Pecan Street Inc.

Final Scientific/Technical Report

February 11, 2014

DOE Award:	DE-OE0000611
Recipient:	Pecan Street Inc.
Project:	Pecan Street Smart Grid Extension Service at the University of Texas
Project Director:	Brewster McCracken
Report:	Final Scientific/Technical Report
Collaborators:	Austin Energy, Oncor and Green Mountain Energy

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Executive Summary

Through funding from the Department of Energy's Electricity Delivery and Reliability Office, Pecan Street Inc., in partnership with Austin Energy and Oncor, developed and tested third-party data access platforms and services for Green Button offerings and for other home energy use data providers. As more utilities seek to offer Green Button-compliant data to their customers, the question continually arises of how this data can be used to help customers better manage their energy use.

The ideal solution is a marketplace in which third-party service providers with expertise in building systems, energy management and consumer behavior can easily access an individual's Green Button data, after getting permission from that individual, and provide energy management services. Through this marketplace, utility customers could shop around for a provider to help interpret their data and provide services to assist in achieving the customer's personal goals, such as reducing monthly electricity bills or reducing greenhouse gas emissions. The industry has identified several challenges in the development of a third-party Green Button marketplace, including big data management, privacy protection, data encryption, cybersecurity verification, ease of use for utility customers and third parties, and development of innovative products and services offerings that excite customers.

To address these challenges, Pecan Street Inc. partnered with Oncor, Austin Energy, Green Mountain Energy and the other members of its Industry Advisory Council to develop a model system and test it using existing product and service offerings.

Oncor's advanced smart meter network extends throughout its Texas service territory, from north Austin through the Dallas-Fort Worth Metroplex up to Wichita Falls, east to Tyler and west to Midland-Odessa. With this advanced smart meter network, residential customers in Oncor's service territory are empowered to access their energy use online through the Smart Meter Texas portal (SMTP), and, to a limited extent, share that data with third parties.

At the beginning of the project performance period, Oncor and the other participants in the Smart Meter Texas initiative were preparing to expand the portal functionality so customers could more easily permit third parties to access their energy use. This would mark one of the nation's earliest adoptions of a system meeting the metrics of the Green Button initiative. Pecan Street added to these efforts, and by extension to Green Button implementation initiatives throughout the country, by testing and refining the third-party data access functionality and establishing a regional extension service to assist other utilities in creating successful Green Button initiatives.

During the project performance period, Pecan Street Inc. successfully created the supporting infrastructure for third-party products and services accessing consumer smart meter data in the

service territory of a utility (Oncor) implementing Green Button-compliant consumer data access provisions. This supporting infrastructure makes it possible for retail utilities and third-party providers to carry out product performance validation for Green Button-compliant consumer offerings in a secure setting prior to a utility agreeing to serve as a channel to market for the third-party's Green Button consumer offerings.

The project team also demonstrated an advanced smart meter network and Green Button-compliant consumer data implementation in the service territory of a utility (Austin Energy) that does not have a smart meter network capable of providing such data access. This demonstration was carried out with the full support and participation of Austin Energy.

Finally, by field testing the SMT third-party data access process and comparing it with the alternative data sharing process piloted using Pecan Street's smart meter research network and its home energy monitoring systems deployment, the project team demonstrated best practices for providing consumers with access to their energy use and value-added services without relying on a utility meter. Demonstrating this model is critical for advancing third-party services in locations where meter data is not available and for serving customers in jurisdictions where utilities lack the infrastructure or authority to provide customers and authorized third-party providers with access to customer data.

To achieve these objectives, Pecan Street established a non-profit consumer smart grid product testing center and a pilot smart grid regional extension service, that included:

- an advanced computing platform and data center located at the Pike Powers Laboratory and Center for Commercialization
- with actual real-time meter data from a dedicated smart meter deployment installed by Austin Energy and Landis+Gyr at the homes of Pecan Street volunteer participants for research, demonstration and validation
- with actual Oncor smart meter data from volunteer participants using Smart Meter Texas's forthcoming third-party data access protocols
- with collected energy use data disaggregated to the circuit and device level by Pecan Street and Intel
- incorporating the nation's deepest-ever consumer energy use and consumer research data from the nation's highest residential concentration of electric vehicles, residential solar PV and smart appliances.

The results of this project provide a pathway to a robust third-party marketplace for value-added products and services utilizing customer's smart meter data. Through Pecan Street's established smart grid product testing center and regional extension service, utilities can learn

about best practices in smart meter data management, customer communications and third-party data access.

Demonstration Summary

Program Objectives

The goals of the Pecan Street Smart Grid Extension Service were to:

- Create supporting infrastructure for third-party products and services accessing consumer smart meter data in the service territory of a utility (Oncor) implementing Green Button-compliant consumer data access provisions. This supporting infrastructure makes it possible for retail utilities and third-party providers to carry out product performance validation for Green Button-compliant consumer offerings in a secure setting prior to the retail utility agreeing to serve as a channel to market for the third-party's Green Button consumer offering.
- Demonstrate an advanced smart meter network and Green Button-compliant consumer data implementation in the service territory of a utility (Austin Energy) that does not have a smart meter network capable of providing such data access. This demonstration is carried out with the full support and participation of Austin Energy.
- Demonstrate best practices for providing consumers with access to their energy use data and value-added services without relying on a utility meter. Demonstrating this model is critical for advancing third-party services in locations where meter data is simply not available, such as non-metered multi-family and condo housing, and for serving customers in jurisdictions where utilities lack the infrastructure or authority to provide customers and authorized third-party providers with access to customers' data.

Program Accomplishments

Building upon its award-winning success in establishing and managing smart grid field trials, Pecan Street successfully recruited over 1,000 volunteer participants from within the Oncor and Austin Energy service territories to participate in the research trial.

The project team leveraged the Smart Meter Texas (SMT) portal, developed through a collaboration between Oncor and regional retail utilities to create supporting infrastructure for third-party products and services accessing consumer smart meter data in the service territory of a utility implementing Green Button-compliant consumer data access provisions. The project team also collected data from its smart meter research network within Austin Energy's service territory to demonstrate best practices for providing consumers with a third-party information tool that gives them access to their energy data and provides a platform for customers to receive value-added services from this data. Energy data routers deployed through this project and

under a separate Department of Energy cooperative agreement provided granular home energy consumption data to test and develop best practices for consumers in areas without Green Button-compliant offerings.

Project data collected from the smart meter research network, SMT and energy data routers flowed to Pecan Street's data center located in an advanced, secure server cluster at the Pike Powers Laboratory & Center for Commercialization. From the database, the project team integrated the SMT and Austin Energy smart meter data, along with data from its deployed network of energy monitoring systems that provide granular data on circuit-level energy use, into multiple third-party online portals and mobile applications. These online and mobile services provided all participants, as well as authorized third parties, with electronic access to individual households' electricity consumption data and enhanced information intended to help the consumer better manage their energy use.

Pecan Street's Cybersecurity and Interoperability Plan was implemented to maintain the privacy and data security of all customer data. This policy has been reviewed and approved by Pacific Northwest National Lab and the U.S. Department of Energy.

Implementation Details

During the project performance period, Pecan Street provided many of its volunteers in the Oncor and Austin Energy service territories with access to their energy use data at a granularity of 15 minutes or less via a third-party web-based portal. In the first phase of the project, the project team achieved the following milestones to expand product developer, researcher and customer access to energy data:

- Launched the nation's first independent Green Button application testing center. Through this testing center, Green Button app developers can:
    - access actual customer data to develop new Green Button apps;
    - receive independent performance verification reports that app developers can take to utilities to facilitate faster market adoption.
- Recruited over 1,000 participants to use one of five third-party consumer-oriented information tools or software products.
- Installed and went live on the nation's first smart meter testing network — dual meter sockets installed in over 200 homes in one neighborhood so utilities and metering technology developers can test and observe smart meters in a real world setting before deciding on their technology approach. Landis+Gyr and Itron installed meters in the network to develop new product capabilities and to demonstrate the capabilities of advanced metering for utilities evaluating advanced metering.

- Prior to the performance period, the project team undertook energy audits in 200 of the participating homes within Austin. During the performance period, the project team undertook a detailed analysis of the energy use in 50 of the participating homes outside of Austin through installation of an energy data router that provides granular, circuit-level data on energy consumption.
- Analyzed customer preferences and behavioral trends through implementation of a sociodemographic survey, review of participant engagement and portal use, surveys on customer satisfaction with the Smart Meter Texas Portal and the Pecan Street-provided third-party portal and testing of messaging most effective at motivating individuals to volunteer for this study.
- Established advanced metering and gateway device testing capabilities at the Pike Powers Lab and Center for Commercialization ("Pike Powers Lab").
- Tested interoperability of third-party tools on multi-platform systems and analyzed system reliability and performance.
- Developed data management protocol consistent with the organization's DOE-approved Cybersecurity Plan that enables integration of data from multiple systems and seamless transmission of that data to third parties.
- Launched the world's largest research database on customer electricity and natural gas use and opened access to this database to utilities, hardware and software developers and university researchers. In the first four months, 104 university researchers from 55 universities in 14 nations joined Pecan Street's research consortium and began carrying out original smart grid research through access to this database.
- Engaged PlotWatt Inc., a Delaware corporation with a principal place of business in Durham, NC, as a consultant to develop, host, and maintain an energy consumption dashboard for program participants. PlotWatt was engaged under a Master Services Agreement executed on December 12, 2012, which grants a license to Pecan Street and Pecan Street's program participants to use the energy consumption dashboard.
- Created large scale disaggregated datasets for two "hackathons" to seed understanding among software developers of how to use electricity data to develop third-party Green Button applications.

The nonprofit testing and demonstration capabilities established by the project team are not controlled by any utility, state or community. Rather, these independent development assets are equally accessible by utilities, regulators, software and hardware developers and university researchers from throughout the nation.

Program enrollment

In June 2013, Green Mountain Energy, a retail utility provider in Oncor's service territory and member of the Pecan Street Research Consortium, partnered with the project team to enroll participants and provide technical support for this project. Green Mountain Energy is a leading retail utility that serves a niche market of customers who prioritize energy efficiency, clean power and environmental stewardship. Their customers were highly responsive to Pecan Street's recruitment messaging and the project team was able to meet its recruitment goal with relative ease.

Infrastructure deployment

To acquire Green Button data, the project team leveraged the Smart Meter Texas data collections system built off of Oncor's broad smart meter deployment and the Pecan Street research meter network infrastructure within Austin Energy's territory, installed under a Department of Energy Smart Grid Demonstration Grant. The Pecan Street research meter network consists of 259 Advanced Metering Infrastructure (AMI) dual-socketed smart meters that are industry standard and act as a Home Area Network (HAN) gateway. Data is collected in 15-minute whole-home readings.

These meters demonstrate an advanced smart meter network and Green Button-compliant consumer data implementation in the service territory of a utility (Austin Energy) that does not have a smart meter network capable of providing such data access. This demonstration is carried out with the full support and participation of Austin Energy. The research meter network is supported by a Landis+Gyr network infrastructure and backend system that securely transmits data from the meter to Pecan Street's database.

Consumer behavior analysis

To enable detailed research on consumer behavior and preferences, the project team developed and administered a biannual survey that captured detailed information on participants, including demographic data, home attribute information, energy use perceptions and portal usability. The survey also documented if the participants felt that access to energy data had any affect on their behavior.

The results of this survey are concatenated to energy use and energy audit data within Pecan Street's secure database, where all data is anonymized and separated from personal identifying information (PII). The survey results were used by the project team to refine its understanding of the Green Button data-enabled third-party products and services, including mobile applications, that customers would find most valuable. As with all research data, the anonymized survey results are also made available to members of the Pecan Street Research Consortium.

Through this field trial, Pecan Street Inc. tested the following five third-party energy use portals:

- PlotWatt
- CheckIt
- eGauge
- Sony
- Pumpkin Pie

Through the biannual survey and customized surveys for each portal, the research team collected data on preferred features, frequency of use and perceived impacts on consumption. For confidentiality reasons, the research team is not able to report on the performance of specific portals. Of the 1,000 participants in the study, 400 completed the biannual survey. Of those participants who responded to the survey, 11% reported that they use the provided portal to monitor their energy use on a daily basis while 28% reported that they check their energy use weekly, 12% reported never having looked at their portal and the remainder reported checking their portal once or twice a month. The majority of participants, 82%, who only had access to the SMT portal reported that they rarely, less than once a month, looked at their SMT portal.

Participants with access to a third-party portal were asked which features they liked or would most like to see in their portal. The responses in order of frequency are:

- Energy use reported by appliance and in real time, which the project team determined to be at 1-minute intervals or less, rather than hourly or whole-home data
- User friendly: ease of use in determining what are the major users of energy within the home and data visualizations
- Consumption reported by kilowatts and by dollars
- Reporting feature that allows the user to easily create custom reports of energy use and export that information
- Data provided through a mobile app rather than only through an online portal
- Functionality that allows the user to set energy use goals that align with their monthly billing cycle and receive alerts when energy use exceeds those goals
- Variety of data visualizations

The majority of participants, 84%, reported that they have changed to their behavior based upon information they received through a third-party portal that shows appliance-level energy use. The most commonly reported changes were turning off lights, fans, appliances and consumer electronics when not needed, setting A/C to a higher temperature when not home,

hang-drying clothing instead of using an electric dryer, and generally feeling more conscientious about electricity use. The majority of participants that only had access to the SMT portal reported that they did not change their behavior based upon this data because they were not provided with actionable information.

Data access and collection

Pecan Street collected energy use data through three systems: Smart Meter Texas, its own smart meter research network and energy data routers that were installed through this cooperative agreement and a separate Department of Energy cooperative agreement. Pecan Street's smart meter research network in the Austin Energy territory has reported data from its network of 259 homes for over a year. The deployed energy data routers, which report 15-minute, circuit- and whole home-level data, consistently report data directly to Pecan Street's database where it is available to project team members.

The project team experienced some challenges in accessing Smart Meter Texas data due to a delay in the release of SMT's third-party API. While data collection and third-party access will be streamlined through access to the full SMT third-party API, the project team employed two mitigation strategies to enable SMT data collection prior to release of the API.

The first strategy employed involved collecting SMT user login information from its participants in Oncor's service territory and manually downloading each individual customer's data on regular intervals. This process proved time-consuming and slowed the rate at which customer data could be loaded into the third-party portal.

The second mitigation strategy was developed in partnership with Green Mountain Energy, who provide their retail utility's SMT API access key. Through its ongoing partnership with Green Mountain Energy (a NRG Retail utility), Pecan Street negotiated an agreement to use Green Mountain's SMT API key to access the SMT backend and pull data for all participating customers.

Data interoperability and cybersecurity

Pecan Street's interoperability requirements ensure that every deployed application is configured to ensure the team can carry out critical project functions such as integrating multiple applications into a single functioning system, inventory monitoring of deployed applications and evaluating the performance of those applications, remote software updates and detecting and correcting faults. The project team was also able to document user interface and ease-of-use issues.

Pecan Street's DOE-approved Cybersecurity Plan ensures data collection and transmission of that data to a third-party is performed without risking the security and privacy of the utility or

the participant. The Cybersecurity Plan is a landmark policy that has been proven effective in creating a framework for the collection, storage, anonymization and management of confidential data and for sharing that data with approved third parties in a manner that ensures the security of participants' privacy and identity. Members of the Pecan Street Research Consortium are currently utilizing the Cybersecurity Plan as a template for development of a broader end-to-end smart grid security fabric product.

Results

Throughout the project period, Pecan Street gained valuable knowledge that will inform its extension services to other utilities, including scaling the availability of an effective third-party consumer-oriented information tool to all residents in the NRG Retail and Austin Energy service territories as well as customers of any utility that offers data in Green Button compatible format. The primary lessons learned during the performance period include team management, consumer preferences, and data collection and data management.

Products Developed and Technology Transfer Activities

Pecan Street operates an Industry Advisory Council through which leading companies and utilities consort on smart grid and clean energy, and it operates a Research Consortium through which graduate students and faculty at research universities around the world access the unique data collected by Pecan Street and collaborate on research that answers questions of interest to industry. Through these two networks the results of Pecan Street's research are quickly disseminated. Members of the Industry Advisory Council join to have access to the organization's unique product testing and development infrastructure and to collaborate on industry challenges. The organization's application to the Department of Energy under FOA 579 was developed in collaboration with members Green Mountain Energy, Oncor and Austin Energy.

In the pursuit of establishing an infrastructure to support utilities in implementing third-party data access, the project team developed a unique database backend to import and store SMT and other meter data from third-party providers. The project team also developed tools to automate export of data into Pecan Street's backend from SMT and the research meter network backend. This database structure is a model for how other third parties could access green button data regardless of whether the utility has an API set-up for export.

To additionally foster interest in third-party energy use data, Pecan Street Inc. hosted "hackathons" during the performance period. The local development community was tapped in search of ground-breaking ideas in energy data utilization by participating in two local "hackathons," one sponsored by AT&T and one sponsored by SXSW Eco. Using the provided Pecan Street data set, taken from the nation's deepest and most detailed database of energy

consumption information, each “hackathon” competition gave teams of programmers a weekend with the data to see what mobile apps the best and brightest minds could come up with.

Pecan Street's data provided for the “hackathons” represented a week's worth of ground truth energy consumption data from five different types of consumer, each with their own separate concerns, habits, usage patterns, spending ability, home type and appliances. Developers could see, minute-by-minute, what level of energy each major circuit in the home was using. Programmers were tasked to come up with a breakthrough idea – more than just displaying power or showing a particularly thirsty circuit, as that market is fairly saturated. Programmers were asked to use their canvas to empower consumers and industry providers with this information, and to provide insights to a home owner about their homes and their lives. The resulting apps aimed to derive new functionality that would be useful not just for homeowners, but also for home developers, appliance manufacturers, utilities, solar panel makers and electric vehicle manufacturers.

Winning ideas included engaging representations of energy consumption, gamification of energy savings among groups of friends, and location-based alerts based on circuit reads in the home when the user was not at home. Each idea contributed to the competition became open-source, and local developers and the energy community at large are able to build on those ideas and continue the progress in energy related software development.

Two companies, joint winners of the SXSW Eco Hackathon, have decided to take the ideas jointly developed by their team and continue to implement them into ongoing commercial and research products in the private sector. These two companies have entered into ongoing business relationships with Pecan Street and have received no-cost commercial development licenses to a large amount of underlying energy consumption data, similar to that which was provided by Pecan Street for the hackathon. Pecan Street looks forward to continuing to work with these and other similarly situated companies to provide support and guidance in the field of disruptive energy innovation.

Knowledge Gained and Recommendations

Early in the project, agreements between the project partners, Pecan Street, Landis+Gyr, Oncor and Green Mountain Energy served to establish effective roles and responsibilities and fostered an atmosphere of collaboration that helped overcome obstacles. Prior to beginning data collection, Pecan Street and Landis+Gyr developed risk mitigation strategies in the event that technical obstacles were encountered when establishing Landis+Gyr’s backend system called Command Center at the Pike Powers Lab & Center for Commercialization. Alternatives were not needed, however, as no problems were encountered with implementation of Command Center. Risk assessment and mitigation plans developed during the early stages of the project

have proven invaluable in progressing the project objectives. Concerted and widespread efforts to communicate the existing end goals of the programs have been essential in garnering new participants.

Effective communications and messaging are critical to recruiting and retaining project volunteers. Broad scale communication efforts need to not only to inform potential participants of the program, but also of the benefits of participating in the program. Issuance of the annual Pecan Street surveys proved to be a beneficial precursor to starting this demonstration project. A supplementary survey is planned to be administered every six months to gather more in-depth information on customer preferences and behaviors around specific technologies, such electric vehicles and rooftop-mounted solar arrays. The surveys are critical to the demonstration as they provide a snapshot of preferences prior to homes receiving access to their energy data through the third-party portal.

The most significant experiences the project team derived are best practices for acquiring and managing high velocities of granular customer electricity use data from multiple measurement technologies and vendors, organizing and managing this information at Pecan Street's data center (housed at its Pike Powers Lab and Center for Commercialization), and configuring the database to ensure the data is structured for typical queries and actions by researchers and product developers.

The project team also developed significant expertise and awareness on the various methods for obtaining third-party access to customer energy data from different utilities and service providers. One significant takeaway is that a third-party customer application must have in place multiple methods for automatically downloading a customer's electricity use data when the customer has authorized such transfers.

Conclusions

Providing customers with access to their electricity use data yields many benefits for the consumer, including more control over utility bills as well as a heightened awareness of what a 'normal' energy use pattern looks like so that abnormalities can be identified, which may be indicative of needed home repairs. By providing third-party access to this data for vendors approved by each customer, a marketplace for products and services will be created that adds greater value to Green Button data. These third parties can provide services that will manage a customer's utility use for them to ensure households stay within their utility budget and/or meet environmental goals, provide home improvement recommendations that will help the customers save energy, and develop mobile applications that visualize energy use data so that customers can more readily turn that data into actionable information.

Based upon feedback from participants and technical challenges encountered during the performance period, the project team learned that an effective third-party platform for value-added energy data is dependent on providing a product that enables and integrates data

collection from multiple sources to provided the most complete picture of energy consumption. Use of the information tool is improved when more details about the home's opportunities for energy savings are provided. However, it is important to provide a tool that can take the lessons learned from comparable homes that have more energy data available and apply those lessons learned to recommendations for homes with minimal energy data available. The Pumpkin Pie app developed by the project team is the only product that offers this service for free through an easy-to-use mobile application that learns and refines its recommendations as more data is gathered from the expanding base of users.

Pecan Street Research Institute

Pike Powers Lab
and
Center for Commercialization

FOA 579 Phase 2

Presentation outline

Milestones

Purpose driving approach

Selected engagement tool

About Pecan Street Inc.

University-based research institute

19 full-time employees

Pecan Street consortium members

Utilities

Austin Energy
NRG
Oncor
Texas Gas (OneOK)
San Diego Gas & Electric
Southern California Edison

Non-utilities

3M
Dell Inc.
Freescale
GM OnStar
Intel
Landis + Gyr
LG Electronics
Schneider
Siemens
UL
Xerox

Milestones

Demonstrated ability to execute

World's largest research database on customer electricity and gas use

Nation's highest residential concentration of EV's

Launched the nation's first independent Green Button application testing center

Carried out over 200 comprehensive energy audits

Demonstrated ability to execute (cont'd)

World's first meter network for 3rd party research and testing

Recruited over 1,000 participants in 3 states

Opened research database to global academic research community. World's largest free data set of disaggregated use.

Over 100 researchers, over 50 universities in 14 nations

Purpose driving approach

Change in peak load

by customer class

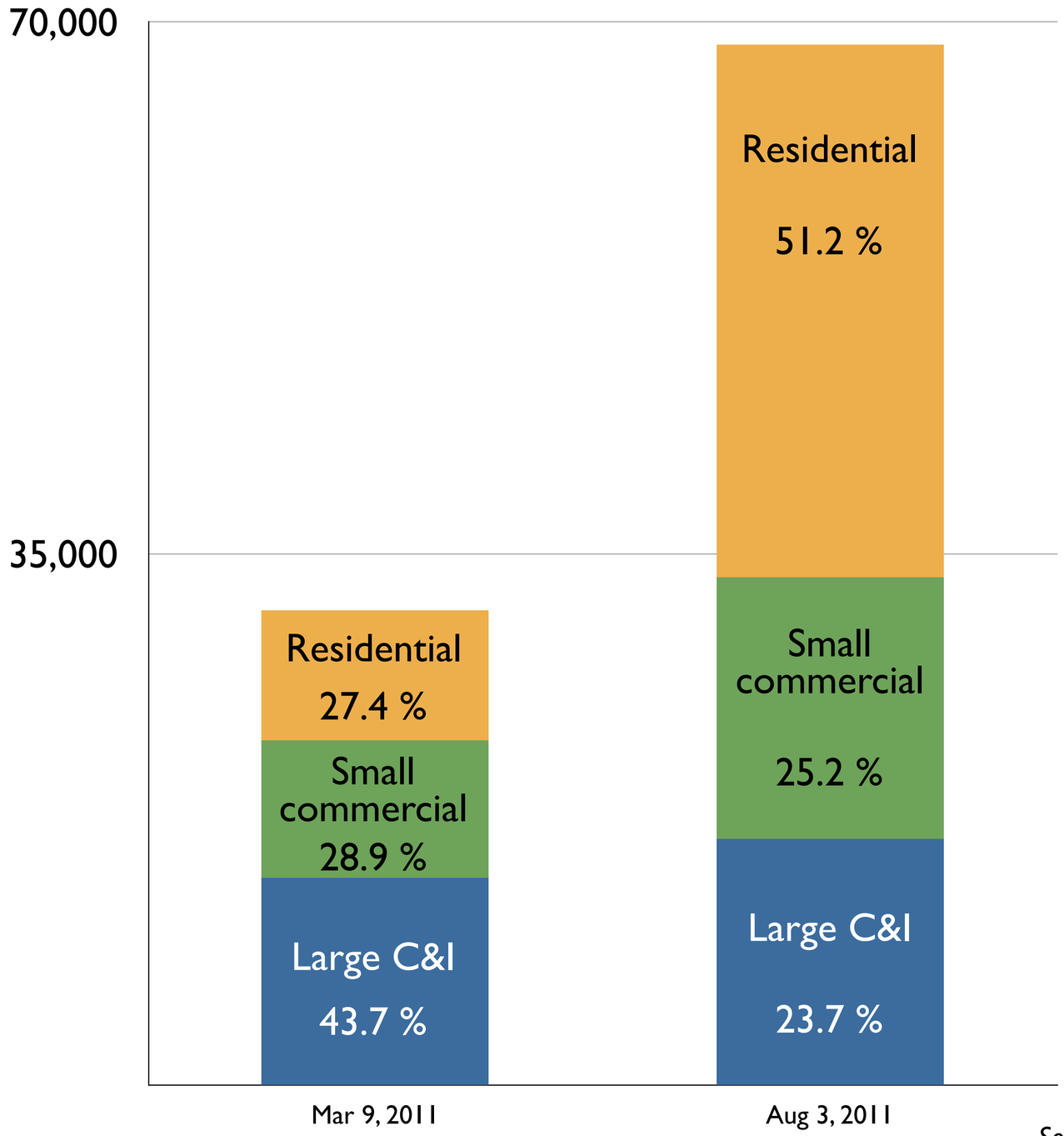
5:15 pm

March 9, 2011

31,262 MW

August 3, 2011

68,416 MW



Source: ERCOT

Afternoon peak (Texas Interconnect)

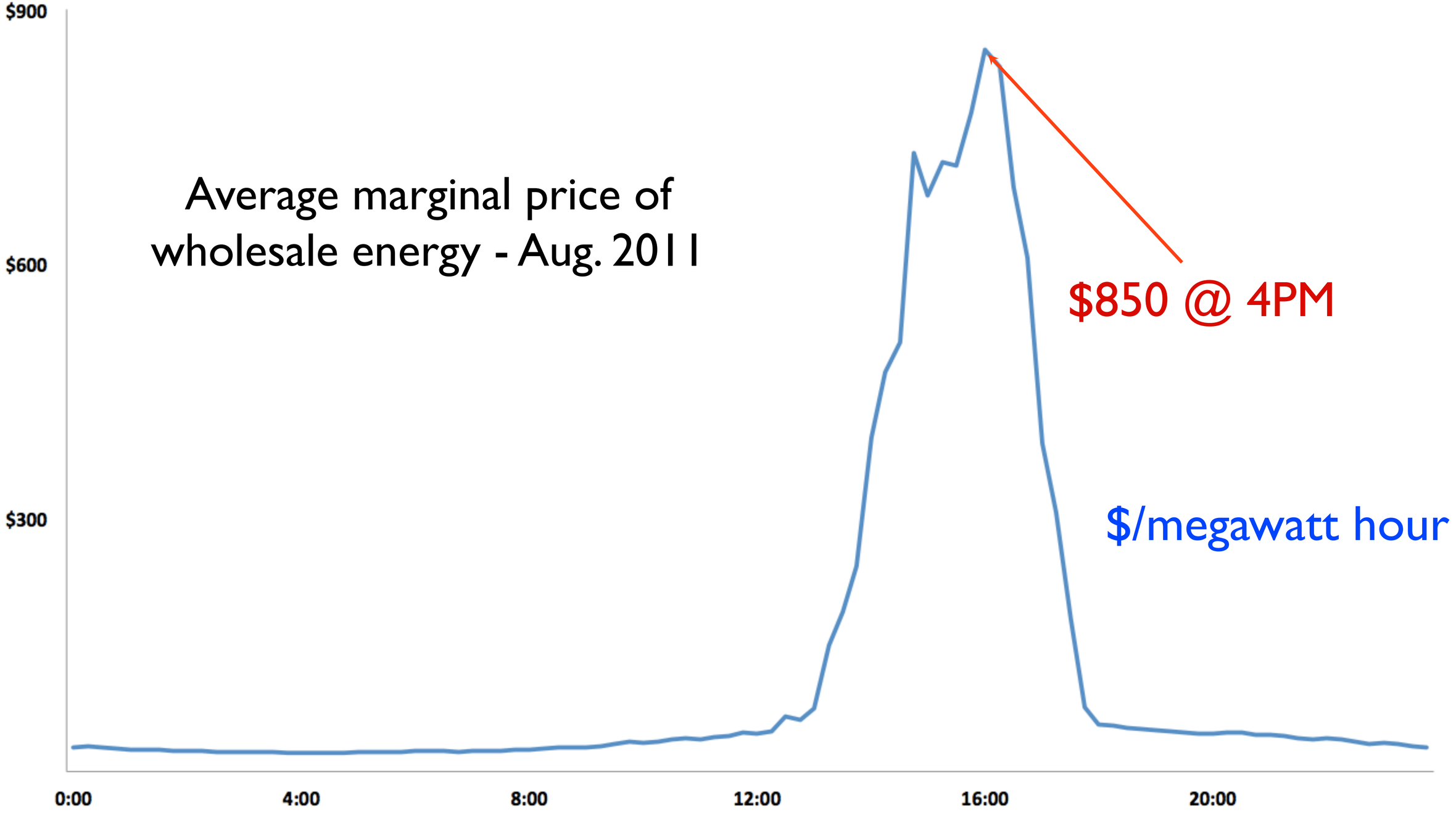
Spring	31,262 MW
Summer	68,416 MW
Increase	37,154 MW
percent increase	119 %

Percentage of total increase in peak demand

Large commercial & industrial	7 %
Small commercial	22 %
Residential	71 %

Procure more generation

Options for
meeting increase
in demand


Average marginal price of wholesale energy - Aug. 2011
$850 @ 4PM
$/megawatt hour
$900
$600
$300
0:00
4:00
8:00
12:00
16:00
20:00

Options for meeting increase in demand

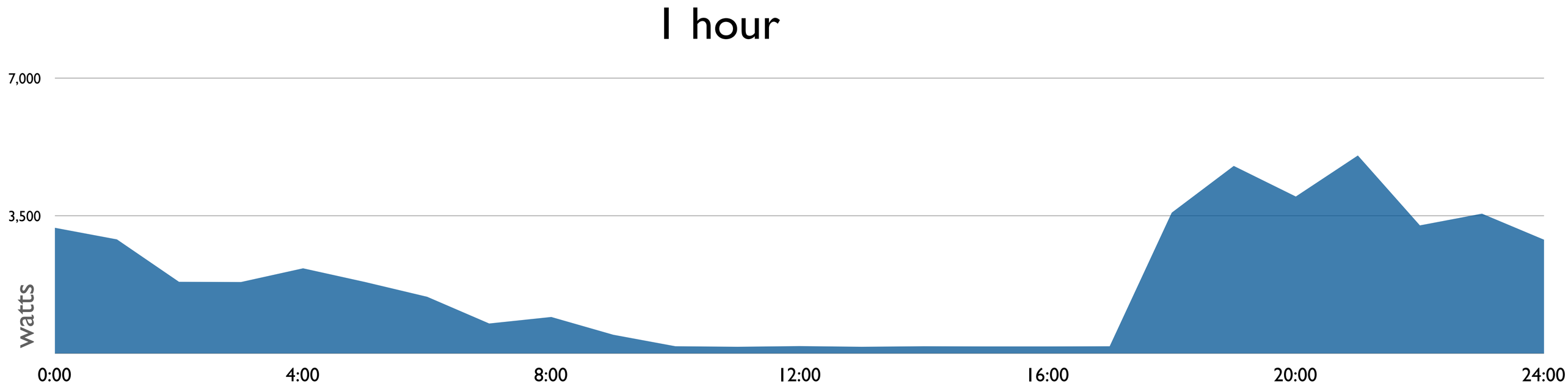
Procure more generation

Ration

Change consumption behavior

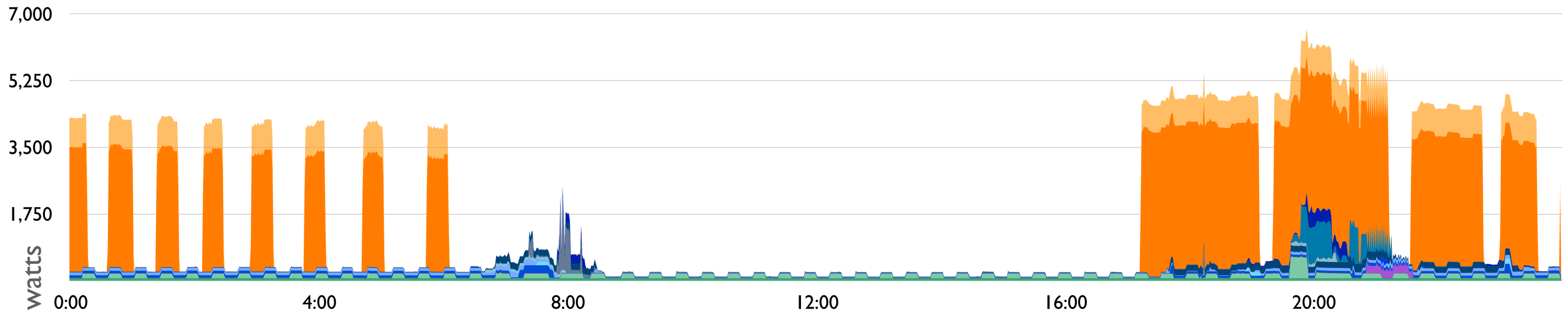
July 31, 2012

Daily electric use: smart meter



Source: Pecan Street Research Institute

Summer day Single home – 1 minute interval *

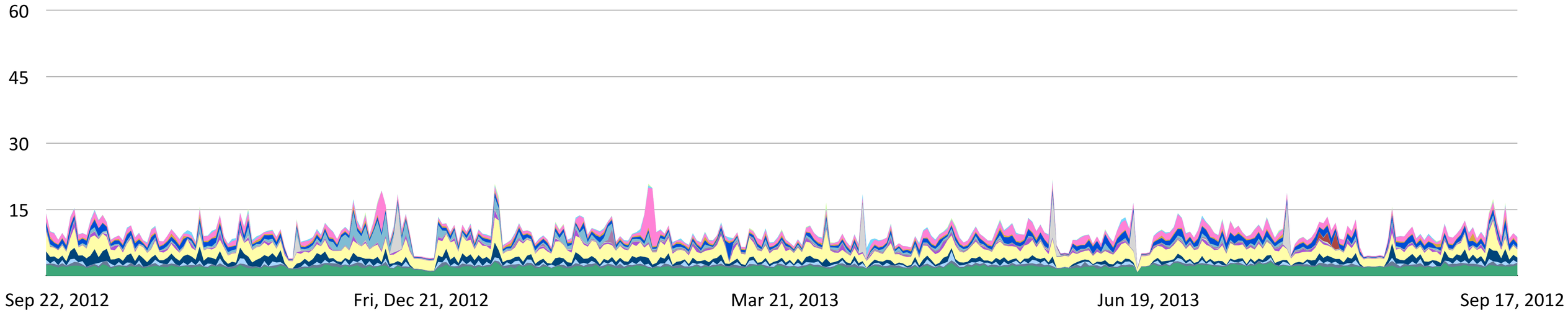


Source: Pecan Street Research Institute

- Other
- Dryer
- Bedroom 2
- Microwave, toaster oven, coffee machine (KSAC 2)
- Dishwasher
- HVAC compressor
- Living Room Always On
- Master bedroom
- Bathroom 2
- Kitchen lights (Kitchen1)
- Living Room
- HVAC air handler
- Refrigerator (KSAC 1)
- Bathroom 1
- General Lights 1
- Washer
- Garage

** All individual circuits measured using customer HAN device*

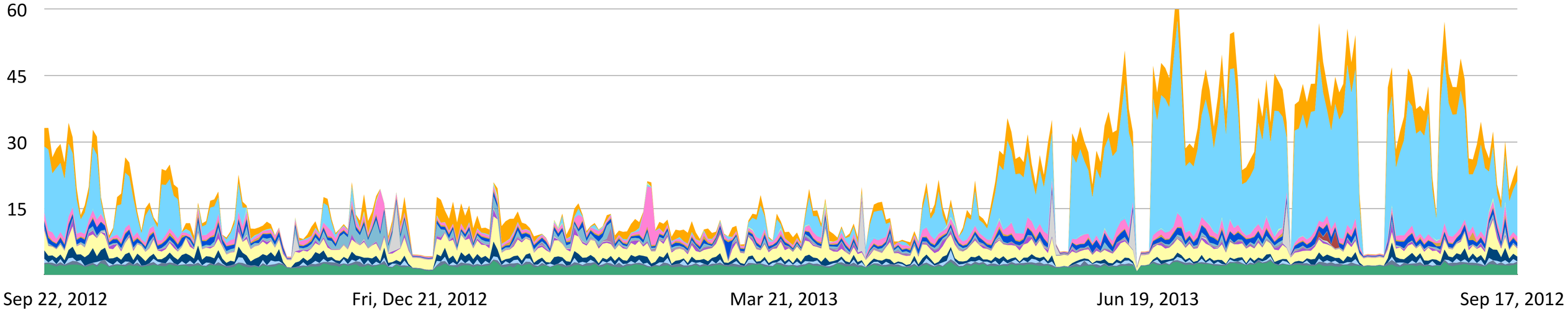
One year Single home – daily electricity use – non-seasonal



Source: Pecan Street Research Institute

Refrigerator [KSAC 1]
Washer/Dryer
General Lights 1 [kW]
Bathroom 2 [kW]
Microwave and toaster oven [KSAC2]
Dining Room
Bedroom-Master [kW]
Dishwasher
Garage
Bedroom 1 [kW]
Kitchen Lights [Kitchen 1]
Plugs 1
Bedroom 2 [kW]
Living Room-TV [kW]
Plugs 2 [kW]
Bathroom 1 [kW]

One year Single home – daily electricity use + HVAC



Source: Pecan Street Research Institute

- Refrigerator [KSAC 1]
- Washer/Dryer
- General Lights 1 [kW]
- Bathroom 2 [kW]
- Microwave and toaster oven [KSAC2]
- Dining Room
- Bedroom-Master [kW]
- AC compressor 1 [kW]
- Dishwasher
- Garage
- Bedroom 1 [kW]
- Furnace-Air Handler 1 [kW]
- Kitchen Lights [Kitchen 1]
- Plugs 1
- Bedroom 2 [kW]
- Living Room-TV [kW]
- Plugs 2 [kW]
- Bathroom 1 [kW]

Residential consumption

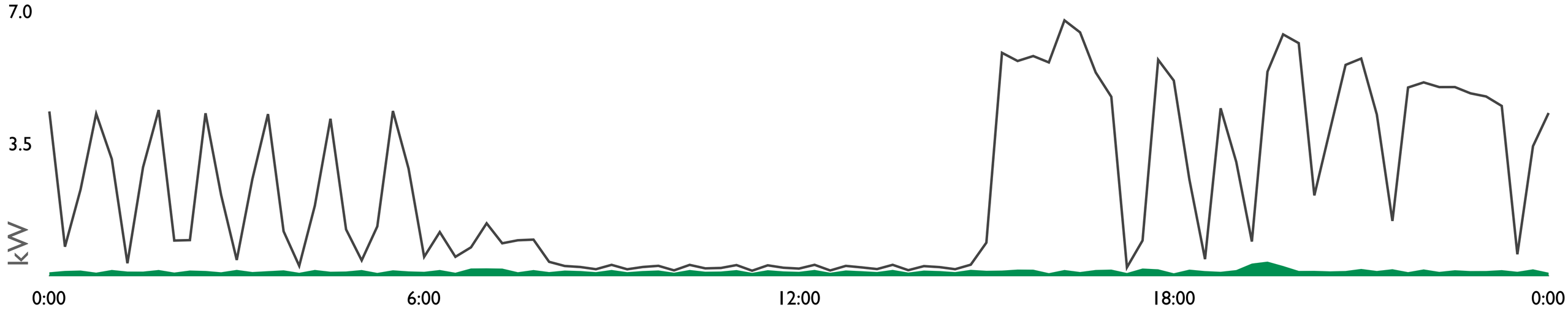
Four Categories of Electricity Use *

Always On

Thermal

Electric-gas substitute

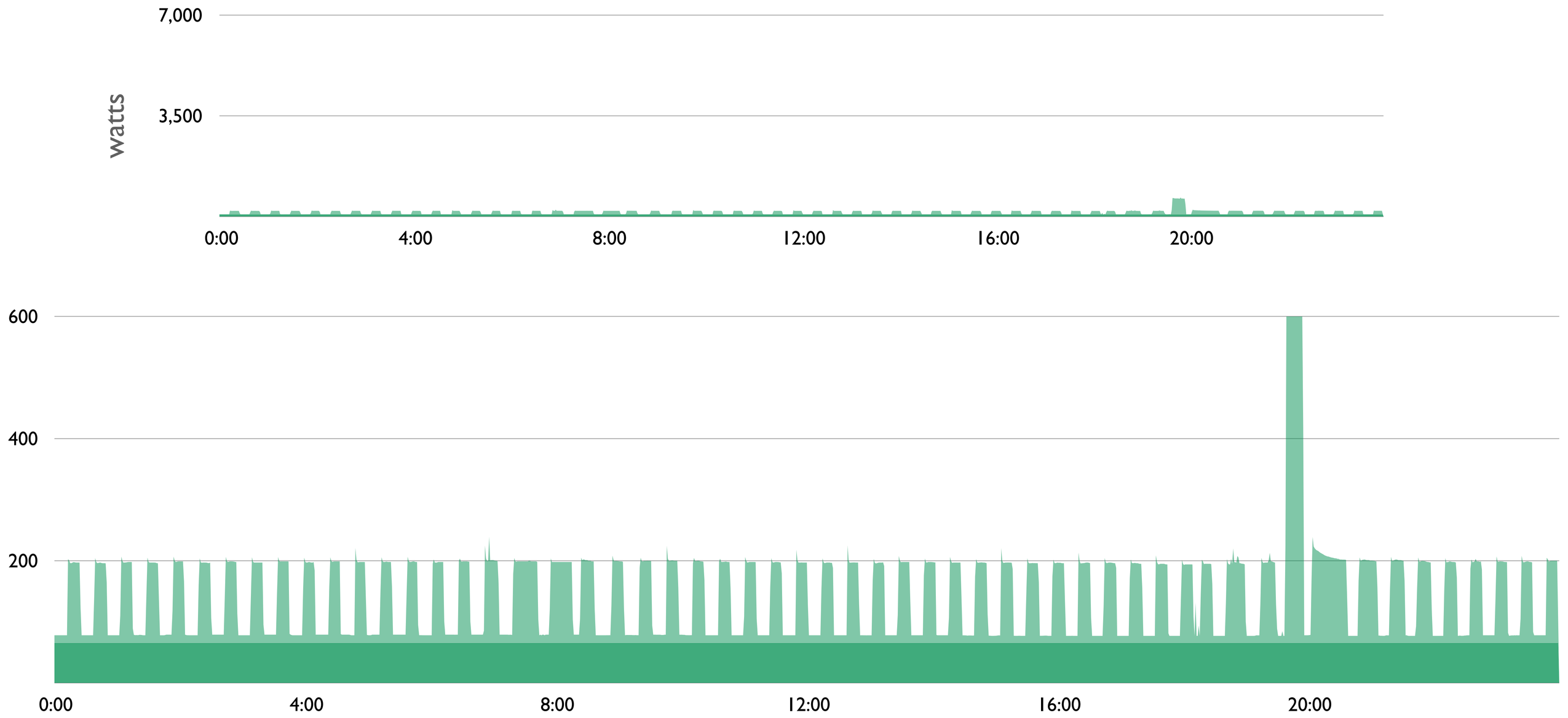
Intentional



Source: Pecan Street Research Institute

* *All individual circuits measured using customer HAN device*

Four Categories of Electricity Use Always On



Source: Pecan Street Research Institute

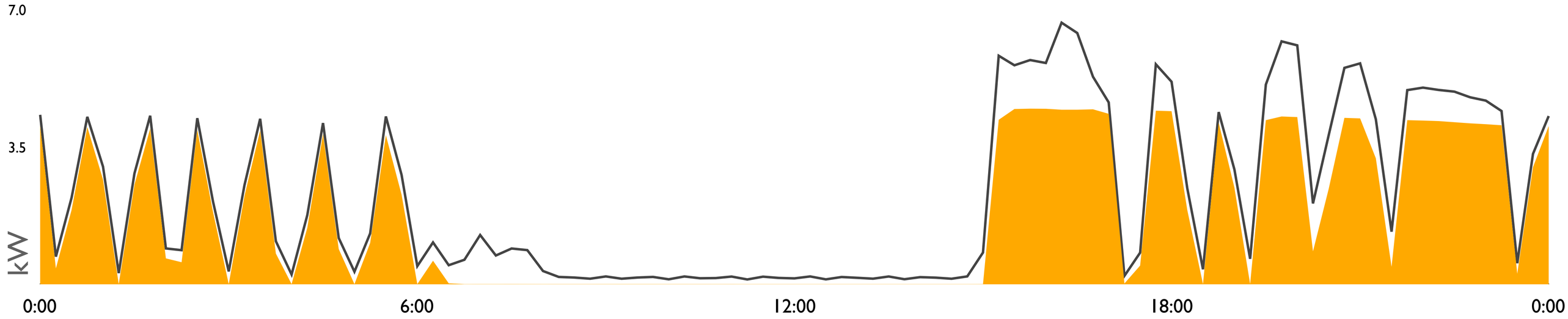
Four Categories of Electricity Use

Always On

Thermal

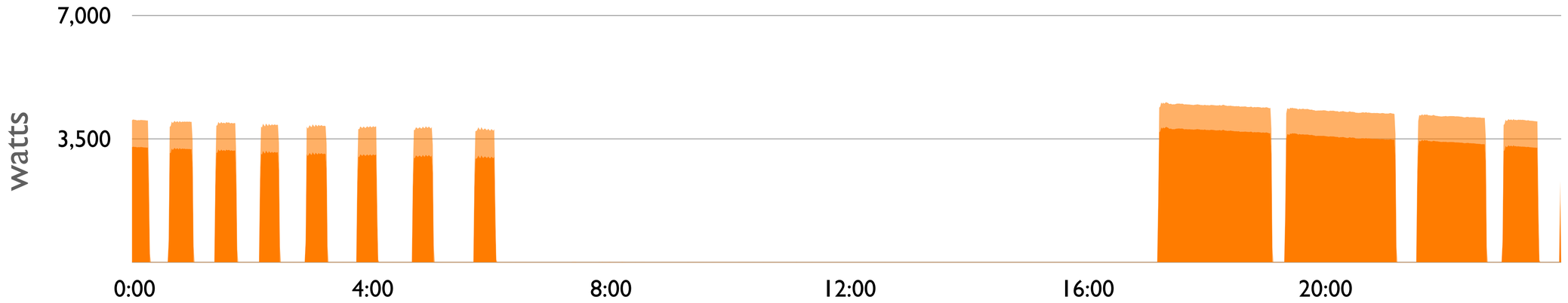
Electric-gas substitute

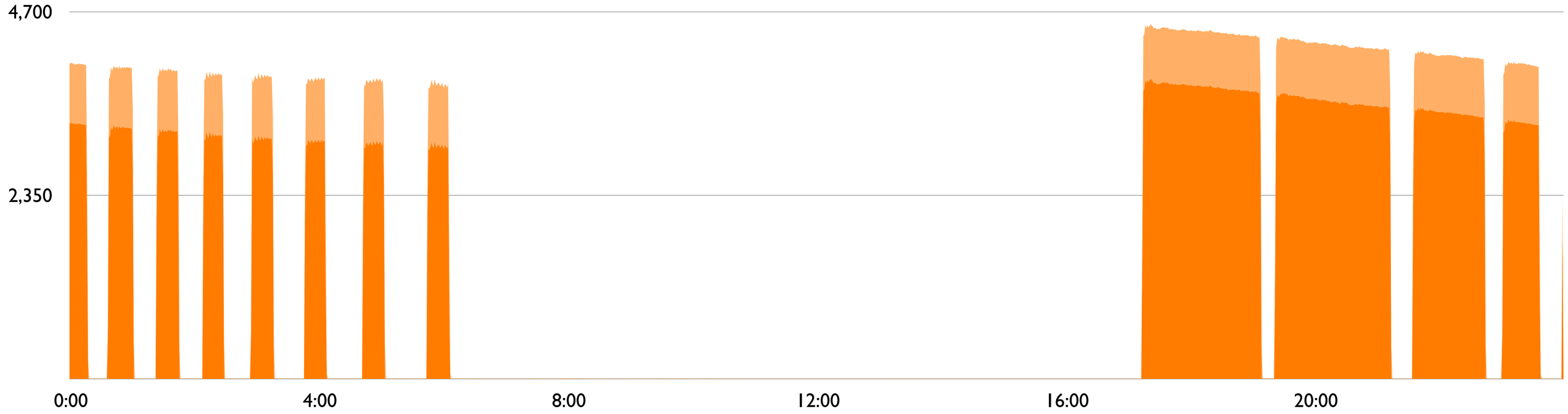
Intentional



Source: Pecan Street Research Institute

Four Categories of Electricity Use Thermal





Source: Pecan Street Research Institute

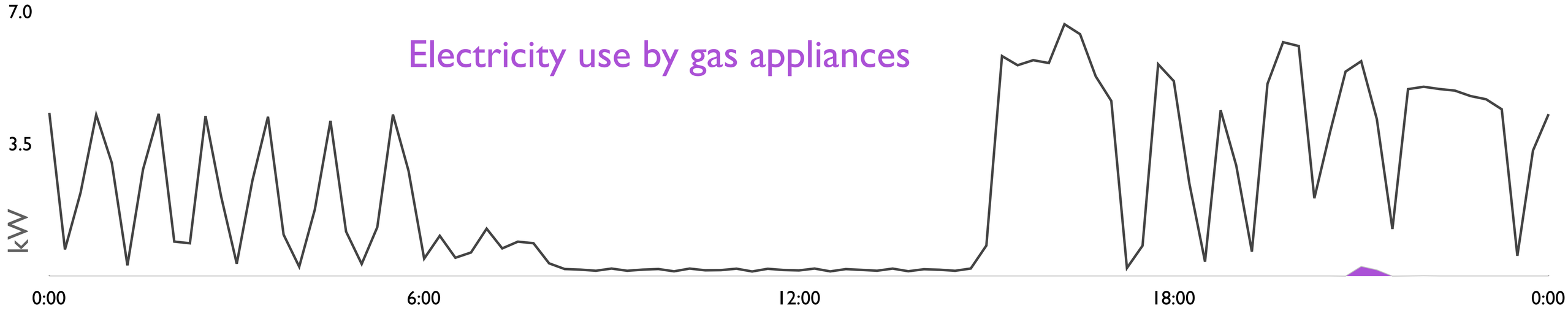
Four Categories of Electricity Use

Always On

Thermal

Electric-gas substitute

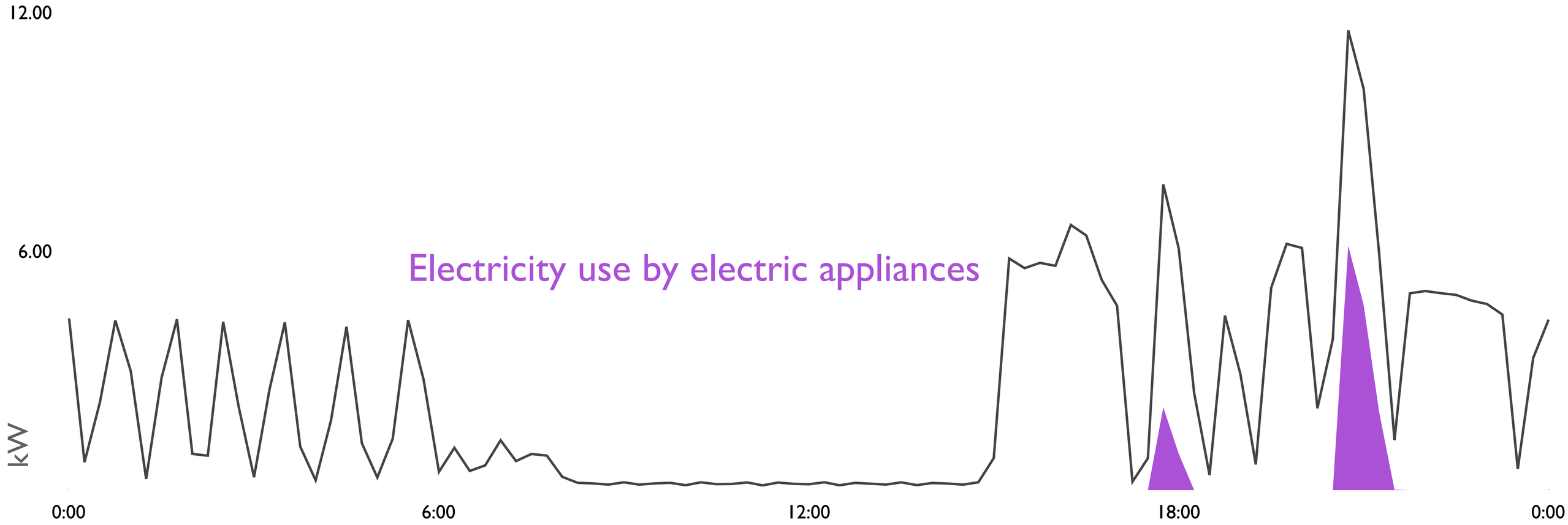
Intentional



Source: Pecan Street Research Institute

Four Categories of Electricity Use

Electric - gas substitutes

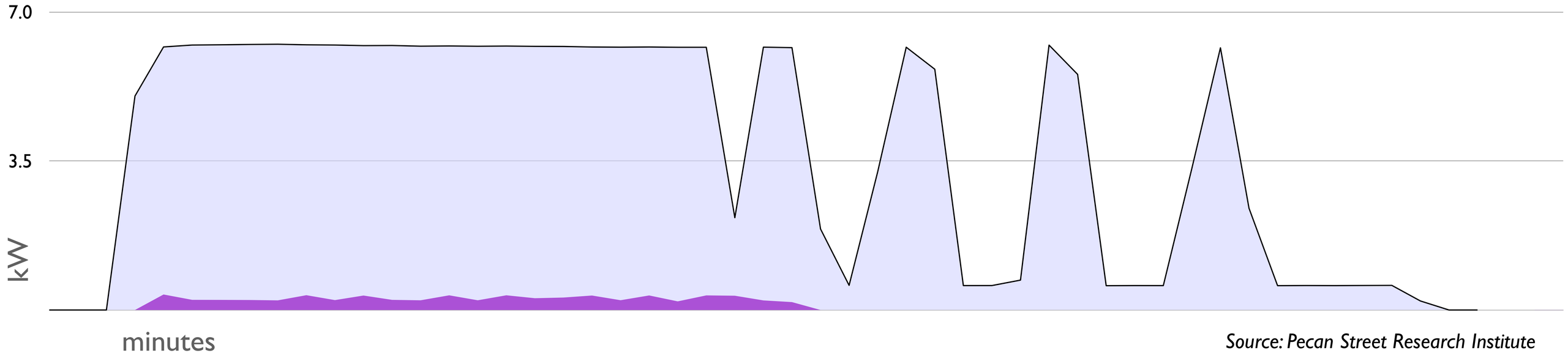


Source: Pecan Street Research Institute

Electricity used for a load of laundry – gas and electric dryers

Electric dryer 38 ¢

Gas dryer 6 ¢



Source: Pecan Street Research Institute

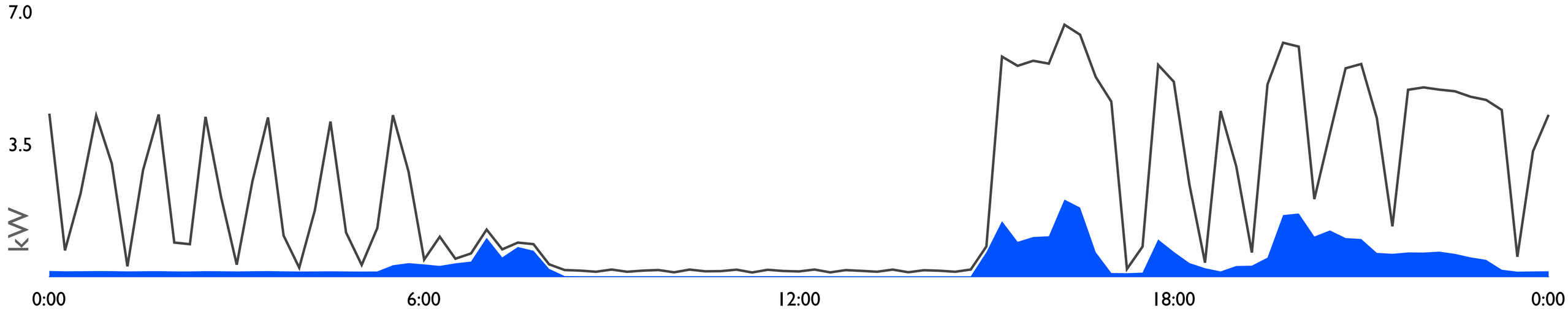
Four Categories of Electricity Use

Always On

Thermal

Electric-gas substitute

Intentional



Source: Pecan Street Research Institute

Four Categories of Electricity Use

Always On

Thermal

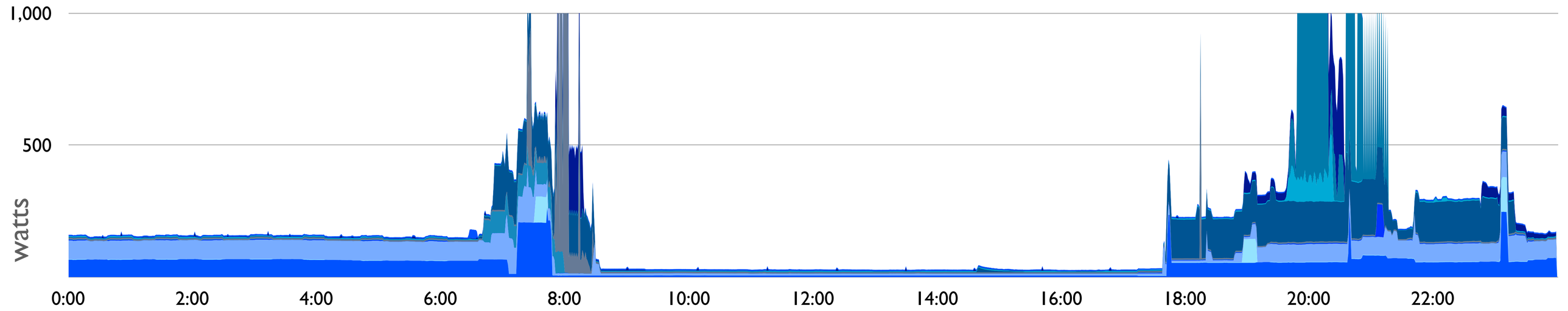
Electric-gas substitute

Intentional

Source: Pecan Street Research Institute

Four Categories of Electricity Use

Intentional

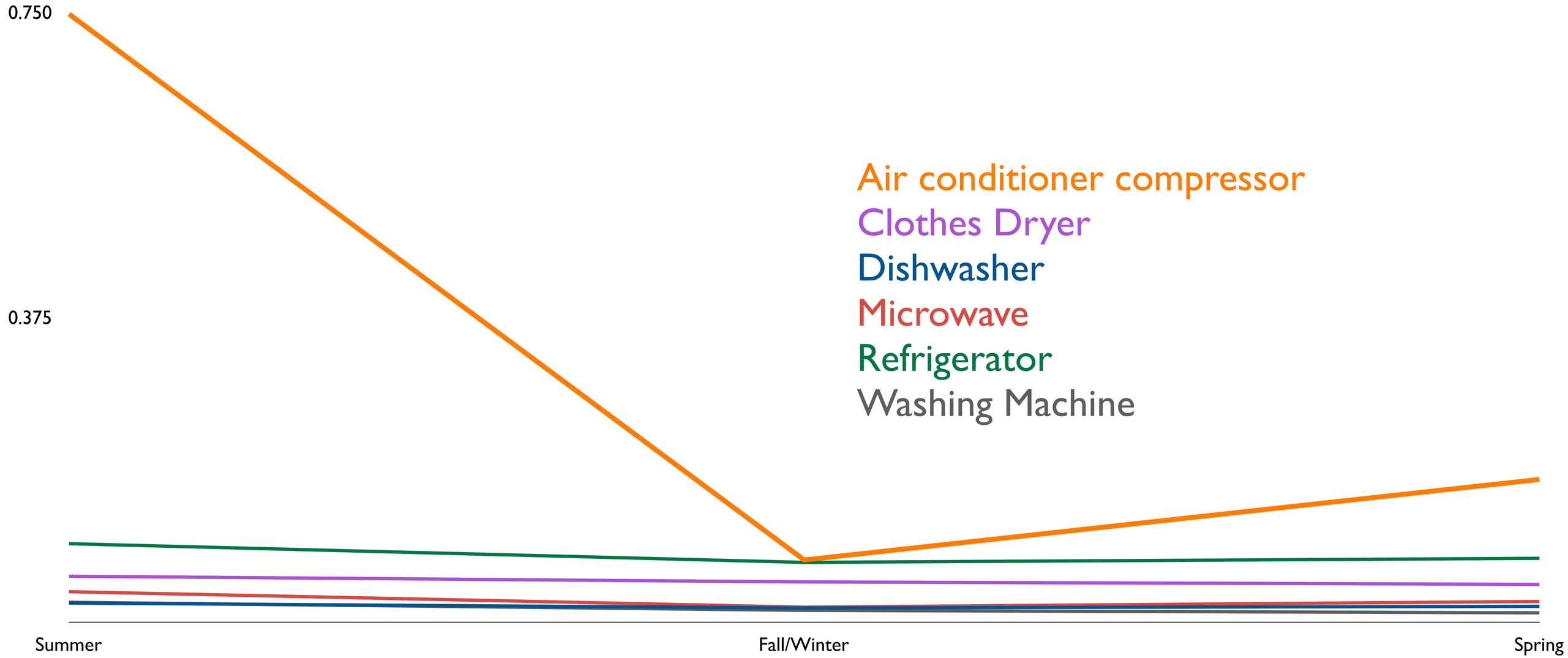


Source: Pecan Street Research Institute

- Master bedroom
- Bathroom 2
- Kitchen lights (Kitchen1)
- Living Room
- Bathroom 1
- General Lights 1
- Washer
- Garage
- Bedroom 2
- Microwave, toaster oven, coffee maker (KSAC 2)
- Dishwasher

Seasonal variation by individual load

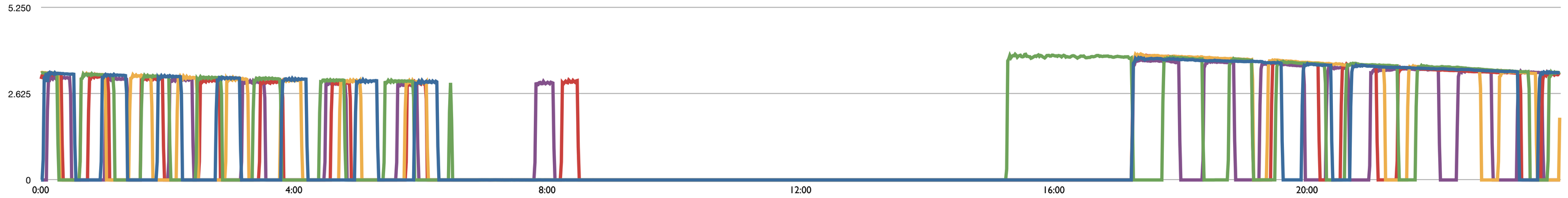
watts per square foot



Source: Pecan Street Research Institute

July 30-Aug. 6, 2012

HVAC compressor • 1 home • 5 days



July 30

July 31

August 1

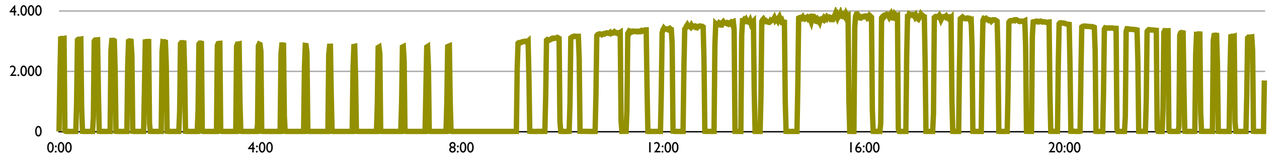
August 2

August 6

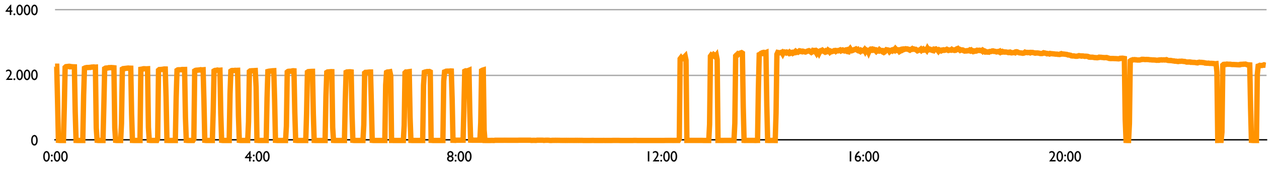
Source: Pecan Street Research Institute

July 31, 2012

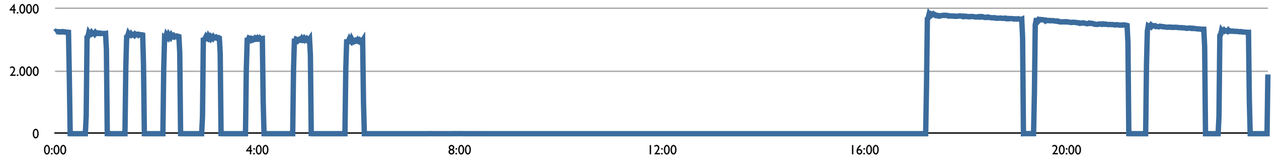
HVAC compressor • 8 homes • 1-minute interval



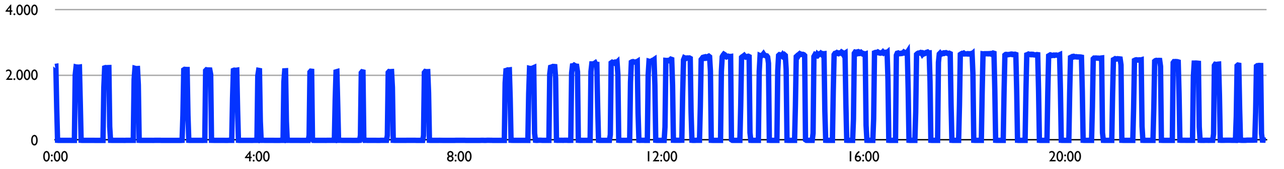
Draw 3.91 kW



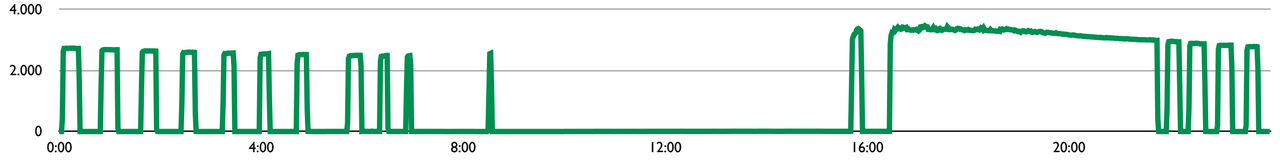
Draw 2.83 kW



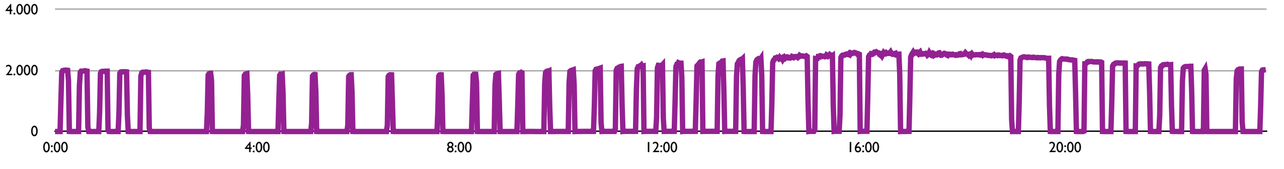
Draw 3.84 kW



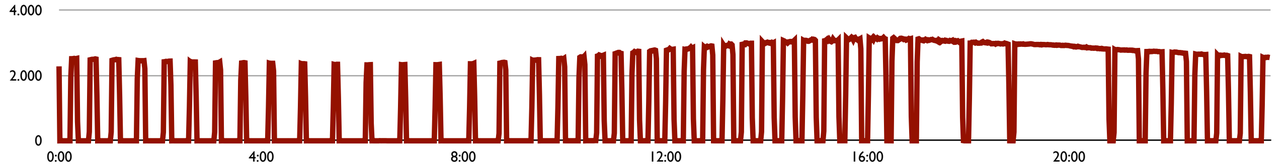
Draw 2.72 kW



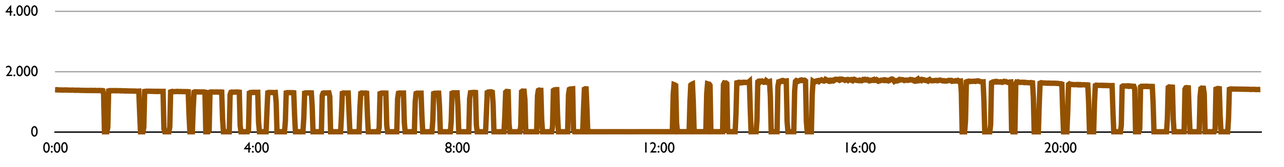
Draw 3.47 kW



Draw 2.61 kW



Draw 3.18 kW

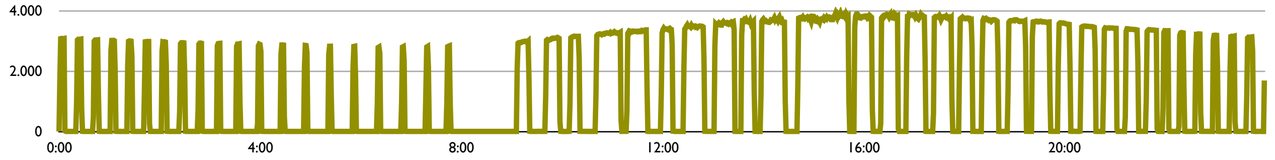


Draw 1.75 kW

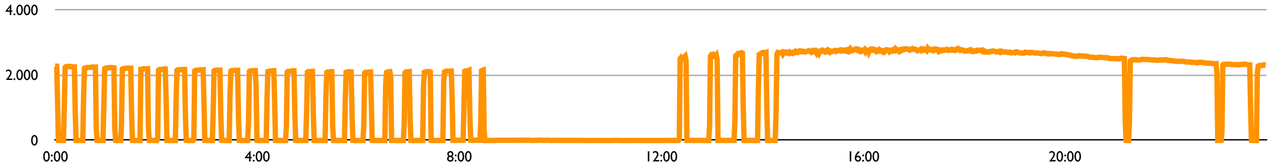
Source: Pecan Street Research Institute

July 31, 2012

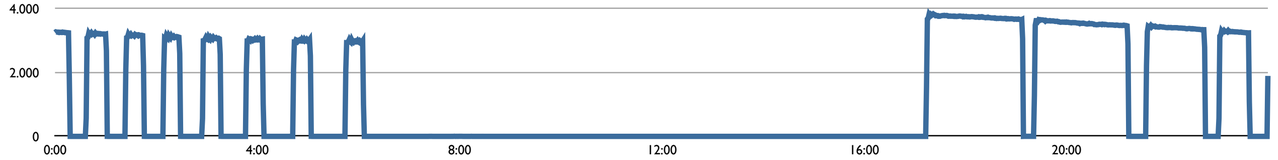
HVAC compressor • 8 homes • 1-minute interval



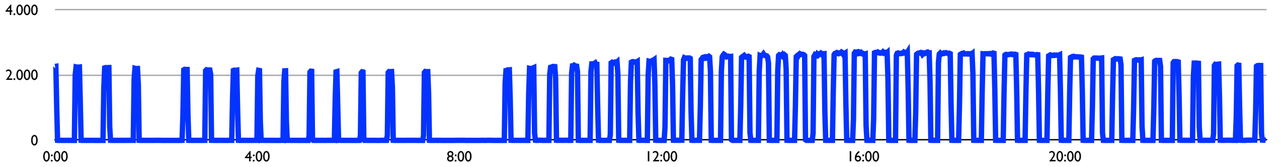
Draw 3.91 kW Total Consumption 35.78 kWh



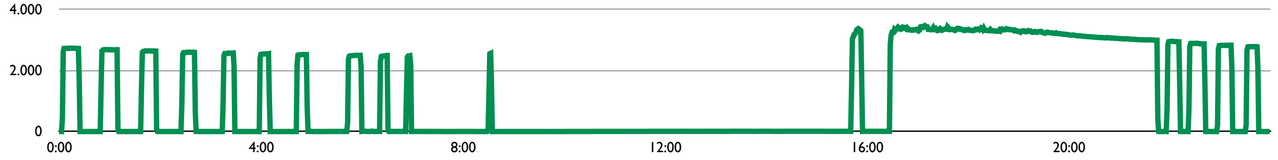
Draw 2.83 kW Total Consumption 34.21 kWh



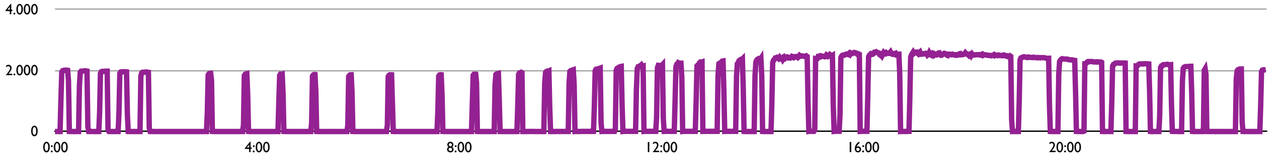
Draw 3.84 kW Total Consumption 28.16 kWh



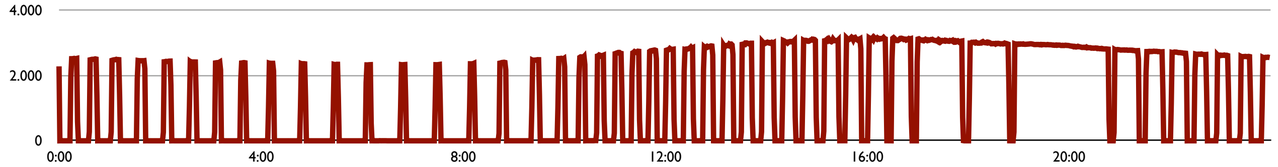
Draw 2.72 kW Total Consumption 20.34 kWh



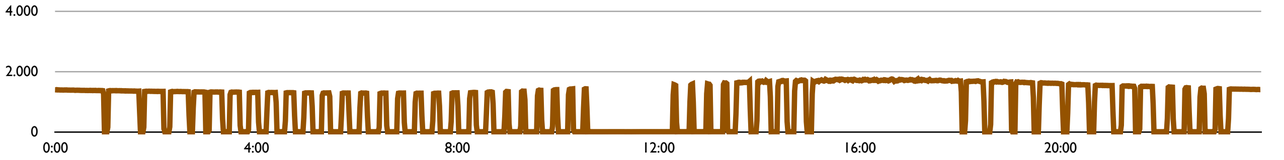
Draw 3.47 kW Total Consumption 27.02 kWh



Draw 2.61 kW Total Consumption 22.22 kWh



Draw 3.18 kW Total Consumption 32.39 kWh

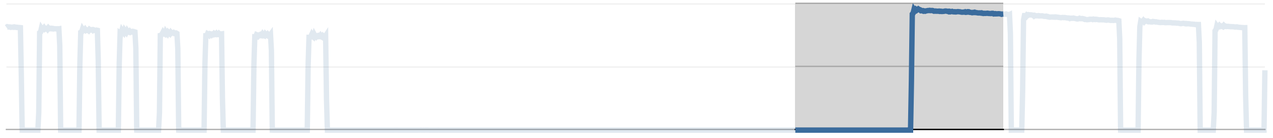


Draw 1.75 kW Total Consumption 20.80 kWh

Source: Pecan Street Research Institute

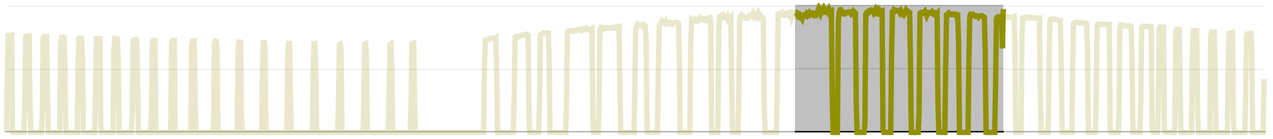
July 31, 2012

HVAC compressor • 8 homes • peak hours only

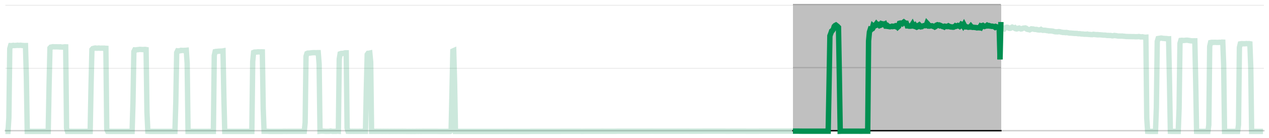


Draw 3.84 kW Total Consumption 6.62 kWh

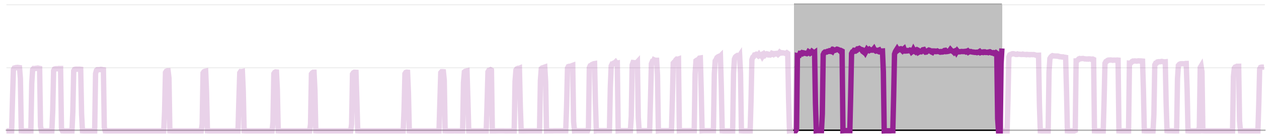
Draw 1.75 kW Total Consumption 6.28 kWh



Draw 3.91 kW Total Consumption 10.66 kWh

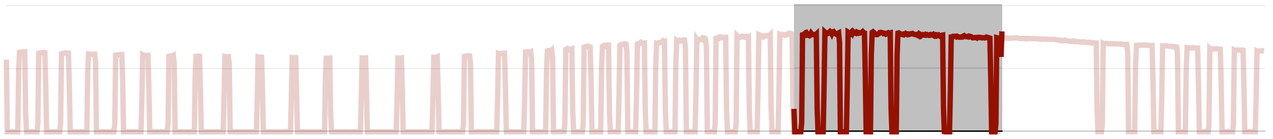


Draw 3.47 kW Total Consumption 9.13 kWh

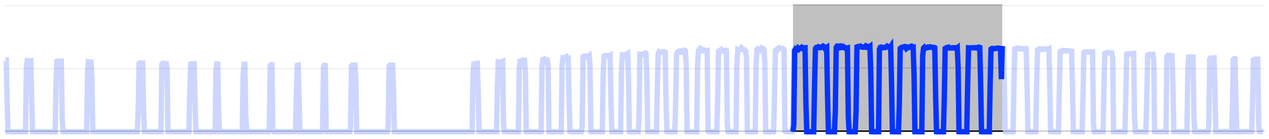


Draw 2.61 kW Total Consumption 8.51 kWh

Draw 2.83 kW Total Consumption 11.05 kWh



Draw 3.18 kW Total Consumption 9.50 kWh



Draw 2.72 kW Total Consumption 6.68 kWh

Source: Pecan Street Research Institute

Device	Top range instantaneous loads
Electric dryer	~ 6 kW

Device	Top range instantaneous loads
Electric dryer	> 6 kW
Pool pump	> 4 kW

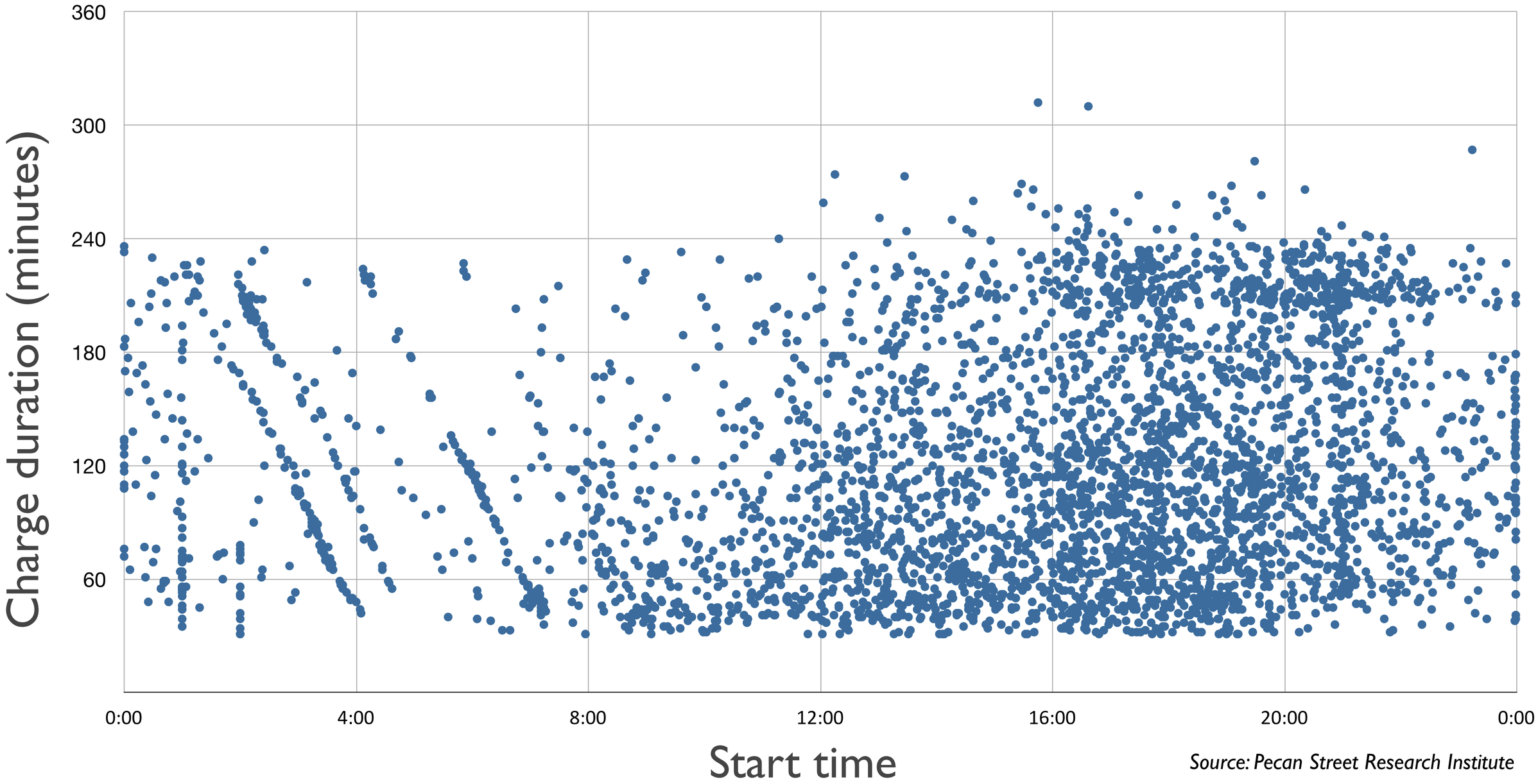
Device	Top range instantaneous loads
Electric dryer	> 6 kW
Pool pump	> 4 kW
Electric oven	+/- 3.5 kW

Device	Top range instantaneous loads
Electric dryer	> 6 kW
Pool pump	> 4 kW
Electric oven	+/- 3.5 kW
Air conditioner compressor	1.75 - 3.9 kW

Device	Top range instantaneous loads
Electric dryer	> 6 kW
Pool pump	> 4 kW
Electric oven	+/- 3.5 kW
Air conditioner compressor	1.75 - 3.9 kW
EV charger (240 v)	3.3 kW
EV charger (120 v)	1.45 kW

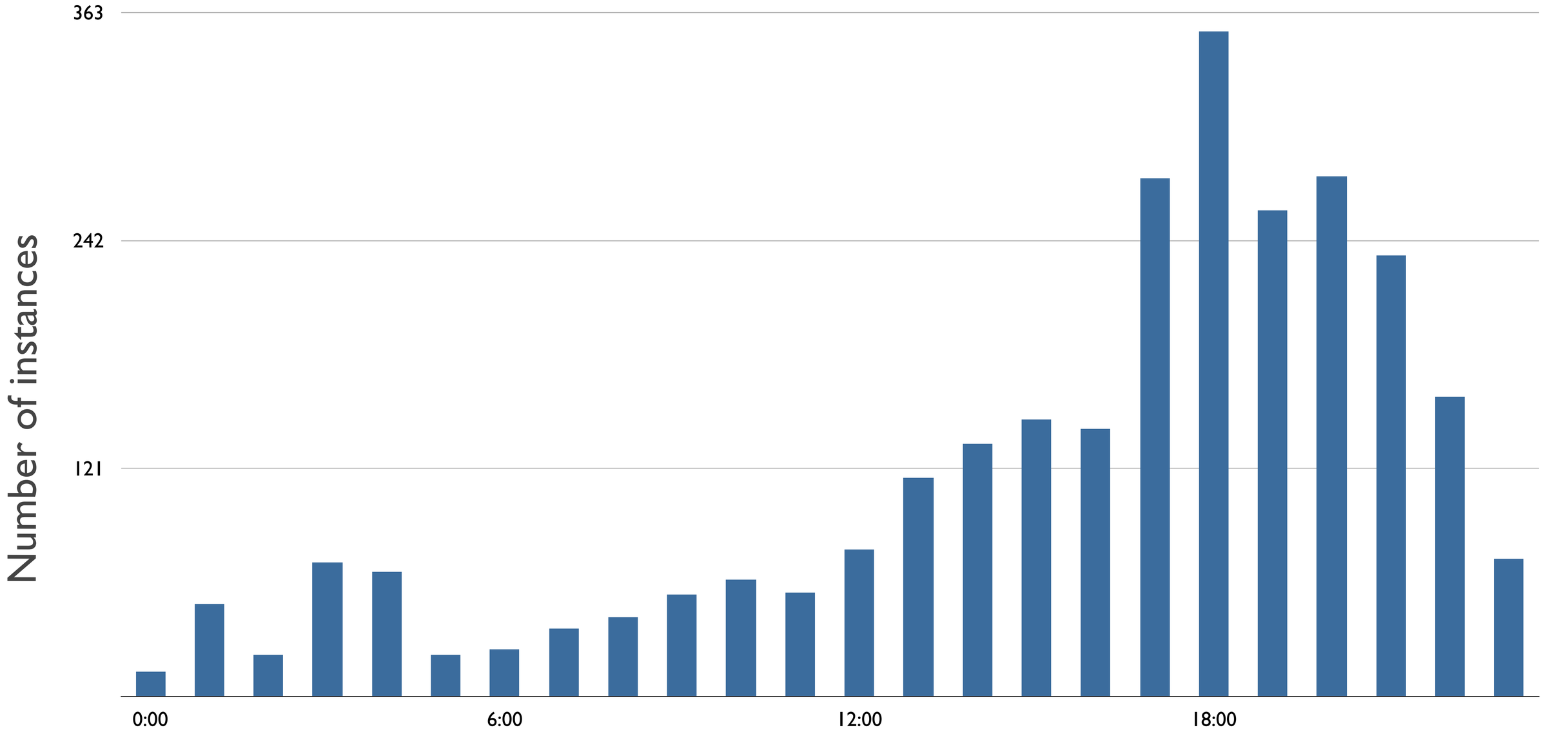
Device	Top range instantaneous loads
Electric dryer	> 6 kW
Pool pump	> 4 kW
Electric oven	+/- 3.5 kW
Air conditioner compressor	1.75 - 3.9 kW
Electric vehicle charger (240 v)	3.3 kW
Electric vehicle charger (120 v)	1.45 kW
Air handler (HVAC)	+/- 0.8 kW

Charging events: duration, start time



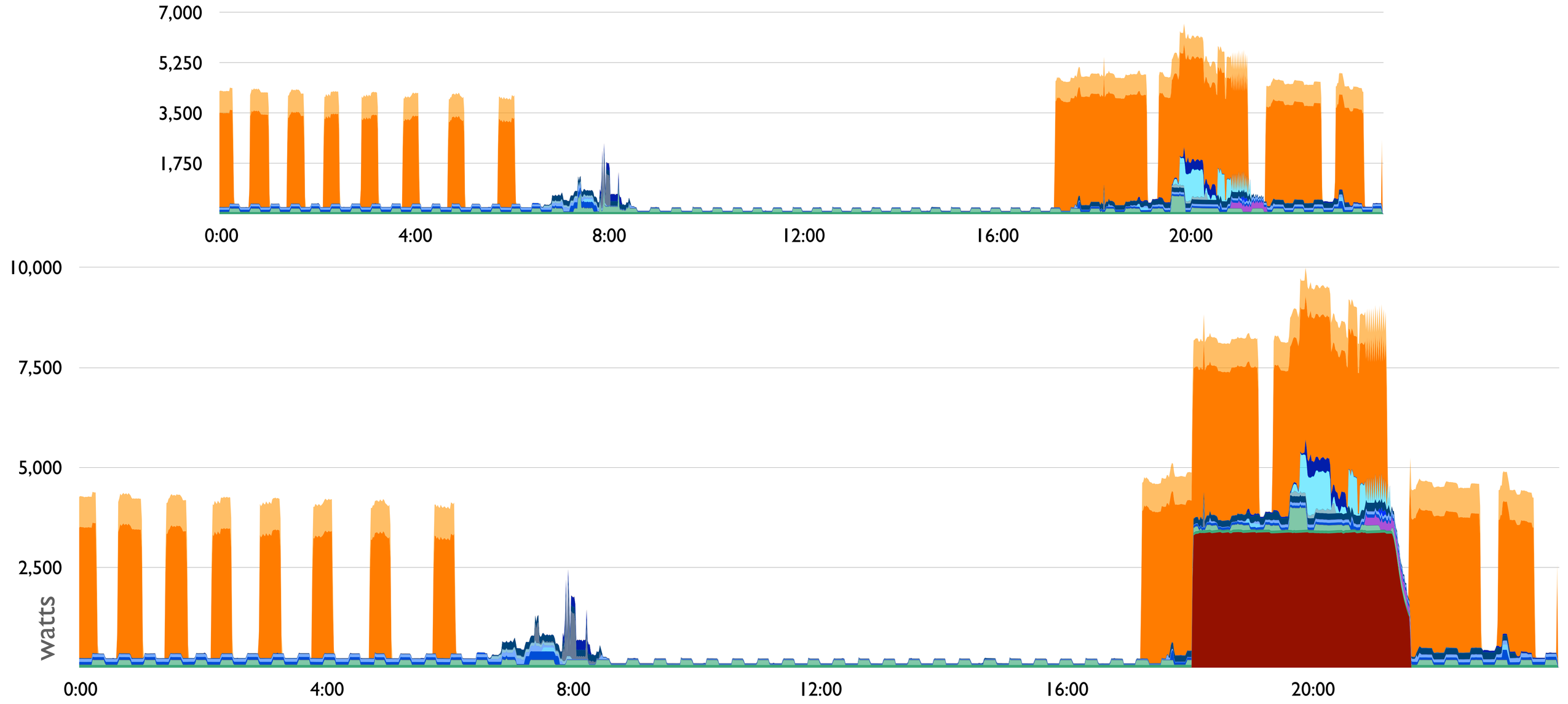
Source: Pecan Street Research Institute

Charge start times: weekday



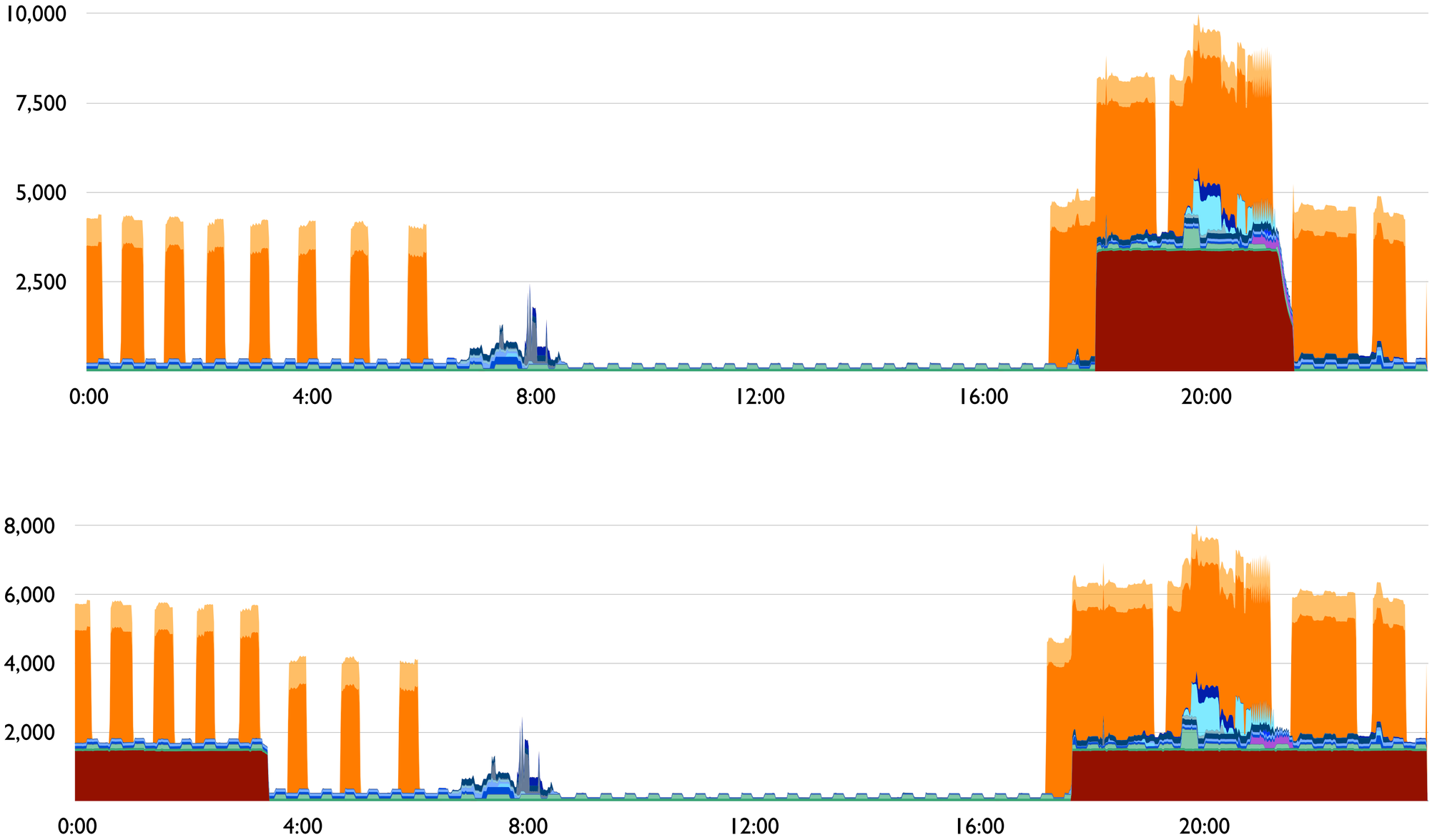
Source: Pecan Street Research Institute

Summer day • Home + EV

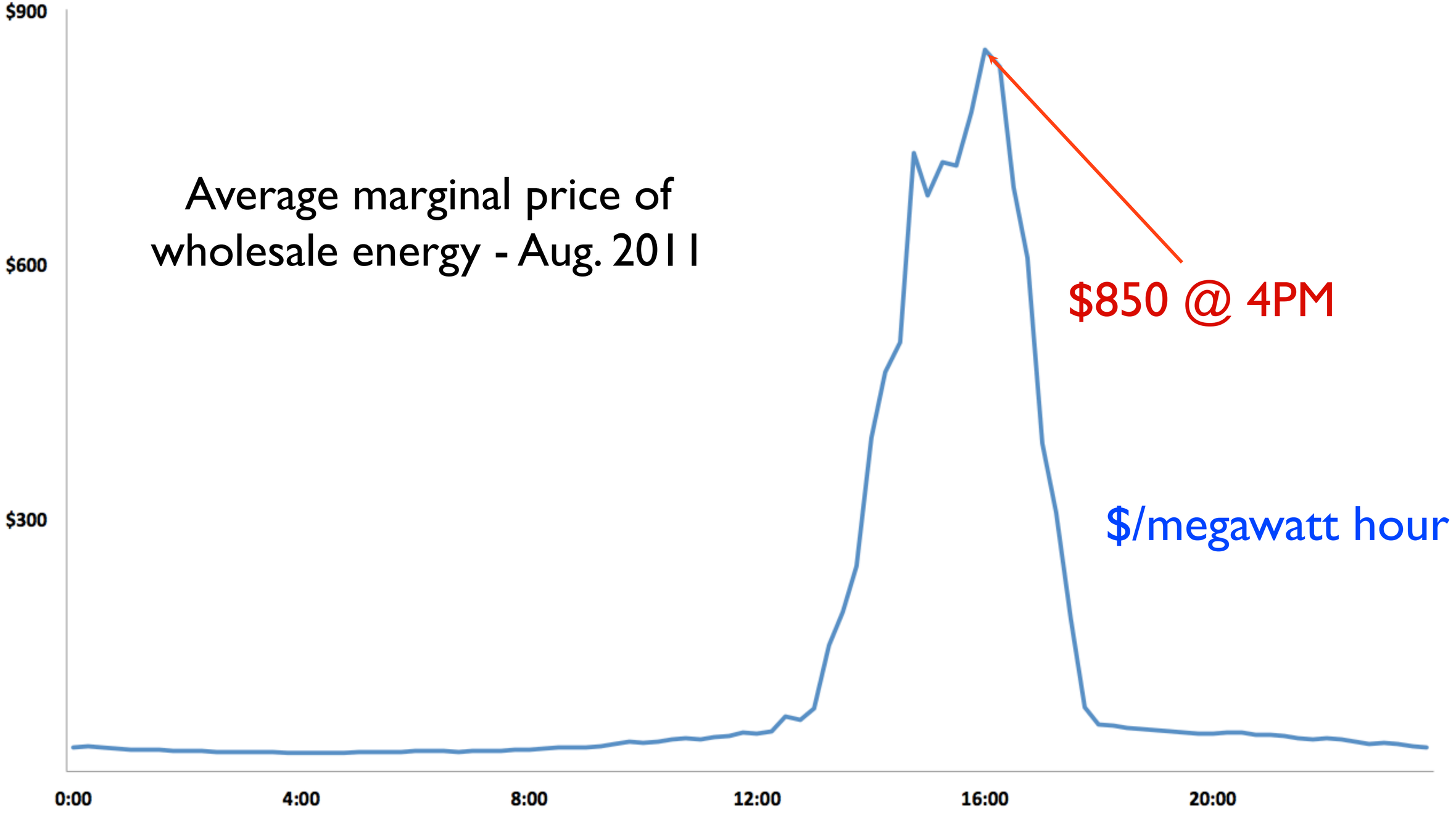


Source: Pecan Street Research Institute

Level 1 compared to Level 2

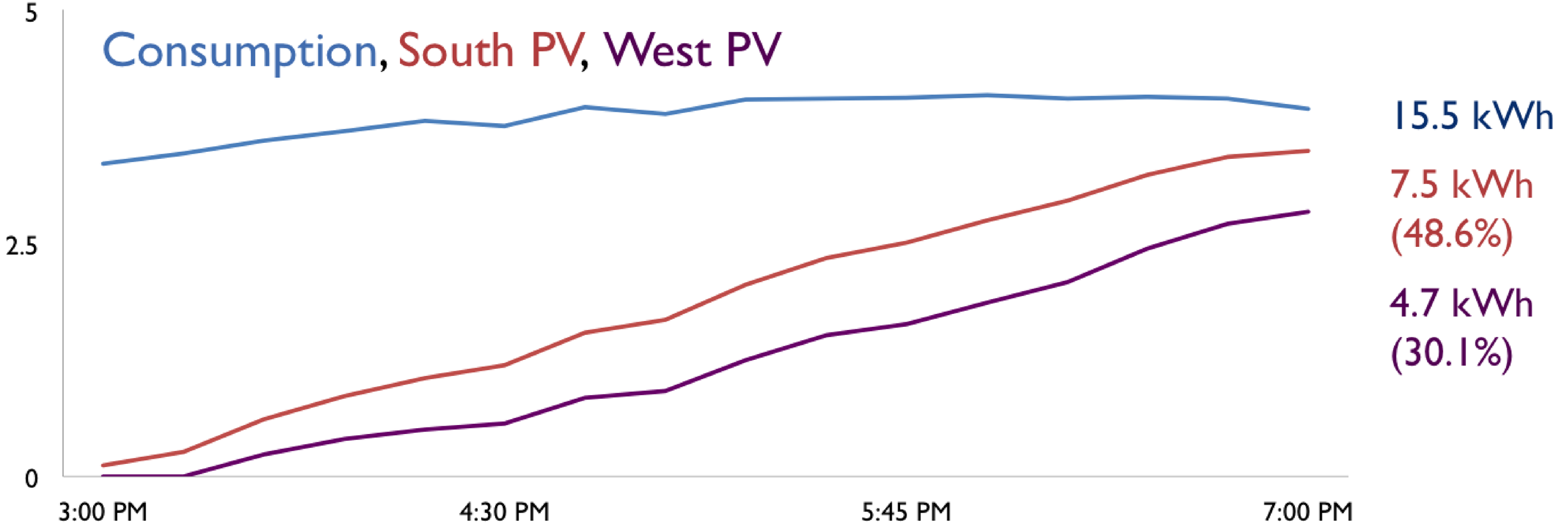


Source: Pecan Street Research Institute


Average marginal price of wholesale energy - Aug. 2011
$850 @ 4PM
$/megawatt hour
$900
$600
$300
0:00
4:00
8:00
12:00
16:00
20:00

August 2011 average

Peak consumption from grid (kW)



Source: Pecan Street Research Institute

Tools to impact behavior

Types of behaviors to impact

Adopt

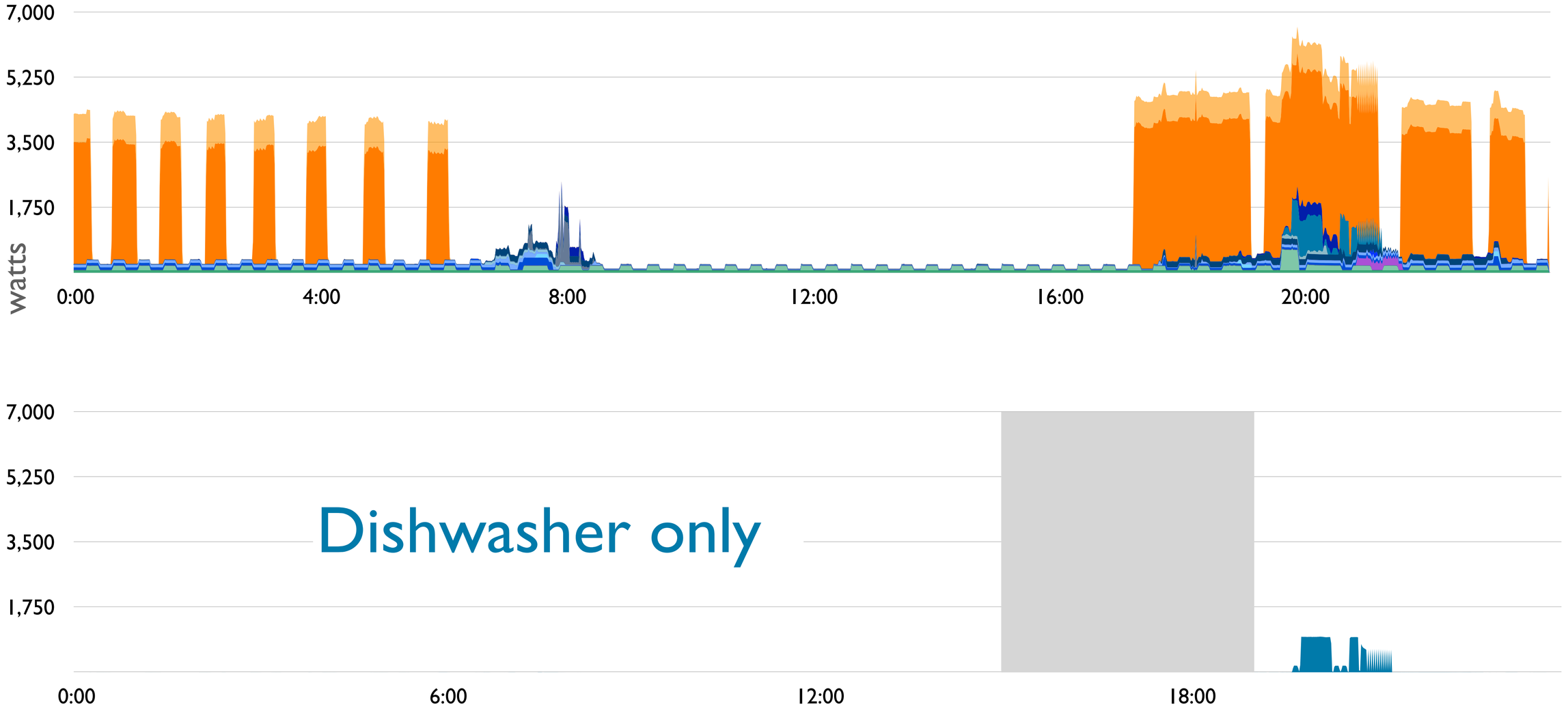
Use

Report experiences to others

Variables that impact effectiveness of tools

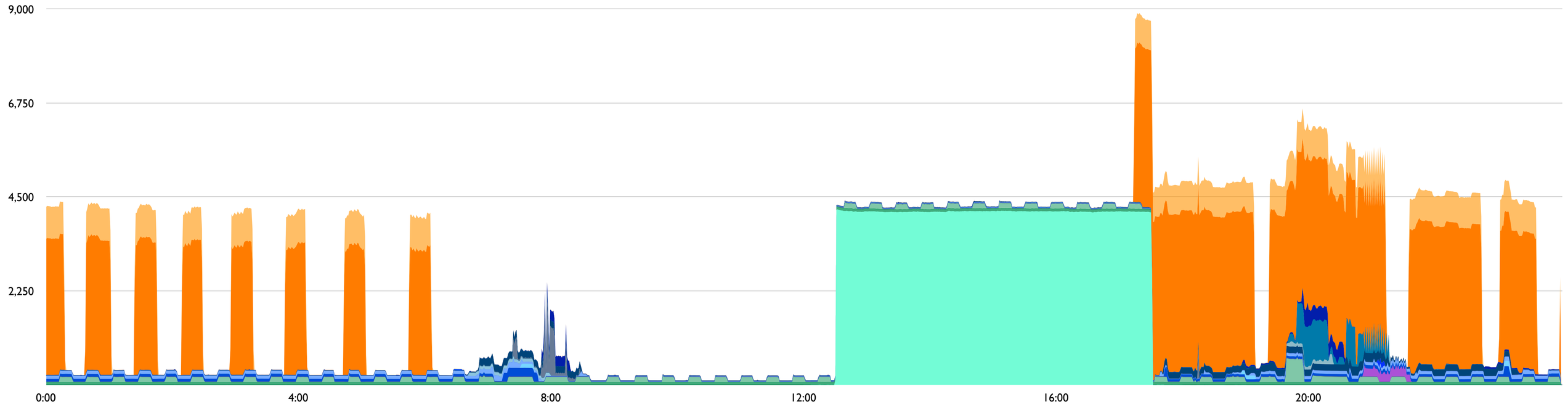
Magnitude and timing

Home – 1 minute interval



Source: Pecan Street Research Institute

Summer day • Whole home + pool pump



Source: Pecan Street Research Institute

Variables that impact effectiveness of tools

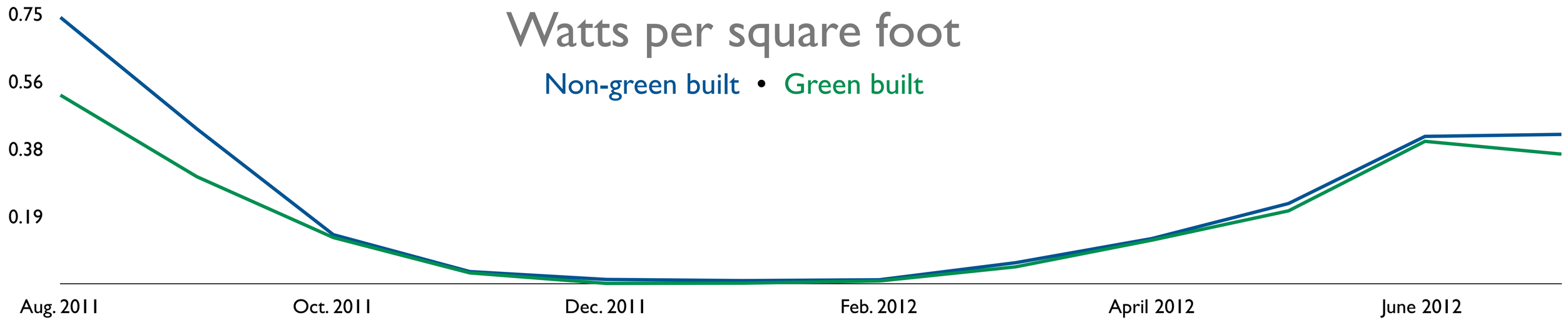
Magnitude and timing

Automated vs. manual

"Set and forget"

Default settings

Thermal



Source: Pecan Street Research Institute

Variables that impact effectiveness of tools

Magnitude and timing

Automated vs. manual

Negative experiences by user

Variables that impact effectiveness of tools

Magnitude and timing

Automated vs. manual

Negative experiences by user

Feedback

On benefits to end user

Diagnostics

Variables that impact effectiveness of tools

Magnitude and timing

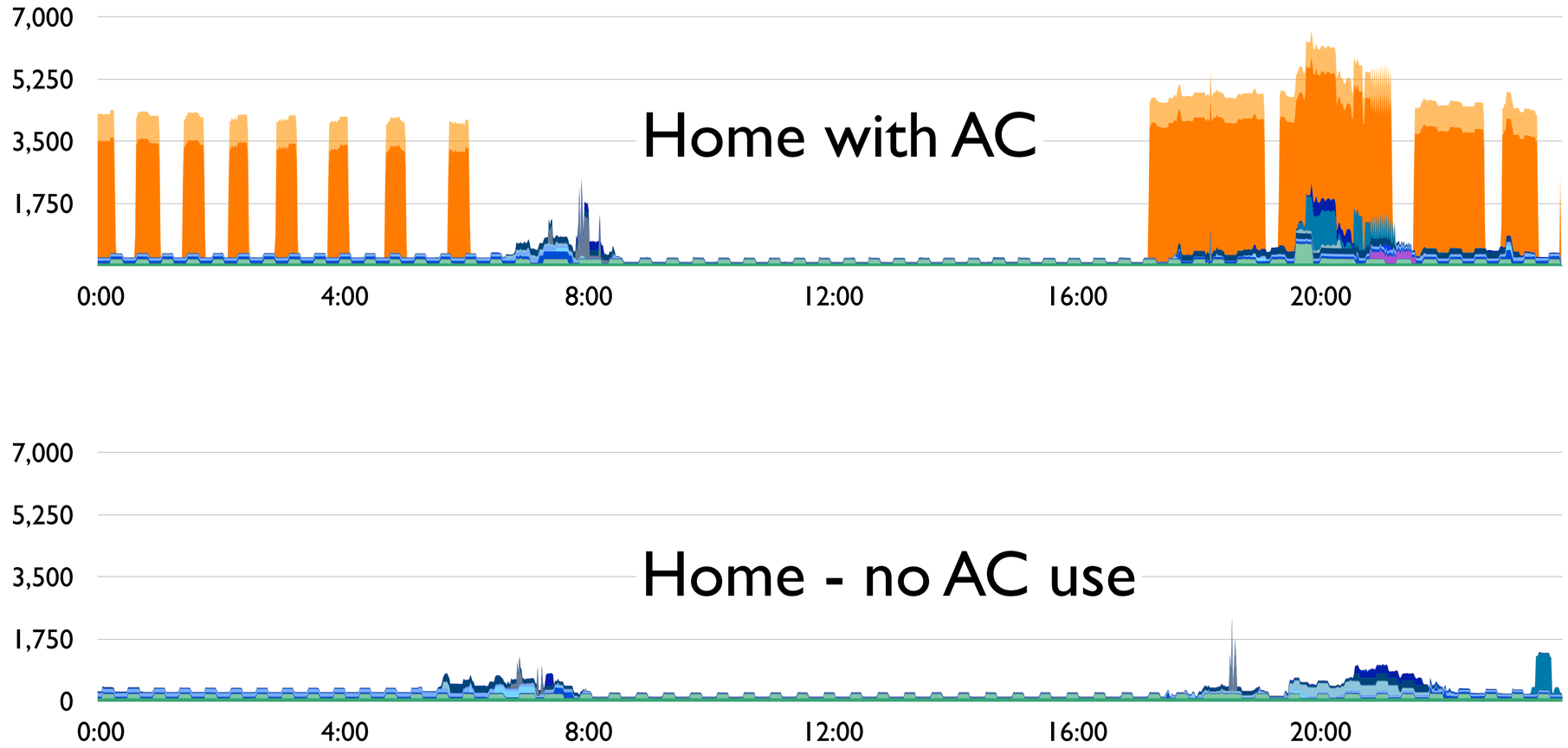
Automated vs. manual

Negative experiences by user

Feedback

Customer ability to respond

Single home – 1 minute interval



Source: Pecan Street Research Institute

Variables that impact effectiveness of tools

Magnitude and timing

Automated vs. manual

Negative experiences by user

Feedback

Customer ability to respond

Thermal efficiency of home

Correlations and findings

Compared to green built homes

Non-retrofitted homes used
38 percent more
electricity for cooling

(per square foot)

Correlations and findings

Compared to retrofitted homes

Non-retrofitted homes used
29 percent more
electricity for cooling

(per square foot)

Behavior tools

Use

Time-of-use pricing

Demand response – AC cycling

Thermostat with default setting

Adoption / Purchase

Seal leaking ducts

Buy gas clothes dryer

Maintain AC compressor

Appliance rebates

Learning thermostat

What is the right tool for you?

When and on what do your customers use electricity?

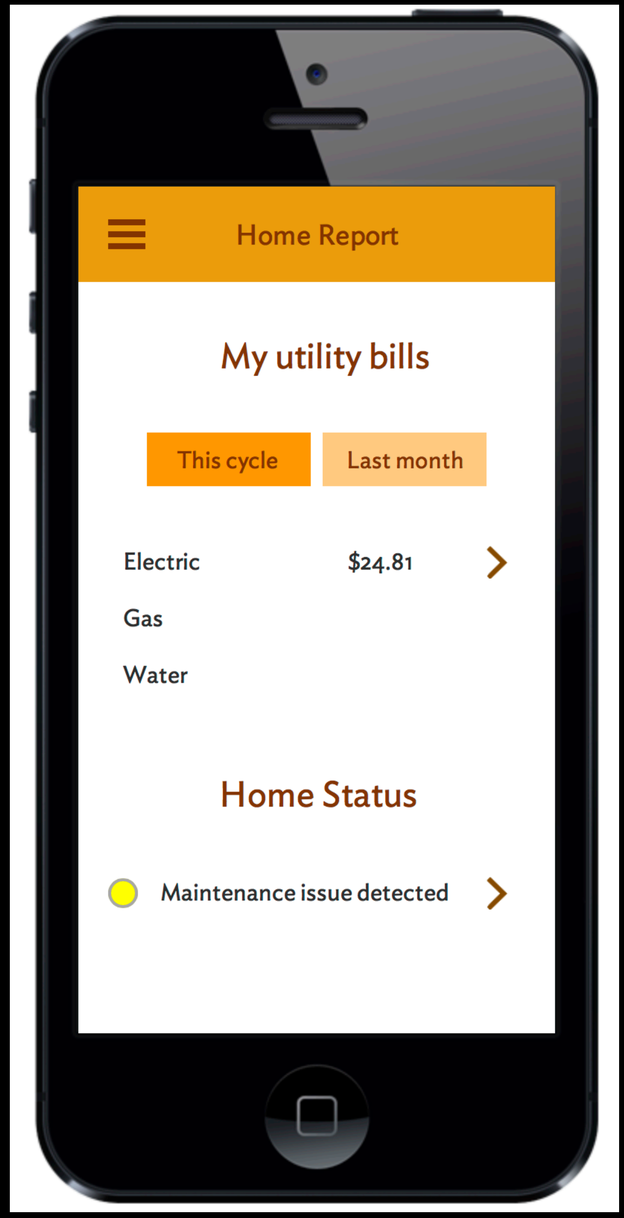
Level of adoption by your customers of non-manual tools
(e.g., insulation, efficient HVAC systems)

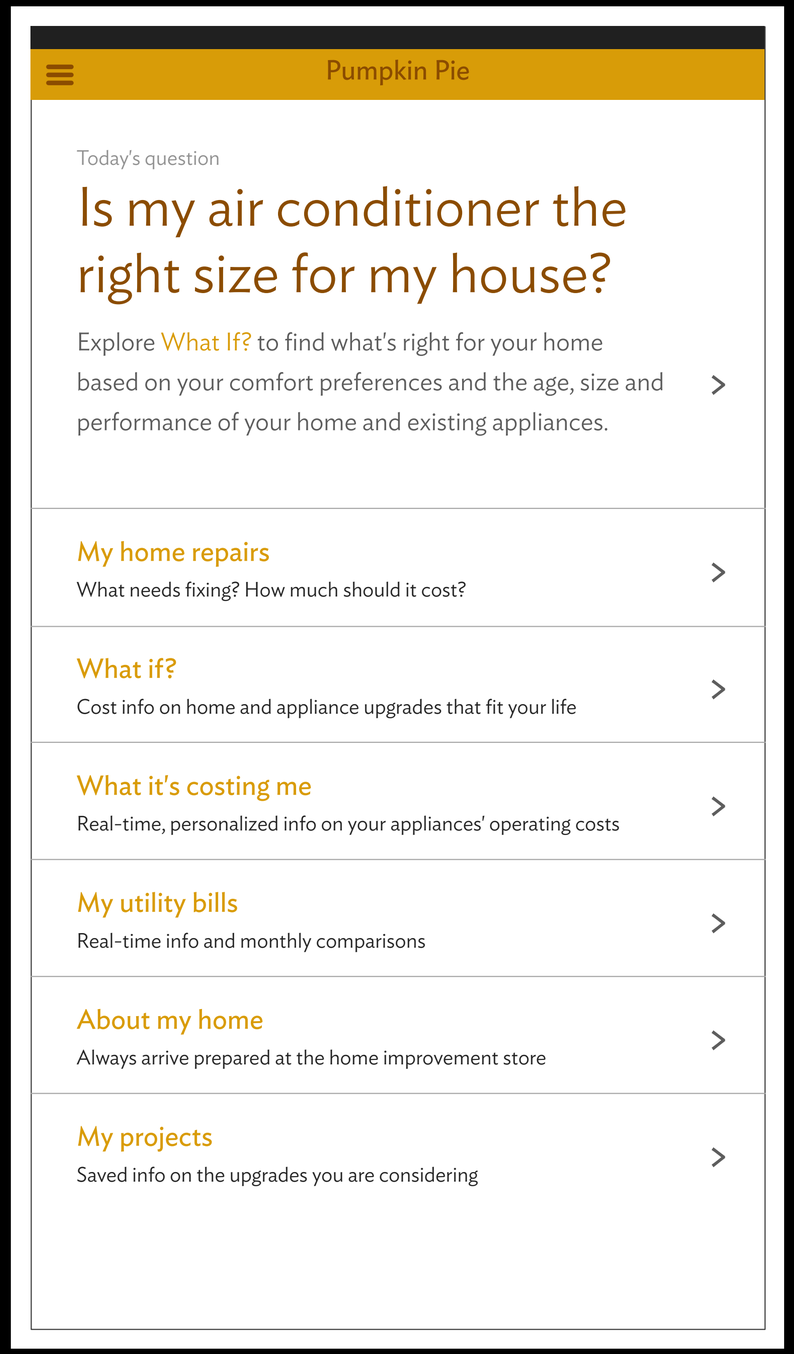
Cost / benefit of new generation

Availability of gas service in your territory

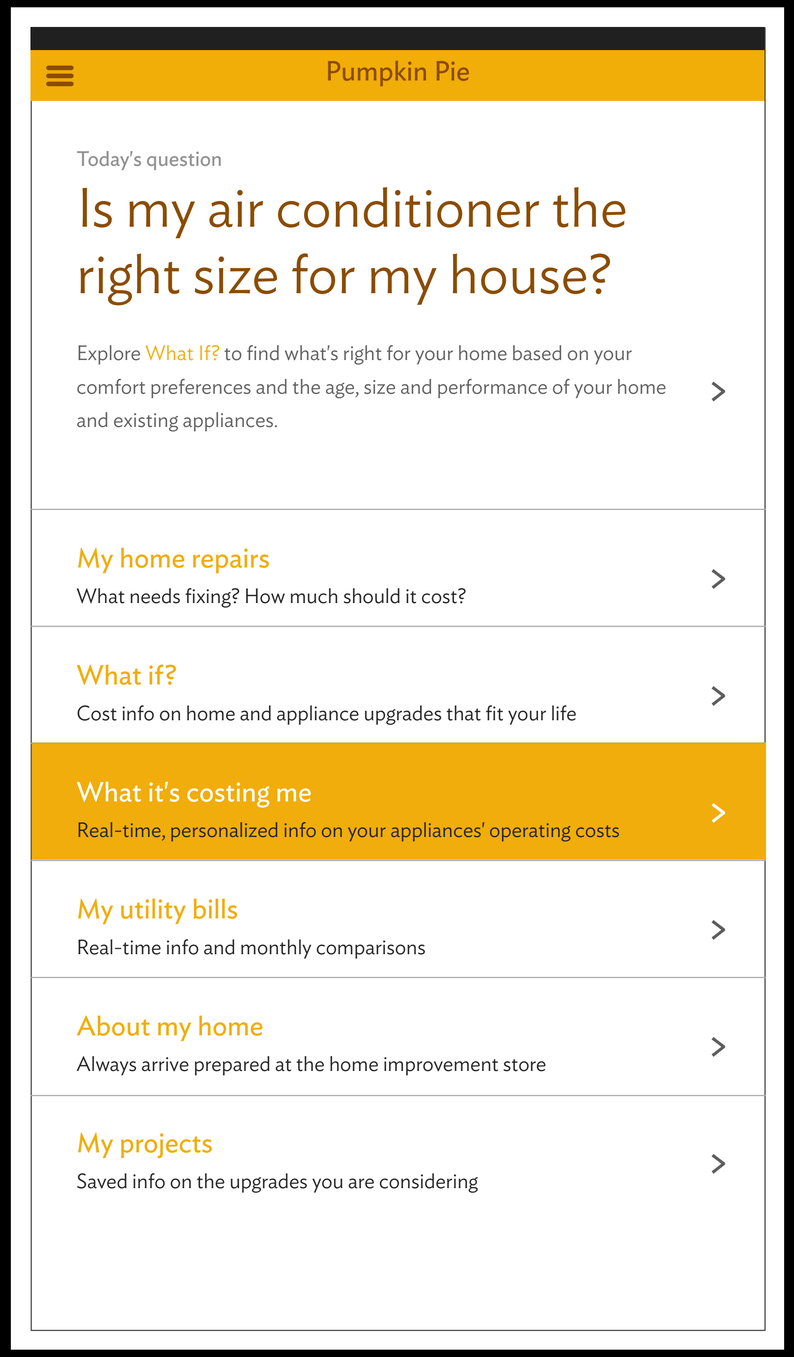
Engagement tool

Pumpkin Pie


Home Report
My utility bills
This cycle
Last month
Electric
$24.81
Gas
Water
Home Status
Maintenance issue detected


Pumpkin Pie
Today's question
Is my air conditioner the right size for my house?
Explore What If? to find what's right for your home based on your comfort preferences and the age, size and performance of your home and existing appliances.
My home repairs
What needs fixing? How much should it cost?
What if?
Cost info on home and appliance upgrades that fit your life
What it's costing me
Real-time, personalized info on your appliances' operating costs
My utility bills
Real-time info and monthly comparisons
About my home
Always arrive prepared at the home improvement store
My projects
Saved info on the upgrades you are considering

Home screen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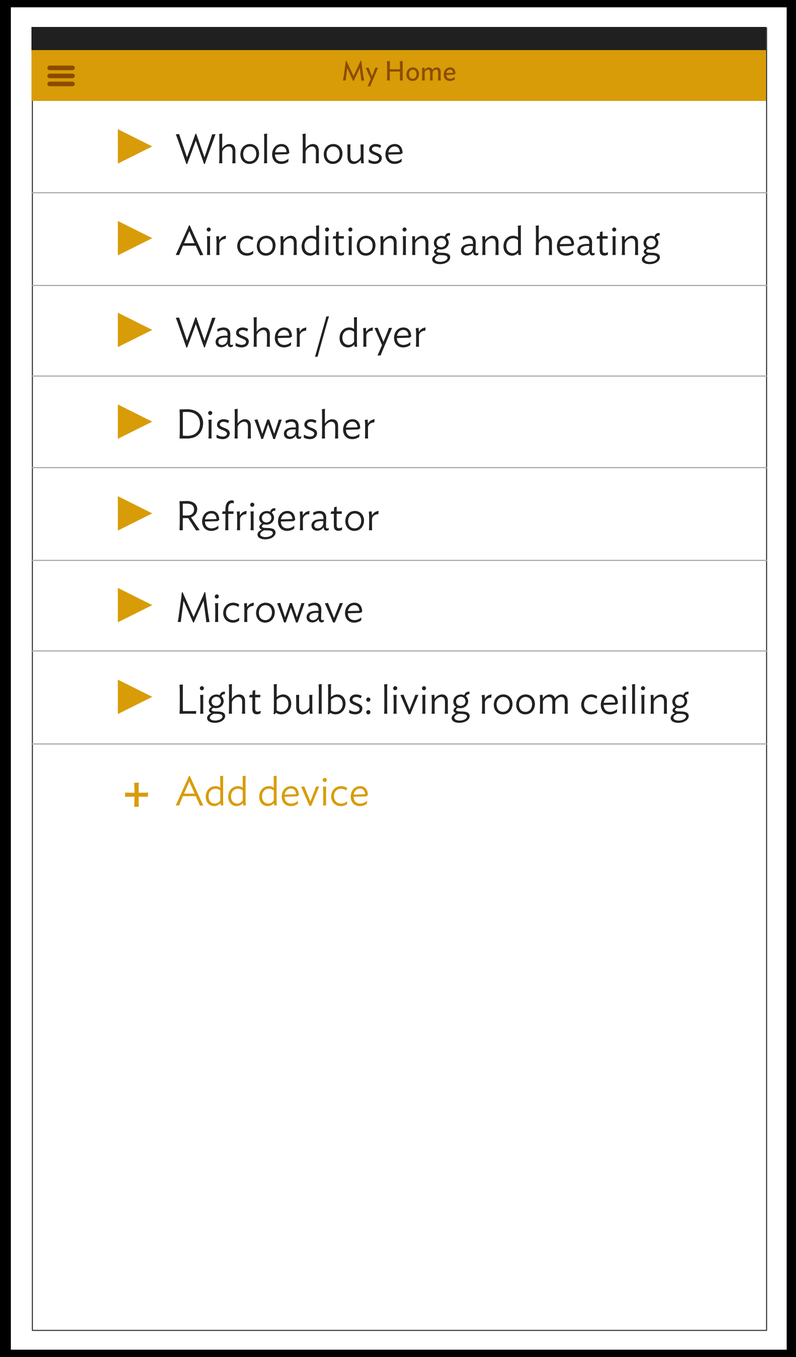
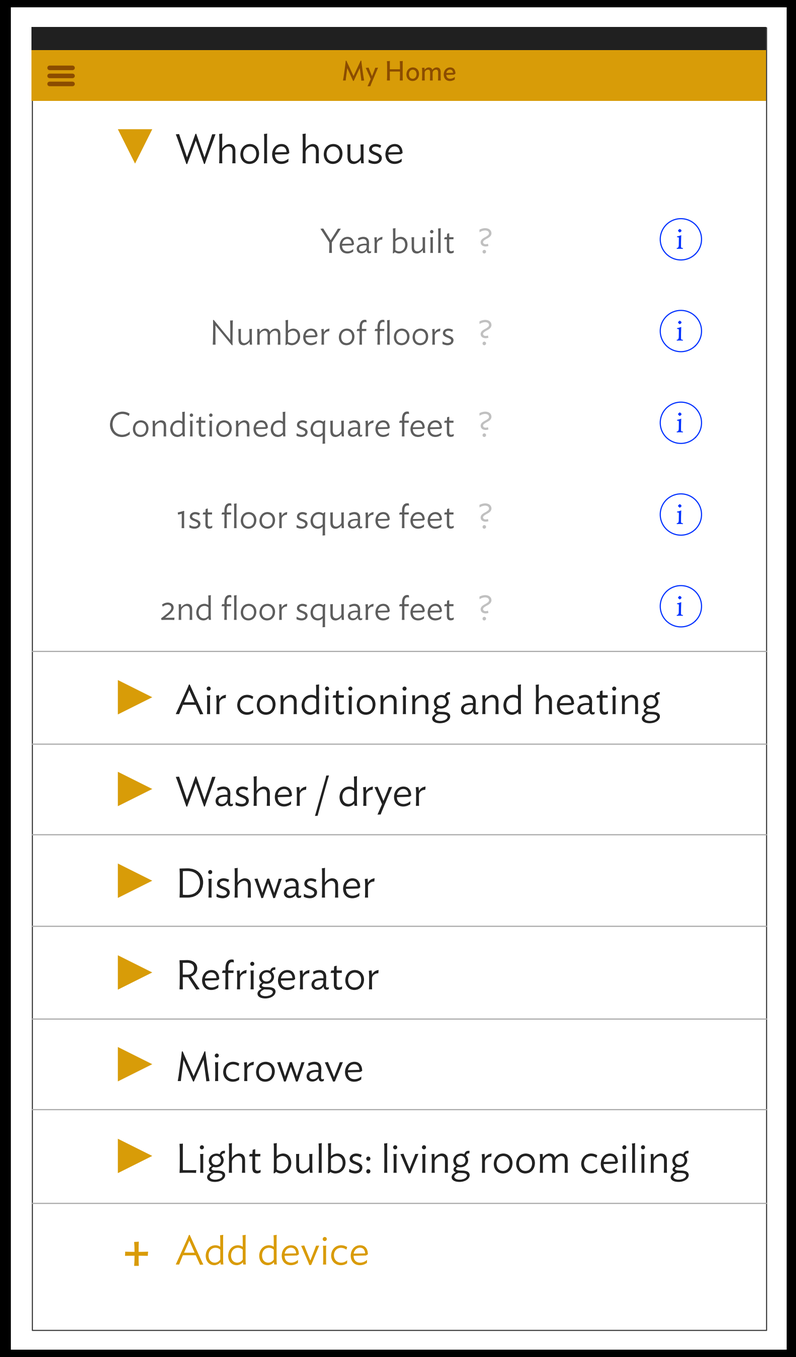
Always arrive prepared at the home improvement store
My projects
Saved info on the upgrades you are considering

Home screen

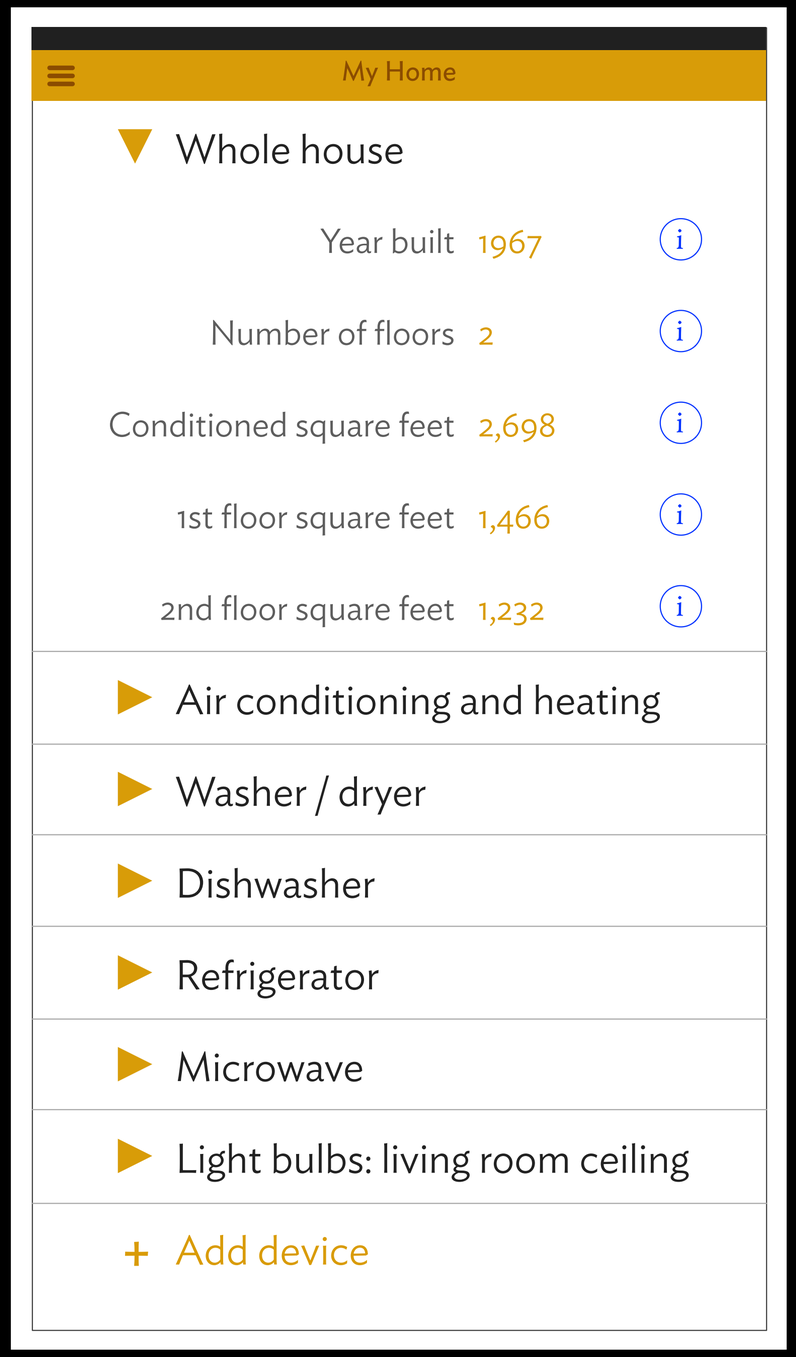

My Home
Whole house
Air conditioning and heating
Washer / dryer
Dishwasher
Refrigerator
Microwave
Light bulbs: living room ceiling
+ Add device

My home



My Home

Whole house tab selected



My Home

Whole house values entered