SROI Analysis for TIB Low Energy Lighting Conversion in Small Cities in Washington State

FINAL REPORT

June 6, 2014

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EXECUTIVE SUMMARY

Introduction

HDR Decision Economics (HDR) conducted a Sustainable Return on Investment (SROI) analysis for Phase II of the TIB Low Energy Lighting implementation project in small cities within Washington State.

SROI is an enhanced form of a cost-benefit analysis (CBA) - a systematic process for calculating and comparing benefits and costs of a project or policy, and is generally conducted to justify an investment or compare projects. The process builds on best practices in CBA and financial analysis methodologies, complemented by advanced risk analysis and stakeholder elicitation techniques. In this analysis, actual financial costs and benefits incurred by project operators/owners are accounted for, in addition to the monetized value of various social and environmental impacts. The monetized impacts accounted for in this analysis include: future capital cost avoidance, operating cost savings, emissions cost savings due to lower emissions of greenhouse gases and air pollutants.

The assessment was originally conducted in August 2013 and finalized in October 2013 (with the Draft Final Report dated October 17, 2013) based on preliminary design and costing data on the number of luminaires to be converted and their wattage, and the wattage and costs of the replacement LED luminaires in six Implementation sites. As of May 2014, actual conversion works are completed or nearly completed at all implementation sites. The actual total conversion costs came well below the originally anticipated costs in most cases and costs assumed for the original SROI analysis. Lower capital installation costs have a positive impact on the project evaluation metrics including the net present value, benefit-cost ratio, and rates of return. Also, more updated information on the proposed conversions has become available for all sites. This report reflects all new information that became available in May 2014.

Methodology and Findings

The assessment was conducted separately and in total for a sample of six pilot implementation LED conversion sites: (1) Ridgefield; (2) Coulee Dam; (3) Benton City; (4) Buckley; (5) Blaine, and (6) Palouse. The results of the analysis were then extrapolated to all small cities in the entire State of Washington. This extrapolation was done using the combined assessment results for all implementation sites, their population, and population of all small cities in the State (defined as cities with population 5,000 or less, for a total population of 240,453). This approach is based on an assumption that the implementation sites provide a good representation of the population per luminaire across the State and the number and type of luminaires that would be converted to the LED light system. Present values of benefits and costs per capita for the pilot implementation sites combined can then be multiplied by total population of the small cities (i.e. 240,453) to obtain total values for all small cities in the entire State (including sample cities). On the other hand, payback period and rate of return metrics can be assumed to be approximately equal to the corresponding metrics for all of the pilot implementation sites combined (as they already represent an average for the implementation sites analyzed).

The analysis was conducted over a projected period of 15 years, from 2014 to 2029. All costs and benefits were evaluated in 2013 dollars and discounted to 2013 using a discount rate of 3%. Summary Table 1 shows the results of the analysis.

The table shows the results from three analytical points of view. Financial Return on Investment (FROI) evaluates the stream of total financial benefits and costs of the proposed initiative to the State and the affected cities. City FROI examines a subset of these results evaluating the flow of financial benefits and

costs accrued to the cities where the projects would take place. City FROI thus represents measures of direct financial benefits and costs to the affected cities. Please note that these benefits represent the combined impacts to the cities/municipal governments and the utilities serving them (which in some cases may actually be operating the luminaires). Since the proposed conversion project would be paid for from state funds and the cost to the cities would be $0, Summary Table 1 shows zero costs for the City FROI and that evaluation metrics such as Benefit-Cost Ratio or rate of return are not applicable (not defined). Finally, SROI evaluates total benefits and costs of the proposed initiative to the entire society by including environmental impacts not accounted for under the FROI analysis.

Summary Table 1 shows that over 15 years, the monetary benefits of the proposed street lighting conversion in the six implementation sites combined would amount to over $2.3 million, and the benefits across the entire State of Washington would amount to over $29 million. These financial benefits include avoided future capital costs, savings in electricity costs, and savings in other operating costs. Since these savings would directly accrue to the affected cities (as the corresponding costs are usually paid for from city budgets), City FROI is by definition the same as FROI. The expected FROI net present value of the project amounts to $1.28 million for the six implementation locations and nearly $16 million across the State.

The SROI benefits and net benefits are somewhat larger as shown in the column labeled SROI as they also include savings in environmental emissions costs (with net present value equal to $1.4 million in the implementation cities and over $17.53 million across all small cities in the state). However, the difference between FROI benefits and SROI benefits is rather small. This is because much of electricity production in Washington State comes from "clean" sources that generate relatively little environmental emissions leading to relatively small reductions in total emissions and emissions costs when electricity use is reduced.

Summary and Conclusions

Summary Table 1 also shows that for all cities combines (and across the State) the FROI Benefit-Cost Ratio is estimated at 2.22, Discounted Payback Period at 5.0 years, Undiscounted Payback Period at 4.6 years, Internal Rate of Return (IRR) at 28%, and Average Annual Rate of Return at 15.2%. The SROI estimates are somewhat improved for all of the above metrics but – as for total benefits and net present value – the difference is relatively small.

The risk analysis was conducted for project evaluation metrics using distributional assumptions for all uncertain model inputs and risk analysis estimation tools. The analysis revealed that there is virtually no risk of project under-performance and the net present value being negative, or the cost-benefit ratio falling below unity. This result holds for both the FROI and SROI perspectives.

In conclusion, the proposed LED conversion project represents a very worthwhile investment from the economic point of view from all perspectives considered in this analysis.

It is also noted here that this update presents a much improved performance profile of the LED conversion project compared to the original analysis from October 2013 and update from December 2013. This is primarily because of lower capital costs of LED luminaires as well as some adjustments in LED luminaires wattage and additional savings in operating costs of new LED luminaires.

Summary Table 1: Summary of SROI Analysis

Metric of Effect, by City	FROI	SROI	City FROI
PV of Benefits	Total, $ Thousand		
All Cities in Sample	$2,323.2	$2,445.8	$2,323.2
Extrapolated to all Small Cities in WA State	**$29,079.3**	**$30,614.4**	**$29,079.3**
PV of Costs	Total, $ Thousand		
All Cities in Sample	$1,045.3	$1,045.3	$0.0
Extrapolated to all Small Cities in WA State	**$13,084.7**	**$13,084.7**	**$0.0**
Net Present Value	Total, $ Thousand		
All Cities in Sample	$1,277.8	$1,400.5	$2,323.2
Extrapolated to all Small Cities in WA State	**$15,994.6**	**$17,529.8**	**$29,079.3**
Benefit-Cost Ratio			
All Cities in Sample	2.22	2.34	NA
Extrapolated to all Small Cities in WA State	**2.22**	**2.34**	**NA**
Payback Period (Discounted)	Years		
All Cities in Sample	5.0	5.0	NA
Extrapolated to all Small Cities in WA State	**5.0**	**5.0**	**NA**
Payback Period (Simple)	Years		
All Cities in Sample	4.6	4.2	NA
Extrapolated to all Small Cities in WA State	**4.6**	**4.2**	**NA**
Internal Rate of Return	Percent		
All Cities in Sample	28.0%	30.3%	NA
Extrapolated to all Small Cities in WA State	**28.0%**	**30.3%**	**NA**
Average Annual Rate of Return on Investment	Percent		
All Cities in Sample	15.2%	16.1%	NA
Extrapolated to all Small Cities in WA State	**15.2%**	**16.1%**	**NA**

1.0 METHODOLOGY

## 1.1 Sustainable Return on Investment Analysis (SROI) Background

Outputs are split into three perspectives: Financial Return on Investment (FROI), City Financial Return on Investment (City FROI), and Sustainable Return on Investment (SROI):

- Financial Return on Investment (FROI) metrics include only the cash impacts.
- City Financial Return on Investment (City FROI) includes the cash impacts only to the location/municipality where the investment is taking place.
- Sustainable Return on Investment (SROI) adds to the FROI the external non-cash impacts which affect the society (items such as greenhouse gases (GHG's) and criteria air contaminants (CAC's)).

Conventional wisdom has always asserted that financial and social goals were in opposition: economic development versus environmental protection was always framed as a zero-sum game. However, today we are quickly realizing that the real opportunity lies in the "blended value" model in which organizations achieve economic success while acting in a sustainable and socially responsible manner. If positive and negative externalities (social and environmental impacts) resulting from organizational operations were quantified, managers and investors could design, manage and fund organizations that maximized the combined financial and social returns.

Most professionals in the Architecture, Engineering and Construction industry rely on basic financial tools to quantify the first costs of sustainable projects and to show the financial return on investment (or FROI) of sustainable strategy benefits. The first instance where these traditional methods often fall short is in the accurate quantification of the benefits that accrue to society as a whole as a result of these decisions. Traditional tools also fall short by failing to incorporate the element of risk. Sustainable project decisions require the forecasting of future costs and benefits and these are subject to uncertainty, which is typically not captured by conventional methods.

Figure 1: High-Level SROI Methodology
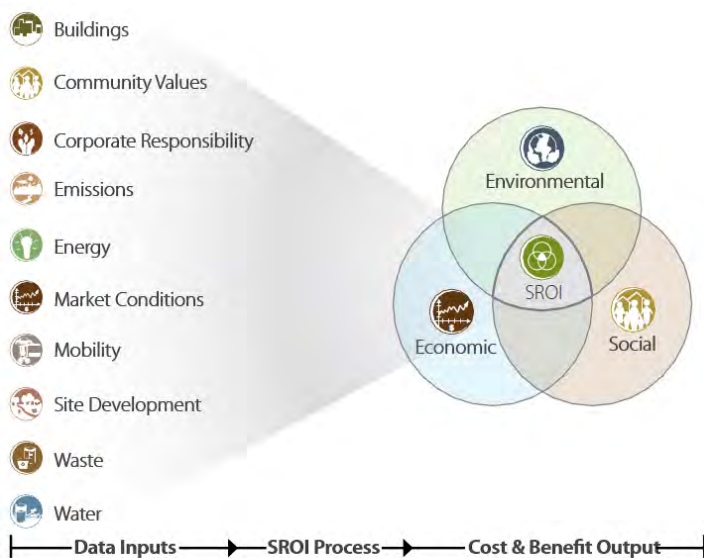
Since traditional analytical methods fall short in accurately quantifying all positive and negative externalities,[1] HDR developed the SROI process. Today, when evaluating public investment, focus should be put on accounting for the impacts of a project on local residents and their communities – including the environment. If positive and negative externalities are quantified, decision makers can design and carry out the project that maximizes the combined financial, environmental and social returns.

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[1] In economics, an externality is a non-internalized cost or benefit resulting from one economic agent's actions that affect the well-being of others. For instance, pollution and other forms of environmental degradation are the result of some production process and are not reflected in the price of the goods or services being produced.

HDR's SROI analysis typically involves four distinct steps:

STEP 1	Develop Structure and Logic Models	Map out economic, social and environmental variables (costs and benefits) and graphically illustrate the calculations required.
STEP 2	Assign Monetary Values and Risk Ranges	Measure the impacts of the project by assigning monetary values and probability distributions, where possible, to each variable.
STEP 3	Develop Consensus among Stakeholders	Bring stakeholders together and develop consensus on model and the assigned values.
STEP 4	Simulate and Quantify Outcomes	Compute SROI metrics such as Net Present Value, Benefit-Cost Ratio, Internal Rate of Return, etc.

Step 3 was omitted for this project, however, the model input assumptions were based on engineering assessments conducted in earlier project phases (and thus already vetted with project stakeholders) or research and guidelines from government organizations compiled and published as a credible source for similar types of assessments.

Risk analysis and Monte Carlo[2] simulation techniques were used to account for uncertainty in both the input values and model parameters. Projections were expressed as probability distributions (a range of possible outcomes and the probability of each outcome). Finally, each model element was developed in terms of, or converted into, monetary values to estimate the overall impacts in comparable financial terms across all benefits and costs.

This analysis produced results on both a financial and a sustainable basis using many of the most recognized evaluation metrics. For example:

Net Present Value (NPV)	The net value that a project generates to the public benefit, calculated as the sum of the present value of future benefit flows less the present value of the project's costs.
Discounted Payback Period (DPP)	The period of time required for the return on an investment to recover the sum of the original investment on a discounted benefit flow basis (discounted Payback Period) or undiscounted benefit flow basis (simple Payback Period).
Internal Rate of Return (IRR)	The discount rate at which the net present value of a project would be zero; represents the annualized effective compounded return rate which can be earned on the invested capital, and is compared relative to the cost of capital.
Average Annual Rate of Return	Annual gains from the project expressed as net benefit in a given year divided by the cumulative project costs.
Benefit-Cost Ratio (B/C ratio)	The overall "value for money" of a project, expressed as the ratio of the benefits of a project relative to its costs, with both expressed in present-value monetary terms.

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[2] Monte Carlo simulations are computational algorithms run many times in order to obtain the distribution of an unknown probabilistic issue. They are most useful in determining: optimization, numerical integration and generation of draws from a probability distribution.

A more detailed description of the SROI methodology can be found in Appendix A.

1.2 Quantified and Monetized Benefits and Costs

The following benefits of the proposed LED street light conversion were quantified and monetized in this assessment.

- Reduction in future capital costs of equipment replacement. LED light fixtures have a longer life cycle than traditional street light luminaires. It is estimated that on average LED light fixtures last 15 to 20 years while high pressure sodium (HPS) light fixtures last only about 7 years. This means that investment in LED lighting will help avoid some capital costs in the entire life-cycle costs of street lighting.
- Operating costs savings. LED street lights have lower operating costs driven by the following factors:
  - Longer life. LED luminaires have a conservative life expectancy of about 15 to 20 years with maintenance cleaning only once half way through the life cycle. HPS luminaires require re-lamping and cleaning approximately every 4 years and have expected life cycle of about 7 years.
  - Higher reliability. It is estimated that LED lights have a lower failure rate than the HPS system. Therefore, LED lighting may be expected to require less re-active maintenance (e.g. in response to reports of luminaires not working properly) and thus lower annual maintenance costs.
  - Lower energy use. LED lights have lower energy consumption and thus lower costs of electricity required to operate them compared to equivalent HPS luminaires.
- Reduction in environmental costs. Since LED lights have lower energy consumption, the amount of electricity production required for the system will be reduced. This will lead to a reduction in environmental emissions including Greenhouse Gas (GHG) emissions and Criteria Air Contaminant (CAC) emissions.

The first and second of the above main bullets represent the financial benefits (FROI benefits) while the last bullet is an SROI benefit.

The benefits of conversion to LED street lights were assessed against the costs of conversion or initial installation costs which included the cost of the fixtures, installation work, design, and construction management.

1.3 Other Model Assumptions and Data

The assessment was conducted separately and in total for all six pilot implementation sites:
- Benton City
- Blaine
- Buckley
- Coulee Dam
- Palouse, and
- Ridgefield.

The results of the analysis were then extrapolated to all small cities (with a population of 5,000 or less) within the entire Washington State. This extrapolation was done using the combined results for all of the six implementation sites, their population, and population of all small cities in the State combined.

An implicit assumption in this approach was that the implementation sites provide a good representation of the population per luminaire across the State and thus the number and type of luminaires that would be converted to the LED light system in the State.[3] Present values of benefits and costs per capita for the implementation sites combined can then be multiplied by total population of the small cities (i.e. 240,453) to obtain total values for the entire State small cities (including sample cities). On the other hand, payback period and rate of return metrics can be assumed to be approximately equal to the corresponding metrics for all of the implementation sites combined (as they already represent an average for the implementation sites analyzed). The table below shows the population of the cities where the implementation projects are taking place and the population of all small cities (defined as cities with population 5,000 or less) in the entire State of Washington that was used in this extrapolation.

Table 1: Population of Implementation Sites Cities and Total Population of Small Cities in the State of Washington

City	Population
Ridgefield	5,210
Coulee Dam	560
Benton City	3,295
Buckley	4,365
Blaine	4,760
Palouse	1,020
All Cities in Sample	19,210
All Small Cities (Population 5,000 or Less) in State of Washington*	**240,453**

Note: Includes all implementation implementation sites cities.
Source: Sales tax database by city.

The analysis was conducted over a period of 15 years, from 2014 to 2029, which corresponds to the estimated life-cycle of LED luminaires. All benefits and costs were expressed in 2013 dollars and discounted to that year using a discount rate of 3%.[4]

It was assumed that in year 1 all luminaires in the sites listed would be converted to LED and would have a residual value of zero at the end of the analysis period in year 15. All operational benefits of the LED light system will be fully realized in year 1. The LED luminaires would require the routine re-lamping and cleaning in year 8 only.

Regarding the existing HPS system, it was assumed that it is *mostly* still in fairly good condition, about half-way through its life-cycle. This is considered to be a conservative assumption based on a small

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[3] An alternative approach to the extrapolation that was contemplated was on the basis of benefits and costs per luminaire in the pilot sites. However, the number of luminaires in the small cities in the rest of the State that would be required for this exercise was not known at the time of the analysis.

[4] The discount rate was selected based on the guidance for benefit-cost analysis in support for applications for the 2013 round of TIGER Discretionary grants. The guidance advised in general to use the real rate of 7% with an alternative rate for comparison of 3%. The guidance also indicated that applicants should use the latter rate when the alternative use of funds to be dedicated to the project would be for other public expenditures, rather than private investment (see 2013 Benefit-Cost Analyses Guidance for TIGER Grant Applicants page 13).

amount of records available from one of the implementation sites.[5] The HPS lights would thus be replaced anyway (on the regular schedule of fixture replacement) in year 8 of the analysis leading to a capital cost avoidance in year 8. To harmonize logically the re-lamping and cleaning costs with this assumption, it was then also assumed that re-lamping and cleaning would take place four years before and four years after year 8 (i.e. in year 4 and year 12).

An exception was made only for the cities of Coulee Dam and Blaine for which it was assumed that the routine replacement of HPS fixtures would take place in year 1. This is because these two cities were already themselves looking into similar LED conversion initiatives due to significant age and degraded performance of their existing HPS street lighting infrastructure.

The model was populated with data collected in the earlier phases of this project and updated in May 2014 as the actual conversion work was being rolled out and completed across all implementation sites. This included information on:
- Number of luminaires to be converted in each city;
- Current HPS wattage of each existing luminaire and the intended LED wattage;
- Costs of HPS fixtures;
- Costs of LED fixtures;
- Fixture installation costs;
- Electricity consumption of HPS and LED luminaires, and
- Maintenance costs of both systems (assumed to comprise both labour and material costs).

The design, installation, and construction management costs related to installation were assumed to be the same for HPS and LED luminaires. The electricity price was assumed at 7.65 cents per kWh (also used in the preliminary analysis in the earlier stage of the project) which was then assumed to increase over time in real terms based on the price forecasts from Energy Information Administration (Annual Energy Outlook 2013, December 2012). GHG and CAC electricity emissions rates (in tons per MWh) for the State were compiled from the US Environmental Protection Agency sources.[6] The unit costs of GHG emissions and CAC emissions (in dollars per ton) were based on US DOT recommendations for valuation of changes in emissions.[7]

To express the ranges of uncertainty in various inputs, luminaire capital and operating costs were assumed to have a high/low variation in the amount of plus or minus 20%, except for LED capital fixture costs which were assumed to have a variation in the amount of plus or minus 5%. The latter assumption is due to the fact that LED fixture capital replacement costs used in this analysis are sourced from the actual bids/proposals to conduct the work in each location and can thus be considered as having a low chance of deviating from the proposed costs. Changes in future electricity prices were assumed to vary by plus or minus 50%. The ranges of uncertainty in the unit costs of environmental emissions were assumed on the basis of literature review on the issue that give an alternative view and assessment of the costs of environmental damage. The detailed input assumptions are presented in Appendix B.

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[5] This assumption effectively reduces the benefit of conversion to LED lighting in the form of avoidance of future capital costs as compared to an assumption that, for example, all HPS luminaires would be replaced in year 1.
[6] GHG Source: U.S. Environmental Protection Agency - eGRID 2012 (2009 Data); CAC Source: U.S. Environmental Protection Agency, 2008 National Emissions Inventory Data & U.S. Energy Information Administration, State Electricity Profiles 2008.
[7] GHG unit emissions costs: Intergovernmental Working Group on the Social Cost of Carbon (IWGSS, Social Cost of Carbon, 2013 Edition). CAC unit emission costs: Corporate Average Fuel Economy for MY 2012-MY 2016 Passenger Cars and Light Trucks.

2.0 RESULTS

2.1 Summary of Results

Table 2 that follows shows a summary of results for key project evaluation metrics (all monetary metrics are in 2013 dollars discounted to 2013). The table shows the results from three analytical points of view:

1. FROI, or financial return on investment to the cities where the conversion is taking place (i.e. implementation sites) and the State combined;
2. City FROI, or financial return on investment to the cities where the conversion is taking place, and
3. SROI, or Sustainable Return on Investment.

FROI evaluates the stream of total financial benefits and costs of the proposed initiative that would accrue to the cities where the conversion projects take place and the State. City FROI represents thus a subset of results for FROI in that it expresses the balance of benefits and costs accrued to just the cities where the implementation projects take place. Please note that these benefits represent the combined impacts to the cities/municipal governments and the utilities serving them (which in some cases may actually be operating the luminaires). Also, note that since the proposed street lighting conversion would be financed from State funds, there is no cost of the proposed initiatives to the cities that benefit from them. Consequently, some performance metrics including cost-benefit ratio, payback period, and rate of return are not defined for the City FROI analytical point of view. SROI evaluates total benefits and costs of the proposed initiative that also includes environmental impacts not accounted for under the FROI analysis.

Table 2 shows that over 15 years, the monetary benefits of the proposed street lighting conversion in the six implementation sites combined are estimated at nearly $2.3 million, and the benefits extrapolated to the entire State of Washington are estimated at over $29 million. As explained earlier, these financial benefits include avoided future capital costs, savings in electricity costs, and savings in maintenance costs. Since these savings would directly accrue to the affected cities (as the corresponding costs are usually paid for from city budgets), City FROI is by definition the same as FROI.

The value of SROI benefits is somewhat larger than FROI benefits due to the additional savings in environmental emissions (GHG and CAC) that are accounted for under the SROI perspective. However, the difference between FROI and SROI metrics is relatively small. This is because much of electricity production in the State comes from "clean" sources (such as hydroelectric) and thus produces relatively little environmental emissions. Over 15 years, the value of SROI benefits would amount to $2.4 million in the six implementation sites and $30.6 million across the entire State of Washington.

The present value of costs of the proposed initiative (both in FROI and SROI terms) is estimated at over $1 million for the six implementation sites and $13.1 million across the State. The resulting expected FROI net present value of the project amounts to nearly $1.3 million for the six implementation locations and nearly $16.0 million across the State. These figures represent the net monetary savings to society from the proposed street lighting conversion. The SROI net benefits are somewhat larger as shown in the column labeled SROI ($1.4 million in the implementation cities and $17.5 million across all small cities in the State).

The Benefit-Cost Ratio, Discounted Payback Period, and Rate of Return on Investment differ somewhat by city. For example, the FROI benefit-cost ratio ranges from a low 1.12 in Palouse to 2.85 in Benton

City. The FROI (discounted) payback period ranges from 11.5 years in Palouse to 0 years in Blaine (i.e. conversion to LED gives net positive benefits immediately after installation). Overall for all cities in the State, the FROI Benefit-Cost Ratio is estimated at 2.22, Discounted Payback Period at 5.0 years, Undiscounted Payback Period at 4.6 years, IRR at 28%, and Average Annual Rate of Return at 15.2%. These can be considered very good performance metrics. The SROI estimates are still improved for all of the above metrics but the difference is relatively small.

In conclusion, the proposed LED conversion project represents a very worthwhile investment from the economic point of view from all perspectives considered in this analysis. It generates a positive net present value and evaluation metrics (Benefit-Cost Ratio, rate of return) that can be considered as beneficial.

Table 2: Summary Results (over 15 Years; 2014-2029)

Metric of Effect, by City and Geographic Area	FROI	SROI	City FROI
Present Value of Benefits	Total, Mean Values, $ Thousands		
Ridgefield	$366.0	$386.5	$366.0
Coulee Dam	$382.5	$403.3	$382.5
Benton City	$216.4	$229.2	$216.4
Buckley	$292.1	$304.9	$292.1
Blaine	$866.1	$914.1	$866.1
Palouse	$200.1	$207.9	$200.1
All Cities in Sample	$2,323.2	$2,445.8	$2,323.2
Extrapolated to all Small Cities in WA State	**$29,079.3**	**$30,614.4**	**$29,079.3**
Present Value of Costs	Total, Mean Values, $ Thousands		
Ridgefield	$158.7	$158.7	$0.0
Coulee Dam	$149.4	$149.4	$0.0
Benton City	$76.1	$76.1	$0.0
Buckley	$157.0	$157.0	$0.0
Blaine	$325.7	$325.7	$0.0
Palouse	$178.5	$178.5	$0.0
All Cities in Sample	$1,045.3	$1,045.3	$0.0
Extrapolated to all Small Cities in WA State	**$13,084.7**	**$13,084.7**	**$0.0**
Net Present Value	Total, Mean Values, $ Thousands		
Ridgefield	$207.3	$227.7	$366.0
Coulee Dam	$233.1	$253.9	$382.5
Benton City	$140.3	$153.1	$216.4
Buckley	$135.1	$147.9	$292.1
Blaine	$540.4	$588.4	$866.1
Palouse	$21.6	$29.4	$200.1
All Cities in Sample	$1,277.8	$1,400.5	$2,323.2
Extrapolated to all Small Cities in WA State	**$15,994.6**	**$17,529.8**	**$29,079.3**
Benefit-Cost Ratio	Ratio, Mean Values		
Ridgefield	2.31	2.43	NA
Coulee Dam	2.56	2.70	NA

Benton City	2.85	3.01	NA
Buckley	1.86	1.94	NA
Blaine	2.66	2.81	NA
Palouse	1.12	1.16	NA
All Cities in Sample	2.22	2.34	NA
Extrapolated to all Small Cities in WA State	**2.22**	**2.34**	**NA**
Payback Period (Discounted)	Years, Mean Values		
Ridgefield	7.2	7.2	NA
Coulee Dam	1.1	1.1	NA
Benton City	6.4	6.4	NA
Buckley	7.5	7.5	NA
Blaine	0.0	0.0	NA
Palouse	11.5	11.5	NA
All Cities in Sample	5.0	5.0	NA
Extrapolated to all Small Cities in WA State	**5.0**	**5.0**	**NA**
Payback Period (Simple)	Years, Mean Values		
Ridgefield	6.0	5.5	NA
Coulee Dam	2.5	2.3	NA
Benton City	7.0	6.6	NA
Buckley	7.5	7.4	NA
Blaine	0.0	0.0	NA
Palouse	7.8	7.8	NA
All Cities in Sample	4.6	4.2	NA
Extrapolated to all Small Cities in WA State	**4.6**	**4.2**	**NA**
Internal Rate of Return	Percent, Mean Values		
Ridgefield	19.1%	20.5%	NA
Coulee Dam	753.3%	2974.0%	NA
Benton City	24.7%	26.5%	NA
Buckley	14.0%	14.9%	NA
Blaine	NA	NA	NA
Palouse	4.8%	5.4%	NA
All Cities in Sample	28.0%	30.3%	NA
Extrapolated to all Small Cities in WA State	**28.0%**	**30.3%**	**NA**
Average Annual Rate of Return on Investment	Percent, Mean Values		
Ridgefield	19.4%	20.5%	NA
Coulee Dam	13.9%	15.1%	NA
Benton City	23.9%	25.3%	NA
Buckley	15.8%	16.4%	NA
Blaine	14.4%	15.6%	NA
Palouse	9.6%	9.9%	NA
All Cities in Sample	15.2%	16.1%	NA
Extrapolated to all Small Cities in WA State	**15.2%**	**16.1%**	**NA**

2.2 Risk Analysis

Table 3 below provides a summary of risk analysis and the risk-adjusted estimates of the key evaluation metrics (for all implementation sites combined). These include the mean value of each metric and the 10% and 90% values of the cumulative probability distribution. The value for the 10% cumulative probability distribution represents a value for which there is a 10% probability of not exceeding, and the 90% cumulative probability distribution represents a value for which there is a 90% probability of not exceeding. Combined, these two ranges represent an 80% confidence interval.

As an example, Table 3 shows that the FROI net present value is estimated to be a mean value of $1,277.8 million. There is a 10% probability that the net present value will not exceed $1,161 million over the project life, and there is a 90% probability that the FROI net present value will not exceed $1,394.1 million over the project life. In other words, the 80% confidence interval for the FROI net present value spans from $1,161 million $1,394.1 million over the 15 years of project life. Similarly, the SROI net present value is estimated to amount to a mean value of $1,400.6 million. There is a 10% probability that the net present value will not exceed $1,277.6 million over the project life, and there is a 90% probability that the FROI net present value will not exceed $1,523.9 million over the project life. In other words, the 80% confidence interval for the SROI net present value spans from $1,277.6 million to $1,523.9 million over the 15 years of project life.

Table 3 demonstrates that for the proposed street lighting conversion project there is virtually no risk of underperformance where the net present value would be negative, or the cost-benefit ratio falling below unity. This result holds for both the FROI and SROI perspectives. The SROI analysis demonstrates a slightly higher value for the project at each probability of realization. The exception to this is for the payback period for which the two values are indistinguishable. Also, project costs have the same values for both the FROI and the SROI perspectives. This is because no additional SROI costs were identified for this project that would go over and above the FROI costs.

Table 3: Results of Risk Analysis, all Implementation Sites Combined (over 15 Years; 2014-2029)

Metric of Effect	FROI By Percentage of Cumulative Probability Distribution			SROI By Percentage of Cumulative Probability Distribution		
	Mean	10%	90%	Mean	10%	90%
PV of Benefits, $000	$2,323.2	$2,205.5	$2,439.7	$2,445.8	$2,321.3	$2,570.3
PV of Costs, $000	$1,045.3	$1,027.2	$1,063.5	$1,045.3	$1,027.2	$1,063.5
Net Present Value, $000	$1,277.8	$1,161.0	$1,394.1	$1,400.5	$1,277.6	$1,523.9
Benefit-Cost Ratio	2.22	2.11	2.34	2.34	2.22	2.46
Payback Period	5.0	4.4	5.8	5.0	4.3	5.8
Payback Period (Undiscounted/Simple)	4.6	4.0	5.2	4.2	3.9	4.8
Internal Rate of Return	28.0%	25.4%	30.7%	30.3%	27.6%	33.2%
Average Annual Rate of Return on Investment	15.2%	14.2%	16.1%	16.1%	14.4%	17.1%

The S-curves diagram in Figure 2 below illustrates further the range of outcomes (at various levels of cumulative probability distribution) for the net present value of the proposed project across all cities. The diagram shows that the S-curve for the SROI analysis lies to the right of the S-curve for the FROI analysis. The SROI net present value is larger than the FROI net present value at each probability

distribution. This demonstrates more favorable project evaluation outcomes for the SROI analysis. However, as pointed out earlier, the difference is relatively small.

In addition, both curves lie entirely within the positive range of net present value realizations. This demonstrates a favorable risk profile of the project with virtually no risk of underperformance or negative net present value.

Figure 2: S-Curves for Net Present Value
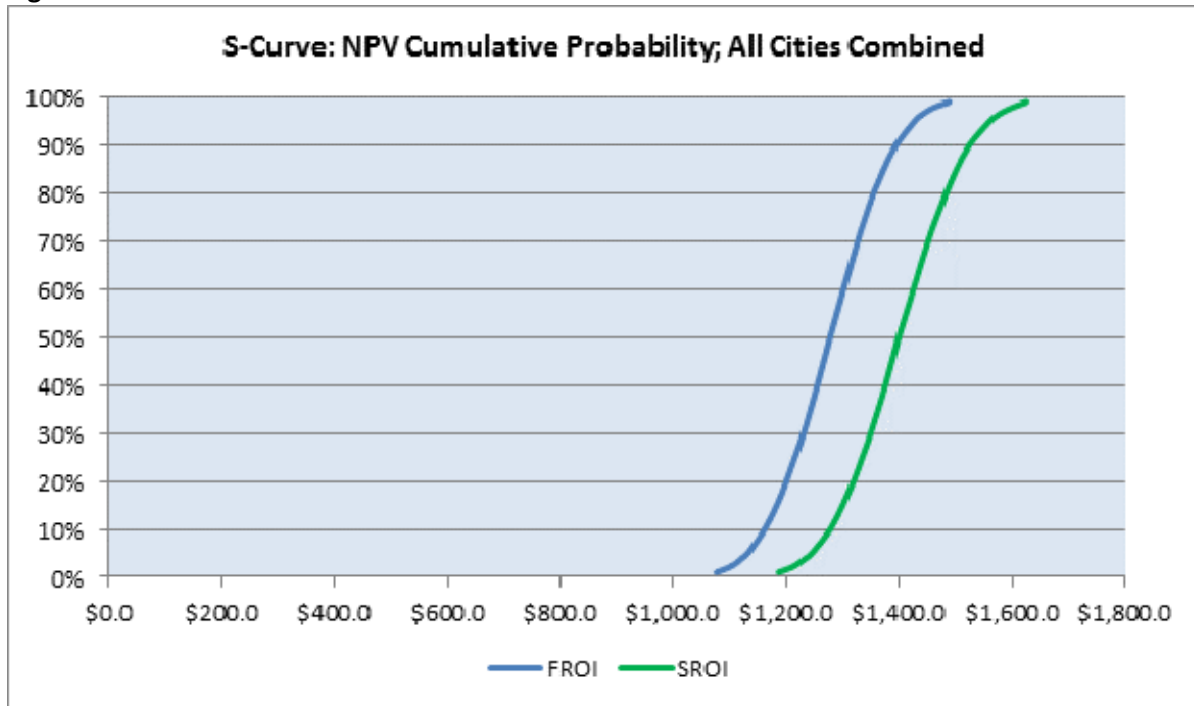
2.3 Conclusions and Comments

The proposed street light conversion project has a very good cost-benefit ratio and payback period, given the life of the assets. The project also has environmental benefits of reducing energy requirements and costs. This compares well with some roadway capital projects which sometime have a negative NPV.

Extrapolating these benefits across the state to moderate and larger cities, it can be argued that the benefits are relevant in the context of moderate and larger cities as well. Given a larger number of luminaires in those cities (in absolute terms and in terms of their density or number per capita), LED street light conversion will very likely have even larger total benefits to the State and individual cities. The payback period, benefit-cost ratio, and rate of return can be expected to be similar to this project to the extent that this project represents a good and relevant mix of replacements in terms of old and new wattage used, and costs of equipment, installation, operation and maintenance.

There are additional beneficial factors and impacts that have not been monetized at this time due to lack of studies in areas where LED installations have been in place for enough time to provide data. These include:

- Potential crime reduction;
- Reduced night time accidents, and
- Satisfaction level of residents.

In addition, with continued research and development, the lighting industry is forecasting luminaire life expectancies increasingly beyond 15 years. Many industry experts are comfortable forecasting 20 years with improvements made in life expectancy of parts and components. With improvements in luminaire system performance and life cycles, the FROI and SROI outcomes will improve as the benefits will continue to be realized for some additional years without the need of additional capital cost.

# APPENDIX A: OVERVIEW OF SUSTAINABLE RETURN ON INVESTMENT (SROI)

Issues related to sustainability, sustainable communities, and sustainable development is at the forefront of social debate today. Sustainable development is typically defined as the pattern of development that "meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development, Brundtland Commission, 1987). Sustainable development combines the financial considerations of development with broader socio-economic concerns including environmental stewardship, human health and equity issues, social well-being, and the social implications of decisions.

While the importance of these issues is widely recognized, organizations are challenged when they try to integrate sustainability considerations into their investment and operating decisions. Traditional financial evaluation tools used to assess an investment project, such as Business Case Analysis or Life-Cycle Cost Analysis (LCCA), rely exclusively on financial impacts. These traditional tools have two primary drawbacks:

1. An inability to accurately quantify the non-cash benefits and costs accruing to both the organization in question and to society as a whole resulting from a specific investment (sustainable benefits and costs).
2. A failure to adequately incorporate the element of risk and uncertainty.

HDR's Sustainable Return on Investment (SROI) process is a broad-based analysis that helps overcome these drawbacks by accounting for a project's triple bottom line – its full range of financial, economic, as well as social and environmental impacts (see Figure B-1).

Figure B-1: SROI Methodology Guides Your Decision Making Process
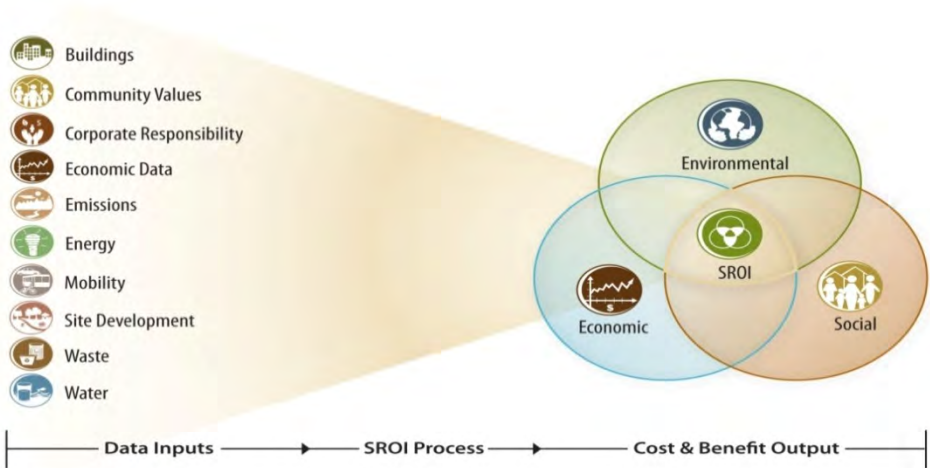
The SROI process builds on best practices in Cost-Benefit Analysis and Financial Analysis methodologies, complemented by Risk Analysis and Stakeholder Elicitation techniques. The SROI process identifies the significant impacts of a given investment, and makes every attempt to credibly value them in monetary terms. Any relevant impacts that cannot be monetized are also identified, and ideally quantified in some way. Results are presented in innovative ways that help clients and their stakeholders prioritize projects, better understand trade-offs, and evaluate risk.

A key feature of SROI is that it converts to dollar terms (monetizes) the relevant social and environmental impacts of a project yet still provides the equivalent of traditional financial metrics (referred to as "Financial Return on Investment (FROI)"). FROI accounts for internal (i.e., accruing to the organization) cash costs and benefits only, while SROI accounts for all internal and external costs and benefits. Figure B-2 below illustrates how traditional financial models differ from SROI.

Figure B-2: Comparison of SROI to Traditional Life-Cycle Costing
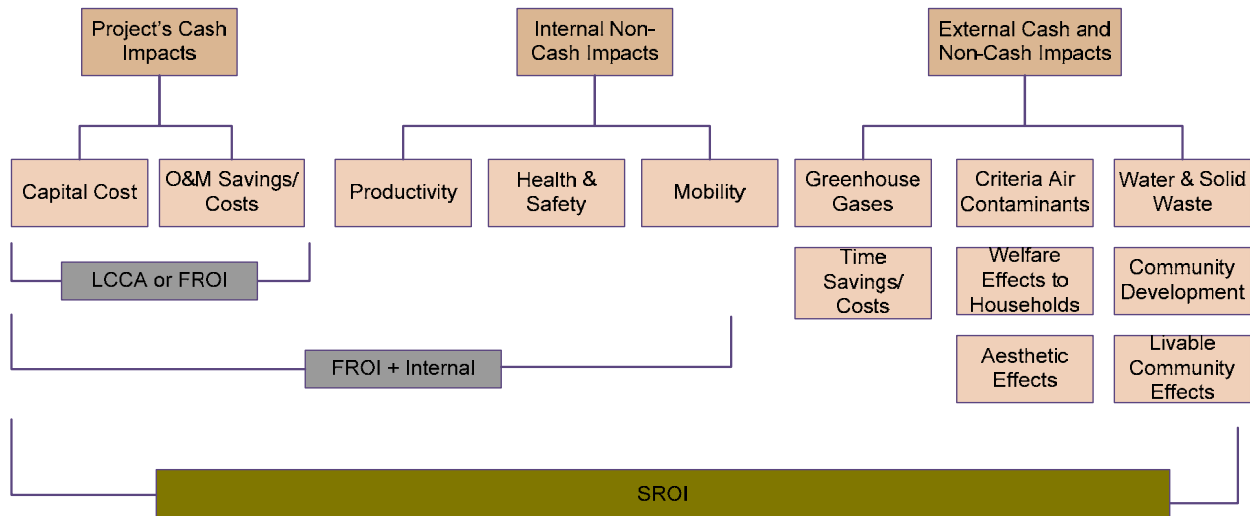
The SROI process includes the traditional financial impacts, such as savings on utility bills or reduced/ higher O&M costs, internal productivity effects and a range of social and environmental impacts that would result directly from the evaluated project. Examples include:

- Value of enhanced productivity from employees working in a green building (e.g., fewer sick days or performing a task more efficiently);
- Quantified and monetized value of reduction in environmental emissions;
- Quantified and monetized value of reduction in generation of waste ;
- Value of time savings and costs resulting from the evaluated project; and,
- Value of quality of life improvements, including improvements to households and broader community.

The SROI process involves four steps:

1. Development of the structure and logic of costs and benefits over the project life cycle. This involves determining the costs and benefits that result from the proposed investment and a graphical depiction to quantify these values. In particular, this step focuses on quantification of all broad (financial and sustainable) costs and benefits.

2. Quantification of input assumptions and assignment of risk/uncertainty, or initial risk analysis. This step involves building the preliminary outline of the SROI model, populating the model with initial data assumptions and performing initial calculations for identified costs and benefits (financial, social and environmental).

3. Facilitation of a Risk Analysis Process (RAP) session. This is a meeting, similar to a one-day charrette, which brings together key stakeholders to reach consensus on input data values and calculations to be used in the model.

4. Simulation of outcomes and probabilistic analysis. The final step in the process is the generation of SROI metrics, including Net Present Value (NPV), Discounted Payback Period, Benefit-Cost Ratio and the Internal Rate of Return, in addition to the traditional financial metrics. Financial metrics are included as a point of comparison and to transparently and comprehensively illustrate the relative merits of all potential investment scenarios being analyzed.

Each of the above steps is discussed in detail below.

Step 1: Structure and Logic of the Cost and Benefits

A "structure and logic model" depicts the variables and cause and effect relationships that underpin the forecasting problem at-hand. The structure and logic model is written mathematically to facilitate analysis and also depicted diagrammatically to permit stakeholder scrutiny and modification during Step 3.

Step 2: Central Estimates and Probability Analysis

Traditional financial analysis takes the form of a single "expected outcome" supplemented with alternative scenarios. The limitation of a forecast with a single expected outcome is clear – while it may provide the single best statistical estimate, it offers no information about the range of other possible outcomes and their associated probabilities. The problem becomes acute when uncertainties surrounding the underlying assumptions of a forecast are material.

Another common approach to provide added perspective on reality is "sensitivity analysis". Key forecast assumptions are varied one at a time, in order, to assess their relative impact on the expected outcome. A concern with this approach is that assumptions are often varied by arbitrary amounts. A more serious concern with this approach is that, in the real world, assumptions do not veer from actual outcomes one at a time but rather the impact of simultaneous differences between assumptions and actual outcomes is needed to provide a realistic perspective on the riskiness of a forecast.

Risk analysis provides a way around the problems outlined above. It helps avoid the lack of perspective in "high" and "low" cases by measuring the probability or "odds" that an outcome will actually materialize. A risk-based approach allows all inputs to be varied simultaneously within their distributions, avoiding the problems inherent in conventional sensitivity analysis. Risk analysis also recognizes interrelationships between variables and their associated probability distributions.

Risk analysis and Monte Carlo simulation techniques can be used to account for uncertainty in both the input values and model parameters. All projections and input values are expressed as probability distributions (a range of possible outcomes and the probability of each outcome), with a wider range of values provided for inputs exhibiting a greater degree of uncertainty. Of note, each element is converted into monetary values to estimate overall impacts in comparable financial terms and discounted to translate all values into present-value terms. Specifying uncertainty ranges for key parameters entering the decision calculus allows the SROI framework to evaluate the full array of social costs and benefits of a project while illustrating the range of possible outcomes to inform decision-makers.

Each variable is assigned a central estimate and a range to represent the degree of uncertainty. Estimates are recorded on Excel-based data sheets (Figure B-3). The first column gives an initial median. The second and third columns define an uncertainty range representing a 90% confidence interval—the range within which there exists a 90% probability of finding the actual outcome. The greater the uncertainty associated with a forecast variable the wider the range.

Figure B - 3: Example of Data Input Sheet *(Illustrative Example)*

Data Input	Median	Low	High	Realized
Percent reduction in electricity use	30.0%	22.5%	37.5%	30.0%
Building sqft	252,752	252,752	252,752	$ 252,752
Cost of electricity per kWh	$ 0.100	$ 0.050	$ 0.250	$ 0.117
Electricity use in kWh per sqft/year	49.33	39.46	59.19	49.33

Probability ranges are established using both statistical analysis and subjective probability assessment. Probability ranges do not have to be normal or symmetrical. In other words, there is no need to assume a bell-shaped normal probability curve. The bell curve assumes an equal likelihood of being too low and too high in forecasting a particular value. For example, if projected unit construction costs deviate from expectations, it is more likely that the costs will be higher than the median expected outcome than lower.

The Excel-based risk analysis add-on tool @Risk transforms the ranges depicted in Figure B-3 into formal probability distributions (or "probability density functions"), helping stakeholders understand and participate in the process even without formal training in statistical analysis.

The central estimates and probability ranges for each assumption in the forecasting structure and logic framework come from one of three key sources, as described below:

- The best available third party information from a variety of sources, including the Environmental Protection Agency, the Department of Energy, the Federal Highway Administration, the Bureau of Labor Statistics, other government agencies, financial markets, universities, think tanks, etc.
- Historical analysis of statistical uncertainty in relevant time series data and an error analysis of forecasting "coefficients," which are numbers that represent the measured impact of one variable (say, fuel prices) on another (such as the price of steel). While these coefficients can only be known with uncertainty, statistical methods help uncover the level of uncertainty (using diagnostic statistics such as standard deviation, confidence intervals, and so on). This is also referred to as "frequentist" probability.
- Subjective probability assessment (also called "Bayesian" statistics, for the mathematician who developed it) in which a frequentist probability represents the measured frequency with which different outcomes occur (i.e., the number of heads and tails after thousands of tosses). The Bayesian probability of an event occurring is the degree of belief held by an informed person or group that it will occur. Obtaining subjective probabilities is the subject of Step 3.

Step 3: Expert Evaluation: The RAP© Session

The third step in the SROI process involves the formation of an expert panel to hold a charette-like one or two day meeting that we call the Risk Analysis Process (RAP) session. We use facilitation techniques to elicit risk and probability beliefs from participants about:

I. The structure of the forecasting framework; and,
II. Uncertainty attached to each input variable and forecasting coefficient in the framework.

In (I), experts are invited to add variables and hypothesized causal relationships that may be material, yet missing from the model. In (II), the initial central estimates and ranges that were provided to panelists prior to the session are modified based on subjective expert beliefs and discussion.

Examples of typical RAP session participants include:

- Client
  - Project tam
  - Technical specialists
  - Financial experts
- HDR
  - Facilitator
  - Economists
  - Technical Specialists
- Outside Experts
  - Public Agencies and Officials
  - Business Groups

Step 4: Simulation of Outcomes and Probabilistic Analysis

In step four, final probability distributions are formulated by the risk analyst (Economist) and represent a combination of probability information drawn from Steps 2 and 3. These are combined using simulation techniques (called Monte Carlo analysis) that allow each variable and forecasting coefficient to vary simultaneously according to its associated probability distribution (see Figure B-4 for a graphical representation of this process).

Figure B - 4: Combining Probability Distributions *(Illustrative Example)*
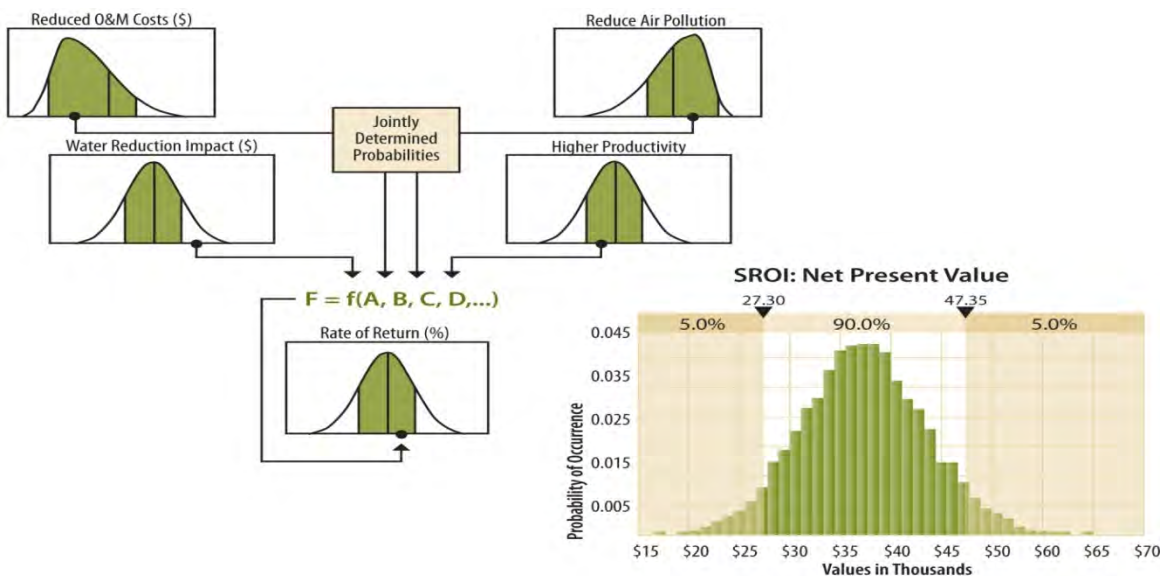
The result of the analysis is a forecast that includes estimates of the probability of achieving alternative outcomes given the uncertainty in underlying variables and coefficients.

For example, probability distribution of NPV of a project is demonstrated in Figures B-5 and B-6. As the figure and the table show, the average expected outcome of the hypothetical project is an NPV of $392.41 over the period of analysis considered. There is a 10% chance that the NPV will exceed $580.11, and a 1% chance that the NPV will exceed $751.29. However, the proposed project also has a downside and a non-zero probability of performing at a much lower magnitude of NPV than the average outcome. Specifically, as the table shows there is a 99% probability that the NPV will exceed the negative $36.29. This implies that there is a risk (about 1% to 2% in this case) that the NPV of the project considered would fall below zero, or generate no net benefits. Examining the table further, one can also determine that there is a risk of underperformance of the project, or the situations when the project generates net benefits that are much lower than the mean expected outcome.

Figure B- 5: Risk Analysis of Net Incremental Benefits of a Project
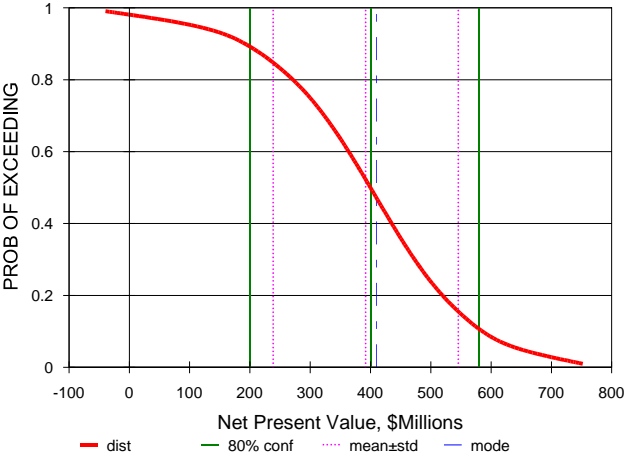
Figure B- 6: Risk Analysis of Net Present Value of a Project (*Illustrative Example*)

Project Net present Value ($ M)	Probability of Exceeding Value Shown at Left
-$36.29	0.99
$128.11	0.95
$200.01	**0.90**
$275.91	0.80
$325.05	0.70
$364.50	0.60
$400.05	**0.50**
$434.81	0.40
$471.95	0.30
$516.08	0.20
$580.11	**0.10**
$636.22	0.05
$751.29	0.01
$392.41	**Mean Expected Outcome**

Using the SROI process, the net present value of a project (as in the example above) and other evaluation metrics can be estimated taking into account the three types if impacts discussed earlier: (1)

only project cash impacts, (2) project cash impacts and non-cash impacts internal to the organization, and (3) all comprehensive societal or sustainable impacts. This allows decision-makers the ability to prioritize worthy—but competing—projects for funding based on the maximum financial and societal returns. In the following example, a project's outcome metrics are synthesized into an intuitive risk analysis model based on estimated return on investment.

A. Compare the financial return on investment and sustainable return on investment. In this example, the mean sustainable return on investment is more than double the traditional return on investment.
B. Evaluate non-cash benefits, such as improvements in employee health and productivity, and the benefits to the larger community.
C. Assess the statistical likelihood that return will fall within an 80% confidence interval. In this example, sustainable return on investment ranges from 15% to 34%.

Figure B- 7: The Sustainability "S" Curve to Optimize the Total Value of Your Projects
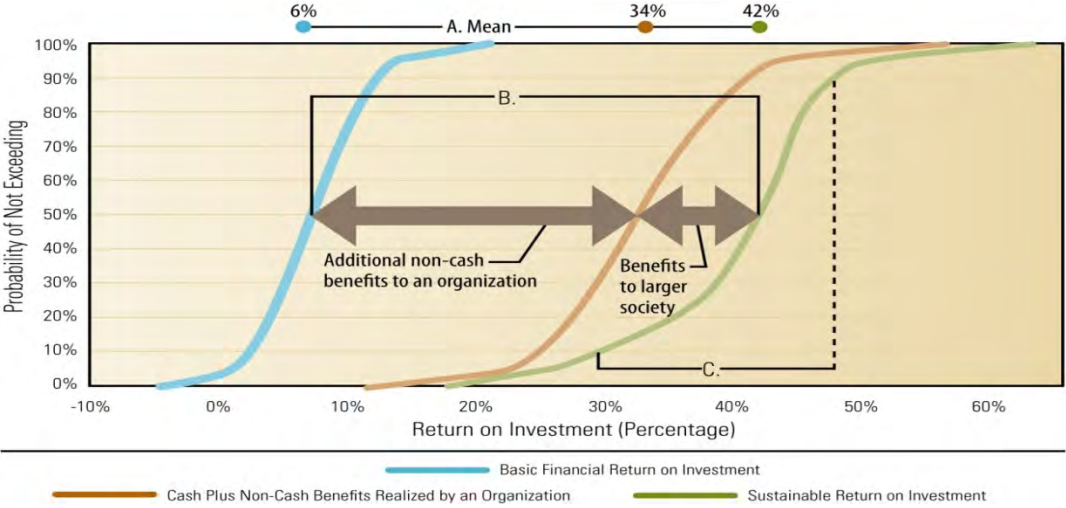
SROI originated from a Commitment to Action by HDR to develop a new generation of public decision support metrics for the Clinton Global Initiative (CGI) in 2007. SROI was developed with input from Columbia University's Graduate School of International Public Affairs and launched at the 2009 CGI annual meeting. Since then, the SROI process has been used by HDR to evaluate the monetary value of sustainability programs and projects with a combined value of over $15 billion. It has been used by corporations and all levels of government.

Sustainable Return on Investment

APPENDIX B: INPUT DATA ASSUMPTIONS

Table 4: Luminaire Replacements by Site

Option	Existing HPS				New LED Luminaires	
	Existing Wattage	Existing System Wattage	Count	Existing kWh/year*	Proposed Luminaire Wattage	Proposed kWh/year
Ridgefield						
1	100	119	56	29,188	42	10,302
2	100	119	74	38,570	56	18,151
	150	183	3	2,405	56	736
	200	241	6	6,333	56	1,472
	250	305	1	1,336	56	245
	400	468	1	2,050	56	245
3	150	183	45	36,069	65	12,812
	200	241	1	1,056	65	285
4	100	119	1	521	168	736
	200	241	35	36,945	168	25,754
5	100	119	4	2,085	168	2,943
	150	183	4	3,206	168	2,943
	200	241	18	19,000	168	13,245
	250	305	23	30,726	168	16,924
	400	468	3	6,150	168	2,208
6	100	119	3	1,564	134	1,761
	200	241	33	34,834	134	19,368
	250	305	40	53,436	134	23,477
Coulee Dam						
1	70	87	40	15,242	29	5,081
2	70	87	4	1,524	65	1,139
	100	119	48	25,019	65	13,666
	150	183	11	8,817	65	3,132
	200	241	6	6,333	65	1,708
3	70	87	18	6,859	52	4,100
	200	241	2	2,111	52	456
4	100	119	1	521	65	285
	200	241	102	107,669	65	29,039
	400	468	1	2,050	65	285
5	70	87	3	1,143	52	683
	100	119	7	3,649	52	1,594
	200	241	39	41,168	52	8,883
6	70	87	9	3,430	37	1,459

Option	Existing HPS				New LED Luminaires	
	Existing Wattage	Existing System Wattage	Count	Existing kWh/year*	Proposed Luminaire Wattage	Proposed kWh/year
Benton City						
1	100	119	144	75,056	55	34,690
	200	241	1	1,056	55	241
	400	468	2	4,100	55	482
2	100	119	2	1,042	55	482
	200	241	36	38,001	55	8,672
3	400	468	7	14,349	260	7,972
4	400	468	11	22,548	184	8,865
Buckley						
1	70	87	5	1,905	43	942
2	100	119	212	110,499	54	50,142
3	200	241	18	19,000	130	10,249
4	250	305	11	14,695	196	9,443
5	400	468	8	16,399	258	9,040
6	150	183	9	7,214	68	2,681
	200	241	16	16,889	144	10,092
	250	305	2	2,672	189	1,656
Blaine						
1	100	119	167	87,044	48	35,110
	200	241	10	10,556	48	2,102
2	200	241	171	180,504	72	53,927
	400	468	2	4,100	72	631
3	400	468	20	40,997	146	12,790
4	100	119	11	5,733	108	5,203
	200	241	93	98,169	108	43,993
	200	241	109	115,058	108	51,561
5	100	119	4	2,085	146	2,558
	200	241	2	2,111	146	1,279
	200	241	39	41,168	146	24,940
	250	305	4	5,344	146	2,558
Palouse						
1	175	208	38	34,620	67	11,151
1	100	127	14	7,788	67	4,108
2	100	119	91	47,431	59	23,516
3	200	241	2	2,111	131	1,148
3	200	241	11	11,611	121	5,830

Source: DKS from earlier project phases and bids

Table 5: Capital and Operating Costs Assumptions

Input Category	Realized Value Used in Analysis	Median	High	Low	Additional Comments
HPS System					
Initial Cost per Luminaire, HPS, $/ unit					
70W	$170.00	$170.00	$204.00	$136.00	
100W	$189.00	$189.00	$226.80	$151.20	
150W	$200.00	$200.00	$240.00	$160.00	
200W	$285.00	$285.00	$342.00	$228.00	
250W	$300.00	$300.00	$360.00	$240.00	
400W	$325.00	$325.00	$390.00	$260.00	
Installation Cost, HPS,$/Luminaire	$110.00	$110.00	$132.00	$88.00	Also used for LED systems if installation cost is quoted.
Design Cost, $/Luminaire	$89.40	$89.40	$107.28	$71.52	
Construction Management, $/Luminaire	$33.00	$33.00	$39.60	$26.40	
Periodic maintenance costs, $ per cycle	$95.29	$95.29	$114.35	$76.23	
Remaining years until fixture replacement (at project start)	7.5	NA	NA	NA	
Figure above rounded up	8	NA	NA	NA	
Life-cycle of cleaning and re-lamping, years (frequency of maintenance)	4	NA	NA	NA	
Remaining Years until next cleaning & re-lamping (at project start)	4	NA	NA	NA	
Years when maintenance takes place	4	NA	NA	NA	
Other, O&M costs, average, $/years	$17.57	$17.57	$21.08	$14.06	
Useful life of fixture, years	15				
LED System					
Site-specific Costs					
Ridgefield					
Installation Costs, $/Luminaire	$79.00	$79.00	$82.95	$75.05	
Material Costs for LED Luminaires, $/Luminaire					
Option 1	$134.35	$134.35	$141.07	$127.63	
Option 2	$247.20	$247.20	$259.56	$234.84	
Option 3	$247.20	$247.20	$259.56	$234.84	
Option 4	$322.40	$322.40	$338.52	$306.28	
Option 5	$322.40	$322.40	$338.52	$306.28	
Option 6	$322.40	$322.40	$338.52	$306.28	

Input Category	Realized Value Used in Analysis	Median	High	Low	Additional Comments
Coulee Dam					
Material Costs and Installation for LED Luminaires, $/Luminaire					
Option 1	$362.50	$362.50	$380.63	$344.38	
Option 2	$436.25	$436.25	$458.06	$414.44	
Option 3	$362.50	$362.50	$380.63	$344.38	
Option 4	$436.25	$436.25	$458.06	$414.44	
Option 5	$362.50	$362.50	$380.63	$344.38	
Option 6	$362.50	$362.50	$380.63	$344.38	
Benton City					
Installation Costs, $/Luminaire	$86.20	$86.20	$90.51	$81.89	
Material Costs for LED Luminaires, $/Luminaire					
Option 1	$158.00	$158.00	$165.90	$150.10	
Option 2	$158.00	$158.00	$165.90	$150.10	
Option 3	$425.00	$425.00	$446.25	$403.75	
Option 4	$344.00	$344.00	$361.20	$326.80	
Palouse					
Material Costs and Installation for LED Luminaires, $/Luminaire					
Option 1 (Ornamental MH)	$1,693.21	$1,693.21	$1,777.87	$1,608.55	
Option 1a (Ornamental HPS)	$1,693.21	$1,693.21	$1,777.87	$1,608.55	
Option 2	$735.29	$735.29	$772.05	$698.53	
Option 3	$840.00	$840.00	$882.00	$798.00	
Option 3a	$735.29	$735.29	$772.05	$698.53	
Blaine					
Material Costs and Installation for LED Luminaires, $/Luminaire					
Option 1 (Ornamental MH)	$326.87	$326.87	$343.21	$310.53	
Option 2	$450.11	$450.11	$472.62	$427.60	
Option 3	$643.01	$643.01	$675.16	$610.86	
Option 4	$402.11	$402.11	$422.22	$382.00	
Option 4 a	$443.64	$443.64	$465.82	$421.46	
Option 5	$402.11	$402.11	$422.22	$382.00	
Option 5 a	$457.48	$457.48	$480.35	$434.61	
Buckley					
Material Costs and Installation for LED Luminaires, $/Luminaire					
Option 1	$369.37	$369.37	$387.84	$350.90	
Option 2	$258.53	$258.53	$271.46	$245.60	
Option 3	$512.40	$512.40	$538.02	$486.78	
Option 4	$796.35	$796.35	$836.17	$756.53	
Option 5	$993.26	$993.26	$1,042.92	$943.60	

Input Category	Realized Value Used in Analysis	Median	High	Low	Additional Comments
Option 6 a - Ornamental	$1,657.27	$1,657.27	$1,740.13	$1,574.41	
Option 6 b - Ornamental	$1,657.27	$1,657.27	$1,740.13	$1,574.41	
Option 6 c - Ornamental	$1,657.27	$1,657.27	$1,740.13	$1,574.41	
Other Assumptions Common to All Sites					
Maintenance costs, $ per cycle	$35.00	$35.00	$42.00	$28.00	Includes cleaning only, no re-lamping is required
Life-cycle of cleaning and re-lamping, years	7	NA	NA	NA	
Other, O&M costs, average, $/years	$3.51	$3.51	$4.21	$2.81	
Useful life of fixture, years	15	NA	NA	NA	
Design Cost, $/Luminaire	$89.40	$89.40	$107.28	$71.52	The same cost as for HPS.
Construction Management, $/Luminaire	$32.30	$32.30	$38.76	$25.84	The same cost as for HPS
Both Systems					
Price of electricity, $/kWh	$0.08	$0.0765	$0.09	$0.06	

Source: HDR and DKS from earlier project phases

Table 6: Assumed Index for Rates of Growth in Real Electricity Prices (2013=1)

Year	Values by Year and Range of Probability Distribution			
	Realized	High	Low	Median
2014	1	1.5	0.5	1
2015	1	1.5	0.5	1
2016	1.02	1.5	0.5	1.02
2017	1.02	1.5	0.5	1.02
2018	1.03	1.5	0.5	1.03
2019	1.02	1.5	0.5	1.02
2020	1.02	1.5	0.5	1.02
2021	1.02	1.5	0.5	1.02
2022	1.03	1.5	0.5	1.03
2023	1.03	1.5	0.5	1.03
2024	1.03	1.5	0.5	1.03
2025	1.03	1.5	0.5	1.03
2026	1.03	1.6	0.5	1.03
2027	1.04	1.6	0.5	1.04
2028	1.04	1.6	0.5	1.04

Source: Calculated by HDR based on energy prices forecasts by Energy Information Agency

Table 7: Unit Costs of CAC Emissions

Air Pollutants	Expected Mean Value	Probability Distribution	$/Short Ton (2013 $)	Source
Nitrogen Oxide	$6,372	Median	$5,391	US DOT /NHSTA (2010)
NOx		Low	$414	Muller et al. (2007)
		High	$16,253	ECDG AEA Technology (2005)
Volatile Organic Compounds	$1,470	Median	$1,322	US DOT /NHSTA (2010)
VOCs		Low	$689	Muller et al. (2007)
		High	$2,844	ECDG/AEA Technology (2002)
Particulate Matter	$256,431	Median	$294,966	US DOT /NHSTA (2010)
PM 2.5		Low	$4,551	Muller et al. (2007)
		High	$354,171	ECDG/ AEA Technology (2002)
Sulfur Dioxide	$32,697	Median	$31,531	US DOT /NHSTA (2010)
SO2		Low	$2,068	Muller et al. (2007)
		High	$67,990	European Commission DG Environment (2002)

Table 8: Unit Costs of GHG Emissions

Greenhouse Gases	Expected Mean Value	Probability Distribution	$/Short Ton (2013 $)	Source	Additional Comments
Carbon Dioxide	$44.73	Median	$37.20	IWGSCC (2013)	Interagency Working Group on Social Cost of Carbon, US Government. For regulatory impact analysis under Executive Order 12866. 2010
		Low	$13.23	Nordhaus (2008)	Nordhaus' 2008 book "A Question of Balance" represents a conservative estimate
		High	$106.33	Stern Review (2006)	The 2006 "Stern Review" study was commissioned by the U.K. government and is widely used in Europe

Table 9: Rate of Growth in GHG Unit Costs

Year	Index Value (2013-100)
2014	1.03
2015	1.06
2016	1.08
2017	1.11
2018	1.14
2019	1.17
2020	1.19
2021	1.22
2022	1.25
2023	1.28
2024	1.31
2025	1.33
2026	1.36
2027	1.36
2028	1.39

Source: Calculated by HDR based on Intergovernmental Working Group on the Social Cost of Carbon (IWGSS, Social Cost of Carbon, 2013 Edition)

Table 10: Assumptions Regarding Emission Rates from Electricity Production in Washington State

Environmental Factor	Emissions, Short Tons/MWH
CO2e	0.144011
CO2	0.143241
CH4	0.000005
N2O	0.000002
NOx	0.000126
PM2.5	0.000005
VOC	0.000001
SO2	0.000046

Source: Compiled by HDR from: GHG Source: U.S. Environmental Protection Agency - eGRID 2012 (2009 Data); CAC Source: U.S. Environmental Protection Agency, 2008 National Emissions Inventory Data & U.S. Energy Information Administration, State Electricity Profiles 2008.