Development of a Web-Based, Emissions Reduction Calculator for Storm Water/Infiltration Sanitary Sewage Separation

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Abstract: This paper presents the procedures developed to calculate the electricity savings and emissions reductions from the infiltration of storm water into sanitary sewage separation using a two-step regression method: one step to correlate the gallons of wastewater treated to the rainfall, and a second step that correlates the gallons of wastewater treated to the electricity consumed during a given period. The procedure integrates ASHRAE's Inverse Model Toolkit (IMT) for the weather-normalization analysis and the EPA's Emissions and Generations Resource Integrated Database (eGRID) for calculating the NOx emissions reductions for the electric utility provider associated with the user.

1. INTRODUCTION

On February 2004, the Texas Commission on Environmental Quality (TCEQ) issued a document entitled "Incorporating Energy Efficiency/Renewable Energy (EE/RE) projects into the Environmental Protection Agency (EPA) mandated State Implementation Plan (SIP): A Guide for Local Entities", which provides guidance on how political subdivisions can assist the TCEQ in taking credit for emissions reductions from energy efficiency measures implemented at the political subdivision level. According to this TCEQ guidance energy efficiency, renewable energy and non-emission distributed generation strategies that may be considered for inclusion as SIP measures comprise, but are not limited to, the Utility Water and Wastewater Energy-Related Improvements. This paper describes a methodology that has been developed for the TCEQ to assess the potential emissions reduction from the implementation of the retrofit measures to city-wide, wastewater distributions.

In come cities the municipal sewer system collects both storm water and sanitary sewage in the same system. During dry weather these sewers carry all the sanitary sewage to the wastewater treatment plant for treatment. However, when rainstorms or snow melt increase the amount of runoff, the combined flow of sanitary sewage and storm water can exceed the capacity of the sewage treatment system, which can cause serious problems when the storm water and sewage mix are discharged untreated into rivers or the sewage backs up into streets and basements. In addition, storm water treated in the sewage treatment plant causes unnecessary energy use. Therefore separating the storm water/infiltration and sanitary sewage reduces the possibility of sewage discharge during heavy rain periods, and saves energy.

2. METHODOLOGY

The methodology developed in this study calculates the potential emission reductions from storm water/infiltration sanitary sewage separation using a two-step regression method: one step to correlate the gallons of wastewater treated to the rainfall, and a second step that correlates the gallons of wastewater treated to the electricity consumed during a given period. The model that was developed uses pre-retrofit monthly data, i.e., wastewater treated and electricity use data, and daily rainfall data corresponding to the monthly period. These data are then processed with the ASHRAE Inverse Model Toolkit (IMT) analysis software (Kissock et al. 2003; Haberl et al. 2003) to evaluate the performance of wastewater collection and treatment system, and any weather dependence using average rainfall data. The pre-retrofit data are weather normalized to the 1999 or 2002 base year through the adjusted regression coefficients based on the growth rate from 1999/2002 base year to the studied year, so the evaluation of the potential savings in 2007 and 2010 can be performed using base-year weather conditions. Finally the potential annual and OSD (Ozone Season Days) emissions reductions are determined using the EPA's eGRID [1], emissions and generation resource integrated database.

2.1 Wastewater Treated versus Rainfall

To investigate the influence of rainfall on the amount of wastewater treated, hourly, daily and monthly wastewater data from several wastewater facilities and the corresponding rainfall data from the nearest NOAA weather stations were obtained. Fig. 1 and Fig. 2 show an annual time-series plot of daily wastewater data from a wastewater treatment facility and the coincident rainfall data. It shows that during the most rainy days, the amount of wastewater treated rose as high as 19 million gallons per day (MGD). Analysis of the input data also shows the wastewater treated in January and December was low compared to other months due to the holidays and school vocation period, which was excluded in the analysis. During the non-rainy days, the amount of wastewater treated averaged 6.32 MGD and varied within a small range, from about 6 to 7 MGD except for several days.

In Fig.3, the average daily wastewater flow was plotted against the daily rainfall data for the period February through November. The application of a two-parameter linear regression to the average daily wastewater treated versus average period rainfall shows that the treated wastewater increases significantly as the daily rainfall increases. The offset of 6.3075 indicates the wastewater treated daily when there is no rain (i.e., this is used to estimate how the municipal sewage treatment system would have operated if there was no storm water or infiltration). The slope of 1.9723 describes the increase of the storm water that infiltrates the sewer system and needs to be treated as the rainfall increases.

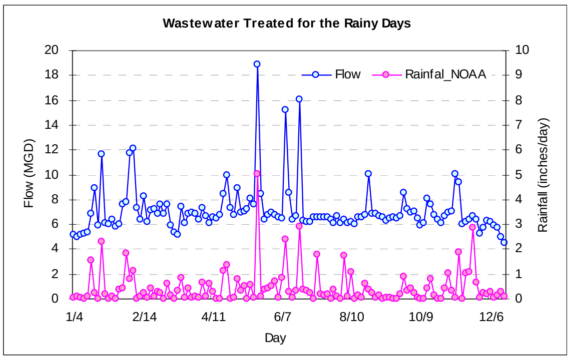


Fig. 1 Wastewater treated for the rainy days

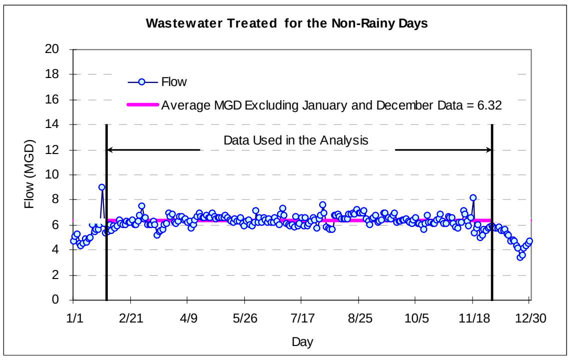


Fig. 2. Wastewater treated for non-rainy days

[1] GRID, ver. 2, is the EPA's emissions and generation resource integrated database. This publicly available database can be found at www.epa.gov/airmarkets/egrid/

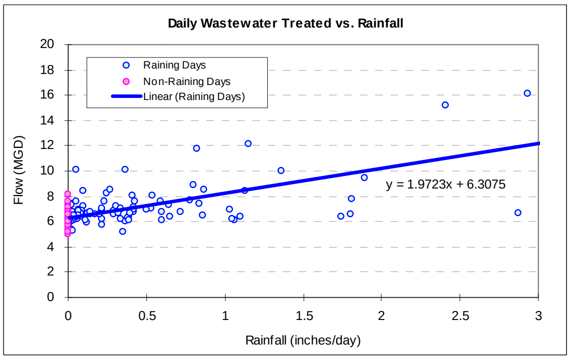


Fig.3. Daily wastewater treated versus rainfall

In the next step, the daily wastewater treated was summed to monthly data and divided by the number of days of each month, and then plotted against the corresponding average daily rainfall of the month, as shown in Fig. 4. The two-parameter linear regression model developed using IMT is shown in Fig. 4 as well.

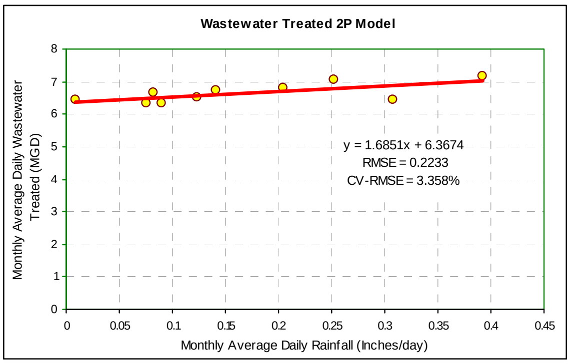


Fig. 4. Monthly average daily wastewater treated versus rainfall

As seen from Fig. 4, the resultant coefficients from the two-parameter monthly model were sufficiently robust to allow for their use in projecting the daily wastewater treated into other weather base years. The offset of 6.3674 from the monthly model is very close to that of the daily model (6.3075). The very low correlation of wastewater flow and rainfall in the college town used for case study is heavily influenced by the relative newness of the city's wastewater infrastructure. Therefore, it is doubtful that much water infiltrates the sanitary sewer system, and combined sewer lines are probably very few. Greater energy savings may be possible for older systems suffering from higher infiltration and having combined storm water/sewage treatment flows by design.

2.2 Wastewater Treated versus Electricity Consumption

To calculate the electricity savings from the reduced wastewater flow through separating storm water/infiltration from sanitary sewage, ASHRAE's IMT was used to determine the statistical relationship between the average daily wastewater treated and the electricity consumption corresponding to the billing period. Fig. 5 shows the two-parameter monthly regression model. The very low correlation of wastewater flow and electricity consumption is partly due to the electricity consumption dataset which includes not only the electricity use for processing the wastewater, but also the office electricity use. In the future it is expected that end-use metered data for only the wastewater treatment will better represent the real savings that may be achieved.

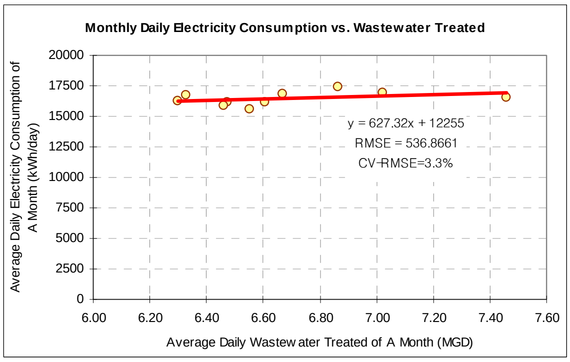


Fig. 5. Monthly average daily wastewater treated versus rainfall

2.3 Calculation of Emissions Reduction

For this analysis special versions of eGRID (2007 eGRID) was used that predicts the 2007 electricity and pollution for utilities in the ERCOT (Electric Reliability Council of Texas) Power Control Area. For the Ozone Season Day (OSD), the TCEQ uses the 2007-OSD eGRID to calculate the daily emissions during Ozone Season Days. The annual 2007 eGRID was used for the annual calculations. Both the annual and OSD calculations assume eGRID's 25% plant capacity factor. In eGRID the NOx production for each power plant is provided for ten electric utility suppliers in ERCOT (i.e., AEP, Austin Energy, Brownsville Public Utility, LCRA, Reliant, San Antonio Public Service, South Texas Corp, TMPP, TNMP, and TXU). In the case of an unknown power provider, the model assigns the utility based on the PUC's 2002 Power Control Authority (PCA) listing[2]. Once the utility provider has been chosen for a given county the eGRID emission factor for 2007 is used for both 2007 and 2010 calculations.

3. APPLICATION

In this section, the developed procedure (Fig. 6) in the emissions calculator is explained in detail.

3.1 User Input

As shown in (c)

Fig. 7, first the user needs to input the percent of storm sewer that can be blocked or percent of infiltration that can be fixed. Next, the user inputs 12 months of data for the wastewater treated and coincident electricity use. Finally, the user provides the growth of their system covering 1999, 2002, 2007 and 2010. This allows the calculations to evaluate the conditions in the base year (i.e., 1999 or 2002), and in the 2007 and 2010 future years.

3.2 First Application of IMT

Next, IMT is run to obtain the coefficients ("a" and "X1") of the two-parameter model for the wastewater and rainfall. The following equation is used in the next step for calculating the normalized daily wastewater treated using daily rainfall data:

Wastewater Treated (MGD) = a + X1 * Daily Rainfall (inches/day)

[2] For more information on the assumptions behind this assignment see the ESL's 2004 Annual Report to the TCEQ (Haberl et al. 2004a, b, c).

3.3 Predict Daily Wastewater Treated in Base Year 1999 and 2002

After running the IMT 2P model, the growth factors input by the user are applied to the coefficients obtained in the previous step. Both the slope (coefficient "X1") and offset (coefficient "a") are adjusted to reflect the growth of the wastewater treatment system from 1999 and 2002 to the input period. Then the weather normalized daily wastewater treated in 1999 and 2002 is calculated based on the adjusted coefficients and daily rainfall data in 1999 and 2002. The wastewater treated annually and in OSD period in 1999 and 2002 are also calculated accordingly.

3.4 Predict Daily Wastewater Treated in Base Year 1999 and 2002 if No Rain

As discussed in the previous section, the offset indicates the wastewater treated daily when there is no rain. Based on this value, the wastewater treated annually and in OSD period in 1999 and 2002 if there is no rain, or in another words, if the storm water is 100% blocked from the sanitary sewer system, is then calculated.

3.5 Second Application of IMT

IMT 2P model is run again to determine the coefficients ("a" and "X1") of electricity consumption versus the wastewater treated. The following equation is then used to calculate the normalized daily electricity consumption using the predicted daily wastewater flow:

Electricity Consumption (kWh/day) = a + X1 * Predicted Daily Waste Water Treated (MGD)

3.6 Predict Daily Energy Consumption in Base Year 1999 and 2002

To calculate daily energy consumption in 1999/2002 first the growth factors input by the user are applied

to the coefficients obtained in the previous step. Only the offset needs to be adjusted to reflect the growth of the wastewater treatment system from 1999 and 2002 to the input period. Then the daily,

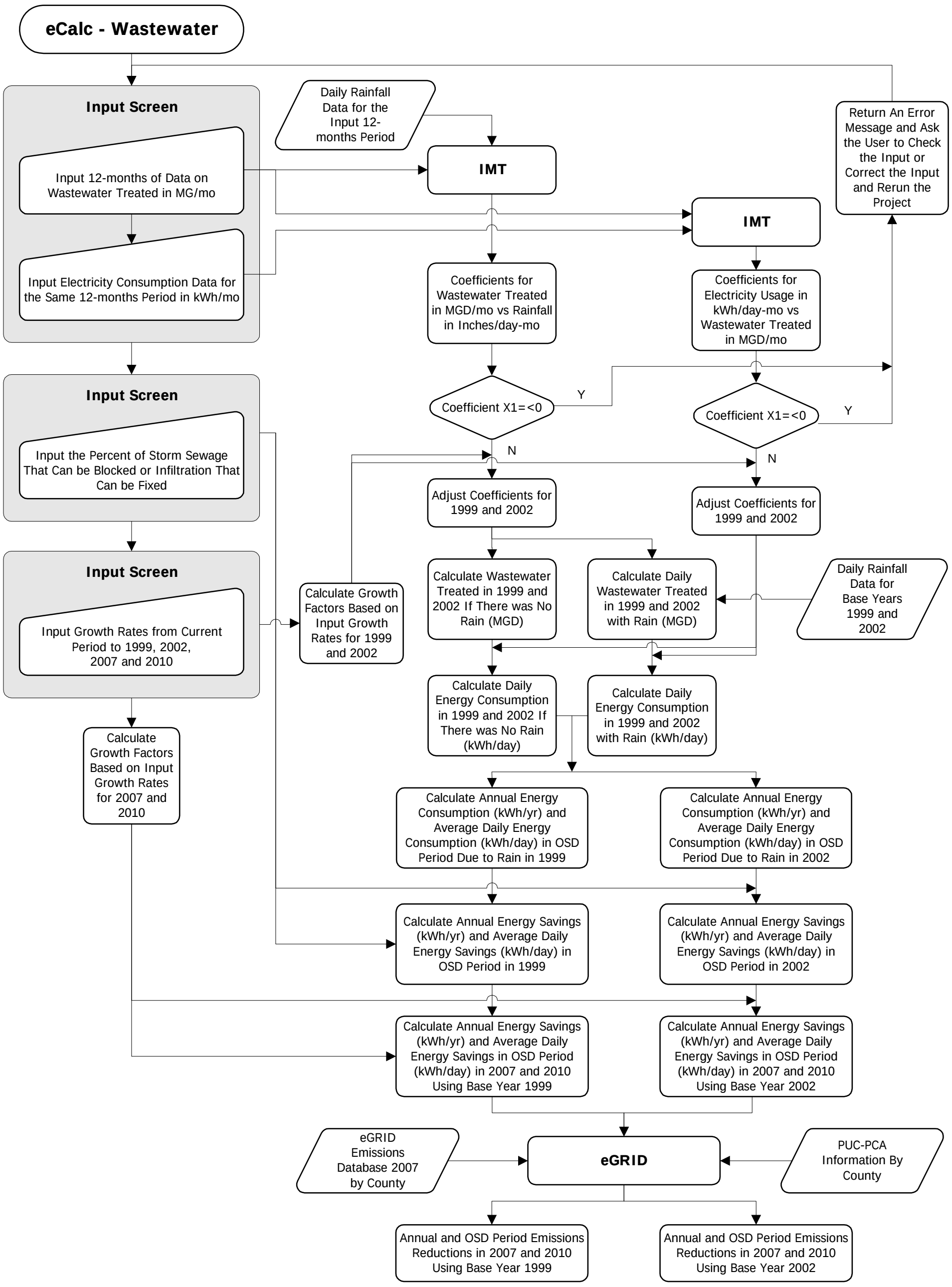
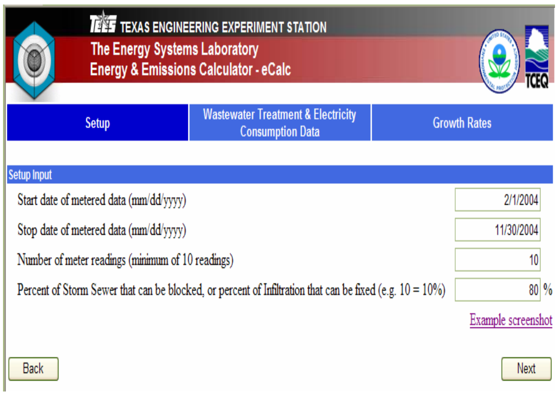


Fig. 6. Description of the procedure

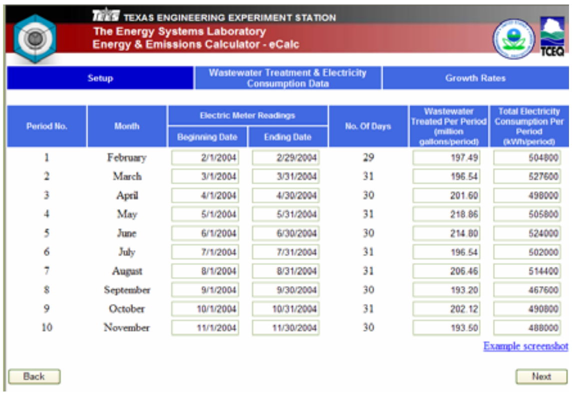
annual, and OSD period electricity consumption in 1999 and 2002 is calculated using the adjusted coefficients and the predicted daily wastewater data in 1999 and 2002.

3.7 Predict Daily Energy in Base Year 1999 and 2002 if No Rain

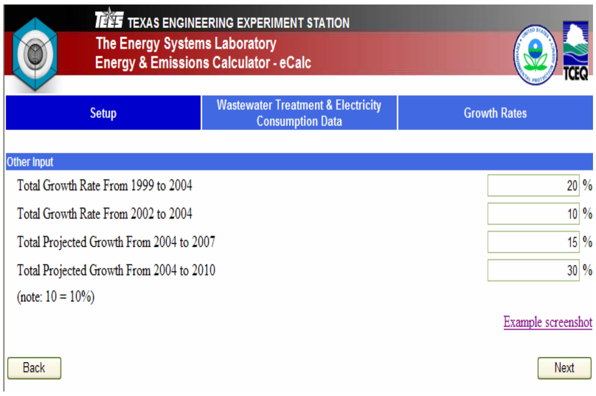
Next, the annual and average daily OSD electricity consumption in 1999 and 2002 is calculated if the storm water is completely blocked from the sanitary sewage using the same method described in previous step.



(a)



(b)



(c)

Fig. 7. Input Screens

3.8 Calculate Energy Savings Due to % of Separation

In this step, the electricity consumption due to the storm water/infiltration is calculated first based on the results from the previous two steps. To evaluate the electricity savings that could be achieved after the retrofit, the percent of storm water that can be blocked or infiltration that can be fixed, which is provided by the user, is applied in the calculation.

3.9 Project Annual and OSD Savings for 2007 and 2010

To project the annual and OSD savings for 2007 and 2010, first the growth factor from 1999 to 2007/2010 and the growth factor from 2002 to 2007/2010 are calculated according to the user input. Then the annual and average OSD electricity savings are calculated based on the base year savings and growth factors from the base year to 2007/2010.

3.10 Project Emissions Reduction in 2007 and 2010

Finally, in the next step the EPA's eGRID database is used to project annual and average daily OSD period NOx, SOx, and CO2 reductions in 2007/2010 using base year 1999 and 2002. Fig. 8 shows a sample of emissions reduction report that will be sent to the user.

4. SUMMARY

The Energy Systems Laboratory (ESL) 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 on the methodology and the procedures that have been developed to calculate annual and OSD period electricity savings and emissions reductions from blocking storm water or fixing infiltration for the municipal sewer system, including the use of ASHRAE's Inverse Model Toolkit in a two-step regression method to weather normalize the calculated electricity savings to the 1999 and 2002 base year and the use of the EPA's eGRID for calculating the NOx emissions reductions for the electric utility provide associated with the user.

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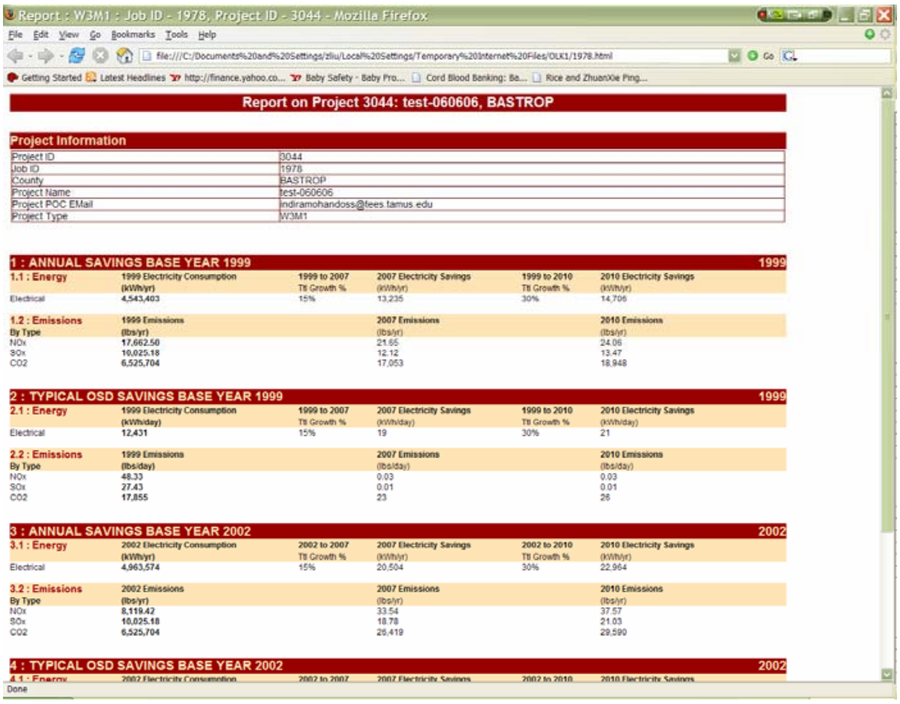

Fig. 8. Sample emissions reduction report

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