DEVELOPMENT OF A MEASUREMENT AND VERIFICATION (M&V) COSTING TOOLKIT

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ABSTRACT

This paper discusses the development of a M&V Costing Toolkit that has been developed to assist the U.S. Army with the standardization of costing procedures for measuring and verifying energy savings from Energy Service Performance Contracts (ESPC) at army bases. This M&V costing toolkit contains pricing for a wide-variety of sensors, data loggers, portable data loggers and transducers used to measure energy savings from energy conservation retrofits to buildings. The M&V costing toolkit also contains a framework for pricing the installation, maintaining the equipment, and the removal of instrumentation associated with the measurement of energy savings. The toolkit includes costing procedures for collecting the data from remote sites, archiving of the data, QC procedures, data analysis, savings reporting, and project closeout costing. This paper presents a general overview of the M&V costing process, various methods for monitoring and verifying savings, and a description of the M&V Costing Toolkit. Two examples of the use of the M&V Costing Toolkit are also presented. Twelve additional examples are provided with the toolkit, including the M&V of boilers, chillers, Energy Management and Control System (EMCS), and lighting retrofits (Haberl et al. 2003b).

INTRODUCTION

Three M&V methods have been developed for the M&V Costing toolkit, including: a) monthly utility billing analysis, b) hourly or daily data analysis, and c) calibrated simulation, which is included under the data analysis methods section. With the exception of the monthly utility billing analysis, each method has several data collection options, including: a) using data loggers, b) using EMCS data and c) using utility interval data recorded by the utility supplier and transferred to the data analyst. Each of these methods is intended to be compatible with the IPMVP (2001) and ASHRAE's Guideline 14 (ASHRAE 2002). Additional references have been included that provide detailed descriptions of some of the M&V methods intended to be used with the report, as well as vendors of data acquisition equipment referred to in this report.

The M&V Costing Toolkit was developed using the MS Excel program. The toolkit consists of three MS Excel workbooks: 1) The Utility.xls workbook represents a stand-alone monthly utility billing analysis method. 2) The Project.xls workbook represents the data analysis and calibrated simulation methods, which is linked to the 3) M&V Equipment Costs.xls workbook, which contains the database of data acquisition equipment that is used in the Project.xls workbook. Both the Utility.xls workbook and the project.xls workbook can be divided into two parts, including the cost summary and detailed costing information. Labor costs and weather information spreadsheets are also included in each of the workbooks.

DESCRIPTION OF THE TOOLKIT

Costing Information Input for the Utility.xls Workbook The costing information input spreadsheet for the Utility.xls Workbook is meant to be a stand-alone procedure, since there is no cost associated with the installation, maintenance and/or removal of the data logging equipment (Haberl and Im 2001). The costing information input spreadsheet for the Utility.xls workbook contains the following elements: a) Data transfer, QC and data entry, b) Data Recovery/Missing Data, c) One time Baseline/Post Retrofit Analysis, d) Ongoing Saving Analysis, e) Reporting, and f) Closeout/Data Transfer.

Utility.xls Workbook: Data Transfer, QC and Data Entry Costs The first section that appears on the data information input spreadsheet for the Utility.xls Workbook involves the actual transfer of data from the utility to the M&V provider. In this section the user can input the number of units for setup costs, any associated supply costs, and labor and administrative categories (see Figure 1). The user then can enter values for the data transfer, QC and database loading, data cleaning, any associated computer costs and other costs. For each of these categories the user enters the hour of labor associated

Data Transfer, QC and Data Entry Costs

Item	A. Unit	B.Supply		C.Labor		D.Admin/unit		E. No. Per yr	F.Total Supply	G.Total Labor	H. Total Admin	I. Total
				Data Base Support Worker		Project PI						
		No.Unit	$/Unit	Hrs	$/Hr	Hrs	$/Hr		(=B x E)	(=C x E)	(=D x E)	(=F+G+H)
Setup Costs		0	$0.00	4	$40	0.5	$116	1	$0	$162	$58	$219
Data Transfer		0	$0.00	0.5		0.1		52	$0	$1,051	$601	$1,652
QC, Database Load		0	$0.00	0.1		0.1		52	$0	$210	$601	$811
Data Cleaning		0	$0.00	10		1		1	$0	$404	$116	$520
Computer Costs	Per Month	12	$10.00	0		0		1	$120	$0	$0	$120
other		0	$0.00	0		0		0	$0	$0	$0	$0
Total Costs									$120	$1,827	$1,374	$3,322

Figure 1: *Utility.xls Workbook: Data Transfer, QC and Data Entry Costs*

Data Recovery/Missing Data

Item	A. Unit	B.Supply		C.Labor		D.Admin/unit		E. No. Per yr	F.Total Supply	G.Total Labor	H. Total Admin	I. Total
				Data Base Support Worker		Project PI						
		No.Unit	$/Unit	Hrs	$/Hr	Hrs	$/Hr		(=B x E)	(=C x E)	(=D x E)	(=F+G+H)
Data Recovery		8	$1.00	8	$40	1	$116	1	$8	$323	$108	$439
Missing Data		12	$1.00	8		1		1	$12	$323	$116	$451
other		0	$1.00	0		0		0	$0	$0	$0	$0
Total Costs									$12	$647	$231	$890

Figure 2: *Utility.xls Workbook: Data Recovery/Missing Data*

One Time Baseline/Post Retrofit Analysis

Item	A. Unit	B.Supply		C.Labor		D.Admin/unit		E. No. Per yr	F.Total Supply	G.Total Labor	H. Total Admin	I. Total
				Data Analyst		Project PI						
		No. Unit	$/Unit	Hrs	$/Hr	Hrs	$/Hr		(=B x E)	(=C x E)	(=D x E)	(=F+G+H)
Setup Costs		1	$0.00	4	$58	1	$116	1	$0	$231	$116	$347
Model Development Costs	Model	1	$0.00	8		1		1	$0	$462	$116	$578
Savings Calculations		1	$0.00	2		1		52	$0	$1,266	$1,266	$2,772
other		0	$0.00	0		0		0	$0	$0	$0	$0
Total Costs									$0	$2,079	$1,617	$3,696

Figure 3: *Utility.xls Workbook: One Time Baseline/Post Retrofit Analysis*

with each item, the administrative hours, and the number of times each year that the process takes place. The spreadsheet then calculates the supply costs, the labor costs, the administration costs and the total costs. In Figure 1 costs are shown for a large retrofit project that relies on monthly utility billing analysis across 100s of meters for a large retrofit project, which uses weather data from the National Weather Service (NWS). In this figure it is estimated that the one-time setup will take 4 hours of time at $40 per hour, and ½ hour of administrative review totaling $219. The data transfer will take ½ hour of time weekly, and a few minutes of administrative review, totaling $1,652 per year. QC and database loading are estimated to take only a few minutes each week, totaling $811 per year. Data cleaning is estimated to take 10 hours over the year, with one hour of administrative review, totaling $520 per year. Computer costs are estimated to be $10 per month, which brings the total cost to $3,322 for the example shown.

Utility.xls Workbook: Data Recovery/Missing Data The next section of the spreadsheet allows the user to enter costing information that is related to the recovery of bad or missing data (see Figure 2). This occurs often in a monitoring project when inappropriate scaling factors are assigned to a channel and need to be corrected. Likewise, periods of missing data may need to be removed and/or replaced with synthesized or imputed data. In this section the user defines the appropriate labor and administrative categories, and the hours associated with the data recovery or missing data tasks. A category has been reserved for "other" costs that can be defined by the user. Since these tasks can occur at different frequencies throughout the year, the user is allowed to enter the number of times per year that each task occurs. In Figure 2 the data recovery is estimated to take 8 hours per year, with 1 hour of administrative review, totaling $439. Missing data are estimated to require $12 in electronic media costs, and will take 8 hours per year, with 1 hour of administrative review, totaling $451, which brings the total costs to $890.

Utility.xls Workbook: One Time Baseline/Post Retrofit Analysis This section of the spreadsheet allows the user to enter costs associated with the creation of baseline statistical models that are based on different channels of data (see Figure 3). In a similar fashion to the other functions a category for

43	**Ongoing Savings Analysis**											
44												
45	Item	A. Unit	B.Supply		C.Labor		D.Admin/unit		E. No. Per yr	F.Total Supply	G.Total Labor	H. Total Admin	I. Total
46					Data Analyst		Project Engineer						
47			No. Unit	$/Unit	Hrs	$/Hr	Hrs	$/Hr		(=B x E)	(=C x E)	(=D x E)	(=F+G+H)
48	Model Development Costs		1	$100	2		0.5		12	$12	$1,388	$347	$1,745
49	Savings Calculations		1	$100	1	$58	0.5	$68	12	$12	$693	$347	$1,052
50	other		0	$0.00	0		0		0	$0	$0	$0	$0
51													
52	Total Costs									$24	$2,079	$693	$2,796

Figure 4: *Utility.xls Workbook: Ongoing Savings Analysis*

54	**Reporting**											
55												
56	Item	A. Unit	B.Supply		C.Labor		D.Admin/unit		E. No. Per yr	F.Total Supply	G.Total Labor	H. Total Admin	I. Total
57					Data Analyst		Project Pl						
58			No.Unit	$/Unit	Hrs	$/Hr	Hrs	$/Hr		(=B x E)	(=C x E)	(=D x E)	(=F+G+H)
59	Setup Costs		1	$1.00	4		1		1	$1	$231	$116	$348
60	Generation Costs		2	$1.00	1	$58	0.25	$116	12	$24	$693	$347	$1,064
61	other		0	$1.00	0		0		0	$0	$0	$0	$0
62													
63	Total Costs									$25	$924	$462	$1,411

Figure 5: *Utility.xls Workbook: Reporting*

65	**Close-out, Data Transfer**											
66												
67	Item	A. Unit	B.Supply		C.Labor		D.Admin/unit		E. No. Per yr	F.Total Supply	G.Total Labor	H. Total Admin	I. Total
68					Data Analyst		Data Base Manager						
69			No. Unit	$/Unit	Hrs	$/Hr	Hrs	$/Hr		(=B x E)	(=C x E)	(=D x E)	(=F+G+H)
70	Close-Out		1	$1.00	2		1		1	$1	$116	$58	$174
71	Data Transfer		1	$1.00	2	$58	1	$58	2	$2	$231	$116	$349
72	other		0	$1.00	0		0		2	$0	$0	$0	$0
73													
74	Total Costs									$3	$347	$173	$523

Figure 6: *Utility.xls Workbook: Close-out, Data Transfer*

5	**Hourly Weather Data**											
6												
7	Item	A. Unit	B.Supply		C.Labor		D.Admin/unit		E. NO. per yr	F.Total Price	G.Total Labor	H. Total Admin	I. Total
8					Data Base Support Worker		Project Engineer						
9			No. Unit	$/Unit	Hrs	$/Hr	Hrs	$/Hr		(=B x E)	(=C x E)	(=D x E)	(=F+G+H)
10	Setup Costs		1	$1.00	2		0.25		1	$1	$81	$14	$96
11	Poling/Transfer		1	$1.00	0.5		0.25		52	$52	$1,051	$751	$1,854
12	QC, Database Load		1	$1.00	0.5	$40	0.25	$58	52	$52	$1,051	$751	$1,854
13	Data Cleaning		1	$1.00	1		0.25		1	$1	$40	$14	$56
14	other		0	$0.00	0		0		0	$0	$0	$0	$0
15													
16	Total Costs									$106	$2,223	$1,530	$3,860

Figure 7: *Utility.xls Workbook: Hourly Weather Data*

supplies has been reserved. The tasks associated with the one-time baseline or post retrofit analysis include setup costs (based on each logger), model development costs, and other costs. To use this portion of the spreadsheet, the user chooses the appropriate labor and administration category, the number of models that are being developed and assigned the appropriate time in hours associated with the tasks shown. The spreadsheet then calculates the supply costs, labor costs, administrative costs and total costs. In the example shown in Figure 3 these costs are estimated to be $347 for setup costs, $578 for model development, $2,772 for savings calculations, totaling $3,696.

Utility.xls Workbook: Ongoing Savings Analysis This section of the spreadsheet allows the user to enter costs associated with the ongoing savings analysis (see Figure 4). Usually, this is required since the analyst that is calculating the savings must apply the baseline models against either a weather-normalized year or against the actual post-retrofit weather data to calculate the savings associated with the retrofit measure. In some cases this may require the creation and application of a post-retrofit model to fill-in missing data in the post-retrofit period, costing categories for the savings calculation and another cost category have also been added. To use this section of the spreadsheet, the user chooses the labor and administrative categories, chooses the number of post-retrofit models and savings calculations, and assigns an hourly labor and administrative charge to each of these tasks, as well

as the number of times per year that this task must be performed. In Figure 4 these costs are estimated to be $1,745 for monthly model adjustments, and $1,052 for savings calculations, totaling $2,796.

Utility.xls Workbook: Reporting The next section of the spreadsheet allows the user to input costing information that relates to the generation of savings or consumption reports (see Figure 5). The costs associated with the reporting of information include a setup cost for each site, report generation costs per site or logger, and a user-defined other cost. In a similar fashion to other costs, the user is allowed to also enter a supply cost. To use the section of the spreadsheet the user selects the labor and administrative categories, the labor and administrative hours associated with each task, and the number of times per year this task is performed. The spreadsheet then calculates the supply costs, labor costs, administrative costs and total costs associated with the reporting function. In Figure 5 these costs are estimated to be $348 for setup costs, $1,064 for report generation costs,

Utility.xls Workbook: Close-out, Data Transfer The next section of the report involves costs associated with the close-out and data transfer tasks (see Figure 6). These tasks are often required when data from an M&V project are to be transferred to another job. The tasks assigned to the section of the spreadsheet include the close-out costs, data transfer costs, and other costs. Supply costs associated with these tasks can also be defined by the user. To use this section of the spreadsheet, the user enters the labor category, administrative category, labor and administrative hours associated with each task, and the number of times each task is to be performed. The spreadsheet then calculates the supply costs, labor, administrative costs and total costs. In Figure 6 these costs are estimated to be $174 for the database close-out costs, and $349 to transfer all data to exportable media, totaling $523.

Utility.xls Workbook: Costing Information Input for Weather Data Each of the workbooks (i.e., Project.xls and Utility.xls) will require some sort of weather data to be acquired either from the National Weather Service (NWS) or from another weather provider. In most instances there will be some sort of cost associated with the acquisition of weather data. To allow for this, the M&V Costing Toolkit has a costing information input for weather data. This section can be reached under the “Weather_Cost” tab of each workbook.

The user is then allowed to enter costing information that includes setup costs, polling/transfer costs, QC and database costs, data cleaning costs and other costs (see Figure 7). The user is also allowed to enter supply cost information for each function. After selecting the labor category and administration category, the user can then assign an hourly labor and administrative value to each task, as well as the number of times per year that the task is performed. The spreadsheet then calculates the total supply costs, labor costs, administration costs and total costs. In Figure 7 these costs are estimated to be $96 for setup costs, $1,854 for 52 weeks of polling, and $1854 for QC and database loading, with $56 for data cleaning, totaling $3,860.

Utility.xls Workbook: Cost Summary In a similar fashion as the Project.xls, the Summary costs for the Utility.xls Workbook provides a summary of the costs from the previously entered data. It is also reached using the tabs at the bottom of the Utility.xls spreadsheet. In this section a summary of the costs is provided, which have previously been calculated in each of the previous sections as shown in Figure 8. In this section of the report the user only needs to update the Overhead and profits associated with the project, which are then applied to the summarized project costs.

Cost Summary

1	Data transfer, QC and database Entry		$3,322
2	Data Recovery/Missing Data		$890
3	One Time Baseline/Post Retrofit Analys		$3,696
4	Ongoing Savings Analysis		$2,796
5	Reporting		$1,411
6	Close-out, Data Transfer		$523
1	Hourly Weather Data		$3,860
	Overheads & Profits	22%	$3,629
	Total Project Costs		**$20,126**

Figure 8: *Utility Workbook: Cost Summary*

Project.xls Workbook: Costing Summary Spreadsheet Each workbook has several worksheets. These worksheets are basically divided into two parts: 1) detailed costing input spreadsheets, and 2) summary spreadsheets as indicated by the tabs that appear at the lower left corner of the spreadsheet.

Figure 9 presents a view of the Costing Summary spreadsheet that is used in both the Utility.xls Workbook and the Project.xls workbook. Each of the Costing Summary spreadsheets has a spreadsheet title in the upper left corner of the spreadsheet to indicate which spreadsheet is active as indicated. The user can change the type of spreadsheet by clicking on the tabs located at the bottom left of the spreadsheet. The choices are: Project_Summary, Project_Cost, Weather_Summary, Weather_Cost, and Labor_Cost.

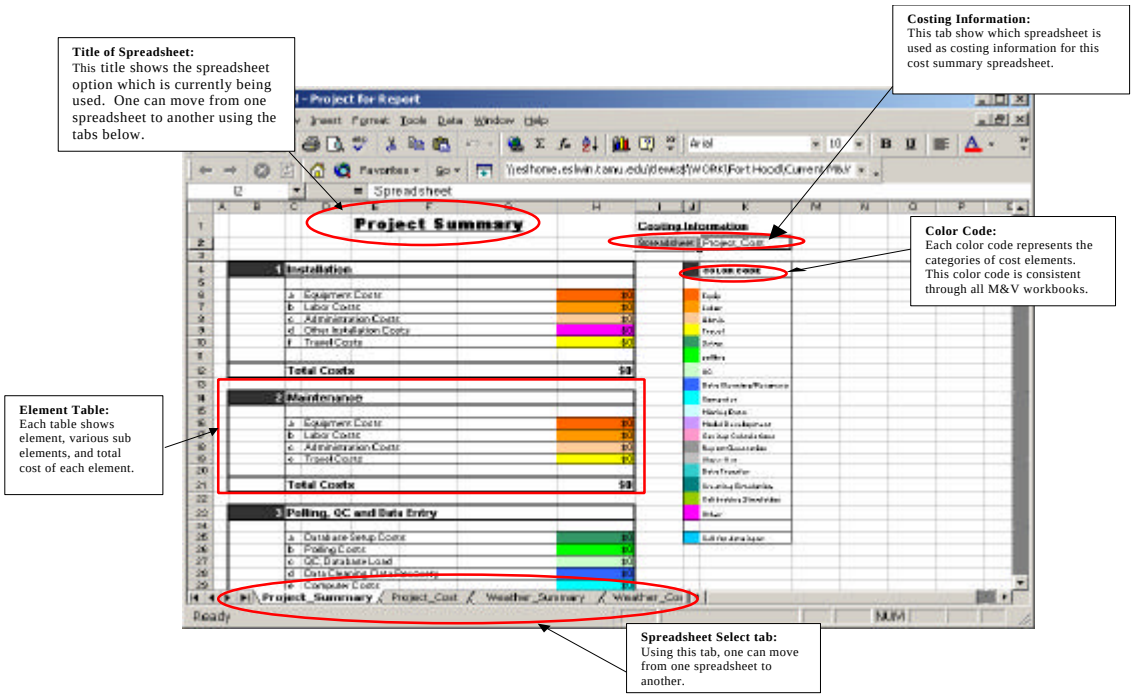

Figure 9: *View of the Cost Summary Spreadsheet*

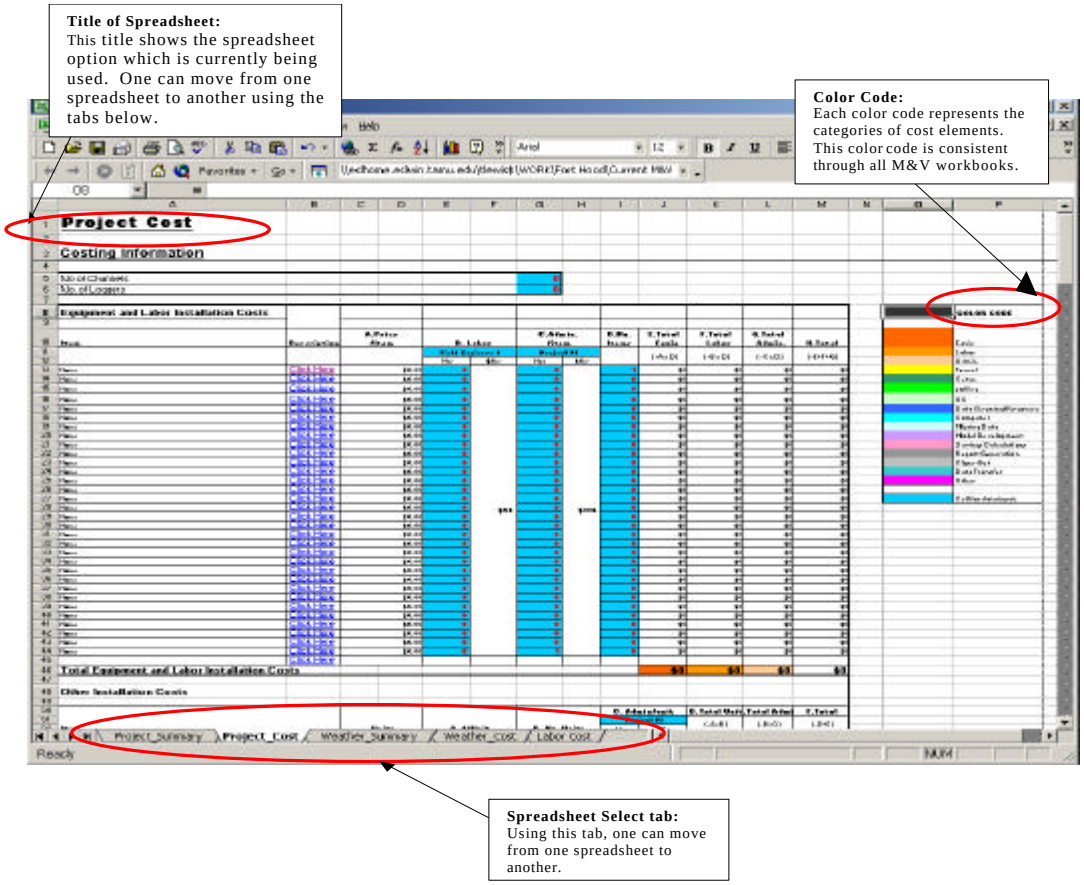

Figure 10: *View of the Costing Information Input Spreadsheet*

In the upper right corner of the Costing Summary spreadsheet the Costing Information Input spreadsheet that is currently being used is indicated. This name should be pointing to the file the user wants to open. All of the spreadsheets are color coded to allow for easier tracking of the major cost categories, including: equipment, labor, administration, travel, setup, polling, QC, data cleaning/recovery, computer costs, missing data costs, model development costs, savings calculation costs, report generation costs, closeout costs, data transfer costs, and other costs.

In the Project_Summary spreadsheet, summary costs are then grouped together under the major cost functions, including: 1) Installation, 2) Maintenance, 3) Polling, QC, and Data Entry, 4) Equipment Removal, 5) Data Recovery/Missing Data, 6) One-time Baseline/Post-retrofit Analysis, 7) Ongoing Savings Analysis, 8) Creating the Basic Simulation Input File, 9) Calibrating Simulation, 10) Use the Calibrated Simulation to Calculate Baseline, 11) Use the Calibrated Simulation to Calculate Ongoing Savings, 12) Reporting, 13) Closeout Data Transfer, 14) Weather Data, and finally an entry for Overhead and Profit, and Total Project Costs. Notice that on the Summary Cost spreadsheet, the only cell that the user needs to edit is the Overhead and Profit, since all other cells are references to other spreadsheets. All other cells in the workbook should not be changed.

Figure 10 shows the Costing Information Input spreadsheet (Project_Cost) for the Project.xls workbook. This spreadsheet is the primary spreadsheet for the entry of the detailed information that appears in the Project_Summary spreadsheet. The most commonly updated information is highlighted in blue. Less frequently updated information remains colorless. The other cell colors relate to the color coded cost categories. This spreadsheet is accessed by clicking on the Project_Cost tab located at the bottom left of the Project.xls Workbook.

Project.xls Workbook: Labor Cost Input Information Labor costs are maintained in the Labor Cost spreadsheet of each workbook. These costs remain the same across all spreadsheets in the workbook. Figure 11 shows the labor cost categories. The blue cells indicate the cells that the user will most frequently change. A fixed 15.5% fringe benefit is applied to all labor costs, yielding a total hourly rate for each category that is used in the workbook.

Project.xls Workbook: Equipment Specifications in the M&V Equipment Costs.xls. An example is shown in Figure 12 of the equipment costing information contained in the M&V Costing Toolkit.

	1	2	3	4
	Personnel	Rate ($/Hr)	Fringe Benefit	Total
			(15.5% of Rate)	
	Project PI	$100	$16	$116
	Project CoPI	$100	$16	$116
	Project Manager I	$75	$12	$87
	Project Engineer	$50	$8	$58
	Data Base Support Worker	$35	$5	$40
	Data Base Manager	$50	$8	$58
	Programming Manager	$75	$12	$87
	Field Engineer 1	$50	$8	$58
	Field Engineer 2	$35	$5	$40
	Data Base Programmer	$35	$5	$40
	Data Analyst	$50	$8	$58

Figure 11: *Labor Cost Information*

In this example, the Enernet Model K20 (Enernet 2001; Highland 2001) is shown, which includes all manufacturer information, and a photograph of the logger (current as of August 2003). The M&V Costing Toolkit contains detailed costing information for data loggers, portable loggers, EMCS, flow-meters, BTU meter, RTDs, potential transducers, current transducers, Watt-hour transducers, RH-Temp sensors, solar sensors, MV transmitter calibrators, wind sensors, modems, signal transmitters, conduit, NEMA enclosures, junction boxes, etc.

EXAMPLE USE OF THE TOOLKIT

General Instruction The e general process for using the M&V Costing Toolkit is as follows:

1. First, choose the M&V Toolkit Workbook (either Project.xls or Utility.xls).
2. The next step is the input process. Most of the input cells are placed in the costing information spreadsheet. In the Project.xls Workbook, this is called ‘Project_Cost’ and for the Utility.xls Workbook, the costing spreadsheet is called ‘Utility_Cost’.
3. After entering all of the required data, you can obtain the total cost from the cost summary spreadsheet. For the Project.xls Workbook, the cost summary spreadsheet is called ‘Project_Summary’ and for the Utility.xls Workbook, the cost summary spreadsheet is called ‘Utility_Summary’.

Thirteen metering scenarios were developed for use with the Project.xls Workbook of the M&V Costing Toolkit. The thirteen metering scenarios are listed below:

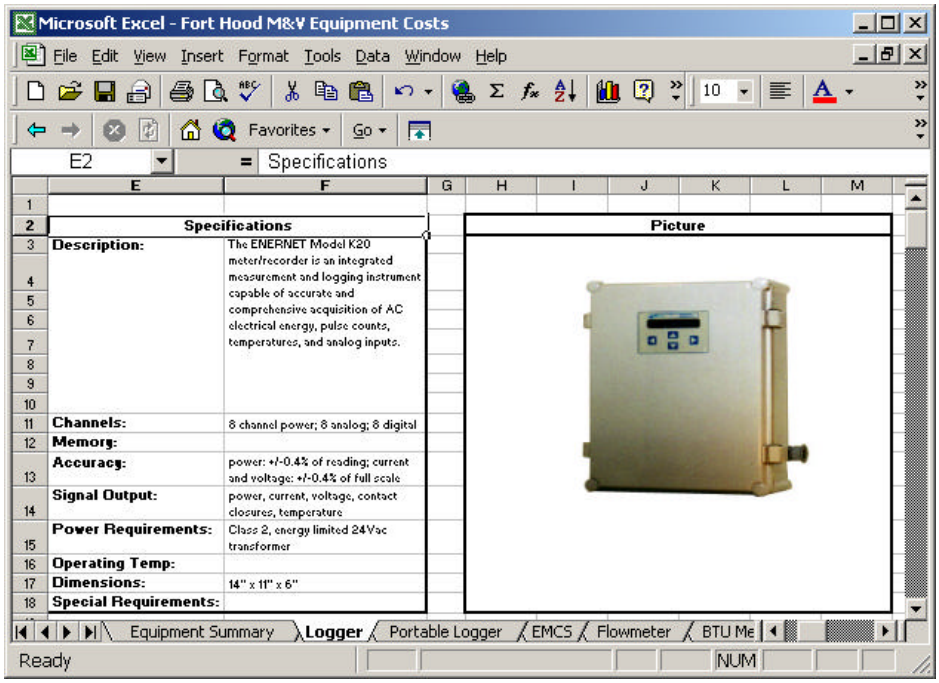

Figure 12: *Example of Equipment Specifications in the M&V Equipment Costs.xls*

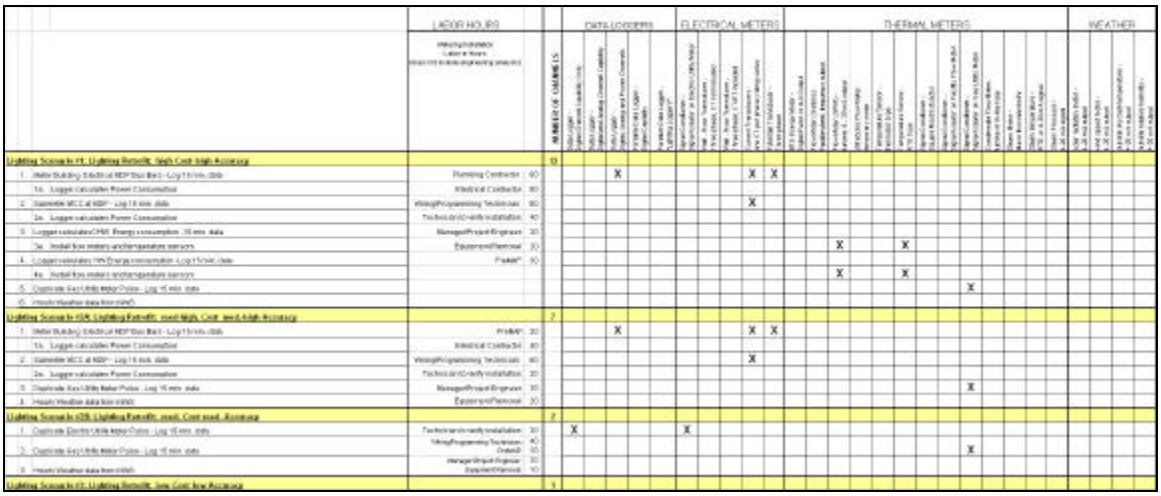

Figure 13: *Metering Matrix for Lighting Scenarios.*

Lighting Scenario #1: Lighting retrofit – high cost, high accuracy ($50,395)
Lighting Scenario #2A: Lighting retrofit – medium-high cost, medium-high accuracy ($27,215)
Lighting Scenario #2B: Lighting retrofit - medium cost, medium accuracy ($22,971)
Lighting Scenario #3: Lighting retrofit – low cost, low accuracy ($18,565)
Chiller Scenario #1: Chiller retrofit – high cost, high accuracy ($39,219)
Chiller Scenario #2: Chiller retrofit - medium cost, medium accuracy ($38,436)
Chiller Scenario #3: Chiller retrofit – low cost, low accuracy ($32,404)
EMCS Scenario #1: EMCS retrofit – high cost, high accuracy ($77,044)
EMCS Scenario #2: EMCS retrofit - medium cost, medium accuracy ($51,571)
EMCS Scenario #3: EMCS retrofit – low cost, low accuracy ($45,731)
Boiler Scenario #1: Boiler retrofit – high cost, high accuracy ($34,596)
Boiler Scenario #2: Boiler retrofit - medium cost, medium accuracy ($25,989)
Boiler Scenario #3: Boiler retrofit – low cost, low accuracy ($18,457)

This next section of the report discusses the use of the Project.xls workbook with an example of one

	LABOR HOURS Metering installation Labor in Hours (does not include engineering analysis)			
			Labor Cost per Hour	Total Cost per Labor Category
Lighting Scenario #1: Lighting Retrofit: high Cost/ high Accuracy				
1. Meter Building Electrical MDP Bus Bars - Log 15 min. data	Plumbing Contractor:	80	$75.00	$6,000.00
1a. Logger calculates Power Consumption	Electrical Contractor:	80	$75.00	$6,000.00
2. Submeter MCC at MDP - Log 15 min. data	Wiring/Programming Technician:	80	$50.00	$4,000.00
2a. Logger calculates Power Consumption	Technician to verify installation:	40	$50.00	$2,000.00
3. Logger calculates CHW Energy consumption - 15 min. data	Manager/Project Engineer:	20	$100.00	$2,000.00
3a. Install flow meters and temperature sensors	PreMAP:	30	$116.00	$3,480.00
4. Logger calculates HW Energy consumption - Log 15 min. data	Equipment Removal:	20	$40.00	$800.00
4a. Install flow meters and temperature sensors				
5. Duplicate Gas Utility Meter Pulse - Log 15 min. data				
6. Hourly Weather data from NWS	**Total Cost**			$20,000.00
Lighting Scenario #2A: Lighting Retrofit: med-high. Cost/ med.-high Accuracy				
1. Meter Building Electrical MDP Bus Bars - Log 15 min. data	Electrical Contractor:	40	$75.00	$3,000.00
1a. Logger calculates Power Consumption	Wiring/Programming Technician:	60	$50.00	$3,000.00
2. Submeter MCC at MDP - Log 15 min. data	Technician to verify installation:	20	$50.00	$1,000.00
2a. Logger calculates Power Consumption	Manager/Project Engineer:	20	$100.00	$2,000.00
3. Duplicate Gas Utility Meter Pulse - Log 15 min. data	PreMAP:	20	$116.00	$2,320.00
4. Hourly Weather data from NWS	Equipment Removal:	20	$40.00	$800.00
	Total Cost			$9,000.00
Lighting Scenario #2B: Lighting Retrofit: med. Cost/ med. Accuracy				
1. Duplicate Electric Utility Meter Pulse - Log 15 min. data	Technician to verify installation:	20	$50.00	$1,000.00
2. Duplicate Gas Utility Meter Pulse - Log 15 min. data	Wiring/Programming Technician:	40	$50.00	$2,000.00
	Manager/Project Engineer:	20	$100.00	$2,000.00
	PreMAP:	10	$116.00	$1,160.00
3. Hourly Weather data from NWS	Equipment Removal:	10	$40.00	$400.00
	Total Cost			$5,000.00
Lighting Scenario #3: Lighting Retrofit: low Cost/ low Accuracy				
1. Whole Building Electric - Log 5 min. data using portable meter	Wiring/Programming Technician:	40	$50.00	$2,000.00
2. Monthly utility bills for electricity use and electric demand	Technician to verify installation:	60	$50.00	$3,000.00
3. Monthly utility bills for natural gas	Manager/Project Engineer:	20	$100.00	$2,000.00
4. Month of lighting loggers to confirm lighting use profiles before & after lighting retrofit	PreMAP:	10	$116.00	$1,160.00
5. Hourly Weather data from NWS	Equipment Removal:	10	$40.00	$400.00
	Total Cost			$7,000.00

Figure 14: *Detailed Labor Costs for Lighting Scenarios.*

of the thirteen scenarios -- Lighting Scenario #1. Four lighting scenarios were developed to illustrate the use of the M&V Costing Toolkit. The metering assumptions for these scenarios are shown in Figure 13, which include the functional type of data logger, electrical metering, thermal metering and equipment for measuring weather data. In this table the hours for the labor for installing the system are shown and the costs associated with the hours is shown in Figure 14.

In Lighting Scenario #1, the savings determination was developed to include: a) electricity savings from lighting retrofit normalized for occupancy, b) cooling savings due to lighting retrofit normalized for weather, c) additional heating gas use to make up for lighting retrofit normalized for weather, d) chiller efficiency performance tracked, and e) boiler efficiency performance tracked.

The analysis methods in Lighting Scenario #1 were to include: a) Daily electricity savings = linear or change-point linear weather dependent model using the ASHRAE Inverse Model Toolkit - IMT (Kissock et al. 2003; Haberl et al. 2003a) (usually a model of weekday/weekend daily lights and receptacle loads versus daily average NWS temperature, b) hourly electric demand = 24 hour weather daytype profiles of lights and receptacle loads electricity using ASHRAE 1093 Toolkit on presorted data (Abushakra et al. 2004; Claridge et al. 2004), c) daily cooling savings = linear or change-point linear weather dependent model of weekday/weekend Motor Control Center (MCC) electricity use versus daily average NWS, d) daily heating increase = linear or change-point linear weather dependent model of weekday/weekend daily

whole-building gas use versus daily average NWS temperature data, e) hourly chiller performance model using ASHRAE 827 RP models (Brandemuehl et al. 1996), f) hourly boiler performance model.

The metering for Lighting Scenario #1 was to include: a) 15-minute whole-building electric using current transducers (CTs) and potential transducers (PTs) on the main feeds, and integrated Watt-hour meter, b) 15-minute sub-metering on MCC using CTs, PTs, and integrated Watt-hour meter (including chillers, pumps, etc.), c) 15-minute whole-building natural gas using existing pulse from gas meter (let's assume this exists), d) 15-minute chiller Btu output using a flow-meter, temperature sensors and integrated Btu meter, e) 15-minute boiler Btu output using a flow-meter, temperature sensors and integrated Btu meter, f) digital/analog DAS with integrated Watt-hour meter, and g) hourly weather data from NWS data.

The advantages of using Lighting Scenario #1 include: a) uses closest NWS data[1], b) analysis uses ASHRAE models, including IMT, ASHRAE 827-RP chiller models , boiler models, and hourly demand models using ASHRAE 1093-RP diversity factor or daytype profile models, c) electricity savings of lighting and receptacles normalized for weather and weekday/weekend, d) separate electricity savings of cooling electricity use normalized for weather and weekday/weekend effects, and e) natural gas take-back[2] normalized for weather and weekday/weekend.

The disadvantages of Lighting Scenario #1 include: a) weather-dependent and weather-independent savings combined into one model, which can be affected by changes to any one of several systems, b) Uses slightly more expensive DAS with integrated Watt-hour meter, c) Uses more expensive thermal metering, Btu meters.

Lighting Scenario #1: Labor Costs The next step involves setting the hourly labor rate for Lighting Scenario #1. In the M&V Costing Toolkit, the user has the ability to set the hourly labor costs using the Labor Costing Information tab. This tab is located at the bottom of spreadsheet and is labeled 'Labor Cost'. Figure 15 shows the pertinent section of the Project.xls workbook that includes the labor costing information. For most projects the user will need to update the hourly billing rates for the different personnel on the project. The total hourly rate is then calculated as 115.5% of the hourly rate for each employee to include fringe benefits. The user can also change the 15.5% fringe benefit rate by changing the formula for fringe benefit in this section of the spreadsheet.

	Labor Cost Information			
1				
2				
3	Personnel	Rate ($/Hr)	Fringe Benefit	Total
4			(15.5% of Rate)	
5	Project PI	$100	$16	$116
6	Project CoPI	$100	$16	$116
7	Project Manager I	$75	$12	$87
8	Project Engineer	$50	$8	$58
9	Data Base Support Worker	$35	$5	$40
10	Data Base Manager	$50	$8	$58
11	Programming Manager	$75	$12	$87
12	Field Engineer 1	$50	$8	$58
13	Field Engineer 2	$35	$5	$40
14	Data Base Programmer	$35	$5	$40
15	Data Analyst	$50	$8	$58
16				
17				
18	Total			$757

Figure 15: *Project.xls Workbook: Lighting Scenario #1: Labor Cost Information*

Lighting Scenario #1: No. of Channels & No. of Loggers For the Lighting Scenario #1 thirteen (13) channels were to be used to record the data from the retrofit. These channels were to be collected by one (1) data logger as shown in Figure 16.

Lighting Scenario #1: Equipment and Labor Installation Costs The first category to appear at the top of the Costing input sheet in Lighting Scenario #1 is for the installation of the Data Loggers, including the Equipment and Labor Installation Costs shown in Figure 17, with details of the labor costs provided in Figure 14. In this scenario, $19,923 is estimated for installation labor costs[3], and $5,982 for equipment costs. The installation includes one 13-channel data logger, power measurements on two, three phase loads (i.e., the whole-building electricity and the electricity used by the motor control center), Btu measurements on the chilled water use, and the hot water use in the building, and the whole-building natural gas use.

Lighting Scenario #1: Other Installation Costs In most installations there will also be other costs associated with the installation that include such tasks as the development of Preliminary Monitoring Analysis Plans (PreMAPs), the ordering of parts, etc. These costs can be significant because they include the job planning, search and pricing of equipment,

[1] The alternative to this would be to install an on-site weather station (Tdb, and RH), which would necessitate the purchase and calibration of instrumentation, and periodic recalibration.
[2] This would be a negative savings.
[3] The $19,923 value is an estimate of the detailed labor cost of $20,000.

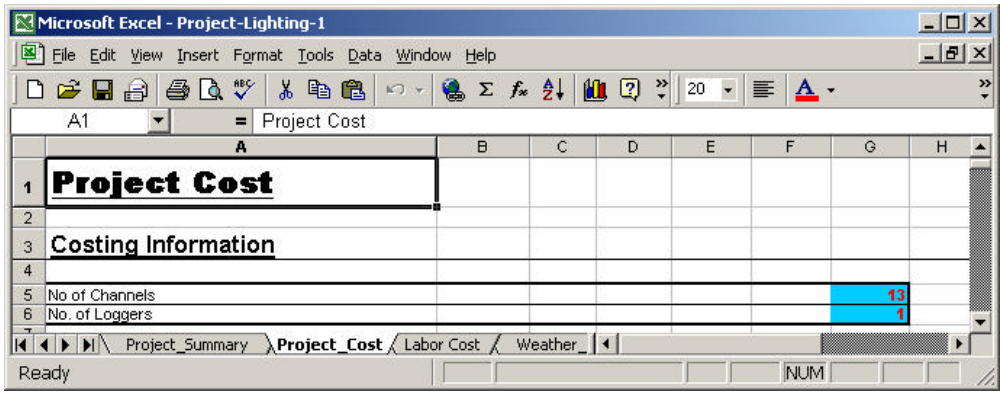

Figure 16: *Project.xls Workbook: Lighting Scenario #1: No. of Channels and Loggers*

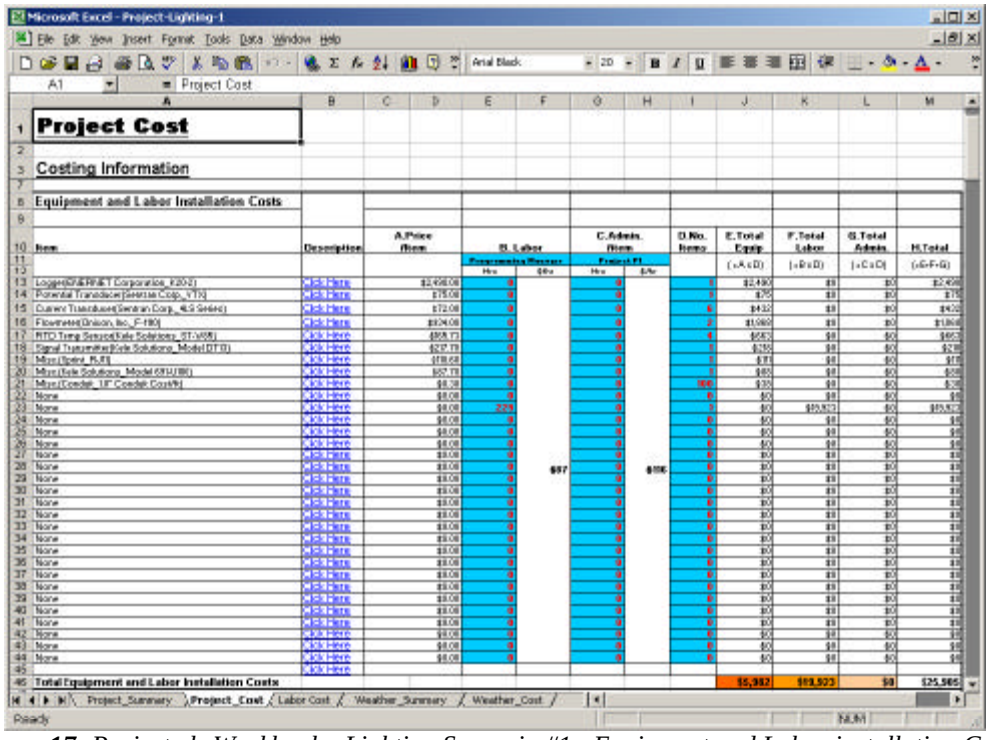

Figure 17: *Project.xls Workbook: Lighting Scenario #1: Equipment and Labor installation Costs*

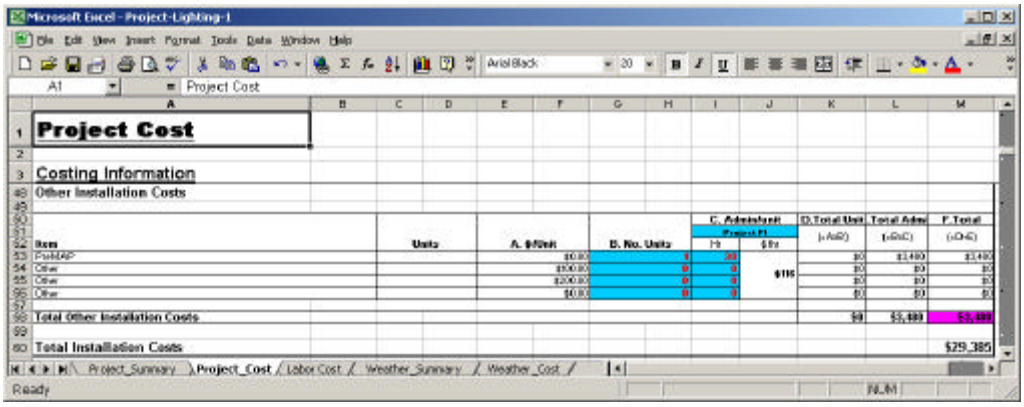

Figure 18: *Project.xls Workbook: Lighting Scenario #1: Other Installation Costs.*

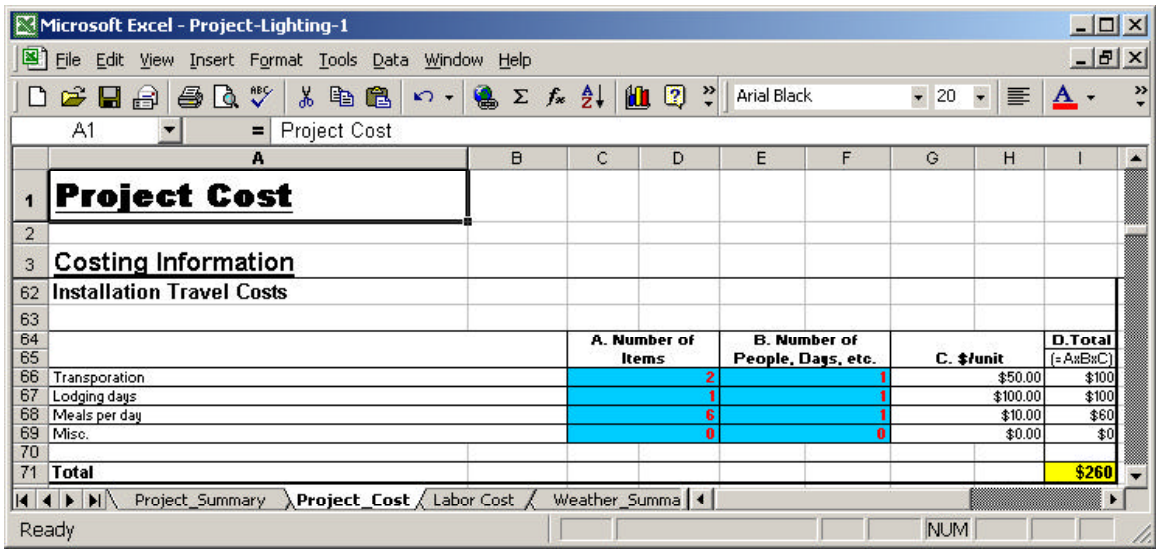

Figure 19: *Project.xls Workbook: Lighting Scenario #1: Installation Travel Costs*

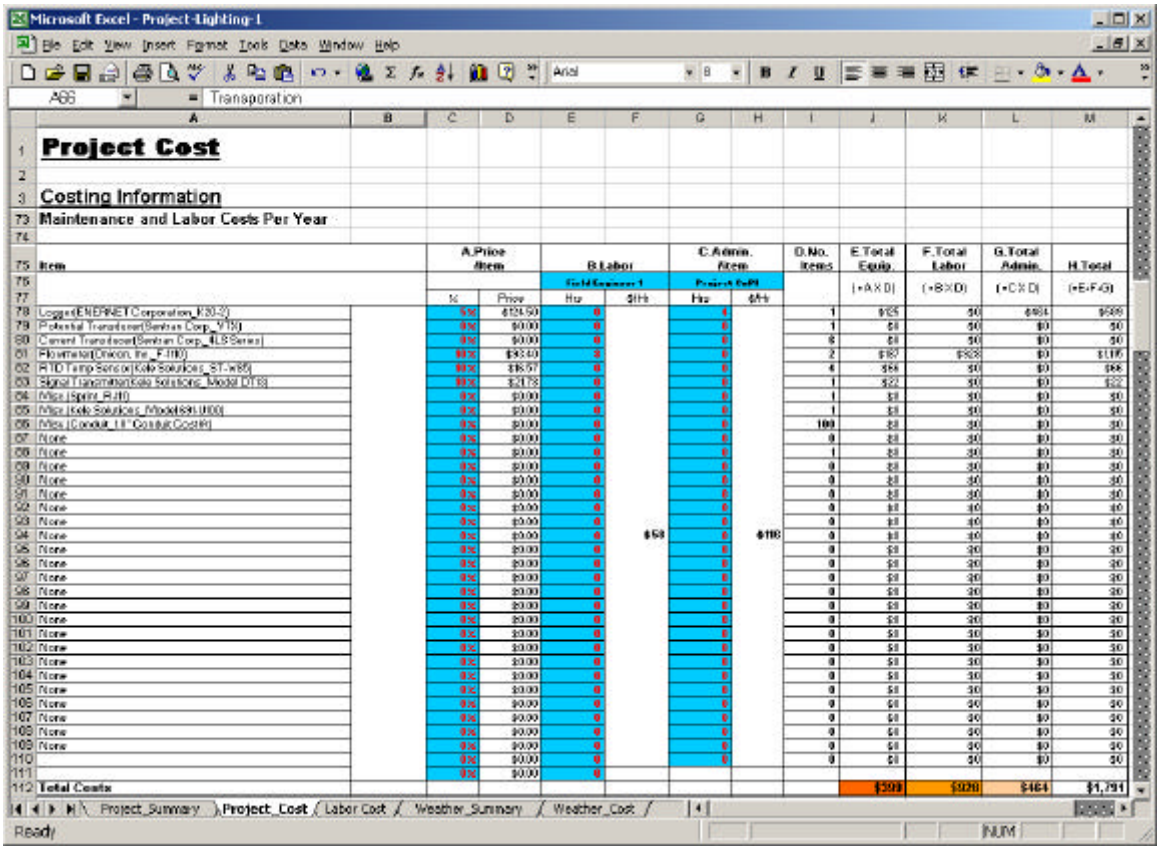

Figure 20: *Project.xls Workbook: Lighting Scenario #1: Maintenance and Labor Costs Per Year*

etc. They can be accounted for using the Other Installation costs section of the spreadsheet. In Scenario #1 (30) hours is estimated for the PreMAP as shown in Figure 18.

Lighting Scenario #1: Installation Travel Costs

For those sites located some distance from the M&V provider, there will be travel costs associated with site visits. These can be accounted for in several areas of the Costing Input Spreadsheet. In Figure 19 the travel costs for Scenario #1 are estimated to contain 2 days of transportation costs at $50/day for the rental car, and one overnight for $100/night, with meals estimated to be three meals for two days equal to six meals at $10 per meal. Total installation travel

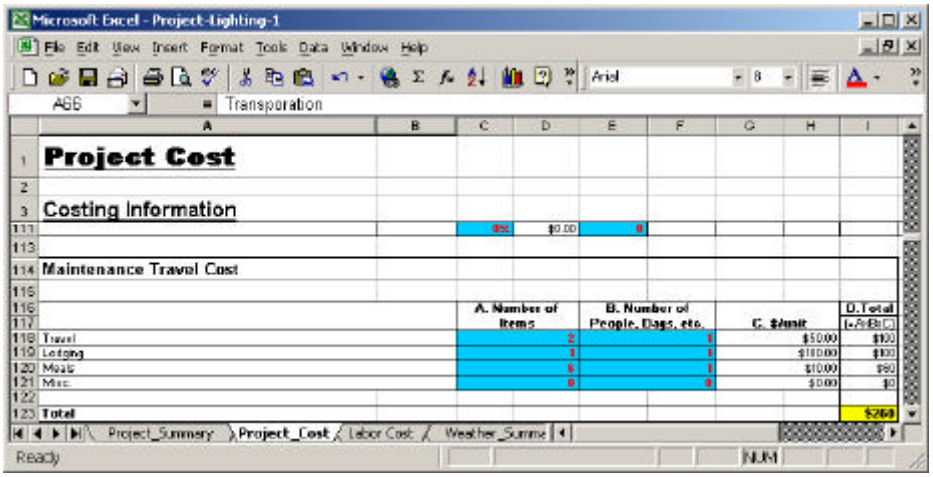

Figure 21: *Project.xls Workbook: Lighting Scenario #1: Maintenance Travel Costs*

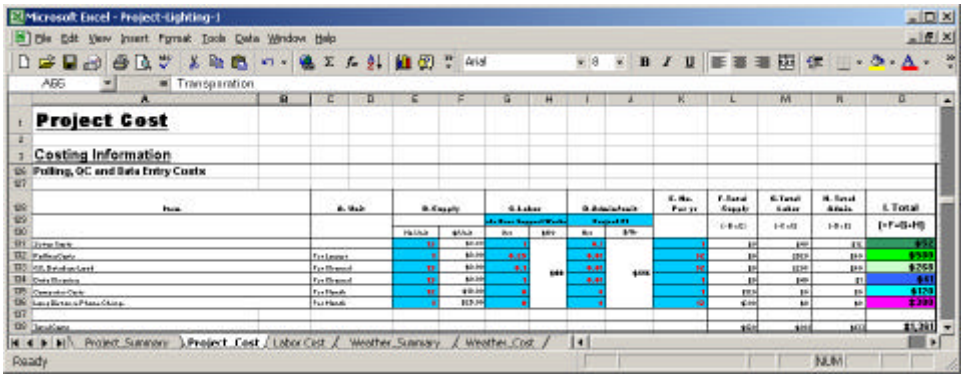

Figure 22: *Project.xls Workbook: Lighting Scenario #1: Polling, QC and Data Entry Costs*

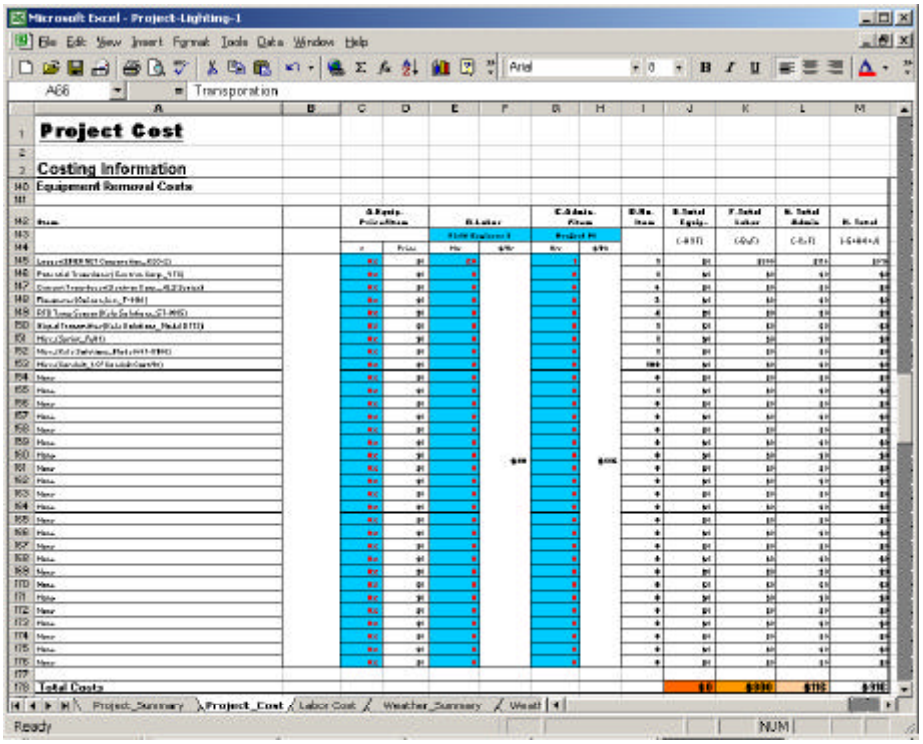

Figure 23: *Project.xls Workbook: Lighting Scenario #1: Equipment Removal Costs.*

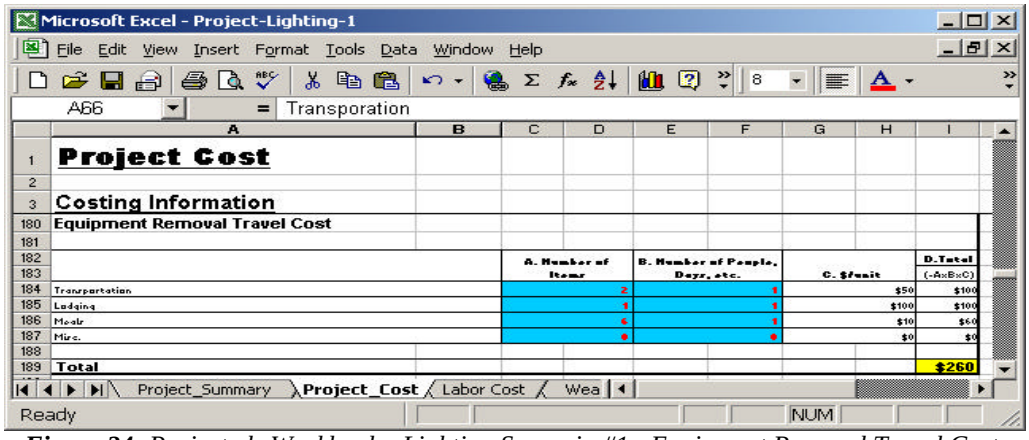

Figure 24: *Project.xls Workbook: Lighting Scenario #1: Equipment Removal Travel Cost.*

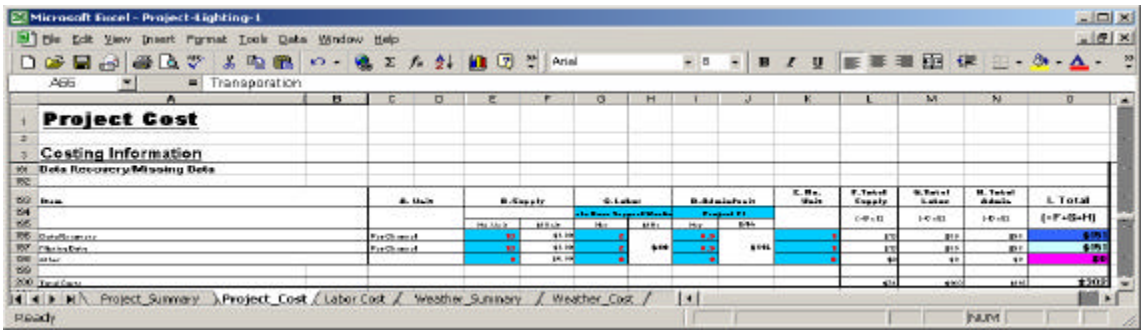

Figure 25: *Project.xls Workbook: Lighting Scenario #1: Data Recovery/Missing Data*

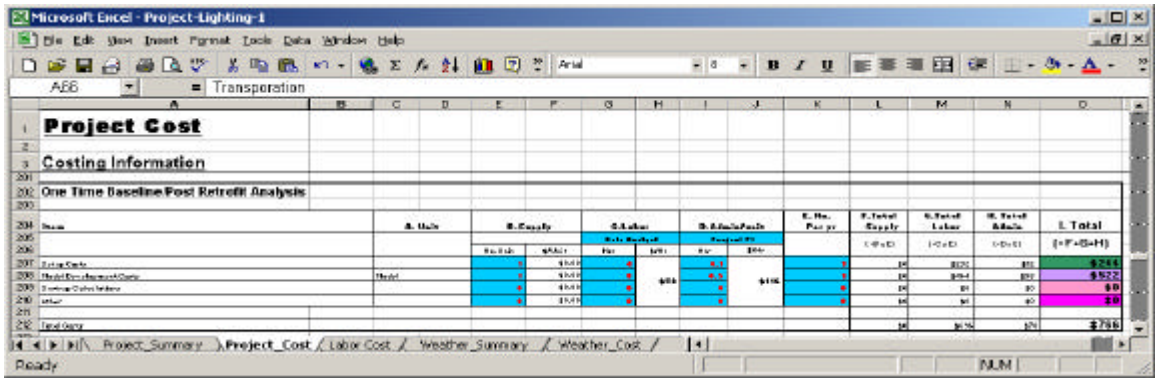

Figure 26: *Project.xls Workbook: Lighting Scenario #1: One Time Baseline/Post Retrofit Analysis*

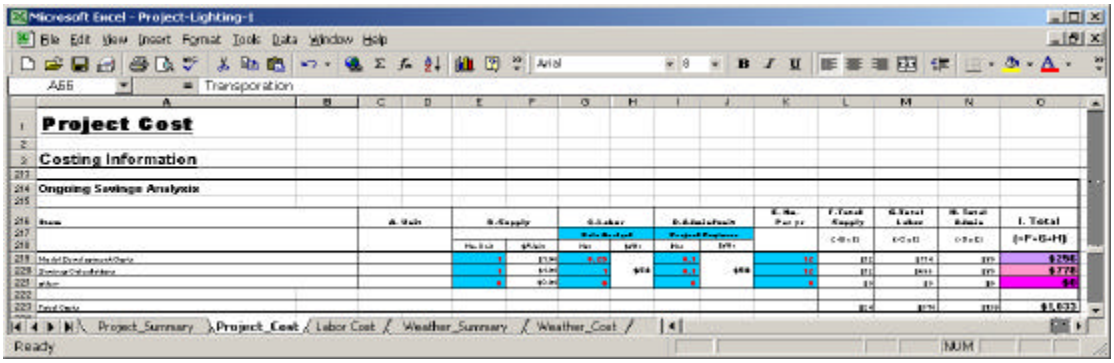

Figure 27: *Project.xls Workbook: Lighting Scenario #1: Ongoing Savings Analysis*

costs for the Project Engineer are estimated at $260. Travel costs for the subcontractors are assumed to be included in their hourly rates.

Lighting Scenario #1: Maintenance and Labor Costs per Year Maintenance and the associated labor costs for the job are shown in Figure 20. The material costs are tied to the installation costs and are calculated as a percent (%) of the price of the original item plus the labor associated with the device during the maintenance trip. In Scenario #1 the material costs are estimated to be significant costs for the logger, flow-meters, temperature sensors, and signal transducers, which total $398 during the maintenance period. Labor costs are estimated to be 8 hours for the field engineer and 4 hours for administration[4]. The travel costs associated with maintenance are shown in Figure 21, and include 2 days of transportation costs (i.e., rental car), one day of lodging for one person, and six meals for one person over two days, for a total cost of $260.

Lighting Scenario #1: Polling, QC and Data Entry Costs The polling, QC and Data Entry costs are shown in Figure 22. These costs cover the labor and material costs associated with setting up the database, and polling routines, the actual downloading of the data and the Quality Control (QC), including: a $52, one-time setup cost for 13-channels, $580 to cover 52 weeks of polling costs for one logger, $268 to cover 52 weeks of QC and database loading, a $41 one-time cost for data cleaning, and $120 for 12 months of computer maintenance, for a total cost of $1,361.

Lighting Scenario #1: Equipment Removal Costs The equipment removal costs are shown in Figure 23. In a similar fashion to the maintenance costs, the material costs are expressed as a percent (%) of the original equipment cost[5]. These costs are estimated to be 20 hours for the field engineer ($800), and 1 hour for administration costs, totaling $916 for the removal of the data logger, and the connected sensors, etc. For this example all costs have been assigned to the logger. In a similar fashion to the installation and maintenance costs, there are also travel costs associated with the equipment removal, estimated to be $260, as shown in Figure 24.

Lighting Scenario #1: Data Recovery/Missing Data Quite often during the course of a metering and verification project there will be periods of missing data or data that needs to be rescaled because of an equipment change-out that requires new scaling constants for the replacement equipment. In Figure 25 the data entry section of the spreadsheet for data recovery/missing data is shown for the Lighting Scenario #1. In the example shown, the data recovery costs are estimated to include $13 for supplies, and take 2 hours ($80) of staff time and ½ hour for administrative review. Similar costs are estimated for the missing data, totaling $302 for the combination of data recovery and missing data.

Lighting Scenario #1: One Time Baseline/Post Retrofit Analysis In most monitoring and verifications projects there will be a need to develop a baseline model, which is needed to project the pre-retrofit energy use into the post-retrofit period. Often, when there are missing data there is also a need to develop a post-retrofit model to fill-in missing data that might occur during the post-retrofit period. To account for the costs of this Figure 26 shows the cost information entry section of the spreadsheet for determining the costs associated with one-time baseline or post retrofit models. In the example shown these costs are estimated to be 4 hours of data analysis for the modeling setup costs ($232), and 0.1 hour for the administrative review ($12), with 8 hours effort for the model development ($522), and 0.5 hours of administrative review ($58), totaling $766. No supplies are estimated for this effort.

Lighting Scenario #1: Ongoing Savings Analysis After the baseline and/or post-retrofit models are created, the coefficients from the models will need to be applied to the data that are being collected in the post-retrofit period. To account for these costs Figure 27 shows the ongoing savings analysis costs. For this example, a small amount of model adjustment occurs each month, which amounts to ¼ hour each month ($174 for the year) and 0.1 hours of administrative review ($70). The savings calculations are estimated to take 1 hour each month ($696), and 0.1 hour of administrative review, which totals $1,033, including $24 in supply costs.

Lighting Scenario #1: Reporting In the Lighting Scenario #1 example, savings are reported each month, requiring an estimated 4 hours of setup costs ($232), and 0.1 in administration review ($12) as shown in Figure 28. The actual report generation then takes 1 hour each month ($696), and includes 0.25 hour of admin review ($348), totaling $1,301, which includes $13 in supplies.

[4] The total 12 hours are estimated for all the equipment maintenance. For illustration purposes only, the 8 hours for the field engineer were assigned to the flow-meter, and the 4 hours for the administration are assigned to the logger. In an actual installation, these costs would be assigned to the equipment needing repair.

[5] In this example, no material costs were assigned to the equipment removal.

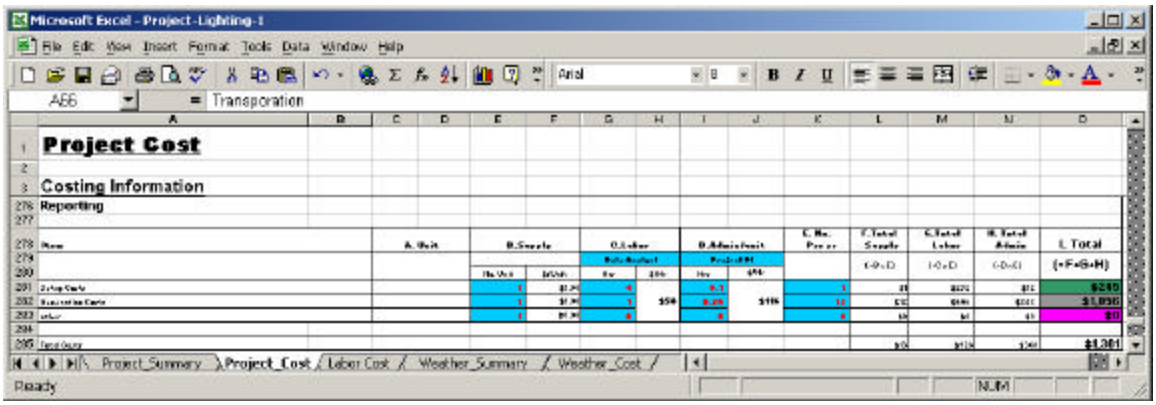

Figure 28: *Project.xls Workbook: Lighting Scenario #1: Reporting*

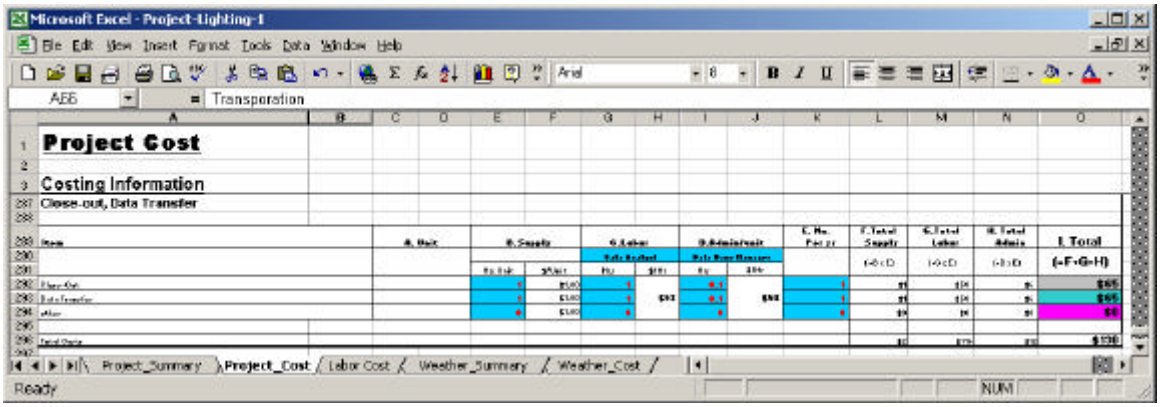

Figure 29: *Project.xls Workbook: Lighting Scenario #1: Closeout, Data Transfer*

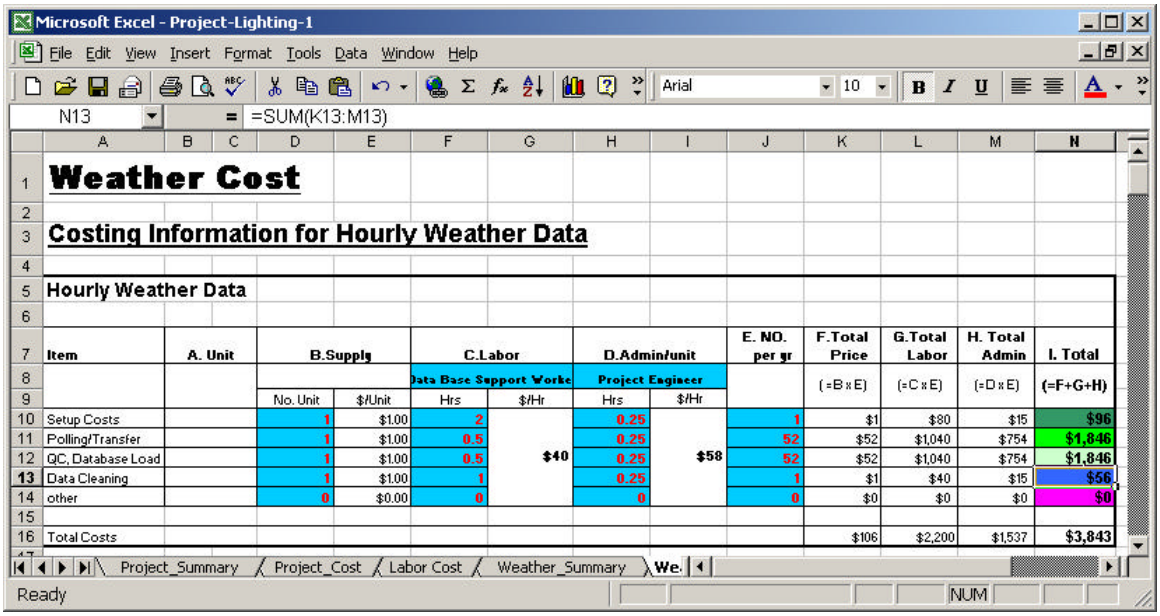

Figure 30: *Project.xls Workbook: Lighting Scenario #1: Hourly Weather Data*

Lighting Scenario #1: Closeout and Data Transfer At the end of the project, the database closeout and data transfer are estimated to take 1 hour of data analysis ($58), and 0.1 hour of administrative review ($6), with similar costs for the data transfer, totaling $130, which includes $2 in supplies as shown in Figure 29.

Lighting Scenario #1: Hourly Weather Data

The costing of the gathering of information from the National Weather Service (NWS) is shown in Figure 30, and includes 2 hours of effort for setup ($80), with ¼ hour for administrative review. Each week there is a ½ hour effort associated with the polling or transfer of the data, with ¼ for administrative review. Similar costs are estimated for the QC and database loading. At the end of the year, 1 hour is estimated for data cleaning, and an additional ¼ hour for administrative review, which totals $3,843 and includes $106 in supplies. The acquisition of hourly weather data from the NWS can require the purchase of data from a third party provider (not shown in Figure 30), which can cost in the range of $1,000 to $3,000 per year depending upon the number of channels.

Cost Summary

Project	1	Installation	$29,645
	2	Maintenance	$2,051
	3	Polling, QC and Data Entry	$1,061
	4	Equipment Removal	$1,176
	5	Data Recovery/Missing Data	$302
	6	One Time Baseline/Post Retrofit Analysis	$766
	7	Ongoing Savings Analysis	$1,033
	8	Creating the Basic simulation Input File	$0
	9	Calibrating Simulation	$0
	10	Use the Calibrated Simulation to Caculate Baseline	$0
	11	Use the Calibrated Simulation to Caculate Ongoing	$0
	12	Reporting	$1,301
	13	Close-out, Data Transfer	$130
Weather	1	Hourly Weather Data	$3,843
		Overheads & Profits 22%	$9,088
		Total Project Costs	**$50,395**

Figure 31: *Project.xls Workbook: Lighting Scenario #1: Cost Summary*

Lighting Scenario #1: Cost Summary Once the detailed cost information has been entered into the cost information spreadsheet, the user then transfers back to the Data Logger summary sheet to view the summary of all costs associated with the project. Figure 31 shows the ten costs categories associated with using long term M&V with data loggers, including a $29,645 one-time cost for equipment installation, a $2,051annual maintenance cost, polling, QC and data entry costs of $1,061, a one-time equipment removal cost of $1,176, a data recovery cost of $302, a one-time baseline model cost of $766, an ongoing savings analysis cost of $1,033, a reporting cost of $1,301, a project closeout cost of $130, and a cost associated with gathering the hourly weather data ($3,843), which totals $50,395, including $9,088 (22%) in overhead and profit costs. Costs for the calibrated simulation are shown as $0 since this project did not require the use of a simulation program. Had these costs been included, those sections of the spreadsheet pertaining to calibrated simulation would need to be completed for the calibrated simulation costs to show on the summary section of the spreadsheet.

SUMMARY

This paper has presented a general overview of the M&V costing process, various methods for monitoring and verifying savings, and a description of the M&V Costing Toolkit. In addition, an example of the use of the M&V Costing Toolkit has also been presented. The methods included in the toolkit include: a) monthly utility billing method, and b) short or long term monitoring with data loggers or EMCS. The example that has been provided illustrates the use of the M&V Costing Toolkit on a large lighting retrofit project. Additional information about the M&V Costing Toolkit, including copies of the distribution spreadsheets and thirteen example M&V scenarios can be found in Haberl et al. (2003b).

ACKNOWLEDGEMENTS

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