DEVELOPMENT OF A WEB-BASED, EMISSIONS REDUCTION CALCULATOR FOR STREET LIGHT AND TRAFFIC LIGHT RETROFITS

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ABSTRACT

Four areas, involving 16 counties, in Texas have been designated by the United States Environmental Protection Agency (EPA) as non-attainment areas because ozone levels exceed the National Ambient Air Quality Standard (NAAQS) maximum allowable limits. These areas face severe sanctions if attainment is not reached by 2007. Four additional areas in the state are also approaching national ozone limits (i.e., affected areas).

In 2001, the Texas State Legislature formulated and passed the Texas Emissions Reduction Plan (TERP), to reduce ozone levels by encouraging the reduction of emissions of NOx by sources that are currently not regulated by the state. Ozone results from photochemical reactions between oxides of nitrogen (NOx) and volatile organic compounds (VOCs) in the presence of sunlight. An important part of this legislation is the State's energy efficiency program, which includes reductions in energy use and demand that are associated with the adoption of the 2000 International Energy Conservation Code (IECC 2000), including the 2001 Supplement (IECC 2001) which represents one of the first times that the EPA is considering State Implementation Plan (SIP) credits from energy conservation and renewable energy– an important new development for building efficiency professionals, since this could pave the way for documented procedures for financial reimbursement for building energy conservation from the state's emissions reductions funding.

This paper presents the procedures that have been developed and used to calculate the electricity savings from street and traffic lighting retrofits, which includes the use of the ASHRAE Inverse Model Toolkit (IMT) for weather normalization, a peak-extractor for calculating peak-day electricity savings, and the use of the EPA's Emissions and Generations Resource Integrated Database (eGRID) for calculating NOx emissions reductions for the electric utility provide associated with the user.

INTRODUCTION

In 2001, the Texas State Legislature formulated and passed Senate Bill 5 to further reduce ozone levels by encouraging the reduction of emissions of NOx by sources that are currently not regulated by the state, including area sources (e.g., residential emissions), on-road mobile sources (e.g., all types of motor vehicles), and non-road mobile sources (e.g., aircraft, locomotives, etc.)[1]. An important part of this legislation is the evaluation of the State's new energy efficiency programs, which includes reductions in energy use and demand that are associated with specific utility-based energy conservation measures, and implementation of the International Energy Conservation Code (IECC), published in 2000 as amended by the 2001 Supplement (IECC 2000; 2001). In 2001 thirty-eight counties in Texas were designated by the EPA as either non-attainment or affected areas[2]. In 2003, three additional counties were classified as affected counties[3], bringing the total to forty-one counties (sixteen non-attainment and twenty-five affected counties) out of the 254 counties in Texas.

In many communities, street lights and traffic lights represent one of the largest categories of electricity used by a city. By retrofitting the street lights with energy efficient lamps such as high pressure sodium and metal halide and traffic lights with light-emitting diode (LED) traffic signals, a city

[1] In the 2003 and 2005 Texas State legislative sessions, the emissions reductions legislation in Senate Bill 5 was modified by House bill 3235, and House bill 1365 (2003), and House bill 2129 and 965. In general, this new legislation strengthens the previous legislation, and did not reduce the stringency of the building code or the reporting of the emissions reductions.

[2] The sixteen counties designated as non-attainment counties include: Brazoria, Chambers, Collin, Dallas, Denton, El Paso, Fort Bend, Hardin, Harris, Jefferson, Galveston, Liberty, Montgomery, Orange, Tarrant, and Waller counties. The twenty-two counties designated as affected counties include: Bastrop, Bexar, Caldwell, Comal, Ellis, Gregg, Guadalupe, Harrison, Hays, Johnson, Kaufman, Nueces, Parker, Rockwall, Rusk, San Patricio, Smith, Travis, Upshur, Victoria, Williamson, and Wilson County.

[3] These counties are Henderson, Hood and Hunt counties in the Dallas – Fort Worth area.

cannot only save energy and money, but can also reduce greenhouse gas emissions and reduce light pollution.

However, many municipalities are not aware of the available choices in technology and energy and emissions savings for street light and traffic retrofits, nor are they aware of procedures for calculating the length of day, or for calculating the emissions from electricity savings, which is often required by environmental decision makers. Therefore, this paper presents the procedures and tools that have been developed and used to calculate the electricity savings from street and traffic lighting retrofits, which includes the use of the ASHRAE Inverse Model Toolkit (IMT) for weather normalization, a peak-extractor for calculating peak-day electricity savings from monthly utility bills, and the use of the EPA's Emissions and Generations Resource Integrated Database (eGRID) for calculating NOx emissions reductions for the electric utility provide associated with the user.

METHODOLOGY

The methodology that was developed for street lights and traffic lights includes two distinct paths for calculating energy savings, one path for users that have pre-retrofit and post-retrofit utility bills (i.e., the utility billing mode), and a second path for users that want to calculate the lamp-by-lamp savings from a group of lamps they intend on replacing (i.e., the design mode).

In the utility bill analysis mode, a linear regression is performed on the pre-retrofit and post-retrofit monthly utility data for street lights and traffic lights using the ASHRAE Inverse Model Toolkit (Haberl et al. 2003; Kissock et al. 2003). ASHRAE's IMT is a FORTRAN 90 application for calculating linear, change-point linear, variable-based degree-day, multi-linear, and combined regression models. The development of the IMT was sponsored by ASHRAE research project 1050-RP under the guidance of Technical Committee 4.7 - Energy Calculations.

The coefficients from this analysis are then used to normalize the data to the 1999 baseline year using the weather data obtained from National Oceanic & Atmospheric Administration (NOAA)'s National Weather Service (NWS) from a nearby weather station (NOAA 1993). The normalized annual energy savings are then calculated for the 1999 baseline year. Using these same coefficients, the peak daily consumption is extracted, which is then used to calculate the peak savings during the Ozone Episode Peak day for 1999[4].

In the design mode the energy and emissions savings are calculated based on the specific information the user provides about the lamp type, lamp code, wattage, and number of lamps for both pre-retrofit and post-retrofit lamps. The annual energy savings are then calculated for the 1999 baseline year, and the peak daily consumption is extracted, which is then used to calculate the peak savings during the Ozone Episode Peak day for 1999.

Street Lighting Analysis: Utility Bill Mode

In the utility bill analysis mode for street lights, first, the monthly energy consumption bill is divided by the number of days in each month to obtain the average daily energy consumption for each billing period (i.e., kWh/day). Second, the average daily temperature data for each billing period is calculated from the nearest NWS station daily temperature data. The data set containing the average daily temperature and average daily energy consumption for each month is then analyzed with the IMT to determine a weather normalized energy consumption as shown in Figure 1, which also shows the coefficients for the regression model for this street light example. The daily energy consumption predicted by applying the 1999 daily average temperature data from NOAA into the developed two-parameter regression model.

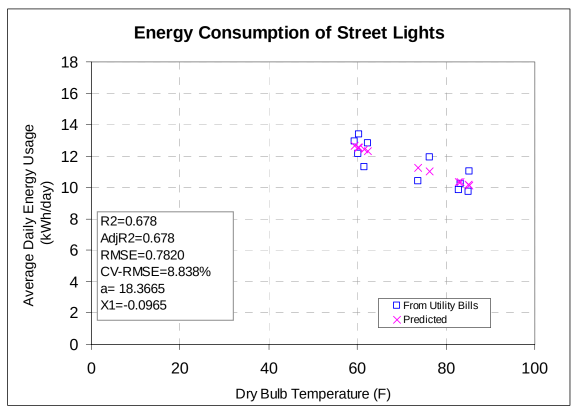

Figure 1. Linear Regression Model for Street Lights

Traffic Light Analysis: Utility Bill Mode

The utility bill analysis for traffic lights follows the same procedure as that of street lights. For traffic light utility meters a 1-parameter regression model (i.e., mean model) was chosen, based on an analysis of more than 20 traffic light utility meters from the

[4] These same coefficients can be used to calculate the average daily savings during an Ozone Episode Season, which commonly runs from July 15th to September 15th for a given year.

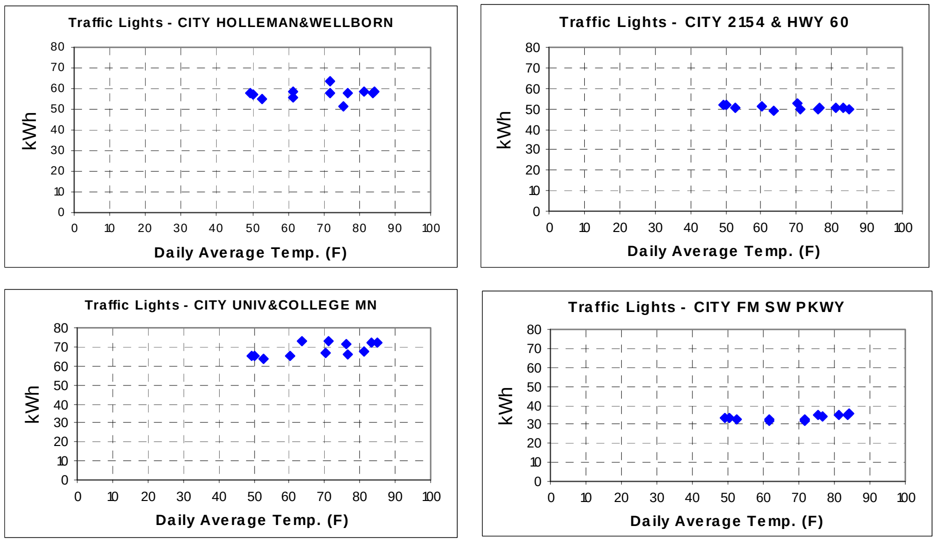

Figure 2. Average Daily Energy Consumption of Traffic Lights

City of College Station, Texas. Figure 2 shows four of these traffic light meters that were analyzed, which clearly show a flat consumption profile when plotted against ambient temperature.

<u>Street Lighting Analysis: Design Mode</u>

Table 1 shows an example of the typical input information and calculation for a street lighting analysis in the design mode. The text in Italics is the input from the user. The lumens/lamp information is provided by the web-based emissions calculator to help the user select the post-retrofit lamps. Once this information has been provided by the user, the calculation of the annual, peak-day and average Ozone Season Day period (OSD) energy savings associated with retrofitting the street lights is completed and the results posted as shown at the bottom of the table. In the example shown, 100 mercury vapor lamps (400W) and 50 mercury vapor lamps (175W), are replaced with 100 high pressure sodium lamps (200W), and 50 high pressure sodium lamps (100W), which yields 108,679 kWh/year savings, 273 kWh/day on the Ozone Episode Day, and 285 kWh/day for the Ozone Season Day (OSD) period. The following equations are used to calculate the electricity consumption and demand savings of street lights retrofits:

Total Demand Savings [kW] = Demand for Pre-retrofit Lamp [kW/Lamp] x Ballast Factor of Pre-retrofit Lamp x Number of Pre-retrofit Lamps [Lamps] – Demand for Post-retrofit Lamp [kW/Lamp] x Ballast Factor of Post-retrofit Lamp x Number of Post-retrofit Lamps [Lamps]

Total Electricity Savings [kWh/yr or kWh/day] = Demand Savings [kW] x Operating Hours [hrs/yr or hrs/day]

A key part of the design-mode calculation for street lights is the determination of the hours of operation for the street lights, which impact the daily energy use during the ozone season. To accomplish this, an equation was developed for calculating the hours between sunset and sunrise[5]. This equation is based on the latitude of the city or county[6]. The calculation then proceeds by calculating the earth's declination about its axis, which depends on the day-of-the-year[7], as follows:

DECLINATION= -23.45 x COS (2π x (10.5 + DOY) /365.25

Next, the hour of the sunrise or sunset (expressed as degrees away from solar noon) is then calculated, using the following expression:

[5] The equation used for calculation of the sunrise to sunset time was from the Solar Engineering textbook by Duffie and Beckman (1991).

[6] This list is contained in a database inside of the emissions calculator, that allows the user to select a county or city in Texas, and then assigns latitude according to the selection.

[7] This expression requires the use of radians for all values inside the parenthesis.

Table 1. Street Lights Design Mode Calculation

Pre-Retrofit:						
Project No.	Type of Lamp	Lamp Code	Watt/Lamp	Approximate Lumens/Lamp	No.of Lamps	
1	*Mercury Vapor*	*MV-400*	*400*	13400~19100	*100*	
2	*Mercury Vapor*	*MV-175*	*175*	6800~7600	*50*	
Post-Retrofit:						
Project No.	Type of Lamp	Lamp Code	Watt/Lamp	Approximate Lumens/Lamp	No.of Lamps	
1	*High Pressure Sodium*	*HPS-200*	*200*	19800	*100*	
2	*High Pressure Sodium*	*HPS-100*	*100*	8000	*50*	
Calculation:						
Project No.	Total Pre-retrofit kW	Total Post-retrofit kW	Sum of kW savings	Lighting Energy Savings (kWh/yr)	Peak Day (Aug 19 1999) Savings (kWh/day)	Avg OSD Savings (kWh/day)
1	46.0	25.0	21.0	91,980	231	241
2	10.1	6.3	3.8	16,699	42	44
Total	56.1	31.3	24.8	108,679	273	285

hsr = arcos (-TAN(LATITUDE) x TAN (DECLINATION))

Finally, the hours of daylight are calculated by multiplying *hsr* by the fraction 2/15, which doubles the number and then divides by 15 degrees per hour. The required hours of nighttime are then calculated by subtracting the hours of daylight from 24 hours in a day. In this way the calculator estimates the hours each day the streetlights operate[8] for given latitude and given day-of-the-year. For example, in Travis County of Texas, for August 19, 1999, which is the peak ozone episode day for 1999, there are 11.01 hours in the day. The calculated average daily operating hours in Ozone Season Day period (August 18 through September 20) is 11.47 hours/day. The average daily average hours of streetlight operation for the whole year is 12 hours per day.

Traffic Light Analysis: Design Mode

Table 2 shows an example of the input information and calculation for traffic light design mode. For each project the user enters the lamp type, lamp code, wattage per lamp, operating hours and the number of lamps for the pre-retrofit and post-retrofit period. To simplify the input for the operating hours[9] the emissions calculator provides a default value for each lamp type that is based on studies of signal cycling at typical automobile traffic intersections in the Dallas-Ft. Worth area[10]. Once the user provides information for a project the emissions calculator calculates the annual, peak-day, and average Ozone Season Day period (OSD) energy savings associated with retrofitting each of the existing incandescent type traffic signals with energy efficient lamps (i.e., LED type lamps). Results for an example calculation are provided in the bottom right of Table 2.

In the example shown in Table 2, which shows the incandescent lamps in an intersection (135W each for 10 green ball, 10 yellow ball, 10 red ball, 2 green arrow and 2 yellow arrow, and 69W each for 4 pedestrian lamp) that are replaced with the same number of LED type lamps, yielding 11,721 kWh/year savings, 32.11 kWh/day on the Ozone Episode Day, and 32.11 kWh/day for the Ozone Season Day (OSD) period. The following equations are used to calculate the electricity savings and demand savings for each type of lamps:

Peak Demand Savings [kW] = (Pre-retrofit Demand [kW/Lamp] x Number of Pre-retrofit Lamps [Lamps] – Post-retrofit Demand [kW/Lamp] x Number of Post-retrofit Lamps [Lamps]) x Coincidence Factor[11]

Total Electricity Savings [kWh/yr or kWh/day] = (Total Pre-retrofit Demand [kW] x Number of Pre-retrofit Lamps [Lamps] – Total Post-retrofit Demand [kW] x Number of Post-retrofit Lamps [Lamps]) x Operating Hours [hrs/yr or hrs/day]

[8] This methodology assumes that the street lights are operated on a photocell, which is the most common mode of operation for streetlights.

[9] This can be a complex input value that is dependent on the configuration and operation of the traffic signals at each site, traffic flow, maintenance interruptions, and the types and numbers of traffic signals.

[10] Values represent the default values contained in the Texas Public Utility Commission's Commercial and Industrial Standard Offer Program.

[11] The coincidence factor is the ratio of coincident demand to maximum demand. This will always be between 0 and 1 because coincident demand should always be less than or equal to maximum demand. The coincidence factor listed in the Table 2 represent the default values contained in the Texas Public Utility Commission's Commercial and Industrial Standard Offer Program.

Table 2. Traffic Lights Design Mode Calculation

Pre-Retrofit:							**Coincidence Factor:**	
Usage Area Type	Type of Lamp	Lamp Code	Watt/Lamp	Annual Operating Hours	No. of Lamps		Usage Area Type	Coincidence Factor
Green Ball	Incandescent	INC12GB	135	3675	10		Green Ball	0.42
Green Arrow	Incandescent	INC12GA	135	875	2		Green Arrow	0.10
Red Ball	Incandescent	INC12RB	135	4820	10		Red Ball	0.55
Yellow Arrow	Incandescent	INC12YA	135	265	2		Yellow Arrow	0.03
Yellow Ball	Incandescent	INC12YB	135	265	10		Yellow Ball	0.03
Pedestrian	Incandescent	INC12PED	69	4380	4		Pedestrian	0.50
Post-Retrofit:								
Usage Area Type	Type of Lamp	Lamp Code	Watt/Lamp	Annual Operating Hours	No.of Lamps			
Green Ball	LED	LED12GB	17	3675	10			
Green Arrow	LED	LED12GA	5	875	2			
Red Ball	LED	LED12RB	15	4820	10			
Yellow Arrow	LED	LED12YA	9	265	2			
Yellow Ball	LED	LED12YB	32	265	10			
Pedestrian	LED	LED12PED	10	4380	4			
Calculation:								
Usage Area Type	Total Pre-retrofit kW	Total Post-retrofit kW	Sum of kW savings	Lighting Peak Demand Savings (kW)	Lighting Energy Savings (kWh/yr)		Peak Day (Aug 19 1999) Savings (kWh/day)	Avg OSD Savings (kWh/day)
Green Ball	1.35	0.17	1.18	0.50	4,337		11.88	11.88
Green Arrow	0.27	0.01	0.26	0.03	228		0.62	0.62
Red Ball	1.35	0.15	1.2	0.66	5,784		15.85	15.85
Yellow Arrow	0.27	0.018	0.252	0.01	67		0.18	0.18
Yellow Ball	1.35	0.32	1.03	0.03	273		0.75	0.75
Pedestrian	0.276	0.04	0.236	0.12	1,034		2.83	2.83
Total	4.866	0.708	4.158	1.34	11,721		32.11	32.11

Table 3: 1999 eGRID Matrix for Selected Utilities in ERCOT.

Area	County	American Electric Power - West (ERCOT) /PCA	NOx Reductions (lbs)	Austin Energy/PCA	NOx Reductions (lbs)	Brownsville Public Utils Board/PCA	NOx Reductions (lbs/year)	Lower Colorado River Auhotrity /PCA	NOx Reductions (lbs)	Reliant Energy HL&P/PCA	NOx Reductions (lbs)	San Antonio Public Service Bd/PCA	NOx Reductions (lbs)	South Texas Electric Coop INC/PCA	NOx Reductions (lbs)	Texas Municipal Power Pool/PCA	NOx Reductions (lbs)	Texas-New Mexico Power Co/PCA	NOx Reductions (lbs)	TXU Electric/PCA	NOx Reductions (lbs)	Total Nox Reductions (lbs)	Total Nox Reductions (Tons)
Austin-San Antonio Area	BASTROP	0.012215415	0.0000	0.466390101	0.0000	0.009021629	0.0000	0.817318002	0.0000	0.007554281	0.0000	0.021706586	0.0000	0.006483441	0.0000	0.011331421	0.0000	0.002453005	0.0000	0.011206033	1.2179	1.22	0.00
	BEXAR	0.055151593	0.0000	0.085459434	0.0000	0.04073191	0.0000	0.149645941	0.0000	0.001884684	0.0000	1.887540372	0.0000	0.077368362	0.0000	0.007707389	0.0000	0.000857605	0.0000	0.004132794	0.4491	0.45	0.00
	HAYS	9.07402E-06	0.0000	0.00034645	0.0000	6.70157E-06	0.0000	0.000607132	0.0000	5.61158E-06	0.0000	1.61244E-05	0.0000	4.81612E-06	0.0000	8.41736E-06	0.0000	1.82218E-06	0.0000	8.32422E-06	0.0009	0.00	0.00
	TRAVIS	0.000828265	0.0000	0.486562876	0.0000	0.00061171	0.0000	0.055118588	0.0000	0.000543576	0.0000	0.001471564	0.0000	0.000440334	0.0000	0.000766124	0.0000	0.000167806	0.0000	0.000758965	0.0825	0.08	0.00
	FAYETTE	0.001485019	0.0000	0.056698717	0.0000	0.001096753	0.0000	0.099360775	0.0000	0.000918369	0.0000	0.002638854	0.0000	0.000788187	0.0000	0.001377553	0.0000	0.00029821	0.0000	0.00136231	0.1481	0.15	0.00
	LLANO	0.007176248	0.0000	0.273992417	0.0000	0.005299979	0.0000	0.480153706	0.0000	0.004437949	0.0000	0.012752072	0.0000	0.003808858	0.0000	0.006656924	0.0000	0.001441079	0.0000	0.006583261	0.7155	0.72	0.00
	CALDWELL		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000	0.00	0.00
	COMAL		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000	0.00	0.00
	GUADALUPE		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000	0.00	0.00
	WILLIAMSON		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000	0.00	0.00
	WILSON		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000	0.00	0.00
Dallas-Fort Worth Area	ANGELINA	0.000494588	0.0000	0.00049881	0.0000	0.000365275	0.0000	0.000825851	0.0000	0.000216196	0.0000	7.12657E-05	0.0000	0.000704579	0.0000	0.002448715	0.0000	0.000837839	0.0000	0.004499471	0.4890	0.49	0.00
	COLLIN	0.007169953	0.0000	0.012538407	0.0000	0.00529533	0.0000	0.020113269	0.0000	0.008218606	0.0000	0.00238641	0.0000	0.062210088	0.0000	0.248405779	0.0000	0.003864706	0.0000	0.018702036	2.0325	2.03	0.00
	DALLAS	0.049181758	0.0000	0.050069935	0.0000	0.036322921	0.0000	0.08284103	0.0000	0.021947182	0.0000	0.007206079	0.0000	0.074651961	0.0000	0.262289147	0.0000	0.082583806	0.0000	0.443320905	48.1797	48.18	0.02
	DENTON	0.004478418	0.0000	0.008248434	0.0000	0.003307512	0.0000	0.013202327	0.0000	0.005532748	0.0000	0.00159686	0.0000	0.042940735	0.0000	0.171878188	0.0000	0.00176352	0.0000	0.008027328	0.8724	0.87	0.00
	JOHNSON	4.90169E-05	0.0000	9.02803E-05	0.0000	3.62012E-05	0.0000	0.000144501	0.0000	6.05567E-05	0.0000	1.74779E-05	0.0000	0.000469992	0.0000	0.001881231	0.0000	1.9302E-05	0.0000	8.78602E-05	0.0095	0.01	0.00
	PARKER	0.000692972	0.0000	0.001276329	0.0000	0.000511791	0.0000	0.002042874	0.0000	0.000856115	0.0000	0.000247092	0.0000	0.006644473	0.0000	0.026595727	0.0000	0.00027288	0.0000	0.001242116	0.1350	0.13	0.00
	CHEROKEE	0.010981286	0.0000	0.011075021	0.0000	0.00811017	0.0000	0.018336302	0.0000	0.004800172	0.0000	0.001582305	0.0000	0.015643707	0.0000	0.054368586	0.0000	0.018602464	0.0000	0.099901318	10.8572	10.86	0.01
	COKE	0.021538872	0.0000	0.000431296	0.0000	0.015907417	0.0000	0.000720531	0.0000	0.000159092	0.0000	0.000153973	0.0000	0.004428762	0.0000	0.000685852	0.0000	0.000152329	0.0000	0.000784005	0.0852	0.09	0.00
	COLEMAN	0.007243808	0.0000	0.00014505	0.0000	0.005349875	0.0000	0.000242324	0.0000	5.35048E-05	0.0000	5.1783E-05	0.0000	0.001489451	0.0000	0.000230661	0.0000	5.12301E-05	0.0000	0.000263671	0.0287	0.03	0.00
	FANNIN	0.020337335	0.0000	0.020510931	0.0000	0.015020028	0.0000	0.033958817	0.0000	0.008889916	0.0000	0.002930428	0.0000	0.028972134	0.0000	0.100690582	0.0000	0.03445175	0.0000	0.185017169	20.1075	20.11	0.01
	FRIO	0.047394602	0.0000	0.004808715	0.0000	0.035003026	0.0000	0.007841019	0.0000	0.002603666	0.0000	0.00120542	0.0000	1.140454367	0.0000	0.070348792	0.0000	0.00103497	0.0000	0.00489394	0.5319	0.53	0.00
	HARDEMAN	0.007011794	0.0000	0.000140405	0.0000	0.005178522	0.0000	0.000234563	0.0000	5.17911E-05	0.0000	5.01245E-05	0.0000	0.001441745	0.0000	0.000223273	0.0000	4.95893E-05	0.0000	0.000255226	0.0277	0.03	0.00
	HASKELL	0.195882927	0.0000	0.003922373	0.0000	0.144668275	0.0000	0.006552794	0.0000	0.001446847	0.0000	0.001400287	0.0000	0.040276892	0.0000	0.00623741	0.0000	0.001385336	0.0000	0.007130046	0.7749	0.77	0.00
	HENDERSON	0.003151289	0.0000	0.003178188	0.0000	0.002327367	0.0000	0.00526195	0.0000	0.001377501	0.0000	0.000454072	0.0000	0.004489259	0.0000	0.015602099	0.0000	0.005338331	0.0000	0.028668582	3.1157	3.12	0.00
	HOWARD	0.001294958	0.0000	0.001306011	0.0000	0.000956384	0.0000	0.002162291	0.0000	0.000566056	0.0000	0.000186592	0.0000	0.001844769	0.0000	0.006411364	0.0000	0.002193678	0.0000	0.011780769	1.2803	1.28	0.00
	HOOD	0.029930315	0.0000	0.030185796	0.0000	0.022104872	0.0000	0.049976957	0.0000	0.013083228	0.0000	0.00431269	0.0000	0.04263809	0.0000	0.148185635	0.0000	0.050702403	0.0000	0.272288493	29.5920	29.59	0.01
	JONES	0.093145673	0.0000	0.001865155	0.0000	0.068792232	0.0000	0.003115966	0.0000	0.000688001	0.0000	0.00066586	0.0000	0.019152349	0.0000	0.002965995	0.0000	0.000658751	0.0000	0.003390459	0.3685	0.37	0.00
	LAMAR	0.001155059	0.0000	0.001164918	0.0000	0.000853063	0.0000	0.001928691	0.0000	0.000504903	0.0000	0.000166434	0.0000	0.001645472	0.0000	0.005718722	0.0000	0.001956687	0.0000	0.010508051	1.1420	1.14	0.00
	LIMESTONE	0.012894146	0.0000	0.015971348	0.0000	0.009522902	0.0000	0.005377657	0.0000	0.097727305	0.0000	0.022202385	0.0000	0.008920477	0.0000	0.005660292	0.0000	0.006824779	0.0000	0.009372537	1.0186	1.02	0.00
	MCLENNAN	0.05325577	0.0000	0.053710353	0.0000	0.039331761	0.0000	0.08892527	0.0000	0.023279319	0.0000	0.007673679	0.0000	0.075867036	0.0000	0.263670465	0.0000	0.090216073	0.0000	0.484489832	52.6539	52.65	0.03
	MITCHELL	0.04519919	0.0000	0.045585003	0.0000	0.033381617	0.0000	0.075472576	0.0000	0.019757603	0.0000	0.006512798	0.0000	0.064389803	0.0000	0.223782162	0.0000	0.076568105	0.0000	0.411195779	44.6883	44.69	0.02
	NOLAN	0.001025023	0.0000	0.001033772	0.0000	0.000757025	0.0000	0.00171156	0.0000	0.000448061	0.0000	0.000147697	0.0000	0.001460226	0.0000	0.005074911	0.0000	0.001736404	0.0000	0.00932506	1.0134	1.01	0.00
	PALO PINTO	0.010167179	0.0000	0.018726099	0.0000	0.007508915	0.0000	0.029972731	0.0000	0.012560783	0.0000	0.00362529	0.0000	0.097486682	0.0000	0.390208375	0.0000	0.004003651	0.0000	0.018224131	1.9806	1.98	0.00
	RED RIVER	0.00311042	0.0000	0.00313697	0.0000	0.002297184	0.0000	0.005193709	0.0000	0.001359636	0.0000	0.000448184	0.0000	0.004431038	0.0000	0.015399758	0.0000	0.005269099	0.0000	0.028296783	3.0753	3.08	0.00
	TAYLOR	0.001885023	0.0000	3.77458E-05	0.0000	0.001392174	0.0000	6.30589E-05	0.0000	1.39233E-05	0.0000	1.34753E-05	0.0000	0.000387593	0.0000	6.00239E-05	0.0000	1.33314E-05	0.0000	6.86139E-05	0.0075	0.01	0.00
	TITUS	0.007854045	0.0000	0.007921086	0.0000	0.005800562	0.0000	0.013114505	0.0000	0.003433183	0.0000	0.001131697	0.0000	0.011188705	0.0000	0.038885545	0.0000	0.01330487	0.0000	0.071451504	7.7653	7.77	0.00
	TOM GREEN	0.00089529	0.0000	1.79273E-05	0.0000	0.000661211	0.0000	2.99498E-05	0.0000	6.61287E-06	0.0000	6.40006E-06	0.0000	0.000184087	0.0000	2.85083E-05	0.0000	6.33172E-06	0.0000	3.25881E-05	0.0035	0.00	0.00
	YOUNG	0.019487528	0.0000	0.019653871	0.0000	0.014392408	0.0000	0.03253983	0.0000	0.008518446	0.0000	0.002807978	0.0000	0.027761517	0.0000	0.096483171	0.0000	0.033012165	0.0000	0.177286126	19.2673	19.27	0.01
	TARRANT	0.029723615	0.0000	0.029977331	0.0000	0.021952215	0.0000	0.049631813	0.0000	0.012992874	0.0000	0.004282906	0.0000	0.042343628	0.0000	0.147162256	0.0000	0.050352249	0.0000	0.270408052	29.3877	29.39	0.01
	WICHITA	0.000471631	0.0000	0.000475657	0.0000	0.00034832	0.0000	0.000787519	0.0000	0.000206161	0.0000	6.79578E-05	0.0000	0.000671875	0.0000	0.002335055	0.0000	0.00079895	0.0000	0.004290622	0.4663	0.47	0.00
	WILBARGER	0.074052599	0.0000	0.001482834	0.0000	0.054691146	0.0000	0.002477252	0.0000	0.000546974	0.0000	0.000529372	0.0000	0.015226485	0.0000	0.002358023	0.0000	0.000523719	0.0000	0.00269548	0.2929	0.29	0.00
	WISE	1.54736E-05	0.0000	2.84996E-05	0.0000	1.1428E-05	0.0000	4.56161E-05	0.0000	1.91165E-05	0.0000	5.5174E-06	0.0000	0.000148367	0.0000	0.000593866	0.0000	6.09324E-06	0.0000	2.77357E-05	0.0030	0.00	0.00
	ELLIS		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000	0.00	0.00
	HUNT		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000	0.00	0.00
	KAUFMAN		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000	0.00	0.00
	ROCKWALL		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000	0.00	0.00
	RUSK		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000	0.00	0.00
Houston - Galveston Area	BRAZORIA	0.011584147	0.0000	0.014348717	0.0000	0.008555409	0.0000	0.004831306	0.0000	0.087798562	0.0000	0.019946702	0.0000	0.008014188	0.0000	0.005085227	0.0000	0.006131406	0.0000	0.008420321	0.9151	0.92	0.00
	BRAZOS	0.002939669	0.0000	0.005414338	0.0000	0.002171077	0.0000	0.008666113	0.0000	0.00363174	0.0000	0.001048192	0.0000	0.02818664	0.0000	0.112822211	0.0000	0.001157589	0.0000	0.005269202	0.5727	0.57	0.00
	GRIMES	0.000352817	0.0000	0.000649825	0.0000	0.000260571	0.0000	0.0010401	0.0000	0.000435879	0.0000	0.000125803	0.0000	0.003382938	0.0000	0.013540833	0.0000	0.000138933	0.0000	0.000632405	0.0687	0.07	0.00
	WHARTON	0.000859628	0.0000	0.00106478	0.0000	0.000634874	0.0000	0.000358518	0.0000	0.006515295	0.0000	0.001480191	0.0000	0.000594711	0.0000	0.000377361	0.0000	0.000454995	0.0000	0.000624849	0.0679	0.07	0.00
	CHAMBERS	0.026549037	0.0000	0.032884994	0.0000	0.019607647	0.0000	0.011072591	0.0000	0.201220447	0.0000	0.045714693	0.0000	0.018367255	0.0000	0.011654537	0.0000	0.014052215	0.0000	0.019298047	2.0973	2.10	0.00
	FORT BEND	0.101391373	0.0000	0.125588538	0.0000	0.074882049	0.0000	0.042286475	0.0000	0.768465451	0.0000	0.17458545	0.0000	0.070144962	0.0000	0.044508942	0.0000	0.053665727	0.0000	0.07369968	8.0096	8.01	0.00
	GALVESTON	0.045304684	0.0000	0.055916435	0.0000	0.033459529	0.0000	0.019985056	0.0000	0.337157707	0.0000	0.07663686	0.0000	0.031980551	0.0000	0.023814611	0.0000	0.510829164	0.0000	0.040215829	4.3706	4.37	0.00
	ROBERTSON	0.003269549	0.0000	0.003701179	0.0000	0.002414708	0.0000	0.003261613	0.0000	0.013959492	0.0000	0.003239267	0.0000	0.00337216	0.0000	0.008271533	0.0000	0.849322645	0.0000	0.015058902	1.6366	1.64	0.00
	HARRIS	0.069468248	0.0000	0.086046924	0.0000	0.051305398	0.0000	0.028972557	0.0000	0.526513718	0.0000	0.119617134	0.0000	0.048059785	0.0000	0.030495279	0.0000	0.036769046	0.0000	0.050495299	5.4878	5.49	0.00
	HARDIN		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000	0.00	0.00
	JEFFERSON		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000	0.00	0.00
	LIBERTY		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000	0.00	0.00
	MONTGOMERY		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000	0.00	0.00
	ORANGE		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000	0.00	0.00
	WALLER		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000	0.00	0.00
El Paso Area	EL PASO		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000	0.00	0.00
Etc.	ANDREWS	6.67623E-05	0.0000	6.73322E-05	0.0000	4.93069E-05	0.0000	0.000111478	0.0000	2.91833E-05	0.0000	9.61985E-06	0.0000	9.51081E-05	0.0000	0.000330542	0.0000	0.000113096	0.0000	0.000607364	0.0660	0.07	0.00
	CROCKETT	0.075441526	0.0000	0.001510646	0.0000	0.05571693	0.0000	0.002523716	0.0000	0.00557233	0.0000	0.000539301	0.0000	0.015512072	0.0000	0.00240225	0.0000	0.000533542	0.0000	0.002746036	0.2984	0.30	0.00
	FREESTONE	0.025200214	0.0000	0.025415319	0.0000	0.018611481	0.0000	0.042078742	0.0000	0.011015592	0.0000	0.003631125	0.0000	0.035899688	0.0000	0.124766801	0.0000	0.04268954	0.0000	0.229256798	24.9154	24.92	0.01
	CALHOUN	0.169651094	0.0000	0.003397105	0.0000	0.125294896	0.0000	0.005675271	0.0000	0.001253092	0.0000	0.001212766	0.0000	0.034883177	0.0000	0.005402121	0.0000	0.001199817	0.0000	0.00617522	0.6711	0.67	0.00
	HIDALGO	0.125605549	0.0000	0.002515134	0.0000	0.092765297	0.0000	0.004201833	0.0000	0.000927759	0.0000	0.000897903	0.0000	0.025826656	0.0000	0.003999599	0.0000	0.000888316	0.0000	0.004571983	0.4969	0.50	0.00
	CAMERON	0.125578894	0.0000	0.0025146	0.0000	0.393419343	0.0000	0.004200941	0.0000	0.000927562	0.0000	0.000897712	0.0000	0.025821176	0.0000	0.003998751	0.0000	0.000888127	0.0000	0.004571013	0.4968	0.50	0.00
	PECOS	0.000135659	0.0000	4.98399E-05	0.0000	0.00010019	0.0000	8.25436E-05	0.0000	2.1488E-05	0.0000	7.49797E-06	0.0000	8.60031E-05	0.0000	0.000238822	0.0000	8.13779E-05	0.0000	0.000436887	0.0475	0.05	0.00
	PRESIDIO	0.000237673	0.0000	4.75918E-06	0.0000	0.000175532	0.0000	7.95078E-06	0.0000	1.75552E-06	0.0000	1.69903E-06	0.0000	4.88697E-05	0.0000	7.56811E-06	0.0000	1.68089E-06	0.0000	8.65119E-06	0.0009	0.00	0.00
	SAN PATRICIO	0.038088543	0.0000	0.000762688	0.0000	0.028130087	0.0000	0.001274161	0.0000	0.000281333	0.0000	0.000272279	0.0000	0.007831658	0.0000	0.001212836	0.0000	0.000269372	0.0000	0.001386405	0.1507	0.15	0.00
	WARD	0.057516808	0.0000	0.058007762	0.0000	0.042478727	0.0000	0.096040254	0.0000	0.025141917	0.0000	0.008287656	0.0000	0.08193722	0.0000	0.284766956	0.0000	0.097434336	0.0000	0.523254261	56.8667	56.87	0.03
	WEBB	0.051854261	0.0000	0.001038333	0.0000	0.038296683	0.0000	0.00173466	0.0000	0.00038301	0.0000	0.000370685	0.0000	0.010662126	0.0000	0.001651171	0.0000	0.000366727	0.0000	0.001887471	0.2051	0.21	0.00
	NUECES	0.556471643	0.0000	0.011142825	0.0000	0.410979117	0.0000	0.018615427	0.0000	0.004110259	0.0000	0.003977989	0.0000	0.11442012	0.0000	0.017719469	0.0000	0.003935514	0.0000	0.020255306	2.2013	2.20	0.00
	UPTON	3.45456E-05	0.0000	3.48405E-05	0.0000	2.55135E-05	0.0000	5.76835E-05	0.0000	1.51007E-05	0.0000	4.97772E-06	0.0000	4.9213E-05	0.0000	0.000171036	0.0000	5.85208E-05	0.0000	0.000314276	0.0342	0.03	0.00
	VICTORIA	0.26869859	0.0000	0.008105145	0.0000	0.198445888	0.0000	0.013404713	0.0000	0.00357559	0.0000	0.002532595	0.0000	0.853462815	0.0000	0.057152747	0.0000	0.002394313	0.0000	0.012017487	1.3060	1.31	0.00
	GREGG		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000	0.00	0.00
	HARRISON		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000	0.00	0.00
	SMITH		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000	0.00	0.00
	UPSHUR		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000	0.00	0.00
	TOTAL	**2.59433808**		**2.15884660**		**2.21670807**		**2.46753295**		**2.26120971**		**2.46530416**		**3.34809944**		**3.09910920**		**2.11715092**		**3.63318167**		**394.85**	**0.20**
Energy Savings by PCA from ESL (MWh)		**0.00**		**0.00**		**0.00**		**0.00**		**0.00**		**0.00**		**0.00**		**0.00**		**0.00**		**108.68**			

Figure 3. Three Groups of Models in the eCalc

Emissions Reductions Calculations

The Energy Systems Laboratory (ESL) has worked closely with the Texas Commission for Environmental Quality (TCEQ) and the EPA to develop acceptable procedures for calculating NOx reductions from electricity savings using the EPA's Emissions and Generation Resource Integrated Database (eGRID) [12]. This procedure calculates annual and peak-day, county-wide NO_x reductions from electricity savings from Energy Efficiency and Renewable Energy projects implemented in each Power Control Area (PCA) in the Electric Reliability Council of Texas (ERCOT)[13] region, one of the 10 regional reliability councils in North America. This procedure also includes a method for assigning a utility to each of the 41 affected counties. eGRID is then used to assign the electricity production to specific power plants, located in different counties throughout the state.

For the analysis in Texas a special version of eGRID was developed by the EPA that reflects the 1999 electricity and pollution for utilities in the ERCOT area. In Table 3 the NOx production for each power plant is provided from the 1999 eGRID database[14], for ten electric utility suppliers (i.e., AEP, Austin Energy, Brownsville Public Utility, LCRA, Reliant, San Antonio Public Service, South Texas Coop, TMPP, TNMP, and TXU). This matrix was utilized to assign the power plant used by the utility provider, once the utility provider had been chosen for a given county.

Using the Emissions Calculator (eCALC)

The emissions calculator, developed by the ESL for the TCEQ, with support from the EPA, is composed of four major elements, including: a web interface, a calculation engine, a weather database, and a general project/operations database. The web interface handles the interaction with the user, which includes receiving the general project information (including their email address for returning the results). Instructions from the user are passed to the calculation engine along with other information kept in the calculator's libraries. Once the user decides on a particular analysis, the calculator then routes their information into one of several legacy models, as shown in Figure 3. Annual and peak-day savings are then passed to the USEPA's eGRID database, where specific emissions data are contained for the electric utility provider associated with the user.

[12] E-GRID, Ver. 2, is the EPA's Emissions and Generation Resource Integrated Database (Version 2). This publicly available database can be found at www.epa.gov/airmarkets/egrid/.

[13] For more information about these procedures see the ESL's 2004 Annual report to the TCEQ (Haberl et al. 2004).

[14] This 1999 eGRID table for Texas, was provided by Art Diem at the USEPA.

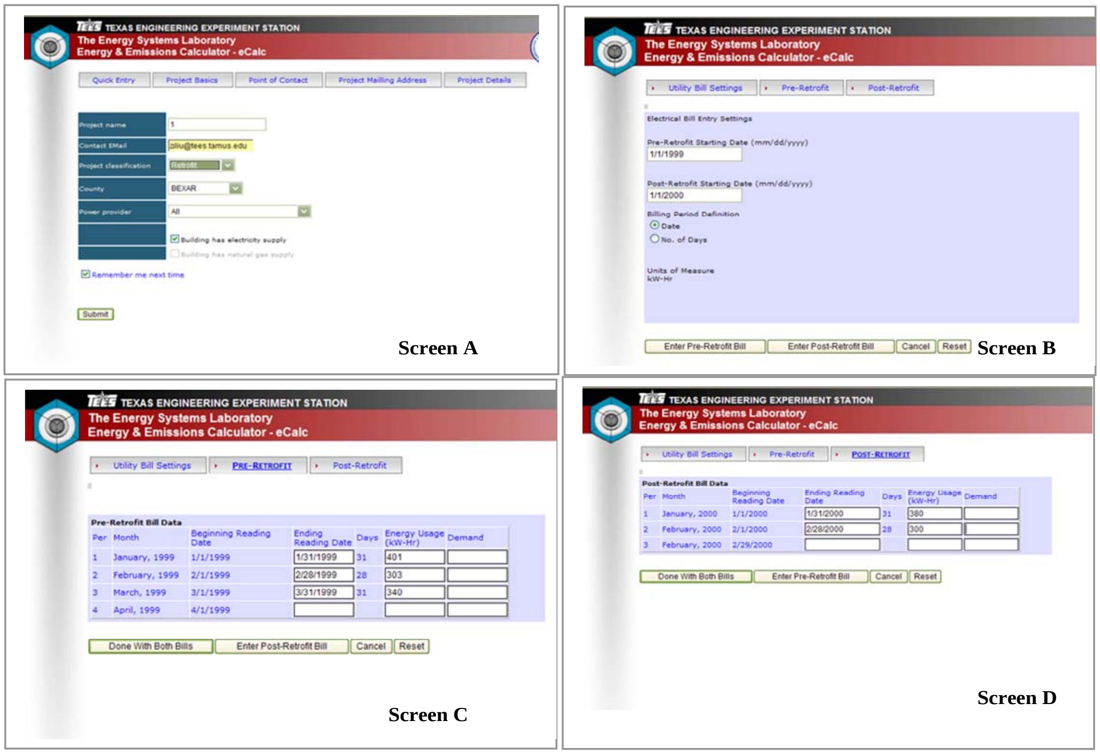

Figure 4. Street Lights Utility Bill Analysis Input Screen

Street Light and Traffic Light: Utility Bill Mode

The user input screens for street lights or traffic lights projects begin with the project input screen, as shown in screen A in When the user submits this type of project to the emissions calculator, they are directed to next screen shown as screen B in Figure 4. This screen asks for the beginning dates for the 12 months of pre-retrofit data and post-retrofit data. After entering this information, the user can then begin entering the pre-retrofit and post-retrofit data into screens C and D as shown Figure 4. When the user completes entering 12 months of both the pre-retrofit and post-retrofit data, they press the “done with both bills” button and the project is submitted for analysis.

When the user submits their street light or traffic light retrofit project for analysis, the emissions calculator performs a series of calculations, as indicated in Figure 5, which were previously described in this paper. For each analysis, the user is required to enter 12 pre-retrofit utility bills and 12 post-retrofit utility bills. In cases where weather normalization is needed, ASHRAE’s Inverse Model Toolkit (Kissock et al. 2003) is used to develop linear models for both the pre-retrofit and post-retrofit period using daily average NOAA weather data from the nearest weather location. IMT then produces pre-retrofit and post-retrofit coefficients that are used to determine the annual energy use in 1999 and the 1999 peak day energy use for the Ozone Episode Day (August 19, 1999). The final energy savings and emissions reductions report as shown in Figure 6 will be sent to the user through email as HTML and XML files.

Street Light and Traffic Light: Design Mode

The user input screens for a new traffic light projects begin with the project input screen shown in Figure 7. When the user submits this type of project to the emissions calculator, they are directed to the screen shown in screen A in Figure 7. This input screen asks for specific information about the lamps in the project. For example, as shown in screen B in Figure 7 for the pre-retrofit mode for traffic lights, the user has specified green ball, green arrow, red ball, yellow arrow, yellow ball, and pedestrian type lamps. This type of lamp-by-lamp information is provided by the user for the pre-retrofit mode (screen B in Figure 7) and post-retrofit mode (screen C in Figure 7). After entering this information for both pre-retrofit and post-retrofit modes, the user then submits the information to the emissions calculator by pressing the “calculate” button.

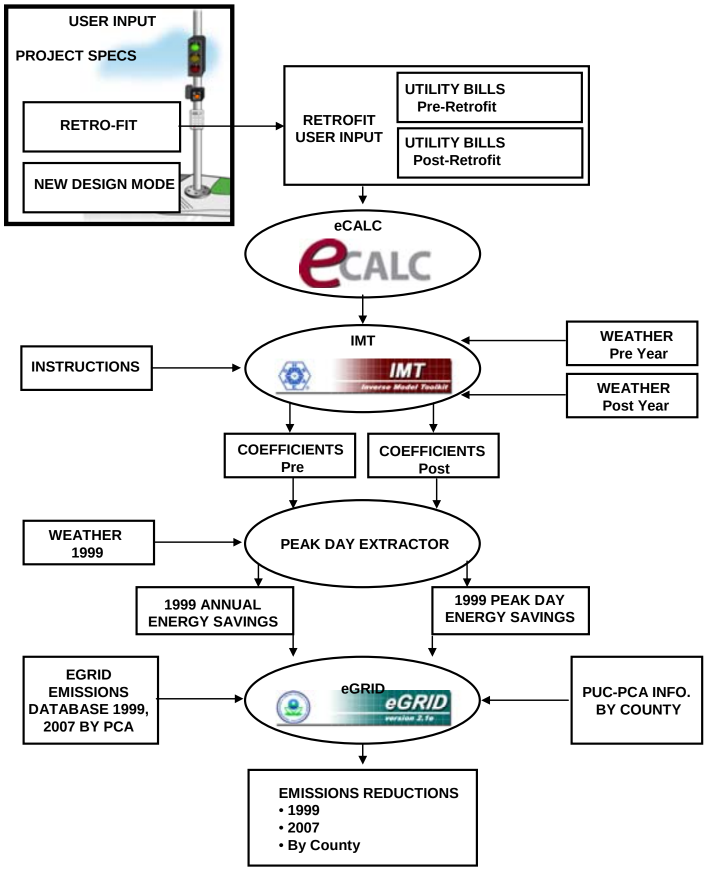

Figure 5. Street Lights & Traffic Lights – Retrofit Analysis Flowchart.

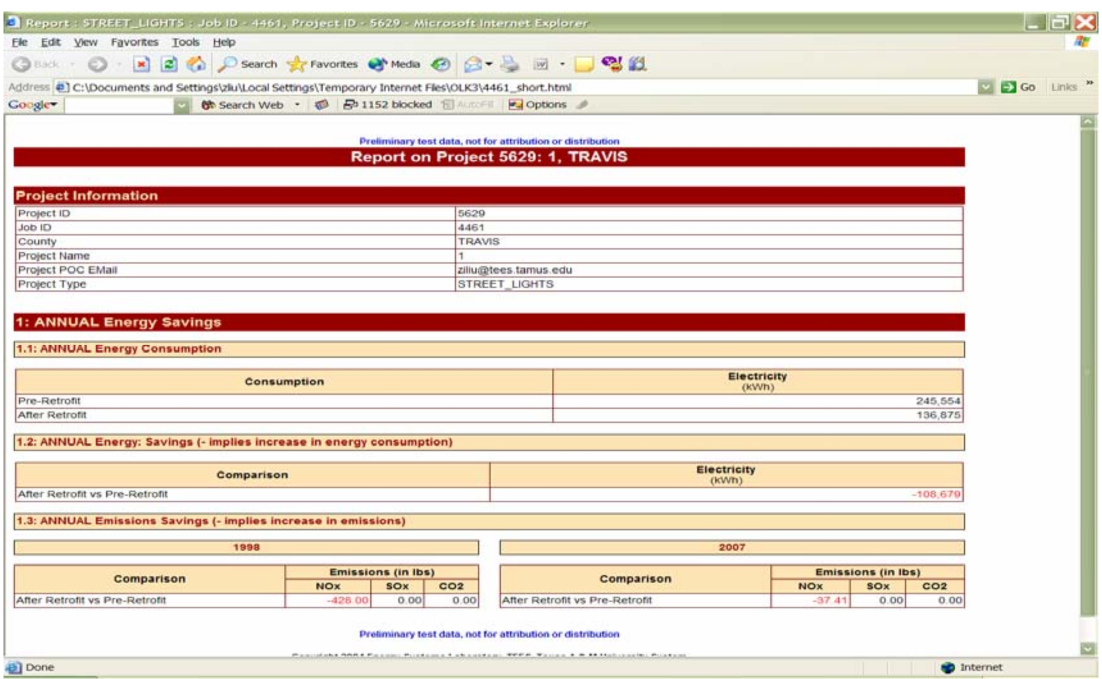

Figure 6. Street Lights & Traffic Lights Energy and Emissions Report.

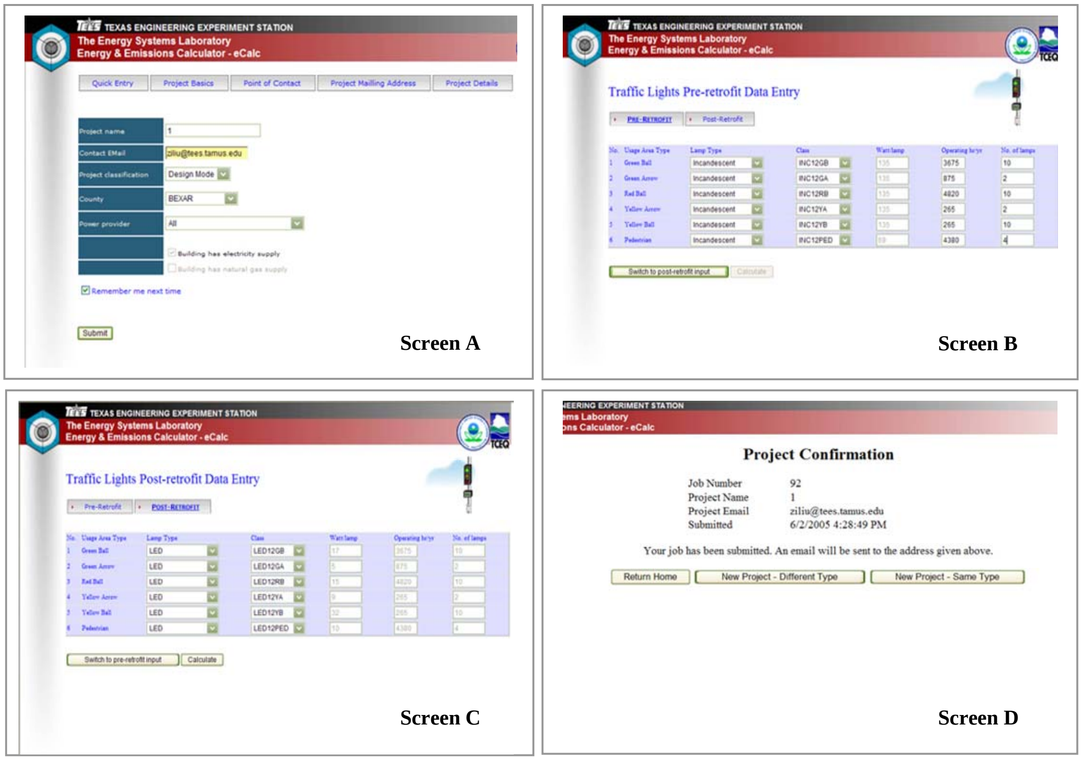

Figure 7. Traffic Lights Design Mode Input Screen

When the user submits their street light or traffic light design-mode analysis project, the emissions calculator compares the pre-retrofit electricity use for the pre-retrofit lamps against the electricity use calculated for the post-retrofit lamps, for the same operating hours, as shown in Figure 8, which includes the calculation of the annual and peak-day electricity savings. In the next step of the analysis, the emissions calculator calculates the NOx, SOx, and CO_2 using the USEPA's eGRID database. These results are then reported by the emissions calculator in a format that is similar to that shown in Figure 6 for utility bill analysis models and then emailed to the user as HTML and XML files.

SUMMARY

The Energy Systems Laboratory has developed an emissions calculator to provide web-based energy and emissions calculations for the evaluation of new building models, community projects and renewables. This paper has provided a detailed description of the procedures that have been developed to calculate the emissions reductions from traffic light and street light projects, including projects that have monthly utility bills, and projects where the user wants to calculate savings from lamp-by-lamp replacements.

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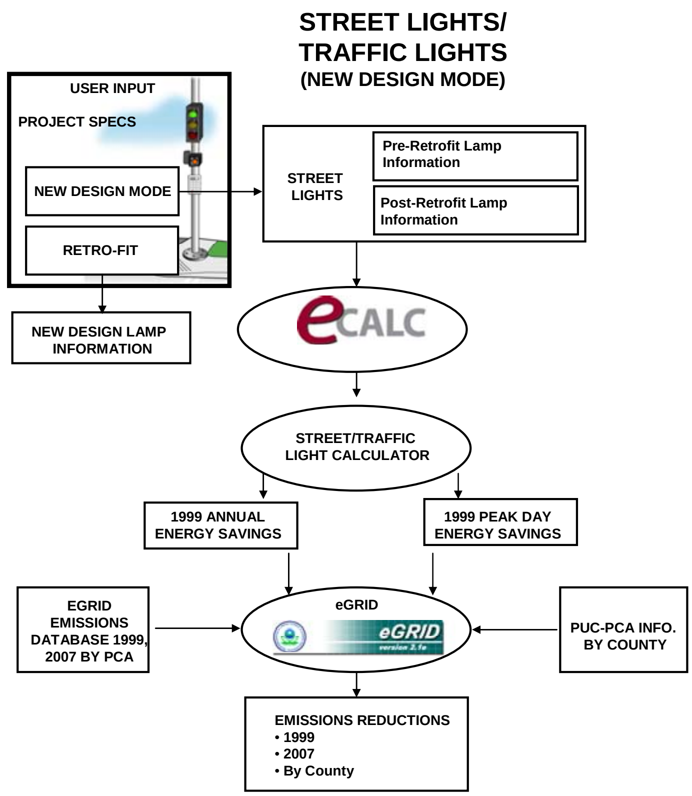

Figure 8. Street Lights & Traffic Lights – New Design Mode Analysis Flowchart.

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