

Prepared for
City of Tucson

Investment Grade Audit City of Tucson LED Lighting Conversion Project

City Project 141077
for State of Arizona Contract
ADSP014-0003466

January 8, 2016

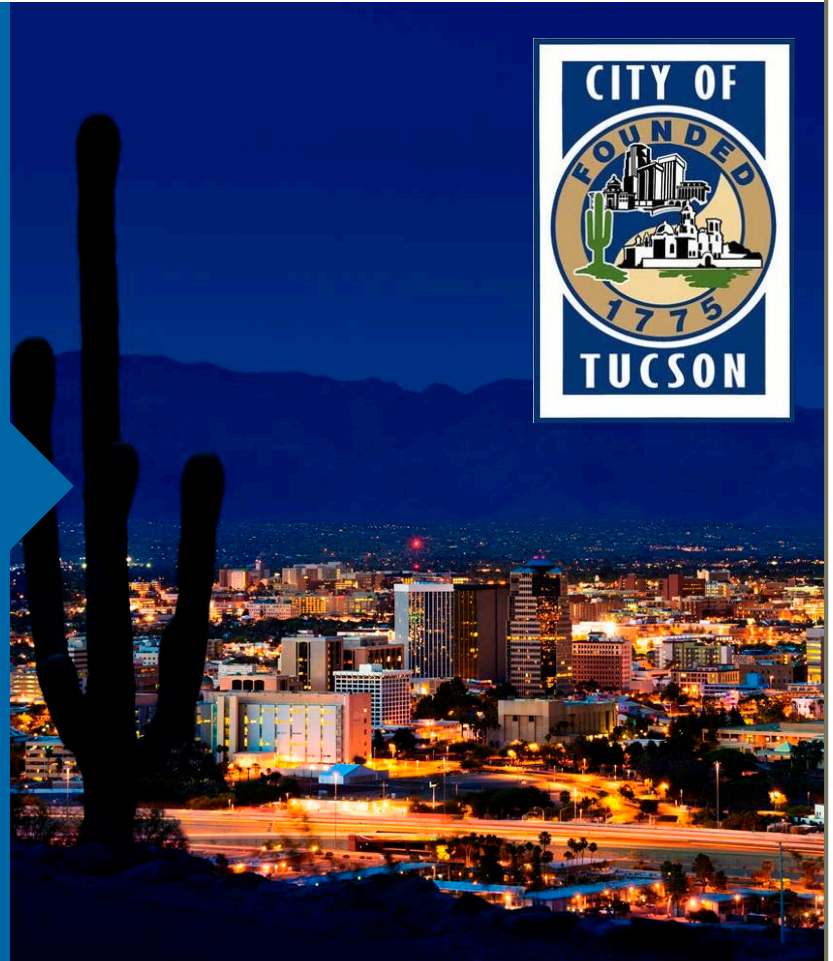
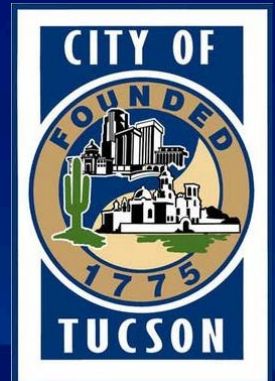


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Executive Summary

Ameresco, Inc. (Ameresco) developed this Investment Grade Audit (IGA) based upon an audit of all of the roadway, underpass and parking garage fixtures throughout the City of Tucson, interviews with City representatives, workshops, utility analyses and energy calculations. The IGA is intended to provide an overall representation of the potential for energy savings at the City of Tucson. Based on the data collected, Ameresco is confident that the implementation of the recommended energy conservation measures (ECMs) will help the City of Tucson reduce energy consumption, improve dark skies lighting environment, and address life cycle concerns of the following existing systems:

- Roadway Lighting
- Decorative & Specialty Lighting
- Underpass Lighting
- Centro Garage Lighting
- City/State Garage Lighting
- Depot Plaza Garage Lighting
- La Entrada Garage Lighting (Tucson Water Building)
- Main Library Garage Lighting
- Pennington Garage Lighting

ES.1 Energy Conservation Measures

The ECMs found to have the best financial performance or those that are of high priority for the City of Tucson include:

- ECM 1: Roadway Lighting and Control Upgrade
- ECM 2: Decorative and Specialty Fixture Upgrade
- ECM 3: Underpass Lighting Upgrade
- ECM 5: Centro Garage Lighting Upgrade with Occupancy and Daylight Controls
- ECM 7: City/State Garage Lighting Upgrade with Occupancy and Daylight Controls
- ECM 9: Depot Plaza Garage Lighting Upgrade with Occupancy and Daylight Controls
- ECM 11: La Entrada Garage Lighting Upgrade with Occupancy and Daylight Controls
- ECM 13: Main Library Garage Lighting Upgrade with Occupancy and Daylight Controls
- ECM 15: Pennington Garage Lighting Upgrade with Occupancy and Daylight Controls

ES.2 Financial Summary

The total potential project savings from implementing these ECMs is anticipated to be **\$2,405,427 per year**. The total implementation cost for the project is **\$15,975,234**. This cost includes detailed audit fees, performance and payment bonds, implementation costs, Arizona Transaction Privilege Taxes, and the State of Arizona contract fee. The project will also qualify for a potential utility rebate in the amount of **\$2,194,368**.

Table ES.0 presents the utility cost savings and construction costs by measure, but excludes third-party consultant fees, detailed audit fees, taxes and performance and payment bonds.

Table ES.0. Energy Conservation Measures Selected for Implementation

Energy Conservation Measure	Electric Savings (\$)	Total Implementation Cost* (\$)	Utility Rebate (\$)	Simple Payback (years)
ECM 1: Roadway Lighting and Control Upgrade	\$2,273,714	\$13,383,460	\$2,096,197	5.0
ECM 2: Decorative and Specialty Lighting Upgrade	\$16,726	\$147,195	\$16,023	7.8
ECM 3: Underpass Lighting Upgrade	\$7,180	\$89,974	\$6,892	11.6
ECM 5: Centro Garage Lighting Upgrade with Occupancy and Daylight Controls	\$15,458	\$207,019	\$10,489	12.7
ECM 7: City/State Garage Lighting Upgrade with Occupancy and Daylight Controls	\$19,339	\$313,500	\$13,115	15.5
ECM 9: Depot Plaza Garage Lighting Upgrade with Occupancy and Daylight Controls	\$12,520	\$193,905	\$8,493	14.8
ECM 11: La Entrada Garage Lighting Upgrade with Occupancy and Daylight Controls	\$1,270	\$22,596	\$1,086	16.9
ECM 13: Main Library Garage Lighting Upgrade with Occupancy and Daylight Controls	\$7,256	\$115,189	\$6,832	14.9
ECM 15: Pennington Garage Lighting Upgrade with Occupancy and Daylight Controls	\$51,964	\$370,168	\$35,241	6.4
Total:	\$2,405,427	\$14,843,006	\$2,194,368	5.3

*Note: The total implementation cost shown excludes ECM independent costs (i.e., audit fees, bonding costs)

In addition to cost savings, the project will deliver the additional strategic benefits to the City:

- Provide sustained energy savings for the term of the agreement
- Enhance reliability and quality of the roadway lighting systems and operations including extended parts and labor warranties on components
- Provide long-term, non-obsolescent assets that continue to deliver cash flow and reliability benefits beyond the debt service term

ES.3 Environmental Benefits

By implementing the nine ECMs recommended by Ameresco, the City of Tucson will accomplish the following:

- Reduce electrical demand by **4,565 kilowatts (kW)** every year
- Reduce electricity consumption by over **22.1 million kilowatt-hours (kWh)** every year
- Reduce the production of over **13,911 tons of carbon dioxide (CO₂)**, **10,962 pounds of sulfur dioxide**, and **17,635 pounds of nitrogen oxides**

In terms of emission reductions, the environmental benefits associated with this energy conservation project are equivalent to...



annual greenhouse gas emissions from removing **3,315** passenger cars from the road,

or



CO₂ emissions from **1,714,960** gallons of gasoline consumed annually,

or



CO₂ emissions from the energy use of **1,392** typical American homes for 1 year,

or



391,170 tree seedlings grown for 10 years,

or



greenhouse gas emissions avoided by not landfilling **5,525** tons of waste.

ES.4 Conclusion

By implementing a performance contract based on this IGA, the City of Tucson will reduce energy consumption, address existing operations and maintenance issues, and upgrade aging infrastructure.

Upon completion of the construction project, Ameresco will monitor the performance of the ECMs for the duration of the contract or for a shorter term if so desired by the City of Tucson. The scope of work for the ongoing M&V services is included in Section F.0.

Ameresco will provide street light ROAM control and garage lighting control training at the end of the construction period. Section I.0 provides additional details about the training services included in the scope of this project. Section J.0 includes details about the proposed O&M services.

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> City of Tucson, Arizona Project Proforma
 S604- LED Lighting Conversion Project

Initial Project Costs:	
Detailed Energy Audit	\$ 50,000
Performance and Payment Bond, Permits	\$ 140,386
Implementation Costs	\$ 14,843,006
Total Initial Project Costs	\$ 15,033,392
Arizona Transaction Privilege Tax (5.265%)	\$ 791,508
Total Ameresco Contract Amount	\$ 15,824,900
State Contract Fee (1.0%)	\$ 150,334
Customer Managed Repair Contingency	\$ 400,000
Net Project Costs	\$ 16,375,234
Construction Period Interest	\$ 274,919
Total Amount	\$ 16,650,153

Financial Assumptions	
Term of Project (years)	10.0 yrs
Term of Financing (years)	10.0 yrs
Estimated Financing Rate	2.50%
Payments per Year (frequency)	2
Discount Rate	2.50%
Energy Escalation rate (annual)	3.00%
O&M Savings Escalation rate (annual)	3.00%
M&V Cost Escalation Rate (annual)	4.00%
O&M Cost Escalation Rate (annual)	4.00%
Project Simple Payback	6.94

Proforma	Initial Values	Year										Totals
		1	2	3	4	5	6	7	8	9	10	
1 Calculated Annual Energy Cost Savings	\$ 2,405,427	\$ 2,477,590	\$ 2,551,918	\$ 2,628,475	\$ 2,707,329	\$ 2,788,549	\$ 2,872,206	\$ 2,958,372	\$ 3,047,123	\$ 3,138,537	\$ 3,232,693	\$ 28,402,791
2 Guaranteed Annual Energy Cost Savings	\$ 2,164,884	\$ 2,229,831	\$ 2,296,726	\$ 2,365,628	\$ 2,436,596	\$ 2,509,694	\$ 2,584,985	\$ 2,662,535	\$ 2,742,411	\$ 2,824,683	\$ 2,909,423	\$ 25,562,512
3 O&M Savings	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4 Utility Rebates (Note 4)		\$ 2,194,368										
5 Total Project Savings (Line 2 + Line 3 + Line 4)	\$ 2,164,884	\$ 4,424,199	\$ 2,296,726	\$ 2,365,628	\$ 2,436,596	\$ 2,509,694	\$ 2,584,985	\$ 2,662,535	\$ 2,742,411	\$ 2,824,683	\$ 2,909,423	\$ 27,756,880
6 Payments for Financing Equipment and Installation		\$ 3,562,461	\$ 1,431,292	\$ 1,496,350	\$ 1,563,322	\$ 1,632,262	\$ 1,710,882	\$ 1,784,242	\$ 1,668,278	\$ 1,937,500	\$ 2,017,527	\$ 18,804,117
7 Payments for Measurement and Verification Services	\$ 13,029	\$ 13,550	\$ 14,092	\$ 14,656	\$ 15,242	\$ 15,852	\$ 16,486	\$ 17,145	\$ 17,831	\$ 18,544	\$ 19,286	\$ 162,684
8 Payments for Operation and Maintenance Services	\$ 75,811	\$ 78,843	\$ 81,997	\$ 85,277	\$ 88,688	\$ 92,236	\$ 88,272	\$ 91,803	\$ 286,958	\$ 99,295	\$ 103,266	\$ 1,096,636
9 Total Payments		\$ 3,654,855	\$ 1,527,382	\$ 1,596,283	\$ 1,667,252	\$ 1,740,350	\$ 1,815,641	\$ 1,893,190	\$ 1,973,066	\$ 2,055,339	\$ 2,140,079	\$ 20,063,437
10 Net Annual Benefit		\$ 769,344	\$ 769,344	\$ 769,345	\$ 769,344	\$ 769,344	\$ 769,344	\$ 769,345	\$ 769,345	\$ 769,344	\$ 769,344	\$ 7,693,443
11 Cumulative Cash Flow	\$ 7,693,443	\$ 769,344	\$ 1,538,689	\$ 2,308,034	\$ 3,077,377	\$ 3,846,721	\$ 4,616,066	\$ 5,385,410	\$ 6,154,755	\$ 6,924,099	\$ 7,693,443	
12 Net Present Value of Cash Flow	\$ 6,733,350											
13 Interest Rate	2.50%											
14 Discount Rate	2.50%											

Note: O&M Costs for Year 8 include cleaning of Major and Collector Roadway Fixtures

Notes:

- 1 This cash flow reflects an estimated tax exempt lease rate of 2.5%. The actual rate will increase or decrease based on market conditions and customer credit rating at the time of lease funding.
- 2 Revenues are based on current utility rate structures and usage information provided for purposes of this project.
- 3 The performance and payment bonds apply only to the installation portion of the contract and do not apply in any way to energy savings guarantees, payments or maintenance provisions, except that the performance bond shall guarantee that the installation will be free of defective materials and workmanship for a period of 12 months following completion and acceptance of the work.
- 4 The amount of the utility rebate(s) are not guaranteed. The final rebate amount will be determined by the utility company.

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A.0 Introduction

The Investment Grade Audit (IGA) is intended to provide an overall representation of the potential for energy savings at the City of Tucson. Based upon an audit of all of the roadway, underpass, and parking garage lighting fixtures throughout the City of Tucson, interviews with City representatives, workshops, utility analyses and energy calculations, Ameresco is confident that the implementation of the recommended energy conservation measures (ECMs) will help the City of Tucson reduce energy consumption, improve dark skies lighting environment, and address life cycle concerns through a combination of retrofits and equipment replacements.

A.1 Project Overview

Ameresco has included nine ECMs in the project developed for the City of Tucson. The ECMs include upgrading the roadway and garage lighting systems with new fixtures and controls included in the scope of work. Implementing these ECMs will provide the following benefits for the facilities:

- Decrease annual electrical energy consumption by **22,100,000 kWh**
- Access utility cash incentive programs worth an estimated **\$2,194,368**

The total potential project savings resulting from implementing the project is projected to be \$2,405,427 per year.

In terms of pollution reduction, the project will avoid the production of over of over **13,911** tons of carbon dioxide (CO₂), **10,962** pounds of sulfur dioxide, and **17,635** pounds of nitrogen oxides per year¹. This reduction in carbon dioxide generation is equivalent to removing **3,315** cars from the road² or powering **1,392** homes each year³. In addition, implementing these ECMs will deliver strategic benefits to the City of Tucson to include:

- Addressing the life cycle replacement needs for the roadway and garage lighting systems
- Providing long-term, non-obsolescent assets that continue to deliver cash flow and reliability benefits beyond term of the debt service
- Improving the environment by providing higher quality lighting and demonstrating the City's commitment to enhancing the lighting environment for both safety and reduced light pollution

¹ Calculated using 1,203 pounds of carbon dioxide reduction per 1,000 kilowatt hours based on the data provided by the EPA Greenhouse Gas Equivalencies Calculator.

² One car produces the equivalent of 5.3 tons of carbon dioxide per year (Source: U.S. Environmental Protection Agency).

³ The average home uses 1,000 kilowatt hours per month.

The proposed ECMs do not materially change lighting systems or any maintenance items and are thus not anticipated to require construction drawings to be stamped by a licensed Professional Engineer.

Ameresco will perform measurement and verification (M&V) services upon completion of construction and annually every year thereafter for the 10-year performance period. Ameresco will provide training for the City of Tucson personnel during commissioning and at the end of construction. (Please reference Section F.0 of the IGA for more details regarding M&V services and Section I.0 for Ameresco's Training Plan for the City of Tucson.)

A.2 Financial Overview

Summary of the costs and savings for the project with this financing structure is:

- Total project cost of \$16,650,153
- Total calculated annual energy savings of \$2,405,427
- Total guaranteed annual energy savings of \$2,229,831 in Year 1 of the performance period

The S604 – LED Light Conversion proforma for the project is provided on the following pages. Please note that these figures include O&M cost in Year 8 to clean major and collector roadway cobrahead fixtures in the amount of \$286,958 and a customer managed repair contingency fund of \$400,000 for repair of underground wiring and other items as the City directs. A net interest rate of 2.5 percent is expected when utilizing Tax Exempt Lease Purchase (TELP) financing and this method of financing has been used in the cash flow.

> City of Tucson, Arizona Project Proforma
 S604- LED Lighting Conversion Project

Initial Project Costs:	
Detailed Energy Audit	\$ 50,000
Performance and Payment Bond, Permits	\$ 140,386
Implementation Costs	\$ 14,843,006
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Construction Period Interest	\$ 274,919
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Payments per Year (frequency)	2
Discount Rate	2.50%
Energy Escalation rate (annual)	3.00%
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Project Simple Payback	6.94

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3 O&M Savings	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4 Utility Rebates (Note 4)		\$ 2,194,368										
5 Total Project Savings (Line 2 + Line 3 + Line 4)	\$ 2,164,884	\$ 4,424,199	\$ 2,296,726	\$ 2,365,628	\$ 2,436,596	\$ 2,509,694	\$ 2,584,985	\$ 2,662,535	\$ 2,742,411	\$ 2,824,683	\$ 2,909,423	\$ 27,756,880
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10 Net Annual Benefit		\$ 769,344	\$ 769,344	\$ 769,345	\$ 769,344	\$ 769,344	\$ 769,344	\$ 769,345	\$ 769,345	\$ 769,344	\$ 769,344	\$ 7,693,443
11 Cumulative Cash Flow	\$ 7,693,443	\$ 769,344	\$ 1,538,689	\$ 2,308,034	\$ 3,077,377	\$ 3,846,721	\$ 4,616,066	\$ 5,385,410	\$ 6,154,755	\$ 6,924,099	\$ 7,693,443	
12 Net Present Value of Cash Flow	\$ 6,733,350											
13 Interest Rate	2.50%											
14 Discount Rate	2.50%											

Note: O&M Costs for Year 8 include cleaning of Major and Collector Roadway Fixtures

Notes:

- 1 This cash flow reflects an estimated tax exempt lease rate of 2.5%. The actual rate will increase or decrease based on market conditions and customer credit rating at the time of lease funding.
- 2 Revenues are based on current utility rate structures and usage information provided for purposes of this project.
- 3 The performance and payment bonds apply only to the installation portion of the contract and do not apply in any way to energy savings guarantees, payments or maintenance provisions, except that the performance bond shall guarantee that the installation will be free of defective materials and workmanship for a period of 12 months following completion and acceptance of the work.
- 4 The amount of the utility rebate(s) are not guaranteed. The final rebate amount will be determined by the utility company.

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A.3 Baseline Overview

Utility account data from the City of Tucson Energy Cap accounting program was used to analyze 1,130 street light utility meters to establish the annual baseline energy consumption. The City provided utility summary data and sample copies of paper utility bills were used to verify Tucson Electric Power (TEP) billing details for Rate 10 Intersection Lighting and Rate 41 Street Lighting accounts. The annual baselines for both rate types are based on a 12 month period from June 2014 to May 2015. A summary of the calculated baseline cost, energy consumption data, and associated energy profiles are provided in Figure A.0 and Table A.0 as part of this Investment Grade Audit.

Figure A.0. Annual Baseline Utility Energy Consumption (kWh) Profile: Rate 10 and Rate 41

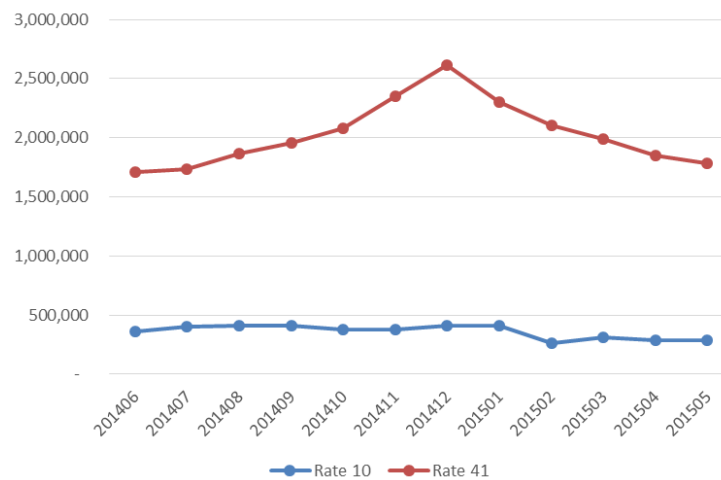


Table A.0. Baseline Utility Energy Consumption

Utility Rate	201406	201407	201408	201409	201410	201411	201412	201501	201502	201503	201504	201505	Grand Total (kWh)
10	360,275	405,095	413,081	409,716	376,006	376,355	411,344	412,015	258,684	308,186	287,778	289,270	4,307,805
41	1,709,036	1,733,362	1,866,621	1,957,255	2,082,203	2,347,636	2,610,639	2,300,628	2,103,017	1,985,163	1,851,799	1,780,656	24,328,015
Grand Total	2,069,311	2,138,457	2,279,702	2,366,971	2,458,209	2,723,991	3,021,983	2,712,643	2,361,701	2,293,349	2,139,577	2,069,926	28,635,820

Table A.1. Baseline Utility Energy Cost

Utility Rate	201406	201407	201408	201409	201410	201411	201412	201501	201502	201503	201504	201505	Grand Total
10	\$ 48,913	\$ 54,811	\$ 56,186	\$ 55,559	\$ 46,550	\$ 44,770	\$ 48,869	\$ 48,759	\$ 31,408	\$ 37,418	\$ 36,037	\$ 40,536	\$ 549,816
41	\$ 180,501	\$ 183,107	\$ 197,101	\$ 210,016	\$ 219,477	\$ 246,427	\$ 273,947	\$ 241,454	\$ 220,739	\$ 212,410	\$ 201,564	\$ 199,565	\$ 2,586,307
Grand Total	\$ 229,414	\$ 237,918	\$ 253,287	\$ 265,575	\$ 266,027	\$ 291,196	\$ 322,816	\$ 290,213	\$ 252,147	\$ 249,828	\$ 237,601	\$ 240,102	\$ 3,136,123

A detailed field audit of the garage lighting systems was performed to verify the existing conditions as the basis of the annual baseline utility cost and energy consumption. The calculated garage baseline is stipulated and separate from the street light baseline presented above as part of this IGA. The garages that are served by a dedicated meter are on the Rate 41 street light rate. The Rate 41 tariff is an energy only charge, as the lights operate during low demand periods of time. The Main Library and La Entrada garage lighting systems are served by the building meter and therefore calculated on Rate 13 Large General Service which includes a demand component.

A.4 Cost Savings Overview

From all ECMs considered and developed, nine ECMs are included in the project. Table A.2 provides a summary of the estimated costs and savings for the recommended ECMs.

Table A.2. Energy Conservation Measures Selected for Implementation

Energy Conservation Measure	Electric Savings (\$)	Total Implementation Cost* (\$)	Utility Rebate (\$)	Simple Payback (years)
ECM 1: Roadway Lighting and Control Upgrade	\$2,273,714	\$13,383,460	\$2,096,197	5.0
ECM 2: Decorative and Specialty Lighting Upgrade	\$16,726	\$147,195	\$16,023	7.8
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ECM 11: La Entrada Garage Lighting Upgrade with Occupancy and Daylight Controls	\$1,270	\$22,596	\$1,086	16.9
ECM 13: Main Library Garage Lighting Upgrade with Occupancy and Daylight Controls	\$7,256	\$115,189	\$6,832	14.9
ECM 15: Pennington Garage Lighting Upgrade with Occupancy and Daylight Controls	\$51,964	\$370,168	\$35,241	6.4
Total:	\$2,405,427	\$14,843,006	\$2,194,368	5.3

*Note: The total implementation cost shown excludes ECM independent costs (i.e., audit fees, bonding costs)

Financing for the project is expected to be in the form of Tax Exempt Lease Purchase (TELP). For the initial project cash flow, it is assumed that interest will begin to accrue at contract closing and is typically capitalized during the installation period. No payments are due by the City of Tucson during the construction period. Payments of principal and interest are due upon final acceptance of the project by the City of Tucson.

A.5 Energy Escalation Rate

A 3.0 percent energy escalation rate has been used in the cash financial analysis for the project. This escalation rate forecast is based on information provided by the US Department of Commerce’s National Institute of Standards and Technology (NIST) 2015 Energy Price Indices and Discount Factors Life Cycle Cost Analysis annual supplement. Table S-4 in the publication provides projected fuel price indices with assumed general price inflation rates. NIST estimates project electricity prices to be 38 percent higher in 2025 assuming general inflation is 3 percent. This equates to an average escalation rate of 3.27 percent per year between 2015 and 2025. A copy of Table S-4 of the NIST publication is provided in Appendix A.1.

A.6 Recommended Measures

Throughout the IGA process, Ameresco evaluated a range of measures that have the potential for energy savings and will also address life cycle issues. The following is a summary of measures that have been evaluated and are included the project.

> ECM 1: Roadway Lighting and Control Upgrade

Ameresco proposes replacing the existing street lighting with new LED technology. The proposed solution will help to reduce the energy and operational expense of the street lighting systems. This measure includes the replacement of the existing technology with LED for the cobrahead, pendant bell, pendant street car and shoebox fixtures. A new wireless control system will be installed that will allow the City to monitor street light assets, quickly identify luminaires that have failed, not operating within normal parameters, monitor power consumption at the fixture level, and control lights individually or in groups for on/off or dimming (on/off can also be controlled by the onboard photocell). These strategies will reduce overall electricity consumption of the lighting system and improve lighting levels. The new LED fixtures and the ROAM Control System comes with a 10 year warranty and Ameresco will repair or replace any warranty components that fail during the 10 years of the financing term. This retrofit will also reduce the amount of sky glare generated by lighting and enable the City to better meet Dark Skies Association guidelines. In addition, this ECM will reduce maintenance costs due to longer life and reduced number of LED fixtures that will require replacement in the future.

> ECM 2: Decorative and Specialty Lighting Upgrade

The City owns and maintains a variety of decorative and specialty fixture street lights. Most of the typical decorative lights utilize screw-in compact type fluorescents lamps and a few LEDs found in the globe, pendant, wall mount and postop fixtures. There are a number of specialty fixtures with high pressure (HPS) and low pressure sodium (LPS) lamps found in the bollard and radius tube fixtures. Ameresco proposes to replace the existing decorative fixtures identified in the IGA with new light emitting diode (LED) technology throughout the entire City of Tucson proper. The proposed project upgrades the existing fixtures and will greatly enhance the quality, consistency and color rendering of the lighting system, thereby reducing the energy and operational expense of the street lighting systems. This strategy will reduce overall electricity consumption of the lighting system throughout the City of Tucson. In addition, ECM 2 will reduce maintenance costs because of longer life of LED lighting as compared to the existing lighting. The LED lamps come with a 5 year warranty and Ameresco will repair or replace any warranty components that fail during the first 5 years of the financing term. The retrofit will also reduce the amount of sky glare generated by lighting and enable the City to better meet Dark Skies Association guidelines.

> **ECM E3: Underpass Lighting Upgrade**

ECM 3 proposes to replace the existing underpass lighting identified in the IGA with new light emitting diode (LED) technology throughout the entire City of Tucson proper. This strategy will reduce overall electricity consumption of the underpass lighting system throughout the City of Tucson. In addition, ECM 3 will reduce maintenance costs because of longer life of LED lighting as compared to the existing lighting. The LED fixtures come with a 10 year warranty and Ameresco will repair or replace any warranty components that fail during the first 10 years of the financing term. The retrofit will also reduce the amount of sky glare generated by lighting and enable the City to better meet Dark Skies Association guidelines.

> **ECMs 5, 7, 9, 11, 13 and 15: Parking Garage Lighting Upgrade with Occupancy and Daylight Controls**

These measures propose to replace the existing garage lighting identified in the IGA with new light emitting diode (LED) technology with occupancy and daylight controls throughout the following parking garages:

- ECM 5: Centro Garage
- ECM 7: City/State Garage
- ECM 9: Depot Plaza Garage
- ECM 11: La Entrada Garage (Tucson Water Building)
- ECM 13: Main Library Garage
- ECM 15: Pennington Garage

The proposed project upgrades the existing lighting fixtures on a fixture-by-fixture basis and will greatly enhance the quality, consistency and color rendering of the lighting system, while meeting all applicable codes and standards, thereby reducing the energy and operational expense of the street lighting systems.

A new control system will be installed that will allow programming of lights with the integration of motion sensor and photo sensor control. Pre-determined dimming options range from dusk and dawn trimming (raising and lowering light output gradually at dusk and dawn). Adding motion sensors to LED luminaires also increases luminaire life because dimmed operation reduces the electrical load and case temperatures on the LEDs and drivers. When dimmed, LEDs generate more lumens per watt, run cooler and last longer. The use of motion sensors also ensures that lights are not on when they do not need to be, but also, that they are on when motion is detected, which enhances site security in any application.

This strategy will reduce overall electricity consumption of the garage lighting system. In addition, this measure will reduce maintenance costs because of longer life of LED lighting as compared to the existing lighting. The LED fixtures come with a 10 year warranty and Ameresco will repair or replace any warranty components that fail during the first 10 years of the financing term. The retrofit will also

reduce the amount of sky glare generated by lighting and enable the City to better meet Dark Skies Association guidelines.

A.7 Measures Removed from Consideration

Several ECMs initially considered were determined to be impractical, economically unfeasible, or otherwise unsuitable for implementation. As such, Ameresco has removed these from consideration or otherwise does not recommend implementation at this time. Additional investigation may warrant further development of some of these measures if so desired by the City of Tucson. The following is a list of measures that were initially considered but are not recommended (NR) at this time.

> ECMs 4, 6, 8, 10, 12 and 14: Parking Garage Lighting Upgrade with Timed Controls

Ameresco evaluated the replacement of the existing garage lighting identified in the IGA with new light emitting diode (LED) technology throughout the following parking garages. The existing control systems would have been reused in this analysis.

- ECM 4: Centro Garage
- ECM 6: City/State Garage
- ECM 8: Depot Plaza Garage
- ECM 10: La Entrada Garage (Tucson Water Building)
- ECM 12: Main Library Garage
- ECM 14: Pennington Garage

The City of Tucson did not want to reuse the existing time controls and instead chose to install a state of the art lighting system control option which utilizes daylight and occupancy control strategies which activates the lights only as needed; which addresses dark skies concerns, enhances security operations, maximizes energy savings, and extends the life of the lighting system.

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B.0 Lighting Equipment Descriptions

The scope of the IGA includes the LED lighting conversion of the existing roadway lighting systems throughout the City of Tucson and 6 parking garages owned by the City of Tucson. Table B.0 lists the total number of roadway and parking garage light fixtures included in the scope of the project. Available floor plans/layout drawings of the parking garage facilities are provided in Appendix B.1 Garage Floor Plan Drawings. A complete inventory of existing equipment is provided in Appendix B.2 Existing Equipment. This section provides a brief description of the roadway lighting systems and each parking garage facility.

Table B.0. Existing Lighting Systems Summary

Lighting Location	Number of Fixtures
Roadway Lighting (cobrahead, pendant, shoebox)	18,330
Decorative and Specialty Fixtures (globes, postops, acorns, bollards, radius tubes)	1745
Underpass Lighting	325
Parking Garages	
Centro Garage	376
City/State Garage	513
Depot Plaza Garage	302
La Entrada Garage (Tucson Water Building)	37
Main Library Garage	190
Pennington Garage	668
Total:	22,486

B.1. Roadway Lighting

> Roadway Lighting Description

The existing roadway light fixtures surveyed are cobrahead, pendant, and shoebox models each containing different types of high pressure sodium (HPS), low pressure sodium (LPS), metal halide (MH), solid state light emitting diode (LED) and induction (IND) technology located throughout the City of Tucson. The street lights are typically controlled individually or as a group by means of dusk-to-dawn photocell sensors.

> Equipment Description

The typical roadway lighting is generally cobrahead fixtures with HPS technology, however there are a number of cobraheads with LPS and LED technology. The shoebox and pendant fixtures are primarily equipped with HPS and MH technology observed primarily throughout downtown and surrounding areas. Table B.1 provides a summary of the existing roadway lighting systems observed during the IGA.

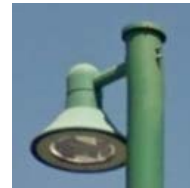
Table B.1. Existing Lighting Summary: Roadway Lighting

Model	Type	Wattage	Count
Cobrahead	HPS	100	1,014
Cobrahead	HPS	150	796
Cobrahead	HPS	250	1,555
Cobrahead	HPS	400	10,050
Cobrahead	LED	53	921
Cobrahead	LED	81	38
Cobrahead	LED	83	2
Cobrahead	LED	117	32
Cobrahead	LED	185	33
Cobrahead	LED	215	49
Cobrahead	LPS	50	28
Cobrahead	LPS	90	2,809
Cobrahead	LPS	135	27
Cobrahead	LPS	180	49
Cobrahead – McGraw Edison	HPS	400	154
Pendant – Bell 400	HPS	400	39
Pendant – Bell Scott 85	IND	85	106
Pendant – SC 400	HPS	400	51
Pendant – SC 400 Cushing	HPS	400	36
Pendant – SC 70	MH	70	45
Pendant – SC 70 Cushing	MH	70	41
Shoebox	HPS	150	22
Shoebox	HPS	250	332
Shoebox	HPS	400	101
Total:			18,330

The McGraw Edison pictured to the right are cone shaped with a double mast arm, nicknamed after the manufacturer. Through the years, these fixtures have been replaced with a typical cobrahead fixture as needed. The remaining McGraw Edison fixtures are located on East Broadway Boulevard and East 22nd Street and will be replaced with new LED cobrahead fixtures requiring a new mast arm and welded saddle connection.



The pendant bell fixtures are typically found in the downtown area west of South Fifth Avenue, along the streetcar tracks on Broadway Boulevard and Congress Avenue. These bell shaped fixtures will be replaced with new LED fixtures of the same bell shape, style and bronze type color.



The fence green cone shaped pendant fixtures will be replaced with new matching fixtures including LED technology. Generally, these fixtures follow the street car tracks in the east downtown area between East Congress Street and East Broadway, from South Toole Avenue to South Fifth Avenue. This type of fixture can also be found on Cushing following the street car path west of I-10, although they are painted a bronze type color.



Powder paint codes have been verified to match all existing fixture colors; however, there will be a variance between the new and existing finish due to the discoloring by the effects of weather over time.

B.2. Decorative and Specialty Fixtures

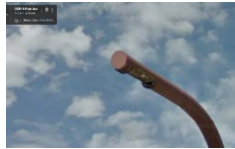
> Decorative Lighting Description

The existing decorative light fixtures surveyed are postop, globes, pendant acorn, bollard and radius tube models each containing different types of high pressure sodium (HPS), low pressure sodium (LPS), metal halide (MH), solid state light emitting diode (LED), induction (IND) technology and compact fluorescent (CFL). The street lights are typically controlled by dusk-to-dawn photocell sensors.



> Equipment Description

The decorative lighting throughout the City of Tucson are typical screw-in type lamps which are generally CFL, however, a few have been upgraded with LEDs as



seen in the globe and postop pictures. There is specialty lighting such as radius tube and bollards containing HPS and LPS technology. Table B.2 provides a summary of the existing decorative lighting systems observed during the IGA.



Table B.2. Existing Lighting Summary: Decorative and Specialty Fixtures

Model	Type	Wattage	Count
Decorative – Bollard	LPS	55	10
Decorative – Globe	FL	20	1,066
Decorative – Pendant Acorn	FL	20	60
Decorative – Pendant Acorn	LED	18	14
Decorative – Postop	HPS	100	268
Decorative – Postop Acorn 20	FL	20	294
Decorative – Radius Tube	HPS	150	8
Decorative – Wall Mount	FL	55	25

Total: **1,745**

B.3. Underpass Lighting Upgrade

> Underpass Lighting Description

The existing underpass lighting fixtures surveyed are typically surfaced mounted to the structure. The types of lighting technology varies among the fixtures but all are controlled by dusk-to-dawn photocell sensors. The City-owned underpass fixtures are found where City roadways pass under or over the interstate system, however, there are a number of railroad and roadway underpasses throughout the City.

> Equipment Description

The typical underpass lighting throughout the City of Tucson is generally wall pack fixtures with HPS technology. There are a number of wall packs with metal halide technology. The underpass fixtures were observed primarily throughout the interstate system and major roadways at the following locations:

Table B.3. Underpass Fixture Locations

Underpass Location
4th Avenue at RR
N Stone at RR
W Speedway Turn Around at RR (east)
W Speedway Turn Around at RR (west)
W Grant at I-10
W Grant at RR
W Speedway at I-10
W St. Mary's at I-10
W Congress at I-10
Cushing at I-10
Cushing at I-10
Starr Pass at I-10
W 29th Road (W Silverlake) at I-10
S Park at I-10
S Park at E Barraza-Aviation Parkway (1)

Table B.4 provides a summary of the existing underpass lighting systems observed during the IGA.

Table B.4. Existing Lighting Summary: Underpass Lighting

Model	Type	Wattage	Count
Wall Pack	MH	70	63
Wall Pack	MH	150	37
Linear Fixtures	HPS	100	137
Wall Pack	HPS	150	37
Total:			325

B.4 Parking Garages

> Lighting Description

The existing parking garage lighting fixtures surveyed are linear, wall pack, shoebox and exit sign models each containing different types of fluorescent (FL), high pressure sodium (HPS), low pressure sodium (LPS), solid state light emitting diode (LED). The parking garages are typically turned on and off by time-of-day scheduling control or the fixtures operate continuously.

> Equipment Description

The typical garage lighting is generally linear fixtures and wall pack models with T8 florescent technology, HPS and LPS technology. Tables B.5 through B.10 that follow, provide a summary of the existing parking garage lighting systems observed during the IGA.

B.4.1. Centro Garage



Table B.5. Existing Lighting Summary: Centro Garage

Wattage with Ballast	Model Number	Number of Fixtures
27	Dome Fixture; Existing (1) 26 Watt Multi Tube Compact Fluorescent Lamp/4 Pin Base/ Electronic Ballast	5
31	Strip Fixture; Existing (1) 32 Watt T8 Linear, 4 Foot Fluorescent Lamp/Bipin Base/Electronic, Instant Start, Normal Light Output (.85<Bf<.95) Ballast	2
43	Wrap; 2'; Pull Chain Fixture; Existing (2) 20 Watt T12 Linear, 2 Foot Fluorescent Lamp/Bipin Base/Magnetic, Standard Ballast	1
46	Wall Pack Fixture; Existing (1) 42 Watt Multi Tube Compact Fluorescent Lamp/4 Pin Base/ Electronic Ballast	14
59	Strip Fixture; Existing (2) 32 Watt T8 Linear, 4 Foot Fluorescent Lamp/Bipin Base/Electronic, Instant Start, Normal Light Output (.85<Bf<.95) Ballast	2
59	Strip; Wire Guard Fixture; Existing (2) 32 Watt T8 Linear, 4 Foot Fluorescent Lamp/Bipin Base/ Electronic, Instant Start, Normal Light Output (.85<Bf<.95) Ballast	341
59	Wrap, Vapor (Water) Proof Fixture; Existing (2) 32 Watt T8 Linear, 4 Foot Fluorescent Lamp/ Bipin Base/Electronic, Instant Start, Normal Light Output (.85<Bf<.95) Ballast	5
129	Wall Pack Fixture; Existing (1) 100 Watt Ed28 Metal Halide Lamp/Screw In, Mogul Base/ Magnetic, Standard Ballast	6
Total:		376

B.4.2. City/State Garage



Table B.6. Existing Lighting Summary: City/State Garage

Wattage with Ballast	Model Number	Number of Fixtures
43	Strip Fixture; Existing (1) 34 Watt T12 Linear, 4 Foot Fluorescent Lamp/Bipin Base/Magnetic, Standard Ballast	6
59	Lay-In; 1x4 (For Flu) Fixture; Existing (2) 32 Watt T8 Linear, 4 Foot Fluorescent Lamp/Bipin Base/Electronic, Instant Start, Normal Light Output (.85<Bf<.95) Ballast	2
80	Canopy Fixture; Existing (1) 55 Watt Tubular, Single Ended Low Pressure Sodium Lamp/Double Contact Bayonet Base/Magnetic, Standard Ballast	416
80	Shoe Box; Pole Mount Fixture; Existing (1) 55 Watt Tubular, Single Ended Low Pressure Sodium Lamp/Double Contact Bayonet Base/Magnetic, Standard Ballast	28
80	Wall Pack Fixture; Existing (1) 55 Watt Tubular, Single Ended Low Pressure Sodium Lamp/Double Contact Bayonet Base/Magnetic, Standard Ballast	28
125	Canopy Fixture; Existing (1) 90 Watt Tubular, Single Ended Low Pressure Sodium Lamp/Double Contact Bayonet Base/Magnetic, Standard Ballast	10
125	Shoe Box; Pole Mount Fixture; Existing (1) 90 Watt Tubular, Single Ended Low Pressure Sodium Lamp/Double Contact Bayonet Base/Magnetic, Standard Ballast	23
Total:		513

B.4.3. Depot Plaza Garage



Table B.7. Existing Lighting Summary: Depot Plaza Garage

Wattage with Ballast	Model Number	Number of Fixtures
19	Strip; 2' Fixture; Existing (1) 17 Watt T8 Linear, 2 Foot Fluorescent Lamp/Bipin Base/Electronic, Instant Start, Normal Light Output (.85<Bf<.95) Ballast	2
28	Wall Sconce Fixture; Existing (1) 26 Watt Multi Tube Compact Fluorescent Lamp/2 Pin Base/Magnetic, Standard Ballast	12
31	Strip Fixture; Existing (1) 32 Watt T8 Linear, 4 Foot Fluorescent Lamp/Bipin Base/Electronic, Instant Start, Normal Light Output (.85<Bf<.95) Ballast	1
59	Strip Fixture; Existing (2) 32 Watt T8 Linear, 4 Foot Fluorescent Lamp/Bipin Base/Electronic, Instant Start, Normal Light Output (.85<Bf<.95) Ballast	1
59	Wrap, Vapor (Water) Proof Fixture; Existing (2) 32 Watt T8 Linear, 4 Foot Fluorescent Lamp/Bipin Base/Electronic, Instant Start, Normal Light Output (.85<Bf<.95) Ballast	260
59	Wrap, Vapor (Water) Proof; Pendant Mount Fixture; Existing (2) 32 Watt T8 Linear, 4 Foot Fluorescent Lamp/Bipin Base/Electronic, Instant Start, Normal Light Output (.85<Bf<.95) Ballast	26
Total:		302

B.4.4. La Entrada Garage



Table B.8. Existing Lighting Summary: La Entrada Garage

Wattage with Ballast	Model Number	Number of Fixtures
31	Strip Fixture; Existing (1) 32 Watt T8 Linear, 4 Foot Fluorescent Lamp/Bipin Base/Electronic, Instant Start, Normal Light Output (.85<Bf<.95) Ballast	3
130	Canopy; Surface Mount Fixture; Existing (1) 100 Watt Bd17 High Pressure Sodium Lamp/Screw In, Medium Base/Magnetic, Standard Ballast	34
Total:		37

B.4.5. Main Library Garage



Table B.9. Existing Lighting Summary: Main Library Garage

Wattage with Ballast	Model Number	Number of Fixtures
31	Strip Fixture; Existing (1) 32 Watt T8 Linear, 4 Foot Fluorescent Lamp/Bipin Base/Electronic, Instant Start, Normal Light Output (.85<Bf<.95) Ballast	3
31	Wrap Fixture; Existing (1) 32 Watt T8 Linear, 4 Foot Fluorescent Lamp/Bipin Base/Electronic, Instant Start, Normal Light Output (.85<Bf<.95) Ballast	30
47	Strip; 2' Fixture; Existing (1) 30 Watt T12 Linear, 3 Foot Fluorescent Lamp/Bipin Base/Magnetic, Standard Ballast	2
130	Canopy; Surface Mount Fixture; Existing (1) 100 Watt Bd17 High Pressure Sodium Lamp/Screw In, Medium Base/Magnetic, Standard Ballast	142
130	Cylinder; Surface Mount Fixture; Existing (1) 100 Watt Bd17 High Pressure Sodium Lamp/Screw In, Medium Base/Magnetic, Standard Ballast	9
210	Flood Light Fixture; Existing (1) 175 Watt Bd17 Metal Halide Lamp/Screw In, Medium Base/Magnetic, Standard Ballast	2
295	Shoe Box; Posttop; Pole Mount Fixture; Existing (1) 250 Watt Ed18 High Pressure Sodium Lamp/Screw In, Mogul Base/Magnetic, Standard Ballast	1
458	Can; 12"; Vertical Lamp Orientation Fixture; Existing (1) 400 Watt Ed28 Metal Halide Lamp/Screw In, Mogul Base/Magnetic, Standard Ballast	1
Total:		190

B.4.6. Pennington Garage



Table B.10. Existing Lighting Summary: Pennington Garage

Wattage with Ballast	Model Number	Number of Fixtures
27	Dome Fixture; Existing (1) 26 Watt Multi Tube Compact Fluorescent Lamp/4 Pin Base/Electronic Ballast	17
59	Strip Fixture; Existing (2) 32 Watt T8 Linear, 4 Foot Fluorescent Lamp/Bipin Base/Electronic, Instant Start, Normal Light Output (.85<Bf<.95) Ballast	2
59	Wrap, Vapor (Water) Proof Fixture; Existing (2) 32 Watt T8 Linear, 4 Foot Fluorescent Lamp/Bipin Base/Electronic, Instant Start, Normal Light Output (.85<Bf<.95) Ballast	1
59	Wrap, Vapor (Water) Proof; Pendant Mount Fixture; Existing (2) 32 Watt T8 Linear, 4 Foot Fluorescent Lamp/Bipin Base/Electronic, Instant Start, Normal Light Output (.85<Bf<.95) Ballast	20
71	Wall Sconce Fixture; Existing (2) 40 Watt Biax Compact Fluorescent Lamp/4 Pin Linear Base/Electronic Ballast	9
112	Wrap, Vapor (Water) Proof Fixture; Existing (4) 32 Watt T8 Linear, 4 Foot Fluorescent Lamp/Bipin Base/Electronic, Instant Start, Normal Light Output (.85<Bf<.95) Ballast	51
112	Wrap, Vapor (Water) Proof; Pendant Mount Fixture; Existing (4) 32 Watt T8 Linear, 4 Foot Fluorescent Lamp/Bipin Base/Electronic, Instant Start, Normal Light Output (.85<Bf<.95) Ballast	541
188	Canopy; Surface Mount Fixture; Existing (1) 150 Watt Ed28 High Pressure Sodium Lamp/Screw In, Mogul Base/Magnetic, Standard Ballast	27
Total:		668

C.0 Base Year Utility Usage

The roadway lighting baseline energy consumption and electric utility rate tariffs included this project were established by combining data from the City of Tucson and Tucson Electric Power (TEP). The City of Tucson and Ameresco collected utility data from TEP where possible. For the basis of this project, the City of Tucson provided three years of detailed historical utility data from the Energy Cap accounting system and actual copies of the monthly utility bills. A summary of the three year historical utility data for all evaluated roadway, decorative, underpass lighting accounts is provided in Appendix C.2. Copies of the electrical tariffs sheets are provided in Appendix C.3. The parking garage accounts are not known and baselines were established based on the detailed field audit quantities, models, types, wattages and observed run-times as stipulated as part of this Investment Grade Audit.

C.1 Electric Service

An Investment Grade Audit was performed on the City of Tucson roadway street lights, underpasses and parking garage luminaries. The IGA included a detailed field survey to verify the location, model, type, wattage and run-time of each existing street light in the City of Tucson inventory provided for approximately 14,500 street lights. In addition, the field survey sited and logged approximately 7,000 unknown street lights not listed in the inventory, for a surveyed total of 24,000 street lights. Of the unknown street lights, there are approximately 3,500 street lights that were determined to belong to the utility provider and removed from the project.

The base year energy consumption data provided in this section is calculated from the fixture quantities, wattages and run-time validated as part of the detailed field audit. The Energy Cap utility summary report data was used to establish the annual energy and cost baseline. The twelve month base year period used to establish the baseline is from June 2014 to May 2015 and reviewed and approved as the basis of the Investment Grade Audit for the roadway street lighting systems. The parking garage baselines were established based on the detailed field audit quantities, models, types, wattages and observed run-times as stipulated and agreed upon as part of this IGA.

Electric energy is supplied to the City of Tucson street lights by Tucson Electric Power under schedules 10 and 41. Utility bills for the parking garages are under schedules 10 and 13. The underground garages at the Main Library and at La Entrada (Tucson Water Building) are on the same schedule 13 as the buildings where they are located, all other garages are on schedule 10. In researching the rate codes, the City informed Ameresco that TEP combined rate 47 accounts with rate 41 accounts and therefore being charged at the same rate as tariff 41.

All of the dollar savings shown in this analysis are calculated by applying the actual rate codes during the Investment Grade Audit to ensure that the projected dollar savings represents the actual billing reduction. Table C.0 lists the calculated annual cost and energy consumption for the existing street and garage lighting systems with controls included in the scope of work. The street light baseline summary is provided in Table C.0. A summary of the rate components is provided in Table C.1 and Table C.2.

Table C.0. Annual Baseline Electricity Consumption and Expenditures

Location	Services/ Accounts	Energy (kWh)	Total Cost (\$)
Street Lights	1,130	27,185,920	\$2,937,785
Centro Garage	(2)	172,266	\$20,291
City/State Garage	(2)	218,329	\$25,716
Depot Plaza Garage	(2)	147,773	\$17,406
La Entrada Garage (Tucson Water Building)	(1)(2)	18,129	\$1,553
Main Library Garage	(1)(2)	106,006	\$8,146
Pennington Garage	(2)	517,136	\$60,912
Total:	1,130	28,303,599	\$3,071,809

- (1) lighting systems on the same schedule 13 meter as the buildings where they are located
- (2) calculated annual baseline based on detailed field survey data

The effective date for the electric rates used for the baseline analysis is July 1, 2013. Tables C.1 and C.2 list the electric energy based charges for each of the different rates. The rates shown include the base power supply charge; this component of the rate changes twice a year based on costs TEP incurs for fuel for its power plants and for purchasing power on the open market. The summer rate is \$0.035111 per kWh and the winter rate is \$0.031532 per kWh based on the effective date of July 1, 2013.

Table C.1. Tucson Electric Power Electricity Rate Tariffs: Rate Schedule GS-10

Rate Schedule	Summer [May-Sept] Charge (\$/kWh)	Winter [Oct-Apr] Charge (\$/kWh)	Customer Charge (\$/month)
GS-10: Small General Service Single Phase – First 500 kWh	\$0.076800	\$0.056800	\$15.50 (PH1)
GS-10: Small General Service Single Phase – All Remaining kWh	\$0.097600	\$0.078800	\$15.50 (PH1)

Table C.2. Tucson Electric Power Electricity Rate Tariffs: Rate Schedule PS-41

Rate Schedule	Summer [May-Sept] Charge (\$/kWh)	Winter [Oct-Apr] Charge (\$/kWh)	Customer Charge (\$/month)
PS-41: Traffic Signal and Street Lighting Service	\$0.035111	\$0.031532	\$0.047600

Table C.3. Rate Code Components: Schedule 41 (Effective Date: July 1, 2013)

Tucson Electric Power Charges		
Delivery Charge Summer (May-Sept)	0.0476	\$/kWh
Power Supply Charge Summer (May-Sept)	0.03511	\$/kWh
Delivery Charge Winter (Oct-Apr)	0.0476	\$/kWh
Power Supply Charge Winter (Oct-Apr)	0.03153	\$/kWh
Purchased Power and Fuel Adjustment Clause- PPFAC	0.00682	\$/kWh
Renewable Energy Tariff	0.008	\$\$\$
DSM Surcharge	0.02466	\$/kWh
ECA Surcharge	0.00019	\$/kWh
Taxes		
Public Utility Gross Receipts Tax	0.75	%

Table C.4. Rate Code Components: Schedule 10 (Effective Date: July 1, 2013)

Tucson Electric Power Charges		
Delivery Service Charge – Electrical Phases	PH1(\$15.50)PH3(\$20.50)	\$\$\$
Delivery Service Charge – Summer (May-Sept) First 500kWh	0.0768	\$/kWh
Delivery Service Charge – Summer (May-Sept) All Remaining kWh	0.0976	\$/kWh
Delivery Service Charge – Winter (Oct-Apr) First 500kWh	0.0568	\$/kWh
Delivery Service Charge – Winter (Oct-Apr) All Remaining kWh	0.0788	\$/kWh
Base Power Supply Charges – Summer (May-Sept)	0.035111	\$/kWh
Base Power Supply Charges – Winter (Oct-Apr)	0.031532	\$/kWh
Purchased Power and Fuel Adjustment Clause – PPFAC	0.00682	\$/kWh
Renewable Energy Tariff	0.0080	\$\$\$
DSM Surcharge	0.02466	\$/kWh
ECS Surcharge	0.000191	\$/kWh
Taxes		
Public Utility Gross Receipts Tax	0.91	%

Table C.5. Rate Code Components: Schedule 13 (Effective Date: July 1, 2013)

Tucson Electric Power Charges		
Delivery Service Charge – Customer Charge	775.00	\$/month
Delivery Service Charge – Demand Charge	15.25	\$/kW
Delivery Service Charge – Summer (May-Sept)	0.0192000	\$/kWh
Delivery Service Charge – Winter (Oct-Apr)	0.013400	\$/kWh
Base Power Supply Charges – Summer (May-Sept)	0.035111	\$/kWh
Base Power Supply Charges – Winter (Oct-Apr)	0.031532	\$/kWh
Green Energy Charges – Purchased Power and Fuel Adjustment Clause – PPFAC	0.00682	\$/kWh
Green Energy Charges – Renewable Energy Tariff	0.0080	\$\$\$
Green Energy Charges – DSM Surcharge	0.02466	\$/kWh
Green Energy Charges – ECS Surcharge	0.000191	\$/kWh
Taxes		
Public Utility Gross Receipts Tax	0.91	%

In order to calculate savings, Ameresco used the actual rate structure and historical consumption for that account. A summary of the marginal rate for each service is provided in Table C.6.

Table C.6. Effective Marginal Electrical Rates

Location	Rate Code	Energy (\$/kWh)
Street Lights	41	0.102
Street Lights – Intersection (120v PH1)	10	0.145
Centro Garage	10	0.145
City/State Garage	10	0.145
Depot Plaza Garage	10	0.145
La Entrada Garage (Tucson Water Building)	13	0.90
Main Library Garage	13	0.90
Pennington Garage	10	0.145

C.2 Utility Incentives

> Tucson Electric Power

The City of Tucson is eligible for the exclusive incentive program through Tucson Electric Power’s Commercial Easy Save Plus (CESP) Program. The program provides financial incentives to customers to help fund retrofits primary to reduce demand on the electrical system and also to reduced energy consumption. Incentives projected in the report are based on the CESP Program. ECMs evaluated as part of this audit which may be eligible for incentives include:

Table C.7. ECMs Eligible for Incentives

Measure	CESP \$/kWh Saved
Roadway Street Lighting	\$0.11
Decorative Lighting	\$0.03 - \$0.10
Underpass Lighting	\$0.10
Garage Lighting	\$0.10

D.0 Energy Conservation Measures

This section outlines the detailed recommendations for the energy conservation measures (ECMs) developed in cooperation with the City of Tucson for this project. The Investment Grade Audit includes a description of the existing conditions, the proposed changes as outlined in the energy savings analysis, a detailed scope of work, and documented the impact these measures will have on the roadway, decorative, underpass, and garage lighting systems. Please reference Table D.0 for the ECMs proposed for the City of Tucson.

Table D.0. Proposed Energy Conservation Measures

Energy Conservation Measure
ECM 1: Roadway Lighting and Control Lighting Upgrade
ECM 2: Decorative and Specialty Lighting Upgrade
ECM 3: Underpass Lighting Upgrade
ECM 5: Centro Garage Lighting Upgrade with Occupancy and Daylight Controls
ECM 7: City/State Garage Lighting Upgrade with Occupancy and Daylight Controls
ECM 9: Depot Plaza Garage Lighting Upgrade with Occupancy and Daylight Controls
ECM 11: La Entrada Garage Lighting Upgrade with Occupancy and Daylight Controls
ECM 13: Main Library Garage Lighting Upgrade with Occupancy and Daylight Controls
ECM 15: Pennington Garage Lighting Upgrade with Occupancy and Daylight Controls

The construction costs include the engineering design costs, permit costs, construction management fees, environmental fees, training, warranty, commissioning and the individual contractor costs for each ECM, as well as for the project as a whole. These costs are based on the assumption that the terms and conditions included within the contract are agreed on by all parties represented therein.

Section F.0 includes the Measurement and Verification (M&V) Plan. The baseline and proposed energy use has been outlined in detail and the savings algorithms are provided. Section G.0 includes the Commissioning Plan for each individual measure.

ECM 1: Roadway Lighting and Control Upgrade

Roadway Lighting

> General Description

ECM 1 proposes to replace the existing street light luminaires identified in the Investment Grade Audit with new light emitting diode (LED) fixtures throughout the entire City of Tucson proper. The proposed project upgrades the existing fixtures and will greatly enhance the quality, consistency and color rendering of the lighting system, while meeting all applicable codes and standards, thereby reducing the energy and operational expense of the street lighting systems.



This strategy will reduce overall electricity consumption of the lighting system throughout the City of Tucson. In addition, ECM 1 will reduce maintenance costs because of the longer life of LED lighting as compared to the existing lighting. The LED fixtures come with a 10 year warranty and Ameresco will repair or replace any warranty components that fail during the 10 year financing term. The retrofit will also reduce the amount of sky glare generated by lighting and enable the City to better meet Dark Skies Association guidelines.

Existing Conditions

The City of Tucson provided access to the Department of Transportation's mapping system and a summary of the street light inventory maintained by the City. A detailed fixture-by-fixture audit of the street light system was performed to verify the street light inventory, as well as locating and documenting new, unknown and utility owned street lights. Utility owned street lights are not included in the scope of this project.

The existing street light fixtures surveyed are cobra head, pendant, and shoebox models each containing different type of high pressure sodium (HPS), low pressure sodium (LPS), metal halide (MH), solid state light emitting diode (LED), and induction (IND) technology. See Table D.1.Existing Roadway Fixtures for the existing street light fixture model, type, wattage, and count for ECM 1 as part of the investment grade audit.

Table D.1. Existing Lighting Summary: Roadway Lighting

Model	Type	Wattage	Count
Cobrahead	HPS	100	1,012
Cobrahead	HPS	150	796
Cobrahead	HPS	250	1,551
Cobrahead	HPS	400	9,867
Cobrahead	LED	53	921
Cobrahead	LED	81	38
Cobrahead	LED	83	2
Cobrahead	LED	117	32
Cobrahead	LED	185	33
Cobrahead	LED	215	49
Cobrahead	LPS	50	28
Cobrahead	LPS	90	2,809
Cobrahead	LPS	135	27
Cobrahead	LPS	180	49
Cobrahead – McGraw Edison	HPS	400	154
Cobrahead – Future Construction	HPS	100	2
Cobrahead – Future Construction	HPS	250	4
Cobrahead – Future Construction	HPS	400	183
Pendant – Bell 400	HPS	400	39
Pendant – Bell Scott 85	IND	85	106
Pendant – SC 400	HPS	400	51
Pendant – SC 400 Cushing	HPS	400	36
Pendant – SC 70	MH	70	45
Pendant – SC 70 Cushing	MH	70	41
Shoebox	HPS	150	22
Shoebox	HPS	250	332
Shoebox	HPS	400	101
Total:			18,330

> **Recommended Modifications**

Ameresco’s approach is to standardize the proposed lighting system, whenever practical. Recommended modifications include replacing high energy consuming fixtures with more efficient types where needed.



The proposed solution will help to reduce the energy and operational expense of the street lighting systems by replacing the existing street lighting with new LED technology for the cobrahead, pendant and shoebox fixtures.

A roadway classification and pole spacing analysis was performed for proper fixture selections to safely light the City of Tucson roadways per the RP-8-14 Roadway Lighting Guidelines. Highway functional classification groups were identified as Major, Collector and Local roadways based on the U.S. Department of Transportation, Federal Highway Classification, 2013 edition as approved by the City of Tucson. To address areas of uncertainty in roadway classification overlap, the City of Tucson Department of Transportation approved an Annual Average Daily Traffic (AADT) volume count of 6,300 as the cutoff point or tie-breaker between Major and Collector roadway classifications. All other roadways with AADT volume counts below 1,100 were considered Local roadways, typically residential areas. All other things being equal, the roadway with the higher AADT would generally be given the higher classification.

Functional classification groups were split into sub-categories based on road width (lane numeration) and then evaluated together with pole location and lane feature attributes. The sub-category analysis included various pole locations: one-side, staggered, opposite, or median mounted configurations, with or without turning lanes and bike path lane features. Table D.2 on the following page summarizes the roadway classification used as part of the Investment Grade Audit.

Table D.2. Roadway Classification

Sub-Category	Intersection	Roadway Classification	Number of Lanes ⁽¹⁾	Pole Location	Pole Spacing (ft)	Lane Feature ⁽²⁾
1	No	Local	1	One-Side	0 - 184	No
2	No	Local	1	One-Side	185-1000	Yes
3	No	Collector	1	One-Side	<125	No
4	No	Collector	1	One-Side	126>	Yes
5	No	Collector	2	Staggered	0 - 1000	Yes
6	No	Major	1	One-Side	0 - 1000	Yes
7	No	Major	1	Staggered	0 - 1000	Yes
8	No	Major	2	One-Side	0 - 1000	Yes
9	No	Major	2	Staggered	0 - 1000	Yes
10	No	Major	2	Opposite	0 - 1000	Yes
11	No	Major	3	Staggered	<193	Yes
12	No	Major	3	Staggered	194>	Yes
13	Yes	Major	3	Median Mounted	0 - 1000	Yes
14	Yes	Collector	2	4 Lights/Intersection	60-80	Yes
15	Yes	Major	3, 4	6-8 Lights/Intersection	80-150	Yes

(1) denotes number of travel lanes in one direction, e.g. one (1) lane of travel represents a two-way street with opposing traffic

(2) represents any number of features in a particular roadway configuration such as a median, bike path, or turning lane

Assumptions:

1. Only fixtures being converted on intersections are cobrahead fixtures; it was assumed that all fixtures on intersections are cobraheads
2. All locals are 1 lane (two-way streets with opposing traffic) and one-side pole configuration
3. All 1 lane collectors are one-side pole configurations
4. All 4 lane roads are staggered pole configurations
5. All majors have a lane feature
6. Intersection lighting is only collector/collector, collector/major, major/major
7. Local/local, local/collector and local/major are not considered intersections

Sample areas were selected to represent each of the sub-categories shown in Table D.2, based on the roadway classification pole spacing analysis. Table D.3 provides a listing of sample area locations representative of each roadway category.

Table D.3. Sample Area Locations

Sub-Category	Sample Area Locations of Typical Straight Road Lighting
1	168 N Carolina Avenue
2	1231 N Palo Verde Boulevard
3	818 N Anita Avenue
4	6962 E Stella Road
5	8859 E Old Vail Road
6	5742 E 29th Street
7	111 W Drachman Street
8	1115 E Grant Road
9	Alvernon (from Broadway to Speedway)
10	S 6th Avenue at W Veterans Boulevard (3538 I-19BUS)
11	6150 E Grant Road/Broadway (C.Club/Alvernon)
12	8778 E Golf Links Road
13	Speedway (from Alvernon to Willmot)
14	E. Grant Road and N Tucson Boulevard Intersection
15	Tanque Verde\Grant-Knob Intersection

The roadway configurations were field measured for each sample area location above and used as the basis of the photometric analysis to select the new fixtures. The following Figure D.0.Sample Checklist and Figure D.1.Photometric Analysis is an actual example of Sample Area 12 of a Major roadway analysis fixture selection. Reference appendices for a complete list of all Sample Area Checklists and Photometric Fixture Analysis developed for the purpose of this Investment Grade Audit.

SAMPLE AREA 12 8778 E. GOLF LINKS RD SITE PARAMETERS		
* ROADWAY DATA:	Dimension units (Check one).	<input checked="" type="checkbox"/> Feet <input type="checkbox"/> Meters
	Number of travel lanes "right side"	3
	Width of "right side" travel lanes	12
	Median width	20
	Number of travel lanes "left side"	3
	Width of "left side" travel lanes	12
	Shoulder and gutter width "right" side: (Distance from edge of drive lane to edge of pavement or curb)	5 (Bike Path)
	Shoulder width "left" side : (Distance from edge of drive lane to edge of pavement or curb)	5 (Bike Path)
	Pavement Type (Most typical Asphalt is R3, Most typical Concrete is R1)	R3
SIDEWALK DATA:	Sidewalk width	6
	Near edge of sidewalk to edge of drive lanes	2
* LIGHT POLE DATA:	Luminaire mounting height	35
	Arm length, horizontal	18
	Luminaires per pole	1
	Pole set-back from travel lane (The distance from near edge of travel lane to pole center. Include shoulder and rain gutter)	15
	Pole spacing (For staggered spacing: the distance along the road between the pole on the "right" side to the pole on the "left" side)	211 AVG (207-215)
	Pole Layout	<input type="checkbox"/> One side <input type="checkbox"/> Opposite <input checked="" type="checkbox"/> Staggered <input type="checkbox"/> Median Mounted

Figure D.0. Sample Checklist

Visual - Roadway Tool

www.Visual-3D.com 

Design Information

Project Name MAJOR FAR - 3 Golf Links Rd. (Heartstone)
 Project Description ATBM E R3

User Name
 Company Name
 Your Phone
 Your Email

Wednesday, September 23, 2015
 JOHN CARATOZZOLO

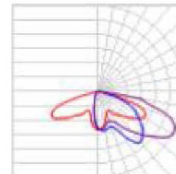
Roadway

Calculation Method	RP-8-2000 2007 errata	Median		
Road Surface	R3	Width	20 ft	
Road Class	Major	Sidewalk		
Pedestrians	Low	Width	Left: 0 ft	Right: 0 ft
Roadway Length	1,000 (9 Pole Locations)	Setback	Left: 0 ft	Right: 0 ft
Lane Quantity	Left: 3 Right: 3	Bikelane		
Lane Width	Left: 12 ft Right: 12 ft	Width	Left: 5 ft	Right: 5 ft
		Setback	Left: 0 ft	Right: 0 ft

Luminaire Information

Left Side - American Electric Lighting:

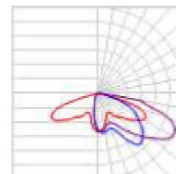
Cycle Spacing:	223.19 ft	Configuration:	Single
Setback:	15 ft	Arm Length:	18 ft
Orientation:	90	Tilt:	0
Mounting Height:	35 ft	Lamp Lumens:	13416
Staggered:	False	Wattage:	115
Light Loss Factor:	0.74	Lamp Count:	1



■ - 0° H ■ - 90° H
 ■ - Max Cd: 67.5° H

Right Side - American Electric Lighting:

Cycle Spacing:	223.19 ft	Configuration:	Single
Setback:	15 ft	Arm Length:	18 ft
Orientation:	270	Tilt:	0
Mounting Height:	35 ft	Lamp Lumens:	13416
Staggered:	True	Wattage:	115
Light Loss Factor:	0.74	Lamp Count:	1



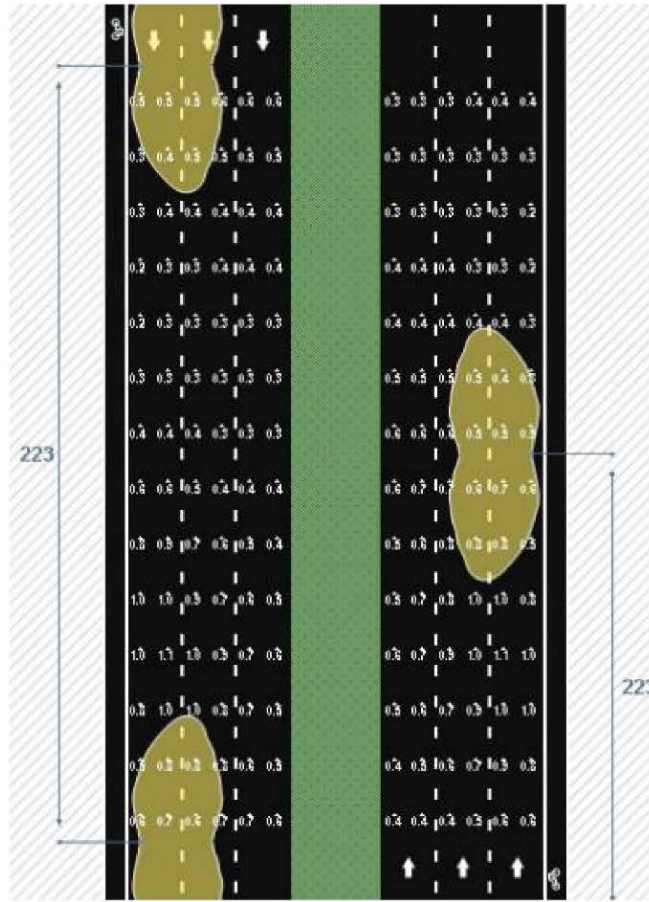
■ - 0° H ■ - 90° H
 ■ - Max Cd: 67.5° H

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Figure D.1. Photometric Analysis View 1

Visual - Roadway Tool



Luminance

Calculation Results

Luminance	Left	Right	Illuminance	Left	Right	Sidewalk	Left	Right		
Average:	0.6	0.6	cd/m ²	Average:	0.8	0.8	fc	--	--	fc
Max:	1.1	1.1	cd/m ²	Max:	1.8	1.8	fc	--	--	fc
Min:	0.2	0.2	cd/m ²	Min:	0.2	0.2	fc	--	--	fc
Ave/Min:	2.4	2.4		Ave/Min:	4.2	4.2		--	--	fc
Max/Min:	5	5		Max/Min:	9.6	9.6				
Lv Ratio:	0.2	0.2								
STV:	3.1	3.1								
						Bikelane				
						Average:	0.4	0.4		fc
						Min:	0.2	0.1		fc
						Ave/Min:	2.9	2.9		
						Ev Min:	0.1	0.1		fc

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Figure D.2. Photometric Analysis View 2

The following table represents a total of 18,330 new roadway fixture selections based on the roadway pole spacing analysis previously described for ECM 1. The cobrahead fixtures (17,557) comprise the largest number of fixtures in the project which are typically found on straight sections of roadways and intersections. The shoebox and pendant fixtures are typically found in the general downtown area on roadways and intersections.

All of the fixtures proposed in this project will be in the 3000K or less color temperature range and compliant with the Dark Skies Association guidelines. See Table D.4. Proposed Fixtures for a complete list of the new fixture selections proposed for ECM 1.

Table D.4. Proposed Fixtures

New Fixture	Model	Count
ATB2_60BLEDE85_480	Cobrahead	359
ATB2_60BLEDE85_MVOLT	Cobrahead	473
ATBM D R3	Cobrahead	10,441
ATBM E R3	Cobrahead	1,309
ATBS E R2	Cobrahead	3,153
ATBS F R3	Cobrahead	326
ATBS H R2	Cobrahead	1,153
ATBM E R3	Cobrahead – Future Construction	189
ATBM D R3	Cobrahead – McGraw Edison	154
GELF2 105 3K	Pendant – Bell 400	39
GBLF2 RETRO	Pendant – Bell Scott 85	106
GELF2 105 3K	Pendant – SC 400	51
GELF2 105 3K	Pendant – SC 400 Cushing	36
GSLF2 053 3K	Pendant – SC 70	45
GSLF2 053 3K	Pendant – SC 70 Cushing	41
ATB0 20BLED10	Shoebox	22
ATB2 40BLED10	Shoebox	332
ATB2 60BLED10	Shoebox	101
Total:		18,330

Fixtures identified as “Cobrahead – Future” in Table D.1 and Table D.4, have been selected to meet future roadway lighting requirements at the following construction project sites:

Table D.5. Future Roadway Requirements

Project No.	Construction Project Location	Current Roadway Classification	Future Roadway Classification
1	22 nd Segmental Bridge: Tucson to Kino, 3 Lanes in Each Direction	Major 2 Lane	Major 3 Lane
2	Broadway, Camino Seco to Houghton: Widen to 2 Lanes in Each Direction (LED Lighting Included in Design of Scope)	Major 2 Lane	Major 3 Lane
3	Broadway, Euclid to Country Club: Widen to 3 Lanes in Each Direction	Major 2 Lane	Major 3 Lane
4	Grant Road, Phases 3 & 4: Alvernon to Swan: Widen to 3 Lanes in Each Direction, Does Not Include Swan Intersection and Alvernon to Palo Verde	Major 2 Lane	Major 3 Lane
5	Grant Road, Phases 5 & 6: Campbell to County Club;: Widen to 3 Lanes in Each Direction (Construction Planned for 2021-2023)	Major 2 Lane	Major 3 Lane
6	Houghton Road: 22 nd to Irvington: Widen to 3 Lanes in Each Direction; Existing Luminaries at Signalized Intersections Only	Major 2 Lane	Major 3 Lane
7	Houghton Road, Valencia to MAC Way: Widen to 3 Lanes in Each Direction; Existing Luminaries at Signalized Intersections Only	Major 2 Lane	Major 3 Lane
8	Kolb Road, Irvington To Valencia: Widen To 3 Lanes In Each Direction	Major 2 Lane	Major 3 Lane
9	Silverbell Phase 2, Goret to El Camino Del Cerro: Widen to 2 Lanes in Each Direction (LED Lighting Included in Design Scope)	Major 1 Lane	Major 2 Lane
10	Valencia, Kolb to Houghton: Widen to 2 Lanes in Each Direction; Existing Luminaries at Signalized Intersections Only	Major 1 Lane	Major 2 Lane

> **Detailed Project Scope**

The ECM 1 scope of work includes the upgrade of 18,330 street light fixtures located throughout the City of Tucson proper. This measure will include the installation of the new fixtures, lamps, mast arms, boots, saddles, and kits needed for a complete project.

The detailed fixture-by-fixture audit of the City’s street light system will be utilized to coordinate the installation of the new fixture. Installation crews will use Trimble (or similar) handhelds and tablets to access the GIS mapping system in the field and to gather information on the existing luminaire, location and new fixture model number for each street light for all City-owned street lights.

The project scope of work includes:

- Surveying the existing street light fixtures for pre-existing damage to the street light pole, mast arm, mounting hardware and wiring
- Reporting any pre-existing damage to the City of Tucson for correction
- Cleaning work area and disposing of any construction debris and removing debris from site
- Complying with applicable local, state and federal codes at the point of installation of new fixtures
- Identifying light to meter/power drop association

Exclusions to the scope of work include:

- Replacing any fixtures due to pole knock down
- Sampling, testing or removing asbestos, lead or other hazardous materials
- Repairing existing damaged or faulty electrical equipment and wiring
- Upgrading electrical distribution system to meet current electrical codes
- Creating, stamping and signing engineering plans and specifications

Ameresco has included lamp and ballast recycling and disposal in the project scope of work. Recycling certificates will be provided to the City of Tucson for all recycled material. PCB ballasts will be disposed of using the appropriate containers and hazardous material handling procedures.

Energy – Roadway Fixture Upgrade Calculations

Detailed calculations for baseline and energy savings for this ECM are provided in Appendices D.1 and D.2. Energy savings for the retrofits are determined by comparing the baseline existing energy consumption (kWh) with the proposed energy consumption (kWh). Total cost savings from the street light fixture upgrade is limited to energy consumption reductions only. No demand savings are claimed since the street lights are operated at off-peak times nor included as a rate tariff.

$$\text{Electricity Savings} = \text{Lighting kWh Savings}$$

$$\text{Lighting kWh Savings} = \text{Base Lighting kWh} - \text{Post Lighting kWh}$$

$$\text{Base Lighting kWh} = \text{Base Light kW} \times \text{Hours}$$

$$\text{Post Lighting kWh} = \text{Post Light kW} \times \text{Hours}$$

Existing energy usage for lighting is calculated from the number of existing street light fixtures and their rated wattages. Existing operating hours of the fixtures were determined based on staff interviews. A summary of lighting run hours by fixture type is presented in the M&V Plan.

Roadway Lighting Control

> General Description

Ameresco proposes to replace the existing street lights with new light emitting diode (LED) fixtures as described in the Roadway Lighting section above. In addition, a new wireless control system will be installed that will allow the City to monitor street light assets, quickly identify luminaires that have failed or are not operating within normal parameters, monitor power consumption at the fixture level, and control lights individually or in groups for on/off or dimming (on/off can also be controlled by the on-board photocell). Dimming options range from dusk and dawn trimming (raising and lowering light output gradually at dusk and dawn) to utilizing the USDOT's "Guidelines for the Implementation of Reduced Lighting on Roadways" for dimming lights at different times of day.

Existing Conditions

The City of Tucson currently controls street lighting with a combination of photocell and shorting caps. A single photocell may control multiple fixtures by activating a contactor that will operate all of the luminaires connected to that circuit. This system provides adequate control for operating the fixture as the sun rises and sets, but it does not let the City operators know when a fixture fails. It also does not provide energy consumption history or tracking capabilities that could be used to identify anomalies in the street lighting system.

> Recommended Modifications

Ameresco recommends standardizing the street lighting with high efficiency light emitting diode (LED) fixtures and the installation of a wireless control system. The Remote Operations Asset Management (ROAM) system produced by Acuity Brands meets all of the specifications outlined by the City of Tucson and will provide monitoring and control capabilities that will alert City staff to failed or failing fixtures, provide on/off and dimming capabilities (scheduled and ad hoc), and provide revenue grade energy consumption metering.

The ROAM Monitoring and Control system offers the City of Tucson the opportunity to wirelessly monitor and control their lighting system. The system is comprised of modules (nodes) that are attached to the ANSI 5- or 7-pin receptacle on the luminaire, which communicate with each other and with gateways to form a robust mesh network capable of bi-directionally transmitting the large quantities of data required for monitoring and controlling lighting system assets. Data from the gateways is transmitted to the Central Management System via a variety of backhaul options (wired, cellular, etc.) where the customer portal will be hosted by the City of Tucson.

> Detailed Project Scope

The scope of work for this Investment Grade Audit is based on the Remote Operations Asset Management (ROAM) system produced by Acuity Brands. There will be approximately 17,500 nodes installed communicating through 12 gateways to the ROAM system located at the City of Tucson Information Technology (IT) center. The roadway and intersection lighting fixtures will be set at an initial output level at 90% of the wattage output and fine-tuned for proper lighting levels once the ROAM system is installed and commissioned. The initial lighting levels will be held at this level from dusk to midnight. From midnight to dawn, the typical roadway lighting wattage will be reduced by 30% using the ROAM dimming strategy. In areas identified as high pedestrian areas, the roadway lighting wattage will be dimmed by 30% from 3 AM to dawn. The intersection lighting will be held to the initial 90% lighting levels described above and will not be dimmed. The dimming strategies described above are the basis of this ECM, however, additional energy savings may be achieved by the City of Tucson by fine tuning the lighting levels and periods of time upon the completion of the LED Lighting Conversion Project.

Hardware

The ROAM system consists of two types of hardware (See Technical Data Sheets for detailed Hardware Specifications):

- **Node:** *A wirelessly enabled bi-directional photocontrol that is backwards compatible with streetlights featuring a NEMA 5 or 7 Pin receptacle. We have included the 5-pin receptacle in our pricing however the City may wish to consider using the 7-pin receptacle to enable the future addition of motion or occupancy sensors inputs, temperature sensors or applications that can leverage the ROAM network infrastructure.*
- **Gateway:** *A network backhaul device that transmits data collected at the node to the ROAM Network Operations Center (NOC)*

A node resides on every luminaire that is to be monitored and controlled. Each node provides monitoring and control functions for the luminaire. The ROAM nodes are designed to be fixture agnostic, and can be installed on any fixture with a NEMA receptacle. ROAM currently offers several different types of nodes tailored for typical lighting applications. They include a “standard” node for 120V to 277V systems and a 480V node.

The ROAM nodes will integrate with the 0-10V dimming driver in the Autobahn luminaires via the ANSI C136.41 receptacle to provide dimming control.

The nodes form a very robust mesh network of devices. These devices communicate through the mesh network to a gateway. The gateway is the backhaul device that collects and transmits all data to and from each node to a Central Management System server where the customer portal will be hosted by

the City of Tucson. The ROAM gateway can be configured for several backhaul methods including cellular and Ethernet.

Network

Upon installation, ROAM nodes and gateways form a robust Wide Area Network (WAN) capable of managing large quantities of data. Each node automatically seeks to communicate with other nodes in order to deliver business critical data to a gateway. Gateways are pre-configured to connect to the central server, and no network configuration is required. The communication packets between the gateway and the central server are encrypted using the AES algorithm, which has been approved by the NSA and is used by the United States Government.

Each ROAM device uses IEEE 802.15.4 standard protocols at 2.4 GHz to form a self-routing, self-healing mesh network with a device to device baud rate of 250kbits. Current deployments have demonstrated device to gateway ratios of 2000 to 1, with emergency capacity capabilities of 5000 to 1. Communication packets within the mesh consist of custom data structures that use an encryption scheme based on the 3DES algorithm.

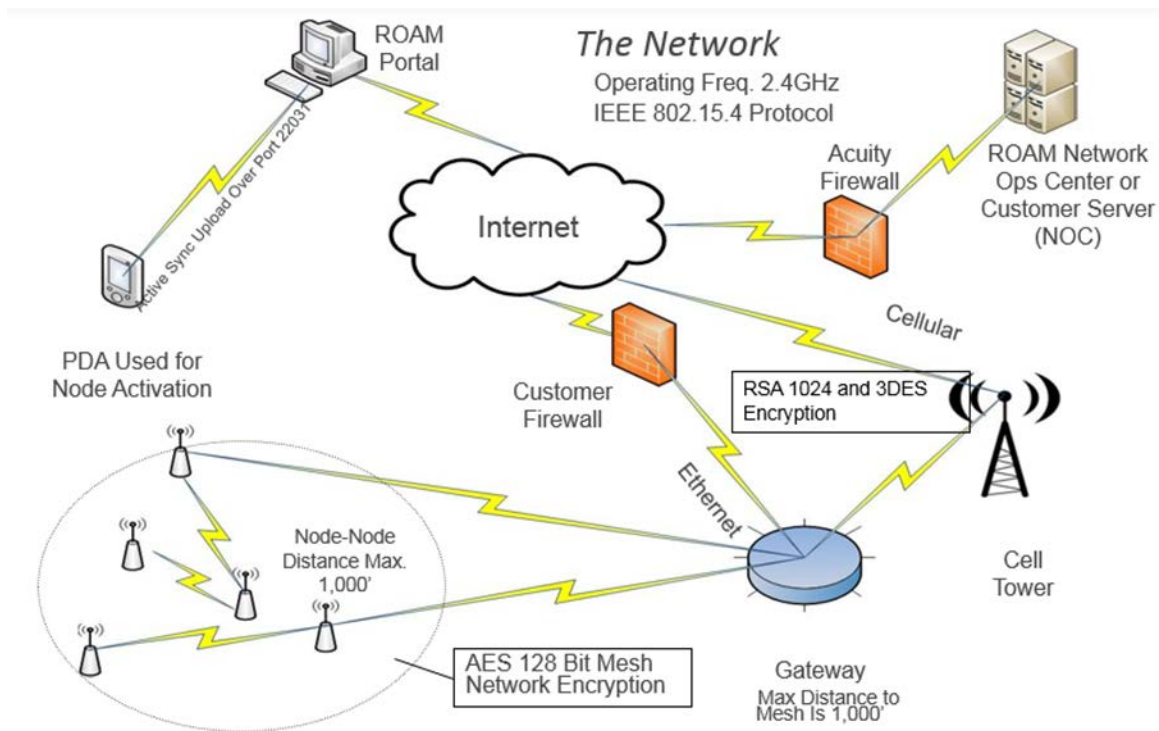


Figure D.3. ROAM Network

Most routing decisions are made at the node level, making the network extremely durable. The time to network restoration after a power outage is generally less than one minute. Immediate commands sent from the ROAM web portal to any device in the field should take no more than 10 seconds.

The network uses two types of messages within the system; standard application data and message alarms. The standard application data propagates through the system on a set interval. These messages include all monitored data (such a power, voltage, operational status, etc.). Reporting intervals for all devices are adjustable. Message alarms are high priority messages that contain critical information (such as over current, over voltage, under voltage, etc.). Alarms propagate through the system in near real time. Command control messages are a type of alarm and also propagate though the system in near real time. All alarms can be set up to communicate with users via email, XML, pager, etc.

ROAM Customer Portal

ROAM nodes are designed to provide security based operation in the event of network failure. If a device is on a schedule and a network failure occurs, the device will continue to execute the schedule. This is possible because each node has an internal clock. A node does experience drift over time (seconds per month) without connection to the network. Since the ROAM system reports non-communicating devices, such outages can be addressed well before any significant drift occurs. In the event of a system wide power outage resulting in a ROAM network outage, every ROAM node will operate as a photocontrol until it re-joins the network and obtains the NTP time stamp. Once a node has a time stamp, any schedule that may have been set will automatically be executed.

The ROAM hardware and network are scalable and can be expanded to work with over 50,000 devices.

The ROAM Portal gives lighting system operators the capability to wirelessly monitor and control their lighting system assets. The portal has been designed for ease of navigation and use while providing for maximum flexibility, operational input and control to the user. ROAM Enterprise shall be a Customer hosted web based system with upgrades and technical support provided for an optional fee.

Information on the portal is displayed using the following views:

- Dashboard
- Reporting
- Grouping
- Work Order Management
- Maps
- History
- Scheduling

> **Dashboard**

The Dashboard view provides the user with a summary level report that shows the status of all of the installed remote monitoring devices. The user is able to quickly determine the operational status of all lighting system assets, particularly those operating outside of “normal operating parameters”.

This view is intended to be an executive level report that can be exported or printed for presentation. Users are also able to interact with the screen and request additional details about the luminaries that are not operating correctly. This information includes basic details about the device, its location, and a seven day history of its activity. Users with the appropriate permission can also create work orders from this screen.

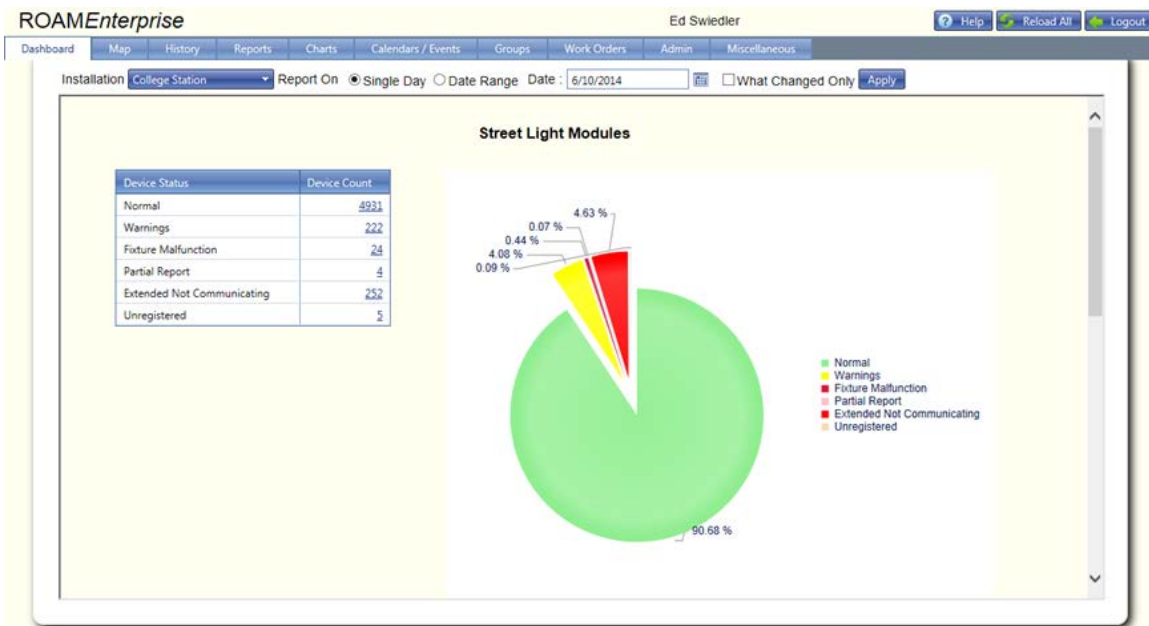


Figure D.4. ROAM Enterprise Customer Portal Dashboard

> **Maps**

The Map view provides a geographical representation of lighting system assets. Map images are provided by a mapping service that is running within the ROAM NOC and licensed from Google. The user is able to navigate around the map by panning, zooming and using predefined bookmarks to quickly locate their subject assets. The user is able to quickly determine which luminaires are operating normally and which ones are not based on icons used to represent each fixture. Annual fees for Google mapping updates for the user hosted system are the responsibility of the end-user.

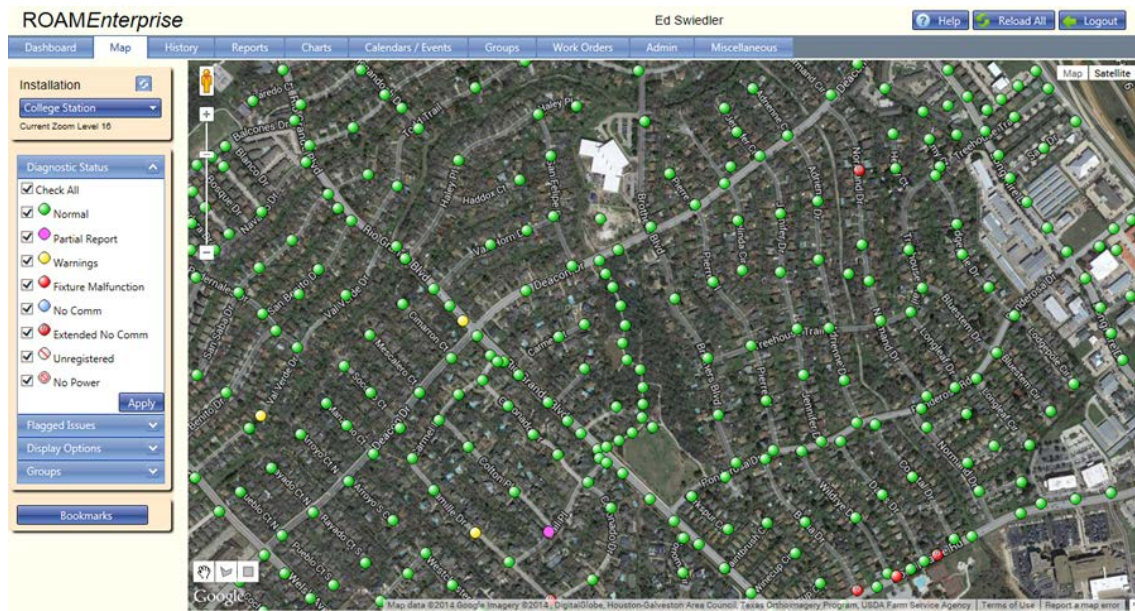


Figure D.5. ROAM Enterprise Customer Portal Map

By placing the mouse over a specific fixture, the user will view asset attributes as well as any additional detail pertaining to its operating status.

Depending on the permission granted to the user, they may be able to perform additional actions from the mapping screen, such as: Relocating a fixture, adding and viewing notes about a fixture, viewing and editing the attributes collected about the fixture during activation, issuing immediate commands to the fixture and creating work orders. Users that have the appropriate permissions are able to issue the following immediate commands:

- Turn On
- Turn Off
- Return-to-Normal Operation (photocontrol)
- Dim

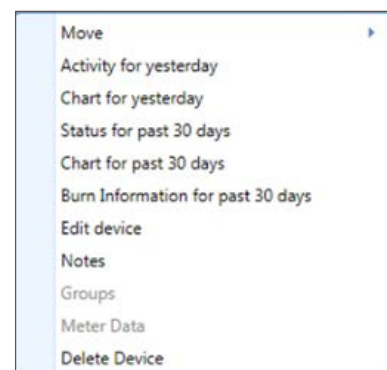


Figure D.6. ROAM Enterprise Customer Portal Map Menu

When issuing a Turn On or Turn Off command the user is required to enter time duration, not to exceed a single day. When issuing a Dimming command, the user must enter both time duration and dimming level (0-100). These commands are immediately issued to the device and the result of these commands can be viewed from the portal. Regardless of other permissions granted, all users have read only access to the information on the portal.

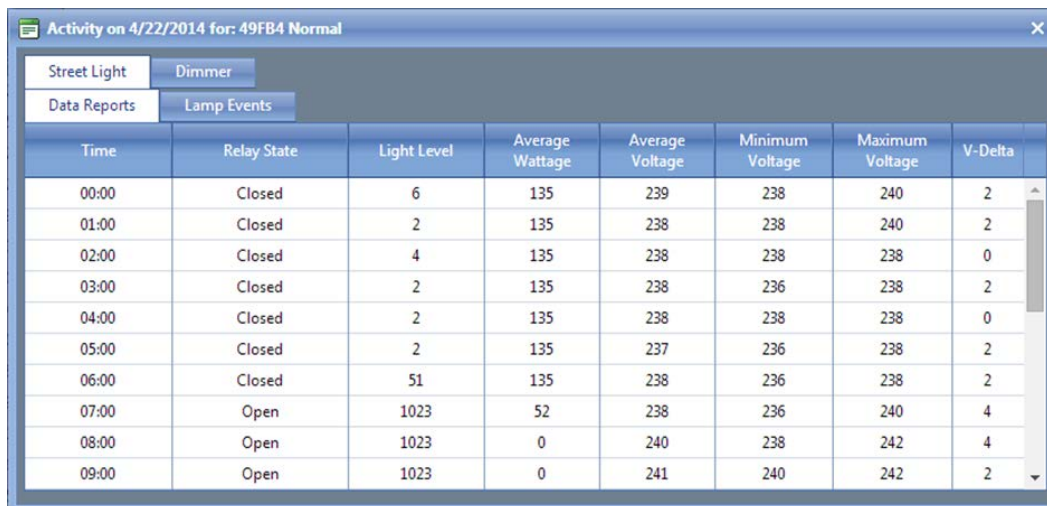
> **History**

The History view provides a user the ability to see the operational history of the luminaires over either a seven day or thirty day time frame. The user has access to multiple filters which allow them to focus on specific assets and operational conditions. From this screen, the user will be able to drill down into the data for any day and see the hourly data collected from the device in report or graphical format. Users with the appropriate permissions have the ability to create work orders from this screen as well.



Mac Id	Pole	Latitude	Longitude	Street Address	W/O	Lamp Type	4/16	4/17	4/18	4/19	4/20	4/21	4/22
483A6	16	32.61927	-117.00282	Heritage Rd	No	LED-140	134	133	133	160	133	133	
49FB4	8	32.62250	-117.00581	Heritage Rd	No	LED-140	135	135	134	134	135	135	135
49FBD	13	32.62025	-117.00360	Heritage Rd	No	LED-140	135	135	135	135	135	135	135
49FBF	18	32.62028	-117.00356	Heritage Rd	No	LED-140	135	135	134	134	134	134	134
49FC5	7	32.62299	-117.00628	Heritage Rd	No	LED-140	134	134	134	134	134	134	134
49FDO	1	32.62074	-117.00378	Heritage Rd	No	LED-140	138	138	149	138	138	138	138
49FDS	9	32.62204	-117.00535	Heritage Rd	No	LED-140	134	133	133	133	133	133	133
49FD9	3	32.62147	-117.00457	Heritage Rd	No	LED-140	138	139	138	138	139	139	139
49FDA	6	32.62302	-117.00624	Heritage Rd	No	LED-140	134	134	143	134	134	134	134
49FDC	17	32.61985	-117.00322	Heritage Rd	No	LED-140	137	137	136	137	136	136	136
49FE6	12	32.62092	-117.00441	Heritage Rd	No	LED-140	136	136	136	136	136	136	136
49FE9	11	32.62117	-117.00482	1267-1273 E Palomar St	No	LED-140	136	136	136	136	162	136	136
49FF2	10	32.62161	-117.00515	Heritage Rd	No	LED-140	134	133	133	133	133	134	134
49FF3	5	32.62253	-117.00576	Heritage Rd	No	LED-140	135	135	135	134	135	135	135
4A02D	14	32.61982	-117.00327	Heritage Rd	No	LED-140	135	136	136	136	136	136	136

Figure D.7. ROAM Enterprise Customer Portal History View 1



Time	Relay State	Light Level	Average Wattage	Average Voltage	Minimum Voltage	Maximum Voltage	V-Delta
00:00	Closed	6	135	239	238	240	2
01:00	Closed	2	135	238	238	240	2
02:00	Closed	4	135	238	238	238	0
03:00	Closed	2	135	238	236	238	2
04:00	Closed	2	135	238	238	238	0
05:00	Closed	2	135	237	236	238	2
06:00	Closed	51	135	238	236	238	2
07:00	Open	1023	52	238	236	240	4
08:00	Open	1023	0	240	238	242	4
09:00	Open	1023	0	241	240	242	2

Figure D.8. ROAM Enterprise Customer Portal History View 2

> Reporting

The reporting view offers the user multiple reports and graphs that can be used to monitor the ROAM enabled luminaries. All reports use a common interface and can be easily exported to Excel, PDF or XML formats. Of particular interest is the Daily Status report. It gives permissioned users a high level of flexibility in viewing and managing their ROAM enabled luminaries through exportable reports. A user is able to interact with the devices listed on any of the reports to view additional details or to see the device on the map. Users with the appropriate permissions have the ability to create work orders from this screen as well.

Installation: College Station Month: April, 2014

Lamp Type	Wattage	Fixtures	Burn Hours	KWH
HPS	100	2,489	437,681.348	55,503.045
HPS	200	1,366	211,920.472	52,203.999
HPS	250	63	10,853.413	3,124.771
HPS	400	888	120,321.210	51,683.741
IND	70	1	0.000	0.000
IND	100	1	179.567	25.666
LED	40	1	176.567	20.524
LED	50	3	533.700	37.003
LED	70	33	7,648.510	469.164
LED	80	1	365.517	15.010
LED	100	1	175.433	25.195
LED	150	9	1,609.614	259.084
LED	250	108	14,564.122	3,757.088
MH	70	3	465.000	42.393
MH	100	409	76,131.297	9,422.604
		5,438	890,146.316	178,669.970

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Export to Excel

Figure D.9. ROAM Enterprise Customer Portal Reporting

> Grouping

The ROAM Portal also includes a grouping feature which allows a user to define a subset of remote devices and store them under a named group. Information about the status of the devices within a group is presented in a format similar to the Dashboard view. Users are able to add and remove devices from a group as needed. These groups may be used in various other ways throughout the ROAM system, such as:

- Report and historical data filters
- Creation of schedules and events
- Issuing immediate commands

ROAMEnterprise Ed Swiedler

Dashboard Map History Reports Charts Calendars / Events Groups Work Orders Admin Miscellaneous

List Dashboard History Commands Scheduling

Installation: College Station

Add Group Refresh

Name	Visible	Priority
Intersection Lights	Yes	100
Overpasses	Yes	50
Stadium Area	Yes	100
Market District	Yes	115

Page size: 50 4 items in 1 pages

Figure D.10. ROAM Enterprise Customer Portal Grouping

> Scheduling

The ROAM Portal also provides for the scheduling of commands to be issued to the remotely controlled devices. A user is able to define and issue both a schedule (covering one or more weeks), as well as events (covering one or more days, consecutive or otherwise). Both schedules and events are issued to groups that have been defined on the Grouping screen. Schedules allow the user to define four time intervals each day to affect the operational status of the device. The user also has the ability to set time intervals based on sunrise and sunset offsets to assist with energy savings. Events are used when there is a need to exercise more control for a specific date or a recurring event. In this case, the user is able to select up to 8 specific times to affect the operational status of the device. In order of priority, an Event will always take priority over a Schedule so it is possible to have both a Schedule and an Event on the same date.

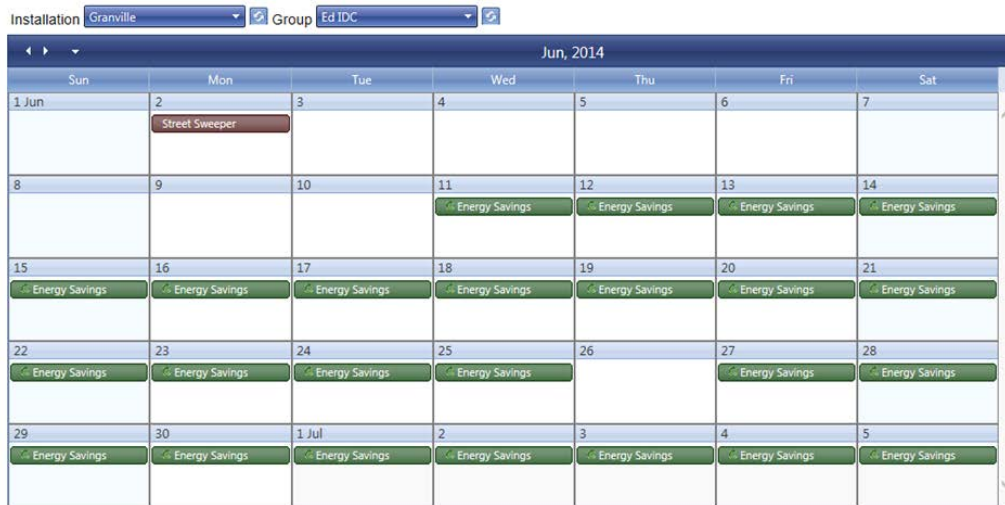


Figure D.11. ROAM Enterprise Customer Portal Scheduling View 1

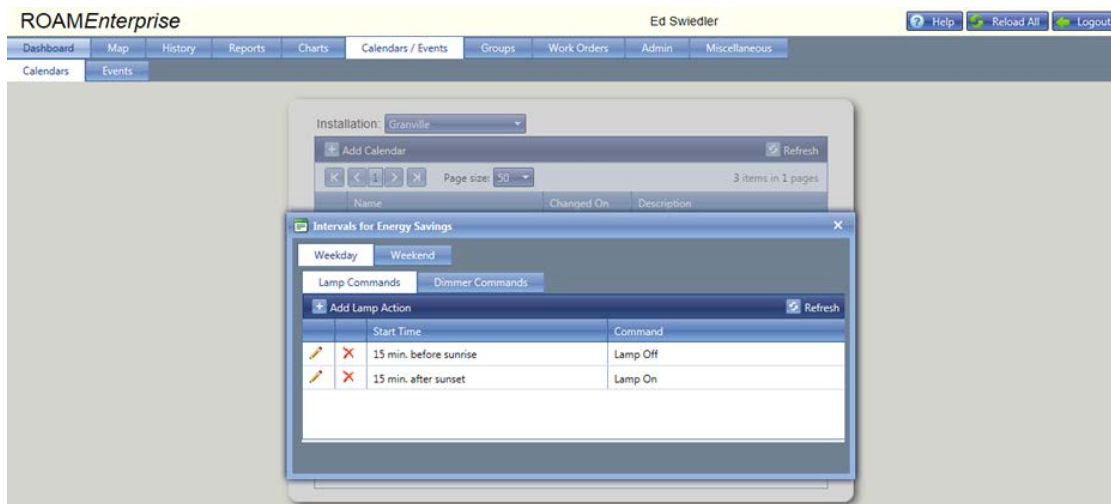


Figure D.12. ROAM Enterprise Customer Portal Scheduling View 2

> Work Order Management

The ROAM portal contains a full-featured Work Order Management module that enables users to create work orders for specific fixtures. Use of this module helps to drive asset performance, reduce repair time, and improve customer satisfaction levels of citizens. ROAM's Work Order Management Module includes the following key features:

- Create work orders from virtually any screen on the portal
- Assign work directly to crews or to crew coordinators
- User-definable repair procedures
- Record and track parts used in repairs
- Track repair dates
- Work orders are printed and can then be completed using bar codes and/or touch screen entry on the handheld
- Work orders can be exported in XML format so they can be integrated into other software applications
- Work order tickets provide operating details to assist field performers in troubleshooting
- System verification and completion of work orders



Figure D.13. ROAM Enterprise Customer Portal Work Order Management Module

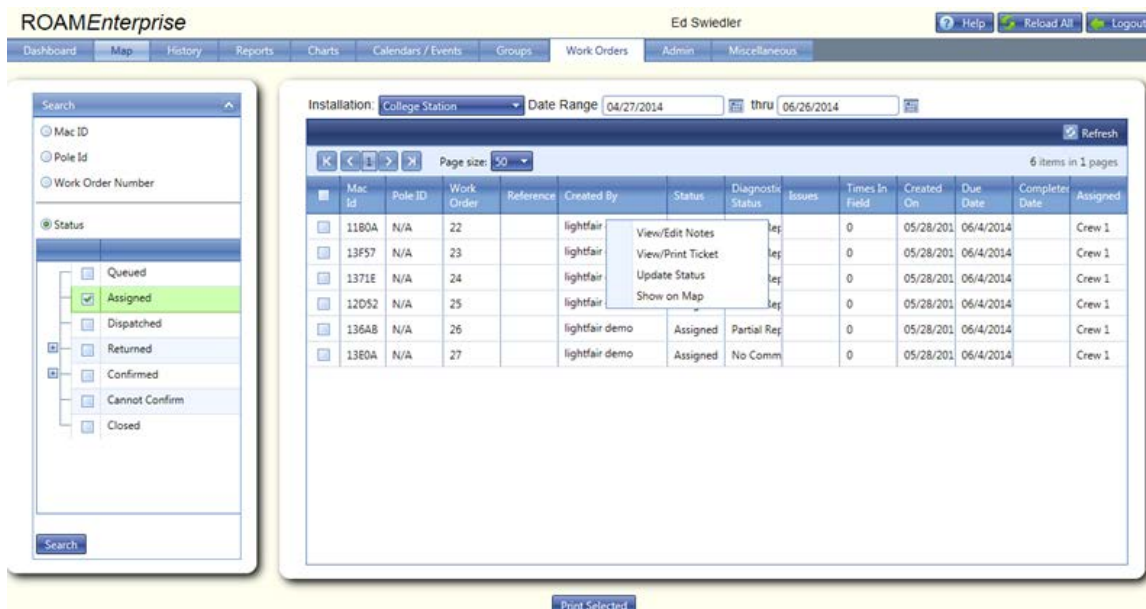


Figure D.14. ROAM Enterprise Customer Portal Work Order Management Module

> Monitoring, Reporting and Diagnostics

ROAM diagnoses the operational status of each fixture based on a 24 hour duty cycle. The following operational characteristics are diagnosed and reported through the ROAM Portal:

Remote Monitoring and Diagnostics

- Fixture Malfunction
- Cycling
- Day-Burner
- Unspecified Malfunction
 - No Communication
 - No Power
- Low System Voltage
- High System Voltage
- High V Delta
- Low Wattage
- Excessive Power Use
- Fixture on a Group Control
- 120V PC on a 240V Fixture
- Power Factor

Reports

- Fixture Status
- Average, Max and Min Power for Each Reporting Interval (typically 1 hour)
- Energy Tracking (KWH reports)
- Burn Hour Report
- Average Line Voltage
- Minimum Line Voltage
- Maximum Line Voltage
- Light Sensor Reading

Events/Alerts

- On/Off Transition Alerts
- Low Voltage Alert (<103V)
- High Voltage Alert (>305V)
- Excessive Current Alert (>14A)
- Improperly Wired Fixture

Arrangements with Fixture Manufacturers

ROAM nodes are compatible with any fixture equipped with an external locking photocontrol receptacle. No special arrangements are necessary to accommodate ROAM nodes and gateways and the equipment is compatible with all fixture types. For dimming applications, ROAM Integral Dimming Control Nodes can be utilized if the fixtures include an ANSI C136.41 receptacle. Otherwise, Dimming Control Modules must be installed inside of the fixture and therefore must fit within the space limitations of a particular fixture. Ameresco's recommendations and pricing include provision of the ROAM Integral Dimming Control Nodes and ANSI C136.41 5-in receptacle.

System Upgrades

Upgrades to the ROAM customer portal, nodes and gateways occur periodically and are intended to improve the functionality and robustness of the system. For the user hosted ROAM Enterprise system, Ameresco has recommended portal upgrades that can be purchased from ROAM on a version specific basis. If necessary, any node and gateway firmware updates can be performed over the air, through a ROAM provided executable file that the end-user can run to perform the upgrade.

Password Administration

Access to various portal functions is controlled by user ID permission levels for the ROAM Enterprise system. The customer is responsible for password administration.

ROAM Installation and Activation Process

The ROAM installation and activation process is a simple, flexible, highly automated and patented process that uses touchscreen technology, along with a barcode scanner, to efficiently capture field data. Asset attributes options such as fixture type, lamp type and wattage, fixture manufacturer, pole type and material, and system voltage are set up in the portal and then exported into a handheld device. The handheld device allows for easy and accurate data capture such as, pole type, pole ID, pole location, fixture attributes, and controller data.



Prior to installing the ROAM node, the installer uses the barcode scanner on the handheld PDA and the loaded asset options to collect the location specific asset attributes. While the installer is collecting the attribute information, the built-in GPS device collects an accurate location of the asset. The attributes and GPS location form the basis of the asset management data base used in the ROAM customer portal and provide the customer with a complete audit of their lighting system.

Once all attributes and a GPS location are collected and stored on the PDA, the installer captures a unique identifier/barcode on the bottom of the ROAM node and replaces the existing photocontrol with that node. The node immediately initiates the monitoring process and begins looking for other nodes within the network to communicate with. The unique identification number is paired with the attribute data and GPS location to form the asset management record for that field asset. All data captured on the handheld PDA is then uploaded to ROAM Enterprise, processed and posted to the ROAM portal and becomes easily accessible to the customer.

The scope of this work includes the replacement of street light fixtures and lamps as needed for a complete project. A complete list of the lighting control project is provided within the appendices.

The project scope of work includes:

- Surveying the existing street light fixtures, poles and wiring for pre-existing damage
- Reporting any damage to the City of Tucson for correction
- Cleaning work areas and disposing of any construction debris
- Complying with applicable local, state and/or federal codes

Exclusions to the scope of work include:

- Repairing existing damaged or faulty electrical equipment and wiring
- Upgrading electrical distribution system required to meet current electrical codes
- Creating, stamping, and signing engineering plans and specifications

> **Energy – Control Upgrade Calculations**

Detailed calculations for energy and cost savings for this ECM are provided in Appendix D.1 and D.2. Energy savings for the retrofits are determined by comparing the baseline existing kWh with the proposed kWh. No demand savings is claimed because the lighting controls savings will not reduce operation during the time that the peak would be typically set.

$$\text{Electricity Savings} = \text{Lighting kWh Savings}$$

$$\text{Lighting kWh Savings} = \text{Post Light kW (from Roadway Light Upgrade)} \times (\text{Base Hours} - \text{Post Hours})$$

> **Energy Savings Proposed**

Ameresco performed detailed lighting calculations to determine the energy savings associated with the Roadway Lighting and Controls upgrade project. The energy savings will result from the operation of more efficient fixtures and dimming control. Direct electric savings are associated with the reduced lamp wattages and the ability to reduce lighting levels during periods of time when there is low pedestrian activity. Table D.6 summarizes the energy savings associated with the Roadway Lighting and Controls project.

Table D.6. Projected Annual Energy and Cost Savings for Roadway Street Lighting with Controls Upgrade

Annual Savings	Units
20,961,974	kWh
\$2,273,714	Utility Cost Savings

Interactions

Savings estimate for this ECM are based on the watt reduction of the lighting fixtures and reduction of energy consumption from the Roadway Lighting and Controls Upgrade. Other ECMs are not expected to interfere with the implementation or performance of this ECM.

Maintenance

While savings are expected to accrue due to the reductions in materials cost and staff hours associated with maintaining the system associated with the long life LEDs at the street light fixtures, no additional maintenance savings have been claimed for the Roadway Lighting and Controls upgrade.

> References

- Electric bills
- Survey data
- Lighting manufacturer catalogs
- Illuminating Engineering Society of North America (IES). Roadway Lighting - Recommended Practices and Guidelines: ANSI/IES RP-8-14
- U.S. Department of Energy (DOE). Advanced Lighting Guidelines. Report Number: DOE/EE-0008, 1993
- Illuminating Engineering Society of North America (IES). IES Lighting Handbook. New York, New York, 1999
- U.S. Department of Transportation (DOT), Federal Highway Administration (FHA). Highway Functional Classification Concepts, Criteria and Procedures, 2013 Edition

> Assumptions

Assumptions made in the development of this proposal include:

- The run hour assumptions for the various types of fixtures are presented in the M&V Plan
- The cost of the project does not include any repair or upgrades of existing electrical distribution systems that are not up to current codes
- All work surfaces are free of asbestos and other hazardous materials. The City of Tucson is responsible for any hazardous material abatement

> Utility Interruptions

Electricity interruption will be isolated to the area of work and its duration minimized through carefully planned installation phasing. Installation schedules will be coordinated with site personnel to minimize the impact on the disruption of street lighting and the flow of traffic.

> Other

Equipment Service Life

The equipment service life for the major components includes:

- Lighting fixtures – 20 years
- LEDs – 50,000 to 100,000 run hours

Warranty

Ameresco provides a 10-year warranty for materials and labor on failed fixtures and control components.

Interface with Existing Equipment

The upgrade of the existing fixtures will have a minimal impact on the architectural aesthetics in typical street lighting applications; Provisions have been made to maintain decorative lighting fixtures appearance. The new lighting system upgrade will reduce the demand and electrical consumption and all components thereof will be fully integrated into the existing lighting systems. Ameresco assumes that the entire Roadway Lighting and Controls system upgrade will comply with the latest codes, standards and local jurisdictions, as well as and other applicable recommend best practices universally accepted throughout the electrical industry. Further, we assume that all existing devices, which are defined in NEC, including, but not limited to fuses, switches, contactors, wiring, etc. are in acceptable condition in order to implement the scope as outlined in the contract documents. All existing junction boxes, pull boxes, underground wiring, street light poles, pole attachment and mounting surfaces, and structures are assumed to be in acceptable condition to allow the installation of the products indicated in the scope. Required upgrades to meet safety or other codes, and/or to prepare the location for the installation, as described above, can be performed on a time-and-material basis.

ECM 2: Decorative and Specialty Fixture Retrofits

> General Description

ECM 2 proposes to replace the existing decorative fixtures identified in the Investment Grade Audit with new light emitting diode (LED) technology throughout the entire City of Tucson proper. The proposed project upgrades the existing fixtures and will greatly enhance the quality, consistency and color rendering of the lighting system, thereby reducing the energy and operational expense of the street lighting systems.



This strategy will reduce overall electricity consumption of the lighting system throughout the City of Tucson. In addition, ECM 2 will reduce maintenance costs because of longer life of LED lighting as compared to the existing lighting. The LED retrofits come with a 5 year warranty and Ameresco will



repair or replace any that fail during the first 5 years of the financing term. The retrofit will also reduce the amount of sky glare generated by lighting and enable the City to better meet Dark Skies Association guidelines.

Existing Conditions

The City owns and maintains a variety of decorative and specialty fixture street lights. Most of the typical decorative lights are screw-in compact type fluorescent lamps and a few LEDs found in the globe, pendant, wall mount and postop fixtures. There are a number of specialty fixtures with high pressure (HPS) and low pressure sodium (LPS) lamps found in the postop, bollard, and radius tube fixtures. Table D.7 summarizes the lamp types and wattages evaluated in this Investment Grade Audit.

Table D.7. Existing Lighting Summary: Decorative and Specialty Fixtures

Model	Type	Wattage	Count
Decorative – Bollard	LPS	55	10
Decorative – Globe	FL	20	1,066
Decorative – Pendant Acorn	FL	20	60
Decorative – Pendant Acorn	LED	18	14
Decorative – Postop	HPS	100	268
Decorative – Postop Acorn 20	FL	20	294
Decorative – Radius Tube	HPS	150	8
Decorative – Wall Mount	FL	55	25
Total:			1,745

> Recommended Modifications

Ameresco's approach is to standardize the proposed lighting system, whenever practical. Recommended modifications include replacing high energy consuming fixtures with more efficient types where needed.

Ameresco proposes replacing the existing decorative street lighting one-for-one with new screw-in LED lamps. The proposed solution will help to reduce the energy and operational expense of the street lighting systems. This measure includes the replacement of the existing technology with LED for the globes, pendant, postop, wall mount and bollard fixtures.



> Detailed Project Scope

The scope of this work includes the upgrade of 1,745 decorative street light fixtures located in the downtown and midtown areas of the City of Tucson. This measure will include the installation of the new lamps, controls, and cleaning of fixture globes and lens for a complete project.

The detailed fixture-by-fixture audit of the City's street light system will be utilized to coordinate the installation of the new LED fixture lamps. Installation crews will use Trimble (or similar) handhelds and/or tablets to access the GIS mapping system in the field to access information on the existing luminaire, location and new fixture lamp for each street light for all City-owned street lights. The audit will also provide the opportunity to identify unique construction issues that may require extra materials or work. This data captured during the audit can also be used to update the City's street light inventory.

The project scope of work includes:

- Surveying the existing street light fixtures for pre-existing damage to the street light lens, pole, mast arm, mounting hardware and wiring
- Reporting any pre-existing damage to the City of Tucson for correction
- Cleaning work area and disposing of any construction debris and removing debris from site
- Complying with applicable local, state, and federal codes at the point of installation of new fixtures
- Identifying light to meter/power drop association
- Cleaning the inside and outside surfaces of the decorative light fixture globes

Exclusions to the scope of work include:

- Replacing any fixtures due to pole knock down
- Sampling, testing, or removing asbestos, lead or other hazardous materials

- Repairing existing damaged or faulty electrical equipment and wiring
- Upgrading electrical distribution system to meet current electrical codes
- Creating, stamping and signing engineering plans and specifications

Ameresco has included lamp and ballast recycling and disposal in the project scope of work. Recycling certificates will be provided to the City of Tucson for all recycled material. PCB ballasts will be disposed of using the appropriate containers and hazardous material handling procedures.

Energy – Decorative and Specialty Fixture Upgrade Calculations

Detailed calculations for baseline and energy savings for this ECM are provided in Appendix D.1 and D.2. Energy savings for the retrofits are determined by comparing the baseline existing energy consumption (kWh) with the proposed energy consumption (kWh). Total cost savings from the street light fixture upgrade is limited to energy consumption reductions only. No demand savings are claimed since the street lights are operated at off-peak times nor included as a rate tariff.

$$\text{Electricity Savings} = \text{Lighting kWh Savings}$$

$$\text{Lighting kWh Savings} = \text{Base Lighting kWh} - \text{Post Lighting kWh}$$

$$\text{Base Lighting kWh} = \text{Base Light kW} \times \text{Hours}$$

$$\text{Post Lighting kWh} = \text{Post Light kW} \times \text{Hours}$$

$$\text{Lighting kWh Controls Savings} = \text{Post Light kW} \times (\text{Base Hours} - \text{Post Hours})$$

Existing energy usage for lighting is calculated from the number of existing street light fixtures and their rated wattages. Existing operating hours of the fixtures were determined based on staff interviews. A summary of lighting run hours by fixture type is presented in the M&V Plan.

> Energy Savings Proposed

Ameresco performed detailed lighting calculations to determine the energy savings associated with ECM 2. The energy savings will result from the operation of more efficient fixtures and dimming control. Direct electric savings are associated with the reduced lamp wattages and the ability to reduce lighting levels during periods of time when there is low pedestrian activity. Table D.8 summarizes the energy savings associated with the Decorative and Specialty Fixture Retrofit project.

Table D.8. Projected Annual Energy and Cost Savings for Decorative and Specialty Fixture Retrofit with Controls Upgrade

Annual Savings	Units
160,234	kWh
\$16,726	Utility Cost Savings

ECM 3: Underpass Lighting

> General Description

ECM 3 proposes to replace the existing lighting identified in the Investment Grade Audit with new light emitting diode (LED) technology for six City of Tucson underpasses. The proposed project upgrades the existing fixtures and will greatly enhance the quality, consistency and color rendering of the lighting system, while meeting all applicable codes and standards, thereby reducing the energy and operational expense of the street lighting systems.



This strategy will reduce overall electricity consumption of the underpass lighting systems. In addition, ECM 3 will reduce maintenance costs because of longer life of LED lighting as compared to the existing lighting. The LED fixtures come with a 10 year warranty and Ameresco will repair or replace any warranty components that fail during the first 10 years of the financing term. The retrofit will also reduce the amount of sky glare generated by lighting and enable the City to better meet Dark Skies Association guidelines.

Existing Conditions

The majority of the underpass lights are wall packs. Table D.9 summarizes the lamp types, locations, counts and wattages evaluated in this investment Grade Audit.

Table D.9. Existing Lighting Summary: Underpass Lighting

Model	Type	Wattage	Count
Wall Pack	MH	70	63
Wall Pack	MH	150	37
Linear Fixtures	HPS	100	137
Wall Pack	HPS	150	37
Total:			325

> Recommended Modifications

Ameresco’s approach is to standardize the proposed lighting system, whenever practical. Recommended modifications include replacing high energy consuming fixtures with more efficient types where needed.



Ameresco proposes replacing the existing wall pack and linear tunnel underpass lighting fixtures with new LED fixtures. The proposed solution will help to reduce the energy and operational expense of the street lighting systems.

> Detailed Project Scope

The scope of this work includes the upgrade of 325 underpass light fixtures throughout the City of Tucson at the following locations:

Table D.10. Underpass Fixture Locations

Underpass Location
4th Avenue at RR
N Stone at RR
W Speedway Turn Around at RR (east)
W Speedway Turn Around at RR (west)
W Grant at I-10
W Grant at RR
W Speedway at I-10
W St. Marys at I-10
W Congress at I-10
Cushing at I-10
Cushing at I-10
Starr Pass at I-10
W 29th Road (W Silverlake) at I-10
S Park at I-10
S Park at E Barraza-Aviation Parkway

This measure will include the installation of the new wall pack fixtures and will be replaced one-for-one with an LED equivalent for a complete project. The existing underpass lighting at S. Park and Aviation includes 137 linear tunnel fixtures. Each fixture contains two 150W HPS lamps and is grossly over lighted where the City has disconnected every other fixture. This underpass will require the removal of the linear fixtures and configuration of new wiring to install 18 LED wall pack fixtures.

Table D.11. New Underpass Fixture Summary

New Fixture	Model	Wattage	Count
W4GLED 10C	Wall Pack	39	63
W4GLED 20C	Wall Pack	72	125
W4GLED 30C (tunnel)	Wall Pack	104	18
Total:			206

The detailed fixture-by-fixture audit of the City’s street light system will be utilized to coordinate the installation of the new underpass fixtures. Installation crews will use Trimble (or similar) handhelds and/or tablets to access the GIS mapping system in the field to access information on the existing luminaire, location and new fixture model number for each street light for all City-owned street lights. The audit will also provide the opportunity to identify unique construction issues that may require extra materials or work. This data captured during the IGA can also be used to update the City’s street light inventory.

The project scope of work includes:

- Surveying the existing underpass light fixtures for pre-existing damage to the mounting location, structure, mounting hardware and wiring
- Reporting any pre-existing damage to the City of Tucson for correction
- Cleaning work area and disposing of any construction debris and removing debris from site
- Complying with applicable local, state, and federal codes at the point of installation of new fixtures
- Identifying light to meter/power drop association

Exclusions to the scope of work include:

- Replacing any fixtures due to knock down
- Sampling, testing, or removing asbestos, lead, or other hazardous materials
- Repairing existing damaged or faulty electrical equipment and wiring
- Upgrading electrical distribution system to meet current electrical codes
- Creating, stamping and signing engineering plans and specifications

Ameresco has included lamp and ballast recycling and disposal in the project scope of work. Recycling certificates will be provided to the City of Tucson for all recycled material. PCB ballasts will be disposed of using the appropriate containers and hazardous material handling procedures.

Energy

Detailed calculations for baseline and energy savings for this ECM are provided in Appendix D.1 and D.2. Energy savings for the retrofits are determined by comparing the baseline existing energy consumption (kWh) with the proposed energy consumption (kWh). Total cost savings from the underpass lighting upgrade is limited to energy consumption reductions only. No demand savings are claimed since the lights are operated at off-peak times nor included as a rate tariff.

$$\text{Electricity Savings} = \text{Lighting kWh Savings}$$

$$\text{Lighting kWh Savings} = \text{Base Lighting kWh} - \text{Post Lighting kWh}$$

$$\text{Base Lighting kWh} = \text{Base Light kW} \times \text{Hours}$$

$$\text{Post Lighting kWh} = \text{Post Light kW} \times \text{Hours}$$

$$\text{Lighting kWh Control Savings} = \text{Post Light kW} \times (\text{Base Hours} - \text{Post Hours})$$

Existing energy usage for lighting is calculated from the number of existing underpass light fixtures and their rated wattages. Existing operating hours of the fixtures were determined based on staff interviews. A summary of lighting run hours by fixture type is presented in the M&V Plan.

> Energy Savings Proposed

Ameresco performed detailed lighting calculations to determine the energy savings associated with this project. The energy savings will result from the operation of more efficient fixtures where direct electric savings are associated with the reduced lamp wattages. Table D.12 summarizes the energy savings associated with the Underpass Lighting.

Table D.12. Projected Annual Energy and Cost Savings for Underpass Lighting Upgrade

Annual Savings	Units
68,923	kWh
\$7,180	Utility Cost Savings

ECM 5: Centro Garage Lighting with Occupancy and Daylight Control

> General Description

This energy conservation measure proposes to replace the existing garage lighting identified in the investment grade audit with new light emitting diode (LED) technology throughout the Centro Garage. The proposed project upgrades the existing lighting fixtures on a fixture-by-fixture basis and will greatly enhance the quality, consistency and color rendering of the lighting system, while meeting all applicable codes and standards, thereby reducing the energy and operational expense of the street lighting systems.



In addition, a new stand-alone control system will be installed that will allow individual programming of each lights with the integration of motion sensor and photo sensor control. Pre-determined dimming options range from dusk and dawn trimming (raising and lowering light output gradually at dusk and dawn). Adding motion sensors to LED luminaires also increases luminaire life because dimmed operation reduces the electrical load and case temperatures on the LEDs and drivers. When dimmed, LEDs generate more lumens per watt, run cooler and last longer. The use of motion sensors also ensures that lights are not on when they are not needed, but also, that they are on when motion is detected, which enhances site security in any application.

This strategy will reduce overall electricity consumption of the garage lighting system. In addition, this measure will reduce maintenance costs because of longer life of LED lighting as compared to the existing lighting. The LED fixtures come with a 10 year warranty and Ameresco will repair or replace any warranty components that fail during the first 10 years of the financing term. The retrofit will also reduce the amount of sky glare generated by lighting and enable the City to better meet Dark Skies Association guidelines.

Existing Conditions

The majority of the garage lights are linear T8 fluorescent fixtures, compact fluorescents and HPS wall packs operated by time clock controls. There are existing LED fixtures, excluding exit signs, which will be upgraded to be consistent with the new fixtures and allow the ability to integrate with the new control system. Table D.13 summarizes the lamp types, locations, counts and wattages evaluated in this IGA.

Table D.13. Existing Lighting Summary: Centro Garage

Wattage	Model	Type	Count
27	DOME;CF4PMT/26/1-E	Compact Fluorescent	5
31	S;FLUBPT8L4/32/1-EIN	Fluorescent	2
43	W-2'-PULL;FLUBPT12L2/20/2-MS	Fluorescent	1
46	WPK;CF4PMT/42/1-E	Compact Fluorescent	14
59	S;FLUBPT8L4/32/2-EIN	Fluorescent	2
59	S-WG;FLUBPT8L4/32/2-EIN	Fluorescent	341
59	WWP;FLUBPT8L4/32/2-EIN	Fluorescent	5
129	WPK;MHSIMED28/100/1-MS	Metal Halide	6
Total:			376

> Recommended Modifications

Ameresco’s approach is to standardize the proposed lighting system, whenever practical. Recommended modifications include replacing high energy consuming fixtures with more efficient types where needed.

As part of the Investment Grade Audit, a photometric analysis of the garage lighting determined that fixtures can be replaced with new LED fixtures on a fixture-by-fixture basis and meet the RP-20-14 Lighting for Parking Facilities guidelines. This proposed solution will help to reduce the energy and operational expense of the street lighting systems.

> Detailed Project Scope

The scope of this work includes the upgrade of 376 garage fixtures located at the Centro Garage. This measure will include the installation of the new LED garage fixtures and will be replaced on a fixture-by-fixture basis for a complete project.

Table D.14. Proposed Lighting Summary: Centro Garage

Wattage	Model	Count
17	LED N 17WS-FC	20
26	LED N 26PG-ML	336
32	LED N 32SL	4
32	LED N 32SL2'-PULL	1
44	LED N 44WWP-ML	5
67	LED N 67PG-T5E-ML	10
17	LED N 17WS-FC	20
26	LED N 26PG-ML	336
Total:		376

The detailed fixture-by-fixture audit of the garage light system will be utilized to coordinate the installation of the new fixtures. Installation crews will use the detailed audit spreadsheet found in the appendices to access information on the existing luminaire, location and new fixture model number for each garage light. The audit will also provide the opportunity to identify unique construction issues that may require extra materials or work. This data will be captured and updated in the detailed audit spreadsheet and can be used to update the City's garage lighting inventory.

The project scope of work includes:

- Surveying the existing garage fixtures for pre-existing damage to the controls, control wiring and electrical power wiring
- Reporting any pre-existing damage to the City of Tucson for correction
- Cleaning work area and disposing of any construction debris and removing debris from site
- Complying with applicable local, state, and federal codes at the point of installation of new fixtures
- Identifying garage lighting system to electric meter association

Exclusions to the scope of work include:

- Replacing any fixtures due to post installation damage
- Sampling, testing, or removing asbestos, lead or other hazardous materials
- Repairing existing damaged or faulty electrical equipment and wiring
- Upgrading electrical distribution system to meet current electrical codes
- Creating, stamping and signing engineering plans and specifications

Ameresco has included lamp and ballast recycling and disposal in the project scope of work. Recycling certificates will be provided to the City of Tucson for all recycled material. PCB ballasts will be disposed of using the appropriate containers and hazardous material handling procedures.

Energy

Detailed calculations for baseline and energy savings for this ECM are provided in Appendix D.2 Savings Calculations. Energy savings for the retrofits are determined by comparing the baseline existing energy consumption (kWh) with the proposed energy consumption (kWh). Total cost savings from the light fixture upgrade is limited to energy consumption reductions only. No demand savings are claimed since the garage lights are operated at off-peak times nor included as a rate tariff.

$$\text{Electricity Savings} = \text{Lighting kWh Savings}$$

$$\text{Lighting kWh Savings} = \text{Base Lighting kWh} - \text{Post Lighting kWh}$$

$$\text{Base Lighting kWh} = \text{Base Light kW} \times \text{Hours}$$

$$\text{Post Lighting kWh} = \text{Post Light kW} \times \text{Hours}$$

$$\text{Lighting kWh Control Savings} = \text{Post Light kW} \times (\text{Base Hours} - \text{Post Hours})$$

Existing energy usage for lighting is calculated from the number of existing garage light fixtures and their rated wattages. Existing operating hours of the fixtures were determined based on staff interviews. A summary of lighting run-hours by fixture type is presented in the M&V Plan.

> Energy Savings Proposed

Ameresco performed detailed lighting calculations to determine the energy savings associated with the Centro Garage Lighting with Occupancy and Daylight Control project. Direct electric savings are associated with the reduced lamp wattages and the ability to turn lights off during pre-determined periods of time when there is low pedestrian activity. Table D.15 summarizes the energy savings associated with the project.

Table D.15. Projected Annual Energy and Cost Savings for Centro Garage Lighting Upgrade

Annual Savings	Units
131,250	kWh
\$15,458	Utility Cost Savings

ECM 7: City/State Garage Lighting with Occupancy and Daylight Control

> General Description

This energy conservation measure proposes to replace the existing garage lighting identified in the Investment Grade Audit with new light emitting diode (LED) technology throughout the City/State Garage. The proposed project upgrades the existing lighting fixtures on a fixture-by-fixture basis and will greatly enhance the quality, consistency and color rendering of the lighting system, while meeting all applicable codes and standards, thereby reducing the energy and operational expense of the lighting systems.



In addition, a new stand-alone control system will be installed that will allow individual programming of each light with the integration of motion sensor and photo sensor control. Pre-determined dimming options range from dusk and dawn trimming (raising and lowering light output gradually at dusk and dawn). Adding motion sensors to LED luminaires also increases luminaire life because dimmed operation reduces the electrical load and case temperatures on the LEDs and drivers. When dimmed, LEDs generate more lumens per watt, run cooler and last longer. The use of motion sensors also ensures that lights are not on when they are not needed, but also, that they are on when motion is detected, which enhances site security in any application.

This strategy will reduce overall electricity consumption of the garage lighting system. In addition, this measure will reduce maintenance costs because of longer life of LED lighting as compared to the existing lighting. The LED fixtures come with a 10 year warranty and Ameresco will repair or replace any warranty components that fail during the first 10 years of the financing term. The retrofit will also reduce the amount of sky glare generated by lighting and enable the City to better meet Dark Skies Association guidelines.

Existing Conditions

The majority of the garage lights are linear T8 fluorescent fixtures, compact fluorescents and HPS wall packs operated by time clock controls. There are existing LED fixtures excluding exit signs which will be upgraded to be consistent with the new fixtures and allow the ability to integrate with the new control system. Table D.16 summarizes the lamp types, locations, counts and wattages evaluated in this IGA.

Table D.16. Existing Lighting Summary: City/State Garage

Wattage	Model	Type	Count
43	S;FLUBPT12L4/34/1-MS	Fluorescent	6
59	L-1X4;FLUBPT8L4/32/2-EIN	Fluorescent	2
80	CAN;LPSDCBT17/55/1-MS	Low Pressure Sodium	416
80	SB-PM;LPSDCBT17/55/1-MS	Low Pressure Sodium	28
80	WPK;LPSDCBT17/55/1-MS	Low Pressure Sodium	28
125	CAN;LPSDCBT17/90/1-MS	Low Pressure Sodium	10
125	SB-PM;LPSDCBT17/90/1-MS	Low Pressure Sodium	23
Total:			513

> Recommended Modifications

Ameresco’s approach is to standardize the proposed lighting system, whenever practical. Recommended modifications include replacing high energy consuming fixtures with more efficient types where needed.

As part of the Investment Grade Audit, a photometric analysis of the garage lighting determined that fixtures can be replaced with new LED fixtures on a fixture-by-fixture basis and meet the RP-20-14 Lighting for Parking Facilities guidelines. This proposed solution will help to reduce the energy and operational expense of the street lighting systems.

> Detailed Project Scope

The scope of this work includes the upgrade of 513 garage fixtures located at the City/State Garage. This measure will include the installation of the new LED garage fixtures and will be replaced on a fixture-by-fixture basis for a complete project.

Table D.17. Proposed Lighting Summary: City/State Garage

Wattage	Model	Count
19	LED RF 29KIT-1X4	2
20	LED N 20WPK-FC	24
27	LED N 27WS-DECO	4
32	LED N 32SL	6
37	LED N 37CH-SBMA	51
37	LED N 37PG-ML	420
67	LED N 67PG-T5E-ML	6
Total:		513

The detailed fixture-by-fixture audit of the garage light system will be utilized to coordinate the installation of the new fixtures. Installation crews will use the detailed audit spreadsheet found in the appendices to access information on the existing luminaire, location and new fixture model number for each garage light. The audit will also provide the opportunity to identify unique construction issues that may require extra materials or work. This data will be captured and updated in the detailed audit spreadsheet and can be used to update the City's garage lighting inventory.

The project scope of work includes:

- Surveying the existing garage fixtures for pre-existing damage to the controls, control wiring and electrical power wiring
- Reporting any pre-existing damage to the City of Tucson for correction
- Cleaning work area and disposing of any construction debris and removing debris from site
- Complying with applicable local, state, and federal codes at the point of installation of new fixtures
- Identifying garage lighting system to electric meter association

Exclusions to the scope of work include:

- Replacing any fixtures due to post installation damage
- Sampling, testing, or removing asbestos, lead, or other hazardous materials
- Repairing existing damaged or faulty electrical equipment and wiring
- Upgrading electrical distribution system to meet current electrical codes
- Creating, stamping, and signing engineering plans and specifications

Ameresco has included lamp and ballast recycling and disposal in the project scope of work. Recycling certificates will be provided to the City of Tucson for all recycled material. PCB ballasts will be disposed of using the appropriate containers and hazardous material handling procedures.

Energy

Detailed calculations for baseline and energy savings for this ECM are provided in Appendix D.2 Savings Calculations. Energy savings for the retrofits are determined by comparing the baseline existing energy consumption (kWh) with the proposed energy consumption (kWh). Total cost savings from the light fixture upgrade is limited to energy consumption reductions only. No demand savings are claimed since the garage lights are operated at off-peak times nor included as a rate tariff.

$$\text{Electricity Savings} = \text{Lighting kWh Savings}$$

$$\text{Lighting kWh Savings} = \text{Base Lighting kWh} - \text{Post Lighting kWh}$$

$$\text{Base Lighting kWh} = \text{Base Light kW} \times \text{Hours}$$

$$\text{Post Lighting kWh} = \text{Post Light kW} \times \text{Hours}$$

$$\text{Lighting kWh Control Savings} = \text{Post Light kW} \times (\text{Base Hours} - \text{Post Hours})$$

Existing energy usage for lighting is calculated from the number of existing garage light fixtures and their rated wattages. Existing operating hours of the fixtures were determined based on staff interviews. A summary of lighting run-hours by fixture type is presented in the M&V Plan.

> Energy Savings Proposed

Ameresco performed detailed lighting calculations to determine the energy savings associated with the City/State Garage Lighting with Occupancy and Daylight Control upgrade project. The energy savings will result from the operation of more efficient fixtures and controls. Direct electric savings are associated with the reduced lamp wattages and the ability to turn lights off during pre-determined periods of time when there is low pedestrian activity. Table D.18 summarizes the energy savings associated with the project.

Table D.18. Projected Annual Energy and Cost Savings for City/State Garage Lighting Upgrade

Annual Savings	Units
164,200	kWh
\$19,339	Utility Cost Savings

ECM 9: Depot Plaza Garage Lighting with Occupancy and Daylight Control

> General Description

This energy conservation measure proposes to replace the existing garage lighting identified in the Investment Grade Audit with new light emitting diode (LED) technology throughout the Depot Plaza Garage. The proposed project upgrades the existing lighting fixtures on a fixture-by-fixture basis and will greatly enhance the quality, consistency and color rendering of the lighting system, while meeting all applicable codes and standards, thereby reducing the energy and operational expense of the lighting systems.



In addition, a new stand-alone control system will be installed that will allow individual programming of each light with the integration of motion sensor and photo sensor control. Pre-determined dimming options range from dusk and dawn trimming (raising and lowering light output gradually at dusk and dawn). Adding motion sensors to LED luminaires also increases luminaire life because dimmed operation reduces the electrical load and case temperatures on the LEDs and drivers. When dimmed, LEDs generate more lumens per watt, run cooler and last longer. The use of motion sensors also ensures that lights are not on when they are not needed, but also, that they are on when motion is detected, which enhances site security in any application.

This strategy will reduce overall electricity consumption of the garage lighting system. In addition, this measure will reduce maintenance costs because of longer life of LED lighting as compared to the existing lighting. The LED fixtures come with a 10 year warranty and Ameresco will repair or replace any warranty components that fail during the first 10 years of the financing term. The retrofit will also reduce the amount of sky glare generated by lighting and enable the City to better meet Dark Skies Association guidelines.

Existing Conditions

The majority of the garage lights are linear T8 fluorescent fixtures, compact fluorescents and HPS wall packs operated by time clock controls. There are existing LED fixtures excluding exit signs which will be upgraded to be consistent with the new fixtures and allow the ability to integrate with the new control system.

Table D.19. Existing Lighting Summary: Depot Plaza Garage

Wattage	Model	Type	Count
19	S-2';FLUBPT8L2/17/1-EIN	Fluorescent	2
28	WS;CF2PMT/26/1-MS	Compact Fluorescent	12
31	S;FLUBPT8L4/32/1-EIN	Fluorescent	1
59	S;FLUBPT8L4/32/2-EIN	Fluorescent	1
59	WWP;FLUBPT8L4/32/2-EIN	Fluorescent	260
59	WWP-PEN;FLUBPT8L4/32/2-EIN	Fluorescent	26
Total:			302

> Recommended Modifications

Ameresco's approach is to standardize the proposed lighting system, whenever practical. Recommended modifications include replacing high energy consuming fixtures with more efficient types where needed.

As part of the Investment Grade Audit, a photometric analysis of the garage lighting determined that fixtures can be replaced with new LED fixtures on a fixture-by-fixture basis and meet the RP-20-14 Lighting for Parking Facilities guidelines. This proposed solution will help to reduce the energy and operational expense of the street lighting systems.

> Detailed Project Scope

The scope of this work includes the upgrade of 302 garage fixtures located at the Depot Plaza Garage. This measure will include the installation of the new LED garage fixtures and will be replaced on a fixture-by-fixture basis for a complete project.

Table D.20. Proposed Lighting Summary: Depot Plaza Garage

Wattage	Model	Count
10.9	LED N 10.9RWS-HC	12
32	LED N 32SL	2
32	LED N 32SL2'	2
37	LED N 37PG-ML	233
37	LED N 37PG-ML-PEN	26
44	LED N 44WWP-ML	11
67	LED N 67PG-TSE-ML	16
Total:		302

The detailed fixture-by-fixture audit of the garage light system will be utilized to coordinate the installation of the new fixtures. Installation crews will use the detailed audit spreadsheet found in the appendices to access information on the existing luminaire, location and new fixture model number for each garage light. The audit will also provide the opportunity to identify unique construction issues that may require extra materials or work. This data will be captured and updated in the detailed audit spreadsheet and can be used to update the City's garage lighting inventory.

The project scope of work includes:

- Surveying the existing garage fixtures for pre-existing damage to the controls, control wiring and electrical power wiring
- Reporting any pre-existing damage to the City of Tucson for correction
- Cleaning work area and disposing of any construction debris and removing debris from site
- Complying with applicable local, state, and federal codes at the point of installation of new fixtures
- Identifying garage lighting system to electric meter association

Exclusions to the scope of work include:

- Replacing any fixtures due to post installation damage
- Sampling, testing, or removing asbestos, lead or other hazardous materials
- Repairing existing damaged or faulty electrical equipment and wiring
- Upgrading electrical distribution system to meet current electrical codes
- Creating, stamping, and signing engineering plans and specifications

Ameresco has included lamp and ballast recycling and disposal in the project scope of work. Recycling certificates will be provided to the City of Tucson for all recycled material. PCB ballasts will be disposed of using the appropriate containers and hazardous material handling procedures.

Energy

Detailed calculations for baseline and energy savings for this ECM are provided in Appendix D.2 Savings Calculations. Energy savings for the retrofits are determined by comparing the baseline existing energy consumption (kWh) with the proposed energy consumption (kWh). Total cost savings from the light fixture upgrade is limited to energy consumption reductions only. No demand savings are claimed since the garage lights are operated at off-peak times nor included as a rate tariff.

$$\text{Electricity Savings} = \text{Lighting kWh Savings}$$

$$\text{Lighting kWh Savings} = \text{Base Lighting kWh} - \text{Post Lighting kWh}$$

$$\text{Base Lighting kWh} = \text{Base Light kW} \times \text{Hours}$$

$$\text{Post Lighting kWh} = \text{Post Light kW} \times \text{Hours}$$

$$\text{Lighting kWh Control Savings} = \text{Post Light kW} \times (\text{Base Hours} - \text{Post Hours})$$

Existing energy usage for lighting is calculated from the number of existing garage light fixtures and their rated wattages. Existing operating hours of the fixtures were determined based on staff interviews. A summary of lighting run-hours by fixture type is presented in the M&V Plan.

> Energy Savings Proposed

Ameresco performed detailed lighting calculations to determine the energy savings associated with the Depot Plaza Garage Lighting with Occupancy and Daylight Control upgrade project. Direct electric savings are associated with the reduced lamp wattages and the ability to turn lights off during pre-determined periods of time when there is low pedestrian activity. Table D.21 summarizes the energy savings associated with the project.

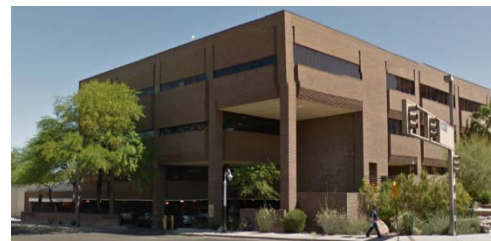
Table D.21. Projected Annual Energy and Cost Savings for Depot Plaza Garage Lighting Upgrade

Annual Savings	Units
106,300	kWh
\$12,520	Utility Cost Savings

ECM 11: La Entrada Garage Lighting with Occupancy and Daylight Control

> General Description

This energy conservation measure proposes to replace the existing garage lighting identified in the investment grade audit with new light emitting diode (LED) technology throughout the La Entrada Garage. The proposed project upgrades the existing lighting fixtures on a fixture-by-fixture basis and will greatly enhance the quality, consistency and color rendering of the lighting system, while meeting all applicable codes and standards, thereby reducing the energy and operational expense of the street lighting systems.



In addition, a new stand-alone control system will be installed that will allow individual programming of each light with the integration of motion sensor and photo sensor control. Pre-determined dimming options range from dusk and dawn trimming (raising and lowering light output gradually at dusk and dawn). Adding motion sensors to LED luminaires also increases luminaire life because dimmed operation reduces the electrical load and case temperatures on the LEDs and drivers. When dimmed, LEDs generate more lumens per watt, run cooler and last longer. The use of motion sensors also ensures that lights are not on when they are not needed, but also, that they are on when motion is detected, which enhances site security in any application.

This strategy will reduce overall electricity consumption of the garage lighting system. In addition, this measure will reduce maintenance costs because of longer life of LED lighting as compared to the existing lighting. The LED fixtures come with a 10 year warranty and Ameresco will repair or replace any warranty components that fail during the first 10 years of the financing term. The retrofit will also reduce the amount of sky glare generated by lighting and enable the City to better meet Dark Skies Association guidelines.

Existing Conditions

The majority of the garage lights are linear T8 fluorescent fixtures, compact fluorescents and HPS wall packs operated by time clock controls. There are existing LED fixtures excluding exit signs which will be upgraded to be consistent with the new fixtures and allow the ability to integrate with the new control system.

Table D.22. Existing Lighting Summary: La Entrada Garage

Wattage	Model	Type	Count
31	S;FLUBPT8L4/32/1-EIN	Fluorescent	3
130	CAN-SM;HPSSIBD17/100/1-MS	High Pressure Sodium	34
Total:			37

> **Recommended Modifications**

Ameresco’s approach is to standardize the proposed lighting system, whenever practical. Recommended modifications include replacing high energy consuming fixtures with more efficient types where needed.

As part of the Investment Grade Audit, a photometric analysis of the garage lighting determined that fixtures can be replaced with new LED fixtures on a fixture-by-fixture basis and meet the RP-20-14 Lighting for Parking Facilities guidelines. This proposed solution will help to reduce the energy and operational expense of the street lighting systems.

> **Detailed Project Scope**

The scope of this work includes the upgrade of 37 garage fixtures located at the La Entrada Garage. This measure will include the installation of the new LED garage fixtures and will be replaced on a fixture-by-fixture basis for a complete project.

Table D.23. Proposed Lighting Summary: La Entrada Garage

Wattage	Model	Count
32	LED N 32SL	3
37	LED N 37PG-ML	26
67	LED N 67PG-T5E-ML	8
Total:		37

The detailed fixture-by-fixture audit of the garage light system will be utilized to coordinate the installation of the new fixtures. Installation crews will use the detailed audit spreadsheet found in the appendices to access information on the existing luminaire, location and new fixture model number for each garage light. The audit will also provide the opportunity to identify unique construction issues that may require extra materials or work. This data will be captured and updated in the detailed audit spreadsheet and can be used to update the City’s garage lighting inventory.

The project scope of work includes:

- Surveying the existing garage fixtures for pre-existing damage to the controls, control wiring and electrical power wiring
- Reporting any pre-existing damage to the City of Tucson for correction
- Cleaning work area and disposing of any construction debris and removing debris from site
- Complying with applicable local, state, and federal codes at the point of installation of new fixtures
- Identifying garage lighting system to electric meter association

Exclusions to the scope of work include:

- Replacing any fixtures due to post installation damage
- Sampling, testing, or removing asbestos, lead or other hazardous materials
- Repairing existing damaged or faulty electrical equipment and wiring
- Upgrading electrical distribution system to meet current electrical codes
- Creating, stamping, and signing engineering plans and specifications

Ameresco has included lamp and ballast recycling and disposal in the project scope of work. Recycling certificates will be provided to the City of Tucson for all recycled material. PCB ballasts will be disposed of using the appropriate containers and hazardous material handling procedures.

Energy

Detailed calculations for baseline and energy savings for this ECM are provided in Appendix D.2 Savings Calculations. Energy savings for the retrofits are determined by comparing the baseline existing energy consumption (kWh) with the proposed energy consumption (kWh). Total cost savings from the light fixture upgrade is limited to energy consumption reductions only. No demand savings are claimed since the garage lights are operated at off-peak times nor included as a rate tariff.

$$\text{Electricity Savings} = \text{Lighting kWh Savings}$$

$$\text{Lighting kWh Savings} = \text{Base Lighting kWh} - \text{Post Lighting kWh}$$

$$\text{Base Lighting kWh} = \text{Base Light kW} \times \text{Hours}$$

$$\text{Post Lighting kWh} = \text{Post Light kW} \times \text{Hours}$$

$$\text{Lighting kWh Control Savings} = \text{Post Light kW} \times (\text{Base Hours} - \text{Post Hours})$$

Existing energy usage for lighting is calculated from the number of existing garage light fixtures and their rated wattages. Existing operating hours of the fixtures were determined based on staff interviews. A summary of lighting run-hours by fixture type is presented in the M&V Plan.

> Energy Savings Proposed

Ameresco performed detailed lighting calculations to determine the energy savings associated with the La Entrada Garage Lighting with Occupancy and Daylight Control upgrade project. The energy savings will result from the operation of more efficient fixtures and existing dusk-to-dawn timed controls. Direct electric savings are associated with the reduced lamp wattages and the ability to turn lights off during pre-determined periods of time when there is low pedestrian activity. Table D.24 summarizes the energy savings associated with the project.

Table D.24. Projected Annual Energy and Cost Savings for La Entrada Garage Lighting Upgrade

Annual Savings	Units
12,100	kWh
\$1,270	Utility Cost Savings

ECM 13: Main Library Garage Lighting with Occupancy and Daylight Control

> General Description

This energy conservation measure proposes to replace the existing garage lighting identified in the investment grade audit with new light emitting diode (LED) technology throughout the Main Library Garage. The proposed project upgrades the existing lighting fixtures on a fixture-by-fixture basis and will greatly enhance the quality, consistency and color rendering of the lighting system, while meeting all applicable codes and standards, thereby reducing the energy and operational expense of the street lighting systems.



In addition, a new stand-alone control system will be installed that will allow individual programming of each light with the integration of motion sensor and photo sensor control. Pre-determined dimming options range from dusk and dawn trimming (raising and lowering light output gradually at dusk and dawn). Adding motion sensors to LED luminaires also increases luminaire life because dimmed operation reduces the electrical load and case temperatures on the LEDs and drivers. When dimmed, LEDs generate more lumens per watt, run cooler and last longer. The use of motion sensors also ensures that lights are not on when they are not needed, but also, that they are on when motion is detected, which enhances site security in any application.

This strategy will reduce overall electricity consumption of the garage lighting system. In addition, this measure will reduce maintenance costs because of longer life of LED lighting as compared to the existing lighting. The LED fixtures come with a 10 year warranty and Ameresco will repair or replace any warranty components that fail during the first 10 years of the financing term. The retrofit will also reduce the amount of sky glare generated by lighting and enable the City to better meet Dark Skies Association guidelines.

Existing Conditions

The majority of the garage lights are linear T8 fluorescent fixtures, compact fluorescents and HPS wall packs operated by time clock controls. There are existing LED fixtures excluding exit signs which will be upgraded to be consistent with the new fixtures and allow the ability to integrate with the new control system.

Table D.25. Existing Lighting Summary: Main Library Garage

Wattage	Model	Type	Count
31	S;FLUBPT8L4/32/1-EIN	Fluorescent	3
31	W;FLUBPT8L4/32/1-EIN	Fluorescent	30
47	S-3';FLUBPT12L3/30/1-MS	Fluorescent	2
130	CAN-SM;HPSSIBD17/100/1-MS	High Pressure Sodium	142
130	CYL-SM;HPSSIBD17/100/1-MS	High Pressure Sodium	9
210	FL;MHSIBD17/175/1-MS	Metal Halide	2
295	SB-PT-PM;HPSSIMED18/250/1-MS (1)	High Pressure Sodium	1
458	C-12"-VERT;MHSIMED28/400/1-MS	Metal Halide	1
Total:			190

(1) This line item is a single 400W HPS fixture in the Main Library and will require 2- LED N 26PG-ML fixtures to replace the single fixture, therefore the higher count of proposed fixtures in Table F.22 Proposed Garage Fixture Sampling Plan

> Recommended Modifications

Ameresco’s approach is to standardize the proposed lighting system, whenever practical. Recommended modifications include replacing high energy consuming fixtures with more efficient types where needed.

As part of the Investment Grade Audit, a photometric analysis of the garage lighting determined that fixtures can be replaced with new LED fixtures on a fixture-by-fixture basis and meet the RP-20-14 Lighting for Parking Facilities guidelines. This proposed solution will help to reduce the energy and operational expense of the street lighting systems.

> Detailed Project Scope

The scope of this work includes the upgrade of 191 garage fixtures located at the Main Library Garage. This measure will include the installation of the new LED garage fixtures and will be replaced on a fixture-by-fixture basis for a complete project.

Table D.26. Proposed Lighting Summary: Main Library Garage

Wattage	Model	Count
32	LED N 32SL	3
32	LED N 32SL2'	2
37	LED N 37PG-ML (1)	149
44	LED N 44WWP-ML	30
52	LED N 52FL	2
60	LED N 60CH-SBMA	1
67	LED N 67PG-T5E-ML	4
Total:		191

(1) See note one (1) in Table F.21. Existing Garage Fixture Sampling Plan

The detailed fixture-by-fixture audit of the garage light system will be utilized to coordinate the installation of the new fixtures. Installation crews will use the detailed audit spreadsheet found in the appendices to access information on the existing luminaire, location and new fixture model number for each garage light. The audit will also provide the opportunity to identify unique construction issues that may require extra materials or work. This data will be captured and updated in the detailed audit spreadsheet and can be used to update the City’s garage lighting inventory.

The project scope of work includes:

- Surveying the existing garage fixtures for pre-existing damage to the controls, control wiring and electrical power wiring
- Reporting any pre-existing damage to the City of Tucson for correction
- Cleaning work area and disposing of any construction debris and removing debris from site
- Complying with applicable local, state, and federal codes at the point of installation of new fixtures
- Identifying garage lighting system to electric meter association

Exclusions to the scope of work include:

- Replacing any fixtures due to post installation damage
- Sampling, testing, or removing asbestos, lead or other hazardous materials
- Repairing existing damaged or faulty electrical equipment and wiring

- Upgrading electrical distribution system to meet current electrical codes
- Creating, stamping, and signing engineering plans and specifications

Ameresco has included lamp and ballast recycling and disposal in the project scope of work. Recycling certificates will be provided to the City of Tucson for all recycled material. PCB ballasts will be disposed of using the appropriate containers and hazardous material handling procedures.

Energy

Detailed calculations for baseline and energy savings for this ECM are provided in Appendix D.2 Savings Calculations. Energy savings for the retrofits are determined by comparing the baseline existing energy consumption (kWh) with the proposed energy consumption (kWh). Total cost savings from the light fixture upgrade is limited to energy consumption reductions only. No demand savings are claimed since the garage lights are operated at off-peak times nor included as a rate tariff.

$$\text{Electricity Savings} = \text{Lighting kWh Savings}$$

$$\text{Lighting kWh Savings} = \text{Base Lighting kWh} - \text{Post Lighting kWh}$$

$$\text{Base Lighting kWh} = \text{Base Light kW} \times \text{Hours}$$

$$\text{Post Lighting kWh} = \text{Post Light kW} \times \text{Hours}$$

$$\text{Lighting kWh Control Savings} = \text{Post Light kW} \times (\text{Base Hours} - \text{Post Hours})$$

Existing energy usage for lighting is calculated from the number of existing garage light fixtures and their rated wattages. Existing operating hours of the fixtures were determined based on staff interviews. A summary of lighting run-hours by fixture type is presented in the M&V Plan.

> Energy Savings Proposed

Ameresco performed detailed lighting calculations to determine the energy savings associated with the Main Library Garage Lighting with Occupancy and Daylight Control upgrade project. The energy savings will result from the operation of more efficient fixtures and existing dusk-to-dawn timed controls. Direct electric savings are associated with the reduced lamp wattages and the ability to turn lights off during pre-determined periods of time when there is low pedestrian activity. Table D.27 summarizes the energy savings associated with the project.

Table D.27. Projected Annual Energy and Cost Savings for Main Library Garage Lighting Upgrade

Annual Savings	Units
75,000	kWh
\$7,256	Utility Cost Savings

ECM 15: Pennington Garage Lighting with Occupancy and Daylight Control

> General Description

This energy conservation measure proposes to replace the existing garage lighting identified in the investment grade audit with new light emitting diode (LED) technology throughout the Pennington Garage. The proposed project upgrades the existing lighting fixtures on a fixture-by-fixture basis and will greatly enhance the quality, consistency and color rendering of the lighting system, while meeting all applicable codes and standards, thereby reducing the energy and operational expense of the street lighting systems.



In addition, a new stand-alone control system will be installed that will allow individual programming of each light with the integration of motion sensor and photo sensor control. Pre-determined dimming options range from dusk and dawn trimming (raising and lowering light output gradually at dusk and dawn). Adding motion sensors to LED luminaires also increases luminaire life because dimmed operation reduces the electrical load and case temperatures on the LEDs and drivers. When dimmed, LEDs generate more lumens per watt, run cooler and last longer. The use of motion sensors also ensures that lights are not on when they are not needed, but also, that they are on when motion is detected, which enhances site security in any application.

This strategy will reduce overall electricity consumption of the garage lighting system. In addition, this measure will reduce maintenance costs because of longer life of LED lighting as compared to the existing lighting. The LED fixtures come with a 10 year warranty and Ameresco will repair or replace any warranty components that fail during the first 10 years of the financing term. The retrofit will also reduce the amount of sky glare generated by lighting and enable the City to better meet Dark Skies Association guidelines.

Existing Conditions

The majority of the garage lights are linear T8 fluorescent fixtures, compact fluorescents and HPS wall packs operated by time clock controls. There are existing LED fixtures excluding exit signs which will be upgraded to be consistent with the new fixtures and allow the ability to integrate with the new control system.

Table D.28. Existing Lighting Summary: Pennington Garage

Wattage	Model	Type	Count
27	DOME;CF4PMT/26/1-E	Compact Fluorescent	17
59	S;FLUBPT8L4/32/2-EIN	Fluorescent	2
59	WWP;FLUBPT8L4/32/2-EIN	Fluorescent	1
59	WWP-PEN;FLUBPT8L4/32/2-EIN	Fluorescent	20
71	WS;CF4PLBX/40/2-E	Compact Fluorescent	9
112	WWP;FLUBPT8L4/32/4-EIN	Fluorescent	51
112	WWP-PEN;FLUBPT8L4/32/4-EIN	Fluorescent	541
188	CAN-SM;HPSSIMED28/150/1-MS	High Pressure Sodium	27
Total:			668

> Recommended Modifications

Ameresco’s approach is to standardize the proposed lighting system, whenever practical. Recommended modifications include replacing high energy consuming fixtures with more efficient types where needed.

As part of the Investment Grade Audit, a photometric analysis of the garage lighting determined that fixtures can be replaced with new LED fixtures on a fixture-by-fixture basis and meet the RP-20-14 Lighting for Parking Facilities guidelines. This proposed solution will help to reduce the energy and operational expense of the street lighting systems.

> Detailed Project Scope

The scope of this work includes the upgrade of 668 garage fixtures located at the Pennington Garage. This measure will include the installation of the new LED garage fixtures and will be replaced on a fixture-by-fixture basis for a complete project.

Table D.29. Proposed Lighting Summary: Pennington Garage

Wattage	Model	Count
27	LED N 27WS-DECO	9
32	LED N 32SL	2
37	LED N 37PG-ML	77
37	LED N 37PG-ML-PEN	531
44	LED N 44WWP-PEN-ML	12
46	LED N 46PG-ML	27
67	LED N 67PG-T5E-ML-PEN	10
Total:		668

The detailed fixture-by-fixture audit of the garage light system will be utilized to coordinate the installation of the new fixtures. Installation crews will use the detailed audit spreadsheet found in the appendices to access information on the existing luminaire, location and new fixture model number for each garage light. The audit will also provide the opportunity to identify unique construction issues that may require extra materials or work. This data will be captured and updated in the detailed audit spreadsheet and can be used to update the City's garage lighting inventory.

The project scope of work includes:

- Surveying the existing garage fixtures for pre-existing damage to the controls, control wiring and electrical power wiring
- Reporting any pre-existing damage to the City of Tucson for correction
- Cleaning work area and disposing of any construction debris and removing debris from site
- Complying with applicable local, state, and federal codes at the point of installation of new fixtures
- Identifying garage lighting system to electric meter association

Exclusions to the scope of work include:

- Replacing any fixtures due to post installation damage
- Sampling, testing, or removing asbestos, lead or other hazardous materials
- Repairing existing damaged or faulty electrical equipment and wiring
- Upgrading electrical distribution system to meet current electrical codes
- Creating, stamping, and signing engineering plans and specifications

Ameresco has included lamp and ballast recycling and disposal in the project scope of work. Recycling certificates will be provided to the City of Tucson for all recycled material. PCB ballasts will be disposed of using the appropriate containers and hazardous material handling procedures.

Energy

Detailed calculations for baseline and energy savings for this ECM are provided in Appendix D.2 Savings Calculations. Energy savings for the retrofits are determined by comparing the baseline existing energy consumption (kWh) with the proposed energy consumption (kWh). Total cost savings from the light fixture upgrade is limited to energy consumption reductions only. No demand savings are claimed since the garage lights are operated at off-peak times nor included as a rate tariff.

$$\text{Electricity Savings} = \text{Lighting kWh Savings}$$

$$\text{Lighting kWh Savings} = \text{Base Lighting kWh} - \text{Post Lighting kWh}$$

$$\text{Base Lighting kWh} = \text{Base Light kW} \times \text{Hours}$$

$$\text{Post Lighting kWh} = \text{Post Light kW} \times \text{Hours}$$

$$\text{Lighting kWh Control Savings} = \text{Post Light kW} \times (\text{Base Hours} - \text{Post Hours})$$

Existing energy usage for lighting is calculated from the number of existing garage light fixtures and their rated wattages. Existing operating hours of the fixtures were determined based on staff interviews. A summary of lighting run-hours by fixture type is presented in the M&V Plan.

> Energy Savings Proposed

Ameresco performed detailed lighting calculations to determine the energy savings associated with the Pennington Garage Lighting with Occupancy and Daylight control upgrade project. The energy savings will result from the operation of more efficient fixtures and existing dusk-to-dawn timed controls. Direct electric savings are associated with the reduced lamp wattages and the ability to turn lights off during pre-determined periods of time when there is low pedestrian activity. Table D.30 summarizes the energy savings associated with the Pennington Garage Lighting with Occupancy and Daylight control project.

Table D.30. Projected Annual Energy and Cost Savings for Pennington Garage Lighting Upgrade

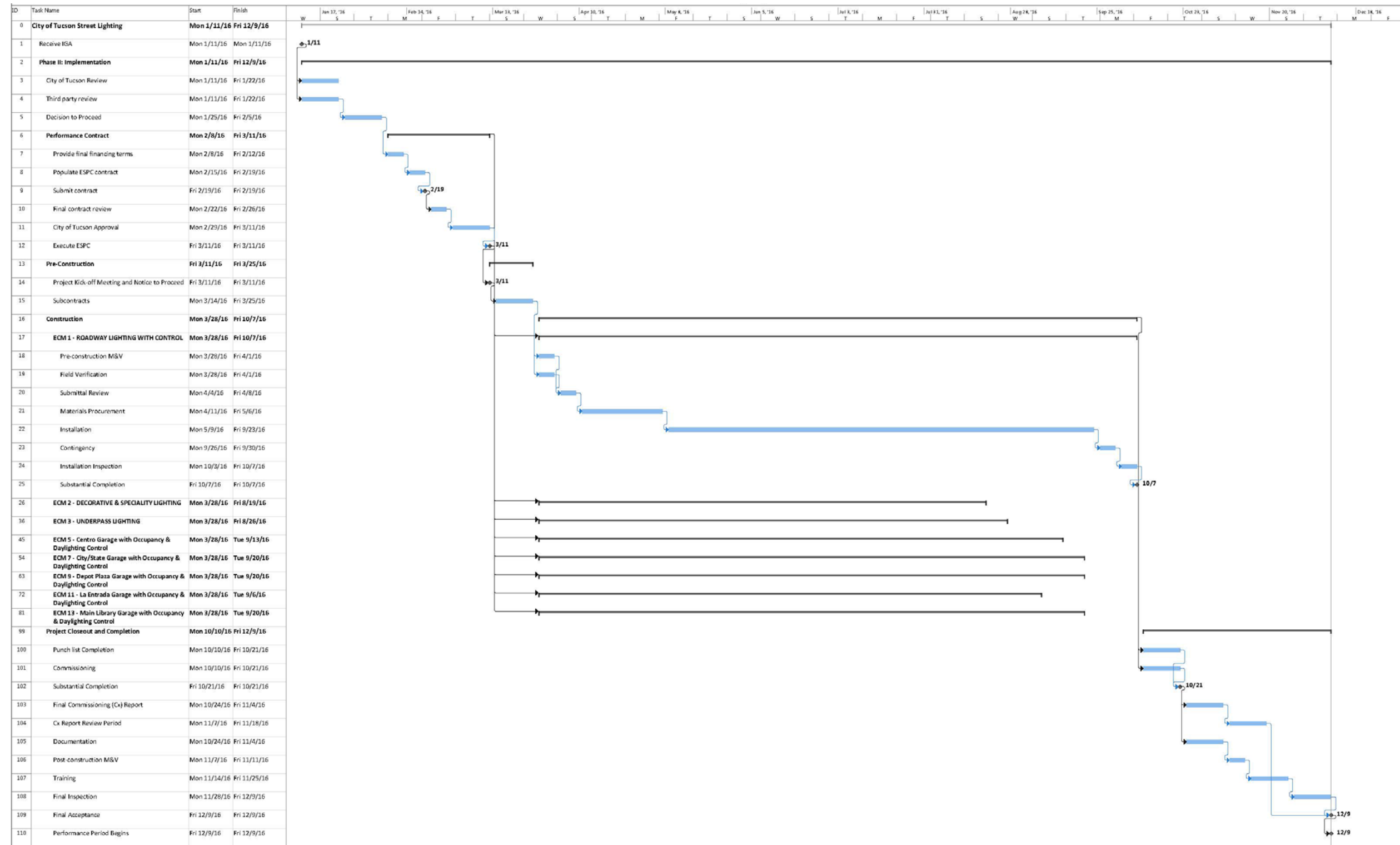
Annual Savings	Units
441,200	kWh
\$51,964	Utility Cost Savings

E.0 Project Schedule

A preliminary construction schedule for the project is provided on the following pages. The total construction duration until project acceptance is estimated to be eight months. Final completion and closeout of the project is expected to take eight additional weeks including commissioning, final inspection, training, documentations and any other final close-out procedures that may be required. The schedule tentatively anticipates construction beginning the last week of March 2016, although this date may change based on the needs and requirements of the City of Tucson. It is estimated that it will take six month to install all of the new fixtures once installation begins in the field.

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> City of Tucson LED Lighting Conversion Project Proposed Construction Schedule



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F.0 Measurement and Verification

The long-term success of any comprehensive energy efficiency program depends on the development of an accurate and successful Measurement & Verification (M&V) plan which cost-effectively quantifies and verifies the performance of the ECMs. For this reason, Ameresco subscribes to industry standard M&V protocols that have been developed in response to the need for reliable and consistent measurement practices. Ameresco used the International Performance Measurement and Verification Protocol (IPMVP) for the development of M&V procedures for this project.

The IPMVP protocol helps allocate various risks associated with achieving energy cost savings, reduces overall performance risk and facilitates better risk management. The protocols have several additional benefits:

- Define the role of verification in energy contracts and implementation
- Discuss procedures with varying levels of accuracy and cost for verifying baseline and project installation conditions and long-term energy savings performance
- Provide techniques for calculating whole-facility savings, individual technology savings, and stipulated savings
- Provide procedures that are consistent, industry-accepted, impartial, and reliable
- Provide procedures for the investigation and resolution of disagreements related to performance issues

The descriptions of the available M&V options provided in this section were developed by summarizing the IPMVP and contains an excerpt taken from that document.

The general approach to determining energy savings in these plans involves comparing the energy use of the system before installation of the ECM (baseline) and after installation of the ECM (post-retrofit). In general:

$$\text{Energy Savings} = \text{Baseline Energy Use} - \text{Post Retrofit Energy Use}$$

The IPMVP protocols define four M&V options (Options A through D) that meet the needs of a wide range of performance contracts and provide suggested procedures for baseline development and post-retrofit verification. These M&V options are flexible and reflect considerations such as complexity of the measure, potential interaction with other measures, and the level of projected savings versus the cost of the M&V services required by each option. The options are summarized in Table F.0.

Table F.0. Measurement and Verification Options

M&V Option	How Savings are Calculated	Typical Applications
Option A: Partially Measured Retrofit Isolation		
<p>Savings are determined by partial field measurement of the energy use of the system(s) to which an ECM was applied separate from the energy use of the rest of the facility. Measurements may be either short-term or continuous of the error they may introduce.</p> <p>Partial measurement means that some but not all parameter(s) may be stipulated, if the total impact of possible stipulation error(s) is not significant to the resultant savings. Careful review of ECM design and installation will ensure that stipulated values fairly represent the probable actual value. Stipulations should be shown in the M&V Plan along with analysis of the significance of the error they may introduce.</p>	<p>Engineering calculations using short term or continuous post-retrofit measurements and stipulations.</p>	<p>Lighting retrofit where power draw is measured periodically. Operating hours of the lights are stipulated.</p>
Option B: Retrofit Isolation		
<p>Savings are determined by field measurement of the energy use of the systems to which the ECM was applied separate from the energy use of the rest of the facility. Short-term or continuous measurements are taken throughout the post-retrofit period.</p>	<p>Engineering calculations using short term or continuous measurements.</p>	<p>Application of controls to vary the load on a constant speed pump used a variable speed drive. Electricity use is measured by a kWh meter installed on the electrical supply to the pump motor. In the base year this meter is in place for a week to verify constant loading. The meter is in place throughout the post-retrofit period to track variations in energy use.</p>
Option C: Whole Facility (Bill Comparison)		
<p>Savings are determined by measuring energy use at the whole facility level. Short-term or continuous measurements are taken throughout the post-retrofit period.</p>	<p>Analysis of whole facility utility meter or sub-meter data using techniques from simple comparison to regression analysis.</p>	<p>Multifaceted energy management program affecting many systems in a building. Energy use is measured by the gas and electric utility meters for a 12-month base year period and throughout the post-retrofit period.</p>
Option D: Calibrated Simulation (Calibrated Building Modeling)		
<p>Savings are determined through simulation of the energy use of components or the whole facility. Simulation routines must be demonstrated to adequately model actual energy performance measured in the facility. This option usually requires considerable skill in calibrated simulation.</p>	<p>Energy use simulation, calibrated with hourly or monthly utility billing data and/or end- use metering.</p>	<p>Multifaceted energy management program affecting many systems in a building but where no base year data are available. Post-retrofit period energy use is measured by the gas and electric utility meters. Base year energy use is determined by simulation using a model calibrated by the post-retrofit period utility data.</p>

Table F.1 summarizes the proposed M&V plans for this project. A detailed description of the plan for each ECM subsequently follows. The results of the M&V services will be reported to the City of Tucson on an annual basis. All specific protocols in the plans must be explained to and accepted by the City of Tucson before construction can begin. If the City of Tucson does not agree with the protocols used to verify the savings, there is potential for significant disagreement once verification efforts begin.

Table F.1. Measurement and Verification Summary Matrix

Energy Conservation Measure	IPMVP Option	M&V Requirements		Measurement and Metering	Stipulated Variables	Performance Period M&V Requirements
		Baseline	Post Retrofit			
ECM 1: Roadway Lighting and Controls ECM 2: Decorative and Specialty Fixture Retrofits ECM 3: Underpass Lighting Upgrade (Fixture Retrofit Savings)	A	Fixture wattages will be determined from measurements taken from a sample of fixtures. Sample size will be decided by post retrofit sample group. Operating hours will be based on discussions with facility personnel and sample short-term metering.	Input power for a statistically significant sample of each retrofitted fixture will be measured at time of commissioning.	Operating hours from the IGA will be used to calculate energy savings during the performance period. Baseline fixture wattage is to be measured prior to retrofit installation. Post-installation wattages will be measured after retrofit installation. If measured values fall within 10 percent of the expected values, the retrofit will be deemed to be operating as expected.	Baseline and post-installation power draw will be stipulated for the term of the performance period after the power draw has passed the +/-10 percent measurement check. Operating hours of each usage group are stipulated as shown in the IGA.	Ameresco will visually inspect a sample of fixtures and lamps to verify the lamp types are as efficient as those proposed in the IGA.
ECM 1: Roadway Lighting and Controls ECM 2: Decorative and Specialty Fixture Retrofits ECM 3: Underpass Lighting Upgrade (Control System Savings)	A	Operating hours of the existing fixtures without dimming or other controls will the same number of hours used to calculate savings from the fixture retrofit.	Short term metering of run hours and reduced power levels of select types of fixtures with controls accomplished using ROAM control trending reports.	Short-term metering of fixtures run hours with and without controls.	Baseline and post-retrofit fixture power draw from Lighting Retrofit ECM. Percentage reduction in annual operating hours. Percentage reduction due to dimming.	Annual inspection on a percentage of retrofitted light controls.

Table F.1. Measurement and Verification Summary Matrix

Energy Conservation Measure	IPMVP Option	M&V Requirements		Measurement and Metering	Stipulated Variables	Performance Period M&V Requirements
		Baseline	Post Retrofit			
ECM 5: Centro Garage ECM 7: City/State Garage ECM 9: Depot Plaza Garage ECM 11: La Entrada Garage ECM 13: Main Library Garage ECM 15: Pennington Garage (Fixture Retrofit Savings)	A	<p>Fixture wattages will be determined from measurements taken from a sample of fixtures. Sample size will be decided by post retrofit sample group.</p> <p>Operating hours will be based on discussions with facility personnel and sample short-term metering.</p>	<p>Input power for a statistically significant sample of each retrofitted fixture will be measured at time of commissioning.</p>	<p>Operating hours from the IGA will be used to calculate energy savings during the performance period.</p> <p>Baseline fixture wattage is to be measured prior to retrofit installation. Post-installation wattages will be measured after retrofit installation.</p> <p>If measured values fall within 10 percent of the expected values, the retrofit will be deemed to be operating as expected.</p>	<p>Baseline and post-installation power draw will be stipulated for the term of the performance period after the power draw has passed the +/-10 percent measurement check.</p> <p>Operating hours of each usage group are stipulated as shown in the IGA.</p>	<p>Ameresco will visually inspect a sample of lamps to verify the lamp types are as efficient as those proposed in the IGA.</p>
ECM 5: Centro Garage ECM 7: City/State Garage ECM 9: Depot Plaza Garage ECM 11: La Entrada Garage ECM 13: Main Library Garage ECM 15: Pennington Garage (Control System Savings)	A	<p>Operating hours of the existing fixtures without dimming or other controls will the same number of hours used to calculate savings from the fixture retrofit.</p>	<p>Short term metering of run hours and reduced power levels of select types of fixtures with controls accomplished using volt-amp hand held meters and/or data loggers.</p>	<p>Short-term metering of fixtures run hours with and without controls.</p>	<p>Baseline and post-retrofit fixture power draw from Lighting Retrofit ECMs 4, 5, 6, 7, 8 and 9.</p> <p>Percentage reduction in annual operating hours.</p> <p>Percentage reduction due to dimming.</p>	<p>Annual inspection on a percentage of retrofitted light controls.</p>

F.1 Utility Rate Summary

Energy savings will be calculated using the applicable billing unit of kWh. Tables F.2 through F.11 summarize the value of each of the different types of utility savings that will be used to calculate dollar savings in each year of the M&V period based on the utility escalation factor.

Table F.2. ECM 1: Roadway Street Lighting – Rate 41

Year	Electricity (\$/kWh)
Construction	0.102
Year 1	0.105
Year 2	0.108
Year 3	0.111
Year 4	0.115
Year 5	0.118
Year 6	0.122
Year 7	0.125
Year 8	0.129
Year 9	0.133
Year 10	0.137

Table F.3. ECM 1: Roadway Street Lighting (Intersection) – Rate 10

Year	Electricity (\$/kWh)
Construction	0.140
Year 1	0.144
Year 2	0.149
Year 3	0.153
Year 4	0.158
Year 5	0.162
Year 6	0.167
Year 7	0.172
Year 8	0.177
Year 9	0.183
Year 10	0.188

Table F.4. ECM 2: Decorative and Specialty Fixtures – Rate 41

Year	Electricity (\$/kWh)
Construction	0.102
Year 1	0.105
Year 2	0.108
Year 3	0.111
Year 4	0.115
Year 5	0.118
Year 6	0.122
Year 7	0.125
Year 8	0.129
Year 9	0.133
Year 10	0.137

Table F.5. ECM 3: Underpass Lighting – Rate 41

Year	Electricity (\$/kWh)
Construction	0.102
Year 1	0.105
Year 2	0.108
Year 3	0.111
Year 4	0.115
Year 5	0.118
Year 6	0.122
Year 7	0.125
Year 8	0.129
Year 9	0.133
Year 10	0.137

Table F.6. ECM 5: Centro Garage – Rate 41

Year	Electricity (\$/kWh)
Construction	0.102
Year 1	0.105
Year 2	0.108
Year 3	0.111
Year 4	0.115
Year 5	0.118
Year 6	0.122
Year 7	0.125
Year 8	0.129
Year 9	0.133
Year 10	0.137

Table F.7. ECM 7: City/State Garage – Rate 41

Year	Electricity (\$/kWh)
Construction	0.102
Year 1	0.105
Year 2	0.108
Year 3	0.111
Year 4	0.115
Year 5	0.118
Year 6	0.122
Year 7	0.125
Year 8	0.129
Year 9	0.133
Year 10	0.137

Table F.8. ECM 9: Depot Plaza Garage – Rate 41

Year	Electricity (\$/kWh)
Construction	0.102
Year 1	0.105
Year 2	0.108
Year 3	0.111
Year 4	0.115
Year 5	0.118
Year 6	0.122
Year 7	0.125
Year 8	0.129
Year 9	0.133
Year 10	0.137

Table F.9. ECM 11: La Entrada Garage (Water Department Building) – Rate 13

Year	Electricity (\$/kW)	Electricity (\$/kWh)
Construction	15.25	0.1126
Year 1	15.7075	0.1160
Year 2	16.1786	0.1195
Year 3	16.6641	0.1231
Year 4	17.1640	0.1268
Year 5	17.6789	0.1306
Year 6	18.2093	0.1345
Year 7	18.7556	0.1385
Year 8	19.3182	0.1427
Year 9	19.8978	0.1470
Year 10	20.4947	0.1514

Table F.10. ECM 13: Main Library Garage – Rate 13

Year	Electricity (\$/kW)	Electricity (\$/kWh)
Construction	15.25	0.1126
Year 1	15.7075	0.1160
Year 2	16.1786	0.1195
Year 3	16.6641	0.1231
Year 4	17.1640	0.1268
Year 5	17.6789	0.1306
Year 6	18.2093	0.1345
Year 7	18.7556	0.1385
Year 8	19.3182	0.1427
Year 9	19.8978	0.1470
Year 10	20.4947	0.1514

Table F.11. ECM 15: Pennington Garage – Rate 41

Year	Electricity (\$/kWh)
Construction	0.102
Year 1	0.105
Year 2	0.108
Year 3	0.111
Year 4	0.115
Year 5	0.118
Year 6	0.122
Year 7	0.125
Year 8	0.129
Year 9	0.133
Year 10	0.137

F.2 Measurement and Verification Plans

ECMs 1, 2 and 3: Fixture Retrofit Savings

- ECM 1: Roadway Lighting
- ECM 2: Decorative and Specialty Fixture Lighting
- ECM 3: Underpass Lighting

The M&V protocol for ECMs 1, 2 and 3 is based on the guidelines of the IPMVP Option A. Option A involves verifying that the measure has the potential to perform and to generate savings. Performance verification techniques include engineering calculations with one-time representative measured values, resulting in measured verification of performance. With the chosen method, hours of operation are agreed upon. Post installation fixture wattages will be determined from one-time post-retrofit spot measurements of representative fixture types.

Ameresco will perform equipment measurements to verify that the performance of the installed equipment will operate at the levels defined within the audit (power input at stated conditions). This will be established by measuring a percentage of fixtures of a defined group. If the lighting systems do not perform as proposed, Ameresco will either change the systems or compensate the City of Tucson. For the site operating hours, Ameresco will not be managing the hours of operation of the equipment and cannot be reasonably requested to assume the risk for this variable. Therefore, the City of Tucson and Ameresco will agree to the run hours for the life of the contract. Table F.12 shows the existing operating hours to be stipulated. The upgraded hours of operation that are less than the existing hours of operation are due to the installation of lighting controls.

Table F.12. Typical Operating Hours

Area Description	Total Annual Dark Hours of Operation (1)
Typical Roadway Lighting	4,314

(1) Based on U.S. Naval Observatory, Astronomical Applications Dept., Washington D.C., Duration of Darkness for 2015, Tucson Arizona

> Energy Savings Calculation Methodology

Savings Algorithms

The general savings calculation is defined as:

$$\text{Electricity Savings} = \text{Lighting kWh Savings}$$

Where:

$$\begin{aligned} \text{Electricity Savings} &= \text{Total electric energy savings (kWh)} \\ \text{Lighting kWh Savings} &= \text{Lighting system electric energy savings (kWh)} \end{aligned}$$

Direct Savings

Energy savings for ECM 1 is generated directly by the watt reduction with the new fixture upgrade. The following was used to determine the annual energy savings for each fixture.

$$\text{Lighting kWh Savings} = \text{Base Lighting kWh} - \text{Post Lighting kWh}$$

$$\text{Base Lighting kWh} = \text{Base Light kW} \times \text{Hours}$$

$$\text{Post Lighting kWh} = \text{Post Light kW} \times \text{Hours:}$$

<i>Lighting kWh Savings</i>	=	<i>Lighting system electric energy savings (kWh)</i>
<i>Base Lighting kWh</i>	=	<i>Base lighting equipment electric energy consumption (kWh)</i>
<i>Post Lighting kWh</i>	=	<i>Post lighting equipment electric energy consumption (kWh)</i>

> Metering Plan

The base year energy consumption data provided in section C.0 Base Year Utility Usage is calculated from the fixture quantities and wattages validated as part of the investment grade field audit. The Energy Cap utility summary report data provided by the City of Tucson was used to establish the annual energy and cost baseline. The twelve month base year period used to establish the baseline is from June 2014 to May 2015 and was reviewed as the basis of the Investment Grade Audit.

Ameresco will measure the fixture input power based on the Federal Energy Management Plan (FEMP) 80/20 accuracy level. The existing fixtures will be measured according to Table F.13 on the following page. To achieve the 80/20 level, Ameresco will measure 265 fixtures for the existing condition. The electric utility accounts that form the basis of the Investment Grade Audit can be found in the appendices.

Table F.13. Existing Roadway Fixture Sampling Plan

Existing Fixture Model and Wattage	Type	Wattage	Quantity	Quantity to Measure
Cobrahead	HPS	100	1,014	11
Cobrahead	HPS	150	796	11
Cobrahead	HPS	250	1,555	11
Cobrahead	HPS	400	10,050	11
Cobrahead	LED	53	921	11
Cobrahead	LED	81	38	9
Cobrahead	LED	83	2	2
Cobrahead	LED	117	32	9
Cobrahead	LED	185	33	9
Cobrahead	LED	215	49	9
Cobrahead	LPS	50	28	8
Cobrahead	LPS	90	2,809	11
Cobrahead	LPS	135	27	8
Cobrahead	LPS	180	49	9
Cobrahead – McGrawEdison	HPS	400	154	11
Decorative – Bollard	LPS	55	10	6
Decorative – Globe	FL	20	1,066	11
Decorative – Pendant Acorn	FL	20	60	10
Cobrahead	LED	18	14	7
Decorative – Postop	HPS	100	268	11
Decorative – Postop Acorn 20	FL	20	294	11
Decorative - Radius Tube	HPS	150	8	5
Decorative – Wall Mount	FL	55	25	8
Pendant – Bell 400	HPS	400	39	9
Pendant – Bell Scott 85	IND	85	106	10
Pendant – SC 400	HPS	400	51	10
Pendant – SC 400 Cushing	HPS	400	36	9
Pendant – SC 70	MH	70	45	9
Pendant – SC 70 Cushing	MH	70	41	9
Shoebox	HPS	150	22	8
Shoebox	HPS	250	332	11
Shoebox	HPS	400	101	10
Wall Pack	HPS	150	106	10
Wall Pack	MH	70	63	10
Wall Pack	MH	100	37	9
Total:			20,281	265

The new fixture energy consumption trending data will be retrieved by means of the wireless ROAM control system to reconcile the proposed condition. All fixtures with ROAM control will be reconciled using the ROAM control system. Sample current measurements will be performed on fixtures where ROAM control does not exist, typically decorative and underpass fixtures to reconcile the proposed condition. The proposed fixtures will be measured according to Table F.14. To achieve the 80/20 level, Ameresco will measure 156 fixtures for the proposed condition.

Table F.14. Proposed Roadway Fixture Sampling Plan

New Fixture Type and Wattage	New Fixture Model Number	New Fixture with Control	Replaces Existing Fixture Model	Quantity	Quantity to Measure
LED 72W	ATB0 20BLED10	ROAM	Shoebox	22	8
LED 138W	ATB2 40BLED10	ROAM	Shoebox	332	11
LED 208W	ATB2 60BLED10	ROAM	Shoebox	101	10
LED 173W	ATB2_60BLEDE85_480/MVOLT	ROAM	Cobrahead	832	11
LED 95W	ATBM D R3	ROAM	Cobrahead	10,595	11
LED 115W	ATBM E R3	ROAM	Cobrahead	1,498	11
LED 39W	ATBS E R2	ROAM	Cobrahead	3,153	11
LED 49W	ATBS F R3	ROAM	Cobrahead	326	11
LED 72W	ATBS H R2	ROAM	Cobrahead	1,153	11
LED 75W	GBLF2	ROAM	Pendant	192	11
LED 153W	GELF2	ROAM	Pendant	126	11
LED 12W	SCREW-IN	NA	Decorative	1,745	11
LED 72W	W4GLED 10C	NA	Wall Pack – Underpass	63	10
LED 138W	W4GLED 20C	NA	Wall Pack – Underpass	125	11
LED 208W	W4GLED 30C	NA	Wall Pack – Underpass	18	7
Total:				20,281	156

For the existing and proposed retrofit power measurements, the measurement will occur at the time of installation and, if the total sample values are within +/- 10 percent of the IGA values, no change will be made. If the total sample values are not within 10 percent, Ameresco will take corrective action for them to be within this limit or use the measured values.

No long-term term monitoring is included as part of this measure, however trending data from the ROAM control system will be used to reconcile the proposed conditions. Ameresco will inspect a sample of fixtures each year on fixtures that are not controlled by the ROAM system. The annual M&V report will be prepared based on the reconciliation reports performed at the end of construction and Ameresco’s inspection. The M&V for this ECM allows for a high level of accuracy in the calculation of savings, while limiting the costs of verification.

ECMs 1, 2 and 3: Control System Savings

- ECM 1: Roadway Lighting Control
- ECM 2: Decorative and Specialty Fixture Control
- ECM 3: Underpass Lighting Control

The M&V protocol for ECMs 1, 2 and 3 is based on the guidelines of the IPMVP Option A. Option A involves verifying that the measure has the potential to perform and to generate savings. Performance verification techniques include engineering calculations with one-time representative measured values, resulting in measured verification of performance. With the chosen method, fixture wattages will be agreed to and based on wattages found in Fixture Retrofit Savings for ECMs 1, 2 and 3. Pre- and post-lighting hour run time of fixtures will be determined from trending data reports generated by the ROAM control system.

Ameresco will accomplish equipment measurements by using the ROAM control system to verify that the performance of the installed equipment will operate at the levels defined within the audit (power input at stated conditions). This will be established by measuring a percentage of fixtures of the defined fixture models. If the lighting controls do not perform as proposed, Ameresco will either change the systems or compensate the City of Tucson.

For the site operating hours, Ameresco does not manage or control the hours of operation of the roadway lighting and cannot be reasonably requested to assume the risk for this variable. Therefore, the City and Ameresco will agree to the Initial Dimming Hours and Off Dimming Hours of operation for the life of the contract. During the initial dimming hours of operation, the energy consumption will be reduced to 90% of the maximum rated wattage output. During the Off Dimming Hours, the fixture wattage rating will be reduced to 30% of the maximum rated wattage output.

F.15. Initial Dimming and Off Hours Dimming Factor

Initial Dimming Hours Factor	Off Hours Dimming Factor
10%	30%

The upgraded hours of operation that are less than the existing hours of operation are due to the installation of lighting controls. Table F.16 Typical Roadway Operating Hours, F.17 High Pedestrian Roadway Operating Hours, and F.17 Intersection Roadway Operating Hours outlines the operating hours to be stipulated for the different roadway applications in this project.

Table F.16. Typical Roadway Operating Hours

New Fixture Models for Typical Lighting Applications	Quantity	Off Dimming Hours (12 AM - Dawn)	Off Dimming Hours (12 AM - Dawn)	Initial Dimming Hours (Dusk to Dawn)	Initial Dimming Hours (Dusk to Dawn)
		Summer	Winter	Summer	Winter
ATB0 20BLED10	22	976	1,353	1,598	2,716
ATB2 40BLED10	276	976	1,353	1,598	2,716
ATB2 60BLED10	92	976	1,353	1,598	2,716
ATB2_60BLEDE85_480/MVOLT	417	976	1,353	1,598	2,716
ATBM D R3	8,761	976	1,353	1,598	2,716
ATBM E R3	1,314	976	1,353	1,598	2,716
ATBS E R2	3,151	976	1,353	1,598	2,716
ATBS F R3	326	976	1,353	1,598	2,716
ATBS H R2	1,149	976	1,353	1,598	2,716
SCREW-IN	1,745	976	1,353	1,598	2,716
GBLF2	147	976	1,353	1,598	2,716
GELF2	51	976	1,353	1,598	2,716
W4GLED 10C	63	976	1,353	1,598	2,716
2,716W4GLED 20C	125	976	1,353	1,598	2,716
W4GL2,716ED 30C	18	976	1,353	1,598	2,716

Table F.17. High Pedestrian Roadway Operating Hours

New Fixture Models for Typical Lighting Applications	Quantity	Off Dimming Hours (3 AM - Dawn)	Off Dimming Hours (3 AM - Dawn)	Initial Dimming Hours (Dusk to Dawn)	Initial Dimming Hours (Dusk to Dawn)
		Summer	Winter	Summer	Winter
ATB2 40BLED10 MVOLT	75	517	717	1,598	2,716
ATB2 60BLED10 MVOLT	45	517	717	1,598	2,716
ATBM D R3	334	517	717	1,598	2,716
ATBS E R2	9	517	717	1,598	2,716
ATBS H R2	56	517	717	1,598	2,716
GBLF2	12	517	717	1,598	2,716
GELF2	3	517	717	1,598	2,716

Table F.18. Intersection Roadway Operating Hours

New Fixture Models for Typical Lighting Applications	Quantity	Initial Dimming Hours (Dusk to Dawn)	Initial Dimming Hours (Dusk to Dawn)
		Summer	Winter
ATB2 60BLED MVOLT	482	1,598	2,716
ATBM D R3	1,608	1,598	2,716

> Control System Energy Savings Calculation Methodology

Savings Algorithms

Energy savings for this ECM are primarily generated directly by reducing the energy consumption at the fixture. The following was used to determine the annual energy savings for each fixture.

$$\text{Lighting kWh Savings} = \text{Base Lighting kWh} - \text{Post Lighting kWh}$$

$$\text{Base Lighting kWh} = \text{Light kW} \times \text{Base Hours} \times \text{Dimming Factor}$$

$$\text{Post Lighting kWh} = \text{Light kW} \times \text{Post Hours} \times \text{Dimming Factor}$$

Where:

<i>Lighting kWh Savings</i>	=	<i>Lighting system electric energy savings (kWh)</i>
<i>Base Lighting kWh</i>	=	<i>Base lighting equipment electric energy consumption (kWh)</i>
<i>Post Lighting kWh</i>	=	<i>Post lighting equipment electric energy consumption (kWh)</i>
<i>Light kW</i>	=	<i>Lighting equipment electric power consumption (kW) (based on post lighting retrofit fixtures)</i>
<i>Base Hours</i>	=	<i>Base hours of operation</i>
<i>Post Hours</i>	=	<i>Post hours of operation</i>

> Metering Plan

Ameresco will log the run time of hour codes based on the FEMP 80/20 accuracy level. The hour code types will be measured according to Table F.19. To achieve the 80/20 level, Ameresco will measure 22 fixtures.

Table F.19. Proposed Roadway Control Sampling Plan

New Fixture Type and Wattage	New Fixture Model Number	New Fixture with Control	Replaces Existing Fixture Model	Quantity	Quantity to Measure
LED 72W	ATB0 20BLED10	ROAM	Shoebox	22	2
LED 138W	ATB2 40BLED10	ROAM	Shoebox	332	2
LED 208W	ATB2 60BLED10	ROAM	Shoebox	101	2
LED 173W	ATB2_60BLEDE85_480/MVOLT	ROAM	Cobrahead	832	2
LED 95W	ATBM D R3	ROAM	Cobrahead	10,595	2
LED 115W	ATBM E R3	ROAM	Cobrahead	1,498	2
LED 39W	ATBS E R2	ROAM	Cobrahead	3,153	2
LED 49W	ATBS F R3	ROAM	Cobrahead	326	2
LED 72W	ATBS H R2	ROAM	Cobrahead	1,153	2
LED 75W	GBLF2	ROAM	Pendant	192	2
LED 153W	GELF2	ROAM	Pendant	126	2
Total:				18,330	22

For the lighting run hour measurements, the measurements will occur once the ROAM system is commissioned and installation is complete and, if the total sample values are within +/- 10 percent of the IGA values, no change will be made. If the total sample values are not within 10 percent, Ameresco will take corrective action for them to be within this limit or use the measured values.

No long-term monitoring is included as part of this measure.

Ameresco will inspect a sample of lighting controls each year to verify their condition and operation. The annual M&V report will be prepared based on the measurements performed at the end of construction and Ameresco's inspection.

Expected Accuracy

The M&V for this ECM allows for a high level of accuracy in the calculation of savings, while limiting the costs of verification.

ECMs 5, 7, 9, 11, 13 and 15: Fixture Retrofit Savings

- ECM 5: Centro Garage Lighting
- ECM 7: City/State Garage Lighting
- ECM 9: Depot Plaza Garage Lighting
- ECM 11: La Entrada Garage (Tucson Water Building) Lighting
- ECM 13: Main Library Garage Lighting
- ECM 15: Pennington Garage

The M&V protocol for ECMs 5, 7, 9, 11, 13 and 15 is based on the guidelines of the IPMVP Option A. Option A involves verifying that the measure has the potential to perform and to generate savings. Performance verification techniques include engineering calculations with one-time representative measured values, resulting in measured verification of performance. With the chosen method, hours of operation are agreed upon. Post installation fixture wattages will be determined from one-time post-retrofit spot measurements of representative fixture types.

Ameresco will perform equipment measurements to verify that the performance of the installed equipment will operate at the levels defined within the audit (power input at stated conditions). This will be established by measuring a percentage of fixtures of a defined group. If the lighting systems do not perform as proposed, Ameresco will either change the systems or compensate the City of Tucson. For the site operating hours, Ameresco will not be managing the hours of operation of the equipment and cannot be reasonably requested to assume the risk for this variable. Therefore, the City of Tucson and Ameresco will agree to the run hours for the life of the contract. Table F.20 shows the existing operating hours to be stipulated. The upgraded hours of operation that are less than the existing hours of operation are due to the installation of lighting controls.

Table F.20. Typical Operating Hours

Area Description	Total Annual Dark Hours of Operation (1)
Typical Roadway Lighting	4,314

(1) Based on U.S. Naval Observatory, Astronomical Applications Dept., Washington D.C., Duration of Darkness for 2015, Tucson Arizona

> Energy Savings Calculation Methodology

Savings Algorithms

The general savings calculation is defined as:

$$\text{Electricity Savings} = \text{Lighting kWh Savings}$$

Where:

$$\begin{aligned} \text{Electricity Savings} &= \text{Total electric energy savings (kWh)} \\ \text{Lighting kWh Savings} &= \text{Lighting system electric energy savings (kWh)} \end{aligned}$$

Direct Savings

Energy savings for ECMs 5, 7, 9, 11, 13 and 15 is generated directly by the watt reduction with the new fixture upgrade. The following was used to determine the annual energy savings for each fixture.

$$\text{Lighting kWh Savings} = \text{Base Lighting kWh} - \text{Post Lighting kWh}$$

$$\text{Base Lighting kWh} = \text{Base Light kW} \times \text{Hours}$$

$$\text{Post Lighting kWh} = \text{Post Light kW} \times \text{Hours}$$

$$\begin{aligned} \text{Lighting kWh Savings} &= \text{Lighting system electric energy savings (kWh)} \\ \text{Base Lighting kWh} &= \text{Base lighting equipment electric energy consumption (kWh)} \\ \text{Post Lighting kWh} &= \text{Post lighting equipment electric energy consumption (kWh)} \end{aligned}$$

> Metering Plan

The base year energy consumption data provided in section C.0 Base Year Utility Usage is calculated from the based on the detailed field audit quantities, models, types, wattages and observed run-times as agreed to stipulate as part of this investment Grade Audit.

Ameresco will conduct required M&V measurements in parking garages that make up at least 75% of the existing kW lamp and ballast fixture groups kW measurements. Ameresco will conduct pre- and post-kW M&V on the existing fixture groups which make up at least 75% of the kW savings. Incandescent lamps will be avoided when possible. The planned measured lamp and ballast fixture groups are shown as quantity of fixtures to be measured in Table F.21.

Since it is possible that a significant lamp and ballast group is in an overall less significant parking garage, 75% kW savings by lamp and ballast fixture group value take priority over parking garage value. This means that 75% of the kW savings will be represented by the measured lamp and ballast fixture groups, regardless of which parking garage that may involve taking the measurements in. It also means that measurements will not be taken in every parking garage.

To achieve the 90% confidence, as per FEMP methodology described in Appendix B Sampling Guidelines in the FEMP M&V Guidelines (V 3.0, 2008 Appendix B, Appendix G [cf V 2.2, 2000, Appendix D]), Ameresco will measure 51 fixtures based on the following Table F.21.

Table F.21. Existing Garage Fixture Sampling Plan

Existing Fixture Code	Existing Technology	Quantity	Quantity to Measure
C-12"-VERT;MHSIMED28/400/1-MS (1)	Metal Halide	1	1
CAN;LPSDCBT17/55/1-MS	Low Pressure Sodium	416	2
CAN;LPSDCBT17/90/1-MS	Low Pressure Sodium	10	2
CAN-SM;HPSSIBD17/100/1-MS	High Pressure Sodium	176	2
CAN-SM;HPSSIMED28/150/1-MS	High Pressure Sodium	27	2
CYL-SM;HPSSIBD17/100/1-MS	High Pressure Sodium	9	2
DOME;CF4PMT/26/1-E	Compact Fluorescent	22	2
FL;MHSIBD17/175/1-MS	Metal Halide	2	1
L-1X4;FLUBPT8L4/32/2-EIN	Fluorescent	2	1
S;FLUBPT12L4/34/1-MS	Fluorescent	6	2
S;FLUBPT8L4/32/1-EIN	Fluorescent	9	2
S;FLUBPT8L4/32/2-EIN	Fluorescent	5	2
S-2';FLUBPT8L2/17/1-EIN	Fluorescent	2	1
S-3';FLUBPT12L3/30/1-MS	Fluorescent	2	1
SB-PM;LPSDCBT17/55/1-MS	Low Pressure Sodium	28	2
SB-PM;LPSDCBT17/90/1-MS	Low Pressure Sodium	23	2
SB-PT-PM;HPSSIMED18/250/1-MS	High Pressure Sodium	1	1
S-WG;FLUBPT8L4/32/2-EIN	Fluorescent	341	2
W;FLUBPT8L4/32/1-EIN	Fluorescent	30	2
W-2'-PULL;FLUBPT12L2/20/2-MS	Fluorescent	1	1
WPK;CF4PMT/42/1-E	Compact Fluorescent	14	2
WPK;LPSDCBT17/55/1-MS	Low Pressure Sodium	28	2
WPK;MHSIMED28/100/1-MS	Metal Halide	6	2
WS;CF2PMT/26/1-MS	Compact Fluorescent	12	2
WS;CF4PLBX/40/2-E	Compact Fluorescent	9	2
WWP;FLUBPT8L4/32/2-EIN	Fluorescent	266	2
WWP;FLUBPT8L4/32/4-EIN	Fluorescent	51	2
WWP-PEN;FLUBPT8L4/32/2-EIN	Fluorescent	46	2
WWP-PEN;FLUBPT8L4/32/4-EIN	Fluorescent	541	2
C-12"-VERT;MHSIMED28/400/1-MS	Metal Halide	1	1
Total:		2,087	51

(1) This line item is a single 400W HPS fixture in the Main Library and will require 2- LED N 26PG-ML fixtures to replace the single fixture, therefore the higher count of proposed fixtures in Table F.22 Proposed Garage Fixture Sampling Plan

The proposed fixture energy consumption will be measured using a volt-amp meter and/or data logger to reconcile the proposed condition by taking sample current and voltage measurements. The proposed fixture quantities will be measured according to Table F.22. To achieve the 90% confidence as per FEMP methodology described in Appendix B Sampling Guidelines in the FEMP M&V Guidelines (V 3.0, 2008 Appendix B, Appendix G [cf V 2.2, 2000, Appendix D]), Ameresco will measure 34 fixtures.

Table F.22. Proposed Garage Fixture Sampling Plan

Proposed Fixture Code	Quantity	Quantity to Measure
LED N 10.9RWS-HC	12	2
LED N 17WS-FC	20	2
LED RF 29KIT-1X4	2	1
LED N 20WPK-FC	24	2
LED N 26PG-ML (1)	336	2
LED N 27WS-DECO	13	2
LED N 32SL	20	2
LED N 32SL2'	4	2
LED N 32SL2'-PULL	1	1
LED N 37CH-SBMA	51	2
LED N 37PG-ML	905	2
LED N 37PG-ML-PEN	557	2
LED N 44WWP-ML	46	2
LED N 44WWP-PEN-ML	12	2
LED N 46PG-ML	27	2
LED N 52FL	2	1
LED N 60CH-SBMA	1	1
LED N 67PG-T5E-ML	44	2
LED N 67PG-T5E-ML-PEN	10	2
Total:	2,087	34

(1) See note one (1) in Table F.21. Existing Garage Fixture Sampling Plan

For the existing and proposed retrofit power measurements, the measurement will occur at the time of installation and, if the total sample values are within +/- 10 percent of the IGA values, no change will be made. If the total sample values are not within 10 percent, Ameresco will take corrective action for them to be within this limit or use the measured values.

Ameresco will inspect a sample of lamps each year on fixtures. The annual M&V report will be prepared based on reconciliation reports performed at the end of construction and Ameresco's inspection. The M&V for this ECM allows for a high level of accuracy in the calculation of savings, while limiting the costs of verification.

ECMs 5, 7, 9, 11, 13 and 15: Control System Savings

- ECM 5: Centro Garage Lighting Control
- ECM 7: City/State Garage Lighting Control
- ECM 9: Depot Plaza Garage Lighting Control
- ECM 11: La Entrada Garage (Tucson Water Building) Lighting Control
- ECM 13: Main Library Garage Lighting Control
- ECM 15: Pennington Garage Control

The M&V protocol for ECMs 5, 7, 9, 11, 13 and 15 is based on the guidelines of the IPMVP Option A. Option A involves verifying that the measure has the potential to perform and to generate savings. Performance verification techniques include engineering calculations with one-time representative measured values, resulting in measured verification of performance. With the chosen method, fixture wattages will be agreed to and based on wattages found in Fixture Retrofit Savings for ECMs 5, 7, 9, 11, 13 and 15. Operating hours will be stipulated to be those used in the IGA.

Ameresco will accomplish equipment measurements by using volt-amp meters and/or data loggers to verify that the performance of the installed equipment will operate at the levels defined within the audit (power input at stated conditions). This will be established by measuring a percentage of fixtures of the defined fixture models. If the lighting controls do not perform as proposed, Ameresco will either change the systems or compensate the City of Tucson.

For the site operating hours, Ameresco does not manage or control the hours of operation of the parking garage lighting and cannot be reasonably requested to assume the risk for this variable. Therefore, the City and Ameresco will agree to the hour of operation for the life of the contract.

The upgraded hours of operation that are less than the existing hours of operation are due to the installation of lighting controls. Table F.23 Parking Garage Operating Hours, shows the overall operating hours to be stipulated for the different parking garage applications in this project.

Table F.23. Parking Garage Operating Hours

Area Description	Total Annual Hours of Operation	
	Existing	Controlled
Centro Garage	7,728	4,024
City/State Garage	5,166	2,917
Depot Plaza Garage	8,511	3,642
La Entrada Garage (Tucson Water Building)	4,014	2,852
Main Library Garage	4,826	2,759
Pennington Garage	6,998	3,027

The total annual hours of operation are averages as different levels of the garage will likely have different savings for sensors. Historically, levels furthest away from the entrance/exit level have lower occupancy (best savings from controls) and levels near the entrance/exit level have higher occupancy (poorest savings from controls), therefore hour codes from the investment grade audit have been included that identify areas of varying occupancy. Reference Table F.24 for areas with varying hours of operation used as part of the Investment Grade Audit.

Table F.24. Parking Garage Hour Codes

Hour Code	Area Description	Total Annual Hours of Operation	
		Existing	Controlled
M/247	Mechanical, 24x7	8,760	NA
M-I	Mechanical Room – Inactive	522	NA
O	Office	3,132	NA
O-OS	Offices, Add New Occupancy Sensor	3,132	2,506
PG	Parking Garage, 12x7, No Daytime	4,380	1,752
PG/247	Parking Garage, 24x7	8,760	3,504
SW	Stairwells	4,385	2,192
SW/247	Parking Garage, 24x7	8,760	4,380
SW/X	Stairwell, 12x7, No Daytime	4,380	2,190
X	Outside Areas	4,380	1,752
Z	24 Hour Areas	8,760	NA
PG/CS	Parking Garage, Off 11pm to 4am Daily	6,933	3,466
PG/CS-ND	Parking Garage, No Daytime	1,822	911

> **Energy Savings Calculation Methodology**

Savings Algorithms

Energy savings for ECMs 5, 7, 9, 11, 13 and 15 are primarily generated directly by reducing the energy consumption at the fixture. The following was used to determine the annual energy savings for each fixture.

$$\text{Lighting kWh Savings} = \text{Base Lighting kWh} - \text{Post Lighting kWh}$$

$$\text{Base Lighting kWh} = \text{Light kW} \times \text{Base Hours}$$

$$\text{Post Lighting kWh} = \text{Light kW} \times \text{Controlled Hours}$$

Where:

- Lighting kWh Savings* = *Lighting system electric energy savings (kWh)*
- Base Lighting kWh* = *Base lighting equipment electric energy consumption (kWh)*
- Post Lighting kWh* = *Post lighting equipment electric energy consumption (kWh)*
- Light kW* = *Lighting equipment electric power consumption (kW) (based on post lighting retrofit fixtures)*
- Base Hours* = *Base hours of operation*
- Post Hours* = *Post hours of operation*

> Metering Plan

Ameresco will log the run time of hour codes based on Table F.23. Parking Garage Operating Hours and Table F.24. Parking Garage Hour Codes. To achieve the 90% confidence as per FEMP methodology described in Appendix B Sampling Guidelines in the FEMP M&V Guidelines (V 3.0, 2008 Appendix B, Appendix G [cf V 2.2, 2000, Appendix D]), Ameresco will measure 44 fixture controls based on the following Table F.25. Proposed Control Sampling Plan.

Table F.25. Proposed Garage Control Sampling Plan

Control Type	Quantity	Quantity to Measure
Fixture Multi-Level Control (PIR Occupancy Sensor w/integrated photocell, tunable max/min dim levels, adjustable time delays, and adjustable Ramp rates)	1,937	44
Occupancy sensor, Wall Switch, 1 Gang, Passive Infrared (utility closet)	1	0
Control Receptacle (ROAM ready)	52	0
Total:	1,990	44

The main control type here is the fixture mounted control. The Control Receptacle (ROAM ready fixtures) are on the pole mounted fixtures on the parking garage roofs. The fixtures do not have ROAM controls but have the receptacle to accept the ROAM controls being utilized on ECM 1, 2, 3 of the LED Light Conversion Project.

For the lighting run hour measurements, the measurement will occur at the time of installation and, if the total sample values are within +/- 10 percent of the IGA values, no change will be made. If the total sample values are not within 10 percent, Ameresco will take corrective action for them to be within this limit or use the measured values.

No long-term monitoring is included as part of this measure.

Ameresco will inspect a sample of lighting controls each year to verify their condition and operation. The annual M&V report will be prepared based on the measurements performed at the end of construction and Ameresco's inspection.

Expected Accuracy

The M&V for this ECM allows for a high level of accuracy in the calculation of savings, while limiting the costs of verification.

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G.0 Commissioning Plan

G.1 Performance Testing and Commissioning Matrix

The performance testing and commissioning matrix for this project is provided in Table G.0. Pre-functional and functional reports will be modified during the design and construction phases based on actual system design and installation. Results of pre-functional and functional testing will be included in the O&M manuals provided to the City of Tucson at the completion of the construction phase.

The commissioning process consists of two main steps: pre-functional check and functional testing. The pre-functional check is the verification process before, during and after construction to ensure the system is installed according to the design intent. This process includes verification of installed equipment according to engineering specifications and submittals, verification of installation work according to manufacturers' specifications, inspections for equipment or installation flaws or inconsistencies, and other related inspection work. Pre-functional checks must be conducted before a full functional testing can be performed. Each subcontractor will be responsible for its own individual checks prior to installing the equipment. Ameresco will be responsible for the project-wide pre-functional checks during and after construction to ensure the system is installed as designed.

The functional test, the second step in the commissioning process, is the process of testing the installed systems to ensure that they operate as designed and can achieve the level of intended performance. In the functional test, operation of each piece of equipment, as well as its operation as part of a system, is verified, including lighting output, power draw, dimming control, etc. The functional test also includes testing system performance under various simulated conditions (e.g., to simulate peak internal fixture temperatures if the test is conducted in the summer). Results of the tests will be recorded, and any discrepancies with design values will be noted. Necessary modifications will be performed to rectify any performance levels that do not conform to design. Generally, Ameresco will be responsible for conducting and supervising the functional test with approved vendors and subcontractor representatives. Maintenance personnel are also encouraged to be involved in the process, as it will help transition the operation and maintenance responsibilities to the City of Tucson.

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Table G.0. Performance Testing and Commissioning Matrix

Energy Conservation Measure	Equipment/ Systems to be Performance Tested	Observations, Tests and Inspections During Construction (Pre-Functional)	Pre-Functional Responsibility	Observations, Tests and Inspections Prior to Acceptance (Functional)	Functional Responsibility	Testing Documentation
ECM 1: Roadway Lighting and Controls	Lighting Fixtures	Visually verify operation of all fixtures as completed.	Lighting Contractor	Measure power input at the switch or fixture for a statistically significant number of fixtures in locations mutually agreed by the client and Ameresco. Verify proper operation of ROAM dimming control and scheduling.	Subcontractor and Ameresco	Lighting commissioning data sheets will be completed for all new fixtures.
ECM 2: Decorative and Specialty Fixture Retrofits	Lighting Fixtures	Visually verify operation of all fixtures as completed.	Lighting Contractor	Measure power input at the switch or fixture for a statistically significant number of fixtures in locations mutually agreed by the client and Ameresco. Verify proper operation of ROAM dimming control and scheduling.	Subcontractor and Ameresco	Lighting commissioning data sheets will be completed for all new fixtures.
ECM 3: Underpass Lighting Upgrade	Lighting Fixtures	Visually verify operation of all fixtures as completed.	Lighting Contractor	Measure power input at the switch or fixture for a statistically significant number of fixtures in locations mutually agreed by the client and Ameresco. Verify proper operation of ROAM dimming control and scheduling.	Subcontractor and Ameresco	Lighting commissioning data sheets will be completed for all new fixtures.
ECM 5: Centro Garage with Occupancy and Daylight Controls	Lighting Fixtures	Visually verify operation of all fixtures as completed.	Lighting Contractor	Measure power input at the switch or fixture for a statistically significant number of fixtures in locations mutually agreed by the client and Ameresco. Verify proper operation of ROAM dimming control and scheduling.	Subcontractor and Ameresco	Lighting commissioning data sheets will be completed for all new fixtures.
ECM 7: City/State Garage with Occupancy and Daylight Controls	Lighting Fixtures	Visually verify operation of all fixtures as completed.	Lighting Contractor	Measure power input at the switch or fixture for a statistically significant number of fixtures in locations mutually agreed by the client and Ameresco. Verify proper operation of ROAM dimming control and scheduling.	Subcontractor and Ameresco	Lighting commissioning data sheets will be completed for all new fixtures.

Table G.0. Performance Testing and Commissioning Matrix

Energy Conservation Measure	Equipment/ Systems to be Performance Tested	Observations, Tests and Inspections During Construction (Pre-Functional)	Pre-Functional Responsibility	Observations, Tests and Inspections Prior to Acceptance (Functional)	Functional Responsibility	Testing Documentation
ECM 9: Depot Plaza Garage with Occupancy and Daylight Controls	Lighting Fixtures	Visually verify operation of all fixtures as completed.	Lighting Contractor	Measure power input at the switch or fixture for a statistically significant number of fixtures in locations mutually agreed by the client and Ameresco. Verify proper operation of ROAM dimming control and scheduling.	Subcontractor and Ameresco	Lighting commissioning data sheets will be completed for all new fixtures.
ECM 11: La Entrada Garage with Occupancy and Daylight Controls	Lighting Fixtures	Visually verify operation of all fixtures as completed.	Lighting Contractor	Measure power input at the switch or fixture for a statistically significant number of fixtures in locations mutually agreed by the client and Ameresco. Verify proper operation of ROAM dimming control and scheduling.	Subcontractor and Ameresco	Lighting commissioning data sheets will be completed for all new fixtures.
ECM 13: Main Library Garage with Occupancy and Daylight Controls	Lighting Fixtures	Visually verify operation of all fixtures as completed.	Lighting Contractor	Measure power input at the switch or fixture for a statistically significant number of fixtures in locations mutually agreed by the client and Ameresco. Verify proper operation of ROAM dimming control and scheduling.	Subcontractor and Ameresco	Lighting commissioning data sheets will be completed for all new fixtures.
ECM 15: Pennington Garage with Occupancy and Daylight Controls	Lighting Fixtures	Visually verify operation of all fixtures as completed.	Lighting Contractor	Measure power input at the switch or fixture for a statistically significant number of fixtures in locations mutually agreed by the client and Ameresco. Verify proper operation of ROAM dimming control and scheduling.	Subcontractor and Ameresco	Lighting commissioning data sheets will be completed for all new fixtures.

G.2 Performance Period Commissioning Plan

Commissioning activities during the contract period will coincide with annual onsite M&V activities and will vary by measure. In general, onsite M&V tasks include interviews with site maintenance personnel responsible for the equipment, reviews of maintenance records and a visual inspection of the equipment. Variations in equipment and/or operation that are or could be negatively affecting system performance will be noted in the annual reconciliation report.

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H.0 Acceptance Procedures

Upon completion of the pre-functional testing and prior to the completion of the functional performance testing, Ameresco will submit Certificates of Substantial Completion for ECMs that provide a performance and financial benefit to the City of Tucson. Punch lists will accompany the Certificates of Substantial Completion; all punch list items that could directly affect the potential to generate energy cost savings must be completed prior to functional performance testing. Note that the warranty periods for equipment and/or systems that are in operation will begin upon execution of the Certificates of Substantial Completion for each ECM.

Functional performance tests will be conducted upon the completion of all punch list items that could potentially affect an ECM's ability to generate energy cost savings. Upon successful completion of these tests, the ECMs are deemed to have the potential to achieve the estimated energy cost and maintenance savings. Ameresco will then formally request an inspection of the work completed from the City of Tucson. A Certificate of Acceptance of Construction Completion and Inspection will accompany the formal inspection request. The Certificate of Acceptance of Construction Completion and Inspection formally acknowledges that the work has been completed, or a portion thereof, and is accepted by the City of Tucson.

Some ECMs may not be able to be completed at that time due to circumstances beyond Ameresco's control. In these instances, a percentage complete will be assigned to the ECM with a punch list of outstanding items. Because the functional performance test will have been completed prior to requesting the final inspection, these items will not typically have an impact on the savings or the potential to achieve savings. All outstanding punch list items will be completed as soon as possible.

O&M manuals will be provided upon completion of all functional performance tests and upon completion of the as-built documentation. All necessary training will be provided as outlined in Section I.0.

Documentation to be provided will include O&M manuals, which (in printed form) will be contained in a sturdy binder printed on 8.5-inch by 11-inch sheets of paper and consist of the following sections and information:

- Section I: System Description
 - A detailed description of each system, including its major components and function
 - Control strategies and sequences describing start-up, modes of operation and shutdown
 - Procedures for the operation of every system, including all required emergency instructions and safety precautions

- Reduced scale schematic or piping and instrument diagram drawings depicting system overviews
- Section II: Equipment Data Sheets
 - Corrected shop drawings, including performance curves, efficiency ratings, features and options
 - Copies of approved certifications and factory test reports, where applicable
 - Wiring and control schematics detailing the operation and control of each component for troubleshooting
 - Manufacturers’ O&M manuals
 - Manufacturers’ spare parts lists
 - Manufacturers’ recommended spare parts inventory lists
 - Manufacturers’ recommended lubricating schedule, including type, grade, temperature, and frequency, as applicable
 - Name, address, and telephone number of the manufacturers’ local representative(s) for each type of equipment for replacement parts and service
- Section III: Maintenance
 - This section will be modified for each project based on the maintenance requirements of the contract
- Section IV: Test Reports
 - Pre-functional reports: Equipment start-up reports and commissioning data sheets
 - Functional reports: System start-up reports and functional performance tests
 - Copies of welder certifications, where applicable
 - Non-destructive testing reports, where applicable
 - Hydrostatic/pneumatic pipe testing reports, where applicable
 - Water treatment analysis and report, where applicable
 - Testing and balancing reports, where applicable
 - Other reports, where applicable
- Section V: Warranties and Guarantees
 - A warranty for each system installed typewritten on company letterhead. The warranty will state the system and components covered, the duration of the warranty period, and emergency contact phone numbers for service and repair
 - Warranties and/or guarantees from subcontractors or equipment suppliers

I.0 Training Plan

Training and orientation on the systems installed will vary depending on the complexity of the specific equipment installed for each ECM. Training will be provided in the following levels:

- **Level 1:** For systems and/or equipment that are essentially direct replacements of existing equipment and where no additional specific skills will be required to perform operations and maintenance functions, training will be limited to a general overview of the equipment installed and a review of the O&M manuals. Training will be directed to the City of Tucson facilities' operations and maintenance personnel. The review of the O&M manuals will provide staff with familiarity with the equipment installed, manufacturers' recommended maintenance procedures and warranty information. Training will be provided at the completion of construction for each of the ECMs.
- **Level 2:** For systems and/or equipment that are new to the site and require some general understanding as to their functions and operations, training will include a minimal amount of classroom time to provide an overview of the technology and any specific maintenance or operational requirements. Following the classroom training, a site tour will be conducted to view the installation and operation of the equipment. Training should occur at both the onset and completion of construction. Equipment cutsheets will be provided at the beginning of construction that provide a general description of the equipment, function and operation. At the conclusion of construction, O&M manuals will provide parts lists and warranty information.
- **Level 3:** For systems and/or equipment that are new to the site and more complex in nature, training will be directed to both the facilities engineering and O&M personnel. In general, training will consist of classroom training followed by hands-on instruction in the field. Training will be provided through a complement of Ameresco personnel, design engineers, installation contractors and manufacturer's representatives, as necessary, and will be dictated by the complexity of the installation, participants' prior experience with the installed equipment, and contractual obligations.

Specifics on the training program, including the schedule and training materials, will be further refined during the design process. In general, training will consist of the following:

- Explanation of the design concept
 - Design intent
 - Energy efficiency considerations
 - Seasonal modes of operation

- Emergency conditions and operation
- Comfort conditions and indoor air quality
- Systems operation
 - Operation of individual components, including instruction from authorized factory technicians, as required
 - Physical location of critical shut-off valves; fire, smoke, and balancing dampers; relief valves; safeties; and control panels
 - System operational procedures for all manual and automatic modes
- Operation of the control systems
 - Sequences of operation
 - Use of graphical user interfaces
 - Alarms and problem indicators
 - Diagnostics and corrective actions
- Service and maintenance
 - Use of the O&M manuals
 - Instruction and logging procedures for lubrication, as required
 - Instruction from authorized factory technicians, as required
 - Troubleshooting and investigation of malfunctions
 - Recommended procedures for collecting, interpreting, and storing specific performance data

The types of training planned for this project has been listed in Table I.0. Training will be provided during the construction, commissioning and acceptance phases as dictated by the complexity of the ECM.

Table I.0. Training Plan

Energy Conservation Measure	Training Level	Training (Hours)	
		Classroom	Field
ECM 1: Roadway Lighting and Controls	3	4	4
ECM 2: Decorative and Specialty Fixture Retrofits	1	N/A	1
ECM 3: Underpass Lighting Upgrade	1	N/A	1
ECM 5: Centro Garage with Occupancy and Daylight Controls	1	N/A	1
ECM 7: City/State Garage with Occupancy and Daylight Controls	1	N/A	1
ECM 9: Depot Plaza Garage with Occupancy and Daylight Controls	1	N/A	1
ECM 11: La Entrada Garage with Occupancy and Daylight Controls	1	N/A	1
ECM 13: Main Library Garage with Occupancy and Daylight Controls	1	N/A	1
ECM 15: Pennington Garage with Occupancy and Daylight Controls	1	N/A	1

A controls training allowance of 8 hours has been provided for the ROAM controls ECM. Use of the allowance will be directed by the City of Tucson IT facilities group. Training by a manufacturer representative can be divided between classroom, field and workstation, as desired. The level of training will be based on access and clearances (i.e. highest level of training for primary operators, lowest level for field technicians, etc.).

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J.0 Operations, Maintenance and Warranty Plan

A well-designed and properly executed maintenance program is a crucial element to long-term ECM performance and savings. In order to maximize the energy savings and equipment performance, the ECMs should be maintained under an ongoing, structured service program for the life of the contract, and ideally beyond. Ameresco has a vested interest in the equipment performance and maintenance required to realize all possible energy savings, which form the basis of our guarantee. Typically, the equipment and systems Ameresco proposes can generally be maintained and serviced by a variety of service entities, including maintenance personnel currently employed by the City of Tucson and/or a combination of service providers.

In this case, Ameresco is providing an extended 10 year labor warranty under an annual Operations and Maintenance contract as shown in the project proformas (5 years on screw-in LED lamps) to supplement the manufacturers material warranties so that the complete system is fully covered for warranty related failures as noted. This does not include failures caused by non-warranty issues such as pole knockdowns, acts of god (weather) or other issues excluded from the manufacturers' warranties.

The primary point of contact for all maintenance, warranty and monitoring operations will be Mr. Steve Croxton, Ameresco's Regional Energy Manager. He will retain overall responsibility for scheduled preventative maintenance, emergency service, and monitoring of energy use for the term of the project. Mr. Croxton will serve as the single point of contact for the City of Tucson throughout the entire operational phase of the project.

J.1 Scheduled Preventative Maintenance

Please reference Table J.0 for a summary of the operations and maintenance (O&M) plan for this project. Detailed descriptions of the included scope for each ECM are presented in the section that follows.

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Table J.0. Operations and Maintenance Matrix

Energy Conservation Measure	Operations Responsibilities		Maintenance Responsibilities		Warranty
	Ameresco	City of Tucson	Ameresco	City of Tucson	
ECM 1: Roadway Lighting and Controls	None	Manage and maintain ROAM control scheduling and dimming operations. Periodic inspections to verify proper operation.	Corrective warranty parts and labor repairs of LED fixtures and controls for 10 years, as required.	The City of Tucson will be first responder on all failure calls and notify Ameresco for warranty service and repairs. Preventive maintenance per manufacturer's recommendations at recommended intervals.	The LED fixtures are covered by manufacturer-provided warranties for 10 years. All equipment warranties and the labor to make warranty repairs will be administered by Ameresco. Ameresco is providing a 10 year warranty on the ROAM System and Components. For warranty purposes, manufacturers may request the defective product be returned for analysis. Ameresco will retain all LED fixtures which fail prematurely and provide to the manufacturer upon request.
ECM 2: Decorative and Specialty Fixture Retrofits	None	Manage and maintain lighting systems. Periodic inspections to verify proper operation.	Corrective warranty parts and labor repairs of LED fixtures for 5 years, as required.	The City of Tucson will be first responder on all failure calls and notify Ameresco for warranty service and repairs. Preventive maintenance per manufacturer's recommendations at recommended intervals.	The LED screw-in type fixtures are covered by manufacturer-provided warranties for 5 years. All equipment warranties and the labor to make warranty repairs will be administered by Ameresco. The screw-in LED lamps have a 5 year labor and material warranty. For warranty purposes, manufacturers may request the defective product be returned for analysis. Ameresco will retain all LED fixtures which fail prematurely and provide to the manufacturer upon request.
ECM 3: Underpass Lighting Upgrade	None	Manage and maintain lighting systems. Periodic inspections to verify proper operation.	Corrective warranty parts and labor repairs of LED fixtures for 10 years, as required.	The City of Tucson will be first responder on all failure calls and notify Ameresco for warranty service and repairs. Preventive maintenance per manufacturer's recommendations at recommended intervals.	The LED wallpack fixtures are covered by manufacturer-provided warranties for 10 years. All equipment warranties and the labor to make warranty repairs will be administered by Ameresco. For warranty purposes, manufacturers may request the defective product be returned for analysis. Ameresco will retain all LED fixtures which fail prematurely and provide to the manufacturer upon request.

Table J.0. Operations and Maintenance Matrix

Energy Conservation Measure	Operations Responsibilities		Maintenance Responsibilities		Warranty
	Ameresco	City of Tucson	Ameresco	City of Tucson	
ECM 5: Centro Garage with Occupancy and Daylight Controls	None	Manage and maintain control scheduling and dimming operations. Periodic inspections to verify proper operation.	Corrective warranty parts and labor repairs of LED fixtures and controls for 10 years, as required.	The City of Tucson will be first responder on all failure calls and notify Ameresco for warranty service and repairs. Preventive maintenance per manufacturer's recommendations at recommended intervals.	The LED garage LED fixtures and controls are covered by manufacturer-provided warranties for 10 years. All equipment warranties and the labor to make warranty repairs will be administered by Ameresco. For warranty purposes, manufacturers may request the defective product be returned for analysis. Ameresco will retain all LED fixtures which fail prematurely and provide to the manufacturer upon request.
ECM 7: City/State Garage with Occupancy and Daylight Controls	None	Manage and maintain control scheduling and dimming operations. Periodic inspections to verify proper operation.	Corrective warranty parts and labor repairs of LED fixtures and controls for 10 years, as required.	The City of Tucson will be first responder on all failure calls and notify Ameresco for warranty service and repairs. Preventive maintenance per manufacturer's recommendations at recommended intervals.	The LED garage LED fixtures and controls are covered by manufacturer-provided warranties for 10 years. All equipment warranties and the labor to make warranty repairs will be administered by Ameresco. For warranty purposes, manufacturers may request the defective product be returned for analysis. Ameresco will retain all LED fixtures which fail prematurely and provide to the manufacturer upon request.
ECM 9: Depot Plaza Garage with Occupancy and Daylight Controls	None	Manage and maintain control scheduling and dimming operations. Periodic inspections to verify proper operation.	Corrective warranty parts and labor repairs of LED fixtures and controls for 10 years, as required.	The City of Tucson will be first responder on all failure calls and notify Ameresco for warranty service and repairs. Preventive maintenance per manufacturer's recommendations at recommended intervals.	The LED garage LED fixtures and controls are covered by manufacturer-provided warranties for 10 years. All equipment warranties and the labor to make warranty repairs will be administered by Ameresco. For warranty purposes, manufacturers may request the defective product be returned for analysis. Ameresco will retain all LED fixtures which fail prematurely and provide to the manufacturer upon request.

Table J.0. Operations and Maintenance Matrix

Energy Conservation Measure	Operations Responsibilities		Maintenance Responsibilities		Warranty
	Ameresco	City of Tucson	Ameresco	City of Tucson	
ECM 11: La Entrada Garage with Occupancy and Daylight Controls	None	Manage and maintain control scheduling and dimming operations. Periodic inspections to verify proper operation.	Corrective warranty parts and labor repairs of LED fixtures and controls for 10 years, as required.	The City of Tucson will be first responder on all failure calls and notify Ameresco for warranty service and repairs. Preventive maintenance per manufacturer's recommendations at recommended intervals.	The LED garage LED fixtures and controls are covered by manufacturer-provided warranties for 10 years. All equipment warranties and the labor to make warranty repairs will be administered by Ameresco. For warranty purposes, manufacturers may request the defective product be returned for analysis. Ameresco will retain all LED fixtures which fail prematurely and provide to the manufacturer upon request.
ECM 13: Main Library Garage with Occupancy and Daylight Controls	None	Manage and maintain control scheduling and dimming operations. Periodic inspections to verify proper operation.	Corrective warranty parts and labor repairs of LED fixtures and controls for 10 years, as required.	The City of Tucson will be first responder on all failure calls and notify Ameresco for warranty service and repairs. Preventive maintenance per manufacturer's recommendations at recommended intervals.	The LED garage LED fixtures and controls are covered by manufacturer-provided warranties for 10 years. All equipment warranties and the labor to make warranty repairs will be administered by Ameresco. For warranty purposes, manufacturers may request the defective product be returned for analysis. Ameresco will retain all LED fixtures which fail prematurely and provide to the manufacturer upon request.
ECM 15: Pennington Garage with Occupancy and Daylight Controls	None	Manage and maintain control scheduling and dimming operations. Periodic inspections to verify proper operation.	Corrective warranty parts and labor repairs of LED fixtures and controls for 10 years, as required.	The City of Tucson will be first responder on all failure calls and notify Ameresco for warranty service and repairs. Preventive maintenance per manufacturer's recommendations at recommended intervals.	The LED garage LED fixtures and controls are covered by manufacturer-provided warranties for 10 years. All equipment warranties and the labor to make warranty repairs will be administered by Ameresco. For warranty purposes, manufacturers may request the defective product be returned for analysis. Ameresco will retain all LED fixtures which fail prematurely and provide to the manufacturer upon request.

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J.2 Service Descriptions

- **System Operation:** Ongoing, normal equipment adjustments necessary to satisfy the building occupants and assure the continued effective and efficient operation of equipment and systems.
- **Preventative Maintenance:** Periodic inspections, tests, calibrations and adjustments needed for sustaining or restoring energy systems to the required level of performance.
- **Corrective Maintenance:** Services needed to replace, rebuild, or restore the level of specified performance of the systems and equipment that are in danger of failing or are otherwise inadequate.
- **Local Maintenance and Support:** The primary point of contact for service support.

J.3 Service Coordination

Mr. Steve Croxton will be the point of contact for all service related issues following the installation of the ECMs. His familiarity with all aspects of the project will afford Mr. Croxton the ability to quickly diagnose system problems and implement any necessary corrective actions.

The scope of services for any and all of the ECMs included with this performance contract or the programs as a whole can be modified or fine-tuned at any time during the contract term. For example, where full coverage is not included, additional services can be provided on a time and materials basis based on pre-negotiated rates. Services can also be provided for equipment not replaced or modified as part of this performance contract.

J.4 Warranty Services

The LED luminaire manufacturers and the control manufacturer are providing a 10 year material warranty on the products. The manufacturers of the screw in LED retrofits will be providing a 5 year material warranty. Ameresco will be providing warranty labor services for the materials. The cost of these labor services have been developed on an annual basis in order to provide the City of Tucson future flexibility to decide how the street lighting and garage lighting operations best meet the City's needs.

The City will be responsible for making an initial evaluation when a fixture is reported to be operating improperly by the ROAM system or from a citizen's report. The City will then contact Ameresco to investigate and repair any situations where there appears to be fixture or controller failure. The City will be responsible for any repairs required that may be due to collisions, wiring infrastructure, or lightning strikes, etc.

The warranty service cost in Year 8 of the performance period includes the cost for Ameresco to clean the lenses on every fixture installed as part of the project. This has been included to help ensure that the light levels are maintained over time. The City can choose to deduct this scope of work from the project if desired in the future.

Table J.1. Warranty Labor Service Cost

Year	Fixture Replacements	Fixture Cleaning
Year 1	\$100,938	Not Included
Year 2	\$104,976	Not Included
Year 3	\$109,175	Not Included
Year 4	\$113,542	Not Included
Year 5	\$118,083	Not Included
Year 6	\$115,154	Not Included
Year 7	\$119,760	Not Included
Year 8	\$124,551	\$191,482
Year 9	\$129,533	Not Included
Year 10	\$134,714	Not Included

J.5 Operation and Maintenance Scope

The following work is a description of Ameresco’s O&M obligations under this contract. Any additional work requested beyond the scope identified below can be performed on a time and materials basis as directed by the City of Tucson, subject to mark-ups identified in the contract.

- > ECMs 1, 2 and 3: Roadway, Decorative, Underpass
- > ECMs 5, 7, 9, 11, 13 and 15: Parking Garages

System Operation

Not applicable for this measure.

Preventative Maintenance

Not applicable for this measure.

Local Maintenance and Repair Support

The primary point of contact for service support for this measure is Mr. Croxton.

K.0 Appendices

The following appendices have been provided electronically as separate files on a flash drive in support of the proposed project for City of Tucson:

- A.1 NIST Energy Price Indices and Discount Factors
- B.1 Garage Floor Plan Drawings
- B.2 Existing Equipment
- C.1 Utility Account Summary
- C.2 Utility Consumption Data
- C.3 Electricity Rate Sheets
- D.1 Baseline Calculations
- D.2 Savings Calculations
- E.1 New Roadway Equipment Cut-Sheets
- E.2 New Garage Equipment Cut-Sheets
- E.3 Sample Area Lighting Layouts
- E.4 New Roadway Fixture Selections