Input Processing
HEMS	Home Energy Management Systems
HVAC	Heating, Ventilation and Air Conditioning

IDSM	Integrated Demand Side Management
IoT	Internet of Things
IRP	Integrated Resource Planning
ISO	Independent System Operator
kWh	Kilowatt-hour
M&V	Measurement and Verification
NILM	Non-Intrusive Load Monitoring
NRDC	National Resources Defense Council
O&M	Operation and Maintenance
PV	Photovoltaic
SDG&E	San Diego Gas and Electric
SoC	System on a Chip
ToU	Time of Use
VEIC	Vermont Energy Investment Corporation

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EXECUTIVE SUMMARY

PROJECT GOAL

This report will provide a summary on a state of the industry study of the Connected Home space, with the goal of developing a deeper understanding of the market players and determining the point of influence in the market and/or technology space that utilities need to address to obtain the value of potential "stacked" energy effects that may be available from orchestration of multiple devices in residential households.

PROJECT DESCRIPTION

The Connected Home Ecosystem encompasses a hardware and/or software platform that monitors and/or controls multiple end-use devices found within a premise or community. The Connected Home leverages technologies and platforms at the residential and small commercial level. These energy-impacting platforms automate and manage energy consumption on behalf of the end-use customer. Current studies have focused on calculating efficiency and/or demand impacts of single devices in the connected home. However, there are very few empirical studies on technology providers and the various connected home ecosystems in the industry that provide energy optimization at a premise level. The process for defining which connected home ecosystems and/or energy optimization features provide the highest overall utility value is not well understood. This project proposes a methodology to classify connected home ecosystems, define a set of customer and utility facing value propositions connected home ecosystems may enable for a utility, and evaluate the ecosystem subclasses' current ability to enable or support these requirements.

PROJECT FINDINGS/RESULTS

This report summarizes three core functions enabled by connected ecosystems: aggregation, orchestration and optimization. Details of these core functions can be found in Figure 1.

Optimization – Use of data and customer inputs to provide autonomous programming and response targeted for a specific need.	**Orchestration** – Coordinated programming and response of end-use loads with a premise.	**Aggregation -** Grouping of end-use loads, typically of the same end-use to respond to particular utility controlled signals.
Examples – Whisker Labs, Tendril	**Examples** – Amazon Alexa, Samsung SmartThings	**Examples** – EnergyHub, AutoGrid.

FIGURE 1 CORE FUNCTIONS ENABLED BY CONNECTED HOME ECOSYSTEMS

Frameworks are available to classify connected devices but there are limited frameworks available to classify connected home ecosystems. To address this need, this report proposes a classification system based on nine technology subclasses that divides the connected home ecosystem space based on technical capabilities and market characteristics. These nine technology subclasses are voice assistants, security and telecom providers, device aggregators, mass-market IoT, traditional trades, monitoring focused, DER management-focused and software-based optimization ecosystems. Table 1 details the evaluation of the nine technology subclasses identified in this report and their general ability to enable core functions associated with connected home ecosystems.

TABLE 1 EVALUATION OF TECHNOLOGY SUBCLASSES AND CORE FUNCTIONS OF CONNECTED ECOSYSTEM

TECHNOLOGY SUBCLASS	ABILITY TO AGGREGATE	ABILITY TO ORCHESTRATE	ABILITY TO OPTIMIZE
Voice Assistants	Medium/High	High	Medium
Security and Telecom Providers	Medium	Medium/High	Low/Medium
Device Aggregators	High	Medium/High	Medium/High
Mass-Market IoT	Medium	Medium	Medium
Hub-Based Mass Market Ecosystems	Medium	High	Medium
Traditional Trades	Medium/High	Medium	Medium/High
Monitoring-Focused Ecosystems	Medium/High	Low/Medium	Low/Medium
DER-Based Management Ecosystems	High	Low/Medium	Medium
Software-Based Energy Optimization Ecosystems	Medium/High	Medium/High	High

Although there are many industry claims made about enabling interoperability within connected devices, this report shows that no technology subclass could completely fulfill all three core functions. As a result, business partnerships and technology interfaces are used by various product providers of connected home ecosystems to complement one another in order to stack benefits. Unfortunately, this environment makes it hard to decouple value propositions attributed to a sole product provider. With that in mind, this project assessed how product and service providers found within the nine technology subclasses are currently equipped to both enable and support those value propositions. See Figure 2.

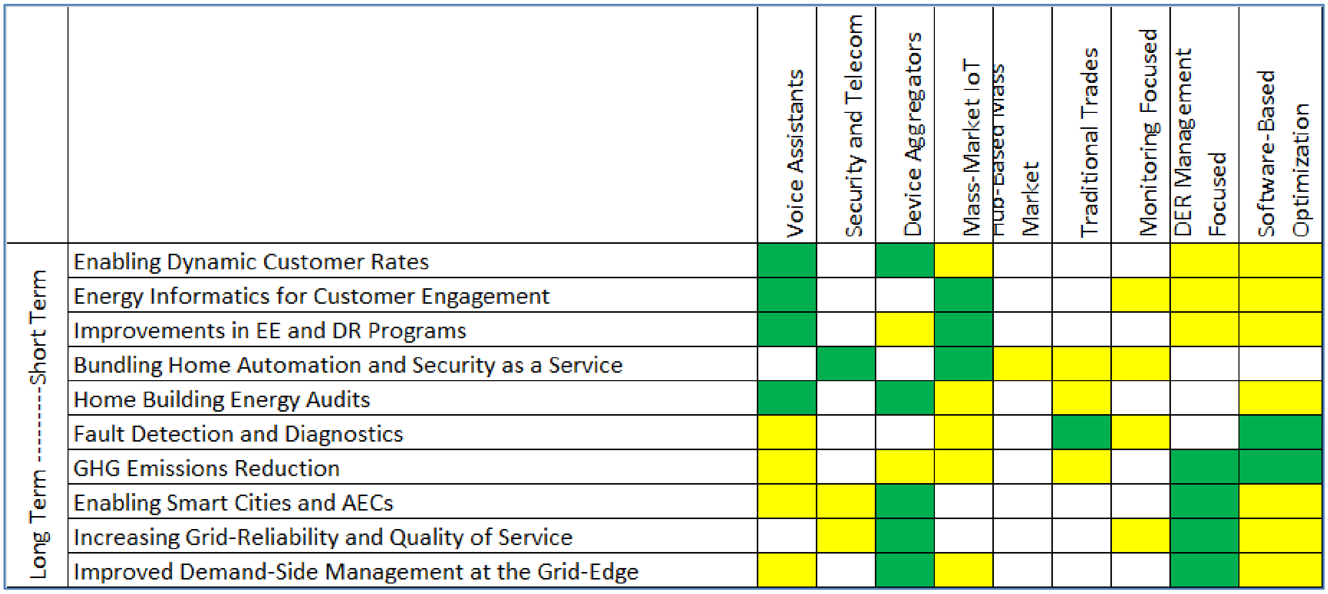

Figure 2 Use Case Analysis for Various Technology Subclasses

Analysis of customer-facing use cases determined that voice assistants followed by mass-market IoT ecosystems currently enabled the most customer-focused use cases. This is a result of market interest in products within both technology subclass and resulting ability to be a single point of orchestration of a mass market end-use devices and a potential point of aggregation of customer insights achieved through customer data collection.

Societal, policy and/or grid-related use cases assessment that although the market is continuing to mature at a rapid pace, most grid and policy related use cases are still in its nascent stages. Device aggregators and DER Management focused ecosystems were defined as enablers of a majority of these use cases due to their ability to aggregate control of multiple end-use loads. They were also selected as enablers as products and services comprising these technology subclasses have experience working with utilities and energy providers in providing grid benefits using behind the meter technologies.

Additional overall project findings include:

- **Emergence of voice control:** Voice offers new methods for providing and receiving customer information, which can lead to proactive messages of utility load management events and can also yield customer insights. Voice control can enable a single point of utility orchestration and also provides the utility additional information it may use to provide personalized options for a customer to interact with his or her utility.
- **Connected device product providers drive level of ecosystem orchestration:** The level of orchestration is driven by the product provider's ability to provide controls and associated data to validate those controls. If a utility or third party is working with software–focused products with no actual hardware, it is important to understand the business relationships of these technology subclasses with the product providers that it claims to be integrated with as well as the controls that can be made available by the end-use devices themselves.
- **Data aggregation is less mature than the device orchestration and control:** Analysis of data collection and aggregation is a good proxy of where orchestration/optimization happens within connected ecosystems. Data is relatively silo' d and only available to particular project partners and exchanged on an as-need basis due to security and privacy concerns and infrastructure costs. As data validation, especially energy related data, is not necessarily needed for orchestration by connected home ecosystems providers, it is important to note that there are still

gaps in the industry in aggregation of data from connected ecosystems needed for energy-related ecosystem orchestration.

- **Data specification can be a potential bridge to standardization:** Most connected ecosystems and products prefer cloud interfaces. As a result, standards are especially difficult to impose. Application Protocol Interfaces (APIs) (not including proprietary web interfaces) facilitated by the manufacturers seems the most effective near-term option for collecting data. Data standards validating performance can also lead to standardization of communication protocols, although like any market/ industry transformational activity, this is a long-term proposition.
- **Debate between cloud vs. local energy monitoring and management:** Many connected ecosystems use distributed intelligence and cloud-based platforms to provide scalability and rapid innovation. However, limited local processing means that ecosystems rely on broadband connectivity to enable orchestration and/or optimization and therefore can be impacted by latency issues. Although local energy management will not be as crucial when it pertains to many of the customer-focused use cases, it is important to understand the tradeoffs between ecosystem scalability and control reliability over the next few years, especially as these ecosystems are considered as grid resources.

Project Recommendations

Analysis of the connected home ecosystem space led to a recommendation of a comprehensive approach interconnecting all facets of the connected home energy ecosystem customer journey (the overall customer experience associated with the connected home ecosystem product and utility energy service) is suggested in order to develop the appropriate customer programs and associated grid services. Comprehensive approaches should lead to utilities providing personalized customer offerings based on a customer's appetite for working with its utility which can potentially be enabled or enhanced by connected home ecosystems. Various levels utility engagement as well as how connected ecosystems enable these levels of engagement are detailed in Figure 3.

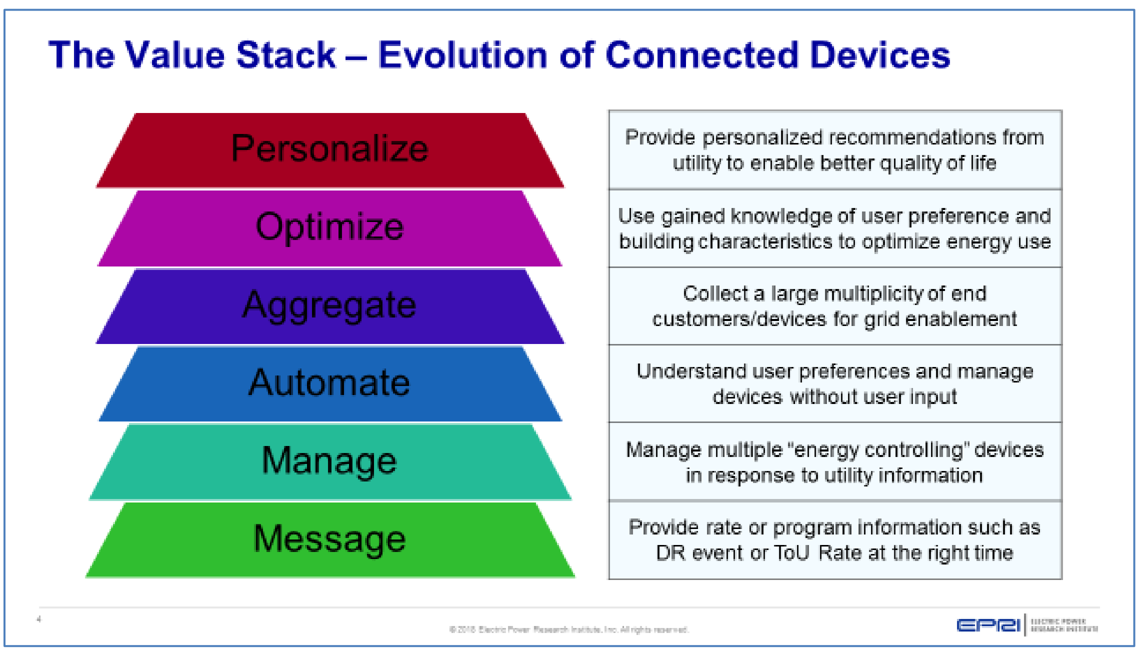

Figure 3: Levels of Utility Engagement Enabled by Connected Home Ecosystems

It is important to remember that orchestration potentially enables automation and coordination of devices and ecosystems (an inherently customer-focused value proposition) while aggregation provides scale (important to manufacturers and utilities). In order to develop long term customer engagement, it will be important to identify technology subclasses that provide customer impact in the short term through enabling the greatest opportunity for orchestration or a mass market of connected devices and ecosystems. The report's analysis identifies that products and services found within the voice assistant technology subclass currently (as of 2018) provides this optimal point of orchestration and products such as Google Home and Amazon Alexa integrate with the most number of connected devices and ecosystems. Section 4 details a scenario in which a utility can potentially partner w/ voice assistants to enable stacked energy benefits as they enable the most use cases as identified in Figure 2. It also details a potential scenario in which a product provider and a utility can work together to enable various levels of utility engagement as detailed in Figure 3. The result of which is stacked values for both the utility and its customers through mass market connected home ecosystem adoption.

It is also important to also understand that grid-flexibility related long-term use cases requires mass adoption as well. It is important for a utility to partner with product and service providers from the device aggregators or DER-based aggregation technology subclass, but in particular, partner with product providers that enable mass adoption required for aggregation. Additional research and evaluation recommendations can be found below.

1. Develop and/or test software for integration of connected devices into grid management: New grid management strategies need to be adopted that integrate customer programs with active grid operations. This could also include development of strategies and technologies for customer cost management. Utilities will need to develop this layer of control using software to enable management of a more unpredictable and fast changing grid.
2. Develop avenues for personalized customer engagement through connected home ecosystems: Developments in connected home ecosystems over the years have allowed new methods to deliver information to customers. Utilities should investigate ways of continuously interacting with their customers through integration with connected home ecosystems.
3. Develop strategies and technologies (software) for customer cost management: As dynamic energy environment requires utilities to transition to more dynamic, time-of-use rates, utilities can provide customer cost management tools to improve customer adoption and satisfaction. Connected ecosystems offer a great opportunity to integrate energy monitoring using utility AMI data with control of multiple end-systems within a premise to provide both cost management advice as well as active energy use management. This can be done through software development through open ecosystems as well as partnerships with connected home ecosystem providers.
4. Continue to investigate the true value of device-level data: Collection of customer data through the entire customer journey can provide additional information on the drivers of customer utility interaction (or non-interaction). This information can potentially be aggregated with other information found within a utility's existing customer information systems. Constant information collection can provide a more comprehensive understanding of how a customer uses energy, and this information could increase the likelihood that customers will participate in other utility programs and services.
5. Understand and evaluate how communication standards and effective useful life of connected ecosystems affect customer ecosystem and utility program cost: Currently, there are several efforts investigating standardization of communication protocols. Although reliability and improved availability is an important metric, it is also important to understand he economic impact of these protocols and how that may affect market potential of connected ecosystems. In addition, there are very few empirical results evaluating the persistence of energy impacts of these ecosystems. It is important to consider the attrition of these energy impacts as well as to continue to monitor attrition when relying on these devices, especially when using them to evaluate grid impacts.

INTRODUCTION

The evolution of home energy management systems has progressed through multiple waves of product development and product availability in the last decade. The history of controls-based residential energy management systems in the last decade can be categorized into three waves: (1) hardware-centric proprietary energy management ecosystems, (2) standalone cloud-based energy management devices and (3) software-centric home energy management ecosystems. See Figure 4.[1]

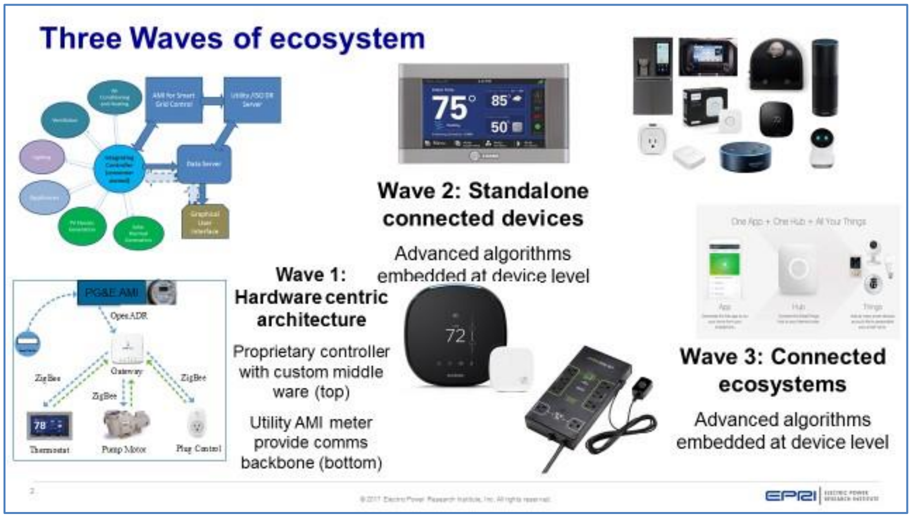

FIGURE 4 PRODUCT ARCHITECTURES FOR CONNECTED DEVICES AND ECOSYSTEMS

The first wave in the mid-2000s saw the emergence of products enabled by the establishment of the 802.15.4 900 MHz networking standard and the emergence of low-cost chip-based networking solutions. During this phase, the emphasis was on different radio technologies – ZigBee vs. Z-Wave vs. Insteon and so on. Each had its role and the focus was to ensure interoperability between devices. With emerging connectivity technologies, the focus was on making different hardware elements work together. Although there were communication protocols in place, these connected ecosystems still required detailed customer integration, both on the hardware and software side. As a result, most mainstream customers could not figure out how to get these different systems to work together. While there was adoption from the early adopters, the cost and complexity made it difficult to get full-scale adoption.

The slower customer adoption of the first generation of home ecosystems and in-home devices led to a slowdown in the home energy space, with many players like Google and Microsoft pulling away from the market. However, advances in consumer electronics and a better understanding of data analytics capability led to the emergence of smart thermostats that packaged energy awareness in a consumer product. At the same time, lighting controls and smart plug strips started emerging as standalone devices with the potential for providing energy savings. Consumer awareness and interest in these products finally set residential and small commercial controls on the path to achieving potential energy savings. These connected devices also enabled the era of Wi-Fi connected devices, in contrast to the

[1] Cite 2017 HEMS EPRI Base Report

previous generation of devices that required a hub or a bridge to connect to the network. The result was a significant decrease in the cost of connected devices (in combination with cost reductions in wireless technologies), along with more targeted messaging that accelerated residential adoption of connected devices. These product providers such as smart thermostat manufacturers such as Nest, ecobee and Honeywell were able to transition the market from the innovator to the early adopter market, which the first generation of home automation did not achieve due to cost and complexity. This increased adoption also significantly advanced the concept of Do-it-Yourself (DIY) for home automation technologies, significantly reducing costs as compared to a "contract" job requiring a controls integrator. Another important step forward was the user interface and customer engagement features that many of these devices provided, which were important in driving mass market adoption of connected devices.

Since 2015-2016, market players in the industry have jump started the third wave of home ecosystems. This new wave was spurred by market interest in home automation as an enabler to improvements in comfort, convenience and control – all at a reasonable price point for consumers. The first wave of connected devices presented consumer barriers through high price points as well as complex integration of devices to hardware-focused home automation systems. Proliferation of smart speakers or voice assistants at a price point as low as $30 and smart hubs with price points as low as $99 or embedded within connected devices themselves have bridged the upfront cost barrier. In addition, voice assistants and connected devices that serve as smart hubs provide value to users such as weather alerts, traffic information and entertainment.

The second wave of connected devices presented interoperability concerns as they primarily focused on single-devices such as smart thermostats or end-uses such as lighting systems or plug loads. Although there were certain products that penetrated the market that claimed interoperability with multiple connected devices, transparency of interoperability—the "what exactly is interoperable" between devices—was not very clear to the consumer.

The third wave of connected devices served not only as an independent value proposition, but also could potentially serve as an entry point to other home automation products such as connected lights, security systems and energy products such as smart thermostats, lighting systems, connected plug loads and appliances. These connected devices were intentionally built as stand-alone smart devices with limited understanding of interactive intelligence between other devices within a particular connected home ecosystem (i.e., the intelligence of the devices is found in individual devices vs. the actual hub themselves). This resulted in in a technology infrastructure enabling innovation that could occur rapidly across multiple devices within an ecosystem without a single entity to develop these algorithms. However, although distributed intelligence allows for innovation in rapid technology change, it is still unclear what interactive effects will occur as a result of these upgrades, in particular for utilities and energy providers looking to leverage these devices to provide energy and non-energy related services to their customers. To better understand the value of this third-generation ecosystem approach, it is important to understand the emerging technology developments provided by connected ecosystems as well as energy drivers associated with these ecosystems.

EMERGING TECHNOLOGY DEVELOPMENTS IN CONNECTED ECOSYSTEMS

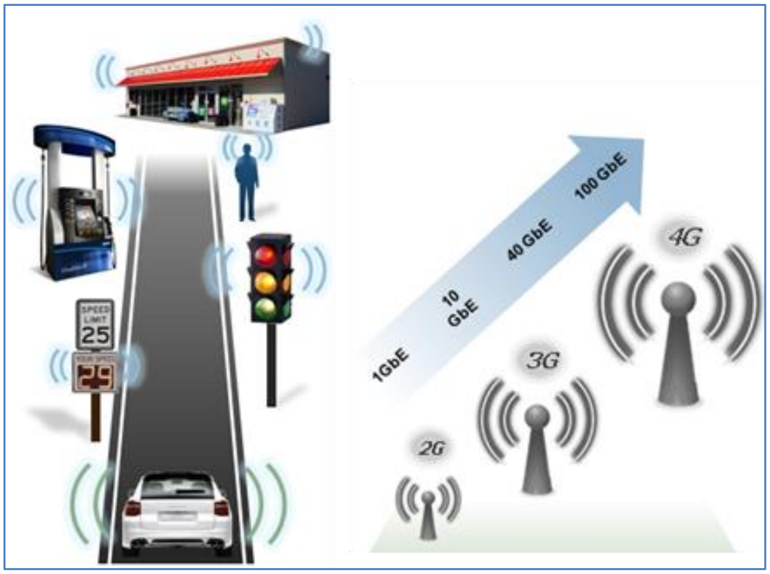

FIGURE 5 ADVANCEMENTS IN WIRELESS COMMUNICATION CAPABILITIES POTENTIALLY LEADING TO SMART CITY DEPLOYMENT

Controls and energy management systems have undergone substantial advances in the last decade, especially around the growth of Internet of Things (IoT) devices and technologies. Traditionally, building controls were restricted to large commercial buildings. However, as the cost of networking and sensors falls, it became more and more feasible to have smart cities that feature sensors in everything from traffic lights to roadways to building doorways and occupied spaces. The evolution of IoT devices is the underlying foundation for developing smart cities. See Figure 5. These sensors could measure anything from motion to pressure to lighting to temperature and humidity. The falling cost also opens the door to smarter controls in smaller buildings as the risk-reward ratio drops for owners and occupants of smaller buildings. The following are detailed technology developments driving the connected home ecosystem space.

IMPROVEMENTS IN VOICE RECOGNITION (FAR-FIELD VOICE AND NATURAL LANGUAGE PROCESSING)

Voice recognition has really taken a hold of the home automation space Since around late 2014-2015 voice capabilities can now be found in smart speakers as well as in smart thermostats. Although voice recognition has been around in the mass market since the 1990s, two key technology developments have led to mass-market proliferation of this features: improved far field voice and natural language processing.

Historically, voice recognition tools have required the user to be in close proximity to a microphone and/or being located in an environment with limited ambient noise. Recent breakthroughs in Far-Field Voice Input Processing (FFVIP) have allowed a new method for interacting with connected devices and ecosystems that does not rely on a user putting a microphone close to their mouth for smart devices to understand commands. This development has resulted in the potential for these connected ecosystems to be part of the ambient environment of a home, since a user can state commands from basically anywhere in the room where the microphone is.

In conjunction with improvements in FFVIP, developments in natural language processing have been able to take a voice signal from a user and generate more actions than previous voice-recognition platforms. Companies such as Google, Amazon, Apple and Microsoft produce devices that can translate not only a set of words and phrases stated by the user, but also better understand context and intent through improvements in Artificial Intelligence (AI) by these large platform providers. The result is improved responses back from these providers, significantly improving the customer experience from voice recognition platforms.

Some of the interesting voice enabled smart energy devices include Amazon Echo, Ecobee 4 thermostats, Google Home hubs, and the Comcast Xfinity home hub. All these devices have a common architecture for voice recognition where the in-home device is essentially a smart speaker and microphone. The microphone listens to specific commands, transmits the commands to the cloud where voice processing software can analyze it and create control sequences (whether it is to change the temperature or the TV channel), and the command is then delivered to the end device. The key customer experience advancement is providing an ambient yet interactive environment where consumers no longer have to navigate through innumerable menus and applications but can interact with their environment through a set of common voice commands.

LOW-COST SENSORS

The cost of sensors, especially in the Internet-of-Things space has significantly decreased and is forecasted to continue to decrease. See Figure 6.[2]

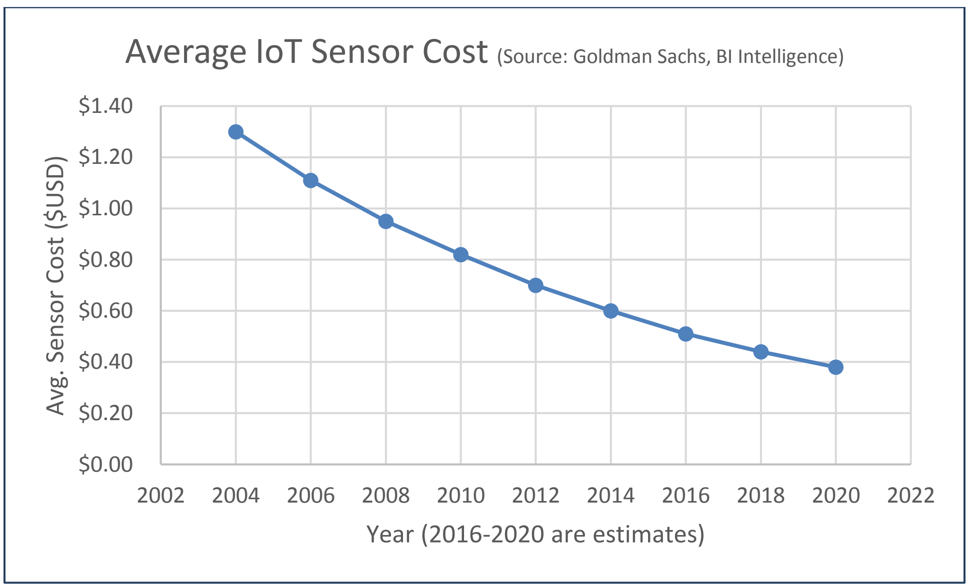

FIGURE 6 AVERAGE IOT SENSOR COST FROM 2004 - 2020

Rapid decrease in sensor costs results in lower overall connected ecosystem cost while providing the information needed for automation. As the number of sensor-based applications grow, there is a growing trend of "sensor on a chip" where integrated temperature, humidity and lighting sensors drive the cost of sensing down below the $1 range. This low cost makes it feasible to have multiple sensors or even a network of these low-cost sensors that can provide more optimal controls. In addition, multiprotocol communication smart hubs were used to interconnect devices that used various communication protocols. Recent developments by System on a Chip (SoC) providers such as Qualcomm have enabled this functionality that used to be provided through another

[2] https://www.theatlas.com/charts/BJsmCFAl

device such as a hub or router to be embedded in IoT devices themselves.[3] The result of advancements in sensor on a chip and SOC capabilities are leading to increased applications, decreased costs and decreased need for customer commissioning of connected ecosystems.

ADVANCES IN WIRELESS NETWORKING

Wireless networking, especially with Wi-Fi but also with cellular and Bluetooth has significantly advanced in the last decade and is seamlessly integrated into many devices used on a day-to-day basis. As previously discussed, with current technologies the total cost for a board with integrated Bluetooth and Wi-Fi along with the processing power and relays is only about $30 – significantly decreasing the overall cost of wireless connectivity through multiple communication protocols. Technology advances in 802.15.4 technologies such as ZigBee and Z-Wave have grown in capability, while Wi-Fi has advanced from just point-point to mesh networks to …. Advancements in combining power and networking such as USB-C, high power USB and Power over Ethernet raise the possibility that the integration of power and networking can develop a low-cost infrastructure for both power and network connected ecosystems.

OPEN SOFTWARE INTEGRATION

ecosystems that arrived a decade ago were hardware-centric and had to depend on proprietary software to ensure that the networked components could reliably deliver customer value. Similarly, high technology in a home built in 2005 was to embed speakers in ceilings and walls and run audio wires behind the drywall for home automation. In the last few years, the number of products and the ecosystem have developed and more importantly, product providers have realized that customers derive value from the software, not the hardware. This has accelerated the development of open software integration using APIs curated by the integrators, which has enabled large ecosystems to grow organically as the cost of integration has decreased substantially. A core piece of the integration is establishing data exchanges.

Ecosystems like the Amazon and Google ecosystems work most effectively using outbound APIs that enable other vendors to integrate into their ecosystem without having to integrate them one by one, which requires using internal staff. This is similar to how the concept of the "app store" grew and created business opportunities for both the integration platform provider and the individual application developers. It can be expected that the universe of smart building applications can grow quite rapidly in the next few years. The same API integration concept is slowly taking hold in the commercial building market where large providers like Siemens and Johnson Controls are now creating "app stores" where emerging technologies such as remote audits and cloud-based optimization can be successfully integrated with the data from building control systems in commercial buildings.

[3] https://www.qualcomm.com/news/releases/2017/02/21/qualcomm-announces-first-commercially-sampling-tri-mode-system-chip

CLOUD BASED DATA MANAGEMENT AND ANALYTICS

All the technology advances described above rely on high performance computing for voice recognition, controls evaluation and integration with multiple devices. This cannot happen without significant advances in cloud computing, data management and analytics. The acceleration of cloud-based data management and algorithmic optimization technologies is a game-changer in this space. It substantially democratizes and opens up the software applications area, which is where consumers see the benefits in terms of better algorithmic optimization, better user interfaces and better controllability for a typical user. This means that innovative firms and even individuals can develop applications to enable automation and energy management. As ecosystems were previously were integrated, this type of technology advancement previously relied on a single product provider.

ENERGY PROVIDER AND UTILITY INTEREST IN CONNECTED ECOSYSTEMS

Historic utility programs have focused on providing utility rebates and/or incentives to customers on emerging technologies and services that have provided Demand-Side-Management (DSM) benefits such as Energy-Efficiency (EE) or Demand Response (DR). Although many of these programs were successful, many utilities are interested in leveraging connected ecosystems to provide not only traditional DSM benefits, but also improvements in these program offerings as well as new energy services and offerings to its customers. For example, a historic barrier and associated solution to customer adoption of emerging technology is incremental cost difference between a baseline technology and its efficient counterpart. Leverage of market interest of these connected ecosystems have led to new program delivery channels such as the Bring-Your-Own-Device (BYOD) model where a customer enrolls their connected device into a utility program in exchange for a rebate or an incentive associated with energy (or estimated energy) reduction.

Increases in proliferation of Distributed Energy Resources (DER) as a result of policy drivers around decarbonization and reduction in costs of DERs have also led to the increased need to retrofit and develop a more flexible energy network. See Figure 7 and Figure 8.[4]

[4] Cite CEC Renewable Energy Tracking 2017.

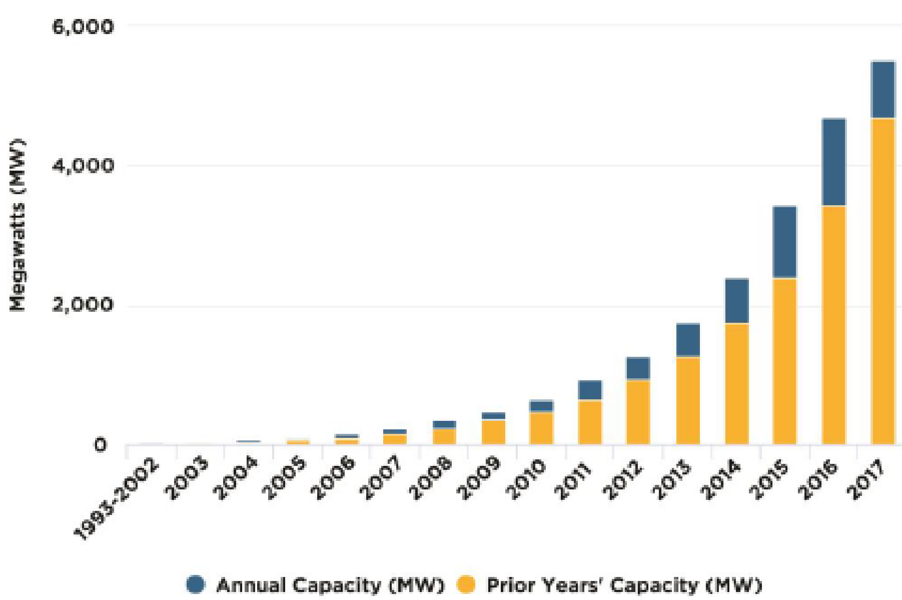

FIGURE 7 CALIFORNIA INCREMENTAL (BLUE) AND TOTAL (ORANGE) BEHIND-THE-METER SOLAR CAPACITY FROM 1993-2017

While Figure 7 shows overall exponential increase in Behind-the-Meter (BTM) solar capacity, Figure 8 shows distribution of these small-scale Distributed Generation (DG) projects in California as of 2017.

Not only does the energy system need to be flexible with respect to time due to the intermittent nature of renewables, Figure 8 depicts it must also consider location as well, since DG projects are not evenly distributed throughout the State. Organic deployment of connected and controllable loads are increasingly penetrating the market, and energy companies within and outside California are interested in leveraging these ecosystems as flexible grid resources.

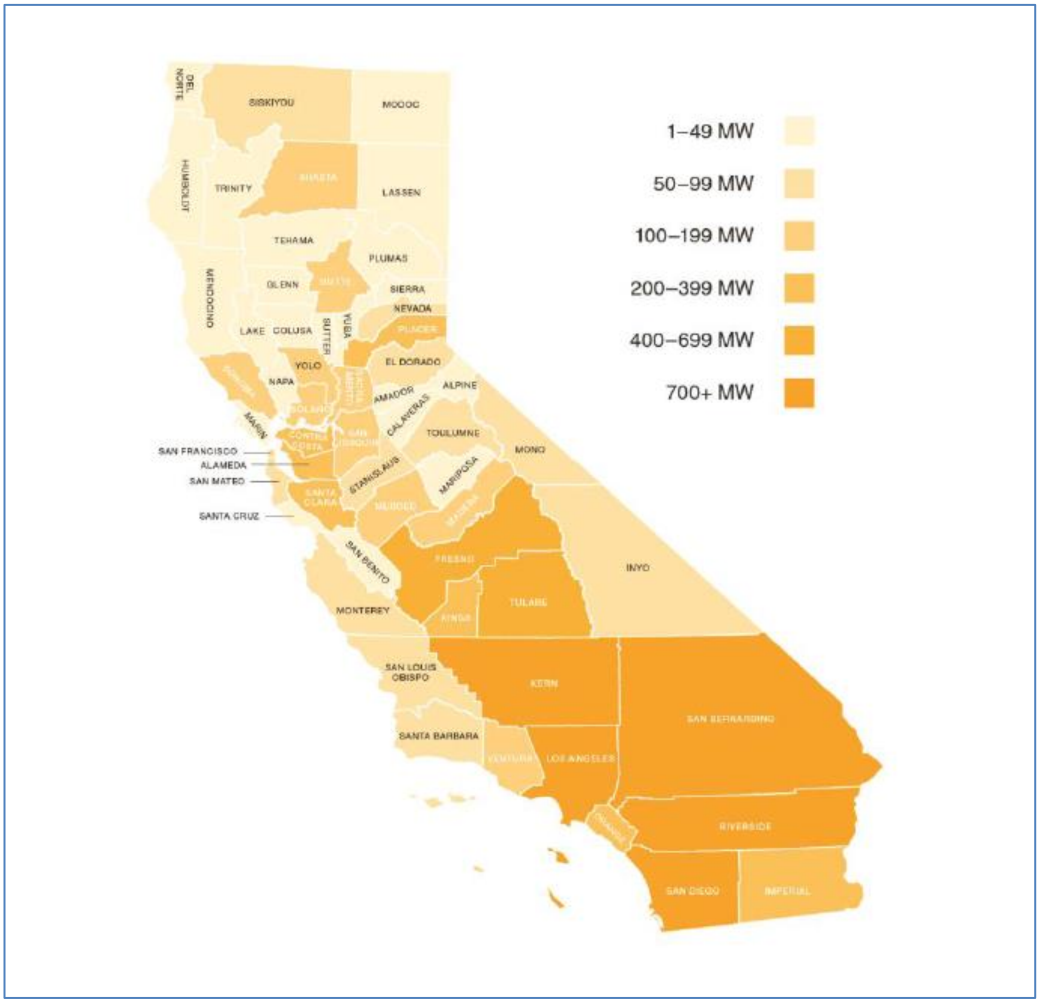

FIGURE 8: MAP SMALL-SCALE DISTRIBUTED GENERATION CAPACITY IN CALIFORNIA IN 2017

Finally, these connected ecosystem providers provide not only automation/controls opportunities, but also provide data that can potentially lead to additional energy and non-energy services provided by utilities. In 2016, a report by Accenture estimated the average customer interacts with their energy provider approximately 20 minutes per year, distributed between 11 minutes with a customer representative and 9 minutes through digital channels.[5] With the majority of customer interaction happening over the phone with a customer representative, it is much more likely that the customer is calling because they have a problem, not because they are interested in new energy services. Advancements enabled by connected ecosystems can provide additional energy services in a manner that is proactive vs. reactive, improving the customer experience.

REPORT LIMITATIONS

As the connected ecosystem space is broad, new, and dynamic, it is important to note the limitations associated with the results presented in this report.

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[5] Cite Accenture 2016 utliity customer survey

- **The Connected Ecosystem Space is undergoing rapid technology and market changes:** The field is so diverse that it is likely that some information will be outdated by the time report is published. As a result, the main focus of this report is to develop a process for categorization and evaluation of connected home ecosystems.
- **The report is not a compendium of connected devices or connected ecosystem providers:** Although is it useful to identify products and services that provide connected ecosystems, it is inevitable that functions of the product providers in the space will change. As a result, this report focuses on technology subclasses defines technical and market characteristics of those subclasses alongside product and service providers that fit that technology subclass at the time this report was written.
- **The report does not provide specifics pertaining to various communication protocols and standards:** Although connectivity and interoperability are main resources questions associated with the connected home space, this report does not go into detail as far as the communication protocols and standards available in the market today. Instead, the report focuses on two specific questions related to "what does the industry want these systems to do?" in terms of functional requirements as well as "how does the industry validate that these systems performed this function" in the form of assessment of data.

REPORT OBJECTIVES

This report defines **Connected Home Ecosystem** as a hardware and/or software platform that **monitors and/or controls** multiple end-use devices found within a premise or community. With this definition in mind, the report investigates how advancements in connected home technology can potentially be leveraged to provide improved grid flexibility and customer services in dynamic energy environments. The report includes a state of the industry study of the Connected Home space to provide a deeper understanding of the market players and value when optimized energy consumption is provided – or not provided – to residential households. In particular, the report looks at investigating "value stacking" or how value multiple value streams can be enabled by utilities and other energy companies as well as potential optimal points of intervention by the utilities. The report accomplishes this objective by addressing the following research questions:

1. Who are the providers, or potential providers of bundled energy services? Examples include hub platforms, service providers, and device manufacturers. What are their business drivers, especially the economic and strategic drivers?
2. What data is used to create bundled energy algorithms via connected home ecosystems? How can these algorithms scale to deliver statistically significant energy savings for utilities?
3. What use cases exist for leveraging connected ecosystems of the future? How do these harmonize customer requirements with providing grid benefits?
4. How can connected home ecosystems and devices help the utility serve as an aggregator and enable the utility to provide aggregated residential energy resources such as smart thermostats for market participation?
5. What are the technical opportunities and limitations for bundled energy services or connected home ecosystems?

REPORT FORMAT

The report is divided into five sections. The first section discusses emerging technology developments in connected ecosystems and energy provider and utility interest in connected ecosystems. The section defines a key set of core value propositions that connected ecosystems can enable and then defines a core set of functions that can be potential capabilities of these connected ecosystems. This framework will be used to assess the connected home space and classify various technology ecosystem offerings into what this report calls technology subclasses. Each technology subclass is evaluated for its technical and market opportunities and barriers, keeping the core value propositions and functions in mind.

The third section defines use cases that a utility can potentially leverage connected devices and connected home ecosystems. These use cases will be characterized and described through a set of functional requirements, a set of core competencies that a technology provider should possess to enable or/or support that use case. The section highlights opportunities made available by data inherently collected by these connected ecosystems. These data are then categorized and each of the technology subclasses in Section 2 are assessed on the ability of the data collected within their respective ecosystems to execute the core functions identified in Section 2.

The fourth section will take the results presented in Section 3 and present somewhat prescriptive methods on how utilities and energy providers can leverage certain technology subclasses to provide the intended value stacking capabilities based on functional requirements and data availability requirements discussed in Section 3. The section provides specific information on the value streams currently enabled, considerations when partnering with technology providers within each subclass as well as existing technology and market gaps that should be considered. Finally, the fifth section summarizes the results from the previous sections and provides recommendations for next steps.

CLASSIFICATION OF CONNECTED HOME ENERGY ECOSYSTEMS

Although there have been many reports classifying connected home energy devices themselves, little research is available to classify the current state of connected home ecosystems available today. To do so, the project team took the following approach:

1. **Identification of Core Value Proposition of Connected Ecosystems:** Connected devices and associated utility programs have enabled a "shared customer relationship" between a product and service provider and the utility. It is important to understand general drivers for these stakeholders to identify core value propositions for each.
2. **Identify Core Functions of Connected Ecosystems:** To enable core value propositions, it is important to categorize/summarize the functions that enable the connected ecosystems to provide value.

It is important to understand the value that these ecosystems potentially bring to the various stakeholders. Increased penetration of dynamic resources coupled with new connected technology has resulted in a new customer/utility/third party "shared customer" dynamic that is especially new in the energy space. As a result, it is important to assess the similar as well as conflicting interests between the various stakeholders related to potential offerings of connected ecosystem solutions. To address this, the report defines the three main core value propositions of connected ecosystems[6] as: (1) grid impacts or how connected ecosystems enable and impact the grid and how these ecosystems can potentially enable grid flexibility; (2) how data and value streams enabled by these ecosystems can result in positive customer interaction and improved customer experience; and (3) how connected ecosystems can potentially collect data from multiple connected devices to provide energy information to the customer and/or develop optimization routines to help the customer or the grid manage end-use loads, resulting in energy management/optimization.

CORE FUNCTIONS OF CONNECTED ECOSYSTEMS

To begin to understand the value of a connected ecosystem vs. a connected device, this report proposes three main functions that a connected ecosystem enables over a connected device: optimization, orchestration, and aggregation. The report defines the core function, provides a brief explanation of how an ecosystem approach improves the current device-specific approach and then provides examples of product and/or service providers that enable this specific core function. See Figure 9 for a summary of these core functions.

[6] Assuming a energy provider/utility program or service offering is involved

Optimization – Use of data and customer inputs to provide autonomous programming and response targeted for a specific need.	**Orchestration** – Coordinated programming and response of end-use loads with a premise.	**Aggregation -** Grouping of end-use loads, typically of the same end-use to respond to particular utility controlled signals.
Examples – Whisker Labs, Tendril	**Examples** – Amazon Alexa, Samsung SmartThings	**Examples** – EnergyHub, AutoGrid.

FIGURE 9 CORE FUNCTIONS ENABLED BY CONNECTED HOME ECOSYSTEMS

Aggregation: This function refers to grouping end-use loads and systems to respond to utility control and rate signals. Functionality is enabled by platforms such as Demand Response Management Systems (DRMSs) and other platforms that serve as enabling mechanisms that provide a single interface to a utility, energy provider and/or third party[7] and that control multiple devices found within a utility service territory. Historically, these aggregation platforms, such as AutoGrid, EnergyHub and Cooper/Yukon[8] have been focused on aggregating similar end-use systems provided by a single product and service provider or providing the capability of aggregating similar end-use devices from multiple product providers.

In the past, it was not uncommon for a utility to have multiple aggregation platforms set up to enable customer choice of products.[9] This infrastructure had certain implementation challenges. It could potentially result in additional utility Integrated Demand Side Management (IDSM) program infrastructure as well as unintended operation and maintenance (O&M) costs. Several utilities across the country have investigated and implemented platforms aggregating multiple customer-sited DERs for operational improvements in conducting residential demand response programs[10][11][12] Ecosystem approaches minimizes the need of multiple aggregation platforms as it enables aggregation

[7] "Utility" in this report can be defined in broad termed to include not only utilities, but energy providers and other third parties providing energy services as well.

[8] Recently procured by Eaton

[9] Cite Presentations by David Logsdon from ConEdison

[10] Cite Innovari Presentation at Baltimore Advisory

[11] Cite interview w/ Jeff Haase for the Smart Thermostat Collaborative.

[12] In this report, distributed energy resources are defined as behind the meter resources connected to the energy system. These include solar, storage, EE, DR and EVs

of both a combination of end-use devices in a particular utility service territory as well as end-use devices from multiple manufacturers.

Orchestration: Orchestration in this report is defined as the coordinated response of multiple end-use loads within a premise. Typically, functionality is enabled by Home Energy Management Systems (HEMS) and/or Home Automation Systems[13]. As previously discussed, HEMS platform in the 2000s focused on hardware-centric, locally managed platforms. As a result, the platforms were fairly expensive and therefore had minimal mass-market penetration. A recent wave of products made available by Samsung (SmartThings), Amazon (Echo) and Google (Google Home) have enabled the opportunity of low-cost optimization of multiple end-use uses at prices as low as $50-$300. In addition, connected device manufacturers such as Nexia, a subsidiary of Ingersoll-Rand, embed functionality within its existing thermostat to enable control of other Nexia devices such as smart plugs and door locks. As a result, an ecosystem-focused approach has enabled coordinated control of multiple end-use devices within a premise at a lower cost than customized HEMS of the 2000s.

Optimization: Optimization in this report is defined as the use of information (typically in the form of data collected by connected devices and ecosystems) to provide autonomous programming and targeted responses to a specific use case. Over the last few years, device manufacturers and associated service providers have collected data on their products to meet objectives such as: (1) improving comfort conditions, (2) identifying operational faults of specific equipment and (3) reducing energy consumption.

Historically, optimization has been focused on improved performance of a single device or system. Ecosystems and optimization routines developed by product and service providers such as Whisker Labs and Tendril[14] provide opportunities to improve the performance of multiple devices within a premise to complete a particular use case.

Through the rest of the report, these three core functions—aggregation, orchestration and optimization—will be used to differentiate opportunities made available by the current state of connected energy management ecosystems in residential markets.

APPROACH

With core functions and key value propositions of connected home ecosystems in mind, the next step is to classify an array of products and service providers in the market. The framework will be implemented to summarize opportunities and barriers with deploying DSM programs within each of the technology subclasses. The approach will be to assess the technology space by addressing fundamental technology and market questions:

- Who are the actual customers of the products? Utilities? Homebuilders? Product providers? Residential customers?
- What are the possible market delivery channels?
- What is the technology subclass's core competency?
- What is/are the core value proposition(s) of the technology subclass?

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[13] "HEMS" in this report constitutes both home energy management systems as well as home automation systems.

[14] It is important to note that the effectiveness of the optimization routines of the product providers

- What are the interdependencies of the subclass's value proposition (if any) with other third parties?
- What is the experience of the technology subclass with utility programs? Current? Future? Is there any interest of product and service providers that partner with these technology subclasses in partnering with utilities?

To present results, the team used the following criteria.

1. **Defining the Technology Subclass:** Classifying the connected home ecosystem space into a set of 5-10 technology subclasses based on factors such as technology core competency and the product's current target customer.
2. **Product and Service Provider Examples:** Provide one or two examples of technology service providers that have currently available products that fit within the technology subclass. It is important to note that this list is not meant to be exhaustive, but a representation of what type of products the subclass if referring to and current examples in the market.
3. **Opportunities:** The technology subclasses were then evaluated to identify the value propositions the subclasses have over: (1) device-level approaches which are the current focus of utility customer programs and (2) in comparison with the other technology subclasses.
4. **Challenges:** Potential barriers and other factors to consider when leveraging these devices.
5. **Emerging Trends:** Discusses emerging product features that these technology subclasses are beginning to develop.
6. **Product Differentiators:** Discuss details, offerings and other factors that may differentiate one product provider from another within a particular subclass.
7. **Utility Use Cases:** Discusses research, pilots, programs and other evaluations done by the utility industry to evaluate the functionality of these technology subclasses.

In addition to the seven criteria, the technology subclasses were also assessed on how they improve the core three functions of connected ecosystems – aggregation, orchestration and optimization.

TECHNOLOGY SUBCLASSES

Through the work, the following nine technology subclasses were identified. Their definitions are also detailed in Table 2:

TABLE 2 TECHNOLOGY SUBCLASSES AND THEIR DEFINITIONS

TECHNOLOGY SUBCLASS	DEFINITION
Technology Subclass	Definition
Voice Assistants	Ecosystems equipped with speakers, microphones and natural language processing capabilities. These systems are able to translate voice activated commands into controllable actions and responses for multiple end-uses within a home.
Security and Telecom Providers	Connected home ecosystems built on security and/or telecom service platforms
Device Aggregators	Ecosystems that are not necessarily connected home ecosystems, but are systems based on technology platforms that aggregate controllable end-uses within a premise or community. Most of these providers are historically Demand Response Management Systems (DRMS)s that are currently used in DSM programs.
Mass Market IoT Ecosystems	Ecosystems historically sold through retail channels and targeted to mass-market customers.
Hub-Based Ecosystems	Home automation systems with a centralized hub as a focal element enabling home automation
Traditional Trades	Ecosystems based on conventional residential end-use product providers providing connected products that are part of an overall home automation system.
Monitoring-Based Ecosystems	Systems based on monitoring equipment that disaggregates premise-level loads and/or monitor circuit level loads.
DER-Based Ecosystems	Technology and platform foundations based on energy monitoring and control of customer-sited DERs such as solar or storage loads.
Software-Based Optimization	Software-based products that partner with product provider(s) that collect and provide additional data parameters to optimize the operation of connected end-use loads within a premise and/or community.

Details on each of technology subclass are provided below.

VOICE ASSISTANTS

FIGURE 10: VOICE ASSISTANTS DISPLAYED AS HOME AUTOMATION ENABLERS AT CES 2018

Historically, devices that could recognize speech were not very effective and led to a poor customer experience. As previously mentioned, advancements in natural language processing and the development of low cost audio sensors has led to products that provide a better customer experience. These products synthesize voice commands as well as the intent of voice command into actionable responses by a connected device or a group of connected devices.

These ecosystems are called voice assistants and have drawn considerable market interest since the first mass-market voice assistant—the Amazon Echo—was released in 2014. Since then, mass market competitors such as Google Home have released competitive products in 2016. Other market players such as Apple (the HomePod) was released early in 2018 and Microsoft (the Invoke) which has stated intentions to release its own competitive product in the future. Market analysis shows that of the 20 million voice assistants sold as of September 2017, there are two main players: Amazon and Google, who own approximately 99% of the market share between the two of them.[15] These ecosystems have garnered much attention in the consumer electronics space. Figure 10 depicts a voice assistant display at the Consumers Electronic Show (CES).

[15] http://fortune.com/2017/09/18/amazon-sells-15m-echos/ ← Cite the actual CIRP publication

In addition to the large number of voice assistant platforms purchased over the last three years, the large market influence of Amazon and Google has allowed connectivity to other connected devices. Both companies have identified over 1,000 compatible connected devices ranging from smart thermostats to audio speakers to emerging energy applications such as Electric Vehicle Service Equipment (EVSE)[16]. Increased customizability of controls and relatively open development platforms have led to increased ecosystem orchestration capabilities. For example, it is estimated that Amazon Alexa Skills, the number of customizable controls developed to provide orchestrated responses of connected devices in a premise, has grown from less than a thousand in Q1 2016 to 15,000 in Q2 2017[17] to 25,000 by Q4 2017[18]. It is possible for a utility to develop Skills (or the Google Actions, the Google Home equivalent) made specifically for a particular service. For example, Just Energy in Texas uses Amazon Echo as a method for customers to ask for bill details, provide energy facts and contact utility customer service staff.[19]

Although there has been considerable interest in the market, especially over the last two years, there are still questions yet to be answered as far as the ability to leverage these voice assistants for specific energy services and programs. Although device orchestrations, one of the core functions of home energy ecosystems, are directly aligned with one of the main value propositions of voice assistants, there are very few long-term utility initiatives evaluating the feasibility of leveraging these platforms for DSM programs. Research is ongoing on how best to use these platforms to enable new DSM program delivery mechanisms and other energy services.[20] Finally, the persistence of the product offering has yet to be evaluated as mass-adoption of the product has not yet occurred.

In summary, voice assistants, currently dominated by two main product providers, Amazon and Google, have the potential of expanding its value proposition of enhancing the customer experience and its core function of enabling premise-level orchestration to the other two value propositions and core functions. Table 3 summarizes the technology capabilities of the Voice Assistant subclass.

TABLE 3: TECHNOLOGY CAPABILITY SUMMARY OF VOICE ASSISTANTS

FEATURE/FUNCTION	DESCRIPTION
Definition	Ecosystems equipped with speakers, microphones and natural language processing capabilities. These systems are able to translate voice activated commands into controllable actions and responses for multiple end-uses within a home.
Example Products	Amazon Echo, Google Home
Emerging Trends	Voice assistants are beginning to embed functionality within other connected devices. Emerging smart home product providers are looking at functionality with these voice

[16] https://www.engadget.com/2018/01/04/amazon-alexa-can-start-charging-your-electric-car/

[17] http://www.businessinsider.com/amazon-alexa-how-many-skills-chart-2017-7

[18] https://www.fastcompany.com/40491523/as-amazons-alexa-turns-three-its-evolving-faster-than-ever

[19] https://www.prnewswire.com/news-releases/just-energy-first-retail-energy-provider-to-offer-compatibility-with-amazon-alexa-voice-service-300267560.html

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	assistants as one of their main product development objectives.
Utility Initiatives	(1) Just Energy (TX) uses Amazon Echo as a method for the customer to ask for bill details, provide energy facts and contact utility customer service staff. (2) Other utility initiatives are looking at voice assistants as primary interfaces for orchestrating demand response of various products within a premise. (3) For a limited time, the Sacramento Municipal Utility District (SMUD) offers a free Google Mini for every Nest Thermostat purchase through the SMUD energy store.[21]
Aggregation	**Medium-High:** There are opportunities to scale customer program offerings and increase market delivery channels as voice assistants have a large market presence. The remaining gap is not technical, but needs to address how to connect voice assistant customer information systems to utility program offerings.
Orchestration	**High:** This is a core value proposition as ecosystem platforms are built with a focus on home automation.
Optimization	**Medium:** Possible, but there is limited knowledge on enabling a data feedback loop to enable energy-based optimization. This has not been the core value proposition of these ecosystems.

However, due to its relatively short time in the market, it will be important to understand and track the persistence of the product offering by:

(1) **Tracking the number of compatible connected devices:** As these voice assistant providers do not necessarily manufacture other products themselves, it is important to monitor both the number and type of compatible connected devices to better understand each voice assistants interest in developing integration with energy-related end-use devices.

(2) **Tracking the number of orchestration modules developed:** Tracking of Amazon Alexa Skills since Q1 2016 has shown exponential growth of the market developing orchestration modules to coordinate control of various connected consumer devices. Continuous tracking of the number of Alexa Skills, Google Actions and other products developed in the future will provide information on the level of interest as well as persistence of the interest in enabling home automation.

It is also important to consider that although current software development environments of voice assistants are relatively accessible, with publicly available forums and communities to enable additional functionality, orchestration modules such as Amazon Skills and Google Actions are reliant on the controllability enabled by the connected device providers themselves.

[21] https://smudenergystore.com/pages/limited-time-offer-our-gift-to-you

SECURITY AND TELECOM PROVIDERS

FIGURE 11: SECURITY ECOSYSTEM OFFERINGS IN SALES OFFICE OF ADVANCED ENERGY COMMUNITY IN HOOVER, ALABAMA

In a previous study commissioned by PG&E,[22] one of the underlying customer value propositions of smart home technologies was enabling security. Historically, security offerings have consisted of hardware; focused platforms connected to the telecom industry and provided by companies such as ADT and Brinks. Recent advancements in IoT have enabled low-cost, more customizable offerings tied to functionality enabled through mobile applications and connected by broadband. Figure 11, taken at a homebuilder showroom depicts interest of other market actors interested in enabling connected home ecosystems through these customer value propositions of security and connectivity. In addition, broadband service providers have shown an interest in providing similar product offerings to expand companies such as Xfinity's and Verizon's value proposition to encompass both security and comfort/convenience a shown in Figure 12.

[22] Cite 2015 HEMS report,

FIGURE 12 SMART HOME DISPLAY SHOWN AT LOCAL BROADBAND SERVICE PROVIDER

These offerings primarily focus on door locks, occupancy sensors and cameras. The trend toward enabling security through IoT has potentially led to an increase in customer interest in procuring home security systems. It is difficult to understand overall market penetration of smart home services attributed to security and telecom services as projections are anywhere from 500,000 to over a million subscribers claimed by IoT-focused home security providers such as Vivint[23] and Alarm.com[24][25]. However, it is estimated that from 2008 – 2018 there has been a 69% increase in the interest of residential customers in procuring a security system in the next twelve months.[26] In addition, there has been recent interest by consumer electronics retailers to provide not only security products, but service and maintenance plans for these products as well.[27]

In additional to the core customer value proposition of providing premise-level security, these ecosystems potentially enable core functions and technology capabilities that may be of interest to utility programs. These include:

(1) **Occupancy Sensing:** It can be assumed that the core technology of any home security system should be accurate occupancy sensing. Leveraging an understanding of whether a residential homeowner/home occupant is present could potentially manage customer comfort as well as grid management needs.

(2) **Value of Maintaining Broadband Connectivity:** Although connected devices have enabled low cost-customer provided networking options, one of the main risks associated with this is the persistence of utility connectivity to these WI-FI solutions over an extensive period of time. One potential solution to these concerns is if the a

[23] https://www.sdmmag.com/articles/92367-2016-SDM-100-Home-Run

[24] http://markets.businessinsider.com/news/stocks/Riding-High-Alarm-Com-1002159618

[25] Note for Alarm.com numbers: (1) Data is self-reported and (2) Data includes residential and commercial customers.

[26] https://www.statista.com/statistics/228854/peoplethat-plan-to-buy-a-home-security-system-usa/. This is the Neilson Scarborough report.

[27] https://www.cepro.com/article/best_buy_smart_home_service_expansion

device's or ecosystem's value proposition extends to other customer values such as security and entertainment, the likelihood of the customer maintaining broadband connectivity will increase.

While promising, it is important to note the current challenges and barriers associated with leveraging security and telecom providers for utility programs. Although general market interest in providing home security is increasing, energy optimization and aggregation offerings have been tied to partnerships with third parties (if at all). As a result, it is important to understand relationship with these third parties to vet and understand the capabilities of leveraging these ecosystems. In addition, it is important to understand market volatility of these services as there have been changes as well as overall consolidation of product offerings over the last few years in this space.[28] Table 4 details overall product capabilities of the Security and Telecom Provider subclass.

TABLE 4 TECHNOLOGY CAPABILITY SUMMARY OF SECURITY AND TELECOM PROVIDERS

FEATURE	DESCRIPTION
Definition	Connected home ecosystems built on historically security and/or telecom service platforms
Example Products	Vivint, Alarm.com, Verizon, ADT and Comcast/Xfinity
Emerging Trends	Utilities using security as an avenue to enable home automation or DSM offerings. In addition, security and telecom offerings are currently being offered as differentiators in new home communities.
Utility Initiatives	(1) An Arizona utility is investigating home automation product offerings through Alarm.com. A joint project with Alabama Power, Southern Company and Signature Homes offers Vivint Smart Home ecosystems as part of their Advanced Energy Community.[29] (2) Reliant Energy offers home security offerings through ADT, Vivint and other providers.[30]
Aggregation	**Medium:** Value propositions of security and controllability of devices within a home enable additional devices can be aggregated into utility customer offerings. Not main product offering as focus has not been historically on providing utility-facing programs, but has been known to provide interfaces for utility aggregation.
Orchestration	**Medium/High:** The primary value proposition with orchestration functions are focused on security (e.g., vacation modes and away modes).
Optimization	**Low/Medium:** Limited in the energy space. The primary focus is on orchestration. Optimization can be enabled, but usually requires third-party partnerships and there is limited

[28] https://www.cepro.com/article/verizon_moves_home_automation_to_nexia_deploys_quantum_z-wave_zigbee_router

[29] Cite Alabama Power press release for this.

[30] Cite source.

	known instances of what data to enable energy optimization is provided to third parties.

In summary, leveraging existing customer value associated with security and controllability and improvements in technology associated with consumer IoT developments, smart home ecosystem providers associated with the security and telecom industry have reached subscriber totals of over one million and show a promising Compound Annual Growth Rate (CAGR) of 26.7% into 2022.[31] Technology capabilities such as occupancy sensing provide intriguing opportunities for improved energy optimization as well as other emerging services. Stacked value propositions of security, controllability and/or entertainment will also potentially address persistence issues associated with mid-term and long-term benefits of these ecosystems.

However, it is important to understand that although promising, a utility must consider additional partnerships or leverage existing third-party partnerships to enable value propositions associated with grid-responsiveness and energy optimization as these have not been the core focus of these platforms. These third-party partnerships would be required to enable core functions of aggregation and optimization. If validation of performance is also of interest, it is important to understand the operational performance data capabilities of these ecosystems.

DEVICE AGGREGATORS

Utility interest in leveraging customer-sited mass-market connected devices and DERs over the last few years has spawned a group of services focused on developing aggregation platforms that potentially minimize the amount of utility infrastructure required to leverage these devices for DSM programs. Primarily focused on demand response functionality, these platforms were generalized as DRMSs. Typically, these platforms were built on controllability of a single type of end-use device such as Direct Load Control (DLC) switches, smart thermostats and connected wall air-conditioners. Originally, these offerings were vertically integrated with these platforms, so there was a limited amount of product providers within a particular end-use. However, recent advancements in product offerings have enabled additional offerings within particular product platforms. These increased product offerings have enabled market-enabling BYOD type platforms, potentially enabling increased market potential of existing utility offerings. In addition, advancements in technology and increased understanding of controllability of devices through existing DSM programs have potentially enabled the development of additional optimization routines that could manage grid needs with customer participation. See Figure 13.

[31] Statista: Digital Market outlook report in 2022.

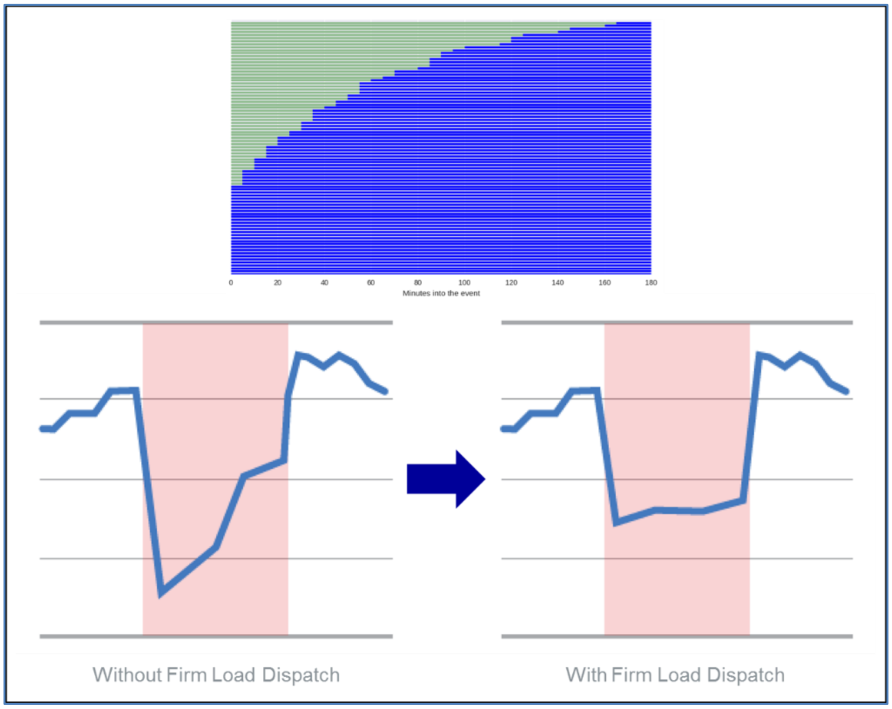

FIGURE 13: . IMPROVED CONTROLLABILITY POTENTIALLY ENABLED BY DEVICE-LEVEL AGGREGATORS

Figure 13 shows the potential of a device aggregator to control DSM events so that the events mimic generation resources.[32] The top chart shows staggered DR dispatch of devices associated with a particular utility program portfolio. The hypothesized result is the associated load shape of this resource portfolio, which more closely resembles the bottom right graph (to mimic generation) vs. the bottom left graph (typical load curve associated with a demand response event).

Not only have these device aggregators shown the extension into various products, many of these providers have also shown interest in aggregating other customer-sited DERs as well. See Figure 14. Historically, assessments have considered the opportunity to dispatch load shed commands through a single unified dashboard to different DERs that have included thermostats and EVSEs as early as 2013.[33]

[32] Cites 2016 EPRI Workshop presentation by Ben Hertz-Shargel

[33] Cite 2013 Edison International Report and Austin Energy Program from AutoGrid EVSE work.

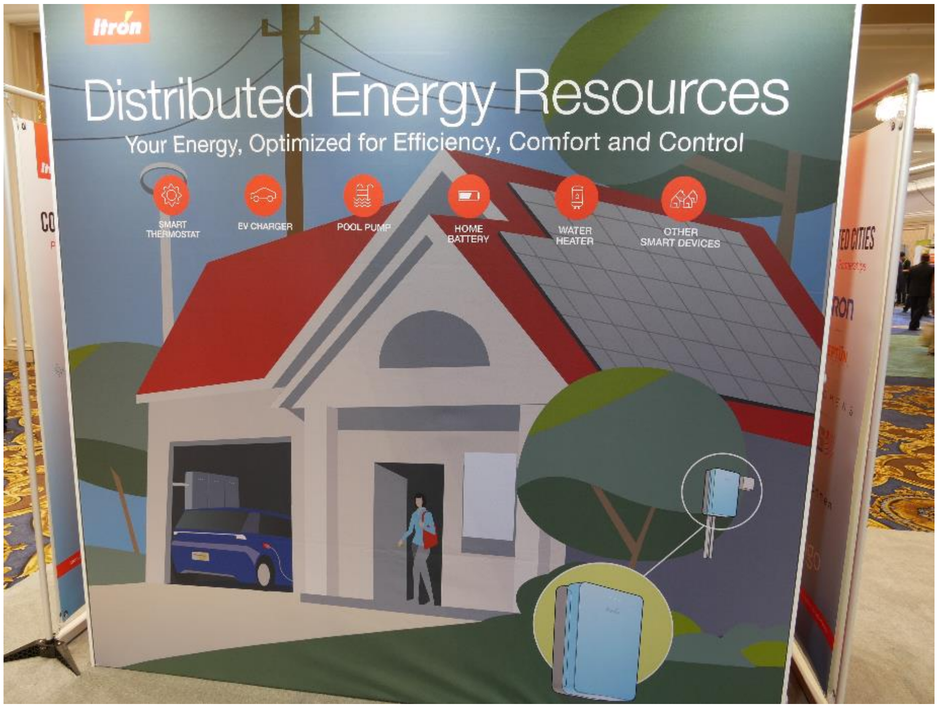

FIGURE 14: EMERGING INTEREST BY AGGREGATORS IN CUSTOMER-SITED DR AND DER ASSETS

Recent interest by these providers has also included working with residential energy storage providers of both batteries and water heaters to provide additional grid resources and assets. However, it is important to note that the coordinated control of DERs (solar inverters, residential storage and EVSEs) and DR resources (thermostats and water heaters) for a specific premise and/or community had not yet been fully vetted by the project team at the time this report was written.

Although promising, it is important to note limitations and considerations when a utility partners with these providers. First and foremost, most of these providers offer software platforms and typically have little to no interaction with the customer themselves. As a result, it is important to understand:

- **Customer support practices**: How customer support will be handled by each of the product providers which the aggregator will enable. Some of these providers have partnered with energy marketplace enablers to assist in customer support/ onboarding to address this.34
- **Variances in controllability**: Level of control of each of the end-use devices in an aggregator's portfolio depend on two main factors: (1) the business relationship between the aggregator and end-use providers and (2) the level of controls developed by the end-use providers and availability to third parties. It is important to identify level of controllability of each end-use as this determines the level of flexibility the aggregator can enable for the grid.
- **Variations in orchestration and optimization routines**: As previously discussed, emerging features of these device aggregators can potentially provide improved orchestration and optimization of utility program resources. However, it is important

[34] http://www.energyhub.com/blog/simple-energy-integration-demand-response-incentive

to understand the overall objectives of the optimization routines as well as the data used to enable the optimization routine. For example, some aggregators provide premise-level resource optimization, an approach that favors enabling building flexibility through dynamic rate signaling. However, others provide community-level resource optimization, an approach that would favor flexibility through controls signaling.

In summary, device aggregators are focused in on the main value propositions of grid-responsiveness (primary) and energy optimization (secondary) enabled by core functions of aggregation and potentially optimization. However, it is important to understand that many of these device aggregators do not offer the products themselves where the customer experience is solely through mobile applications (if any). It is important to understand relationships with the aggregator and partner providers to understand impacts to customer experience. In addition, it is important to understand and trend both: (1) number of partner product providers, (2) controllability provided by those product providers and (3) type of optimization routine implemented by these device aggregators. Table 5 provides a summary of the technology capabilities of Device Aggregators.

TABLE 5 TECHNOLOGY CAPABILITY SUMMARY OF DEVICE AGGREGATORS

FEATURE	DESCRIPTION
Definition	Ecosystems that are not necessarily connected home ecosystems, but are systems based on technology platforms that aggregate controllable end-uses within a premise or community. Most of these providers are historically Demand Response Management Systems (DRMS)s that are currently used in DSM programs.
Example Products	EnergyHub, AutoGrid, iTron/Comverge, Cooper/Yukon/Eaton, SkyCentrics, Virtual Peaker
Emerging Trends	Continued incorporation of various DERs, including energy storage, water heaters and Electric Vehicle Supply Equipment (EVSE) within their current aggregation platform. Some are improving orchestration and optimization routines to continue to mimic typical utility generation resources.
Utility Initiatives	A Kentucky utility uses a device level aggregator to optimize the use of smart thermostats, connected water heaters and battery storage to help its customers manage a residential coincident demand charge.
Aggregation	**High:** The core competency is device-level aggregation, with many key product providers focused on aggregating multiple product providers within an end-use as well as multiple end-uses and DERs.
Orchestration	**Medium/High:** Possible, but depends on the product provider and typically depends on third party support and/or partnerships.
Optimization	**Medium/High:** Some aggregators provide energy optimization, but optimization objectives need to be clarified (e.g., premise level vs. community level energy optimization).

MASS MARKET IOT PLATFORMS

FIGURE 15 MASS MARKET IOT PRODUCT OFFERINGS TRADITIONALLY FOCUSED ON SINGLE DEVICES

Since around 2012, controllable, connected devices have been of interest to both the consumer and utility marketplace. As space conditioning has historically been the largest energy use in residential applications, the development of the connected thermostat was the first enabling device to be investigated by utility programs and was the main focus of this report. The first market participants were Nest Labs and ecobee, with products appearing in the market in late 2011. Since then, growth has been significant, with an estimated 3.5 million smart thermostats sold in 2016 with Nest, ecobee and Honeywell being the three main vendors. [35] Market projections of smart thermostats have the smart thermostat market varying from anywhere between 20 million units worldwide[36] to 45 million thermostats in North America alone.[37] The variability in the estimate is due to the heterogeneous nature of data regarding values, geographic locations analyzed and growth rates.

Energy and demand impacts of these thermostats have been studied over the past five years. Whether the thermostats result in energy reduction or energy increases depends on factors such as climate zone, program market delivery channel, thermostat type and other factors.[38] PG&E has investigated energy impacts attributed to smart thermostats through deployment of thermostat assessments. The results were inconclusive in 2013[39] and revealed energy reduction opportunities in 2016[40].

Figure 15 shows that mass-market IoT has historically focused primarily on just single devices. However, platforms such as the Works with Nest platform were introduced in 2015 so vendors could include other connected devices within their product offerings. Applications to DR functionality were investigated by the project team in 2016.[41] Recent expansions by

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[35] Cite DoE BTO thermostat source.

[36] Cite Navigant Smart Thermostat Study

[37] Cite IoT analytics study.

[38] Cite EPRI 2016 Connected Device Workshop.

[39] Cite 2014 Study

[40] Cite PG&E 2017 ET Study

[41] Cite 2016 170B Base Report.

mass-market IoT providers have been primarily focused on enabling security[42] as well as home automation.[43] A summary of Mass-Market IoT Platform capabilities is detailed in Table 6.

TABLE 6 TECHNOLOGY CAPABILITY SUMMARY OF MASS-MARKET IOT PLATFORMS

FEATURE	DESCRIPTION
Definition	Ecosystems historically sold through retail channels and based on mass-market customers.
Example Products	Nest Labs, ecobee, Honeywell, LG, Whirlpool
Emerging Trends	Ecosystem expansion includes new end-uses and new device compatibility. Product providers working with utilities and energy providers to develop device optimization of operation of devices with utility signals (e.g., rates and control signals)
Utility Initiatives	Mass-Market IoT providers have conducted several utility programs, pilots and assessments over the last 10 years. However, there is very little information on utility initiatives leveraging mass-market IoT as focal points of multi-device aggregation and/or orchestration within a premise.
Aggregation	**Medium:** Some providers have the ability to provide their devices to aggregation platforms, but this varies based on aggregation capabilities and willingness. At the time this report was written, no providers have demonstrated the ability to aggregate multiple end-use devices for utility DSM purposes.
Orchestration	**Medium:** Varies by product provider, but these platforms can sometimes be included in the connected home ecosystem and included in orchestration or orchestrated control of various devices.
Optimization	**Medium:** Optimization is a core value at the device level but only potentially at the ecosystem level. Requires better understanding of optimization of devices vs. ecosystem and overall end goals of optimization.

In summary, customer experience is the main value proposition associated with mass-market IoT devices, with varying levels of interest in working with utilities to provide energy management and grid-responsiveness value propositions. Recently, these providers have taken various approaches in increasing mass market adoption of their particular technologies and ecosystems, such as providing interfaces and interoperability with other technology subclasses discussed in this report. In addition to providing these products to a subclass, recent efforts by product providers of this subclass show the possibility of being centering elements of the ecosystem themselves. When they are the sole element in a more vertically integrated solution, it is important to understand premise-level orchestration and optimization capabilities.

[42] https://nest.com/press/nest-expands-into-home-security/

[43] https://techcrunch.com/2017/05/03/ecobee-is-building-alexa-into-its-thermostats-and-light-switches/

HUB-BASED MASS MARKET ECOSYSTEMS

FIGURE 16 HUB-BASED ECOSYSTEMS ARE PROVIDED BY PROGRESSIVE HOMEBUILDERS AS SMART-HOME ENABLERS

Figure 16 shows that progressive homebuilders have an interest in leveraging products found within this technology subclass to enable smart home functionality in the new home developments. This technology subclass has many of the same characteristics as the mass-market IoT providers. The biggest difference is that where mass-market connected devices are the centering element of the ecosystem, mass-market smart home hubs require a centering gateway or "hub" to enable smart home functionality within an ecosystem. When this report was written, the largest player in this space is SmartThings, a Samsung product. Sales figures are not available, so the project team based used mobile application and online retail reviews as proxies. Based on this analysis, it is estimated that SmartThings hubs sold by the top two smart thermostat manufacturers were in the range of hundreds of thousands in 2016. However, the growth of the SmartThings platform can also be measured by the over 10,000 connected device providers that it works with, a substantial portfolio considering that the SmartThings product has been on the market for less than five years. While there are other products on the market, there does not seem to be another competitive product with the market uptake of SmartThings at the time this report was written. A summary of Mass-Market Hub-Based Ecosystems capabilities is detailed in Table 7.

TABLE 7 TECHNOLOGY CAPABILITY SUMMARY OF MASS-MARKET HUB-BASED ECOSYSTEMS

FEATURE	DESCRIPTION
Definition	Home automation systems with a centralized hub as a focal element enabling home automation
Example Products	SmartThings

Emerging Trends	Some manufacturers are embedding the hub as part of other connected devices, which increases the likelihood of the device maintaining connectivity.
Utility Initiatives	None identified.
Aggregation	**Medium:** Requires additional third-party development as this has not been a focus.
Orchestration	**High:** The core value proposition is the ability to control multiple end-uses.
Optimization	**Medium:** Possible, but requires additional development as this has not been the core focus of these technology subclasses.

Although promising for energy optimization and grid responsiveness, hub-based ecosystems have not developed in these areas as the core function enabled by these providers is orchestration and control of multiple connected devices within a premise. In addition, many residential IoT providers have shown interest or have already begun embedding hub-based functionality within other connected devices. Televisions, refrigerators[44] and residential lighting fixtures[45] (the "device as a hub" concept) have been the focus areas of embedding hubs functionality by product providers. It will be important to understand how important energy management/optimization and grid-responsiveness is to these hub-based ecosystems in the future as it has not historically been the focus.

TRADITIONAL TRADES

HVAC and water heaters providers have primarily focused on the development of heating, cooling, ventilation and water heating systems. The word "customer" to these technology subclass providers usually does not refer to the residential customer themselves, but the HVAC and plumbing trades that service these residential customers as well as home builders, developers and architects that specify their products.

Recent interest in providing improved connectivity for the grid and, more importantly the residential consumer has led to many of these traditional trade providers investigating developing ecosystems to encompass their products. Capabilities of these Traditional Trades are detailed in Table 8.

TABLE 8 TECHNOLOGY CAPABILITY SUMMARY OF TRADITIONAL TRADES

FEATURE	DESCRIPTION
Definition	Ecosystems based on conventional residential end-use product providers providing connected products that are part of an overall home automation systems.
Example Products	Trane/Nexia, Carrier, Rheem, AO Smith

[44] https://techcrunch.com/2017/01/04/lg-smart-hub/

[45] https://www.techhive.com/article/3022773/lighting/sonys-new-smart-light-does-just-about-anything-you-can-possibly-think-of.html

Emerging Trends	Traditional HVAC and water heating providers are moving toward offering more home ecosystem capabilities on their higher-end products.[46]
Utility Initiatives	None identified.
Aggregation	**Medium/High:** Many providers have some form of fleet-level management system to enable trade value propositions such as Fault Detection and Diagnostics (FD&D)
Orchestration	**Medium:** Has not been the core-focus of these providers, but potentially can be made available within a provider's particular ecosystem or by providing their products to other technology subclasses.
Optimization	**Medium/High:** Potentially these providers should understand their particular systems better than other third parties, but this needs to be further evaluated.

Traditional trades provide unique opportunities for partnerships as they have the following advantages over technology subclasses:

- **Better understanding of the systems that they control**: As they also manufacture the HVAC and water heating systems, they should have a better understanding of the data returned from the overall ecosystem than a third party. This could potentially result in deeper insights into the operational performance characteristics of controlled systems within the ecosystem.
- **Fleet level asset management**: Similar to device aggregation platforms provided by some of the other technology subclasses, these providers usually have asset management systems in place for trade allies and preferred service contractors of their systems that receive information on operational performance. This potentially provides FD&D capabilities to provide predictive maintenance suggestions to building owners, occupants and/or managers. This is very important as changes to HVAC and/or water heating typically come during non-operational or improper operation scenarios. Prediction and prevention of failure is an important method to minimize customer complaints due to inoperable systems. It is important to understand the exact capabilities of these fleet asset management systems as they vary from one product provider to another.

[46] Cite Rheem Econet

MONITORING-FOCUSED ECOSYSTEMS

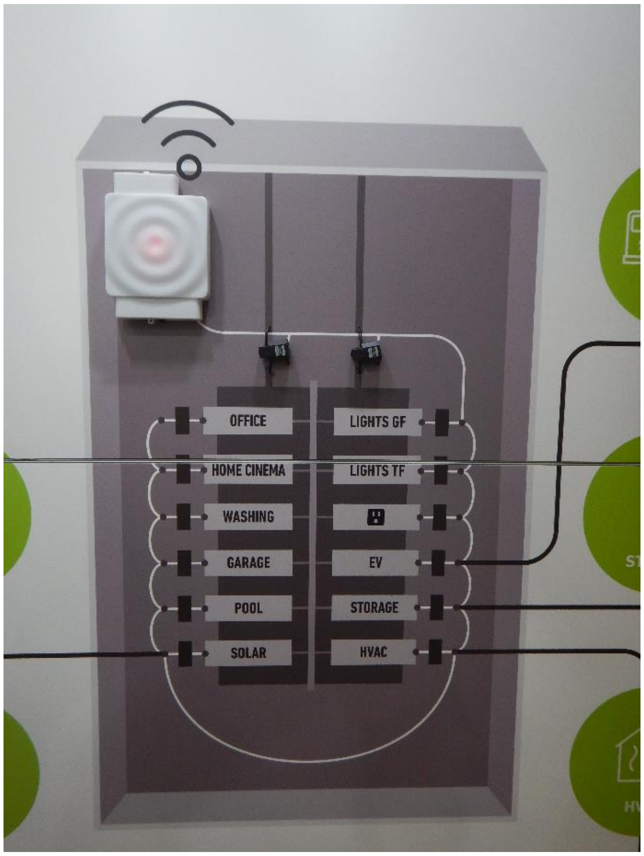

FIGURE 17 MONITORING FOCUSED ECOSYSTEMS CAN COLLECT HIGH-RESOLUTION DATA FOR BETTER LOAD ATTRIBUTION

A 2010 American Council of Energy Efficient Economy (ACEEE) study shows that 4-12% energy reduction can potentially be realized through the use energy feedback tools focused on energy monitoring.[47] Data monitoring-focused ecosystems can be divided into two-subcategories:

- **Non-Intrusive Load Monitoring (NILMs):** Refers to measuring electric power or energy at the whole premise to estimate energy use attributed to individual end-loads within that premise. Premise-level data can either be gathered through circuit level monitoring at the main panel level or collection of AMI data.
- **High resolution data monitoring equipment:** Typically, "customer data" as defined by the utility constitutes either quantitative data identified by AMI infrastructure or qualitative data obtained through customer surveys. This report will differentiate this subcategory from NILMs as circuit-level monitoring at a higher level of detail (monitoring at circuit level vs. home level). Typically, this is done by circuit breaker level metering from product providers such as SiteSage, Schneider Electric and Curb.

Common to both are dashboards or User Interfaces (UI)s provided to residential customers. An example of an energy dashboard is shown in the Figure 18:

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47 http://aceee.org/sites/default/files/publications/researchreports/e105.pdf

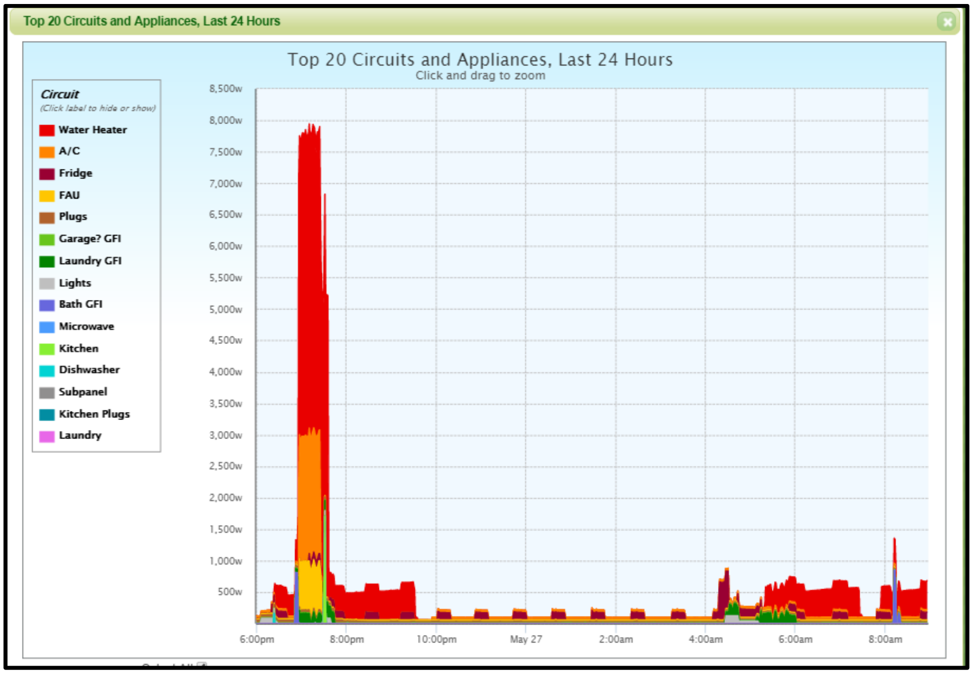

Figure 18 Sample Dashboards of Data monitoring at the Circuit Breaker Level

Most products within this subclass are based on the hypothesis that energy feedback provided to residential customers can result in reduced energy consumption. Since the technology relies on feedback mechanisms intended to invoke behavioral response, it can be assumed that the success of product providers within this technology subclass will be based on usability and messaging provided by the product's UI.

An emerging function is the ability to not only monitor but control devices as well. However, control of these devices will typically be at the circuit breaker level so it is important to understand the implications and risks associated with load-level control of various circuits within a residence. Data monitoring ecosystem capabilities is summarized in Table 9.

Table 9 Technology Capability Summary of Monitoring-Focused Ecosystems

Feature	Description
Definition	Systems based on monitoring equipment that disaggregates premise-level loads and/or monitors circuit level loads.
Example Products	Bidgely, Chai Energy, Eaton, Rainforest Automation and Curb
Emerging Trends	Some product providers are embedding monitoring-focused industry technology into industry infrastructure, such as electricity panels and/or circuit breakers. Some product providers are also consolidating product offerings on AMI meter reading or data monitoring vs. developing additional device controllability.
Utility Initiatives	Several electric utilities are investigating the capabilities of a smart electric circuit breaker.[48] Other utilities have evaluated

[48] Cite Energy Management Circuit Breaker Project

	impacts of leveraging load disaggregation technologies for residential DSM programs.
Aggregation	**Medium/High:** Ability to aggregate data from multiple premises and many of them have some form of fleet-level platform to manage multiple premises.
Orchestration	**Low/Medium:** Limited to no functionality in general, although some platforms provide some level of controllability. Most orchestration is based on information that drives behavioral change.
Optimization	**Low/Medium:** Limited to no functionality. Mostly based on information that drives behavioral change.

The core value proposition of monitoring-based ecosystems is providing residential customers with tools for energy management. As a result, it is important to understand all functions of these technology subclasses associated with the customer experience. Possible metrics for assessment include: (1) ability of UI to understand persistence of use of the energy dashboard and (2) how the products within the subclass will improve the customer experience.

DER-Based Management Ecosystems

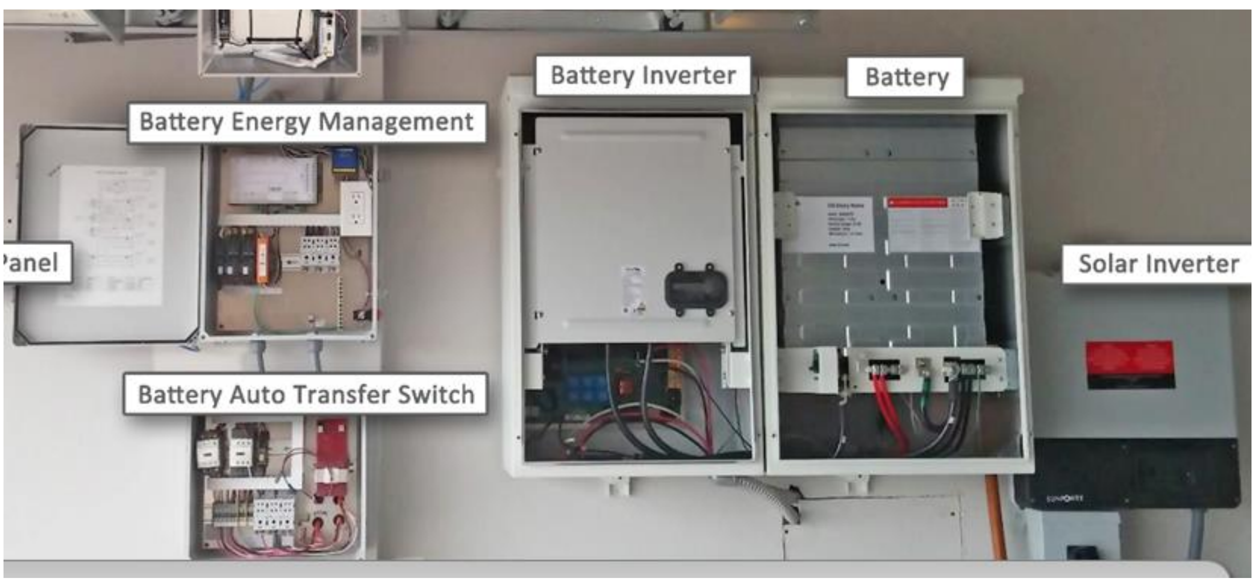

FIGURE 19 DER-BASED MANAGEMENT SYSTEM INSTALLED IN SOUTHERN CALIFORNIA

Interest in management of customer-sited DG on the electric grid has resulted in a similar interest in energy storage and smart inverter products. Figure 19 shows a particular Southern California system with an interest in management of these customer-sited resources. In turn, associated Battery Energy Management Systems (BEMS) were created to manage solar/energy storage assets at the premise level. The project team identified interested by some providers within this technology subclass in increasing their portfolio of controllable loads to include customer-sited DERs other than energy storage.[49] However,

[49] https://www.greentechmedia.com/articles/read/solarcitys-system-for-self-supply-in-hawaii-includes-pv-storage-water-he

recent interviews with many of these providers indicate a consolidation of focus to premise and/or fleet-level management of various solar/storage assets within a community. The interviews only identified one possible product provider in this technology subclass that is looking to expand its integration offering to include DERs other than solar and storage. A summary of DER-Based Management Systems ecosystem capabilities is detailed in Table 10.

TABLE 10: TECHNOLOGY CAPABILITY SUMMARY OF DER-BASED MANAGEMENT SYSTEMS

FEATURE	DESCRIPTION
Definition	Technology and platform foundations based on energy monitoring and control of customer-sited solar and storage loads.
Example Products	SunPower, Tesla, Sunverge, eGear, Sonnen, SunRun
Emerging Trends	While some providers have interest in including DERs outside solar/storage optimization, others have consolidated product offering to focus on the core competency of solar/storage optimization.
Utility Initiatives	Arizona Public Service (APS) is leveraging Sunverge batteries as part of its customer-sited storage program. Hawaiian Electric Company (HECO) deployed a solar/storage/ thermostat/water heater program in 2016.[50]
Aggregation	**High:** Most providers have some form of fleet level aggregation platform.
Orchestration	**Low/Medium:** Not many (if any) provide orchestration capabilities as the core focus is solar/storage asset management.
Optimization	**Medium:** Optimization routines are focused on solar/storage optimization.

Although utility value propositions of energy management and grid responsiveness shows promise for this technology subclass, it is important to understand the customer value of residential energy storage. In addition, it will be important to track progress of product providers found within this technology subclass and their interest and progress with integrating with other customer-sited DERs could potentially increase its value in core functions such as orchestration and optimization.

SOFTWARE-BASED ENERGY OPTIMIZATION ECOSYSTEMS

Providers of these ecosystems, similar to others, do not develop the equipment themselves, but develop optimization routines leveraging data collected from partner device providers as well as outside resources such as environmental information that builds energy and comfort models. This potentially results in energy optimization, the main value proposition of this technology subclass. Many of these product providers have roots in developing optimization models for particular devices such as smart thermostats. With the increasing interest in an ecosystem approach, many of these providers are interested in developing energy and comfort models that optimize the multiple end-uses found within the premise. A summary

[50] Cite HECO program in 2016.

of the technology capabilities of Software-Based Optimization Ecosystems is provided in Table 11.

TABLE 11 TECHNOLOGY CAPABILITY SUMMARY OF SOFTWARE-BASED OPTIMIZATION ECOSYSTEMS

FEATURE	DESCRIPTION
Definition	Software-based products that partner with product provider(s) that collect and provide additional data parameters to optimize the operation of connected end-use loads within a premise and/or community
Example Products	Whisker Labs, Tendril
Emerging Trends	Incorporation of additional connected, end-use technologies that optimize premise-level performance or fleet-level performance.
Utility Initiatives	Xcel Energy is deploying Tendril, which aggregates AMI information and smart thermostats for utility DR and EE programs.[51] The City of Fort Collins uses Whisker Labs to enable integrated EE and DR programs.[52]Hawaiian Electric Company (HECO) is looking at providing a solar/storage/thermostat/water heater program in 2016.[53]
Aggregation	**Medium/High:** Ability to aggregate data from multiple end-uses and premises. Dependent on relationship with project partners.
Orchestration	**Medium/High:** It appears there are providers that are developing this functionality.
Optimization	**High:** Many of these products are moving toward optimization use cases for the utility and customer. Can be considered a key core function.

Leveraging the key value proposition of energy management and optimization, there is a potential for utilities to leverage this subclass to enable programs and services. However, as products and services within this technology subclass does not necessarily provide the products themselves, it is important to understand these considerations:

- **Customer support practices:** How customer support will be handled by this technology subclass and/or the product providers.
- **Variances in controllability:** Like device aggregators, the level of control of each of the end-use devices depend on two main factors: (1) the business relationship between aggregators and end-use providers and (2) the level of controls developed by the end-use providers and availability to third parties.
- **Variations in optimization routines:** As previously discussed, these providers typically develop energy and comfort models to optimize energy performance of their ecosystem with the intention of not affecting occupant comfort. It is important to understand and vet these optimization routines before mass deployment.

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[51] Cite Utility Dive Article

[52] Cite City of Fort Collins Offering.

[53] Cite HECO program in 2016.

SUMMARY:

This section proposed a methodology for dividing connected home ecosystems based on nine technology subclasses and then assessed each as a group through a set of core functions (aggregation, orchestration and optimization). The results of this analysis are summarized in Table 12.

TABLE 12 EVALUATION OF TECHNOLOGY SUBCLASSES AND CORE FUNCTIONS OF CONNECTED ECOSYSTEM

TECHNOLOGY SUBCLASS	ABILITY TO AGGREGATE	ABILITY TO ORCHESTRATE	ABILITY TO OPTIMIZE
Voice Assistants	Medium/High	High	Medium
Security and Telecom Providers	Medium	Medium/High	Low/Medium
Device Aggregators	High	Medium/High	Medium/High
Mass-Market IoT	Medium	Medium	Medium
Hub-Based Mass Market Ecosystems	Medium	High	Medium
Traditional Trades	Medium/High	Medium	Medium/High
Monitoring-Focused Ecosystems	Medium/High	Low/Medium	Low/Medium
DER-Based Management Ecosystems	High	Low/Medium	Medium
Software-Based Energy Optimization Ecosystems	Medium/High	Medium/High	High

The tables in this section show that although there are technology subclasses with the infrastructure to support core value propositions, none of the subclasses, in general, enable the core functions and, in turn, unlock the associated high-level value propositions. When assessing a product offering, therefore, little to no vertically integrated connected home ecosystems can be identified. The result is technology and service partnerships requiring existing interdependencies that are hard to decouple. These interdependencies and issues with product stability and volatility are main concerns as utilities identify customer programs using with these systems that are associated with rapid technology change. The high-level outcome is that aggregation is the most developed core function followed by orchestration and then optimization. Many of the connected ecosystems provide some form of device or multiple device level aggregation. Utility or fleet level portals are common for most of the technology subclasses and provide core value propositions for each technology subclass. However, as energy drivers such as energy management are not the main customer value proposition, energy optimization is usually not the first priority of many of the technology subclasses.

This deep dive into the nine subclasses revealed the following four high-level takeaways:

- Portable wireless speakers/voice assistants and smart home kits are both expected to have over 55% CAGRs.[54] With new channels such as homebuilders interested in providing these products as standard, it is important to better understand how to develop the appropriate technology to enable core functions of connected ecosystems.
- The level of orchestration is driven by the product provider's ability to provide controls and associated data to validate those controls. If a utility or third party is working with software–focused products with no actual hardware, it is important to understand the business relationships of these technology subclasses with the product providers that it claims to be integrated with as well as the controls that can be made available by the end-use devices themselves.
- Various technology classes such as device aggregators, DER-focused providers and software optimization products provide unique opportunities to optimize customer connected devices and ecosystems. However, it is important to understand key objectives of the optimization routines and potential issues with the optimization routines when deployed at scale.
- DER providers provide a unique opportunity to manage both distributed generation and end-use loads within a premise. These ecosystems also usually have some form of local controller or local energy management system, making these ecosystems potentially less susceptible to disruptions to broadband services. However, it is important to assess the overall value of emerging technologies such as customer-sited storage, in particular in residential applications, as well as DER providers' development roadmap to understand each provider's intention to include DERs other than customer sited solar and storage. This can potentially indicate the particular product provider's ability to enable premise level orchestration and optimization.

This section demonstrates that no technology subclass is able to satisfy the three high-level value propositions as there are no technology subclasses that completely execute the three core functions of a connected ecosystem. The following section will go into detail about grid and customer value propositions and examine how data can be used and leveraged to valuate and attribute these to specific functions

[54] Consumer Technology Association; 2017 Statista estimates

EVALUATING CORE VALUE PROPOSITIONS OF CONNECTED ECOSYSTEMS

As Section 2 focuses on core functions of connected home ecosystems (the "what" these ecosystems provide), this section will be a deep dive into the core value propositions of the connected home (the "why" these ecosystems provide what they do). To accomplish this task, it is important to understand the three core value propositions associated with connected ecosystems when they are considered by an energy provider or utility. These core value propositions are:

1. **Customer Engagement:** As energy companies and utilities try to improve overall customer experience in order to provide additional energy services, retain and recruit energy customers[55] and improve overall customer metrics such as JD Power scores, these energy companies and utilities can leverage the inherent market pull and data collected by these connected home ecosystems to improve the delivery of existing customer programs, provide additional energy services and improve overall customer experience and overall engagement.
2. **Grid-Responsiveness:** Increases in behind-the-meter DERs will result in the need for more flexible energy management by utilities both at the Independent System Operator (ISO) as well as the Distribution System Operator (DSO) level. Many energy providers are investigating grid-responsiveness of these behind-the-meter devise to enable grid-flexibility.
3. **Energy Cost Management:** Many utilities and energy providers are investigating new, more dynamic rates to match actual costs of energy to larger portions of its residential customers. In California IOU service territories, Time of Use (ToU) rates will be the default rate for residential customers in 2019. Many other utilities across the country have piloted other forms of dynamic rates which include Critical Peak Pricing (CPP) and/or demand charge components. As a result, utilities and energy companies are investigating these connected home ecosystems as energy cost management tools to help their customer manage dynamic energy environments.

As the main focus of this report is to investigate value stacking or how single technologies or products from certain technology subclasses can enable multiple value propositions, this report will dive deep into these three core value propositions and identify specific use cases that a utility or energy company can potentially enable by leveraging connected home ecosystems. The use cases will then be defined by using a set of functional requirements and then assessed for technical and market maturity and identified as short (available within the next 3 years) medium (possible within the next 3-5 years) and long term (over 5 year) use cases. This project will also pose research questions that a utility or energy company needs to consider for each of these use cases. It is important to note that some use cases are divided up into phases to better understand short, medium and long term feasibility associated with each use case. Finally, the technology subclasses defined in chapter 2 will be evaluated for their ability to enable and/or support each use case.

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[55] In competitive retail energy markets

Table 13 summarizes how each technology subclass current ability to provide the core value propositions associated with connected home ecosystems

TABLE 13 CORE VALUE PROPOSITION OF CONNECTED HOME ECOSYSTEMS

TECHNOLOGY SUBCLASS	CUSTOMER ENGAGEMENT	GRID-RESPONSIVENESS	ENERGY COST MANAGEMENT
Voice Assistants	High – Key value proposition is improved engagement.	Medium – Requires third party integration and device orchestration	Medium/High – Can be used as another method to message changes in energy cost and optimize based on preference
Security and Telecom Providers	Medium/High – Focus in on security and entertainment offerings	Medium – Requires 3rd party is not main focus	Medium – Potentially, but requires 3rd party integration
Device Aggregators	Low/Medium – Not-real focus and reliant on partnering IoT providers	High – Core value proposition	Medium – Can provide energy cost management
Mass-Market IoT	High -Key value proposition	Medium/High – Many have experience in DR programs	Medium/High – Many providers working w/ utilities developing algorithms for energy cost management.
Hub-Based Mass Market Ecosystems	Medium/High – Dependent on end-use IoT providers	Medium – Potential, but has not been core focus	Medium – Requires 3rd party development
Traditional Trades	Medium – Potential, but not has been historic focus	Medium – Has not been historic focus, but recent interest	Medium – Has not been historic focus, but recent interest.
Monitoring-Focused Ecosystems	Medium – UI/UX dependent	Low/Medium – Limited controllability by some providers	Medium – Provides increased attribution of energy cost but limited controllability
DER-Based Management Ecosystems	Medium – For DERs and limited for other end-uses	High – Core value proposition	Medium/High – Can potentially provide energy-cost management
Software-Based Energy Optimization Ecosystems	Medium – Dependent on end-use device providers	Medium/High	Medium/High

Table 13 shows that currently, no technology subclasses provides all three core value propositions at a high level. This has resulted in a market of product provider partnerships to enable many full product offerings. To better understand which technology subclasses are best suited to stack multiple energy and non-energy benefits for utilities and energy companies, it is important to dive deeper into specifics as it pertains to particular use cases that connected home ecosystems can provide.

CONNECTED HOME ECOSYSTEM USE CASE ASSESSMENT

To better understand the opportunities, from a customer programs, energy services and grid-management perspective, it will be important to understand and define the potential value propositions associated with utilities leveraging these connected ecosystems. To do so the steps this report takes is to (1) define the potential use case, (2) assess technology and market maturity of connected ecosystems servicing this use case, (3) how connected ecosystems improve these current state and (4) define a list of functional requirements associated with each use case. Finally, two technology subclasses will be identified as the best enablers that have the technology infrastructure and market drivers to enable a particular use case. Additionally, 3 technology subclasses are identified that can support a use case. A technology subclass's ability to enable can be defined in this report as that products classified in that particular technology subclass has the ability to be a centering ecosystem of a particular use case. Support use case can be defined as that products of that particular technology subclass has the technical characteristics and market factors that allow the products of that technology subclass to participate in a particular use case. Support also means that these ecosystems can also be enablers, but additional development and business relationships need to be created. It is important to note that although only 2 enablers and 3 supporters were identified for each use case, it is possible that other products within each subclass can enable and/or support these use cases. A summary of the results of that analysis are detailed in Figure 20

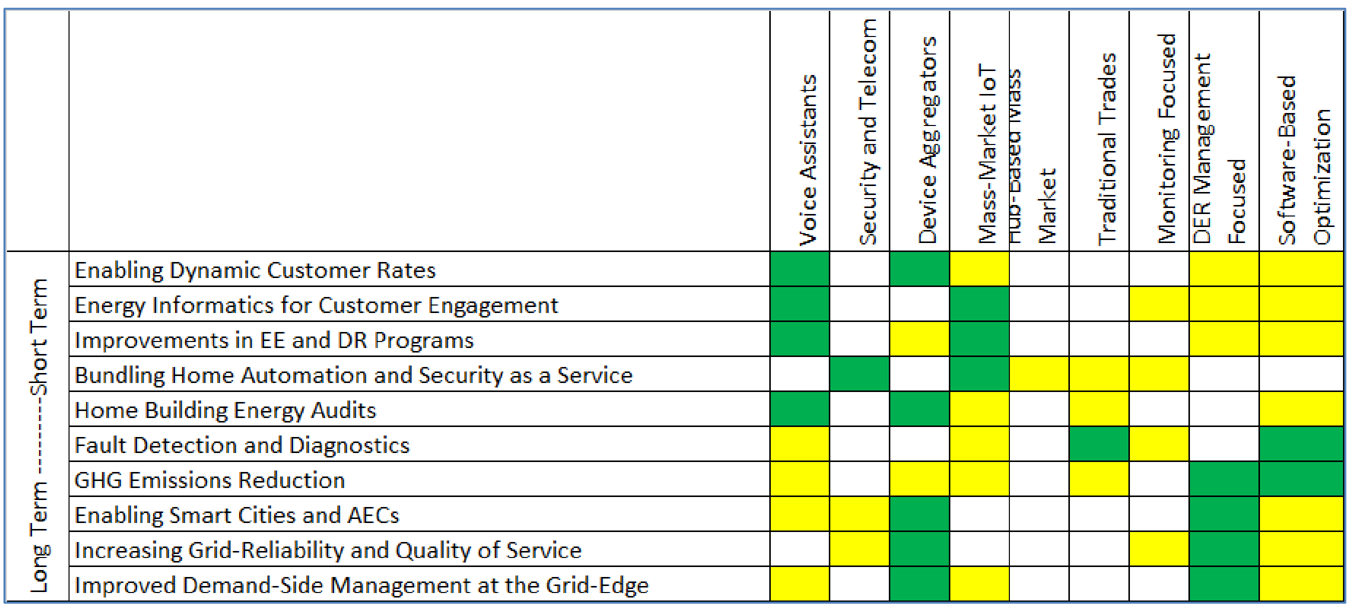

FIGURE 20 USE CASE ANALYSIS RESULTS FROM TECHNOLOGY SUBCLASSES

Note that Figure 20 also shows determination of technology and market maturity associated with connected ecosystems servicing these particular use-cases. What is important to note here is customer-facing use cases enabled by core value propositions of customer engagement (primarily) and energy cost management (secondarily) are ready in the short term, while use cases focused on grid management and flexibility are more medium term and long term use cases. This is a result of a market currently focused on deployment of customer-facing products and services. The next part of this section will dive deeper into particular use cases, with specific focus on the short to mid-term use cases.

Improvements in Energy Efficiency and/or Demand Response Programs

Connected ecosystems possess the potential to improve the delivery of EE and/or DR programs. For example, on the EE side, customer rebates and/or incentives provided to the customer are based on deemed values quantified through field trials or estimated using energy calculation tools. The result is a detailed Measurement and Verification (M&V) procedure. One proposed method of improving this process is to move from deemed values associated with potential EE benefits of particular technologies, but providing incentives on a pay-for performance basis. Pay-for-performance programs can be defined an incentive structure based on savings estimated through data collection during a performance period. A report commissioned by the National Resources Defense Council (NRDC) with the support of the Vermont Energy Investment Corporation (VEIC) provides a fairly comprehensive list of pay-for-performance EE programs conducted in the United States.[56] These programs require continuous data validation and auditing associated with energy-related performance. Improvements in program delivery such as pay-for-performance EE programs could potentially use a combined set of AMI data to calculate EE impacts while an aggregated set of connected home ecosystem data can be used map energy reduction to particular measures and interventions. These ecosystems could potentially be used as: (1) data aggregation tools to validate savings and (2) device orchestration and energy optimization platforms that coordinate the control of multiple end-uses within a premise.

For DR, reduction in customer acquisition cost, improvements in customer comfort in DR events and aggregation of multiple connected devices through a single utility aggregation platform to reduce infrastructure cost of managing DR programs now and in the future. For example, San Diego Gas and Electric (SDG&E) is looking to aggregate multiple residential end-uses to provide whole-home demand response - DR where multiple end-use systems within a premise are triggered by a single DR signal delivered by the utility either through an in-home gateway. SDG&E is investigating three approaches to enable whole home demand response: (1) a standards-based approach, (2) a hub/AMI-based approach and (3) API-based approach. Whole home DR can be defined as both aggregation and orchestration of control of 2 or more end-use loads within a premise. The concept enables a single reference call for DR events compared to the use of multiple DR portals and dashboards to enable different end-uses. There is also a potential to use data from the various devices to optimize response based on max load shed while accounting for customer preference. Connected home ecosystem could potentially enable whole home demand response so that the system would: (1) Aggregate and/or orchestrate at least 2 end use loads or DERs within a premise, (2) understand customer preference via inputted or predictive feedback during a demand response event and (3) validate response and evaluate customer energy impacts to an event using a combination of devices and utility-provided data. Ecosystems could potentially be used as: (1) an aggregation tool to control multiple end-use loads through a single utility point of control, (2) orchestrate control of multiple end-use devices and (3) possibly develop and/or work with other third parties to develop energy/comfort optimization routines.

This report identifies mass-market IoT as an EE and DR program improvement enabler for its inherent ability to potentially to collect data associated with these devices. These providers also have the opportunity to orchestrate and develop and/or partner with third parties to develop orchestration and/or optimization routines that enable many of the

[56] https://www.nrdc.org/sites/default/files/pay-for-performance-efficiency-report.pdf

functional requirements needed to improve current EE and DR program delivery. Two outstanding research questions associated with partnering with mass-market IoT providers is: (1) If orchestration and optimization routines are implemented via mass market IoT ecosystems, what is the effect on customer comfort when implementing the energy/demand optimization routine? And (2) What is the achievable energy and/or demand potential associated with the connected devices and ecosystems that the ecosystems integrates or can be integrated with.

Voice assistants also is identified as an EE and DR program improvement enabler through its ability to orchestrate multiple customer end-uses and other products and ecosystems associated with other technology subclasses. In addition, voice commands and alerts can be programmed to provide users feedback for example on when demand response events are occurring. Voice assistants could also provide another method (through voice commands) of responding or opting out of a demand response event. The next phase of development can potentially collection of data through the use of parameters that can be used for proxies for occupancy and analysis of historic responses to DR events to automate response.

ENABLING DYNAMIC CUSTOMER ENERGY RATES

Enabling dynamic customer rates is using connected ecosystems to enable both monitoring, control and/or optimization of connected devices in a dynamic utility rate environment (ToU, CPP, demand, etc.) The connected home ecosystem concept potentially enables a single point of asset monitoring, management and coordinated control of multiple devices within a premise. In addition, current optimization algorithms are usually silo' d within a device. There is an opportunity to optimize responses of multiple devices based on utility rate signals and customer preference. In order for a connected ecosystem to enable dynamic customer rates, the ecosystem must be able to receive signals from the utility, must be able to orchestrate and optimize control of 2 or more end-use loads or DERs within a premise, (3) understand customer preference via inputted or predicted feedback of certain rate signals and (4) validate response and evaluate customer and energy impacts to an event using a combination of devices and utility provided data.

Currently, Consolidated Edison (ConEd) in New York is piloting a Smart Rate Pilot in which the utility is looking at understanding customer responses to dynamic rate signals and how connected devices such as smart thermostats and DERs such as customer-sited energy storage systems can help customers manage energy consumption.[57] The pilot is summarized in Figure 21.[58]

[57] https://www.coned.com/-/media/files/coned/documents/business-partners/business-opportunities/smart-home/rev-demo---smart-home-rate-rfi-track-1.pdf?la=en

[58] Cite ConEd Smart Rate Presentation

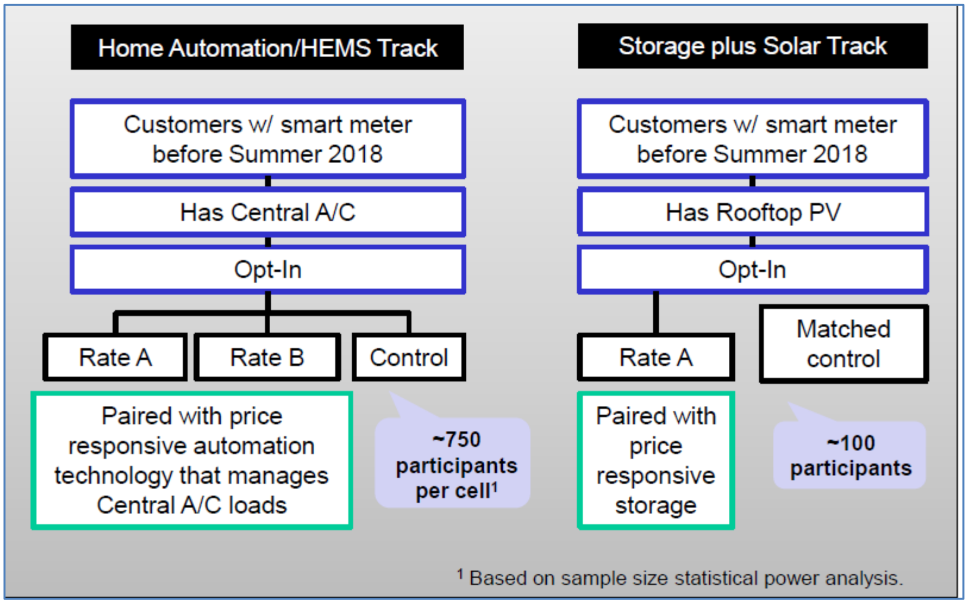

FIGURE 21 CONED SMART RATE PILOT DESIGN FOR HOME AUTOMATION AND ENERGY STORAGE

Figure 21 shows that the two tracks, home automation and solar plus storage, will focus on control of single loads, HVAC and storage respectively, to help respond to dynamic rates. Connected ecosystems potentially offer the opportunity to coordinate control of multiple end devices and DERs within a premise.

Another project exploring dynamic rates is being led EPRI. Through funding from the California Energy Commission (CEC), EPRI is developing and Open Demand-Side Resource Integration Platform used to show how dynamic rates can be sent by a utility to a group of mass-market connected devices and DERs. Figure 22[59] represents an example scenario on how multiple end-use devices can be respond (both monitored and controlled) to specific rate signals. As the figure shows, most mass market connected devices requires a single point of aggregation, usually located via some form of cloud-based aggregation platform that serves as an aggregator of utility rate signals, residential device optimization routines and data collected from mass-market connected devices.

[59] Cite Open DSRIP presentation to the CEC.

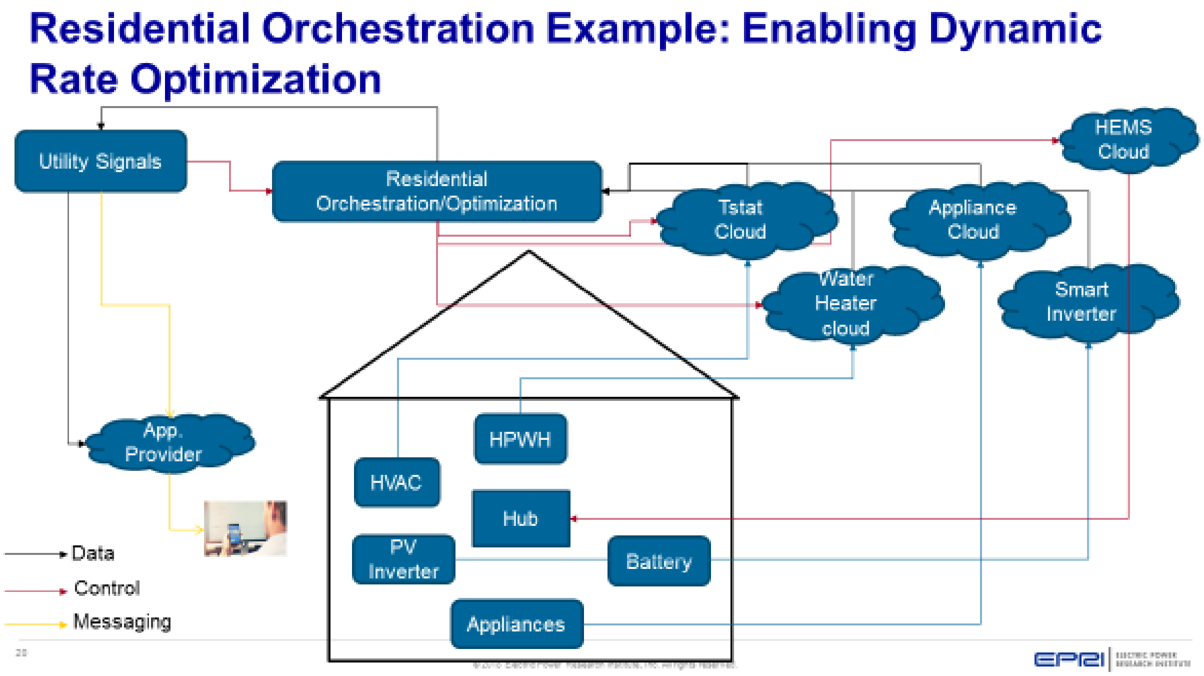

FIGURE 22 CONNECTED ECOSYSTEM ARCHITECTURE (ONE OF MANY) THAT ENABLES DYNAMIC RATE MANAGEMENT

Device aggregators and voice assistants were identified as use case enablers as they currently have capabilities to both aggregate and orchestrate the largest amount of connected devices in response to dynamic rate signals provided by the utility. In addition, voice assistants provide novel ways to: (1) provide a message to a customer of rate changes and (2) orchestrate energy optimization routines previously defined by the customer. Existing gaps and research questions include what is the level or orchestration and control that these platforms provide? For example, investigation of device integration shows limitations as far as controllability of DERs such as EVSEs when leveraging voice assistants. This assessment shows that only data to understand what the EVSE is doing and not controls of what the EVSE should do can be leveraged through the use voice commands enabled by products associated with the voice assistant technology subclass. It is important to understand level of device integration when partnering with particular voice assistant and device aggregator providers.

A potential development strategy with the use of voice assistants is to first develop an energy company or utility Amazon Alexa Skill and/or Google Home Action that alerts the customer of changes in the cost of energy. The next step would be to identify connected devices and DERs that allow voice assistants to either collect data or control those particular devices. The next step would be to investigate enhancement of the energy program-related skill or action to include knowledge of a combination of energy optimization and customer preference. A final, longer term enhancement is to aggregate data collected from both responses as well as data from connected devices and provide a more predictive version of the device orchestration in response to customer events where devices are orchestrated based on historic customer responses to particular rate signals. See Figure 23 for depiction of the three phases of enabling dynamic customer rates.

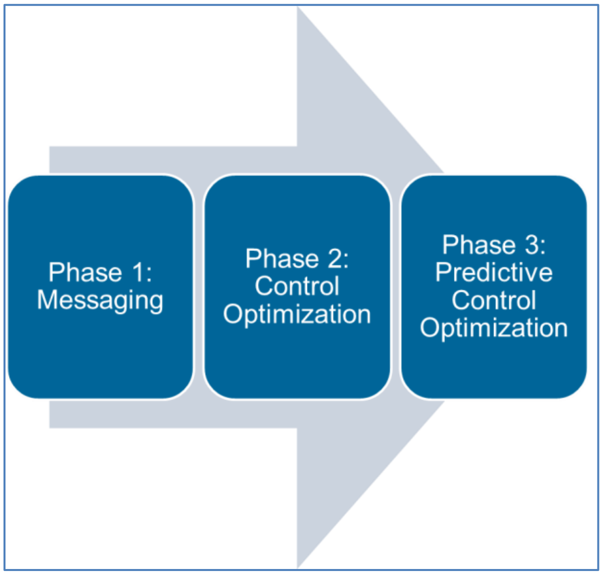

FIGURE 23 THREE-PHASED APPROACH TO PROVIDING SERVICES TO ENABLING DYNAMIC CUSTOMER RATES

It is expected that level of controllability and automation will vary from one customer to another. However, the three phased approach provides options for utility customers to choose the level of automation desired, resulting in the ability for a utility or energy provider to provide personalized levels of responses based on customer rates.

In addition, one may notice that there is a potential to use historic responses and data collected from connected home ecosystems to help better provide customer services, rates and programs to the customer. See the next section for greater details.

ENERGY INFORMATICS FOR CUSTOMER ENGAGEMENT

Energy informatics can be defined as using data and communication capabilities of connected ecosystems to provide energy information – utility facing and otherwise. The connected home ecosystem concept enables an aggregated set of information retrieved from data from multiple devices as opposed to just utility information and/or single device information. The hypothesis is that data in the aggregate provides a greater picture of customer preference, building performance and energy usage than data in silos or premise-level AMI, typically defined by utility as the "grid-edge" data.

To complete this use case, if attribution is important to an energy provider, the ecosystem should disclose how data is used estimated, calculated and measured to create the insights, message and other services provided.

Voice assistants and mass market IoT connected ecosystems were chosen as enablers. Voice assistants provide a new way of collecting information. For example, these ecosystems offer an opportunity to interact with the customer as well as collect data from their respected devices on how customers are using their systems. There is a potential for energy providers to leverage this data to help better understand how customers are using energy-related connected devices. This information can be leveraged into better product offering such as ideal rates for the customer as well as potential additional energy efficiency, demand response and/or other energy related services that he/she may be interested in.

For example, when a customer interacts through a utility-created program created through the use of voice assistants, he/she may be prompted to answer a few simple questions to better understand his/her propensities for adopting certain energy-related services. This "conversational intelligence" can be paired with "ambient intelligence' collected from the customer through device sensors on he/she historically uses devices found within that connected home ecosystems. Both result in personalized utility offerings enabled by voice assistants.

Although there are opportunities, there are still outstanding research barriers associated with the use of connected ecosystems for energy informatics. First, although premise-level orchestration or control is available, this does not mean that device-level data is aggregated or shared with third parties. In many cases, a separate pathway is required to aggregate data from multiple customer end-use devices, a requirement to enable energy informatics. This is primarily a result of a combination of security and privacy concerns associated with data aggregation that potentially could aggregate data and/or limited infrastructure or business need to aggregate data that enable energy informatics.

Research is ongoing in the energy industry as it pertains to customer energy informatics that can be gleaned directly for analysis of AMI data, with many products such as Grid4C that focus on providing customer insights on performing data analysis of just AMI data. It is important to assess the value and potential of providing personalized utility product and service offerings that can be realized by just using AMI data in parallel with investigation of incorporating device level data and data collection tools achievable through connected home ecosystems before full scale integration of device data into utility business systems such as Customer Information Systems (CIS).

HOME BUILDING ENERGY AUDITS

The use of environmental, occupancy, customer preference and other available data to determine building characteristics to enable utility weatherization programs is also a potential use case for connected ecosystems. Data to enable a building audit can either be collected through information retrieved from building owners or occupants through surveys measured through AMI, or collected through data monitoring systems. The connected home enables home energy audits by potentially using a set of aggregated set of collected information at a lower cost and less intrusive that traditional energy audits.

FIGURE 24 PERFORMING BUILDING ENERGY AUDITS USING THERMAL IMAGING

Figure 24 shows how thermal imaging using infrared cameras can identify opportunities for weatherization. These along with other in-person audits have been the traditional method of understanding opportunities for efficiency upgrades. This activity could potentially be replaced by data collection made possible by low-cost sensors enabled by connected home ecosystems. Sacramento Municipal Utility District (SMUD) has investigated how indoor temperature data analytics, a data parameter potentially collected by connected home ecosystems, can help understand building envelope and be used to enable home energy audits. Survey analysis, typically collected through paper or in-person interviews can be replaced with other methods enabled by advancements in artificial intelligence. Tools such as chatbots and smart speakers can potentially replace paper surveys or personal interviews to provide a low touch option to get stated preferences or other baseline conditions.

Voice assistants as well as device aggregators were identified as the two enablers of home energy audits. With its core proposition aggregation, device aggregators can potentially provide an aggregated set of information to a utility or third party that helps them understand thermal characteristics of a building. This information includes environmental data using temperature and humidity sensors found within smart thermostats and other connected devices. Using this, the utility or energy provider can then provide a set of potential energy efficiency upgrades to a home owner.

Voice assistant could potentially enable a new method of home energy audit. See Figure 25

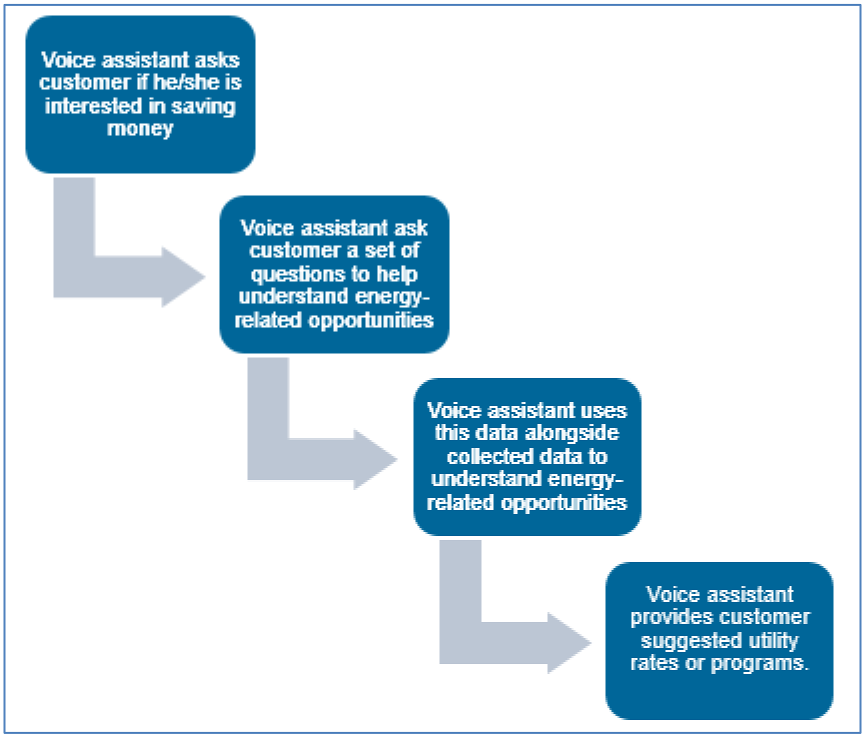

FIGURE 25 CUSTOMER DATA COLLECTION ENABLED BY VOICE ASSISTANTS

Figure 25 shows a scenario where the voice assistant can be used to collect a set information from a customer such as "does he/she own a thermostat?", "does he/she plan on owning an electric vehicle?" or "does he/she have flexibility on when they do laundry?" Data collected from this form of customer survey can then be used to help identify other potential energy efficiency opportunities or other energy services in which the customer is interested in. This set of conversational intelligence can help lead to a customer participating in additional utility programs and services which leads to a strengthened relationship between the customer and its energy provider. One potential energy service that can be offered is fault detection and diagnostics which will be discussed in the next section.

FAULT DETECTION AND DIAGNOSTICS

Fault Detection and Diagnostics (FD&D) can be defined as identifying instances where systems, appliances and devices within that system are not functioning as intended. This can be identified based on operational history and signal patterns compared to nominal system expectations. As many customer-facing systems such as water heaters and HVAC systems are only serviced and replaced at point of failure, this provides a customer proactive information on when he/she needs to consider to take action vs. historic reactive responses. A common analogy is the "Check Engine Light" or other diagnostics tools provided by automobiles to its drivers to indicate that the vehicle is not operating properly before system failure resulting in customer inconvenience. Connected home ecosystems can help identify these faults through use of an aggregated set of data to provide deeper insights into the fault. For example, identification of what the fault is vs. just identifying that a fault is there is possible through the use of an aggregated set of information from multiple devices within an system vs. data from a single device.

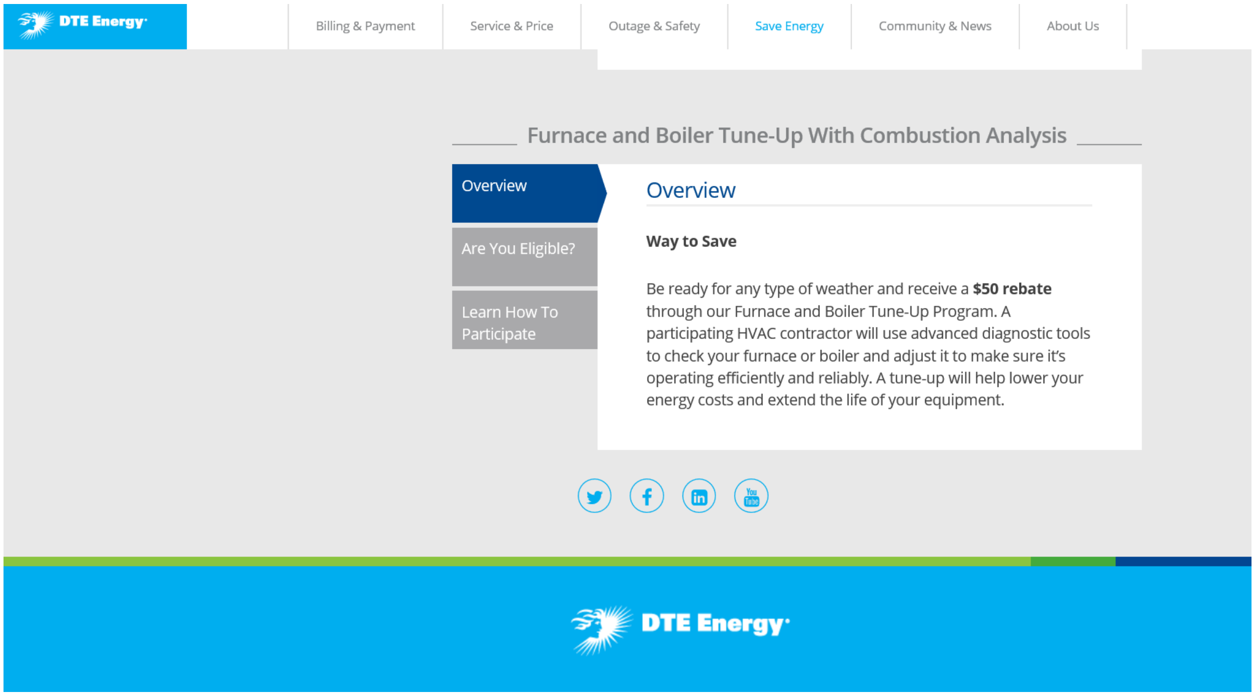

FIGURE 26 FURNACE AND BOILER TUNE UP PROGRAM PROVIDED BY DTE ENERGY

Proactive measures are being made by utilities such as DTE Energy in Michigan. See Figure 26. DTE is running furnace and boiler tune-up programs where customers are given a $50 rebate in exchange for an HVAC contractor will do an HVAC and/or water heater audit to ensure it is operating properly. Potentially, this can be replaced by the use of data and advanced analytics achieved through low-cost sensors made available from connected home ecosystems to understand inefficiencies in system operation without the need for an in-person audit and more importantly, before system failure. New connected water heaters, smart thermostats and intelligent HVAC equipment now offer these sensors and analysis of data collected from these sensors could enable FD&D at a relatively lower cost. To enable this, the ecosystem would have to: (1) aggregate and predict system operation characteristics of 2 or more end use loads or DERs, (2) identity system faults through comparison of typical operation vs. current conditions and (2) message to the customer or utility of the type of fault.

Products and services provided within the traditional trades and software-based optimization technology subclasses were defined as enablers of this use case. Traditional trades, usually the manufacturers of particular end-uses, would have a competitive advantage over products and services from other technology subclasses. Products and services from this technology subclass should have a better understanding operating characteristics and associated data of their devices and systems. Products and services provided within the software-based optimization subclass were determined as enablers as their core value proposition is focused on collection and aggregation of data from multiple devices comprising a system. Therefore, it can be assumed that products within this technology subclass would have the infrastructure and capabilities to understand typical operating conditions of a system and identify whether that system was operating properly.

Bundling Home Automation and Security as a Service

Relying on core value propositions such as customer control and security, connected home ecosystems can potentially provide coordinated control and management of a particular premise. Utilities and energy providers have the potential to partner with these products and services to enable both energy and non-energy related value propositions. For example Salt River Project, a utility in Arizona is investigating the use of partnerships w/ security providers to provide security, energy management and home automation services to its residential customers. Mass market IoT and security and telecom providers were identified as enablers as their core ecosystem technology and target market focuses in on home automation and/or home security. Mass-market IoT is the newest entrant into home security. However large market players such as Nest Labs and Honeywell have considerably included connected end-use technologies such as security cameras and doorbells since around 2015-2016. For example, the installation of security cameras, connected doorbells with cameras and smoke detectors provided by mass-market IoT ecosystems such as nest and Honeywell can not only reduce energy consumption, but also reduce customer home insurance costs. Mass market IoT providers such as ecobee have shown interest in home automation through the development of a connected light switch enabling home automation throughout a home.

Remaining Societal and Grid-Related Use Cases

The remaining use cases focus on how connected home can enable societal, policy and/or grid-related use cases. These use cases include:

(1) **Enabling Smart Cities and Advanced Energy Communities:** Use of data and controls to provide coordinated responses to community-level events such as emergency notification, information gathering and outage management.

(2) **Reduction of Greenhouse Gas Emissions through Efficient Electrification and Increased DER Uptake:** Leverage of market interest in connected technology that results in increased uptake of efficient end use devices and improved demand-side management of customer-sited end use devices and DERs.

(3) **Improved Demand-Side Management at the Grid-Edge:** Use of data and controls of customer-sited DERs and end-use devices to help balance load fluctuations associated w/ increased DER uptake and electrification.

(4) **Increasing Grid Reliability and Quality of Service.** Use of customer-sited DERs to manage behind the meter end use loads to help maintain grid stability, especially in cases of abnormal grid operations.

It is important to note that these use cases are not mutually exclusive. Many of these use cases focus on the need for coordinated aggregation, orchestration and optimization of behind-the-meter customer end-use DERs in synchronous w/ utility and energy provider needs and objectives in the short term. However, there is long-term interest in control of these DERs in response to utility distribution system needs. Device aggregators and DER Management focused ecosystems were defined as enablers of a majority of these use cases due to their ability to aggregate control of multiple end-use loads. They were also selected as enablers as products and services comprising these technology subclasses have experience working with utilities and energy providers in providing grid benefits using behind the meter technologies.

However, providing grid benefits using mass-market connected home ecosystems is still in its nascent stages. Additional research needs to be completed in the connected home ecosystem as a whole to better understand long-term strategies associated with its effects on customer-sited DERs and how/if it needs to be accounted for in grid planning activities, an activity that uses 30-50year time horizons. For example, as many of the controls are still in nascent stages for customer-sited DERs such as energy storage, grid planners consider these as loads, suggesting the need to increase infrastructure to support these deployments in the event that controls do not operate to the grid's advantage. Additional research and monitoring of operational performance into these controls is still needed, especially at it pertains to DERs such as residential energy storage systems.

Closely coupling controls and/or rates to help connected home ecosystems help manage grid needs without compromising customer comfort is still in its nascent stages as well. Research into better understanding how connected technology can be used as a grid resource is one main recommendation associated with this report.

With the first portion focused on what use cases can the connected home, the second section of this chapter will focus on the use of data and how to evaluate those use cases are enabled.

DATA FROM DEVICES: OPPORTUNITIES AND GAPS FOR VALIDATING ENERGY USE CASES OF CONNECTED HOME ECOSYSTEMS

With the technology subclasses identified and assessed for how each can enable or support a particular utility energy journey, it may be important to understand methodologies to validate that those functions were successfully executed. In the previous section, a methodology for assessing enabling connected home ecosystems was evaluated using a series of core functional requirements intended to enable use cases. Using the controls systems analogy of a closed-loop system, data validation is essentially the feedback loop validating system performance and enabling continuous evolution of the energy journeys.

Connected ecosystems can potentially help utilities understand adoption, use and the associated grid impact of residential sited DER which includes smart devices, efficient technologies and systems, residential photovoltaic (PV) systems and electrical and thermal energy storage systems. Customer data analytics in the utility space has usually focused on load analysis made available by either Advanced Metering Infrastructure (AMI) data, customer survey analyses or exhaustive sub-metering commissioned by load shape groups for Integrated Resource Planning (IRP) activities. Market penetration of advanced customer-sited communicating devices provides the opportunity to collect substantial amounts of data that can potentially be used to supplement these traditional utility data acquisition methods. Connected devices inherently embed low-cost sensors that have the potential to collect device-level information at significantly lower costs and at greater granularity than traditional sub-metering techniques. This is particularly impactful in residential and small commercial spaces where equivalent data streams have historically been rather costly.

Historically, customer data in the industry was located in silos. Utilities and product providers did not need to exchange data with one another which results in limited transparency of what data is collected, stored and leveraged. The inherent value proposition associated with ecosystem-based appropriate is the notion that data in order to validate core functions or energy-related use cases is aggregated at some point. This means that as the connected home ecosystems both monitor and control multiple end uses, there is a potential to leverage this infrastructure to aggregate data in order to better understand how customers are using connected devices and the resulting energy use associated with that. This data can potentially provide a better understanding of how customers are adopting, responding and using energy end-use technologies. Although the connected ecosystems potentially enable avenues for data transactions between connected devices, it is unclear where valuable data resides within connected device ecosystems as there are few vertically integrated product solutions and very few transparent data aggregation platforms on the market today.

To assess value and opportunities when leveraging data made available by connected ecosystem providers to continue to drive utility-focused data specifications based on particular utility use cases, this report takes a two-step approach. The first step is understanding the current state on how/if data is collected from connected devices and ecosystems today. The second step is to answer five fundamental questions:

- **What?:** Identify the high-level data parameters associated with data from connected ecosystems. The intent is not to create an exhaustive list of data parameters made available by each end use, but to classify data parameters collected by these devices.
- **Why?:** Justify why this data is important (if important at all) and how this data enables core ecosystem functions and particular utility use cases.
- **Who?:** Determine which technology subclasses have historically provided data to utilities and third parties. The intent is to determine which providers have the technical and legal infrastructure in place to enable these data transactions.
- **Where?:** Identify the general location where data is stored by each technology subclass. It can be assumed that following data pathways is a good proxy for identifying where energy optimization potentially occurs.
- **When?:** Evaluate if and when data is accessible to utilities and third parties and barriers to accessibility.

it is important to understand a few baseline conditions associated with driving utility specifications around data collected from connected devices. These baseline conditions are summarized below:

1. **Method of data reporting is not uniform from one product provider to another:** Analysis of data associated from smart thermostats identifies various levels of data availability and methods of reporting. This is most likely a result of various factors including data storage, perceived use cases for data and existing infrastructure of current product and service providers.
2. **Data specifications are available for certain connected devices and certain use cases:** As previously mentioned, smart thermostats were the first set of connected devices that sparked interest from utility programs and associated standards organizations and research institutions. The interest is a result of harmonizing the need to conduct continuous evaluations of quantifiable and verifiable energy impacts while accounting for rapid technology change common in software driven solutions. As a result, organizations such as the United States Environmental Protection Agency (US EPA), the Consortium of Energy Efficiency (CEE) and the Electric Power Research Institute (EPRI) have developed smart thermostat data specifications to facilitate developing frameworks on how data is collected from manufacturers and service providers for DSM needs.
3. **Tools for data analysis are appearing in the market:** One of the current technology gaps is the lack of transparent tools that quantify energy impacts

associated with connected device data. Recently, open source tools have been made available; an example is VEIC's Smart Thermostat Analytics Toolkit (STAT).[60]

4. **Data specifications still need to be validated for effectiveness:** While some use cases are more mature than others, the valuation of data from connected ecosystems is still in its nascent stages. It will be important to continually validate the effectiveness of each data specification as more use cases are identified and more devices are enabled by connected ecosystems. It is important to also validate these specifications when compared to other methods such as completing the same use cases using only AMI data.
5. **Data specifications are needed for other customer-sited connected devices:** Smart thermostats are the first set of customer-procured connected devices that have the potential to be leveraged as both customer engagement tools as well as grid resources. As other devices and systems continue to follow suit (such as water heaters and EVs), it will be important to continue develop data specifications for other customer-sited connected devices to understand how residential homeowners and occupants are using energy associated w/ systems monitored and/or controlled by connected devices - an area of rapid technology change.
6. **Data is typically made available by third Parties through flat file transfers or APIs:** In addition to data made available through dashboards provided to utilities and third parties, the most common methods of data transfer are either flat file transfer through some form of Secure File Transfer Protocol (SFTP) or via API commands through RESTful commands to a particular product provider's server.
7. **Data is still most valuable in the aggregate:** Although data from devices are a potentially powerful tool to understand how residential customers are using and will continue to use electricity, it is important to understand that data from one particular product or one particular entity has its limitations. Utility DSM programs such as EE programs are based on: (1) attribution, (2) calculation and (3) persistence, so it is important to understand factors such as data collected from each device, how that data is reported (calculated, estimated or measured) and the accuracy and precision of the sensors that collect the data. Connected ecosystems potentially provide methods of aggregation.

CLASSIFICATION AND EVALUATION OF CONNECTED ECOSYSTEM DATA

To assess the value of data for connected devices it is important to categorize data parameters made available by connected ecosystem providers, provide examples of these data parameters and then provide example benefits to utilities and partnering third parties of the access to these data parameters.

- **Availability data** can be defined as parameters or indicators that determine what devices are available and/or controllable within a given premise or community. Availability data are provided in the form of energy portal readings that identify which resources are available at a given time or through APIs collected by third parties on device connectivity status. In addition, absence of data in instances where data is expected can also be used as a proxy for data availability. Availability data allows third parties to understand what devices and ecosystems are installed in a particular community and/or premise. These data also allow for an understanding of

[60] https://www.veic.org/resource-library/smart-thermostat-analytics-toolkit

what is activated/online in case of load control events. Grid-responsiveness-related use cases will require availability data.

- **Locational data** can be defined as data that indicate the location of a device and/or premise. Locational data are delivered through an energy portal that is sometimes provided by third parties and product providers. Locational data allows third parties to understand where devices are installed. Integrating information with utility systems would allow for targeted demand-side management activities focused on specific areas. Grid-responsive use cases will require locational data, especially those that have a spatial component.
- **Device performance data** can be defined as data parameters—estimated calculated or measured—that indicate operational characteristics of a device and/or ecosystem. Performance data can be anything from HVAC runtime collected from smart thermostats to the State of Charge (SoC) of energy storage systems to the state of operation of residential smart plug strips. Device performance data can serve as proxies for how often/when a device is being used. Analysis of this information can also be used to provide third parties an understanding of whether a device is operating properly and is also used for use cases such as FD&D.
- **Customer preference data** can be defined as data parameters that can potentially be used as an indicator will choose to use a system under certain conditions. Preference data can be the mode of operation of connected water heaters to temperature setpoints for thermostats to occupancy and schedule information for home security systems. Analysis of this data provides parameters that can serve as proxies for how often/when a device is being used and can potentially be leveraged to indicate propensities to respond to a particular stimulus. Customer preference data can be used in use cases where customer segmentation and targeting is important.
- **Environmental data:** Data parameters that monitor, collect and/or gather indoor and/or outdoor conditions in which the connected devices and/or ecosystems are installed. These data can include indoor temperature and outdoor temperature as well as humidity readings. These parameters can indicate the conditions in which an ecosystem is commissioned. Analysis of this information can also be used to understand environmental changes caused by that ecosystem which can be used to better understand ambient premise conditions.
- **Energy data:** consists of measured, calculated or estimated energy data. These data can include energy values collected by circuit-level metering systems or estimated kilowatt-hour (kWh) values from disaggregated AMI meters. These data are typically used to support utility customer data to better attribute customer energy use.
- **Customer data:** Consists of data that indicates an owner/user of a connected system. This data includes login information of the various users of a particular ecosystem and/or serial numbers of particular devices. Customer data allows third parties to tie devices and ecosystems to particular customers and premises. This is critical in most use cases as it ties connected ecosystems to other utility or energy provider facing data streams.

To complete the assessment of device level data, each technology subclass was assessed for ease of data availability and how/if this data can be leveraged to improve core functions enabled by connected ecosystems. The assessment relied on the project team's experience in working with product providers from each technology subclass as well as self-reported information from these manufactures found through other connected device initiatives.[61] In addition, location of data (whether it is stored on the cloud or is on local storage provided by the device) was assessed to better estimate where optimization or orchestration occurs. Results of this analysis are detailed in Table 14. For more detailed results, please refer to Appendix A.

TABLE 14 DEVICE DATA ASSESSMENT FOR EACH TECHNOLOGY SUBCLASS

Technology Subclasses	Location and Availability		How/If Improves Core Functions		
	Ease of Data Availability	Data Location	Aggregate	Orchestrate	Optimize
Voice Assistants	Low.	Cloud	◕	●	◑
Security and Telecom Providers	Low	Cloud	◑	●	◑
Device Aggregators	High.	Cloud	●	◑	◕
Mass-Market IoT.	Medium.	Hybrid - mostly cloud	●	◕	◑
Hub-Based Mass-Market IoT	Medium.	Hybrid – mostly cloud	◑	◕	◑
Traditional Trades	Medium.	Hybrid	◑	◑	◑
Monitoring-Based	High.	Cloud-base	●	◔	◔
DER Based Management Ecosystems	Medium.	Hybrid	●	◑	◕
Software-Based Optimization	High	Hybrid – mostly cloud	◕	◑	●

Key

●	Capable of enabling core function
◕	Capable of enabling, but need to consider market/partner factors
◑	Capable, but requires additional partnerships/tech. development
◔	Potential, but has not been point of focus
○	Not capable/No involvement

Analysis of device-level data shows that device aggregators, monitoring-based and software-based optimization providers are the technology subclasses projected to have the highest level of data. This is a result of the value proposition associated with data aggregation. Voice assistants and security and telecom providers have the lowest level of data availability. The project team hypothesizes that this is due to inexperience with working with third parties in this data exchange due to internal data analytics capabilities (for voice assistants) and the premium on data security and privacy of customer information (for security and telecom providers).

Data location can potentially be used as a proxy for where energy optimization routines occur between each ecosystem technology subclass. Although not as important for use cases that rely solely on data monitoring, this will be important for control use cases where control latency will be an issue such as many of the long-term grid-facing value propositions will require. In device-level environments, there is some data collected and analyzed at the device level. However, analysis of data location in a connected ecosystem environment identifies that much of the data is collected and stored in cloud-based environments, which results in lower hardware costs, enabling controls scalability and customization. Note that there are instances such as DER-based management systems and some Hub-Based Mass-market IoT systems where there is local data collection and associated energy management. This can probably be attributed to the need for a shorter feedback loop and the need for greater connectivity reliability to energy management and optimization routines. In the future, it will be important to identify cost/benefits of cloud-based aggregation for particular customer and grid facing use cases.

As the technology subclass assessment in Section 2 shows, each technology subclass is not fully equipped to enable all three core functions enabled by connected ecosystems. Very few vertically integrated solutions are available in the market resulting in interdependencies of various technology subclasses with one another. This results in difficulty attributing impacts or functionality and tying it to a particular device or system. Identifying the best

[61] Cite: (1) 2013 Base Report and (2) 2016 smart thermostat study.

intervention points where data is aggregated to validate the energy use case will address this issue.

SUMMARY

This section focuses in on the identification of customer and/or grid-focused use cases that connected ecosystems can/are potentially provide/providing. Functional requirements detailing the key characteristics that enable and/or support these use cases were also provided. Technology subclasses identified in Section 2 were then assessed for the ability to support and enable these use cases based on their technical capabilities and market characteristics. The overall results of use case analysis of how products and services associated with each technology subclasses enables particular utility use cases show that technical and market maturity of customer-focused use cases are ready or will be ready through additional short-term research while many grid-related use cases require medium and long term assessment due to the market's focus on providing customer core value propositions of customer engagement.

Analysis of customer-facing use cases determined that voice assistants followed by mass-market IoT ecosystems currently enabled the most customer-focused use cases. Use cases such as enabling dynamic customer rates, energy informatics, improving EE and DR programs and building energy audits were all identified as potential use cases that voice assistants can enable. Focus groups and consumer studies of the connected home show that most voice assistants and mass-market IoT and the associated brands (such as Amazon, Google and Nest Labs) that provide ecosystems within these technology subclasses are perceived by customers as the best brands for smart home technology. They also are perceived to be best suited to enable whole home integration or be integrated into whole-home solutions.[62] Enabling multiple use cases as well customer perception of enabling technology integration results in products and services found within the voice assistant and mass-market IoT technology subclasses be focal points of residential orchestration, which enables stacked value propositions to both utilities and its customers.

Customer and utility in voice assistants is driven by: (1) currently voice assistants appear to be a single point of orchestration in which other connected device home ecosystems and products found within technology subclasses integrate with, (2) provides unique ways to potentially collect information from users through the use of a combination of both ambient and conversational intelligence and (3) have the potential to be a centering point of home automation in a majority of homes over the next five years. In summary, a utility can potentially leverage these type of connected ecosystems to provide **personalized energy journeys**, various levels of utility interaction that a utility can provide its customers associated with these use cases. A proposed hierarchy of these use cases is summarized below in Figure 27.

[62] Site Gut Check Connected home exploration studies.

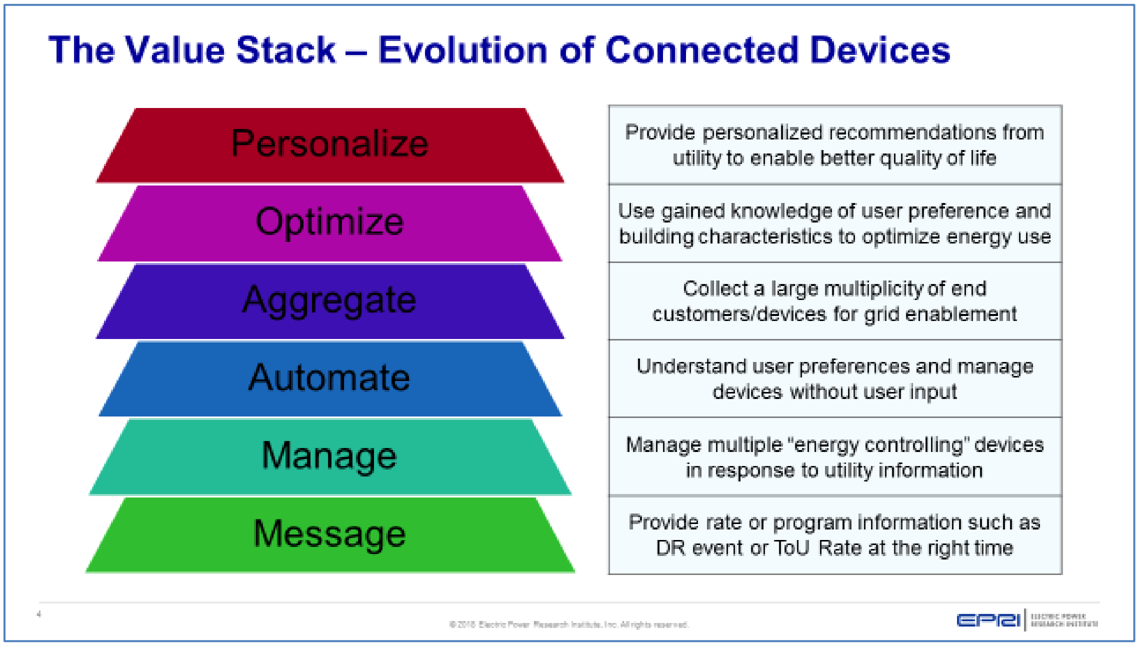

FIGURE 27 VALUE STACK EVOLUTION OF CONNECTED DEVICES

The hierarchy depicted in Figure 27 shows that not only can use cases be stacked together by particular technology subclasses, but levels of utility interaction can also be realized to enable personalization. The figure can be used as a high-level roadmap in evaluation of potential product partners and how can enable personalized energy journeys. An example of this effort that offers one method of delineating market, utility and utility/market partnership role is detailed in Table 15:

TABLE 15 MARKET AND UTILITY ROLES TO ENABLED PERSONALIZED ENERGY JOURNEYS TO RESIDENTIAL CUSTOMERS

Function	Market Role	Utility/Energy Provider Role	Utility and/or Market Role
Message	Provide the hardware and orchestration platform	Utility provides rates and/or control signal	Create effective messaging around utility and/or control signal
Manage	Provide the tools for orchestration: Enable open access to hardware manufacturers and other product providers.	Provide rates, control signals and common specifications around particular use cases to manage end use loads. Provide opportunities to fill in the gaps where tools are not provided by the market currently..	Provide input and/or data that provides opportunities to balance utility needs with customer comfort.
Automate	Provide (and integrate) residential orchestration platforms through home automation and security systems	Provide rates, control signals and common specifications around particular use cases enabled by home automation. Provide opportunities to provide business case for energy management and automation.	Provide input and/or data that provides opportunities to balance customer comfort while reducing overall cost of service to both customer and utility.
Aggregate	Develop platforms and business relationships for aggregation	Develop financial mechanisms to reward aggregation	Work on common specifications that enable data and controls aggregation
Optimize	Understand customer preferences. And develop algorithms to optimize for customer comfort and economics (e.g., rate optimization, shared energy use)	Create programmatic incentives to reward optimization. Fill in the energy-related concept gaps where needed. Provide opportunities to prove business case for energy optimization	Provide opportunities for data sharing through common specifications based on particular use case(s) that enable vetting of energy optimization in environments of rapid technology change.
Personalize	Work with utility industry to understand personalization needs and how to deliver it with shared customer value prop.	Create related energy use cases mapping for personalization use cases. Engage (and reward) market to deliver personalized energy offerings to customers.	Develop utility/market partnerships that enable energy-related personalization to shared customers.

Table 15 shows a proposed utility/market development partnership that potentially leads to a utility or energy provider offering various options and tools to how its customer can potential balances energy costs with other drivers through the use of connected home ecosystems. Utilities can potentially offer rates, common control signals and other mechanisms that help the customers make energy-related choices. However, it is important to continue to develop utility business cases that understand the main core value propositions of the connected home which focus on customer comfort, convenience, control and security.

Moving forward, for the utility, it will be important to understand how to develop common data and control specifications and associated standards to incorporate and leverage connected homes as part of utility grid planning and operations. It will also be important to understand and evaluate how communication standards affect customer ecosystem and utility program cost. Currently, there are several efforts in investigating standardization of communication protocols and data of connected devices in order to provide grid flexibility. Although reliability and improved availability is an important metric especially as the energy system becomes more dynamic, it is important to note that no current standards that comprehensively addresses these future grid requirements. As these develop, it is not only important to track and demonstrate technology developments, but also further understand the economic impact of these standards and how that may affect market potential of these connected ecosystems to achieve other use cases desired by a utility or energy provider. This is most likely a longer term effort as this will combine a historic planning activity where utilities must plan for 30-50 year investments considering technologies that are subjected to rapid technology change. In addition, it will be important to understand Investigation of the use of aggregation platforms, device and DER aggregation, will be important to assess technology gaps associated with incorporating current aggregators focused on either DR (thermostats, water heaters, etc.) or DER (solar and storage) to utility grid operation activities – especially important in areas where capital investment by the utility is/will be costly.

As this section focuses in on the what functions enable desired outcomes achieved through connected ecosystems deployment, it is important to understand the environment in which these systems reside. There may be instances where coincident, conflicting signals from the utility, the customer and even local intelligence may convolute the understanding on how an ecosystem responds to a set of functional requirements. With this in mind this section also recognizes it also important to understand how data can be used to validate if use cases are realized by connected home ecosystems. The section details an approach for characterizing data made available by connected devices and connected ecosystems as a whole. Understanding that there are very few vertically integrated connected home ecosystems thus resulting in interdependencies with various product providers and technology subclasses working together through technical and business relationships, it is important to follow data exchanges between technology subclasses and/or identify areas of intervention in which a 3rd party or utility can access data at the aggregate to satisfy validation of a particular energy journey.

To assess feasibility of this technology subclasses in Section 2 were then analyzed for their ability to share data with third parties. In addition, these technology subclasses were assessed based on the data that they provide to enable core functions made available by connected ecosystems. Through these results, it was determined that no one subclass could enable all three core functions – validating the results presented throughout this report.

In addition, this section predicts where the location of the subclass's data lies to predict where optimization happens within each subclass. The analysis shows that with a few exceptions that show local intelligence or optimization, most data is stored in cloud-based environments to minimize overall hardware costs. The distributed intelligence associated with cloud-based architectures of these individual devices leads to rapid innovation by many players in the marketplace, not any single one. However, limited local processing means that these aggregation of cloud-based platforms, a core technology characteristic of connected home ecosystems, rely on broadband connectivity and server uptime to enable any sort of orchestration and/or optimization and are therefore subjected to latency issues. It is important to understand the tradeoffs between ecosystem scalability and control reliability over the next few years, especially as these ecosystems are considered as grid resources.

VALUE STACKING: LEVERAGING CONNECTED ECOSYSTEMS FOR CUSTOMER AND GRID BENEFITS

As the previous sections focused on developing a framework to assess and analyze capabilities of connected home ecosystems, this section will propose a potential scenario in which a utility can deploy connected home ecosystems to achieve multiple utility value propositions. The proposed scenario will include the centering connected home ecosystem technology subclass that will be leveraged by the utility, considerations in deployment of that ecosystem, how that ecosystem can potentially achieve multiple utility customer value propositions today, attempt to achieve personalization as shown in Figure 27 based on customer's appetite to make energy-related choices with influence from the utility and finally, current market and technology gaps associated with this proposed scenario. It is important to note that this proposed scenario understands regulatory constraints that utilities have in providing certain energy services. However this scenario did not rule out any activities or recommendations due to these constraints. Instead the scenario will focus on how to develop comprehensive program offerings that can enable and stack energy value propositions to both the utility and its customers.

The scenario was selected based on results presented in Section 3. These results suggested that voice assistants enabled the most customer-centric energy related use cases which are potentially realized today and in the short term. Therefore, the first scenario will focus on leveraging voice assisting as centering point to enable device-level orchestration.

LEVERAGING VOICE ASSISTANTS.

The premise of this scenario is to leverage three main drivers enabled by voice assistants

(1) The projected exponential growth of voice assistants such as Google Home and Amazon Echo over the next few years: Previous cost and complexity issues associated with enabling home energy management have been solved by these ecosystem enablers as they provide a home automation system at price points low as $100 or even less. It is important to note that over 60% percent of users planning to use these voice assistants in order to control other smart home devices.[63] This results in a low cost residential gateway that a utility can leverage to enable various levels of device orchestration and messaging to its customers. This potentially reduces utility or product provider evaluation costs and potentially program costs associated with incentivizing technology deployment.

(2) Advancements in far field voice natural language processing allowing for effective voice commands. Historically voice control was limited by the inability of system to recognize voice commands unless users were close to a microphone. In addition, there were also limitation in the amount of commands in which a system could recognize. Advancements in far field voice and natural language processing as detailed in Section 1 have increased the capabilities of voice recognition exponentially. This has led to improved artificial intelligence, conversational (through

[63] https://techcrunch.com/2018/01/12/39-million-americans-now-own-a-smart-speaker-report-claims/

survey-type interactions with the customer) and ambient (through data collection), that will lead to improved personalization in which could potentially allow utility to provide options to its customers based on how much he/she wants to interact with both the connected home ecosystem and the utility.

(3) The interest of other connected devices and ecosystems to integrate with voice assistants: Previous barriers in residential IoT that have stymied market adoption have been interoperability of connected devices with one another. Historically, connected home ecosystems provided a fixed set of devices that were compatible with particular ecosystems. The advent of the voice assistants and its low cost touch point have not only drawn interest of the customer, but also other connected IoT manufacturers as well. Software platforms enabled by these voice assistants also have provided a unique way for third parties and other connected device manufacturers to integrate with their platform. This has resulted in a broader range of compatible products within a single ecosystem that in previous years was not possible. This can potentially lead to the valuation of not only use cases that voice assistants enable, but other products found within other technology subclasses looking to integrate w/ voice assistants as well within a single utility deployment.

The result of a utility or energy provider leveraging these three main drivers is an organic point low-cost orchestrated control of multiple devices within a premise. These include connected devices that have the potential to save energy and reduce demand such as smart thermostats, connected water heaters, lighting controls and plug strips. This also includes other potential devices of interest such as smart cameras, locks and doorbells that could potentially collect data that when accessed, can improve understanding of customer preferences. As energy providers such as Reliant and Direct Energy have set precedent and developed integration pathways to aggregating of utility customers, it is safe to assume that there are no technical barriers to leveraging these platforms as points of device and ecosystem aggregation. However, as current product providers of these ecosystems currently do not have mature energy verticals within their organization and energy management is not their main driver for development, energy optimization is usually not part of voice assistant provider's main development roadmap. However, there is an opportunity to enable energy optimization through a variety of avenues such as: (1) developing tools that inform the customer of bill status and future load control or rate changes and/or (2) developing and/or partnering with energy optimization providers to develop coordinated control scenarios.

In addition to the potential of a platform that enables energy and demand benefits, it is important not only for EE/DR benefits, but also the additional information that can be received and the additional services that may be offered throughout the customer journey. For example, through a performance, preference, environmental and/or interaction data collected by these ecosystems and possibly combined with information retrieved through by the development of a list of questions that the voice assistant can ask the customer, a relatively low-touch energy audit can be obtained that would help the utility offer personalized suggestions on utility products such as optimal service rates that the customer should consider to reduce bill costs and suggested demand-side management measures that could help the customer save energy. In turn, the utility gets a deeper understanding of how a customer uses energy.

Finally, as voice assistants have increased the amount of compatible connected devices and connected ecosystems subclasses over the last few years have investigated how best to integrate with these voice assistants, additional services enabled by those technology ecosystems can also be realized. For example, manufacturers and ecosystems that can be categorized in the Traditional Trades have focused on integration with voice assistants. As a result, system fault detection and diagnostics enabled by products and ecosystems comprising the traditional trades subclass can also be realized and messaged through voice assistant platforms. However, it is important to understand the level of data collection and controls made available by products and ecosystems to a utility's voice assistant product partners.

To provide a roadmap into how a utility could enable multiple value propositions resulting in enabling personalized energy journeys (See Figure 27 Value Stack Evolution of Connected DevicesFigure 27) for shared customers using voice assistants, a similar approach to Table 15 will be used. The approach focuses on developing a hypothetical scenario that divides responsibilities between what market actors such as product and service providers would be in charge of vs. what an energy company or a utility needs to provide to this technology subclass. See Table 16.

TABLE 16 LEVERAGING VOICE ASSISTANTS TO ENABLE VARIOUS LEVELS OF UTILITY/CUSTOMER INTERACTION

Function	Market Role	Utility/Energy Company Role	Utility/Market Partnership
Message	Provide hardware and tools to enable messaging	Utility provides rates and/or control signals	Create effective messaging around utility prices and control signals
Manage	Provide the tools for orchestration: Enable open access to hardware manufacturers	Provide rates, control signals and common specifications around premise-level device management.	Create data exchange platform or process that helps provide opportunities to balance utility needs with customer preference.
Automate	Provide residential orchestration platform through core product. Provide or enable tools for residential orchestration.	Provide rates and/or control signals around home automation.	Create data exchange platform or process that helps provide opportunities to potentially improve overall comfort while reducing cost of service to customer and utility. Vet business cases around this.
Aggregate	Enable device aggregation through current product offering.	Develop financial mechanisms to reward aggregation	Vet business cases to data aggregation. Develop data and controls specifications.
Optimize	Provide tools such as skills and actions that help manage end-use loads.	Create programmatic incentives to reward optimization. Fill in energy-related inputs (rates/controls) when needed. Provide opportunities to prove out business cases for	Work together to develop optimization routines, skills and/or actions that help balance customer comfort and dynamic rates.
Personalize	Provide tool for aggregation and device orchestration.	Create portfolio of various rate structures, technologies and other enabling tools that foster customized energy-related choices for their customers.	Develop utility/market partnerships that enable energy-related personalize to a shared customer base.

Table 16 shows one hypothetical method for a utility/voice assistant partnership to be enabled that results in various levels of utility to customer interaction. This table also can be used as roadmap in terms of utility and product and service development that could lead to personalized energy journeys to particular utility customers. As previously mentioned, several utilities such as Direct Energy, ComEd and Baltimore Gas and Electric (BGE) are starting to use Alexa Skills and Google Actions to be another way of communicating to its customers.

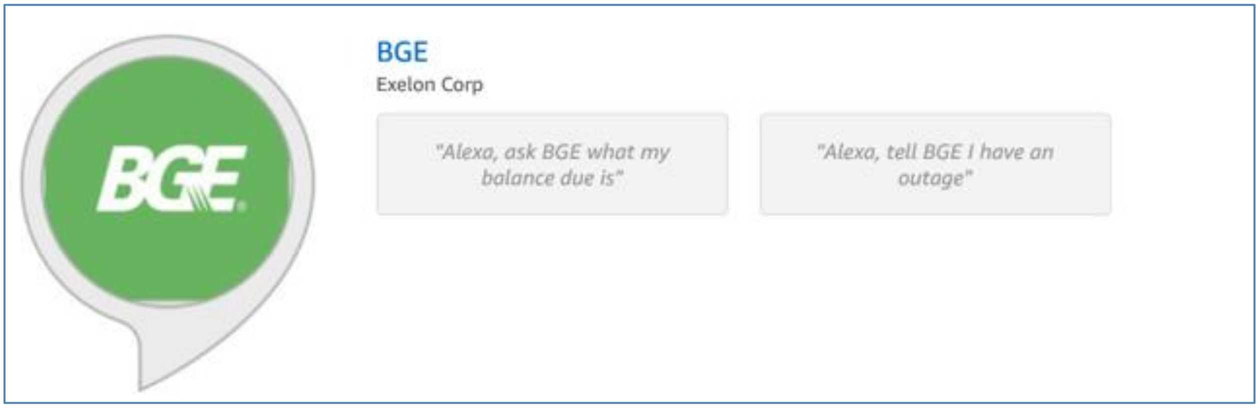

FIGURE 28 ALEXA SKILLS PROVIDED BY BALTIMORE GAS AND ELECTRIC

Figure 28 shows that BGE has developed an Alexa skillset around messaging and receiving messages to and from its customers respectively about specifics pertaining to bill inquiries and outage management. It is not out of the realm of possibility that these skills can be enhance to not only include messaging, but controls and/or optimization commands to other IoT devices.

There are still remaining general research questions that need to be addressed. For example, although device orchestration is realized, little is understood about the information and data that is retrieved from voice assistants. Analysis detailed in Table 16 as well as research gained by current field demonstration projects[64] show current differences in how controls are enabled vs. how can be collected. See Figure 29.

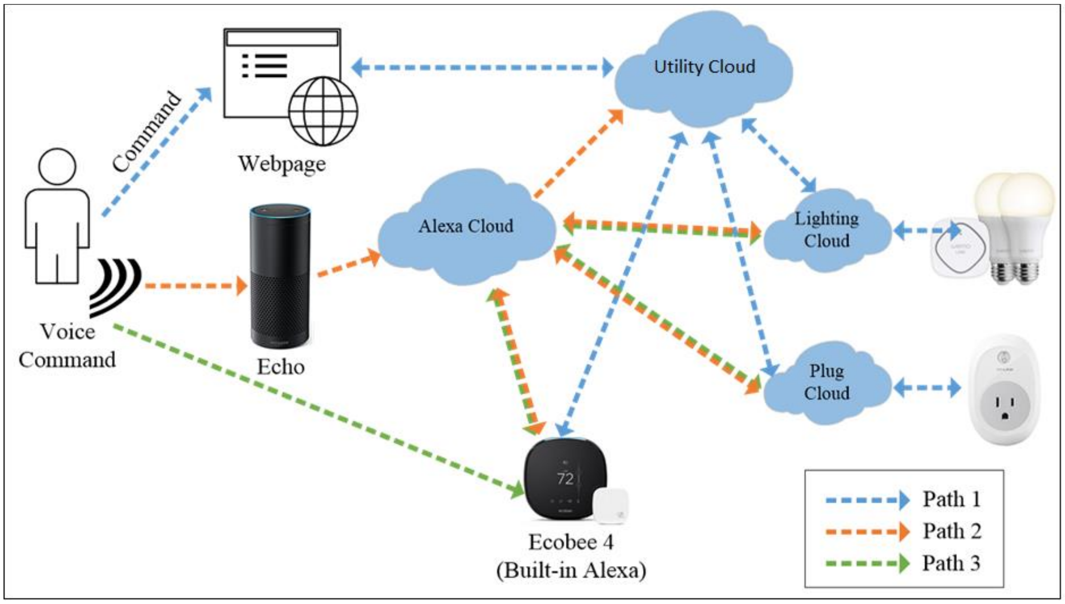

FIGURE 29 TYPICAL DATA (BLUE) AND CONTROL (ORANGE AND GREEN) PATHWAYS USING VOICE ASSISTANTS

64 Cite EPRI 2018 Voice assistant research and San Diego Whole Home Demand Response Project.

Figure 29 shows that although the voice assistant's cloud can be leveraged as a single point of orchestration (control), data collection and aggregation is not done/not currently available through the voice assistant's cloud. As a result, an additional data aggregation layer is required if data collection from these devices is desired and, in turn, governed by the parameters made available by that connected device provider. In addition, as these ecosystems have only been commercially available for less than 5 years at the time this report was written, very little is known about how persistent people are using these voice assistants. Additional research is necessary to better understand the effective useful life of these ecosystems as far as providing these customer value propositions. However, current research focused on usability of voice assistant's trends show that usage of voice assistants tends to increase over time. See Figure 30.

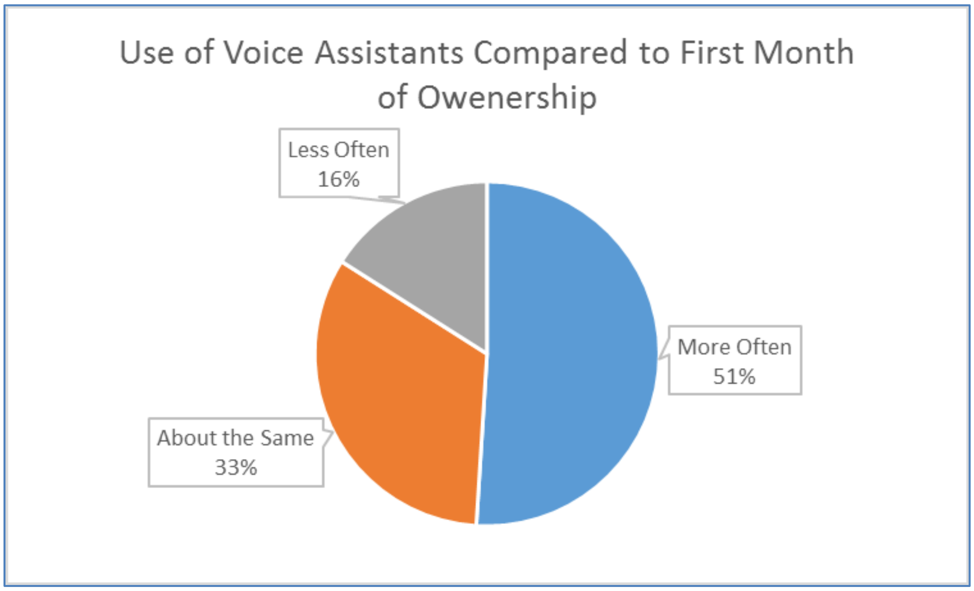

FIGURE 30 CUSTOMER USE OF VOICE ASSISTANTS COMPARED TO FIRST MONTH OF OWNERSHIP

Figure 30 shows that preliminary results trend to voice assistants showing continued persistence of use. Note that these results only show short-term usability (after one month). It will be more important to show usage for over year-periods of time versus months.

SUMMARY

This section focuses on a prescriptive example on how a utility can partner with a product provider to enable multiple value propositions to its customer. The section chooses to do so by developing a scenario in which a utility can evaluate how multiple value propositions can be enabled by voice assistants, a technology subclass selected because of its ability to enable multiple use cases as assessed in Section 3. In addition, the technology subclass was chosen for its ability to enable personalized energy-related services based on a customer's interest in working with its energy provider as well as how he/she uses the ecosystem itself. Current technology and programmatic gaps were also identified such as the need to develop data aggregation platforms to better understand customer usage of residential connected devices was completed in this section.

SUMMARY, RECOMMENDATIONS AND NEXT STEPS

The report tracks the transition from hardware-focused customized energy management systems to device-level IoT to ecosystem approaches which are the focus of development at the time this report was written. Although ecosystems are not new, there has been a transition from centralized, local energy management (phase 1), to Wi-Fi communicating devices with web and mobile applications that serve as primary interfaces to the customer (phase 2), to a third wave of communicating ecosystems using not only mobile apps, but new methods of customer interaction and device aggregation (phase 3).

Recent utility interest in these new ecosystems stem from providing increased customer services, reduction in system energy and demand, improved grid resilience and outage management and enabling greater grid flexibility. However, due to the rapid nature of technology development and the industry trend of moving away from vertically integrated solutions, it remains a challenge to attribute specific value propositions to particular ecosystems as well as components comprising a connected home ecosystem.

The report summarizes three core functions enabled by connected ecosystems: (1) aggregation or grouping of end-uses to respond to particular utility control signals, (2) orchestration which focuses on coordinated programming and response of end-use loads within a premise and (3) optimization which is the use of data and other customer inputs to provide autonomous response targeted for a specific need.

Frameworks are available to classify connected devices based on type of end-use, but there are limited frameworks available to classify connected home ecosystems. As a result, this report proposes a classification system based on nine technology subclasses which divides the connected home ecosystem space based on technical capabilities and market characteristics. Product and service classification to these nine technology subclasses identified five main themes:

- Connected ecosystems are enabling new value streams to potential project partners. With considerable market interest, avenues of customer adoption such as through homebuilders, via broadband and security service providers and through ecommerce platforms allow for new methods and program delivery channels for utilities to increase connected energy ecosystem adoption at a considerably lower cost than traditional program delivery channels.
- There is rapid penetration of some segments of connected devices. Two examples include:
    - In only 3 years after entering the market, it is estimated that over 20 million voice assistants such as Amazon Alexa and Google Home have been purchased. With continuing growth of users of these large market players, low cost entry points of these products and continued interest from third parties to develop functionality integrating their products to these platforms, voice assistants are a potential critical point of residential communicating device orchestration over the next few years.
    - Smart thermostats comprise a considerable market segment. That number can be expected to increase rapidly in the next couple of years as the new ENERGY STAR rating takes hold and new market delivery channels such as homebuilders now see a premium in providing smart thermostats as part of their standard offering.

- Much as is said about enabling interoperability within connected devices. However, when one looks at the industry from an ecosystem approach, one may find interdependencies between product providers when enabling system aggregation and/or orchestration for energy optimization. The report shows that no technology subclass (See Table 12) could completely fulfill all core functions. As a result, business partnerships and technology interfaces appear to be the strategy of the various ecosystems to complement one another in order to stack benefits. Following data transactions between product partners is one proxy to understanding points of aggregation. However, data aggregation is typically not made available to third parties, especially at the ecosystem level, due to barriers such as security and privacy concerns. Unfortunately, this environment makes it hard to decouple value propositions attributed to a sole product provider.
- Level of orchestration is driven by a product provider's ability and willingness to provide data and controls to third parties. This is important to note especially with software-focused technology subclasses.
- It is important to understand root intentions of optimization routines provided by software providers, and to understand the extensibility of implementing these optimization routines on various use cases. These routines are typically developed for a single use case or a minimal set of use cases and utility requirements. It is important to understand extensibility to other similar, albeit nuanced use cases due to variability in utility requirements and program delivery approaches across the country.

The next step was to identify use cases in which connected ecosystems can be leveraged to provide customer and/or grid benefits. A set of use cases were defined and secondary research was completed to see if there were any existing utility initiatives that were assessing these customer and utility facing use cases. As the main focus of many product providers focus on improving customer engagement, many of the customer-related use cases such as enabling dynamic energy rates and improved energy informatics can potentially be realized by connected home ecosystems in the short term.

Technology subclasses were assessed for their ability to enable or support particular use cases and was summarized in Figure 20. Analysis of customer-facing use cases determined that voice assistants followed by mass-market IoT ecosystems currently enabled the most customer-focused use cases. Use cases such as enabling dynamic customer rates, energy informatics, improving EE and DR programs and building energy audits were all identified as potential use cases that voice assistants can enable. Enabling multiple use cases as well customer perception of enabling technology integration results in products and services found within the voice assistant and mass-market IoT technology subclasses be focal points of residential orchestration, which enables stacked value propositions to both utilities and its customers. In summary, a utility can potentially leverage these type of connected ecosystems to provide personalized energy journeys, various levels of utility interaction that a utility can provide its customers associated with these use cases. A proposed hierarchy of these use cases is summarized below in Figure 27.

The remaining use cases focus on how connected home can enable societal, policy and/or grid-related use cases. This research identified that although the market is continuing to mature at a rapid pace, most grid and policy related use cases are still in its nascent stages. Use cases that are grid-flexibility focused and accounting impacts of devices that are subject to rapid technology change is a new paradigm in grid planning which has to look at 30-50 year horizons and grid operations which still requires additional evaluation on the reliability of controls made available by connected home ecosystems. Device aggregators and DER Management focused ecosystems were defined as enablers of a majority of these use cases due to their ability to aggregate control of multiple end-use loads. They were also selected as enablers as products and services comprising these technology subclasses have experience working with utilities and energy providers in providing grid benefits using behind the meter technologies.

Section 3 concludes with an assessment of data made available by connected ecosystems, and assessment of what data can be leveraged from each technology subclass with the goal of moving toward data specification and standardization for each energy journey. Analysis completed in Section 3 concludes that:

- **Value of the device/ecosystem is NOT exclusive to the benefits of the ecosystem operation itself.** Customer journeys begin with a customer's call to action/interest in the ecosystem all the way until the device or ecosystem is decommissioned or no longer used. It is important to vet and devise a comprehensive strategy to leverage and collect information through all facets of the customer journey and maximize engagement throughout. This strategy should consider including: (1) enhancing utility marketplaces that showcases a utility's buying power by providing discounted pricing and rebates that only a utility can provide to a customer (2) conduct clickstream analysis and conversion rates on these utility marketplace and incorporation of these results into utility contact record management or customer information systems and (3) the ability to collect information on how the customer uses these ecosystems to better understand how a customer interacts and orchestrates the use of energy using devices within his/her premise. Leveraging these three items would help the utility continue to be a customer's trusted energy advisor while also developing personalized energy solutions tailored to specific customer needs.
- **Voice is offering new methods of providing and receiving customer information:** As web and mobile applications were the main methods of interaction with connected devices a few years back, recent market interest in platforms with mature voice recognition capabilities such as Google, Amazon, Microsoft and Apple have enabled a new way of interacting with connected ecosystem platforms through home speakers, wearables and mobile phones. This enables the potential for more interactive customer engagement throughout the operation of the ecosystem. This can include proactive bill alerts that can be set up by the customer to warn him/her of high energy usage and possible attribution to certain behaviors, (2) voice reminders of utility pricing or demand response events, (3) enabling personalized orchestration of connected ecosystems during these utility events and (4) continuous collection of information through a combination of ambient and conversational intelligence. The result of this is potentially enabling multiple utility benefits such as enabling a single point of utility orchestration and providing the utility additional information that it may use to provide personalized energy journeys to a utility customer.
- **Data aggregation is less mature than the device orchestration and control:** Analysis of data collection and aggregation is a good proxy of where orchestration/optimization happens within connected ecosystems. Although there are exceptions, data is relatively silo' d and only available to particular project partners and exchanged on an as-need basis due to security and privacy concerns. As data validation, especially energy related data is not necessarily needed for orchestration by connected home ecosystems, it is important to note that there are still gaps in the industry in aggregation of data from connected ecosystems needed for utility programs. This data can include pre-post

optimization data to calculate energy reduction as well as location and availability data for current and emerging demand response/load control programs.

- **Premise-level orchestration of solar, storage AND connected loads is of interest, but there are very few ecosystems in the market today.** There has been considerable interest over the years from many ecosystem platforms to expand their compatible product offerings. Device level aggregators, DER management platforms and energy optimization providers have shown interest in providing a single point of DER management, but none were identified as available beyond proof of concept validation at the time this report is written.
- **Debate between cloud vs. local energy monitoring and management:** Although technology subclasses such as hub-based mass market IoT and DER based management systems offer some local energy monitoring and management capabilities, many connected ecosystems use distributed intelligence and cloud-based platforms to provide for scalability and cost considerations. Cloud-based platforms have the ability to acquire, store, manage, and analyze large amounts of data from connected devices that other architectures cannot. The distributed intelligence in individual devices leads to rapid innovation by many players in the marketplace, not any single one. However, limited local processing means that these ecosystems rely on broadband connectivity and server uptime to enable any sort of orchestration and/or optimization and are therefore subjected to latency issues. Although local energy management will not be as crucial when it pertains to many of the customer-focused use cases, it is important to understand the tradeoffs between ecosystem scalability and control reliability over the next few years, especially as these ecosystems are considered as grid resources. Tracking progress in edge computing is one way to understand progress in local energy management.
- **Data from connected ecosystems is not complete and most valuable in the aggregate:** As data is still relatively silo' d, there is an opportunity to gain a better picture of customer interaction and resultant energy impacts from connected ecosystem deployment and usage. These insights should be compared to utility AMI data analytics methodologies. If proven effective, AMI, connected ecosystem and CIS data should be aggregated. Aggregation of AMI, CIS and ecosystem data can also potentially provide a better picture of how customer behavioral or ecosystem optimization drivers are influencing energy consumption and attribute it to specific ecosystem features. This can be used to not only provide specifications utility program eligibility, but also targeted utility program, service and/or rate offerings. Leveraging customer use cases can assist in developing data needs.
- **Data specification can be a potential bridge to standardization:** Most connected ecosystems and products continue to avoid allowing local control of their appliances and prefer proprietary cloud interfaces as previously discussed. As a result, standards are therefore especially difficult to impose and instead reliance on APIs (other than proprietary web interfaces provided by product providers) facilitated by the manufacturers seems the most effective near term option for collection of data. There are success stories in proactively influencing the supply base to explain the importance and usefulness of having a level of standardization in the dataset. Data standards validating performance can also lead to standardization of communication protocols although like any market/ industry transformational activity, this is a long-term proposition.

RECOMMENDATIONS

The electric power system is changing with forces such as decarbonization, and renewable energy penetration. As a result, the role of the utility is evolving to be a manager of what can be called the "grid of things"[65]. An essential part of this transition will be engagement, management and access not only of the connected ecosystems themselves, but the influence and management of energy prosumers. This can continue to enable a utility to play the role of a trusted energy advisory even in a shared customer space. Enabling customer adoption of connected ecosystems through incentives or education will be helpful only if the utility is ready to embed customer engagement throughout the entire customer journey.

As a result of the research, a comprehensive approach interconnecting all facets of the connected home energy ecosystem customer journey is suggested in order to develop the appropriate customer programs and associated grid services. This includes: (1) understanding the voice of the customer, (2) collection of data and information during program participant acquisition process, (3) leverage market-ready technology delivery channels and consideration of appropriate trade allies and (4) collection of data and identification of opportunities to engage customers through new methods of messaging enabled by these ecosystems. Comprehensive approaches should lead to utilities providing personalized customer offerings based on a customer's appetite for working with its utility. The connected home ecosystem can possibly increase a customer's appetite for working with the utility by providing personalized energy related products such as suggested energy rates or efficiency programs that would help benefit the customer. Detailed recommendations can be found below. Connected ecosystems that enable multiple utility-related customer product use cases coupled by providing personalized options based on customer needs is one potential way for a utility to remain the trusted energy advisor to its customers. Additional recommendations are detailed below:

- **Leverage Market Drivers and Technology Providers Currently Available to Build Long Term Engagement:** The next few years provide a unique opportunity to leverage smart home "market pull." Voice assistants have grown in exponential numbers over the last three years and can potentially serve as a point of device aggregation and control orchestration as they continue to see the largest interest by both connected device and ecosystem providers as well as residential and commercial users. Other ecosystems also have unique ways of providing additional customer value. Security providers are being leveraged to lower property insurance costs, broadband providers are embedding smart home functionality in traditional cable and Wi-Fi offerings and traditional trades such as HVAC and water heater manufacturers enabling fault detection and diagnostics. Aggregators and energy optimization platforms also have unique value propositions in understanding utility customer program needs as they have historically supported energy efficiency and demand response programs. These platforms also provide the ability to control and manage multiple product providers and end-uses. Some having development roadmaps focused on enabling grid flexibility. However, although all these subclasses are promising, there is no single ecosystem that can enable all three core functions – aggregation, orchestration and optimization. The utility is in a unique position to bundle and partner with these service providers in order provide a comprehensive energy management solution to residential customers. This can be done by

[65] Cite PG&E's Grid of Things initiative.

remembering the core functions of connected home ecosystems. It is important to remember that orchestration potentially enables automation and coordination of ecosystems (an inherently customer-focused value proposition) while aggregation provides scale (important to manufacturers and utilities). In order to develop long term customer engagement, it will be important to identify technology subclasses that provide customer impact in the short term through enabling the greatest opportunity for mass connected device orchestration. The report's analysis identifies that products and services found within the voice assistant technology subclass provides this optimal point of orchestration and products such as Google Home and Amazon Alexa integrate with the most number of connected devices and ecosystems currently. Section 4 details a scenario in which a utility can potentially partner w/ voice assistants to enable stacked energy benefits. It is also important to also understand that grid-flexibility related long-term use cases requires mass adoption as well. It is important for a utility to partner with product and service providers from the device aggregators or DER-based aggregation technology subclass, but in particular, partner with product providers that enable mass adoption required for aggregation.

- **Develop and/or Test Software for Integration of Connected Devices into Grid Management:** DR programs have traditionally focused on peak load management. However, the grid is becoming more variable, both at the transmission level and the distribution level. New grid management strategies need to be adopted that integrate customer programs with active grid operations. This will require connecting devices with the information at the edge of the grid such as data indicating distribution system constraints. Utilities will need to develop this layer of control through software to be able to manage a more unpredictable and fast changing grid, both at the bulk level and the grid edge.
- **Investigate Collecting Information and Customer Data Throughout the Entire Customer Journey:** Collection of customer data during the purchasing process, customer onboarding and throughout the operation of the ecosystem can provide additional information on the drivers of customer utility interaction (or non-interaction). Utility partnerships with market delivery channels as well as utility marketplaces and webpages provide unique ways of "low-touch" data collection as well as messaging value of the utility through presentation of incentive offerings as well as other discounts potentially enabled by the power of the utility to provide quantities of scale to product providers. This information can potentially be aggregated with other information found within existing utility's customer information systems and grid planning activities. Constant information collection can provide a more comprehensive understanding of how a customer uses energy therefore leading to customer propensities to participate in other utility programs and services.
- **Develop Avenues for Personalized Customer Engagement through Connected Home Ecosystems:** Developments in connected home ecosystems over the years have allowed new methods to deliver information such as voice reminders and messages through social media applications to customers. Utilities should investigate ways of continuously interacting with their customers through integration with ecosystems that provide these functions. The potential for continuous customer interaction can provide customer value through applications such as proactive bill reminders, new ways of customer messaging load control of rate changes and enabling home energy audits. More importantly, this can potentially result in continuous collection of customer information which can

result in personalized utility product offerings such as rate that would result in reduced energy costs as well as suggested DSM programs and other energy related services.

- **Develop Strategies and Technologies (Software) for Customer Cost Management:** As transition continues to more dynamic and time-of-use rates for customers, utilities can provide customer cost management tools to improve customer adoption and satisfaction. Connected ecosystems offer a great opportunity to integrate energy monitoring using utility AMI data with control of multiple end-systems within a premise to provide both cost management advice as well as active energy use management. This can be done through software development with open ecosystems.
- **Develop Data Specifications:** ENERGY STAR has provided a unique way of standardization based on a focus on data collection to adapt to rapid technology change. Continue to develop data specifications based on prioritized utility use case list that meet utility measurement and verification requirements.
- **Understand and Evaluate How Communication Standards Affect Customer Ecosystem and Utility Program Cost:** Currently, there are several efforts in investigating standardization of communication protocols of connected devices in order to provide grid flexibility. Although reliability and improved availability is an important metric especially as the energy system becomes more dynamic, it is important to note that no current standards comprehensively addresses these future requirements. As these develop, it is not only important to track and demonstrate technology developments but these protocols, but also further understand the economic impact of these protocols and how that may affect market potential of these connected ecosystems.
- **Continue to Investigate Effective Useful Life of Connected Ecosystems:** Reliance of customer broadband connection is an opportunity to provide low-cost connectivity to customer procured devices. However, there are very few empirical evaluating the persistence of energy impacts and grid controllability of these ecosystems. The project team has previously interviewed several product providers[66] and have conducted connected device pilots of their own[67] and have found anywhere from 5-15% attrition from year to year based on loss of device connectivity to broadband. It is important to consider this attrition as well as continue to monitor attrition when relying on these devices, especially when considering these devices for grid impacts. As a fairly new technology, it will be important to conduct assessments and work with respective technology subclasses to better understand the effective useful life of these connected ecosystems in order to do cost calculations for utility programs.

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[66] Cite interviews with Tyson Brown formerly from KCP&L

[67] Cite LES Smart Thermostat Pilot Analysis

APPENDIX A

The following tables detail some of the rationale of the data assessment results detailed as part of Section 3.

TABLE 17: DATA ASSESSMENT DEEP DIVE – EASE OF AVAILABILITY AND DATA LOCATION

TECHNOLOGY SUBCLASS	EASE OF AVAILABILITY	DATA LOCATION
Voice Assistants	Low but Potential. Requires partnership w/ voice assistant providers.	Found within vendor-specific clouds.
Security and Telecom Providers	Low but Potential. But it is important to note that customer data transfer to third parties is not common.	Found within vendor-specific private clouds.
Device Aggregators	High. But details are contingent on data sharing agreements of aggregated devices/ecosystems	Cloud-based
Mass-Market IoT.	Medium. Depending on IoT provider. Depends on data sharing agreements.	Usually found within vendor clouds. Some information can be found within device
Hub-Based Mass-Market IoT	Medium. Depending on IoT provider	Most found within vendor clouds. Some via local energy management.
Traditional Trades	Medium. Depending on existing data infrastructure	Found within vendor clouds. Some information can be found within the device.
Monitoring-Based	High. Depending on existing data infrastructure	Cloud-based
DER Based Management Ecosystems	Medium. Depends on data sharing agreements.	Some cloud-based. Some via local energy management.
Software-Based Optimization	High. Depending on data sharing agreements	Cloud-based. Few via local energy management.

TABLE 18 DATA ASSESSMENT DEEP DIVE – HOW TECHNOLOGY SUBCLASSES IMPROVE CORE FUNCTIONS (AND WHERE DOES IT OCCUR)

TECHNOLOGY SUBCLASS	AGGREGATE	ORCHESTRATE	OPTIMIZE
Voice Assistants	Able to collect asset and availability information. (Cloud)	Can coordinate responses based on customer data at a particular premise (Cloud)	Potentially but software needs to be developed that provides utility optimization (Cloud)
Security and Telecom Providers	Potentially. But availability and location information has been historically proprietary. (N/A)	Can coordinate responses based on customer data/input at a particular premise (Cloud)	Potentially, but requires partnership w/ other technology subclasses (N/A)
Device Aggregators	Core competency. Able to collect asset and availability information.	Potentially, but has not been historic focus of these type of providers (Cloud)	Many are moving toward utility optimization use cases (Cloud)

Technology Subclass	Aggregate	Orchestrate	Optimize
	Level depends on product partners (Cloud)		
Mass-Market IoT.	Able to collect asset and availability information. Depends on existing infrastructure. (Cloud0	Many are moving toward customer control orchestration (Mostly Cloud but some local)	Some are moving toward utility optimization use cases (Cloud)
Hub-Based Mass-Market IoT	Potentially. But depends on existing infrastructure. (Cloud)	Core competency. Can coordinate responses at a particular premise. (Local and Cloud)	Potentially, but orchestration has really been the core focus. (Local and Cloud)
Traditional Trades	Potentially. But depends on existing infrastructure. Potential dependency on third party cloud. (Cloud)	Some are moving toward customer-controlled orchestration. Potentially dependency on third party cloud. (Cloud)	Many have infrastructure for non-kWh utility use cases such as HVAC and water heating audit programs (Cloud)
Monitoring-Based	Able to collect asset availability and location (Cloud)	Can enable orchestration, but usually limited (N/A)	Data can be used to enable optimization, but limited by itself (N/A)
DER Based Management Ecosystems	Able to collect asset availability and location (Cloud)	Potentially, but has not been the historic focus (Local and Cloud)	Many are moving towards utility optimization use cases (Local and cloud)
Software-Based Optimization	Able to collect asset and availability information. Level depends on partners (Cloud)	Potentially, but usually is not the core focus (Cloud)	Many are moving towards utility optimization use cases (Cloud)

REFERENCES

Author (Date), Title. Edition, Place: Publisher [This is the proper format for references.]