How Forward-Looking Product Specifications, Strategic Engagement and Competition Drive Adoption of Best-in-Class Technologies

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ABSTRACT

In 2010, Pacific Gas and Electric (PG&E) Company sponsored the launch of the LED Accelerator Program (LEDA), a market development program that promotes the highest performing and best quality LED lighting products. Using tiered incentives and engaging strategically with the market, LEDA leverages the buying power of large commercial customers to stimulate manufacturers to produce and sell best-in-class LED products. At the same time, LEDA builds the capacity of the supply chain to accelerate adoption beyond the program's direct reach. LEDA's market development strategy helped develop a competitive market for best-in-class LED lighting technologies. The Program's LED Qualifying Product List (QPL) used Energy Star and Design Lights Consortium (DLC) standards for quality and efficacy as the lowest tier in the Program, meaning customers, designers, and manufacturers were all seeking to deploy better performing technologies to access more lucrative incentives. Near the end of 2015, DLC created similar specification tiers as LEDA. Thus, in 2016 LEDA aligned its program design requirements with DLC's premium tier and started requiring networked controls in order to lead the market towards deeper energy savings and harmonize LED specifications across the country for national customers. This paper highlights the program design best practices that led LEDA to receive ACEEE's 2012 Exemplary Market Transformation Program award. It also explores the newly added measures that are repositioning LEDA towards a new technology market development program for state-of-the-art technologies.

Introduction: Challenges and Opportunities for Market Development Programs

The majority of demand side management (DSM) funding in the country is directed toward resource acquisition, prioritizing cost-effective, claimable energy savings. The resource acquisition regulatory framework typically heavily favors metrics such as $/kWh and Total Resource Cost (TRC) to ensure ratepayer value. While this weighting may be appropriate for resource acquisition programs, it is not an effective strategy to evaluate the success of market development and transformation efforts.

Market development, while critically important to market transformation initiatives, is not market transformation. Market development is the stage when behaviors are starting to change and the adoption grows from 0% to 5-15% adoption (bridging the chasm[1]), whereas market transformation is a state when behaviors have changed. Program funding exists for emerging technologies demonstrations, voluntary resource acquisition programs, and codes and

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[1] According to the diffusion of innovations theory from Everett Rogers, there is a chasm between the early adopters of the product and the early majority.

standards; however there is a glaring funding gap for market development activities. Market development focuses specifically on bridging the chasm by implementing large-scale deployments that replicate performance and build consumer confidence, and developing the capacity of the supply chain to facilitate a competitive market. As a subcomponent to larger market transformation efforts, market development program planning, implementation, and evaluation requires a holistic approach to product, supply-chain and workforce development, information dissemination, and product standardization. These critical aspects of a market transformation initiative are often not valued in resource acquisition models; the longer term goals and more dynamic set of key performance indicators (KPIs) requisite for a market transformation effort create points of tension in a predominantly resource acquisition model (Prahl, 2014). In addition to resource acquisition metrics, LEDA continually monitors and assesses a multitude of market development KPIs to inform intervention and transition strategies for each Program cycle's modifications, including:

- How many manufacturers are making the products?
- How long has the product been commercially available?
- How competitive are the prices and warranties compared to the standard practice – both currently and relative to previous periods?
- What is the adoption of the product within major distribution channels?
- What is the awareness of value proposition among major distributors and buyers?
- What specifications, standards, and third-party ratings exist for the product?

The concerted focus on non-resource program elements such as phasing deployments, case studies, and workforce and supply chain development is difficult to include in resource acquisition programs because it can compromise cost-effectiveness. As a result, the resource acquisition regulatory framework has posed challenges for LEDA. However, PG&E and the implementation team have struck a balance between the forward-thinking goals of market development, and the immediate needs of the resource acquisition regulatory environment.

LEDA's Market Development Strategy

In general, early adopter customers understand and value both energy and non-energy benefits (NEB). While these customers are willing to be among the first to adopt a new technology, they are typically not willing to take undue risks and need additional education and technical support to feel comfortable implementing a project with this new technology. Retail organizations are a well-suited target segment for early stage technology adoption because they have significant buying capacity, value NEBs such as warranty and light quality on a similar platform as energy and cost savings, and have significant savings opportunities due to longer-than-average operating hours. As illustrated in Figure 1, NEBs such as light quality and maintenance cost savings[2] are increasingly becoming the driving force behind customer buying decisions (Baumgartner, 2011). Customer preference for certain non-energy product features were

[2] For example, changing out a 70 watt halogen PAR38 lamp, rated life 1,500 hours, costing $4.25/lamp compared to a 15 watt (70 watt equivalent) LED PAR38 lamp, rated life 25,000 hours, costing $24/lamp would save $122/lamp in just maintenance costs. Assumptions: LED lasts 17x as long as halogen, $72 in halogen equipment replacement cost, conservative 5 minutes to change out lamp at $35/hour labor cost is $50 in labor costs.

the impetus for LEDA's metrics pertaining to color rendering index (CRI), R9, correlated color temperature (CCT), and five year warranties. Given this context and customer profile, when LEDA was conceived in 2009 the overarching market development strategy was to: 1) Maintain a forward-looking product specification, 2) Encourage manufacturers to produce high performing products, and 3) Target large buyers who could obtain competitive pricing on large orders.

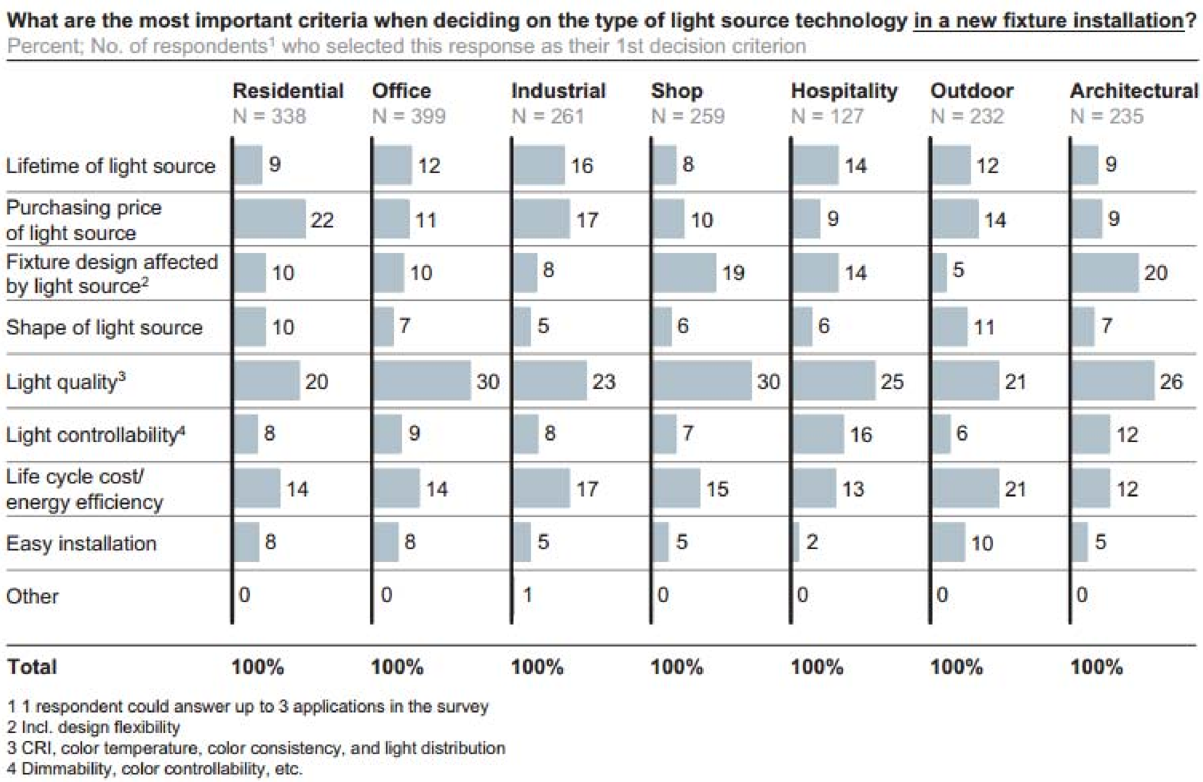

Figure 1: Decision criteria for new fixture installation in new buildings/structures. *Source:* Baumgartner, 2011.

Forward-looking Product Specifications

LEDA updates its specification annually based on program and industry trends. An analysis of program performance by tier and product category compared to previous years and the national market indicates how the market is developing. This analysis also informs decisions on where incentives can be emphasized or deemphasized to drive adoption. The LEDA team reviews DLC and ENERGY STAR QPL and DOE's Lighting Facts database to analyze the LED market, looking primarily at efficacy, CRI and warranty. In general, the top five percent of products are included in the highest tier and the top 6-20 percent are eligible for the lower Tier. The team also reviews upcoming regulatory requirements and other data sources – such as the California Energy Commission Voluntary LED Lamps specification for the residential sector (which drives the commercial sector), Consortium for Energy Efficiency residential and commercial LED lamps specifications, DOE's Better Buildings Troffer Specification, and DOE's Market Transformation studies. This analysis ensures that LEDA specifications are above these requirements.

LEDA shares its proposed program specifications with LED manufacturers at the beginning of each year. Discussions take place to assess market barriers and trends in LED pricing, product development, and market adoption. The LEDA team works with manufacturer product designers to identify products that are close to LEDA specifications and at times has influenced the redesign of certain products. The goal is to encourage better product features and illustrate how LEDA incentives can improve project economics for their customers.

When LEDA was being developed in 2009, the lighting market was in transition. The ENERGY STAR specification was just being finalized; however there was no ENERGY STAR QPL. At this time, LEDA qualified LEDs based primarily on efficacy and warranty, and launched with a narrowly focused measure mix. The program targeted the savings opportunities of LED lamp products over halogens and integrated ceramic metal halide products for accent lighting in retail applications. LEDA's specification included multiple tiers, using the ENERGY STAR specification as the program's lowest tier, and intentionally valued quality and efficacy on equal footing. In 2010 when the program launched, no manufacturer product met the highest tier. However, when a large retail customer agreed to retrofit stores if the project qualified for the highest tier incentive, one manufacturer satisfied the request. The project was so successful that the customer released a solicitation for a second phase, at which time four manufacturers responded with prices 40 percent below phase one when there was only a single manufacturer bidding.

In 2010, manufacturers were unwilling to fully stand behind the lifetimes of their products, which can be 15-25 times that of incandescent or halogen products and two to three times as long as fluorescent products of the same product category. This resulted in warranties of roughly three years as opposed to the true product's expected lifetime of five years for PAR lamps. Therefore, LEDA required five years for LED PAR lamps. LEDA required a warranty period of seven years for troffers in 2015, opposed to the typical five year warranty for troffers. Extending the warranty increases value of lifetime savings, and the overall customer value proposition. In several LEDA projects, manufacturers extended their warranties to meet LEDA requirements, providing an unusually direct example of how the program was influencing behavior of both customers and manufacturers. This trend toward longer warranties gained popularity in the LED industry. Of the ENERGY STAR MR lamps that qualified in 2014, 22% had five-year warranties. Lamps that qualified in 2015 jumped to 33%, and so far in 2016, 57% of lamps that qualify have five-year warranties. In addition, LEDA required manufacturers to warrant lumen depreciation more than 30%, to warrant all components of the LED system over the warranty lifetime, and to indicate the maximum power supply case temperature for the driver. LEDA also strongly encouraged manufacturers to address color shift. All of these features enhance the quality of LEDs and increase the customer value proposition.

Striking a balance between efficacy and quality was a challenge because efficacy and color quality is more expensive than raising just one of those traits. LEDA has attempted to advance the market on both fronts to avoid supporting inferior products that ultimately create customer confidence issues (as was experienced with first-generation LED and compact fluorescent lighting). However, the natural tendency of the market is to move toward the lowest common specification (such as DLC) for metrics of quality such as color rendering. LEDA CRI specification is 85, and although the mass market continues to favor a lower CRI barely qualifying for the DLC's listing, there is a growing number of 85 CRI troffers available in the market.

Perhaps more importantly, when designing interior lighting to achieve an environment of quality color rendition and light, the R9 value — the color fidelity of saturated red — is an important factor to consider. The human visual system seems to be particularly sensitive to red hues, yet saturated reds (and other saturated colors) are not included in the traditional CRI metric which is based on faithful rendering of pastel (non-saturated) colors (Wei, M, 2014). Thus, light sources of many types, and LEDs in particular, can achieve good CRI values while offering a very weak rendering of saturated red colors. In effect, CRI alone does nothing to encourage effective rendering of the saturated reds that are so key to human visual perception. A negative R9 value is possible and seen in inferior LED products. The color of many items, including meat, fish, vegetables and fruit, can be adversely affected by the inaccurate rendering of the color red; thus, the R9 value is of great importance to retail organizations such as grocery stores and was essential to the LEDA specification given the target customer segment.

This tiered specification model was recently embraced by several leading industry specifications; the DesignLights Consortium introduced a "DLC Premium" tier in August 2015, the Consortium for Energy Efficiency introduced a three-tiered system for LED lamps in January 2015, and most recently ENERGY STAR released ENERGY STAR 2.0. Given this shift, LEDA has aligned its top tier specification with the DLC's top tier to harmonize with larger market forces.

Customer Engagement

LEDA has had significant success helping retailers implement a multi-phase procurement model. In the first phase, customers implement a "pilot" to validate manufacturer claims. In particular, customers have expressed a need to validate performance pertaining to flicker, dimmer compatibility, and color variation (if applicable). In subsequent phases, the buyer increases the project scale and more manufacturers compete for the business. Often national buyers implement projects in areas of the country where utility rates are the highest, typically on the West Coast and East Coast. Between phases, buyers develop confidence and the stakes increase for sellers – often by an order of magnitude. As the size of the solicitation increases for follow on project phases, several new manufacturer products enter the market, which creates healthy competition. This competition facilitated by more manufacturers competing for market share results in significantly reduced project costs and a new precedent for national-scale procurements.

For example, the same retailer who provided the first project in the program participated in LEDA three times from 2010-2012, capturing two percent of the national market share of LED PARs installed during that time. As illustrated in Figure 2, over the course of the customer's three projects, several new manufacturers with hundreds of new products had entered the market and prices reduced 56% from $62/klm in 2010 to $27/klm in 2012. Given the greatly improved project economics, it was quickly replicated in Southern California Edison's (SCE) territory[3] and in New York – demonstrating LEDA's influence. In the first phase of the project, only a small percentage of the products on the DLC QPL met the LEDA CRI specification. In

[3] From 2011-2013, SCE also implemented the LEDA program, allowing for tremendous economies of scale in retailer purchasing and program marketing costs. However, SCE's LEDA program was cancelled due to the $/kWh metric exceeding the desired threshold. This is a good example of how the resource acquisition regulatory framework inhibits comprehensive market development approaches.

subsequent phases, the customer effectively timed their purchase and sized their order so that it made economic sense. This “pilot-first then larger deployment” model is difficult to tolerate in any industry under pressure to maximize savings or profit in the current quarter. To achieve larger program savings, implemeneters often feel obligated to press for larger projects rather than accept longer project development timelines that may be needed to successfully promote better quality products that initially cost more.

LEDA’s market developmemnt strategy ackowledges the element of time inherent to the diffusion of innovation, and the implementation team does not force large projects on customers who would benefit from an initial pilot.

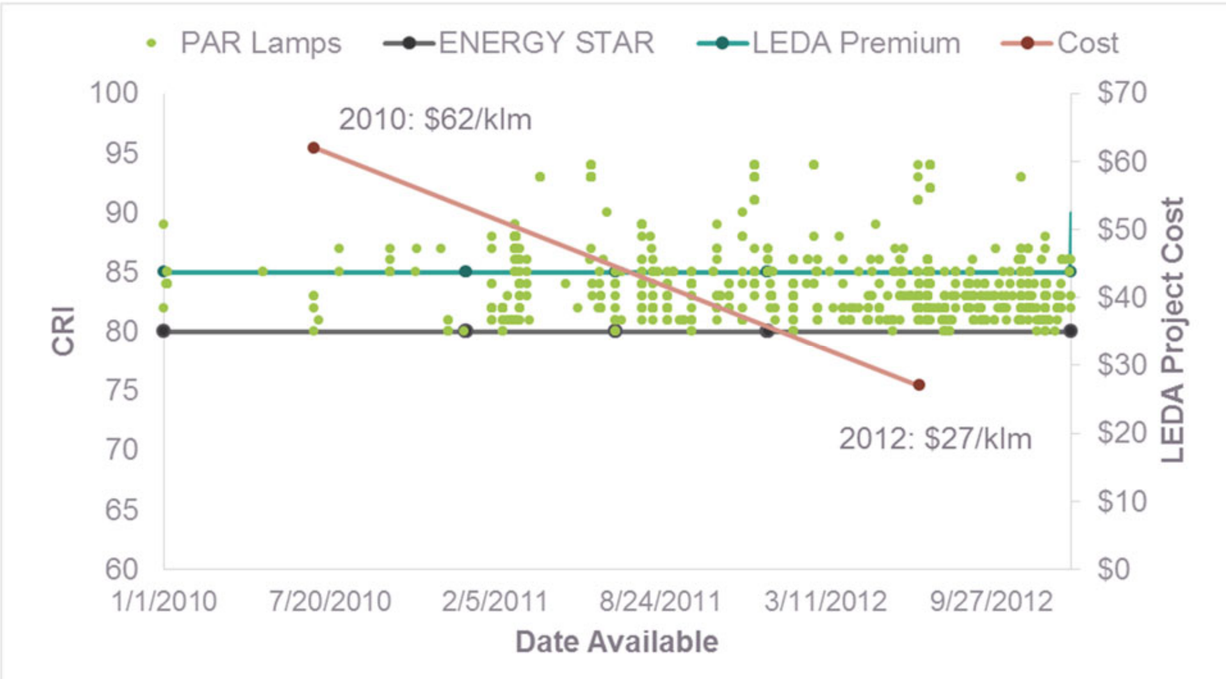

Figure 2: CRI dispersion of LED PAR lamps over time correlated to LEDA project costs. *Source*: PG&E, 2016 and DLC, 2016.

Similarly, in 2012-2013, a major retailer had four different manufacturers competing to install 11,000 low and high bay fixtures in two million square feet of space at a cost of $35/klm. In 2015, a different major retailer installed 11,000 low and high bay fixtures at $16/klm. At the same time, this second retailer also implemented the same project in New York using the same product specification developed through the LEDA program, again demonstrating influence beyond PG&E’s territory.

One of the highly successful pilots implemented through LEDA involved track lighting in a grocery store. The project evaluated the performance of a 15 watt LED fixture as a potential replacement for a variety of low voltage 50 watt halogen MR16 track lighting applications and sought to understand the customer’s internal product selection and overall decision-making processes to install LED fixtures across multiple locations (Kisch, 2013). The result of the study was that the LED product specification used for the LEDA pilot project was adopted as the default technology for all store retrofits and new construction designs nationally. PG&E’s emerging technology and LEDA program investments influenced a major buyer’s future purchasing decisions – an exceptional example of successful market development.

Supply Chain Development

Market intervention strategies can target different supply-chain actors, including manufacturers, distributors, sales representatives, installers, commissioning agents and customers. Market development efforts such as LEDA focus engagement on a subset of those actors, primarily manufacturers, large buyers, and buyer representatives. Many of the largest retailers rely on a relatively small group of lighting specialists to assist with facility design. These experts hold significant influence over the buying decision, and often times maintain primary responsibility for identifying and recommending the most cost-effective and highest quality light sources. However, working with this group of market actors is not the desired program model for accelerating adoption in other customer segments as their focus does not extend beyond the retail sector. Developing the midstream channel (distributors, sales representatives, installers, commissioning agents and others) is a primary goal of a market development effort. Effectively engaging midstream market actors influences stocking and sales practices, which has been proven to cost-effectively address savings opportunities in the larger market.

In 2012, PG&E created two midstream pilot incentive programs for LED replacement lamps: a midstream distributor pilot, which provides incentives to distributors for LED lamps, and a direct install model. Over a period of three months, the distributor pilot incentivized sales of 878 replacement lamps (66% of LED lamps incentivized under both pilot offers) to 29 PG&E customers who bought an average of 35 lamps per location. Over a five month period, the direct install pilot incentivized 451 lamp sales to 25 PG&E customers who bought an average of 16 lamps per location (Lande, 2013). LED lamps were transitioned to PG&E's distributor lighting program in the following year. As illustrated in Figure 3, in program year 2014, PG&E's distributor lighting program processed 147,800 lamps and LEDA processed 13,300 lamps, demonstrating how effectively timing the transition from a market development intervention strategy to a midstream intervention strategy can dramatically increase market saturation. The increased performance through the midstream channel continued, and in 2015 PG&E's distributor lighting program sold nearly 300,000 LED lamps.

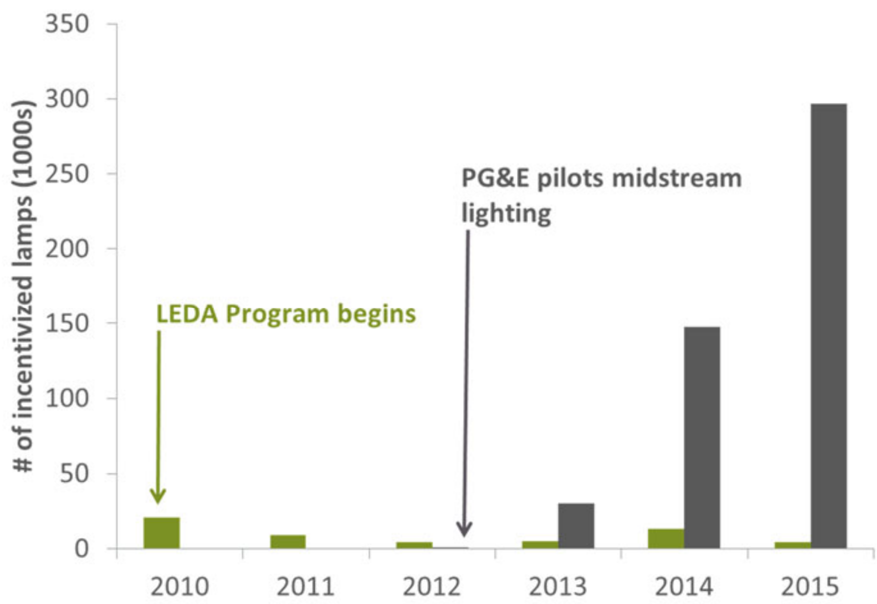

Figure 3: LEDA created the necessary LED market conditions from 2010-2012 for other programs with greater volume to gain traction in later years. *Source*: PG&E, 2016.

PG&E's decision to transition LED lamps to the distributor lighting program was aligned with LEDA's market development strategy. There was a great deal of competition and the technology had replicated superior performance numerous times through the LEDA program. This transition was supported by Navigant Research's 2015 update to the *Adoption of Light-Emitting Diodes in Common Lighting Applications*, which reported that LED lamps had transitioned to the "early majority" stage of adoption as shown in Figure 4. The LEDA program demonstrating performance at scale and the midstream pilot preparing the midstream channel for LED lamps to transition into the midstream program each served equally important roles in facilitating continued uptake in the market.

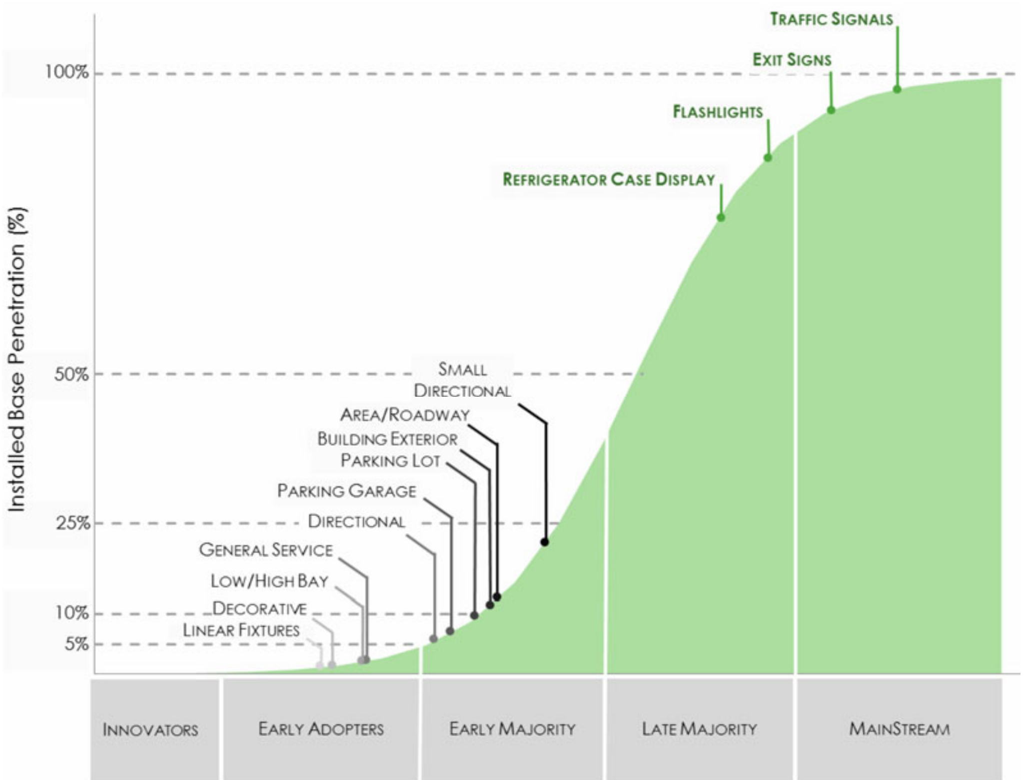

Figure 4: Penetration rates of LED lighting applications. *Source:* Department of Energy, Energy Efficiency & Renewable Energy, Adoption of Light-Emitting Diodes in Common Lighting Applications, Prepared for U.S. DOE SSL Program, Revised June 2015. *Source:* Navigant, 2015.

How LEDA is Evolving to Continue to Drive the Market

As awareness and understanding of LED technology has become much more robust amongst buyers and supply-chain actors, PG&E began offering deemed incentives through the contractor and distributor channels, causing LEDA to deemphasize certain measures – LED lamps in 2013 and LED troffers in 2016. This shift to mass market LED programs implemented through midstream channels is necessary, but sacrifices some performance because mass-market LED products tend to meet minimum requirements for inclusion on either the ENERGY STAR or DLC QPLs. While LEDA continues to offer incentives for better quality lamps and troffers, the program cannot rely on savings from these measures because the deemed incentive programs provide streamlined processes with competitive incentive levels. Thus, in 2016 LEDA expanded the eligible customer segments beyond retail, expanded eligible measures beyond LED lighting, and is developing a measurement and verification (M&V) approach that calculates savings using a normalized meter baseline.

New Sectors

Whereas chain retail provides the greatest savings opportunities due to long operating hours and large projects, decreasing trends in pricing have made projects cost-effective for a much wider audience. In 2016, LEDA added several new sectors including: warehouses, grocery stores, retail affiliated offices and garages, banks, healthcare and social assistance buildings, restaurants, and new construction over 100,000 square feet. In general, these customers provide large savings opportunities and a deeper appreciation for the breadth of product features than the average buyer.

The implementation team uses a three-pronged channel strategy to engage customers: industry associations, equipment sales representatives, and PG&E Business Energy Solutions (BES) representatives. For the most part, industry associations and equipment sales representatives organize by vertical, allowing the implementation team to form strong relationships with individuals who have aligned interests. Furthermore, in the first quarter of 2016, PG&E's BES representatives organized by vertical so that they could better serve like customers, allowing the implementation team to work more closely with specific BES representatives to develop sector-specific projects that can be shared and replicated. While seemingly similar, each segment has definitively different sales drivers and challenges to implementing projects, in particular, when the project involves controls.

For example, chain retail has focused on the light quality to enhance the buyer experience, so the advanced control features enable retailers to both optimize light levels in different areas of the store and analyze buyer behavior via occupancy sensor data. Furthermore, wayfinding products that communicate with buyers via their smart phone regarding the location of products of interest (based on previous buyer behavior) are entering the market. In warehouses, controls can be used to optimize stocking locations, locating the most commonly moved products toward the loading areas to minimize the lighting demand that is responding to through traffic from forklifts in the warehouse. In commercial offices, asset management and employee comfort and productively are notable NEBs creating value for customers. While NEBs are relatively unproven, LEDA's implementation team must effectively characterize these value streams appropriately to be successful. Thus, as LEDA works with early adopters to implement projects involving controls, the implementation team will also be engaging with PG&E's Emerging Technologies department to pursue new pilots that further validate and quantify both the energy and NEB value streams.

New Measures

Customers are increasingly interested in LEDs, lighting and HVAC controls, the combination of stationary storage with solar photovoltaics, electric vehicles, and bringing the Internet of Things (IoT) to their facilities. Thus, the program is repositioning as a whole building market development program that capitalizes on the growing opportunities that exist for integrated controls that leverage device-level data to enact intelligent control strategies. The new measures added to LEDA in 2016 include:

- Advanced Lighting Controls: Advanced lighting controls can be networked to allow remote programming of individual fixtures or zones, giving facilities managers fine-grained control over their energy use and ensuring that light is only delivered where it is most useful. LEDA requires that a networked control system satisfy the DLC requirements[4] because introducing a new specification is likely to confuse the market and

[4] DLC features include: networking of luminaires and devices, occupancy sensing, daylight harvesting, task tuning, continuous dimming, software reconfigurable zoning, and ability to report energy savings (kW, kWh, demand savings compared to original lighting system, energy savings compared to original lighting system).

not have desired influence. However, LEDA is promoting other attributes not required by DLC, including: load shedding (DR), scheduling, personal control, plug load control, graphical user interface, localized processing/distributed intelligence, BMS/EMS/HVAC integration, device monitoring/remote diagnostics, operational and standby-power, and visible light communication.

- New LED Products: Exterior lights have been added to LEDA in anticipation of California Independent System Operator's (CAISO) forecast of change in peak times from 1-5 PM during the summer to 4-8 PM. Type C LED Tubes with external driver and network controls have also been added due to the technology reaching a mature stage where product quality and safety have been demonstrated to a sufficient degree. Lastly, while there are likely to be few projects, OLEDs have been added as a measure in recognition of their unique value proposition and application.
- Integrated HVAC Controls: Emerging HVAC controls offer increased energy benefits similar to lighting controls. They can be individually monitored and controlled, providing better insight into energy use and more granular control to minimize inefficient use. For smaller facilities like banks, customers can have the HVAC controls integrated into the networked lighting control system. The temperature and humidity sensors can be installed on the lights, essentially making the lighting system the backbone of HVAC system (like an EMS).

The LEDA team continues to characterize and refine the value proposition for networked controls, working closely with PG&E's Automated Demand Response (AutoDR) program to layer LEDA's energy efficiency incentives with PG&E's AutoDR-enablement incentives. LEDA provides lucrative incentives for energy efficiency benefits associated with LEDs and advanced control technologies,[5] and PG&E's AutoDR program offers lucrative incentives[6] that can be layered onto an energy efficiency project to cover up to 100% of project costs. A hypothetical project for Tier II LED lighting and advanced HVAC and lighting controls could secure the following incentives:

- LED lighting: $0.24/kWh +$150/kW (LEDA program)
- LEDA lighting and HVAC controls: $0.24/kWh (LEDA program)
- AutoDR advanced HVAC: $350/kW shed (AutoDR program)
- AutoDR advanced lighting: $400/kW shed (AutoDR program)

A key challenge for networked controls, and the IoT in buildings, is that the traditional supply chain for building technologies is not particularly well-suited for software. Distributors, contractors, and other sales channels typically profit on marking up equipment – a single-transaction profit model. Manufacturers similarly profit from one-time transactions, with exceptions for energy saving performance contracts and emerging "Lighting as a Service" models. However, software pricing generally uses the "as a Service" model that receives a significant portion of the revenue from follow on payments. Thus, the value proposition for midstream market actors to sell software is unclear and LEDA will need to work with

[5] Tier 1 = $0.17/kWh +$150/kW; Tier 2 = $0.24/kWh +$150/kW
[6] $200/kW for general AutoDR; $350/kW for advanced HVAC; $400/kW for advanced lighting (up to 100% of project cost paid for by incentive)

manufacturers to help develop midstream distribution channels in order for the industry to fully recognize the benefits of integrated controls.

Real-time Performance Validation

Organizations such as the Northeast Energy Efficiency Partnerships (NEEP), California IOUs, and others have attempted to develop lighting controls calculators. However, there is great variance in product features and a general lack of research on how the different features interact to provide savings. The reality is that savings derived from controls are largely driven by behavior. In September 2015, California Assembly Bill (AB) 802 passed, allowing the baseline measurement to transition from the Database for Energy Efficiency Resources (DEER) to "at-the-meter" impacts (if the IOU and CPUC guidelines which currently under development due by September 2016 allow it). This represents a tremendous opportunity for LEDA to increase its claimable resource acquisition impacts going forward, both from LED retrofits and metered energy savings from controls.

To capitalize on this opportunity, the implementation team is piloting a M&V methodology that leverages vendor-reported data and normalized whole building interval meter data from PG&E to claim "experienced," not calculated, energy savings as measured at a meter against a normalized meter baseline. Participant zip codes are matched to the nearest weather station to obtain a daily average temperature for a minimum of one, and up to two, baseline years. Daily temperatures from associated stations determine heating degree days (HDD) and cooling degree days (CDD) and the algorithm applies a least squares regression analysis to build a model to normalize (weather-independent) energy usage data. Measured actual energy consumption is compared to the weather-normalized regression model projection for what usage would have been under pre-retrofit conditions, and a highly accurate calculation of actual energy savings as measured at the meter on an hourly basis is produced. Figure 5 shows two stores – one that completed an LED retrofit at the start of 2015 (Richmond) and another where the project was canceled and never implemented (Tracy). The blue line is the metered energy consumption and the green line is the weather-normalized regression analysis. For both stores, the regression model is a very good correlation to the metered consumption, however the Richmond location experienced over 33% energy savings due to the lighting retrofit. Using regression analysis to measure energy savings both allows PG&E to increase claimable energy savings from LEDA projects and accurately capture the operational efficiency savings from the advanced control technologies that were added to LEDA in 2016. Even more importantly, this "at the meter" approach allows for the contributions from controls and synergistic effects to the whole building to be measured and accounted for. In future program models, the "at the meter" approach will allow for payments to be made to vendors and customers for energy savings on an "as measured" performance basis. Such an approach provides a strong incentive for monitoring and maintaining savings over time because the incentive is paid based on persistent energy savings.

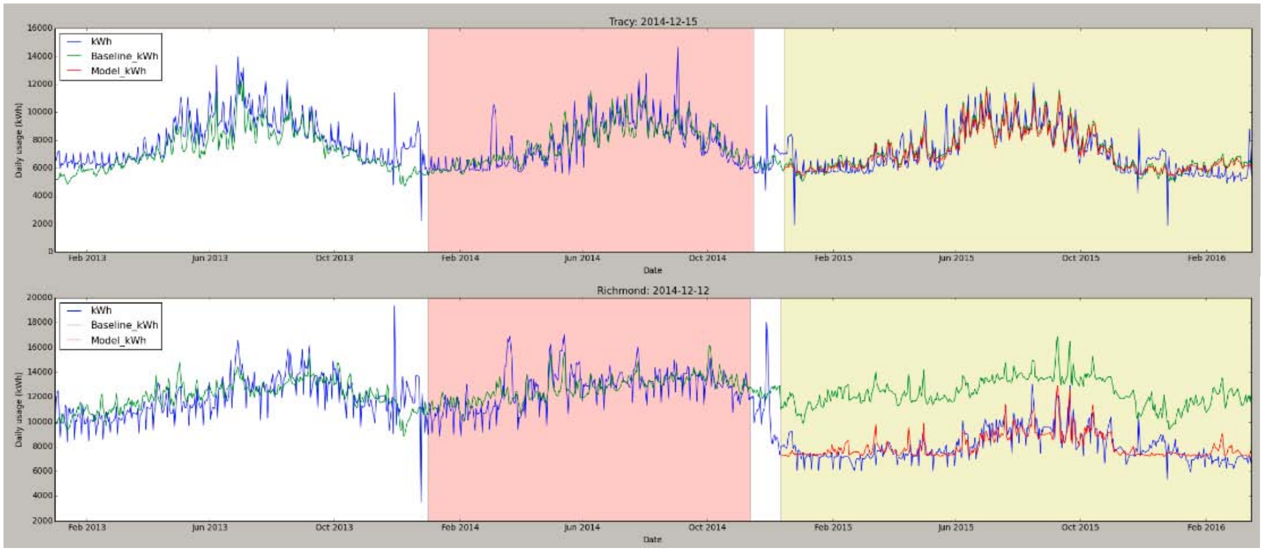

Figure 5: Weather-normalized regression analysis for two similar buildings – one that implemented a LED retrofit and one that did not. *Source*: Energy Solutions, 2016.

Conclusion

LEDA has tracked product availability, warranty, efficacy, lifetime, CRI, lumen maintenance, power factor, and R9 to inform program design modifications and target ripe opportunities for energy savings and market development. The emphasis on non-energy product features does not necessarily fit the typical energy efficiency resource acquisition regulatory structure. However, integrating the non-energy interests of the target market into the product specification and sales proposition has proven effective. To date, LEDA has worked with 12 Fortune 500 companies and more than 80 manufacturers to implement projects. The buying capacity of large commercial customers has stimulated manufacturers to produce and competitively price high efficiency, best-in-class LED products.

From a resource acquisition standpoint, LEDA has thrived on customers' long operating hours and ability to scale successful projects across multiple locations. However, the implementation team's patience and understanding of how customers value NEBs, such as an enhanced shopper experience, has proven to be a successful model for engaging chain commercial customers. The team lets technologies deliver on their promise, and then proposes much larger scale projects when customers are confident in the technology and more competition exists in the market.

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References and Notes

Baumgartner, T., F. Wunderlich, and D. Wee. 2011. "Lighting the way: Perspectives on the global lighting market." Munich, Germany. McKinsey & Company, Inc. http://www.2012.smartlighting.org/pdf/MCKINSEY_LIGHTING_THE_WAY_AHEAD.pdf

DesignLights Consortium Qualified Products List. http://designlights.org/qpl

Kisch, T., J. Steuben, and T. Pang. 2012. "A Scaled Field Placement of Advanced Track LED Fixtures in a Grocery Environment." PG&E. ET Project Number: ET 12PGE3351

Lande, J. and G. Barker. 2012. "Midstream Commercial Incentives for LED Replacement Lamps: Emerging Technology and Channel Assessment Project." PG&E. ET Project Number: ET 12PG3301

Prahl, K. and K. Keating. 2014. "Building a Policy Framework to Support Energy Efficiency Market Transformation in California." San Francisco, CA: California Public Utilities Commission.

Rogers, E.M., 2010. Diffusion of innovations. Simon and Schuster.

Wei, M., K. Houser, A. David, and M. Krames. 2014. "Perceptual responses to LED illumination with colour rendering indices of 85 and 97, Lighting Research and Technology." http://lrt.sagepub.com/content/early/2014/08/22/1477153514548089