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GATEWAY Demonstrations

Investing in Their Future: Portland's Purchase and Conversion of an LED Street Lighting System

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Investing in Their Future: Portland's Purchase and Conversion of an LED Street Lighting System

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Introduction

The City of Portland, Oregon is midway through the process of converting its street lighting system from the previous generation high-pressure sodium (HPS) to modern light-emitting diode (LED) technology. In getting to this point, the City purchased a large portion of its street lighting system and encountered a range of issues among the stakeholders, some of which were expected and some not. As these issues may be more or less common to other municipalities pursuing street lighting purchases and conversions, this paper identifies some of the challenges encountered and details of how they were addressed to help inform and facilitate future lighting transitions elsewhere. Preliminary discussion of the results and lessons learned are also included.

A. High Pressure Sodium Era (Prior to conversion)

Portland has roughly[2] 55,100 street lights serving an area of about 147 square miles over a network of approximately 3,949 lane miles of paved streets. Approximately 49,000 of these are standard cobra head fixtures and 5,500 are post-top lights, the latter including a mix of historic ornamental and more modern versions that are primarily located downtown (Figure 1). About 600 shoebox and other more specialty types round out the inventory. In all, there were more than 60 combinations of fixtures and poles installed around the city prior to the lighting conversion. The Portland Bureau of Transportation (PBOT) maintains the system that includes traffic signals, street lights, and intelligent transportation systems (ITS) with a staff of about 40 engineers, electricians, and other technical personnel.

In the early 1980s, Portland purchased all of the street light fixtures and mast arms that it did not already own from Portland General Electric (PGE, an investor-owned utility), along with most of the existing street light-only (SLO) poles. However, approximately 38,000 poles in the system played dual roles by also supporting distribution wiring or other utility or communications equipment, and were therefore retained by PGE. In addition, two more groups of about 4,400 SLO poles owned by PGE and 1,600 SLO poles owned by the City were more practically maintained by the utility for reasons that included proximity to high-voltage equipment or lines. Over the next few decades, PGE continued to maintain about 44,000 poles and the City-owned fixtures installed on them, leaving ~11,000 SLO poles and luminaires in the system that were owned and maintained by the City.

From a billing perspective, PGE offered three tariff options:

- Option A: The utility both owned and maintained the equipment, and billing was based on total cost including a capital recovery fee for the City's use (or rental) of that equipment. Following the City's purchase of all fixtures and mast arms in the early 1980s, there were no more complete street light units (fixtures, mast arms, wiring and poles) in this category, so that only about 4,400 poles and their associated circuit wiring were billed under this option.
- Option B: The City owned but the utility maintained the equipment, and billing included corresponding energy and maintenance components. All fixtures and mastheads mounted on

[2] All pole and fixture quantities reported in this document are approximate and often change monthly due to new installs, removals, and billing corrections.

approximately 42,400 poles owned by PGE met these criteria, along with about 1,600 SLO poles owned by the City (but maintained by the utility for practical reasons).

- Option C: The City owned and maintained all fixtures, poles, mastheads, and wiring, and billing was for energy only; about 11,000 units were in this category.

In all cases, the utility's maintenance responsibility was primarily held to the timely replacement of lamps. The utility was not responsible for replacing customer-owned fixtures or ballasts as part of the standard contract (i.e., the existing rate tariff), but would do so at added cost,[3] and the utility had authority to disconnect power to any fixture deemed unsuitable for operation.

Figure 1. Sample of street/area lights and poles in Portland, OR

B. LED Lighting Evaluation

The City's decision to convert to more efficient street lighting involved political, technical, and financial issues. From a political perspective, the public utility had very good relationships with City and regional leadership, which gave them a great deal of influence in pursuing their own preferred courses of action.

[3] Most recently reported at labor rates of $133/hr for straight time and $189/hr for overtime, according to PGE (2015).

PGE also had more staff to understand LEDs and related technologies, as well as a more established communications network with other utilities and funding for travel and training to ask questions and gain additional knowledge. From Portland's perspective, the costs for the system initially appeared prohibitive given that existing system maintenance funding was lacking within the City, and they also had to overcome some internal resistance to change that is not uncommon among public agencies.

Despite these challenges, PBOT was an early investigator of LED street lighting. Staff did regularly attend Illuminating Engineering Society (IES) conferences and kept close tabs on the quickly developing technology. PBOT was one of the first public agencies to join the Department of Energy's Municipal Solid-State Street Lighting Consortium and was active on the Consortium's Executive Committee and technical task groups. PBOT had already begun pilot demonstrations involving early LED products (along with others, most notably induction) to investigate their market readiness and suitability for Portland's street lighting system.[4] These early investigations showed favorable potential for a city-wide conversion to LED, and PBOT began planning its implementation despite the fact that the utility's street lighting tariff still lacked an LED option. This situation eliminated the financial incentive to support a transition.

In 2010, the City petitioned the Oregon Public Utilities Commission (OPUC) to require PGE to offer an LED-based tariff. Portland simultaneously formed a regional street lighting group with the nearby cities of Gresham, Lake Oswego, Salem, and other agencies like Washington County to collectively pursue a new tariff with OPUC. PGE was responsive to the group's efforts, but in 2011 also revealed that they were interested in getting out of the business of maintaining infrastructure they did not own, i.e., eliminating Option B from their tariff portfolio. From PGE's perspective, Option B street lights were primarily a pass-through cost and thus were not generating appreciable revenue while at the same time exposing the company to liability risk.[5]

In October 2012, OPUC granted PGE the right to eliminate Option B lights from their portfolio for any customer making the decision to install energy efficient LEDs. Under the new LED tariff, customers wanting LEDs were given the choice to convert Option B lights to either Option A or Option C. The decision furthermore allowed PGE to stipulate that conversion of any portion of a customer's system from Option B to Option C triggered the requirement for all lights to be scheduled for such conversion, even those not changed to LED. Thus, the corresponding alternatives subsequently open to customers were either (1) converting to Option A, selling their assets and renting them back or (2) converting to Option C and purchasing all remaining components (poles, fixtures, mast arms, and circuit wiring) and subsequently maintaining the entire system themselves.

During the same time period, PGE presented an offer to the Portland Mayor's office to purchase the entire Option B portion of the street lighting system back from the City, i.e., proposing the conversion of

[4] See, for example, the DOE GATEWAY report on Portland's Lija Loop published November 2009, or a later comparison of multiple street lighting products (including non-LED) in the GATEWAY report on Cully Boulevard published August 2012.

[5] In all cases, the utility assumes no liability by charging the tariff. The City was responsible for ensuring sufficient light levels and proper distribution of the luminaires selected for any given location. However, any light reported as nonfunctioning and not repaired within a court-determined "reasonable" timeframe presents potential liability in a future lawsuit.

all Option B components back to Option A. However, the City had already determined that owning their lights was more cost-effective than renting them during their earlier purchase in the 1980s.[6] PBOT responded with an economic analysis comparing the PGE proposal with a City-led initiative. The analysis included the following details.

1. Maintenance

Re-lamping HPS street lights has been traditionally scheduled in Portland on a 5-year cycle, or as emergency outages dictated. Re-lamping of street lights carries significant costs for traffic control, lane and ramp closures, and occasionally off-hour shift work to avoid conflict with light rail trains. While the costs of maintaining a traditional system can be high, the LED products are expected to require much less maintenance than the conventional HPS system, and therefore should offer significant maintenance savings.

Given that PBOT had by then maintained 11,000 Option C street lights for decades, assuming maintenance of the additional Option B street lights seemed relatively straightforward despite the fact that the new work would require a different classification of electrician (i.e., journeyman linemen – see corresponding discussion under Section II Negotiations). PBOT had already developed a sophisticated outage reporting system, including a hotline, web-based reporting forms, and smart phone apps, and in fact this system was already notifying PGE on about 50% of the Option B outages. Coupled with the lower maintenance requirements of LEDs and the ability to contract out for qualified workers to service lights on utility poles, it was not difficult to see how PBOT could take on the servicing of Option B lights.

2. Total Monthly Billing

Table 1 shows the monthly payments the City made to PGE for street lighting over the year between July 1, 2013 and June 30, 2014. The $5.9 million combined total includes energy and maintenance for Option A poles and Option B fixtures and poles where applicable, but energy only for Option C equipment. In addition, the City was paying approximately $1 million for annual maintenance on the Option C street lights and for equipment replacement in the components it owned, bringing the sum total to about $6.9 million during this year's period.

Payments were expected to increase considerably if Portland sold the system back to PGE because the restructured payments would have to include a cost recovery component for converting the entire system to LED.[7] Portland's cost of capital through tax-exempt general bond issuance is typically in the range of 3% to 4% (and even less in today's market), whereas financing through the utility not only involves higher commercial financing rates but also profit and overhead. PGE indicated a "Levelized Annual Revenue Requirement" of 12.9%, including a cost of capital of 8.033%, in an analysis supporting

[6] Based on an independent study presented to the Portland City Council following purchase of the lighting system in 1980, including 30,694 lights and 2,255 poles, from PGE for $3M (MTA, 1983).

[7] PGE's proposal to the Mayor in December 2012 indicated that the City would save $345,000 per year from the existing street light bill by switching to Option A LEDs assuming current rates and lighting levels. However, a third-party assessment funded by PBOT estimated an annual savings of $1.5 million if the City retained the system and converted to LED on its own ("'Economic Analysis of Proposed LED Conversion Program,' conducted by Reed Schmidt of Bartle Wells Associates, provided to Tod Rosinbum, Portland Bureau of Transportation, September 28, 2012).

the creation of a new "Schedule 95" rate tariff that would include LED products, i.e., significantly higher than the City's own available rate.[8]

Table 1. Portland, OR monthly billings for street lighting, 2013-2014

	Schedule 91 Summary[a]		Schedule 32 Summary[a]	
DATE RANGE	KWH	TOTAL PAID[b]	KWH	TOTAL PAID[b]
July 1 - July 11, 2013	1224274	$174,776	46535	$4,293
July 11 - Aug 12, 2013	3438588	$484,320	93491	$9,073
Aug 12 - Sept 11, 2013	3349079	$476,075	259217	$24,000
Sept 11 - Oct 10 , 2013	3416646	$484,818	150643	$14,566
Oct 10 - Nov 8, 2013	3339669	$477,833	162981	$15,841
Nov 8 - Dec 11, 2013	3338802	$477,896	163474	$16,008
Dec 11, 2013 - Jan 13, 2014	3411627	$485,936	170665	$16,759
Jan 13 - Feb 12, 2014	3337120	$476,737	150332	$16,193
Feb 12 - Mar 12, 2014	3334141	$482,959	156926	$16,460
Mar 12 - Apr 10, 2014	3348768	$483,873	165973	$17,033
Apr 10 - May 12, 2014	3302649	$469,136	173523	$17,427
May 12 - June 11, 2014	3308766	$474,289	169598	$16,970
June 11 - June 30, 2014	2082945	$299,377	133963	$13,110
TOTAL	40,233,073	$5,748,026	1,997,321	$197,732

Source: PBOT

[a] Schedule 91 pertains to unmetered street lights and Schedule 32 to metered lights.

[b] Includes energy and maintenance for Option A and Option B lights and poles, but energy only for Option C.

PBOT ultimately reconfirmed that in their judgement the City was better off owning their street lighting system and therefore recommended that Portland purchase the remainder of their street lighting system from PGE and finance the additional purchase and installation of LED products separately. The Mayor's Office and the City Council concurred.

II. Negotiations

After the City decided to acquire the remainder of the street lighting system, several related issues needed resolution before the City and PGE could agree on what constituted the system and what its present value was. The existing system had evolved significantly over several decades and by then included components of various ages and combinations of ownership. The issues were identified, negotiated if necessary, and mostly resolved during a series of public meetings involving PBOT, OPUC, and PGE. Examples follow.[9]

- ***Considerations related to boundaries between the street lighting system and utility equipment, and its related maintenance.*** Utility work generally involves a level of qualification different from that of city electricians, due to the frequent proximity and interaction with high current / high voltage equipment, which requires different training. Utilities generally employ

[8] "Schedule 95 Street and Highway Lighting" handout provided in negotiations meeting, May 9, 2012.

[9] The examples provided are intended more to illustrate the diversity of topics that arose than be a comprehensive treatment of them. Individual subjects may be of less or greater relevance to conversion programs elsewhere.

journeyman linemen for street lighting maintenance and repairs. This also means that utility equipment often falls under a different safety code (the National Electric Safety Code or NESC) than city equipment (which uses the National Electric Code or NEC); one example of the resulting difference is the lack of a requirement for Underwriters Laboratories (UL) listings on utility equipment. A variety of such key differences exist between the NEC and the NESC, and hence among city- and utility-owned equipment and procedures. These differences can complicate the transfer of property and related procedures between parties that adhere to the different codes, often requiring modification to meet the newly applicable (and usually more recent) version.

Further complicating the transfer of the system was defining what it specifically included. Whereas the City might have originally viewed the "street lighting system" as consisting only of luminaires, mast arms, and poles, PGE saw the system as also including all circuit wiring beyond each step-down transformer, starting with the first pole at distribution voltage downstream. Some of this wiring can be located underground in utility service tunnels or other access points. Aside from its additional valuation in the purchase agreement, access to circuit wiring may require entry into areas containing other utility-owned equipment. Issues arose related to protecting non-utility maintenance workers from exposed equipment that could be certified to different safety standards than what they are trained for, and who should pay for any required modifications. A related issue is protecting the utility-owned equipment in these common areas from potential unauthorized access by insufficiently qualified personnel. Ultimately, the PGE tariff document establishes that anyone conducting maintenance or other work on the system is required to comply with all OSHA and other requirements, and that all such work must be performed by a Qualified Worker, meaning essentially either a journeyman lineman or someone with equivalent training.

- ***The need for and cost of pole repair and upgrades.*** Unfortunately, many of the utility-owned SLO poles in Portland did not even meet existing NESC requirements due to ineffective grounding, [10] and needed to be repaired before the City could take full possession. Such modification added significantly to the purchase price of the pole itself, and a predictable issue arose as to who should pay for bringing these poles up to the present, and possibly different (NEC vs. NESC), code. PGE eventually agreed to bond and ground all metal poles before transferring ownership to the City, and over the next year completed work on about 90% of these. Ultimately, the City requested and received a compensatory price discount on the remaining stock as a more expeditious alternative to completing the transition. [11]

  In addition, many of the poles were decades old and were due for replacement. From a utility perspective, they were selling the system "as is" and did not yet see these upgrades as necessary apart from the sale. In contrast, the City preferred to receive a system in good working order through this transaction and did not have sufficient budget to cover extensive

[10] According to the relevant governing document (U.S. DOC, 1941).

[11] It was also discovered that about 1,600 of the Option B (City-owned, utility-maintained) poles required similar correction, which was undertaken at City expense.

repairs evident even before the purchase. In this case, the City ultimately accepted the poles in their present condition as long as they met minimum safety requirements, and will use the savings from owning rather than renting them for any repairs or replacements needed.[12]

- ***The challenges of multiple players*.** Each organization involved in a transaction is likely to have its own perspective, which may introduce or amplify the challenges faced. A case in point in this instance occurred when PBOT and PGE verbally agreed to a purchase of approximately 4,300 PGE SLO poles at a price of $1.1 million. PBOT staff applied a small buffer and prepared a "not to exceed" budget request of $1.3 million for the City Council, who granted approval. Transactions of more than $100,000 trigger a review and approval by OPUC, however. Although some OPUC staff members were present at the time of the verbal agreement, at the time of the review other OPUC staff members subsequently viewed this amount as insufficient compensation to the utility rate payers and raised the purchase price to $1.6 million.[13] Not having a formally documented agreement meant that PBOT was required to return to the City Council with a supplemental request to increase the approved budget.
- ***Changing relationship with PacifiCorp.*** Some poles in a portion of the downtown and northeast sections of the city were owned by a second utility, PacifiCorp, which was receiving monthly payment through the City's payments to PGE via an arrangement between PGE and PacifiCorp that was established in the 1980s. However, with the installation of LED street lights and conversion of other equipment from Option B to Option C, the previous billing and maintenance arrangement between PGE and PacifiCorp was deemed no longer applicable, and was terminated as soon as the City completed the conversion to Option C. A completely new billing process with PacifiCorp was required. In the end, the City now maintains the inventory database, with PacifiCorp billing the City directly for energy costs. The City also coordinates directly with PacifiCorp on maintenance of street lights on PacifiCorp-owned poles.
- ***Coordination with communications companies.*** About 277 of the 4,300 poles purchased from PGE included one or more attachments by communications companies. Previously, these companies had contracts and paid monthly rental fees to PGE to use space on each pole. Because the City does not have a corresponding pole attachment program, the communications companies have the option to either purchase the pole (with PBOT still owning the luminaire) at the same price established by OPUC or remove their attachments. This decision process is still underway.
- ***Installation of new lights on existing distribution poles.*** After passage of the Schedule 95 tariff accommodating LED products, PGE needed to establish requirements for customer installation of street lights on PGE poles. Although these requirements were not negotiated, discussions were important to clarify the associated understanding between PGE and the City. Essentially,

[12] The cost of purchasing these poles divided by PBOT's annual bill for renting them yields a simple payback of less than 4 years.

[13] Specifically, OPUC requirements added $439,787 for 1 year of rent on 4,257 poles and $34,854 for 5 years of attachment fees on 277 poles.

the City now installs a new luminaire in accordance with NESC clearance requirements, and leaves a 3-foot "pig tail" for PGE to connect and energize it.

- ***Transfers of lights to new poles.*** Another issue requiring coordination involves existing City luminaires and their transfer from one pole to another. Because they are already working onsite, PGE transfers City-owned lights when poles are replaced as a matter of convenience to all parties, but the City must handle anything other than the electrical connection. For example, if a vehicle hits a utility pole and the street light is salvageable, PGE will ensure that the site is safe and will reinstall and energize the light. For planned pole replacement and transfers, however, PGE notifies the City to transfer the luminaire to the new pole and PGE then energizes it.
- ***Direct-buried circuits.*** Direct-buried circuits were a common practice into the 1980s, and involve wires buried directly in the ground rather than in conduits or duct banks. Often these circuits include splices that are relatively inaccessible, and associated utility records can be vague or nonexistent. Initially, PGE suggested that the City purchase and own all direct-buried circuits associated with the street lighting system. However, PGE could not provide adequate records to locate these circuits and the circuits were unfused with no disconnects, meaning that City electricians would be unable to safely access and disconnect them without PGE's assistance. Moreover, some of these circuits may provide power to other customers and thus are not exclusively used for street lighting. Due to these circumstances, PGE agreed to maintain the direct-buried circuits until they "catastrophically fail," at which point PGE will install a junction box and the City will upgrade the associated wiring to current standards.

III. Status

Resolving the issues raised during project negotiations delayed the project's planned rollout by more than two years. Even when project momentum eventually returned, some of the finer details and final transactions remained to be worked out. Ultimately, PBOT issued its initial Phase I luminaire specification in April 2013 to replace the approximately 45,000 cobra head fixtures mounted on utility poles in the system, followed by the Phase II luminaire specification for ornamental post-tops in March 2015. A few aspects of the bid documents and process deserve special attention here.

The invitation to bid noted that the new street lights "must be sufficient to light streets to city street lighting standards," but that the City was specifically looking for field-adjustable output (involving manually adjustable settings vs. dynamic controls) in anticipation of the LEDs potentially appearing too bright for some residents and road users, which in fact turned out to be the case (see further discussion under Results). The invitation also established that the technology and pricing would be reviewed annually due to the continuing rapid rate of improvement in both performance and cost, clarifying the expectation that ongoing manufacturer market price reductions would be similarly reflected in decreasing future price quotes provided to the City. To date, this anticipated development has also been

borne out as, for example, prices for the 100 W replacement product have dropped from $155 per unit in the second half of 2014 to $124 per unit in the first half of 2015.[14]

A separate solicitation invited contractors to bid on the installation of the LED street lights on utility poles. Because these were originally installed under NESC rules, contractors would be required to use journeyman linemen or qualified workers with equivalent training pursuant to utility tariff requirements. In the end, the resulting cost of replacing an existing HPS luminaire with an LED luminaire under a group installation process (i.e., replacing lights block-by-block in geographically successive order) amounted to only $74.26 each, not including traffic control or flagging.

The City received multiple bids for each solicitation and made their final selections only after reviewing trial mockups using samples provided by the manufacturers. These were reviewed by PBOT engineers for conformance to the specifications and by maintenance electricians for ease of installation. As of August 2015, PBOT has passed the halfway point in their conversion, having installed approximately 22,500 LED luminaires. The cobra head conversion is expected to be complete by December 2016. The purchase and installation of the ornamental post-tops (Figure 2) is waiting on approval of funding and is therefore not yet scheduled.

Figure 2. Ornamental post-top with LED retrofit

Finally, a very effective aspect of the solicitations has resulted from PBOT's working with the other local municipalities and counties who comprised the regional street lighting group and arranging for them to "piggyback" on PBOT's contract with the winning bidder. As part of the proposal, the winning contractor agreed to extend identical prices and services to other public agencies under similar terms and conditions, although these are to be executed under separate, direct contracts with the other agencies and they do not affect the contractor's obligation to Portland. This means that, for a relatively small (~1%) transaction fee to the City of Portland, these other cities can avoid the costs of undertaking their own requests for proposal while also benefiting from PBOT's bulk purchase price, as long as they are content with similar luminaires. Thus far, not only have the regional municipalities of Gresham and Lake Oswego taken advantage of the cooperative agreement, but its reach may be extending far beyond its original vision as other Oregon municipalities including Salem, Eugene, Springfield, McMinnville, as well as Vancouver, Washington, are reportedly considering following suit.

[14] This development also illustrates the kind of evolving benefit available to an agency that owns the lights rather than one renting them, as such cost Improvements might not be immediately reflected in the monthly payment of the latter.

IV. Results

Initial public response to the new street lights has been largely positive, although some reactions to the whiter light have been less so. As expected, the brighter appearance of the LEDs led to a few initial requests to lower illumination levels, and to some concerns over glare and light trespass. The luminaires selected by PBOT for the cobra head replacements (Figure 3) offer three output levels, controlled by the fixed internal setting of connections to the power supply. Output levels for this single product can thereby be set to 3000 lumens, 4100 lumens or 5000 lumens at the different power draws of 29 W, 42 W, and 54 W, respectively. Based on initial feedback from residents that the 4100 lumen output was perceived as too much light, PBOT has been configuring all residential units at the lowest available output level, drawing 29 watts. Compared with the existing 100 W nominal HPS lamps being replaced (approximately 118 W including the ballast), this conversion represents a 75% reduction in power use.

Figure 3. LED cobra head replacement luminaire

Collector and arterial roadways in Portland previously used 150 to 400 W nominal HPS cobra head luminaires, which are being replaced with the LED products ranging from 63 to 180 W, for an overall average power reduction of approximately 64%. Crews installing the lights are pleased with the ease of installation and report that each luminaire replacement requires only about 15 minutes. A crew typically consists of only two staff and a bucket truck (Figure 4).

Thus far, out of the box failure rates and other operating issues typically associated with new installations have been very low, with a warranty return rate of just over 0.5%. This is in line with LED experiences elsewhere.[15]

Moving forward, the LED conversion has contributed to an increased awareness of street lighting and a revaluation of PBOT lighting standards. PBOT is in the process of reviewing those and redefining their recommended practice for the City. Combined with the new lighting standards will be consideration of the needs of bicyclists and pedestrians, as well as other PBOT goals such as Vision Zero and Equity.[16]

[15] See, for example, the April 2014 MSSLC webinar on Maintenance Practices for LED Street Lights.

[16] Vision Zero is a City of Portland goal to eliminate traffic deaths and serious injuries on roadways over the next ten year period. Portland defines its Equity goal as "City services are administered and delivered in such a way that gives Portlanders access to the opportunities necessary to satisfy their essential needs, advance their wellbeing, and achieve their full potential." The guidelines under this goal will use an "equity lens" that includes socio-economic considerations to review ongoing and future City development.

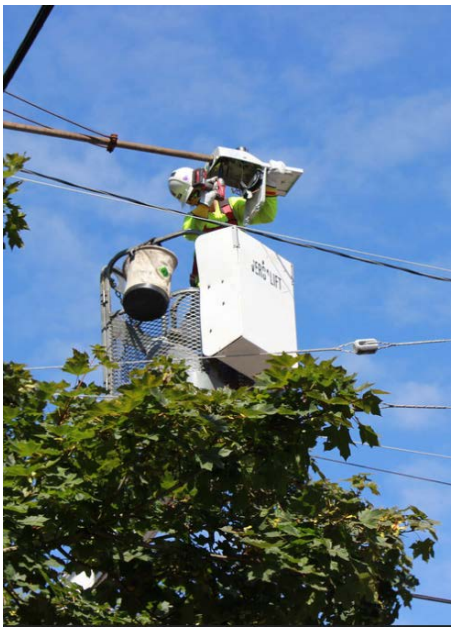

Figure 4. Installation of LED cobra head replacement luminaire in Portland, OR, July 2015

PBOT has an approved annual budget of about $7 million for operating the street lighting system and is being allowed to retain the savings for other needs. Projected dollar savings from the completed conversion exceed $2 million per year, and thus are expected to repay the total $18.5 million investment in the upgraded system (including pole purchases) within about 8 years. Beyond that point, the savings will be used for system maintenance and put into a capital replacement fund for poles and circuits, and the next round of luminaire replacements.

PGE has eliminated Option B equipment from its latest rate tariff (Schedule 95), as planned. Option C has been expanded to include customer-owned luminaires that are mounted on utility-owned poles, so that the customer is now responsible for maintaining their own lights using Qualified Workers as discussed previously. Any installation of LED equipment, which requires use of the latest rate tariff, triggers a requirement for that customer to convert all of their street lights to that tariff and eliminates Option B. This transition is required either within 5 years following the utility's group replacement cycle, or else within 3 years according to a mutually agreed upon schedule.

Option C charges are as follows:

Transmission and Related Services Charge:	0.171¢ per kWh
Distribution Charge:	4.832¢ per kWh
Energy Charge:	5.279¢ per kWh
Total:	10.282¢ per kWh

These charges assume that the luminaire operates dusk to dawn daily, as controlled by a photoelectric relay, for an average annual operation of 4,100 hours. PGE electric charges for HPS also assume energy use for the ballast. For example, a 100 W HPS fixture is calculated to consume 43 kWh per month, which incorporates a ballast power draw of 25 W. The energy charge for LED is simply its rated energy consumption for 4,100 hours annually divided by 12 to determine an average monthly rate. LED luminaire charges are allocated in 5 W increment bins for luminaires under 100 W and 10 W bins for luminaires 100 W and over.

V. Lessons Learned

In reviewing their experience to date, PBOT has identified several valuable suggestions for others pursuing similar conversions.

- The project should appoint a leader who can provide an effective communications strategy and implement new agency standards. This leader should have the ability to see both sides of the argument, remaining flexible and finding fair compromises that are key to moving forward.
- Information should be presented to the agency leadership that speaks to the goals of the community, with the support of technical experts. This increases the momentum of the proposed plan by making it easier for City officials to get behind it.
- Comparing a City with a public utility is difficult if not starting from an "apples to apples" perspective. For long-term cost estimates, Portland City Officials assumed private sector partners would complete any maintenance work in a manner similar to the public utility. This eliminated a key argument of the utility that ongoing costs would be less than if City personnel conducted the work.
- Cooperation among the municipalities and customers within a given utility service territory is an effective approach for requesting a change that will affect all parties, such as, for example, modifying a tariff to include a new technology or objecting to a proposed rate increase. This is of particular value to smaller customers in the region who might not be afforded sufficient attention otherwise. In this instance, the utility became more responsive to its customers regarding a requested rate tariff to include LED technology (ultimately producing the new Schedule 95) after municipalities in the region formed a collaborative and approached the utility collectively.
- The cooperative agreement among regional customers, such as that established between Portland and its surrounding communities for purchasing luminaires, is also of particular value to the smaller customers in the region. Not only can they save money by avoiding the need to prepare and carry out their own technical solicitation, but they are able to take advantage of the bulk purchase prices and negotiating power of the larger entity. Such advantages extend into, for example, cheaper options available through a negotiated third-party service contract.
- It is important to publicly document any mutual agreement among the relevant parties to establish and cement its existence. Neglecting to do so in one instance here enabled OPUC to significantly increase a transaction price after PBOT and PGE had already informally agreed on it. This ultimately led to a better result for PGE customers but cost PBOT not only more money but the additional effort of having to return to the City Council after the "deal" had already been made. Documenting the earlier agreement in the public record may have prevented this situation.
- Use of consultants or other independent agencies to prepare technical and financial analyses lends credence to the values being provided, both to internal decision makers in helping guide

and bolster staff decisions and to external audiences when a particular case needs to be made, for example, during negotiations with the utility and public utility commission.

- Such independent analyses can also be extremely valuable in responding to questions about the project schedule and related equity issues. Along these lines, PBOT consulted with the Coalition for a Livable Future to review its plans prior to starting the project, and developed an Equity Report Card in the process to help guide their work as they progressed through the LED conversion. As PBOT balanced other needs (e.g., ensuring service disruptions were minimized), they also used this Equity Report Card to monitor progress and continuously assess the equity focus to the work. Documentation of these procedures and resulting findings have proved invaluable to the City in responding to the community in the time since.
- Involving other City bureaus early provides a high return to the project. In this case, PBOT worked with three other agencies: the Office of Management and Finance on developing financing strategies; the Bureau of Planning and Sustainability to support the benefits of the project and allow a portion of the savings to be used to purchase green power; and the Parks and Recreation Bureau in offering to include their lights in the conversion. This level of collaboration and the resulting momentum undoubtedly contributed to the City Council's unanimous support for the project.
- The substantial savings achieved can be used for numerous related beneficial purposes, if it can be retained by the agency. One example in PBOT's case is using some of the savings to fund infills to currently underserved neighborhoods, where previously the only option was a neighborhood "buy a light" program. Such benefits can also help address equity concerns, as noted earlier.
- A generally higher color temperature combined with a smaller aperture (i.e., area from which the light emanates) leads to a common perception of LEDs as being "brighter" than the products they are replacing. PBOT received a number of requests to reduce "brightness" in the early stages of installation even though the lumen output of the LEDs was already lower than the HPS products they had replaced. PBOT eventually chose the lowest luminaire output setting as the default in residential neighborhoods, and this seems to have largely resolved the issue. Conducting multiple mock ups with open invitations for public input may help identify such issues earlier in the process.
- The use of off-the-shelf geographic-information system (GIS) digital tools greatly helped to streamline Portland's conversion process and offered capabilities that would simply not have been available otherwise. PBOT carefully constructed this system to enable simultaneous real-time updates to the street lighting inventory. Providing this capability allows engineers and technicians in the office, as well as the general public, to follow progress on the conversion throughout the city. As contractors change an HPS light fixture to LED, they select the corresponding light on the map and update its conversion status (including date and serial number for warranty purposes). The procedure developed reduces the need for paper copies and provides more information directly from the installer. This in turn allows the City to track

material needs and update billing precisely and accurately, in order to predict future costs for materials and labor. An accompanying comment field enables the contractors to make notes, such as supplementary observations about pole or circuit repairs needed, or lights that have been mis-mapped or are missing altogether. PBOT rates the overall experience using GIS mapping software and off the shelf technology as extremely positive, reporting that the associated savings have been substantial. PBOT overwhelmingly recommends the process to other public agencies.

VI. Conclusion

The process of upgrading Portland's street lights to LED was more complicated and lengthy than PBOT originally envisioned. A number of issues and circumstances arose during the intended purchase and conversion processes that increased both their cost and times to complete. Patience and persistence have been required in large measure, along with collaborative working relationships with the other parties involved.

Ultimately, the City and its residents are largely pleased with the results. Other public agencies interested in pursuing similar efforts would be well advised to also anticipate similar issues and requirements, both expected and unexpected, in their own endeavors. The value can be well worth the investment.

VII. References

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