# CHAPTER VI

## *Case Study: Wisconsin Electric Power Company*

### 6.1 Introduction

As yet, very little mention has been made of utility involvement or interest in SDHW systems. Part of this project's motivation, however, was to examine such a possibility. With the increase in popularity of residential air conditioning, electric utilities often experience their highest demand in the summer on the third or fourth consecutive hot day. The utility needs to be able to meet the peak demand by having enough generating plants available or by being able to purchase power from another utility. Since almost all utilities in the country are summer peaking however, not all of them can purchase the extra power needed to meet the peak demand (Cragan, 1994). At some point in the chain, there needs to be extra generating capacity that is used during the summer and sits idle during the rest of the year. While idle, however, these plants still need to be maintained, which costs the utility money and leads to the increased cost of electricity during the summer.

If, however, a large number of houses in the utility's service district have solar water heating systems installed then there is in essence a diversified power generator capable of reducing the peak demand seen by the utility. Peak demand reduction is accomplished by the SDHW systems meeting the service area's water heating demand and allowing the utility to concentrate on the air conditioning demand.

The benefit of utility involvement in SDHW is not limited to the utility itself. As previously mentioned, one of the obstacles to solar energy's market penetration has been high initial costs and the nonexistence of a maintenance network (Peters, Robison and Winch, 1997). Since the utility would benefit from a large-scale SDHW initiative however, they stand in a position to promote it as well. The utility could purchase a large number of SDHW systems and lease them to customers for a monthly fee. Ideally, the customer would see a decrease in electric bill, would not have to spend a large amount of money to install an SDHW system, and would be able to call upon the utility for maintenance issues. There are also obvious benefits to the environment as well stemming from reduced $CO_2$, $SO_2$ and many other chemical emissions.

A fair amount of research has been done to date concerning the idea of a large scale SDHW initiative by a utility. Cragan investigated a number of economic issues involved with the problem and worked out the basics of modeling the economic and energy impact on the utility (Cragan, 1994). Trzesniewski then extended the work and wrote a TRNSYS based program called EUSESIA which performs an impact evaluation (Trzesniewski, 1995). Because of its basis in TRNSYS, EUSESIA can be used to characterize the impact of any SDHW system design. It was used to investigate the impact of photovoltaic heated water systems on a utility (Williams, 1996) and it lends itself perfectly to investigating the impact of three-season systems as well.

For the purposes of this analysis, a utility in Milwaukee, Wisconsin was chosen. A Wisconsin location offers a number of advantages. First, it is not an area of the country that is likely to be thought of as a great place for solar. Furthermore, it has a significant thermal penalty associated with choosing a three-season system. Showing that a three-season system works well from an economic standpoint in such a location therefore carries more weight. Milwaukee was also chosen because of data availability. Data files containing actual (not generated) 1991 weather data and utility load data were available for the Wisconsin Electric Power Company (WEPCO), located in Milwaukee.

## 6.2 The Three-Season System from a Utility's Point of View

To this point, the three-season system has been analyzed and evaluated from a single consumer's point of view. The economic analysis showed the dynamics of an SDHW recuperating its initial cost by saving the homeowner money on monthly fuel bills. These dynamics change when the system is owned by a utility. First, the income producing flag C in equations 3.2.7 and 3.2.8 changes from 0 to 1, adding more terms to and decreasing the values of both $P_1$ and $P_2$. The life cycle savings will go up or down depending on whether $P_1$ or $P_2$ decreases more. Second, while tax incentives for solar installations are no longer available to individuals, they are still available to businesses, including utilities, further increasing solar's attractiveness. These economic factors affect both the three and four-season SDHW systems. However, there are important differences that may make one system a more attractive alternative.

Three-season systems offer a utility a number of benefits over four-season systems. Interestingly the benefits are much the same as for individual customers but since many systems are involved, have much higher value. Foremost, the three-season system costs less to install, having less equipment. Saving $500 per system on 1000 systems in the service district is a very big incentive. Second, the systems run solely on water and therefore the glycol charge never has to be checked or topped up, saving the utility one service call per system each year. Maintenance costs on the three-season system will also theoretically be lower as the system is off for half the year. All the while, there is no reason that the utility would decrease the monthly lease rate on the system. The overall effect is that the utility's profit margin is higher for a three-season system than for a four-season system. Another advantage of the three-season system is that most utilities need extra generating capacity only during the summer. Since the three-season system only operates during these times, its output is more tailored to the utility's needs.

The disadvantage of a three-season system is that it requires at least two service calls each year: once in the spring to turn it on, and once in the fall to shut it down. Theoretically, the four-season system would only require a check up service once a year to ensure that it is operating as intended.

## 6.3 EUSESIA

EUSESIA performs an economic impact analysis of a diversified energy generator on either a single utility or on a consortium of utilities. The second option takes into account the fact that a utility is one of a group and can purchase power to meet its energy demand from neighboring utilities.

Performing an EUSESIA analysis involves a number of steps. First, a TRNSYS deck is created that models the solar alternative currently under investigation. The output of this deck must be a file that shows the hour of the year, and the electric demand of the solar alternative. Second, a deck must be run that will provide the basis of comparison. The deck edhw.trd models an electric domestic water heater with which any solar alternative can be compared (Trzesniewski, 1995). Its output file also shows each hour of the year and the system's energy demand.

The next step in performing an EUSESIA analysis is to characterize the utility by examining its load and determining the order in which it will turn on their various generating facilities. To do so, marplant.trd is run to determine the marginal plant at each hour of the year (Trzesniewski, 1995). The marginal plant is a schedule that determines the order in which plants will be brought on line to meet the demand. It takes into account the total demand upon the utility at each hour of the year, the operating costs of each generating plant in the area, and all the scheduled plant outages due to maintenance. The marginal plant is determined to be the next least expensive plant to operate that is not already running.

Once the marginal plant schedule has been created for the location in question, another TRNSED deck (utility.trd) is used to determine the energy contribution from a large number of SDHW systems. Utility.trd (Trzesniewski, 1995) calculates the difference in demand between the solar alternative and the electric heated base case, and determines the amount of money that the solar alternative saves the utility. The savings are then used in a $P_1$ $P_2$ analysis that takes into account the utility's required capital investment in order to offer the SDHW program. An output file shows a detailed analysis of the energy saving and economic benefits of the SDHW alternative.

## 6.4 WEPCO Impact Analysis Results

The EUSESIA analyses compared both a four-season and a three-season SDHW system ensemble with conventional EDHW systems. There were assumed to be 1000 such SDHW ensembles in the WEPCO service area. Table 6.4.1 shows the differences between the two installations.

**Table 6.4.1: Three and Four-Season System Parameters**

| | Three-Season System | Four-Season System |
|---|---|---|
| Collector Slope (degrees) | 35 | 40 |
| System Installed Cost ($) | 1500 | 2000 |
| System Maintenance Cost ($/yr-system) | 15 | 30 |

Figures 6.4.2 and 6.4.3 show the EUSESIA results for both the three and four-season system. The three-season system had the same collector area but was sloped at $35^{o}$ in accordance with the three-season optimum.

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              Electric Utility Solar Energy System Impact Analysis:

          Impact of a Large Scale Implemention of a Solar Energy System
                            on an Electric Utility

******  Energy and Environmental Impact Summary fo r the First Year  ******
Results based on: 1000 solar systems

            Energy Reduction (kWh)     Energy Savings ($)
                4006710.                    64672.

            Emission Reduction (lbm)   Emission Savings ($)
    CO2         4679570.                        0.
    SO2           34608.                      692.
    NOX           22594.                        0.
    N2O              74.                        0.
   Parts           1943.                         0.
    CH4              48.                        0.
     HG               0.                        0.
   NUKES              0.                        0.
                                              692.

            Demand Reduction (kW)       Demand Savings ($)
                    619.                    21240.

                                       Total Savings($)
                                            86604.

******  Economic Analysis Summary  ************* ***************************

  Present Worth of Investment         - $      2000000.
  Present Worth of OM&A               - $       430740.
  Present Worth of Energy Savings      $       928557.
  Present Worth of Emission Savings    $          9938.
  Present Worth of Demand Savings      $       304969.
  Present Worth of Depreciation        $       543009.
  Present Worth of Downpayments        $       140000.
  Present Worth of Lease Payments      $      1413810.
  Present Worth of Tax Credit          $       200000.
  Present Worth of Energy Subsidy      $            0.
  Present Worth of Customer Retention  $            0.
  Present Worth of Delay Value         $            0.

   Present Worth of Life C ycle Savings  $      1109550.
   Levelized Savings of Option          $       113010.
Rate of Return of Option                       19.5 %

******  System Performance Summary and Customer Savings  *******************
 Results based on averag e system performance

          Elc (kWh)   Sol (kWh)   Del (kWh)    SF    Savings ($)
   JAN      489.        247.        242.      .495        15.49
   FEB      437.        148.        289.      .660        18.46
   MAR      475 .        164.        311.      .655        19.92
   APR      446.         84.        363.      .813        23.21
   MAY      438.         68.        370.      .844        23.66
   JUN      414.         17.        397.      .959         29.60
   JUL      415.         20.        395.      .952        29.46
   AUG      419.         34.        385.      .919        28.71
   SEP      428.         56.        372.      .869        27.73
   OCT      460.        161.        299.      .650        19.12
   NOV      459.        276.        182.      .397        11.65
   DEC      478.        275.        204.      .426        13.03

   YEAR    5358.       1550.       3809.      .711        260.04


 Option Capacity Reduction Ratio
          0.363
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**Figure 6.4.2: EUSESIA Analysis Output for a Four-Season SDHW Installation**

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              Electric Utility Solar Energy System Impact Analysis:

          Impact of a L arge Scale Implemention of a Solar Energy System
                            on an Electric Utility

 ******  Energy and Environmental Impact Summary for the First Year  ******
Results based on: 1000 solar systems

            Energy Reduction (kW h)     Energy Savings ($)
                2501610.                     40498.

            Emission Reduction (lbm)   Emission Savings ($)
    CO2         2835840.                         0.
    SO2           20895.                       418.
    NOX           13887.                         0.
    N2O              47.                         0.
   Parts           1193.                         0.
    CH4              29.                         0.
     HG               0.                          0.
   NUKES              0.                         0.
                                               418.

            Demand Reduction (kW)      Demand Savings ($)
                    709.                     24326.

                                        Total Savings($)
                                             65241.

******  Economic Analysis Summary  *****************************************

  Present Worth of Investment         - $      1500000.
  Present Worth of OM&A               - $       215370.
  Present Worth of Energy Savings      $       581469.
  Present Worth of Emission Savings    $         6000.
  Present Worth of Demand Savings      $       349269.
  Present Worth of Depreciat ion        $       407256.
  Present Worth of Downpayments        $       140000.
  Present Worth of Lease Payments      $      1413810.
  Present Worth of Tax Credit          $       150000.
  Present Worth of Energy Subsidy      $            0.
  Present Worth of Customer Retention  $           0.
  Present Worth of Delay Value         $           0.

  Present Worth of Life Cycle Savings  $      1332440.
  Levelized Savings of Option          $       135712.
  Rate of Return of Option                       28.7 %

******  System Performance Summary and Customer Savings  *******************
 Results based on average system performance

          Elc (kWh)   Sol (kWh)   Del (kWh)    SF    Savings ($)
   JAN      489.        489.         0.      .000          0.00
   FEB      437.        437.         0.      .000          0.00
   MAR      477.        473.         4.      .008          0.24
   APR      449.        441.          9.      .019          0.56
   MAY      459.         62.       396.      .864         25.35
   JUN      439.         14.       425.      .968         31.63
   JUL      444.         19.       425.      .958         31.67
   AUG      443.         30.       414.      .933         30.83
   SEP      442.         49.       393.      .889         29.27
   OCT      463.        152.       311.      .672         19.92
   NOV      458.        456.         2 .      .003          0.10
   DEC      478.        478.         0.      .000          0.01

   YEAR    5477.       3099.      2378.      .434        169.59


 Option Capacity Reduction Ratio
           0.412
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**Figure 6.4.3: EUSESIA Analysis Output for a Three-Season SDHW Installation**

Table 6.4.1 highlights some of the important results of the EUSESIA analysis.

**Table 6.4.1: Highlighted Results of EUSESIA Analysis**

| | Four-Season System | Three-Season System |
|---|---|---|
| Energy Reduction (kW-hr) | $4.0 \times 10^6$ | $2.5 \times 10^6$ |
| $SO_2$ Emissions Reduction (lbm) | 34608 | 20895 |
| Demand Reduction (kW) | 619 | 709 |
| Rate of Return (%) | 19.5 | 28.7 |
| Capacity Contribution Index (-) | 0.363 | 0.412 |

There are a number of interesting results to the EUSESIA analysis, which highlight the comparative benefits of the three-season system. From an energy standpoint, the four-season system ensemble reduces the annual energy requirement on the utility more than the three-season system ensemble. If, however, only the peak demand periods are examined, then the three-season system has a greater benefit to the utility. This result confirms that the three-season system meets the utility's generation demands better than the four-season system. Along with a greater overall demand reduction, the four-season system also provides greater sulfur dioxide emission reduction. In fact, the four-season system has greater emission reductions all around but $SO_2$ emissions are the only ones for which the utility gets monetary credit.

From an economic standpoint, the three-season system is of greater benefit to the utility. The reduced installation and maintenance costs associated with the three-season system result in a higher rate of return on the utility's investment. Furthermore, the capacity contribution index is higher for the three-season system. The capacity contribution index (CCI) compares the relative capacity contributions to overall utility reliability. An important feature of the CCI is that it takes into account the effect of the demand-side project on an interconnected utility system, not just an isolated system (Arny, 1994). The three-season SDHW initiative contributes more to the area utilities' ability to meet their peak demand than does the four-season system.

## 6.5 Modifications to EUSESIA

EUSESIA makes an assumption, which while justifiable and undoubtedly correct was deemed inappropriate to this analysis. In generating a base case, a domestic water heating system is modeled using the file edhw.trd (Trzesniewski, 1995). The storage tank in this model contains two heating elements at one third and two-thirds the height of the tank. The SDHW system on the other hand contains a tank with only one heater. It was found that running the SDHW system with the solar radiation set to zero (representing an Electric Domestic Hot Water system (EDHW)) yielded a solar fraction when compared with the EDHW system. EUSESIA calculates the solar fraction as the difference in demand between the SDHW and EDHW systems. The difference in heater configurations was causing a difference in demand between the two systems, and therefore a non-zero solar fraction.

It should be stated that the models are correct and that comparing a four-season SDHW system and the EDHW system with two tank heaters will yield valid results. However, the three-season SDHW system needs to have the same demand as the EDHW system during the off season so the comparison becomes invalid. Therefore, the base case for comparison was modified to be the SDHW system with no solar radiation all year long.  Alternatively, a second heater could have been added to the SDHW system but doing so would disturb the stratification of the tank and erase this benefit from the SDHW system.  In order to model the three-season system, the solar radiation was set to zero during the freezing months to ensure that the demand of the system was equal to that of the EDWH system.

## 6.6 Conclusions

Because of its reduced installation and maintenance costs, a three-season system ensemble is of greater benefit to Wisconsin Electric Power Company by a significant margin.  The utility can expect almost a 30% return on their investment as opposed to a 20% return for a four-season system.  Since the four-season ensemble runs throughout the year, its overall energy reduction is greater in Milwaukee.  However the utility has little use for the diversified generator during the winter so in reality the four-season ensemble is a burden during off peak times when it heats water at perhaps greater expense than the utility generated electricity.  Say for example, that the utility has plenty of generating capacity on a winter day and could shut down a number of their power plants, thereby generating electricity at a very low cost and gaining a high profit margin.  At this time, the four-season system ensemble would still be operating, conceivably generating energy at much higher cost to the utility, reducing the utility's profit margin.