Energy Efficient Cities Initiative

GOOD PRACTICES IN CITY ENERGY EFFICIENCY

Portland, United States - LEDs for Traffic Signals

Project title	Light Emitting Diodes (LEDs) for Traffic Signals
Sector	Public Lighting
Type of project	Traffic signal bulb replacement with financial lease
City and country	Portland, Oregon, USA
City population	575,930
Capital cost/initial investment	US$ 2.2 Million
Annual % energy reduction	80% (4.9 million kWh/year)
Project status	Completed

Project Summary

In 2001, the City of Portland replaced most of its incandescent traffic signal lights with new, highly efficient light-emitting diodes (LEDs). Using an innovative leasing arrangement to amortize the investment costs, Portland's Signal and Street Lighting Division was able to replace 13,382 red and green existing incandescent lamps with LEDS. The project resulted in 4.9 million kilowatt-hours (kWh) of annual savings in energy consumption (representing an 80% reduction in energy usage), and a reduction of about 2,880 tons of annual CO_2 emissions. While the project benefitted from a special tax credit and utility rebate, its economics were favorable regardless – the total investment of $2.2 million (before incentives) resulted in annual utility bill and maintenance savings of $380,000 per year, or a payback of 5.8 years (down to 3.1 years with the incentives). However, since the lamps were leased to the City, no upfront investment was required. The energy savings also helped the City avoid budgetary repercussions from an unexpected 40% electric rate hike from the power utility.

1. Introduction

The City of Portland is located in the Northwestern state of Oregon in the United States of America. As of July 2009, its estimated population was 575,930, making it the most populous city in Oregon and the 29th most populous municipality in the United States. It is referred to as the country's "green" city, and is among the global leaders in environmental friendly practices.

As part of its efforts to promote energy efficiency within city government, Portland's Signal and Street Lighting Division launched a program in 1999 to explore options to upgrade traffic signal lighting in its 7,000 traffic light signals. Unlike street lights, which only operate 12 hours per day, traffic signals have 24-hour loads. A feasibility study was undertaken and a decision made to use light emitting diode (LED) technology.[1]

Since signalized intersections were introduced, incandescent bulbs have been their principal light source. Apart from LEDs, the other technologies considered and tested for use in traffic signals include cold cathode technology, electroluminescent panels, and radio frequency induced fluorescence fiber optics. However, the most promising alternative to incandescent signals at that time appeared to be LED traffic signals.[2] Operating hours for the three lamp colors also differs, with red lamps usually lit 50% of the time, green lamps about 45%, and amber or yellow lamps only about 5%. Given this, the City did not consider replacing the yellow incandescent signals, as their low operating times made the LED retrofit uneconomic.

LEDs are the most developed technology for the market, have a mature market infrastructure, and are more cost-effective than other sources. Most manufacturers expect this market to continue to grow and for LED signals eventually to be the norm in traffic control. A comprehensive life cycle assessment[3] conducted by Osram, the German lighting company, demonstrates that LEDs are also the most environmentally friendly lighting product. The City had first considered converting its traffic signals to LEDs in 1995. But in the 1990's, green LEDs were unavailable and red LEDs too expensive. In 2001, an unexpected 40% electricity rate hike (due to California's power crisis), availability of short-term utility rebates, and lower LED prices helped sway city authorities to proceed with an LED program.

The program goals were to reduce the energy consumption and operating costs of Portland's traffic signal system, avoid a large unbudgeted capital outlay from an unexpected electric rate hike, and complete a retrofit project quickly to take advantage of short-term utility rebates. Under this project, the City replaced 13,382 red and green traffic signal incandescent light bulbs with energy saving LEDs. Prior to adopting the LED modules, the City utilized incandescent light bulbs with a short two-year life span for traffic signal indications, after which the signals needed to be re-lamped. Re-lamping the incandescent light bulbs was time-consuming and expensive, and required a two-

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[1] LED is a different lighting technology than the incandescent lighting systems commonly used in traffic light applications. LEDs are composed of thin layers of semiconducting materials that emit light when a voltage is applied across the LED layers, forming a light producing "chip." LEDs produce colored light, and the use of different semiconducting materials results in different light colors being produced. This makes the LED technologies especially attractive for applications that require colored light, for example, traffic signals. In contrast, incandescent lamps produce only white light, which must be filtered through a colored lens for use in traffic signals. Incandescent lamps also produce a considerable amount of light outside the visible spectrum, which is emitted as heat, making incandescent lamps an inefficient method of producing light for traffic signals.

[2] Fluorescent lamps, while also energy efficient, are not feasible for traffic lamp applications due to their slow fire-up times.

[3] The methodology followed the procedures set down in ISO 14040/44, an industry standard. The life cycle analysis considered nearly all aspects of the manufacturing process, emissions created in each stage, and six different global warming indexes, including the amount of greenhouse gas emissions; acid rain potential; eutrophication (excessive algae); photochemical ozone creation; release of harmful chemical compounds; and the resulting scarcity of gas, coal, and oil.

vehicle maintenance operation: a one-bucket truck and one traffic-control pickup. The bucket truck consisted of a crew member elevated inside a bucket to the height of the traffic signal, while the traffic-control pickup followed with a warning sign. Although roads were not required to be closed to accommodate the maintenance crew, there were significant traffic delays in the city.

2. Project Description and Design

In spite of the lower LED prices, the entire project was very capital intensive at US$2.2 million. Since the City of Portland only budgeted for periodic re-lamping, it was difficult for it to secure the entire budget necessary to retrofit all the lamps as planned. The City also wanted to take advantage of the short-term financial incentives being offered by the utility companies (Portland General Electric [PGE] and Pacific Power) for energy efficiency projects completed before 2002. And the City hoped to take advantage of Oregon's Business Energy Tax Credit (BETC). The Oregon State Department of Energy offers the BETC to tax-paying entities who invest in energy conservation, recycling, renewable energy resources, and less-polluting transportation fuels. The BETC was not available to the City directly as a public entity; it benefited from the BETC through an arrangement where the tax credit was taken by one of its private sector partners (see below).

Portland's Signal and Street Lighting Division devised an innovative way to finance the program. The City had used leasing schemes in the past, mostly for very capital intensive equipment, such as fire engine trucks, but had never used it for something as simple as lamps. It thus entered into a public-private partnership (PPP) with a leasing company it had worked with in the past, the Dooling Lease Management Corp., which acted as a financial broker and agreed to arrange the equipment lease for the project. Under this arrangement, the City procured the lamps and installation contract, but the lamps were leased back to the City from a local bank (Western Bank) through Dooling Leasing. In this way, the City could maintain control of the project while spreading capital costs out over a six-year lease agreement, allowing it to pay the costs as energy and maintenance savings from the project accrued. As noted earlier, the PPP allowed Western Bank to receive the BETC tax credit, which was used to offer the City a reduced monthly lease payment. The lease agreement also allowed the City to complete the project before the end of 2001 and claim the short-term energy efficiency rebate offered by the utilities.

Portland's Office of Sustainable Development provided critical support for this project. Staff analyzed the project's cost-benefit, facilitated utility rebate requests, and arranged the LED lease-option. The staff in the Signals Group of Portland's Office of Transportation was also instrumental, issuing the bids for equipment and installations and signing off on lease paperwork. Both offices' staff were able to assess this opportunity and manage the project without incurring additional labor costs.

Once the lease was in place, the City competitively procured 13,382 LED traffic signal bulbs – a total of 6,900 red and 6,400 green LED lamps, 140 flashing amber beacons, and a few light-rail transit signals. In October of 2001, the City signed a contract with an electrical contractor, E.C. Construction, to implement the LED conversion. In addition to the switch out, a minor modification was made to the signal head, which required removal of the base and reflector of the incandescent bulbs to accommodate the LED lamps. These lamps included a mix of 12-inch, 150 W balls (replaced with 22 W LEDs), 8-inch, 67 W incandescent balls (also replaced with 22 W LEDs), and turn arrows in both colors. The project was implemented according to plan in four months, and the City paid off the lease by August 2007 in monthly installments of $30,000.

3. Cost, Financing, Benefits, and Effects

The full retrofit program had total capital costs to the City of Portland of approximately US$2.2 million. Using the BETC, Dooling Leasing received a tax credit worth 35% of the project's total cost (nearly $800,000), which was received over time. In turn, the leasing company reduced the cost of the City's lease by about 22%, saving the City nearly $500,000. With the additional rebates offered by the utilities, the net cost to the City for the project was reduced to US$1.5 million.

Before the retrofit, the signal lamps used about 6.1 million kWh each year. At an electric rate of $.069/kWh, the baseline electric costs were about $420,000 per year. After the retrofit, the new LED signal lamps drew about 1.2 million kWh/year – representing an annual electric cost of $85,000. Subsequently, the program saved some 4.9 million kWh/year, representing $335,000 per year in energy cost savings (see Table 1). These savings are equivalent to powering over 350 Portland homes each year, and led to annual CO_2 emissions reductions of some 2,880 tons.

Table 1. Summary of Program Costs

	BEFORE	AFTER	SAVINGS
Lamp Type	6900 Red Incandescent 6400 Green Incandescent Others	13,385 LEDs	
Lamp Wattage	59-142 Watts	20-22 Watts	
Average Lamp Life	~ 2 Years	~8 Years	
Approx. Lamp Cost	$2 /lamp	$100-130/lamp	
Kilowatt Hours/Year	6.1 Million	1.2 Million	4.9 Million
Electricity Cost/ Year	$420,000	$85,000	$335,000
Maintenance Cost/Year	$60,000	$15,000	$45,000

In addition to the energy cost savings, the new LED signal lamps had a life span that was four times longer than the incandescent bulbs. This resulted in considerable savings in the signal-system replacement and maintenance costs. Compared to the two-year life span of the incandescent bulbs, LEDs' life span is eight years, reducing transportation maintenance costs by $45,000 a year in off-hour call-out costs and replacement bulbs. In addition, the City was able to save 1,400 hours of valuable staff time per year previously used for group re-lamping and apply that time to other maintenance needs. After the incentives received and savings were factored in, the project had a net payback of only 3.1 years – a net return on investment of 32%.

The project's completion yielded other unintended benefits; for example, the revision of the State of Oregon's administrative rules to allow the sharing of tax credits without a lease arrangement. Today, for any project focused on energy efficiency, any equipment supplier or installation contractor can provide a tax credit "pass-through," equal to 27% of the project's costs.

4. Project Innovation

The financing mechanism adopted for this project was innovative and an inspiration for other organizations facing budget constraints. By using a leasing arrangement, the City of Portland was able to overcome the full capital cost budget hurdle and allow the project to pay for itself over time – as the project benefits accrued to the City. Such a scheme is quite simple to arrange and much simpler than typical energy performance contracting mechanisms using energy service companies, or ESCOs.

Another major innovative element of the program was the use of LEDs. When the project was first conceived in the late 1990s, LED technology was still relatively new and its use in traffic signals was novel. The adoption of LED modules for traffic light signals enhanced traffic safety by eliminating catastrophic failures of the bulbs, which occasionally occurred with incandescent technology. Unlike an incandescent bulb, which has only one filament, an LED signal is made out of a matrix of several dozen LEDs, so the signal continues to function even if several of these miniature diodes stop working. When the filament of an incandescent bulb fails, the display goes dark, creating a safety hazard and requiring immediate replacement. The LED signals are brighter than incandescent traffic signals, a characteristic that also enhances intersection safety. Additionally, LEDs eliminate the "sun-phantom effect," common in incandescent traffic lights, whereby all colors seem to light up when sunrays fall directly on these signals. This problem is eliminated when LED signals are used because these signals contain no reflectors. These modules are brighter and emit light more evenly, making them more visible in foggy conditions. The LED signals require very low power to operate--it is feasible to run the signals with battery back-up during power failures--and cause less wear and tear to the intersection wiring. There is, however, one drawback in the use of LED traffic lights: During heavy snowstorms, LED signals may not generate enough heat to melt the snow that may accumulate in front of the lenses. However, this was not a major problem in Portland, where severe snowstorms are rare, but might be an issue in colder climates.

Finally, the City's innovative ability to access government incentives to allow the project to proceed was important to improve the project's cost-benefit profile. This not only reduced the perceived risks of the project, which employed a new technology and new financing scheme for public lighting, but also helped ensure the project would be approved, eliminating the need to compete with many other priority projects for the same funding resources.

5. Lessons Learned

This project's success was due to the strong technical assessment conducted by the City of Portland upfront, the innovative use of project financing, and the use of rebates and tax incentives. The successful PPP allowed the City to lease the lamps without incurring the substantial upfront investment cost, which may have prevented the project from occurring at all or having it implemented in phases. As a result, the project was fully implemented, generated strong savings for the City, yielded significant energy savings, and resulted in an improved and more reliable traffic signal system.

Another lesson learned was that full-scale retrofit programs can create more uneven budget obligations in later years, which need to be considered. Prior to the project, the City, as was the case for most cities, arranged for the traffic signal lamps to be replaced on a rotating basis, replacing only a portion each year. Such a strategy allowed for more stable budget outlays while creating a steady, manageable bulb replacement system for the City's maintenance staff. While the LED program was a clear success, all the bulbs were at the end of their useful life by early 2009. At this time, the City needed to secure the capital budget to replace all of them at once, which for some cities may not be a feasible option.

The project also demonstrates that appropriate financial incentives can be successful drivers of environmentally friendly projects and new technologies, and can help overcome market barriers facing such technologies. Use of time sensitive rebates and/or financing for new, innovative and/or capital-intensive energy efficient technologies can help public agencies and their citizens learn about new technologies and encourage their adoption. As communities get more comfortable with the new technology, they tend to be more willing to fund it on their own without the need for future subsidies. Alternatively, economic incentives may work to increase the demand for a particular product or technology, driving down costs to a point at which incentives may not be needed. In this case, the City was willing to replace all the LEDs with new LEDs, showing that the effects of the demonstration were successful.

6. Financial Sustainability, Transferability, and Scalability

The project was financially viable, with a payback period of only about 3.1 years. The City of Portland actually replaced all the older LEDs with new LED bulbs, showing that the project was sustainable. The fact that the quality and efficiency of the LEDs were high while the costs since the initial retrofit in 2001 fell made the LEDs' viability even more attractive. The success of this project encouraged the City to adopt LED technology for all red and green traffic light signals by the Fall of 2009. In 2009, the first generation LED lamps used in 2001 had reached their end-of-life use, and along with many others were retrofitted by 8-9 W, fourth generation LED modules. This time the project was funded with some U.S. Federal stimulus money, but did not utilize the state's BETC. The project resulted in over 20% energy savings for the City.

Overall, U.S. cities report over $10.4 million in savings' every year by replacing outmoded light bulbs in street traffic lights with high-efficient LED bulbs. This simple solution is working for big cities like Denver ($218,000/year savings), Kansas City

($95,000/year), and Salt Lake City ($50,000/year), as well as for smaller cities, such as Keane, New Hampshire ($3,854/year). Passasic, New Jersey, reduced its annual energy bill by $65,000 by changing the light bulbs at just 40 intersections.

Traffic signals are well-suited to the colored light generated by LEDs. The LED traffic signals offer significant savings in energy consumption and operational costs to state and local governments. The maintenance costs related to initial installation and replacement are low, particularly when the change is done as part of a scheduled service routine. Thus, adoption of this advanced technology for public lighting has become routine business practice in most cities in developed countries. This technology will be especially attractive to jurisdictions with high utility prices and municipalities responsible for operational energy costs.

Such applications also apply to developing countries globally. Almost 20% of global electricity consumption is used by lighting applications, which correspond to 2,651 TWh/ year; 70% of this energy is being consumed by inefficient lamps.[4] Using current economic and energy efficiency trends, it is projected that global demand for artificial light will rise 80% by 2030, with a great deal of this increased demand linked to growth in developing economies. As governments in developing countries work to provide lighting to almost 1.6 billion people currently without access to electricity, they have the opportunity to select sustainable technologies to meet their energy needs, and thereby avoid a fossil-fuel model that is environmentally unsound, inefficient and costly.

Estimates indicate continued improvements of LEDs' cost effectiveness, as the cost per lumen of these lamps has been steadily falling even as performance has consistently improved. By the year 2000, the cost per lumen for red LEDs had dropped to US$.06/lm. At this price, LEDs in a typical 25-lm application contribute only $1.50 to the cost of the complete unit. Future enhancements in LED technology will continue to improve their performance and reliability while driving down costs. According to the U.S. Department of Energy, LED luminaries are expected to result in cost reductions of approximately 20% per year, representing a factor of about three by 2015 and a factor of about 35 by the end of 2025. Thus, in the near future, with the cost barrier removed and many governments[5] passing measures to completely phase out incandescent bulbs, it is expected that solid-state lighting technologies like LED will revolutionize artificial lighting globally.

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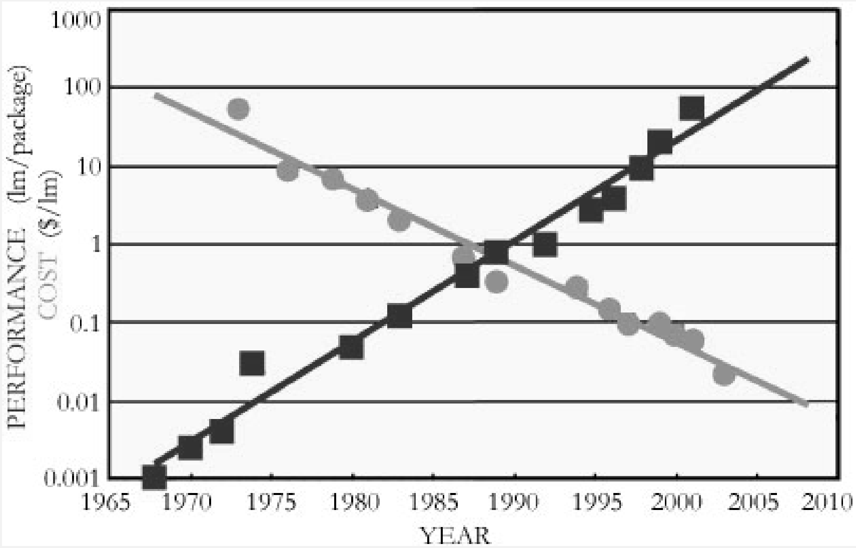
[4] "Lights Labours Lost Policies for Energy-efficient Lighting," International Energy Agency (2006)

[5] Some examples include the European Union (2009), Ireland, Australia, Argentina and Philippines (2010), United States (2014), United Kingdom (2011) and Canada (2012).

Figure 1: Evolution of performance in lumens per package (red squares) and cost in dollars per lumen (blue circles) for commercially available red LEDs



At the same time, the future market penetration of LEDs will depend on the continued cost reduction of this technology. The high cost of LEDs has been the biggest barrier hindering advancement of the technology, and many municipalities feel they simply cannot afford LED technology for public lighting projects. However, factors like government subsidies for electricity, high import duties, lack of financial resources, and uncertain inflation rates and tax/tariff policies prevalent in developing countries also create price and information distortions and discourage energy savings technologies. Additionally, under the current economic system, utility prices do not reflect environmental and social costs associated with fossil fuels' production and utilization. Accounting for these externalities through full-cost pricing, removal of energy subsidies, or offering financial incentives in favor of environmental friendly lighting technologies like LEDs, will be an important step for the diffusion of advanced lighting technology in developing countries. Since adoption of LEDs leads to significant cost reduction in operational and maintenance costs, they offer an attractive alternative with a low payback period to municipalities with high utility and operational costs. A shift in thinking towards a progressive cost analysis--one accounting for life-cycle costs, environmental benefits, comparison to all viable and potential technologies, along with future price reduction projections--would allow procurement officers to make more informed decisions.

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ANNEX: CITY AND PROJECT PROFILE

CITY PROFILE

1. Name of the City	**Portland, Oregon (USA)**
2. Area	**134.3 sq mi (347.9 sq km)**
3. Population	**575,930 (2009)**
4. Population Growth Rate	**1.8%**
5. GDP of the City	**US$110 billion (for metro area)**
6. GDP Growth Rate	**n/a**
7. GDP per Capita	**US$41,800 (for metro area)**

PROJECT PROFILE

1. Project Title	**Light Emitting Diodes (LEDs) for Traffic Signals**
2. Sector	**Public lighting**
3. Project Type	**Traffic signal replacement with financial lease**
4. Total Project Capital Cost	**US$2.2 million**
5. Energy/Cost Savings	**4.9 million kWh/year (80%)**
6. Internal Rate of Return	**32%**
7. Project Start Date	**OCT-2001**
8. Project End Date	**FEB-2002**
9. % of Project Completed	**Completed**

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