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Society of Cable Telecommunications Engineers
International Society of Broadband Experts

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From the Editors

Thank you for downloading SCTE ISBE Journal of Energy Management V2 N2. Energy management is an important and varied topic. There are many ways to go about improving energy management. We are fortunate to have the SCTE ISBE Energy 2020 Program to help prioritize what solutions we should be examining. The purpose of this journal is to expand our possibilities and consider additional standardization and recognition of industry operational practices that can lead to improved energy conditions across our wide variety of consume.

In this issue, fleet, energy procurement, increasing critical facility resiliency through renewable energy microgrids, and consideration of managing energy in the age of Internet of Things (IoT) are presented. If you have feedback on this issue, have a new idea, or would like to share a success story please reach out to us journals@scte.org for consideration in an upcoming issue.

SCTE/ISBE Journal of Energy Management Senior Editors,

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SCTE Energy Management Subcommittee Chair

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Five Factors for Effective Energy Procurement and Working Strategically with Energy Procurement Professionals

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1. Introduction

Energy procurement should be a comprehensive process for defining and meeting your energy goals. Through these steps your company can get the most out of the deregulated energy market today and for the foreseeable future.

- Use a consultant who becomes an addition to your company's effort to drive revenue through energy procurement and conservation.
- Use an energy broker who is constantly interacting with both the wholesale and retail markets. The best are constantly forecasting change.
- Understand your energy profile to effectively bid into the market.
- Your energy broker must be your advocate to negotiate a contract balanced to include your safeguards and interests, not just those of the supplier.
- Truly cash-in on greener energy in multiple ways.

2. Good Energy Consulting Can Be Priceless, Really

A good energy consultant knows how to translate big-picture goals into achievable tactics. Your facility's energy consumption depends on the interaction between a whole host of hardware and software products, from heating and cooling systems to sensors and thermostats. All of these puzzle pieces are subject to decay, and new innovations constantly bring about the opportunity to save money on energy.

Good energy consultants come trained and are keeping up on the latest in the energy sector. And they will be monitoring the markets full time.

A good energy consultant will continuously help your company stay informed and educated. The energy consultant will make it an on-going objective to identify the most viable energy saving solutions for your company. Ultimately a good consultant will become an addition to your company's efforts to drive revenue through energy efficiency and conservation.

It's generally cheaper and quicker to access a consultant's knowledge than it is to acquire the necessary education to amass the same body of knowledge. If you're limited to your company's own internal knowledge you may miss things that would have been obvious to a consultant. You should wonder as your in-house staff are often getting pulled in more than one direction, that your company is not able to consistently monitor the state of the markets, or is keeping abreast of the best and most efficient ways to implement the newer versions of everything that comes out.

Now the good part, energy consultants can be most cost effective if you find one that is compensated on the backend, through the energy supplier's own margin. With that partnership, you don't have to hire an in-house energy manager and then worry that once you have a good plan in place, if your in-house energy manager then may not have as much to do.

The best of energy consultants will know wide-ranging approaches in association with energy. For example, did you know that switching to LEDs could actually be beneficial for the health of employees? New LED technology has allowed LEDs to actually mimic natural light very convincingly, and exposure to natural light during the day helps to keep people's circadian rhythm in balance, which leads to better sleep at night. For employees that are prone to migraines or headaches, the flickering that comes from fluorescent lights can really aggravate the pain. LEDs never flicker, which may help to decrease headaches.

3. The Energy Broker as Your Advocate

Energy and sustainability markets are highly volatile. Key to good energy procurement is an understanding of both wholesale and retail market intelligence to identify trends and spot opportunities or unfavorable developments. A truly active energy broker should also:

- Understand power generation and delivery
- Monitor regulatory developments
- Participate in International Organization for Standardization (ISO) meetings
- Advocate for end users (i.e. your company)

Having an energy broker on your side and one who is supplier neutral will give you the best chance at achieving the most savings.

An effective energy broker continuously interacts with the retail energy markets. One who will spot trends especially ahead of your next spend or contract renegotiation and who keeps up with government policy. Most importantly, they should be continuously forecasting change versus reacting to the market.

A full-service energy broker will manage requests for proposals (RFPs) to the market on your company's behalf, assist with contract negotiations and perform price risk assessments and will consider your company's energy usage and goals from each of operations, accounting and environmental perspectives.

The most comprehensive energy brokers are those who have up-to-date intelligence of the wholesale market, i.e. they know the prices the suppliers are paying for their energy.

For small companies, an energy broker will leverage energy spends into a larger energy pool of like-minded customers. Aggregation groups also help to reduce a supplier's risk of which is passed back to the individual companies in the group.

4. Your Energy Profile is Key

The first step to reducing your energy budget is with a smart energy procurement strategy. When shopping for energy, it's important to understand your energy profile. Your energy profile represents your energy usage over time. One reason this is important is your energy broker can then consider putting your energy profile out to the market in "blocks" that mimic the wholesale blocks suppliers use for their purposes, reducing certain costs.

Other than a block approach, a comprehensive energy broker will know other structures for energy procurement including fixed priced, index priced and hybrid products and Ddemand Response as a means to cost effectively manage your energy spend during peak grid periods.

There are a number of pricing structures of which a good energy broker will use to take your energy profile to market. They should structure your energy spend based on your company's objectives which are anchored primarily in cost goals and disposition towards risk.

A good energy broker will also consider your company’s metering costs. For example, if you have low usage and a large capacity plan, you may have a lower price per unit (megawatt hour for example), but you’re also likely paying higher base charges. If your usage is low, then you aren’t taking advantage of the lower price per unit enough to recoup the cost of the base charges. Conversely, your company may be using a lower capacity plan than you need thus driving up your utilities. While it is true that your base charges are lower, you are also likely paying a much steeper rate for high consumption. A plan that comprehensively matches your energy profile must also be part of the goal.

5. A Contract to Control Risk

Controlling risks starts with performing commodity analysis and providing this to the customer in a single comprehensive source for price information and market dynamics. i.e. the customer must be informed to be able to set effective objectives. This comprehensive source must be focused on the energy user rather than the energy speculator (e.g. stock market investor).

Once a pricing structure has been identified that meets your company’s goals, the contract negotiation must be driven to suit your company’s objectives for risk and pursuit of potential lower prices, not just that of the supplier’s objectives.

Contracts provided by retail energy providers (i.e. suppliers) will be naturally designed to suit the supplier and to safeguard their interests in terms of supply. This is diametrically opposed to your company’s interests and safeguards, and the energy broker should get involved as your company’s advocate, to create a more balanced contract. The energy broker should also provide hedging advisories that would protect your company against price increases.

6. The Real Advantages of Being Greener

By reducing your company’s dependence on traditional energy use through off-grid technologies like solar and wind, you can also reduce the impact of energy shortages and price.

Yet operational costs are so prominent today that it’s easy to overlook anything else. The social cost of a faulty energy policy can be just as high or higher, not only in dollar amounts, but in the public’s negative perception of your brand as failing to fulfill your corporate social responsibility

Think also, the more your employees believe in your company and the work they do on a daily basis, the harder they are likely to work and the more devoted they will be. Energy management helps to improve working conditions and it gives employees something to get behind and believe in.

Your company’s carbon footprint is measured by the amount of greenhouse gas emissions emitted either directly or indirectly. Your company should have a strategy to reduce it through technological developments, better process and product management, or changed procurement or carbon capture. Your energy consultant and broker should also naturally assist with utilizing your company’s renewable energy credits and carbon credits. With these, your company will be able to create tangible display of its assistance to the community and the environment.

These steps can be even more solidified through use of an energy consultant or broker with Leadership in Energy and Environmental Design (LEED) accredited professionals who can evaluate your company’s facilities and advise your company on ways to earn LEED points and obtain LEED certification for your facilities. Or there are other measures of success programs such as EPA’s Energy Star, however whatever program you choose, consider the benefits of the marketing value behind the program(s) you may use to enhance your brand.

7. The Tools are Available Now

Good energy consultants can be can be engaged as a revenue driver and not as a cost factor, if chosen effectively. An effective consultant becomes an active member of your energy procurement operations of which should be constant and proactive. Energy profiling and market analysis with bid sampling is a service funded by the suppliers, and is an activity that should be done regularly, such as every 6 months for example. An effective energy broker will work as your company's advocate to assure best structure, pricing and contract. It is through these steps that your company can best mitigate the inherent risks of deregulated energy procurement, and make it instead a predictable spend. And a naturally comprehensive energy program will cash in on the benefits of renewable credits both financially and socially within your community and customer base.

8. Abbreviations

LED	light emitting diode
RFP	request for proposal
LEED	Leadership in Energy and Environmental Design
ISO	International Organization for Standardization
ISBE	International Society of Broadband Experts
SCTE	Society of Cable Telecommunications Engineers
EPA	Environmental Protection Agency

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Energy Management for the Internet of Things

Data Model and Business Model Considerations

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1. Introduction

Energy management has emerged as critically important to cable industry cost structures and business continuity. The industry's Energy 2020 initiatives address energy management in cable facilities and access networks, and the industry has developed a Voluntary Agreement to meet Energy Star® requirements for set-top boxes.

The cable industry Internet of Things (IoT) ecosystem might include devices within customer premises, devices in cable plant - so-called Industrial Internet of Things, and even devices in the wider world such as Smart City devices like parking meters or municipal watering systems. Many of these devices will have relatively small energy consumption footprints, but their rapid proliferation could lead to large aggregate energy consumption. On the other hand, the very nature of some of these devices, such as lighting controls, has a core function that itself reduces energy consumption.

The industry's home automation businesses offer support and management of a wide variety of smart devices including lights, music players, sprinkler systems and many more. This paper discusses the business context and possible approaches to energy management services, both as extensions to current services and potentially new domains. Also, this paper considers managed services that cable operators might provide to commercial and residential customers.

Interoperability of devices and energy applications across multiple system operator (MSO) systems can reduce costs and speed adoption. Finally, the paper will present a high-level data model for capturing heterogeneous device behavior and making the data available for energy management purposes.

2. Business Context for Analysis

This section provides a brief business context for the energy management analysis, to characterize the landscape of services and devices that might be covered. Different companies will have different business models and address different sets of vertical markets; this section is intended to provide an illustrative set for the purposes of analysis.

2.1. How Service Providers Approach the Subscriber New Market

Cable service providers have engaged in the Internet of Things via the provision of a new line of business around home automation. Comcast's Xfinity Home, Cox Home Life and others have been added to the traditional triple-play bundle. These programs offer several services and devices that leverage Internet-connected devices, but have been led by home security services. The home security value proposition is a proven one, thanks to the history of ADT and other long-time providers. At the same time, the cable service providers believe their architecture, support of diverse non-security devices, and cost structure all enable competitive entry at an advantage over incumbent providers. Indeed, Comcast recently announced they had signed up more than one million customers to the Xfinity Home service.

Based on this success, the home security service serves not only as the financial basis for further offerings and stronger customer retention, but the technical architecture provides a platform for easy integration of further devices, both those available direct from the service provider as well as "bring-your-own" devices purchased by the customer at retail. Ultimately, the vertical market overviews in this paper assume they are built on top of the existing security platform. This platform can include touchscreen controllers, smart phone apps, and application programing interfaces or APIs for device integration.

2.2. Vertical Market Overviews

Cable service providers are addressing several vertical markets at this time, and are assessing entry into others. This section provides brief overviews of five vertical markets. Home entertainment is considered out of scope for this paper; CableLabs and the NCTA are directly addressing energy management for in-home entertainment devices via the previously mentioned Voluntary Agreement.

2.2.1. Home Security

Home security services come in two basis flavors. One is "Alarm" services, which connect the home system directly to first responders in the event of security or fire events. The second is known as "Monitoring", and provides security information to the customer, who then decides on further actions. The customer may in this case be able to create settings to alert her to events that might need immediate attention.

2.2.2. Home Automation

Home automation devices and services span a wide range of use cases. Some, like music players, connect to streaming content services that are outside the scope of the home security/home automation service provider. Others, for example light bulbs, are stand-alone devices that may require nothing more than on-off signaling, and do not require additional subscription fees or relationship with the service provider.

2.2.3. Health Care

There are two distinct classes of health care devices. The first class comprises wristbands, bathroom scales, and other self-monitoring devices. The second class includes those provided as part of physician-directed in-home health care. The latter is out of scope for this paper.

2.2.4. Smart Cities

The Internet of Things extends beyond the home into a wide range of activity. Commercial firms are building increasing intelligence into manufacturing processes, logistics management and other areas, sometimes known as the Industrial Internet of Things. However, service provider customers are increasingly traveling with their smart devices, and encountering intelligence built into commercial and municipal spaces in a phenomenon known as the smart city.

Service providers, especially now that several offer full wireless communication services, may wish to extend their home automation offerings outside the home. Smart city applications gaining traction today include public safety and security, citizen services, smart street lighting, smart parking and other intelligent transit, and utility and smart grid development.

In terms of customer behavior, the connected car is probably the largest nexus between in-home and outside-the-home automation. In-home alarm services could tie into the customer's smart phone. So-called geo-fencing applications (open the garage door when customer within ¼ mile of home) and others imply coordination between a customer's in-home and outside-the-home activities; and in-vehicle systems from entertainment to GPS might very well call for service provider integration.

Beyond the B2C service provision, municipalities themselves are a target market for service providers, either as extension of residential services beyond the home, or as part of service provider commercial service offerings. As many municipalities support sustainability goals, energy management will be a key component of offerings from service providers.

2.2.5. Special Use Case – In-home Devices that Serve an Explicit Energy Management Function

Nest (the smart thermostat) and other home energy management platforms represent another potential set of devices and services that might become part of a managed service provided by MSOs. Not unlike home automation, programmable thermostats, temperature sensors, programmable appliances such as washer/dryers might all benefit from cloud based management which could maintain a history of usage and apply machine learning to predict and optimize behavior. A managed service might tie into local utility data services to take advantage of favorable pricing or automated demand response. For example, scheduling a dishwasher to operate at the optimal time for energy load and pricing benefits the entire community and could reduce costs for customers.

In the commercial realm, similar automatic energy management systems that are evolving within the cable plant itself could apply to a general commercial realm. Cloud based systems could monitor and optimize energy usage in a variety of commercial settings, from boilers, to traditional water heaters by way of example.

2.3. Device Ecosystem Characteristics

Service to each vertical market comprises support for a broad set of devices in that space. The device ecosystems described below in each vertical are intended to be illustrative.

Power consumption in these devices is determined by the interplay of device design choices, service provider management and expected consumer behavior.

Devices consume energy as part of their design function, for example the load of a light bulb while it is providing illumination. Increasingly, retail customers are pushing manufacturers to reduce device energy consumption, for example, reference to Energy Star® ratings. Service providers seeking to reduce power consumption may also factor energy efficiency into buying decisions. Procurement requirements for battery components are offered in Joe Rodolico’s recent Journal article. Rodolico notes, “To truly maximize IoT device battery life beyond this paper’s recommendations, device designers must employ smart software to conserve battery life: sleep the device for the maximum time the application will allow and ensure device functions take as little time as possible.” [4] As Rodolico points out, service providers “need to reduce costly service calls for replacing batteries.”

One alternative to batteries is hard-wired connections to power, through plug in modules or wired versions of products like thermostats. In these devices, further energy considerations should focus on so-called phantom or “vampire” loads, drawing power when in standby mode. Lawrence Berkeley Laboratories has published a table of standby power measurements for various consumer electronics devices, which give some idea of potential energy loads that may also be a characteristic of newer IoT devices. [5]

Customer behavior, especially in leveraging device and service capabilities, is also an energy management consideration. Geo-fencing capabilities enable customers to trigger device behavior according to their location; for example, automatically opening a garage door when their car is within a quarter-mile of home. Geo-fencing implies always-on, standby power to receive such automated commands.

One final consideration turns on how customers manage their devices. A service provider may be providing a hub for integrating devices, but customers may have more than one such aggregation point – Comcast provides its own Xfinity home touch pad, but some devices that “work with Nest” are integrated into the Nest ecosystem through the Nest thermostat as a hub. These business models will affect the degree of control service providers will be able to exert to achieve energy management goals.

Finally, before being overwhelmed by the growing number of connected devices entering the home, service providers should keep in mind the trend toward sensor fusion – multiple sensors are being integrated into single chipsets, and single devices carrying multiple sensors. Sensor fusion may provide another approach to help achieve overall energy budgets.

2.3.1. Home Security

Home security and home monitoring services generally come with a common set of basic components.

- Window Sensors – These are generally battery powered.
- Motion Sensors – These are generally battery powered.
- Keypads or Touchpads - These are more commonly hardwired, especially in the security/alarm service category and backed up by a DC battery in the event of commercial power loss.

Add-on Components

- Cameras – indoor and outdoor cameras generally call for plugging into household power. According to Nest, for example, “Power consumption depends on what the camera is doing. For example, when its Night Vision LEDs are on, the camera uses more power than when they’re off. Even when it’s working its hardest, the camera never uses more than 7 watts.” Some doorbell-connected cameras come with Low or Medium power draw settings, but sometimes these affect performance, such as how long they take to wake up and provide a video or photo of a visitor.
- Smart Door Locks - Some brands come with a hub or controller that itself is usually plugged in and drawing some standby power.
- Smoke Detector – May be battery powered or hardwired; some states’ insurance requirements may require hardwiring.

2.3.2. Home Automation

Beyond security and automation, the variety of home automation devices continues to proliferate. A few examples, including those emerging in the entertainment space, will illustrate some of the energy management considerations.

- Lighting – Lighting seems like a straightforward energy management situation, but there are complexities in the new world of smart home automation.
  - Bulbs – Philips’ Hue-branded light bulbs were early entrants to the smart home appliance and device market. The bulbs are LEDs, and so right away their 8.5 watt power usage represents a savings over conventional 60 watt bulbs that generate the same amount of light.

It is worth noting that controlling the Hue bulbs through a service provider dashboard includes talking to the separate Hue controller device, which is always plugged in, a power draw of 1.4 watts. Further, even in the off state, each bulb draws around 0.4 watts in order to remain in contact with the network. “A week in the off state would use as much power as a 60 Watt bulb turned on for one hour.” [6]

  - Lighting Systems - Part of the benefits of home automation lighting systems is to more precisely turn off lights that are not in use, as set to certain day/time schedules. Smart switches and dimmers may be reached via Wi-Fi, in which case the systems often come with a hub controller or “smart bridge” with attendant power draws.
- Garage Door Openers – Garage door openers, have always included remote control connectivity, and are now available with further capabilities. One feature is moving the remote functionality into a smart phone app, which in turn means adding a smart hub or controller for Wi-Fi connectivity. Other new features include remote checks of whether the door is open, and connections to geo-fencing features as described earlier. Garage door opener may draw as much as 8 watts of standby power, every hour it is plugged in, whether it is doing anything or not. That’s 70 kWh a year for doing nothing.” [7]
- Music Players – Networked speakers, for example the Sonos system, are always plugged in to power the speaker and to receive commands over home Wi-Fi. Speakers may draw as much as 3.8 watts even when idle. [8]

2.3.3. Health Care

FitBit, FuelBand and others are the tip of an iceberg of health and fitness related devices. These are driven by business models that encourage “quantified self” tracking, participation in social networks, and other non-medical products and services. As noted earlier, medically-prescribed home health care and monitoring are outside the scope of this paper

- Connected Bathroom Scales – These devices are typically battery powered, and report weight, body fat percentage, and heart rate data over Wi-Fi to a smart phone application, or a connected hub.
- Sleep Monitors – Sensors that go under the pillow or even are built into mattresses are a more recent addition to the catalog of smart devices. These have similar characteristics as other sensors, with battery power and hub interconnection.

2.3.4. Smart Cities

Smart Cities is a popular catchphrase for municipal government efforts to manage classic urban problems, like traffic congestion or budget shortfalls, through smart controllers. A sampling of devices that are having intelligence built in or added on includes:

- road sensors
- street lights
- parking meters
- closed circuit cameras

As noted in section 2.2.4, connected cars are likely to play a key role in the intersection of a customer behavior inside the home and outside the home. This is not a segment where device energy management comes into play so much as that cars may be a focus of some of the service provider managed services that are described in section 3 of this paper.

2.3.5. Special Use Case – In-home Devices that Serve an Explicit Energy Management Function

Smart thermostats, networked electrical outlets/ power strips, and home electric car charging stations are devices that have energy consumption profiles, but all of these also play into an explicit energy management function in the home. These are appearing alongside traditional, high load appliances like washers, dryers, dishwashers and electric furnaces. The latter have been showing up, for example, as large appliances that are now networked into local utilities to contribute to peak demand reduction in many jurisdictions. These dynamics inform the energy management approaches described in the next section, in particular, managed services provided by cable service providers.

3. Energy Management Approaches in the Device Ecosystems

3.1.1. Devices in the home

Energy services might naturally fit as an 'add-on' service to home security and automation services. Utilizing the same basic software paradigm, proprietary and open interfaces to a range of energy controller and consuming devices could support ingest of data and issuance of commands by a cloud based system. An 'adapter' layer maps manufacture-specific protocols to a common data model that is exposed to applications. The intelligence activating optimizations is encoded as applications in the cloud, accessing historical and real-time 'stream' data pouring off devices.

3.1.2. Devices in a commercial facility

As with the home energy management scenario, a cloud based managed service implements adapter to interface with any number and variety of devices. Specific algorithms addressing use cases for commercial domains would execute as applications within a generalized framework that supports data ingest and command/control protocols.

3.1.3. Smart City

MSOs might be well positioned to support energy management, and other functions such as smart watering, via platforms similar to those described for residential and commercial scenarios. Where MSOs have a mature and scalable energy management framework targeted to its traditional customer base, such a platform might support the types of applications useful for many Smart City use cases. This value proposition might be enhanced where MSOs also provide solutions for connectivity, such as a wireless footprint and other communications infrastructure such as LoraWAN.

4. Energy Management Data Model for the Internet of Things

This section presents a high-level data model for capturing heterogeneous device behavior and making the data available for energy management purposes.

The SCTE Adaptive Power System Interface Specification (APSIS), issued as SCTE 216 2015, defines a generalized model for energy measurement and control of a wide variety of devices. Based upon the IETF energy management (eman) platform, the data model includes a high-level information model that includes a comprehensive generalization of energy consuming and producing devices, and a ‘binding’ to the SNMP protocol. The information model can be supporting by any number of encodings and transport technologies by defining protocol specific bindings. Protocol bindings for JSON, XML, YANG/NET-CONF, IPDR, and others are possible.

An open source reference implementation of APSIS is currently under development within the Linux Foundation’s OpenDaylight (ODL) project. ODL is a Software Defined Networking (SDN) controller that manages device connectivity on behalf of applications. Applications using the framework can be relieved of the “necessary plumbing” involved with device discovery and connectivity, session management, topology maintenance, security, and other code-heavy services. The ODL energy management (eman) plug-in provides a RESTful interface for applications, and can map these API to any collection of energy aware devices.

Figure 1 provides a high-level diagram of the IETF energy management (eman) information model.

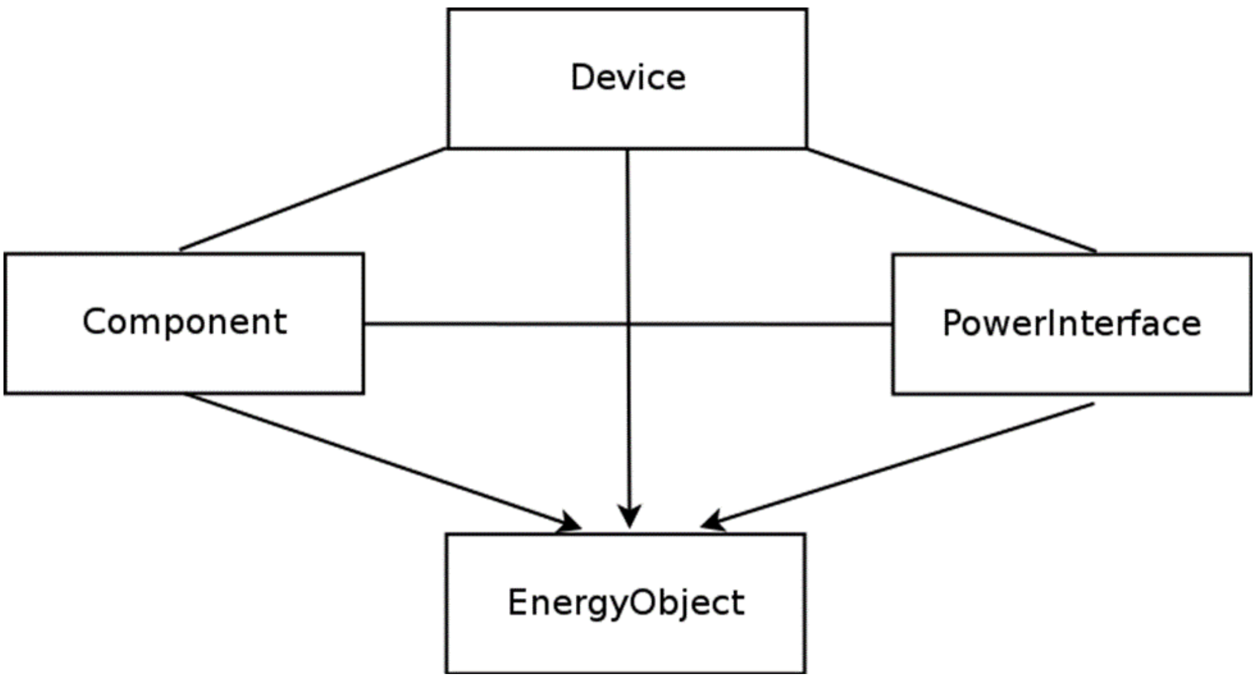

Figure 1 - Energy management Information Model - Device view

This figure illustrates the key structural elements of the IETF energy management information model. As illustrated, a logical device, which might typically represent a physical device like a router, Converged Cable Access Platform (CCAP) device, or thermostat, may include a tree of power interfaces and sub-components. Power interfaces allow a system to build a view of the power topology. This topology will describe which elements provide power to those elements that consume it. Components allows the system to gain visibility into complex systems; for example, where a device supports multiple ports or cards.

Each of these objects are specializations of an EnergyObject which contains power and energy measurement tables and power states that may be configured; therefore, each element can be measured and controlled as appropriate.

Figure 2 illustrates the main features of the EnergyObject, which encapsulates the measures and controls that may be exposed by devices and components.

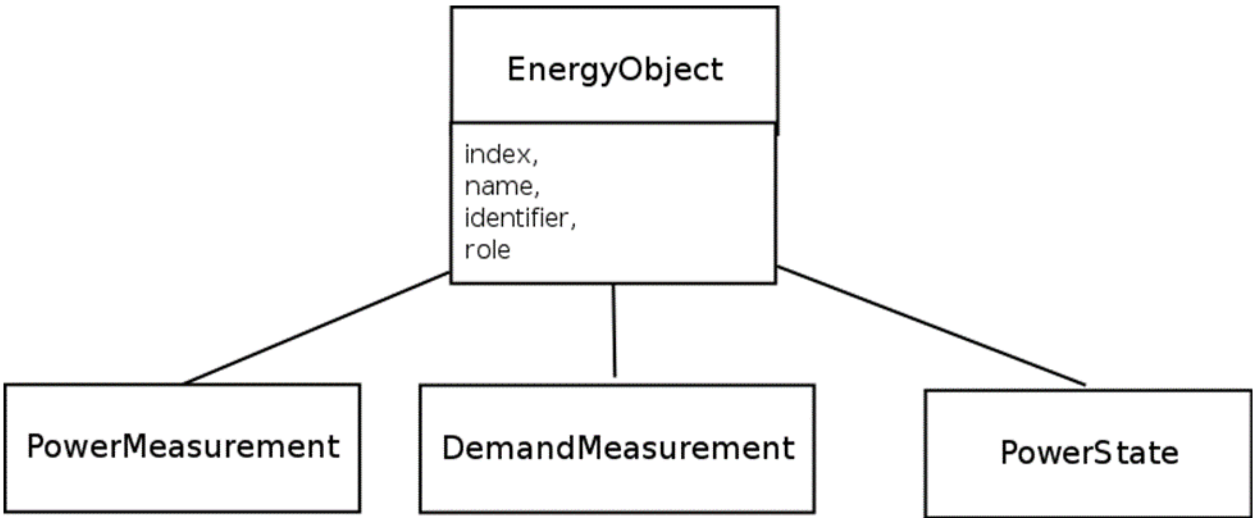

Figure 2 - Energy management Information Model - Object view

Power and energy represent somewhat different concepts. Using the analogy of automobiles, power indicates the rate of transfer of energy, as a speedometer reading shows the velocity of a car. Energy indicates the accumulated transfer of energy over a period of time, much as your odometer shows the distance traveled. The PowerMeasurement object indicates reading of power at a given time, expressed in Watts, and the DemandMeasurement object indicates the amount of energy delivers or consumed with a span of time, expressed in kilowatts/hour.

The PowerState object provides controls to set the power state of a device, power interface, or component. The object defines a comprehensive set of power states, including various sleep modes as well as simple on/off.

This section provides a simple view of the information model. The APSIS specification provides context and normative reference to the relevant IETF energy management (eman) documents. The information model is described in RFC 7364, and other RFCs define SNMP MIB encodings of the model.

The OpenDaylight energy management (eman) plug-in defines a YANG encoding, which in turn defines an HTTP REST API.

5. Conclusions

The energy consumption impact of the new world of the Internet of Things has the potential to be quite large. This paper demonstrates that a careful inventory of device designs and behaviors will likely yield a set of successful energy management strategies. The challenge will be to monitor the incoming pipeline of new devices, the volume of which is likely to remain large for several years to come.

6. Abbreviations

API	application programming interface
APSIS	adaptive power system interface specification
B2C	business to consumer (as opposed to business to business)
CCAP	converged cable access point
eman	energy management
GPS	global positioning system
IETF	internet engineering task force
IOT	internet of things
IPDR	internet protocol data record
JSON	JavaScript object notation
LED	light emitting diode
LoRaWAN	long range, low power wide area network
MIB	management information base
NCTA	The Internet and Television Association (formerly National Cable Telecommunications Association)
ODL	OpenDaylight
RESTful	representational state transfer web services
SNMP	simple network management protocol
XML	extensible markup language
YANG/NET-CONF	“Yet Another Next Generation” data modeling language for data sent over the NETwork CONFiguration protocol

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Increasing Resiliency Through Renewable Energy Microgrids

A Technical Paper prepared for SCTE/ISBE by

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1. Introduction

This paper describes a methodology to quantify the economic and resiliency benefit provided by renewable energy (RE) in a hybrid RE-storage-diesel microgrid. We present a case study to show how this methodology is applied to a multi-use/ multi-function telecommunications facility in southern California. In the case study, we first identify photovoltaic (PV) and battery energy storage system (BESS) technologies that minimize the lifecycle cost of energy at the site under normal, grid-connected operation. We then evaluate how those technologies could be incorporated alongside existing diesel generators in a microgrid to increase resiliency at the site, where resiliency is quantified in terms of the amount of time that the microgrid can sustain the critical load during a grid outage.

We find that adding PV and BESS to the existing backup diesel generators with a fixed fuel supply extends the amount of time the site could survive an outage by 1.8 days, to 3.5 days for the PV/diesel/BESS hybrid system. Furthermore, even after diesel fuel supplies are exhausted, the site can continue to operate critical loads during daytime hours using just the PV/BESS when there is sufficient solar resource. We find that the site can save approximately $100,000 in energy costs over the 25-year lifecycle while doubling the amount of time they can survive an outage.

The methodology presented here provides a template which may be applied to other sites interested in quantifying the energy, economic, and resiliency benefits of RE.

2. Background

Electricity system resiliency focuses on preventing power disruption and, when an outage does occur, restoring electricity supply as quickly as possible while mitigating the consequences of the outage. Resiliency is a high priority for telecomm facilities, which can experience millions of dollars of losses during outages. Traditionally, diesel generators have been used to provide backup power during outages. Renewable energy is starting to play a role in energy resiliency for two primary reasons.

First, the US has seen an increase in the number of high-impact and high-cost natural disasters - seven of the ten costliest storms in US history have occurred in the last ten years (Ton 2015). These high impact incidences have exposed the fact that existing approaches to energy resiliency are not sufficient in many communities. Numerous weaknesses were exposed during these incidences, including: lack of refueling options for backup diesel generators, unreliable operation of backup generators, interruptions in natural gas and other fuel supplies, and aging infrastructure (Marqusee 2017).

Second, the market is experiencing a significant decrease in the cost of renewable energy (RE) systems, most prominently photovoltaics (Barbose 2016), and battery energy storage systems (BESS) (GTM Research/ESA 2017). These cost decreases have led to a significant increase in the number of deployed RE and storage systems (GTM Research/ SEIA 2017 and GTM Research/ESA 2017).

The combination of fuel supply interruptions in many of the recent natural disasters, and the increased cost-effectiveness of RE and BESS has generated significant interest in using RE technologies both for economic benefit as well as for backup power to sustain critical loads during grid outages. Unlike conventional back-up generation such as diesel gensets, which sit idle most of the time, the combination of BESS, RE, and demand management technologies can be operated for economic gain during the 99% of the time that the grid is functional. The grid-connected benefits of RE and BESS microgrids include offsetting bulk energy purchases, reducing peak demand charges, performing energy arbitrage, and providing ancillary services. With the appropriate inverters and controls these same systems can be islanded to form a microgrid, along with diesel generators, to sustain critical electrical loads for the site/facility during grid outages. A hybrid diesel-RE microgrid system such as this can sustain longer outages for a given amount of diesel fuel by reducing the run-time of the diesel generator, increasing the energy resiliency of the site.

The cable industry has recognized the importance of lowering energy consumption, cutting energy costs, and reducing dependence on the grid. They have formed the Energy 2020 program, a multi-year campaign through the Society of Cable Telecommunications Engineers (SCTE) Energy Management Program, to envision and enable what energy will look like in cable in the year 2020, targeting maximum customer uptime and enabling capacity growth via successful organizational, customer and environmental energy solutions (SCTE 2017). At the time of publication, the goals of the program are to:

- Reduce energy intensity by 15% year on year
- Reduce energy costs by 25% on a unit basis
- Reduce grid dependency by 10%
- Optimize technical facilities and datacenters footprint by 20%

This paper focuses on the role of renewable energy in meeting the first three of these goals: reducing energy consumption, energy cost, and grid dependency of telecomm sites.

3. Methodology

This section describes the methodology for quantifying economic and resiliency benefit provided by RE in microgrids, and summarizes key analysis inputs and assumptions.

3.1. Modeling Approach

3.1.1. The REopt Model

We used NREL's Renewable Energy Optimization (REopt) modeling platform for energy system integration and optimization to evaluate RE and storage technologies to minimize energy costs and increase resiliency (Cutler et al 2017). The REopt model is formulated as a mixed integer linear program that seeks to minimize the life-cycle cost of energy at a site over the analysis period, subject to a variety of constraints. The life-cycle cost of energy includes all of the costs associated with providing energy to the site, including the cost of purchasing energy from the utility grid (in present value), the capital cost of building new technologies, present value of operating and maintenance (O&M) costs, income from utility or state incentive programs, and any tax benefits. The model performs an energy balance at every time step where loads must be met by some combination of renewable and conventional generation, purchased energy from the utility grid, discharges from energy storage, or dispatchable load. This energy balance is solved for the first year and then is assumed to repeat for each of the ensuing years in the analysis period, with recurring costs escalated and then discounted in the cash flow. The output of the REopt model is a set of cost-optimal sizes for each technology in the candidate pool, and the net present value that would be achieved if the technologies in the solution were to be implemented. The optimal dispatch strategy for each technology required to achieve the net present value is also provided.

3.1.2. Quantifying Economic Benefits of RE and Storage

One of the critical elements in comparing resiliency associated with RE (or hybrid) systems to generator-only systems is capturing the grid connected benefits associated with the RE technologies. The REopt model was used to simulate the business-as-usual case, where the site continues to purchase their energy services from their serving utility. During grid outages the critical loads are served by a backup diesel generator. REopt was also used to optimize the hybrid RE/storage case, where the size and operation of the system are optimized by the model. In this case, the RE systems were able to operate for financial benefits during grid-tied operation, and were also able to serve the critical loads during grid outages.

3.1.3. Quantifying Increased Energy Resiliency Due to RE and Storage

Another key element in evaluating hybrid diesel-RE systems in the context of energy resiliency is quantifying the additional energy resiliency provided by the RE portion of the systems. In this section, we describe an approach for quantifying the extended outage survivability associated with an RE system. Using REopt, the RE system is sized for maximum economic gain under grid-connected operation, where the RE system can offset grid purchases of electricity, reduce peak demand charges, and/or engage in energy arbitrage.

Outage survivability is defined as the probability that a site can supply energy to the critical loads for an outage of X hours given a certain set of energy assets. It is defined as a probability because the ability to survive an outage of a given duration depends on when that outage occurs during the day/year (impacting the load during the outage), and – for sites with RE systems – the concurrent RE resources.

With a traditional diesel generator and a fixed amount of fuel onsite the outage survivability varies as a function of the outage duration. For example, at a telecommunications facility the outage survivability, or probability, would typically be 1 (100%) for the first 24 hours of an outage (given sufficient fuel), and tails off quickly as the fuel supply is exhausted. For a hybrid RE/generator system, the outage survivability for longer outages increases due to the ability of the RE systems to offset some of the generator fuel consumption. To determine the increased energy resilience provided by RE, the outage survivability is calculated first with only the existing diesel or gas backup generators and fixed fuel supply. Then, the outage survivability is calculated again with the hybrid RE/storage system included in the simulations (along with any existing diesel or natural gas backup generators), making it possible to quantify the increase in outage survivability attributable to the RE systems.

To calculate the outage survivability as a function of hours, random grid failures are injected into the REopt model. These outages are random in both occurrence and duration, with each variable being sampled independently from a uniform distribution. The outage occurrence can occur in any hour in the year, and the outage duration can take any value between 0 and 336 hours (two weeks). In each simulation the model will either fail to have sufficient resources to meet the critical loads, or it will be able to meet those loads and will dispatch those systems during the outage (as well as during the remainder of the year). For this analysis 1000 optimization simulations were executed. The results were binned by 24-hour blocks, and the outage survivability was calculated for each 24-hour period from 24 to 336 hours (1 to 14 days). Each range has an average of 77 simulated outages.

3.2. Model Inputs

The modeled site is a multi-use/ multi-function facility, which includes administrative offices, a warehouse, a production studio, a technology center for research and development, a customer service center, and a hub site delivering cable services to the surrounding community.

3.2.1. *Load and Utility Rate Tariff Data*

The site was modeled using actual electrical load data, measured over one year on 15 minute intervals. The average load is approximately 150 kW, ranging from a minimum of 120 kW to a maximum of 250 kW in the summer. Total annual energy consumption is 1,400,000 kWh. We assumed the critical load was a flat 155 kW, based on standby generator ratings and input from the site.

The site is in an unregulated market and is served by Southern California Edison (with rate tariff TOU-GS-3 Option B) for delivery, and Constellation Energy for energy charges. The site's total 2015 electric energy cost was $250,000. The combined SCE and Constellation Energy rate tariff is shown in Table 1 and includes on peak, mid peak, and off-peak summer and winter energy and demand charges.

Table 1 - Current Electric Rate Tariff, Combined SCE Option B and Constellation Energy

All year		
Fixed monthly charge	$453.25/meter	
Facility demand charge	$19.38/kW	
June-September	**Energy Charge ($/kWh)**	**Demand Charge ($/kW)**
Noon-6 p.m., weekdays	0.15856	15.51
8 a.m.-noon, 6 p.m.-11 p.m., weekdays	0.12541	3.05
All other hours	0.10878	0
October-May	**Energy Charge ($/kWh)**	**Demand Charge ($/kW)**
8 a.m.-9 p.m., weekdays	0.12156	0
All other hours	0.1131	0

If the site installs a PV, it will be eligible to switch to SCE TOU-GS-3 Option R. This tariff is favorable for PV because the highest energy charges occur during times of peak PV generation. It is less favorable for BESS because there are no time-of-use demand charges. Table 2 shows the combined SCE TOU-GS-3 Option R and Constellation Energy rate.

Table 2 - Future Electric Rate Tariff, Combined SCE Option R and Constellation Energy

All year		
Fixed monthly charge	$453.25/meter	
Facility demand charge	$12.78/kW	
June-September	**Energy Charge ($/kWh)**	**Demand Charge ($/kW)**
Noon-6 p.m. weekdays	0.35634	0
8 a.m.-Noon, 6 p.m.-11 p.m., weekdays	0.17259	0
All other hours	0.12762	0
October-May	**Energy Charge ($/kWh)**	**Demand Charge ($/kW)**
8 a.m.-9 p.m., weekdays	0.1404	0
All other hours	0.13194	0

3.2.2. Candidate Technologies

The following candidate technologies were included in the model for consideration and are further described below: utility grid, PV, BESS, and diesel generators. These technologies were selected for consideration based on expert guidance and recommendations, though other technologies may also play a role now or in the future.

a) Utility Grid: The utility grid is assumed to be able to supply an unlimited amount of electricity up to the transformer rating serving the site. Energy from the grid incurs only the costs specified by the tariff structure; there are no capital or O&M costs.

b) PV: The NREL REopt software utilized hourly capacity factors to model the production of PV during every hour of the year. The hourly capacity factors were obtained from PVWatts (Dobos 2013) for the specific location, assuming fixed open rack, south-facing, standard PV panels with a tilt equal to latitude and using a typical meteorological year 2 (TMY2) weather file for Los Angeles (the closest available TMY2 weather file). We assumed system losses of 14% for soiling, electrical wiring losses and availability; an inverter efficiency of 0.96%; and annual performance degradation of 0.5% per year (Jordan 2010). The annual average solar capacity factor was 18%. An installed cost of $2.13/W and an operating and maintenance cost of $0.02/W-year were estimated based on published market research and input from subject matter experts within NREL (Feldman 2014). The system was expected to last 25 years. Electricity produced by the PV in the model could be used to serve the electrical load, charge the battery, or be exported to the grid.

c) BESS: The battery storage module was based on the characteristics of lithium-ion batteries. The model was able to optimally select and size both the energy capacity of the battery and the power electronics that determine instantaneous power charge and discharge capacity. Battery capacity was assumed to cost $520 per kWh and power electronics $1000 per kW (Anderson 2016). The life expectancy of the battery was assumed to be 10 years, and the present value replacement cost of $200/kWh and $200/kW was included in the model. The battery was modeled with a combined round-trip efficiency of 82.9% and discharge was restricted to ensure that the state of charge never dropped below 20%. The battery can be charged by the PV, grid, or generator (during outages) and discharged to the electric load.

d) Diesel generators: The site has two existing diesel generators rated at 75 kW and 230 kW. We assumed tank capacities of 150 and 400 gallons of fuel, respectively, which would last approximately 24 hours at full load or 44 hours at 50% load. The performance of the existing diesel generators were modeled using a linear fuel consumption rate with slope of 0.6 gallons per kWh and y-intercept of 1.4 gallons per hour, based on fuel consumption data for a 230 kW generator. The minimum turn down ratio was assumed to be 30%. There was no capital cost associated with the generators as they were already in place and would therefore not constitute a new expense. The O&M cost was assumed to be $0.02 per kWh produced, and it was expected that the system would last 25 years. A lumped model of the diesel generator was used, meaning that all of the generating capacity specified by the model was assumed to be in one large generator rather than multiple smaller generators. Spinning reserve and operating reserve were not considered as part of this analysis. The diesel generator could directly serve the electrical load or charge the battery, only during outages.

3.2.3. Economic Assumptions

We assumed that RE technologies would be built immediately and would continue to produce energy for the duration of the analysis period, which was assumed to be 25 years. We assumed that the cost of purchasing energy from the utility grid escalates each year at an escalation rate of 0.1%, and the O&M cost associated with RE and BESS also escalates at a rate of 0.1% (NIST 2015). The utility costs and incurred O&M costs in the out-years were then discounted to the present.

We assumed a third party develops and finances the RE and BESS, and the site (the energy off-taker) purchases energy from the developer. There is no upfront cost to the site, but we assume the developer earns a 10% rate of return before taxes, which is reflected in the energy costs the site would pay to the developer. The site specified a 7% discount rate, which was used to discount all energy purchases to the present (including any potential energy purchases from a third-party developer).

We assume that the system owner has sufficient earned income that any and all available tax incentives are fully monetized. These tax benefits include the 30% investment tax credit (ITC) and 5 year depreciation under the modified accelerated cost recovery system (MACRS) for both PV and storage (DSIRE 2016). A 35% corporate tax rate is assumed to calculate the value of the ITC and MACRS. The capital cost used as the basis for MACRS is decreased by 50% of the value of the ITC. Because the ITC and MACRS are not available upfront, but rather are captured in future years, their values are discounted at the 10% discount rate. We also assumed the BESS would qualify for the California Self Generation Incentive Program (SGIP) which was valued at $0.36/Wh at the time of the analysis. Finally, we assume the site can net meter up to 100% of the annual load and the excess above 100% is credited at the November 2016 net surplus compensation rate of $0.02532/kWh (SCE 2016).

We assumed that the energy produced by the PV system degrades by 0.5% per year. We assumed the BESS lasts ten years based on calendar degradation and the cost of one replacement BESS was included in year ten. The BESS may not last the entire ten years if it experiences an excessive number of deep charge / discharge cycles, so we post-processed the BESS dispatch using the "rain flow" cycle counting algorithm (Downing 1982) to verify the ten-year assumption.

3.3. Assumptions

Key assumptions are summarized in Table 3.

Table 3 - Model Key Inputs

Input	Assumption
Technologies considered	PV, BESS, existing diesel generators
Objective	Minimize lifecycle cost of energy
Analysis period	25 years
Ownership model	Third-party owned
Discount rate for TWC	7%
Developer discount rate	10%
Corporate tax rate	35%
General inflation rate	0.1% per National Institute of Standards and Technology (NIST)
Utility cost escalation rates	0.1% per NIST
Incentives	30% Federal ITC for PV and BESS 5-year MACRS depreciation $0.36/kWh SGIP
Net metering limit	1 MW
Value of electricity exported to grid above net metering limit	$0.02532/kWh
Interconnection Limit	None
PV capital cost	$2.13/kW
PV O&M cost (includes one inverter replacement)	$0.02/W-year
BESS capital cost	$520/kWh plus $1000/kW
BESS replacement cost (year 10)	$200/kWh plus $200/kW
Solar resource	TMY2 solar data
Typical load	15-minute load data provided by the site; average load of 150 kW ranging from a minimum of 120 kW to a maximum of 250 kW. Total annual energy consumption is 1,400,000 kWh.
Critical load	155 kW flat load

4. Results of the Economic and Resiliency Analysis

4.1. Grid-Connected System Optimization

We first evaluated technologies that would minimize the life-cycle cost of energy at the site under normal, grid-connected operation. In this approach, the RE assets in the microgrid are optimally selected and sized for maximum economic gain during normal grid-connected operation; although these assets may increase the duration of outage for which the critical load can be sustained, this is not considered during the optimization process. Once the RE assets are optimally selected and sized, a series of stochastic simulations is completed to analyze how the resulting microgrid, which also includes the existing conventional generation of specified size and fuel reserve, performs during grid outages of random lengths throughout the year. In this way, the contribution of RE toward increasing the resiliency of the site can be quantified, even though improved resiliency was not actually an optimization criteria.

We found that the site can minimize their cost of energy by installing an 845-kW DC PV system and a 16 kW, 32 kWh BESS and switching to the SCE TOU-GS-3 Option R rate. The initial cost (borne by the developer) of the PV system would be approximately $1.8 million, and the cost of the BESS would be approximately $33,000. Site electrical work including a duct bank, manholes, pad-mounted switch, and communications required for medium voltage interconnection would be approximately $400,000. The PV system would generate 91% of the site's energy requirements.

The PV system is sized such that it offsets all energy charges. While it only generates 91% of the site's energy requirements, it generates some of that energy during on-peak hours, and so exported energy is credited at a high rate. The site then purchases utility energy during mid-peak and off-peak hours, when energy costs are lower. Therefore, the site can offset all of their energy costs even though they only generate 91% of their energy consumption. The site still pays demand charges and fixed charges so the net bill is positive. The net present value of the investment is $602,000.

We also evaluated a second scenario in which the model is constrained to build a BESS of at least 155 kW, 155 kWh which would sustain the 155 kW critical load at the site for one hour (as required for the selected microgrid configuration, see section 4.2.1). A BESS with a 155 kW inverter and a slightly larger 172 kWh capacity is the most cost-effective size under this constraint, with a net present value of $519,000. These results are summarized in Table 4.

Table 4 - Cost-Optimal Grid-Connected Results

Scenario Description	Base Case (SCE Option B)	PV/BESS Case (SCE Option R)	PV/BESS Case-Larger Battery (SCE Option R)
PV Size (kW DC)	0	845	845
BESS Size (kW, kWh)	0	16, 32	155, 172
PV Cost (without incentives) [a] ($)	$0	$1,803,644	$1,803,644
PV Cost (with incentives)[b] ($)	$0	$896,822	$896,822
BESS Cost (without incentives) ($)	$0	$32,640	$244,440
BESS Cost (with incentives)[b] ($)	$0	$10,448	$90,313
BESS Replacement Cost (without incentives), Year 10 ($)	$0	$9,600	$65,400
BESS Replacement Cost (with incentives),Year 10 ($)	$0	$7,171	$48,854
Site Electrical Work [c]	$0	$402,500	$402,500
Annual O&M ($/year)	$0	$16,900	$16,900
Average Annual PV Generation (kWh/year)	0	1,299,682	1,299,682
Year 1 Electric Load (kWh)	1,423,513	1,423,513	1,423,513
Year 1 Electric Charges ($)	$169,517	$0	$0
Year 1 Demand Charges ($)	$70,378	$28,668	$25,802
Year 1 Fixed Charges ($)	$5,439	$5,439	$5,439
Year 1 Total Utility Charges ($)	$245,334	$34,107	$31,241
Avoided Utility Costs ($)	$0	$211,227	$214,093
Year 1 Payment to Developer ($)	$0	$161,643	$172,212
Year 1 Savings ($)	$0	$49,584	$41,881
Lifecycle Cost ($)	$2,822,767	$2,220,894	$2,303,702
Net Present Value ($)	$0	$601,873	$519,065

[a] Includes PV, inverter, step-up transformer
[b] Includes present value of ITC, MACRS, and SGIP
[c] Includes duct bank, manholes, pad-mounted switch, and communications required for medium voltage interconnect

Figure 1 shows how the PV and BESS work together (in conjunction with grid purchases) to meet the site load at lowest cost. The site consumes utility electricity during nighttime hours when utility prices are low and PV is not generating. During the day, PV meets the full load, and excess PV is used to charge the BESS or is exported back to the utility. The BESS is strategically discharged between 4-7 p.m., as PV generation is tailing off, to slightly reduce peak demand. Because the BESS is small compared to the site load its impact is small, but it does provide some savings through a small reduction in peak demand.

Figure 2 shows how this operating strategy translates into utility bill savings. By shifting to SCE TOU-GS-3 Option R, the site reduces its demand charges by 59%. The largest savings occur during the summer months when utility peak pricing applies, and smaller savings on the part-peak, off-peak, and facility demand charge are earned year-round.

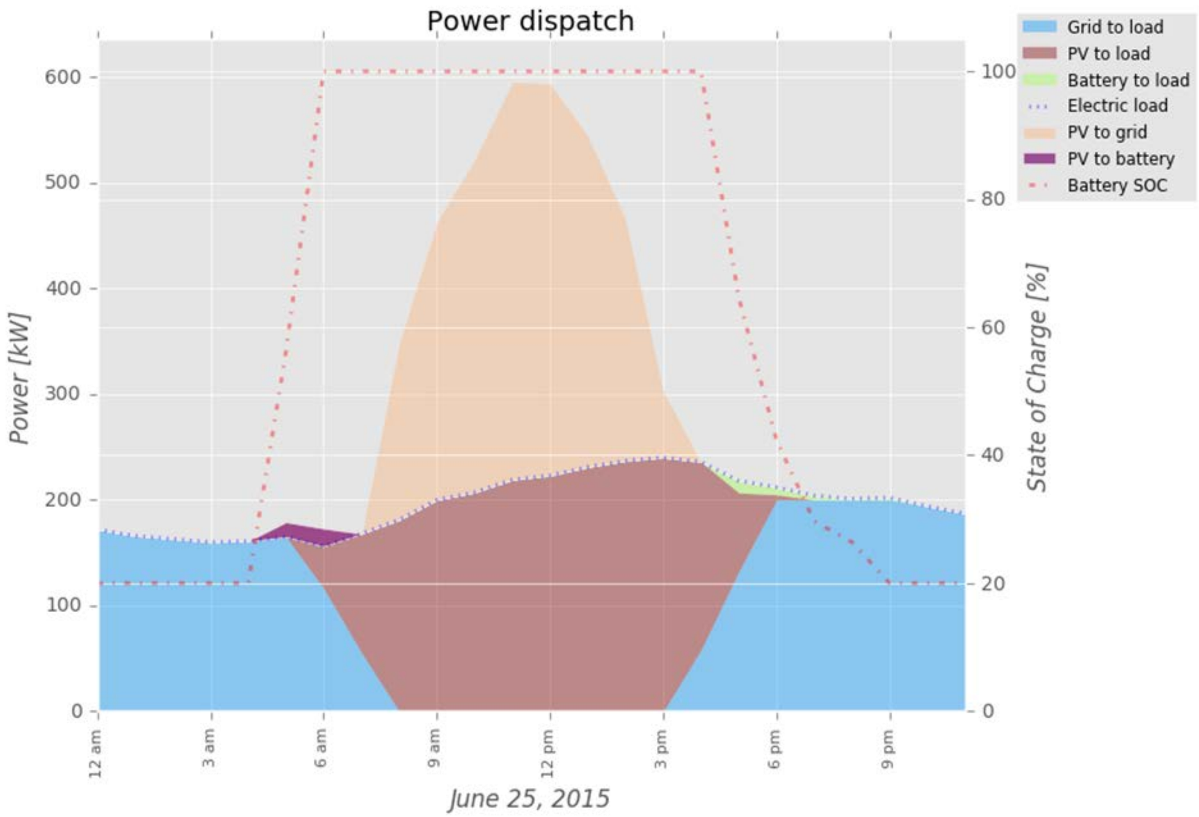

Figure 1 - Dispatch Strategy For One Day In June 2015

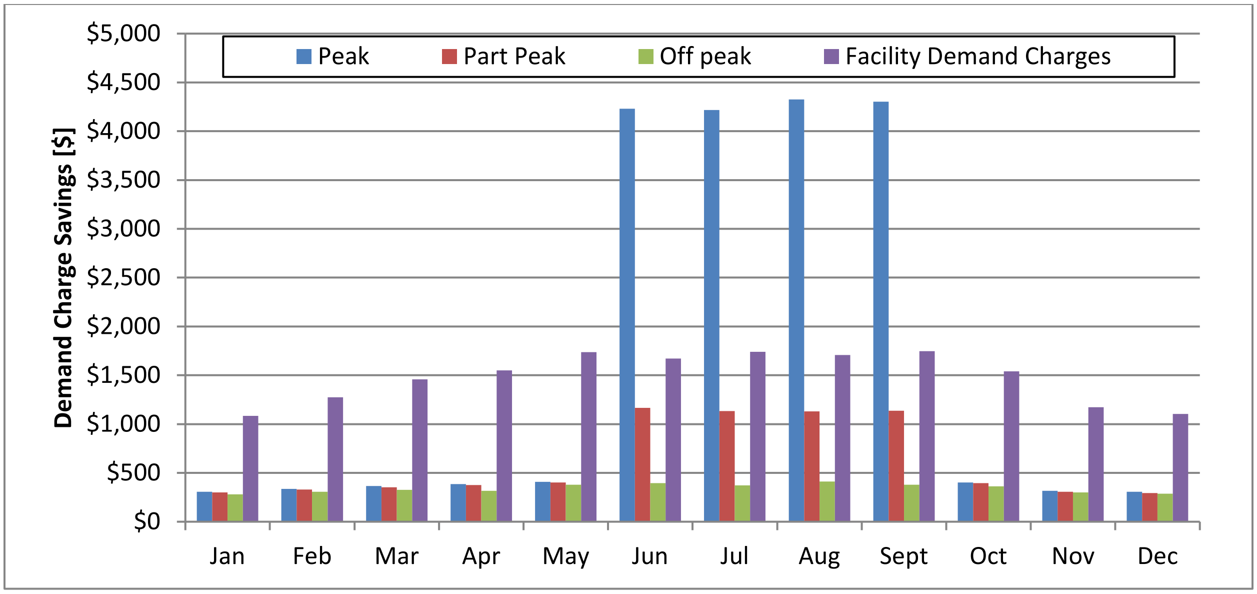

Figure 2 - Monthly Demand Charge Savings

4.2. Resilient System Optimization

4.2.1. Microgrid Configuration

Next, we evaluated microgrid configurations that could be used to integrate PV and BESS alongside existing diesel generators to increase resiliency at the site. We considered two potential microgrid configurations:

1) An independent system where the PV/BESS and generators operate independently, with PV/BESS supplying critical loads for part of the time (generally during the day) and then transferring loads to the standby generators when solar energy and battery state of charge are inadequate (generally at night). Uninterruptible power supply (UPS) equipment carries the critical loads during the transition between energy sources, and power to critical loads is undisturbed. Keeping the existing generators separate from the PV/BESS reduces the complexity of controls and communications, and reduces the overall cost. The BESS is sized to support the full critical load for one hour in this scenario. There will be cloudy periods or early morning/ late afternoon hours when PV generation will not be able to supply the full load. During those times, the BESS needs to carry the load until PV generation supplies the full load or until the battery state of charge reaches a low threshold and the load is transferred to the generators.
2) An integrated system where all energy resources operate in an integrated fashion and are centrally controlled. The PV, BESS, and diesel generation operate together to supply microgrid loads. Because the diesel generators can operate at the same time as the PV, they can carry the load during periods when the PV generation is not able to supply the full load, and so the BESS does not need to be sized for the full load in this scenario. The integration of the PV/BESS with the existing generators requires modifications to existing equipment as well as more complex controls and communications, resulting in higher installation cost.

We evaluated the capital cost and resiliency of each configuration, and selected the independent configuration because it provided the same amount of resiliency as the integrated system, but at lower cost. Only the independent configuration is presented here.

4.2.2. RE's Impact on Resiliency

We simulated a series of grid outages from 0-14 days in length that occur at random times throughout the year to identify how long the base case system (two diesel generators with a combined size of 305 kW and fuel storage of 550 gallons) could sustain the critical load. We then simulated the same outages for the proposed RE system, where the diesel generator is augmented with the PV and BESS. In order to calculate the probability of surviving an outage, all of the simulated outages were binned into 24 hour periods. Outages between 1 and 24 hours are binned as 1 day, 24-48 hour outages are binned as 2 days, and so on. The proportion of outages that the system can sustain in each bin is reported. For purposes of this analysis, we assume diesel fuel supplies to the site have been compromised and fuel deliveries are not being made during the outage. After diesel fuel supplies are exhausted, the site could continue to operate some loads during daytime hours using just the PV/BESS when the solar resource is adequate.

We found that adding the 845-kW DC PV system and a 155 kW, 172 kWh BESS to the existing 305 kW of diesel generators extended the amount of time the site could survive an outage by 1.8 days (from 1.7 to 3.5) with 90% probability. Figure 3 shows the number of days of outage the base case (generators only, shown in red) can sustain compared to the RE case (generators plus solar and storage, shown in blue). For example, in the base case, the diesel generator can power 86% of simulated outages 1-2 days in length, but only 2% of outages 2-3 days in length. When the generator is combined with the PV and BESS, 98% of outages 2-3 days in length can be sustained.

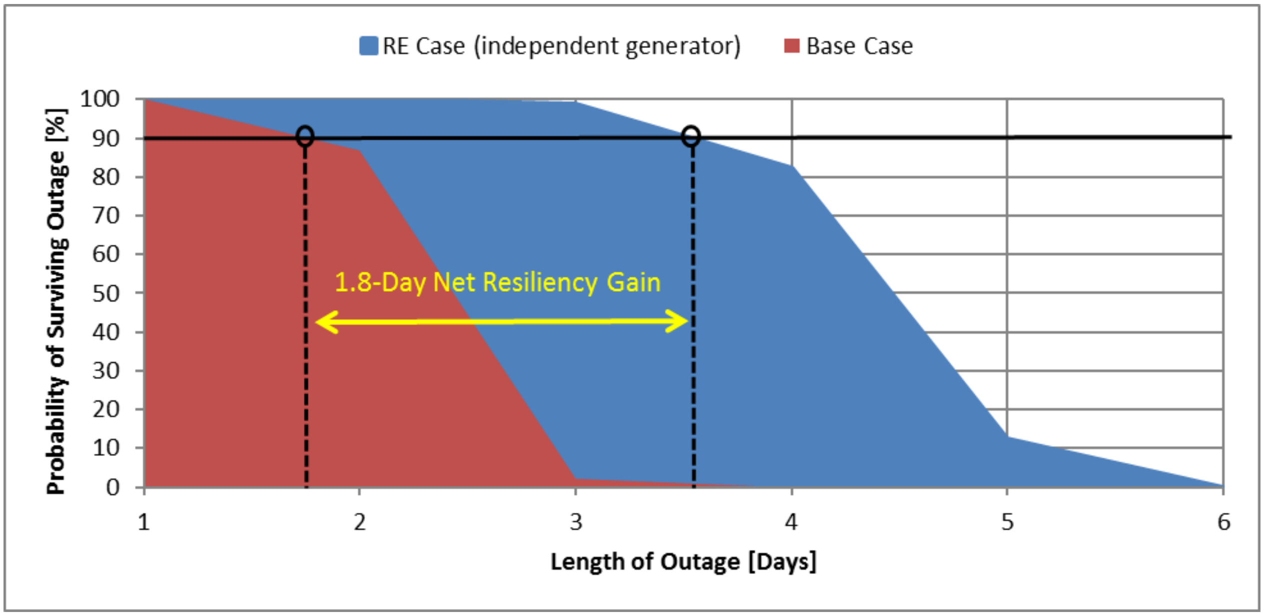

Figure 3 - The PV and BESS Extend Outage Survivability by 1.8 Days at 90% Probability

An example of the microgrid operating strategy is shown for one day in Figure 4. The generators meet the load during the night. In the morning when the sun comes up and the PV starts generating, the PV charges the BESS until the PV generation and the BESS state of charge are high enough that they can meet the load on their own without the generators. The load is then transferred to the PV/BESS system and the generators turn off. The BESS and PV power the load together from 7–8 a.m. when PV generation is not yet high enough to meet the load by itself. At 8 a.m., when PV can fully meet the load, the BESS stops discharging. Excess PV generation is used first to charge the BESS and then remaining excess is curtailed. In the evening, PV generation decreases, until the PV and BESS can no longer meet the full load. Some of the PV generation is curtailed because the BESS is already fully charged. At this point, the generators turn on again and supply the load overnight. By allowing the generators to turn off during daytime hours, the diesel fuel supply is extended, allowing the critical load to be sustained an additional 1.8 days with 90% probability.

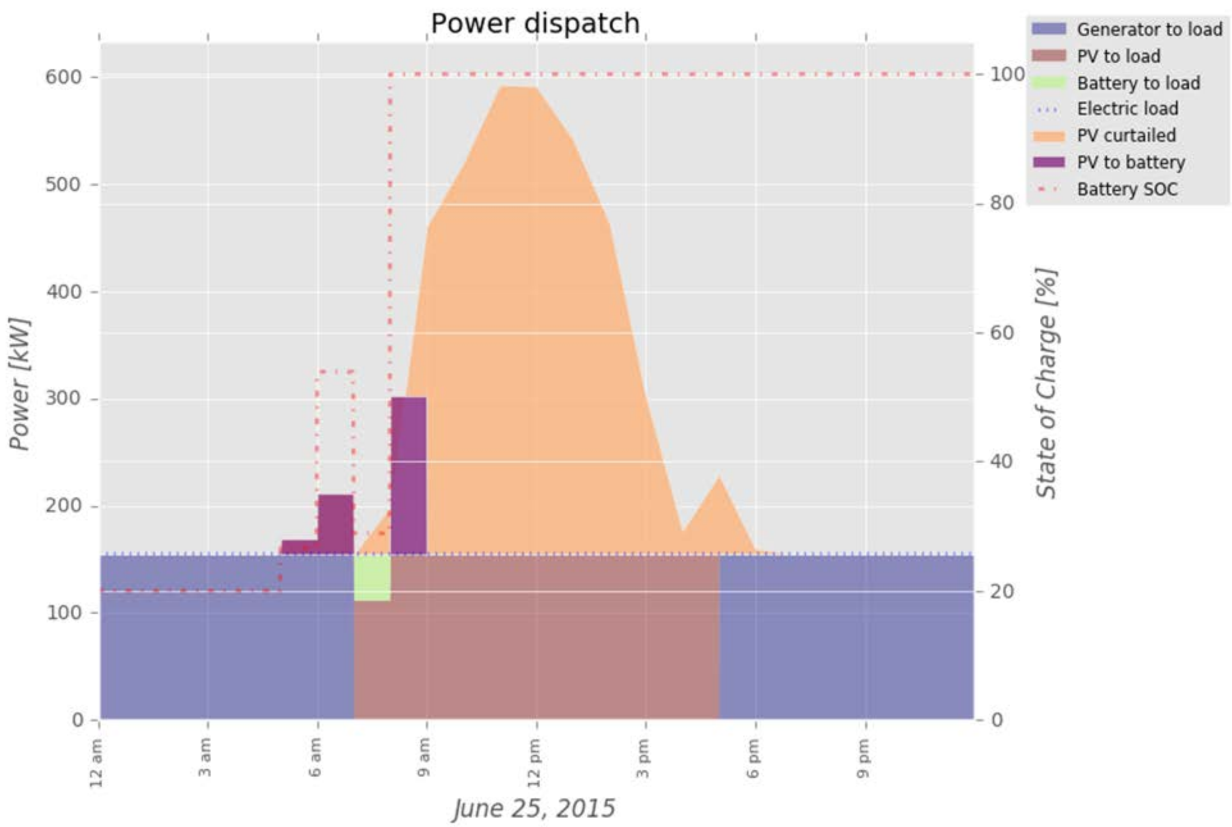

Figure 4 - The Solar Plus Storage System Reduces The Amount Of Time The Generator Is Needed

4.2.3. Microgrid Cost Estimate

We developed a rough order of magnitude cost estimate for the microgrid. SCE may have certain requirements regarding islanded operation and protection for their grid that could require a manual isolation of the microgrid from SCE's network, and/or a permissive signal may be required by the utility before the microgrid can operate. The costs associated with meeting SCE requirements for islanded operation are not included. Both configurations require a trained operator to maintain microgrid operations. We assume this person is already employed at the site, and no additional cost for this person is included.

Table 5 shows the rough order of magnitude costs. By implementing the independent system, the site saves $104,000 over the lifecycle of the project, and extends the survivability of the site by 1.8 days to a total of 3.5 days. The inclusion of the microgrid costs reduce the total NPV of the PV/BESS system from $519,065 to $104,065, but this delivers the added resiliency benefits while still saving $104,065 for the site over the analysis period.

Table 5 - Microgrid Cost Estimate

Description	Independent
PV and BESS Installation Costs BESS (before incentives) [a]	$2,450,584
Microgrid Additional Costs [b]	$415,000
Total PV, BESS, Microgrid Cost	$2,865,584
Net Present Value ($)	$104,065
Added Resiliency (days)	1.8

[a] Includes PV, BESS, and site electrical work

[b] Includes additional rough order of magnitude costs for system integrator, system controller/software upgrades, engineering/design, testing/commissioning, and other contractor costs

5. Conclusions

The results of this analysis indicate that installation of a grid-connected 845-kW DC PV and 16 kW, 32 kWh BESS system, via third-party financing, would save the site $50,000 per year in energy costs. Over the 25-year lifecycle, after accounting for the upfront investment, the site would save $602,000 in present dollars. The system would provide 91% of the energy required by the site during normal grid-connected operations.

If the PV and BESS were also integrated into a microgrid, the site would gain an extra 1.8 days of resiliency as compared to the existing diesel back-up system, while saving the site $104,000 over the 25-year lifecycle. Additionally, if diesel fuel supplies are exhausted during an outage, the site could continue to operate critical loads during daytime hours using just the PV/BESS.

There are additional benefits of an RE microgrid that were not captured in the lifecycle cost analysis. This analysis does not place an economic value on the added survivability. During a grid outage, the business-interruption cost to the site could be significant. This value is not included in the economic analysis, but should be considered in the investment decision.

The electricity load, utility rate tariff, technology installation costs, incentives, and solar resource play a critical role in determining the economic viability RE and storage, and therefore every system must be evaluated on a case-by-case basis. This paper describes a methodology to quantify the economic and resiliency benefit provided by renewable energy (RE) in a hybrid diesel-RE microgrid which may be applied to other sites interested in quantifying the energy, economic, and resiliency benefits of RE.

6. Abbreviations

BESS	battery energy storage system
DC	direct current
ITC	investment tax credit
kW	kilowatt
kWh	kilowatt-hour
MACRS	modified accelerated cost recovery system
NIST	National Institute of Standards and Technology
NREL	National Renewable Energy Laboratory
O&M	operations and maintenance
PV	photovoltaics
RE	renewable energy
REopt	Renewable Energy Optimization
SCE	Southern California Edison
SCTE	Society of Cable Telecommunications Engineers
SGIP	Self Generation Incentive Program
TMY	typical meteorological year
AP	access point
bps	bits per second
FEC	forward error correction
HFC	hybrid fiber-coax
HD	high definition
Hz	hertz
ISBE	International Society of Broadband Experts
SCTE	Society of Cable Telecommunications Engineers

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Where is Your Fleet Focus?

A Letter to the Editor prepared for SCTE/ISBE by

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1. Introduction

With $20 billion in revenue and 60,000 employees, Cox Enterprises is one of the nation's largest private companies. Cox is a leader in the communications, media and automotive services industries. The company was founded in 1898 by James M. Cox and continues to be led by third and fourth generation members of the Cox family. This year, the company is celebrating the 10th anniversary of its national Cox Conserves sustainability program. Through Cox Conserves, the company seeks to send zero waste to landfill by 2024 and become carbon and water neutral by 2044. The program seeks to inspire eco-friendly behavior among Cox's operations, employees and customers, as well as in the communities it serves. Cox's fleet plays an important role in decreasing the company's carbon footprint.

The Cox Enterprise Fleet Team is comprised of 130 employees ranging from fleet operations managers and coordinators to shop managers and technicians who oversee a fleet of over 13,500 assets. Through the operation of 34 maintenance shops strategically placed across the nation, our team conducts the majority of the fleet's maintenance and repair in-house and leverages a partnership with a third party maintenance provider for all vehicles outside of our shop footprint.

Our team is in continuous pursuit of building efficiencies into our fleet practices, embracing new technologies and innovations, and measuring our successes through continual benchmarking and metric reporting. We will outline our highest prioritized strategies below and share how a business can optimize the management of their own fleet.

2. Importance Of Proper Fleet Selection And Care

Fleet vehicles are an operational necessity for many businesses and have a direct impact to the bottom line success of a company. It is important to evaluate and understand the functions an asset will be required to perform when selecting fleet vehicles. Factors to consider include:

- duty cycles
- environment
- cargo needs
- equipment or tool storage
- driver ergonomics
- productivity time studies
- work flows
- manufacturer availability
- fuel types
- alternatives fuels

While each of the reasons listed above are not mutually exclusive, all have an impact on the productivity of the workforce and success of the organization.

At Cox Enterprises, we work very closely with our internal operations and safety teams when designing and building a vehicle. Engaging these teams at inception increases the vehicle's odds of acceptance from the operators and smooth transition to deployment. Collaborating with budget holders and finance teams is highly recommended as there can be instances where a vehicle's design may not meet financial constraints of the budget.

It is equally important to consider the care and maintenance requirements when selecting a fleet vehicle. For vehicles maintained and serviced in-house, the shops must be evaluated for proper configuration, equipment, diagnostics, tooling, and technical training. When considering a dealer or service network, it is important to understand the capabilities and support infrastructure in place. In either scenario, ensure that the maintenance facility is properly equipped and technicians are trained to work on your fleet prior to delivery of new vehicles and/or technology.

It is imperative to have a healthy working partnership with vehicle Original Equipment Manufacturers (OEMs) and up-fitters. Our OEMs have become increasingly fluent in our operational needs and growing initiatives to “green” our fleet. By establishing a strong relationship with our OEM account managers, Cox Fleet has been able to incorporate green and safety packages in fleet level vehicles and leverage pricing strategies on high volume assets. Participating on an OEMs advisory board or vendor council provides another avenue to express your fleet needs directly to the OEM. Keep in mind there is strength in numbers and your needs may be the same as another fleet which, when organized, can deliver considerable momentum when dealing with the OEMS.

So what do you do when your OEM cannot provide you a particular technology as a part of their standard vehicle specification? Cox Fleet engages with our up-fit partners in order to explore “green technologies” that can incorporate into our vehicle configurations. A primary example would be our electric over hydraulic boom trucks which eliminated reliance on idling to run a power take-off (PTO). We work with our up-fitters and emphasize the importance of considering vehicle weights in our builds and remain cognizant that for every pound of weight spared equals fuel savings and carbon emission reduction.

3. Importance Of Optimization Of Fuel Use

Where does your fuel go? Fuel always tops the list when discussing fleet expenditures and management. Cox Enterprises consumes millions of gallons of fuel across the country on an annual basis in support of our business operations. For any fleet, fuel management can manifest into other financial and environmental impacts. Fueling vehicles consumes employee productive time, contributes to carbon emissions, and is a volatile and unpredictable market. There are many resources in the automotive industry that assist fleet managers with tracking fuel usage, determining actual MPG, management of idle time, and predicting budget spends.

One of the buzz words in the fleet industry is telematics. In simplest terms, telematics is data generated by a vehicle that can be transmitted into a consumable format. What your company does with the data is up to you. Telematics is known primarily for vehicle locating to support routing of work, assisting with productivity, and supporting the optimization of fuel economy. Telematics provides vehicle diagnostics data which can help with fuel management and other programs outlined below:

- **Vehicle Idle Time Management** – As a vehicle idles, it is consuming fuel and adding a cost to the company, contributes to carbon emissions, promotes unnecessary engine wear, and decreases the life of other engine fluids that have a petroleum base.
- **Driver Behavior** – Driver behavior has been reported by industry research to have up to a 35% impact on the fuel economy of any vehicle. By using telematics data to identify hard acceleration, speeding, and hard braking a company can promote safer, cost-effective driver training programs aimed at safety while increasing fuel economy.
- **Preventative Maintenance Reporting** – Telematics can report on vehicle health before a failure or catastrophic event occurs. There are a host of indicators, including but not limited

to, tire pressure, oil level, oil life, engine component failure, which can have a direct impact on fuel economy.

- **Routing –** Routing can have a rather large impact in miles driven and idle time of a vehicle depending on your business model. Combining real-time telematics, work applications, and a robust routing tool can provide drivers with safe and direct routes to each work location. Smart routing will not only improve productivity but assist in the management of miles an operator drives on a daily basis.

Optimizing the use of petroleum goes far beyond fuel management or consumption. Petroleum is used in the manufacturing of tires, lubricants, and oils used in vehicles. Tires are a large expense for all fleets and should be closely managed as they have a direct impact on fuel economy and carbon emissions. A simple tire program to monitor and manage tire wear, tire load ratings, and air pressure will be an indication of how efficient and safely vehicles operate. Under inflation of tires promote early tread wear and replacement, creates road friction, and decreases fuel economy.

Gone are the days of the standard 3,000 mile oil change. Along with changing technology on vehicles, fuels and fluids are being designed with various additives that extend or maintain their performance attributes. In addition to the enhancements of fuels and fluids, a business can integrate fluid management programs to test current condition of oil during services, use recycled oils and fluids where possible, or even incorporate the use of biodegradable fluids for certain functions.

With all of the considerations above, fuel management boils down to your company's objectives. Are you trying make a financial impact? Is environmental responsibility important to you? What resources do you have in place to manage fuel?

4. Factors To Consider For A "Green" Fleet

What is a "green" fleet and why does it matter? Going green requires an investment of time, money, and resources but, with the proper commitment, can yield an incredible payoff. Determining what type of payoff your company requires is the next step to evaluating what green efforts you want to pursue. We believe that a green initiative should pay off in multiple areas including social responsibility, productivity, and financial returns. Each green initiative is weighed in these capacities but other factors are considered before a finalizing which initiatives we will pursue. Other areas of consideration include:

- Federal or state mandates
- Vehicle or technology availability
- Infrastructure support
- Alignment with the company sustainability plan

At the end of the day, the right thing for the environment is the right thing for the bottom line because our focus is to leave the company and the planet in a better place for the next generation. In order to achieve this our sustainability plan focuses on three key areas: carbon neutrality, landfill waste, and water neutrality.

As a large fleet we play a significant role in achieving these goals, especially when it pertains to carbon emissions. We are taking steps to improve the way our fleet looks and operates by changing vehicle models, upfit packages, and driver behavior. We discussed the tracking of fuel and changing driver behaviors to reduce our carbon emissions, however, that only considers the operator. Focusing centrally on the asset, we have made similar reductions by migrating to hybrid units on sedans and SUVs, implementing alternative fuels where operationally efficient, making vehicles lighter through the use of alternative materials, right-sizing the vehicle, and utilizing electric motors rather than PTO driven motors wherever possible.

Our first challenge in our initiative was how to define a “green vehicle”. Unfortunately, “green” is vaguely defined in the fleet industry and a growing buzz word leveraged largely as a marketing strategy to sell products or promote upstanding business stewardship. In order to ensure we had a solid baseline that would withstand scrutiny we decided to standardize our categories around the United States Environmental Protection Agency (EPA) definition. We identified any OEM eco-conscious technologies and modifications to the chassis or up-fit components, such as electronic motors, that eliminated the need to idle and optimizing engine parameters. Once we agreed on these classifications we were able to begin establishing our baseline, implementing our strategies, monitoring the results, and reporting out the impact by category and initiative.

Once you decide to implement and launch a green initiative it is vital to track against your objectives to ensure you are getting the desired results. It is highly recommended that you make use of a solid fleet management system (FMS) to track your inventory, associated spend and fuel consumption, and capture any supporting attributes against these assets.

5. Fleet Visibility And Team Productivity

Cox Fleet has implemented a scalable FMS that provides foundational support to our core business of managing fleet inventory and shops yet is nimble enough to keep in lockstep with our innovative pursuits. As mentioned before, there was an expressed need to track our green fleet which we were able to facilitate through adding attributes to our inventory for easy identification and reporting.

Our team leverages this robust tool to report on many key performance indicators (KPIs) of fleet management such as:

- **Fleet Age and Mix** – overview of the fleet makeup and replacement scheduling
- **Fleet Utilization** – identifying underutilized and underperforming assets
- **Fuel Performance and Mileage** – actual realized MPG and distance traveled
- **Fleet Expenses** – calculating cost per mile and annual total expenses
- **Vehicle Repair Metrics** – detail of a vehicle repair by maintenance codes.

The importance of implementing an FMS, especially if your team is scattered across a large geographical footprint like ours, is keeping everyone connected. Our system standardizes our data inputs, provides consistent visibility to our fleet’s performance, and alleviates a multitude of manual processes which optimizes our productivity. The empowerment our team receives through leveraging this technology affords us the time and focus to pursue new fleet endeavors while providing a command center to track those initiatives.

6. Conclusion

In conclusion, whether your role is to focus on the quality and mix of your fleet, the management of fuel, or the pursuit of fleet sustainability efforts, it is key to state your model clearly and utilize tools to manage and report on your performance.

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