Results and Possible Dissemination of the Polish Efficient Lighting Project - the DSM Pilot.

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1 - SYNOPSIS

The paper presents the results of the measurements and the analysis of cost effectiveness of the Polish Efficient Lighting Project (PELP) - Demand-Side Management (DSM) Pilot Project.

2 - ABSTRACT

Compact Fluorescent Lamps (CFLs) consume about one-fourth of the power for the same light output compared with traditional incandescent lighting. The Polish Efficient Lighting Project (PELP), sponsored by Global Environmental Facility and managed by International Finance Corporation, sought to reduce domestic electricity consumption in Poland through promotional and educational campaigns and CFLs subsidized at the manufactures' level. The project included a demand-side management (DSM) component in which measurements of electric power consumption, peak loads, and power quality were measured before and after wide-scale installation of CFLs in selected areas of three cities. The goal of the DSM-Pilot was to demonstrate to power utilities that they can benefit from reducing the peak load by deferring the investments on the grid side.

The effects of the PELP project could be observed both in the significantly increased sales of CFLs and the decrease in electricity consumption. The success of the sales can be attributed to eliminating the market barrier that normally plagues CFL sales. The second success of the project was the reduction of the evening peak load 15-16%, thus precluding the need for new investments in transmission. The third success of the project was the decrease in electricity consumption in households (up to 30%). The paper presents the results of the measurements and the analysis of cost effectiveness of such DSM projects from the power utility perspective. The paper also discusses the possibility of extending the PELP-DSM experience to other areas of electricity use, such as electric motors.

3 - INTRODUCTION

A characteristic feature of the Polish power sector is the 90% domination of hard and brown coal fuels (Gula et al. 1998). The use of these fuels is accompanied by the emission of greenhouse gases and, despite installation of pollution control equipment, there continue to be significant emissions of particulate matter and gases causing acid rain. An efficient way to reduce those types of environmental damage is the reduction of energy consumption, particularly electricity. The analysis of the energy consumption structure in Poland indicates that the household share in the total energy consumption accounts for 30-40% (Gula et al. 1998). This is a very high value in comparison with highly developed countries, and holds the potential for hitherto only partially exploited energy savings.

Consideration of these facts has given rise to the idea of reducing domestic electricity consumption by replacing traditional filament-bulb lighting with the compact fluorescent lamps (CFL). Such sources consume about one-fifth of the power for the same light output and have a lifetime almost ten times longer. Although the CFLs save energy, consumer resistance to the adoption of more energy efficient lighting products is high. One of the dominating barriers is the relatively high price of CFLs and lack of consumer awareness that the replacement of an incandescent lamp by a CFL is a profitable investment despite the relatively high price of the latter.

As a result of a market study conducted by the Polish Foundation for Energy Efficiency (FEWE) and International Institute for Energy Conservation (IIEC) during 1993, an electricity conservation program: The Poland Efficient Lighting Project (PELP) was proposed. PELP was developed by the International Finance Corporation (IFC) (Ledbetter et al. 1998), the private sector affiliate of the World Bank Group, and funded with 5 million USD from the Global Environment Facility (GEF). PELP was a nationwide program designed to greatly increase the sale of CFLs. One of its four main components was a demand-side management (DSM) pilot. Its description is given below.

4 - PURPOSE OF THE DSM PILOT

The DSM pilot was designed to use CFLs to help introduce DSM to Polish electric utilities, in particular, to introduce the concept of using DSM to defer distribution and transmission investments in the Polish electric system. The idea of using DSM to defer investments in distribution and transmission systems can be placed in the larger context of a utility planning concept known as distributed utilities (DU). The DU concept seeks to identify small-scale “distributed” electric resources both supply- and demand-side that can be alternatives to traditional electric grid and central power station investments. Examples of distributed supply-side resources include small-scale supply-side resources such as diesel generation sets and photovoltaic panels that are installed near local load centres. Examples of distributed demand-side resources include programs and end-use equipment intended to reduce electric loads, such as efficient lighting and electric water heater load controllers. Both these resources are small relative to traditional central generation resources; and they are distributed throughout the electric system, located near the loads they serve. Locating resources near load centres allows electric utilities to avoid or defer expensive transmission and distribution systems upgrades that would otherwise be needed to move power to local load centres from distant central generation power plants.

The DSM pilot was intended to demonstrate to the Polish electric utility industry, in real field conditions, the potential benefits of a demand-side program implemented in a DU analytical framework. Specifically, the pilot aimed to reduce peak power loads in geographic areas where the existing electric power grid capacity was inadequate to meet existing electric loads or soon would be inadequate to meet future load growth.

The DSM pilot was implemented with the help of many organisations, most notably, the Polish Network “Energie Cities”; the University of Mining and Metallurgy in Krakow, the municipal governments of Chelmno, Elk, and Zywiec; and the power distribution companies of Torun, Bialystok, and Bielsko Biala.

5 - IMPLEMENTATION OF THE DSM PILOT

The DSM pilot was initially designed to be led and implemented by selected electric power distribution companies in Poland, but their reluctance to engage in such a role forced the pilot to be redesigned. (Among other things, their reluctance was based on the belief that a project that would result in reduced electricity sales couldn't possibly be good for their business.) The new pilot design depended on the majority involvement and leadership of municipal governments, with power distribution companies providing a supporting role. Municipal governments were thought to be good candidates for majority involvement in the DSM pilot:

_ *they had a strong political interest in reducing the energy costs of their citizens;*
_ *they had a public mandate to engage in activities that improved the environment.*

Three cities and their regional electric utilities were selected to participate in the DSM pilot: Chelmno (a city of about 22,000 inhabitants in north-central Poland), Elk (a city of about 54,000 inhabitants in north-east Poland), and Zywiec (a city of about 35,000 inhabitants in south-central Poland). The cities were selected because they were willing and able to participate and they had areas with grid capacity problems the DSM pilot was designed to address. While the entire areas of all three cities participated in the DSM pilot, several target areas within the cities were established for intensive CFL promotion and electric load analysis.

The backbone of the DSM pilot was a CFL subsidy/coupon system, which was designed to persuade large numbers of people in selected areas to purchase and install CFLs. The cost of CFLs sold through the pilot was subsidised with $100,000 of PELP project funds. The subsidies were directed at participating CFL manufacturers in exchange for their agreement to certain negotiated wholesale prices and delivery arrangements.

The subsidised lamps were made available to the residents of the three cities using discount coupons. There were three types of coupons, labelled A, B, and C. The A and B coupons, which offered the highest price discounts, were delivered only to those residents living in the target areas. The C coupons were delivered to the remaining residents of the participating cities. (A small number of C coupons were also delivered to residents in the target areas.) The subsidy level for each coupon type and the discounted CFL prices are shown in Table 1. In all three cities, the A and B coupons were valid only for the first two weeks of the pilot's operation. This timeframe was established to encourage residents in the target areas to make their CFL purchases quickly so that it would be easier to measure the effect of a massive CFL installation on the electric grids in the target areas (where measurements of electricity use were focused). The C coupons were valid for six weeks, after which the pilot CFL sales ceased.

Table 1. Subsidies (and prices) per coupon and CFL Type (prices are averages over wattages)

CFL Type	**Subsidy (price) by Coupon Type**		
	A	**B**	**C**
Electronically Ballasted (Twin Tube)	4.50 (4.66)	3.50 (5.88)	2.50 (7.10)
Magnetically Ballasted (Glass Enclosure)	3.05 (3.38)	2.40 (3.99)	2.00 (4.96)
With Parabolic Reflector	3.30 (9.62)	2.80 (10.23)	2.00 (11.21)
All subsidies (prices) are given in U.S. dollars, 1 USD = 2.95 PLN			

To achieve a high level of sales at the retail stores, a large-scale public education and promotion campaign was implemented. The campaign included numerous promotional events at local schools, public places, and included installing CFLs in the church of a popular parish priest, after which CFL sales surged.

A high level of CFL sales was achieved in the three cities: more than 33,000 CFLs were sold in six weeks. A large number of CFLs were sold per household, which is especially notable given the low average incomes of the areas involved. Table 2 shows the number of CFLs sold per household in the three cities, as well as in their target areas. Sales per household outside of the target areas (All of Chelmno and All of Elk) were achieved with strict limits on the availability of CFLs that could be purchased with coupons. Sales of CFLs per day to these areas continued to grow strongly until the supply limitation was encountered.

Table 2. CFL Sales per Household

Name of Area	No. of CFLs
Chelmno Target Area: Parkowa 2 (P4)	5.36
All of Chelmno	1.82
Elk Target Area: Zatorze	3.76
Elk Target Area: Centrum	1.78
All of Elk	1.10
Zywiec Target Area	9.66

6 - ELECTRIC LOAD ANALYSIS

A primary goal of the DSM pilot was to determine the impact of the CFL installation on critical locations with capacity problems in the distribution system, including the peak demand, load shape, and energy impacts. Secondary goals of this analysis included the following:

_ developing a way to estimate impacts that can be achieved for various types of residences as a function of the number of CFLs installed per household
_ examining if other end uses could be used as targets for similar programs
_ determining if power quality impacts from CFLs would prevent their use in such high concentrations.

Engineers from the electric power distribution companies in Elk and Chelmno (Torun ZE and Bialystok ZE, respectively) identified the primary trouble spots in residential areas of their distribution systems. These areas had grid components (cables or transformers) whose use was nearing their rated capacities. These neighbourhoods were selected as the target areas for the DSM pilot. The points on the grid serving these areas in Chelmno and Elk were the focus of the electric load measurements and analysis completed as part of this pilot. Load measurements were taken using meters that measured both real and reactive power at each of the grid measurement points. The meters recorded average power over every 15-minute interval. Short-term measurements were also taken of the current harmonic distortion, before and after CFL installation, on the low-voltage (0.4-kV) lines. Measurements were taken continuously for a period of over 100 days, from mid-January to early June, in most cases.

It was known at the outset of the DSM pilot that the measurements would not begin in time to directly measure the peak day (the day of the year when the peak electric load occurs), much less to establish baseline consumption before the peak day. Therefore, the metered data had to be analysed to project both the baseline (pre-CFL) and post-CFL periods back to the daylight and weather conditions of the peak day (January 1).

To analyse the impact that lamp sales from the DSM pilot had on peak electric loads, least squares multiple regression models were constructed that considered influences from outdoor temperatures, daylight availability, cloudiness, evening lighting behaviour patterns, and the fraction of lamp sales achieved to date. These models were tested for each 15-minute period of the day, and a routine was written to select the model form for each 15-minute period that produced the best fit with the measured data. The models that behaved properly and met statistical significance screens were used to predict peak loads on the peak day, both before and after the CFL installation. Reliable grid models were developed for three locations in Chelmno with pure or nearly pure residential loads (P4, P5, and P6). Reliable models were not found for other locations because other locations had significant commercial or industrial loads.

To allow a cross-check of the grid-level analysis, an end-use level analysis was also completed. This analysis was based on data collected from 259 of households and end-use points throughout Chelmno and Elk. The end-use data had two basic types of samples, fixed and rotating. The fixed sample included 30 households each in Elk and Chelmno, which were monitored from February to June of 1997. This sample was intended primarily to allow longitudinal (time series) analysis of changes in lighting and energy use. The rotating sample consisted of about 80 households in each city. A subset of the end-use metering equipment was moved or “rotated” among

households in the rotating sample, monitoring energy and lighting use in each household for about one week. This sample was intended to improve the reliability of the latitudinal analysis (use differences among housing types and demographic groups).
Data collected from the households included the percentage on time, by hour, for all the major lighting points, the rated electric power for each of these lighting points, as well as some smaller samples of percentage on-times and rated power for many other major household electricity users, such as refrigerators, freezers, clothes washers, and water heaters.

Data from the metered residences were used to construct lamp on-time models, which like the grid models, were least squares multiple regression models. They accounted for the seasonal variation in daylight, cloud cover, and temperature and for demographic variation between households, to the extent possible. The process used to develop the lamp on-time models was similar to that used for the grid models in that all possible combinations of variables were considered for each one-hour measurement period for each lighting point measured. The end-use models were used to project lighting load shapes back to the peak day.

Estimates of the per-CFL peak lighting load reductions were produced using lighting load shapes similar to those above, data on the number and wattage of CFLs sold for each of the measured areas in Elk and Chelmno, and a procedure for allocating purchased lamps among the most used lighting points according to their pre-CFL installation installed wattage. Peak savings per CFL are highest in areas where lower CFL penetrations were achieved because most CFLs in these locations are installed in high-use fixtures, such as the kitchen and the biggest room. Residents in locations with higher CFL penetrations installed the additional lamps in lower-use fixtures, such as baths and halls, driving down the per-CFL peak savings.

Table 3 compares estimates of demand savings on the peak day using the grid and end-use models for the P4, P5, and P6 target areas, the areas for which successful grid models were developed. Remarkably good agreement exists between the savings estimates from the grid models and the lamp end-use models, although the savings from the grid model for P4 decline faster in the evening.

During the local peak hour of 20:00 on the peak day of the year (January 1), the end-use savings correspond to a 15% reduction in total electric peak demand for P4, a 16% reduction for P5, and a 15% reduction for P6.

Measurements were also made to assess the power quality impact of the CFL installations in the areas of Chelmno and Zywiec that achieved the highest level of CFL penetration. Measurement in both cities do not reveal any influence on voltage distortion from installing CFLs. Measurements of current distortion in Chelmno reveal a small increase after CFL installation, while measurements of current distortion in Zywiec make conclusions difficult to draw. Measured increases of current on the neutral lines in Chelmno were small, and total current on the neutral lines were still well within safety standards after the CFLs were installed.

Table 3. Peak Demand Savings from Grid and End-Use Models (kW)

Hour	P4		P5		P6	
	Grid	End Use	Grid	End Use	Grid	End Use
1-17	2.7	2.6	0.66	0.32	0.31	0.37
18	22.2	22.0	3.83	3.18	3.32	3.43
19	24.5	22.1	3.60	3.19	3.28	3.45
20	20.8	(a) 24.1	3.8	(b) 3.51	3.10	(c) 3.78
21	14.8	22.8	3.35	3.18	2.98	3.43
22	13.5	18.1	2.80	2.61	2.38	2.82
23	14.3	11.9	2.68	1.69	2.00	1.84
24	9.8	6.2	1.53	0.86	1.35	0.95

(a), (b), (c) 15%, 16%, and 15% reduction in peak demand, respectively.

PANEL 2

7 - DU/DSM ANALYSIS

The monitored grid points were all screened for their suitability to support an analysis of the economic impacts of the DSM program within a DU framework. The P4 area in Chelmno was selected for the analysis based on the successful load analysis modelling results for the site, as well as the availability of the grid characteristics and economic data.

The P4 is at a point on the Chelmno grid that serves 486 flats. The load is almost all residential, except for a 7-kW circulation pump and a small fraction of street lighting (4.4 kW). A single 15/0.4-kV, 250-kVA transformer serves the load centre. The transformer operates during winter peaks at about 75% of its nominal capacity; and because of load growth, it is quickly nearing the time for an upgrade. A spreadsheet model was developed to conduct the analysis. The model is a stochastic model that uses Monte Carlo simulation to simulate many possible future load growth scenarios for P4. A stochastic model was selected because of the highly uncertain nature of local area electric load growth and because it helps capture the value of applying DSM in a DU framework. (The smaller investments and capacity additions associated with DSM allow a utility to better follow uncertain future load growth and to reduce the probability of over-investing in grid capacity). In general, the model develops DSM and grid upgrade investment requirements in response to simulated load growth scenarios and grid characteristics. It then calculates, for both a No DSM scenario and a DSM scenario, the net present cost of the investments and produces results in the form of probability distributions of those costs. The model accounts for grid energy losses and can produce results for 1 to 20 year investment horizons. To mimic the highly uncertain future load growth for the P4 site, a probability distribution was defined and then used to produce sample future load growth scenarios for the model. A truncated normal distribution was used, with a mean of 4.5%, a maximum value of 9%, and a minimum value of 0%. Expert judgement was used in defining the distribution rather than fitting a distribution to historic data because the economy and residential electricity use is changing so rapidly that historic load growth data are of little use in projecting future loads.

Cost data on investment options were also obtained for both grid upgrades and the DSM pilot. Grid upgrade costs were obtained from Torun ZE, and costs for the DSM pilot were estimated assuming that Torun ZE paid all the costs for program implementation and did not conduct the research program described in this report. In other words, the costs for the DSM pilot were estimated as if the program were being implemented in the normal course of business by Torun ZE. Calculating the costs in this manner resulted in a per-CFL program cost of 13 Polish zloty (4.40 USD), (This estimate does not include the purchase price of CFLs, nor the costs of retailing them, as in the DSM pilot, these costs were paid by the residents).

The model also accounted for lost net revenue that results from selling less electricity after CFLs are installed. Using lighting load shapes, estimates of per-CFL reductions in electricity use were produced by hour for each month of the year, yielding per-CFL lost revenue. The cost of purchasing electricity to supply these lighting points was also estimated by hour and by month of year, which was then subtracted from the lost revenue estimates to yield net lost revenue. Given that residential lighting is primarily consumed during evening peaks, when the power purchased by Polish electric distribution companies is most expensive, net lost revenue is much lower than the lost revenue estimate (about one-third for P4).

The first and most important question addressed in the DU/DSM analysis was if this had not been a research effort and if Torun ZE had paid all costs of promoting and distributing the CFLs in the P4 area, would this program have been a cost-effective investment for Torun ZE? This analysis strongly indicates the answer is “yes.”

Figures 1 and 2 illustrate possible future net present cost outcomes and their probabilities, assuming a 10-year analysis horizon, for both a DSM and No DSM scenario. The plots for the DSM scenario reflect the net present costs of grid upgrades, DSM program costs, and net lost revenues from pursuing a strategy of implementing the DSM pilot in the first year and then upgrading the grid only when subsequent load growth consumes existing grid capacity at P4. Similarly, the No DSM scenario plots reflect the net present costs of only grid upgrades, based on pursuit of a “business-as-usual” strategy. Figure 1 contains histograms of the probability distributions for the two scenarios. As shown, the mode (most likely cost) of the distribution for the DSM scenario occurs at about 47,000 USD and has a probability of occurrence of about 20%. On the other hand, the mode of the No

DSM distribution is substantially higher, at about 57,600 USD, and has a much higher probability of about 45%.

Figure 2 contains cumulative probability distributions for the two scenarios, indicating for each point on the curves the probability that the net present cost will be less than the cost associated with that point on the curve. Figure 2 also shows the probable savings from implementing a DSM strategy instead of a No DSM strategy. (The savings curve is the difference between the net present costs of the DSM and No DSM scenarios.)

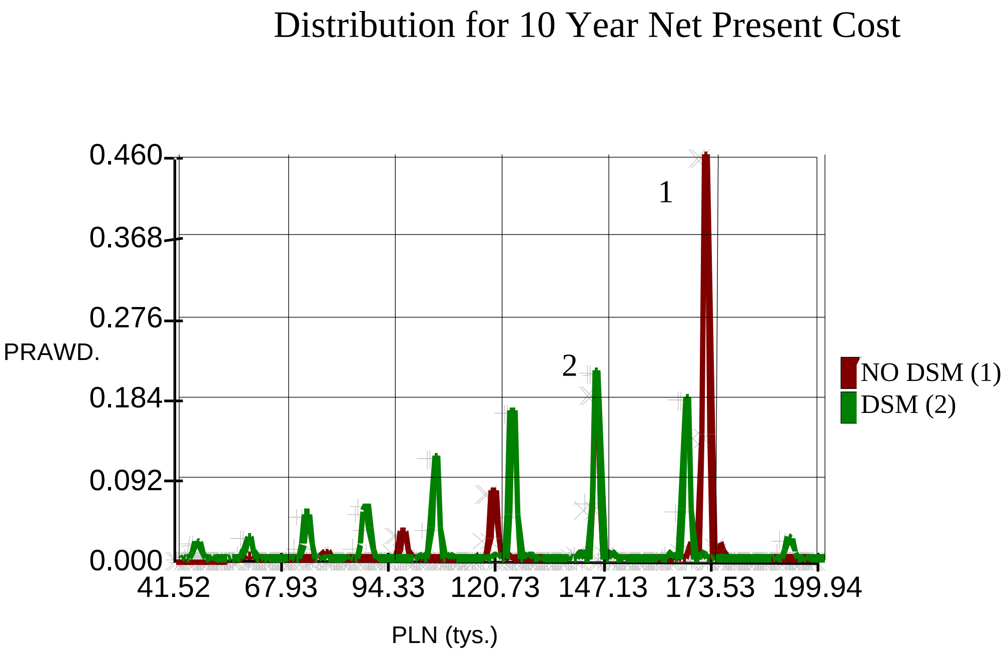

Figure 1. *Net Present Costs and probabilities of occurrence over 10 - Years.*

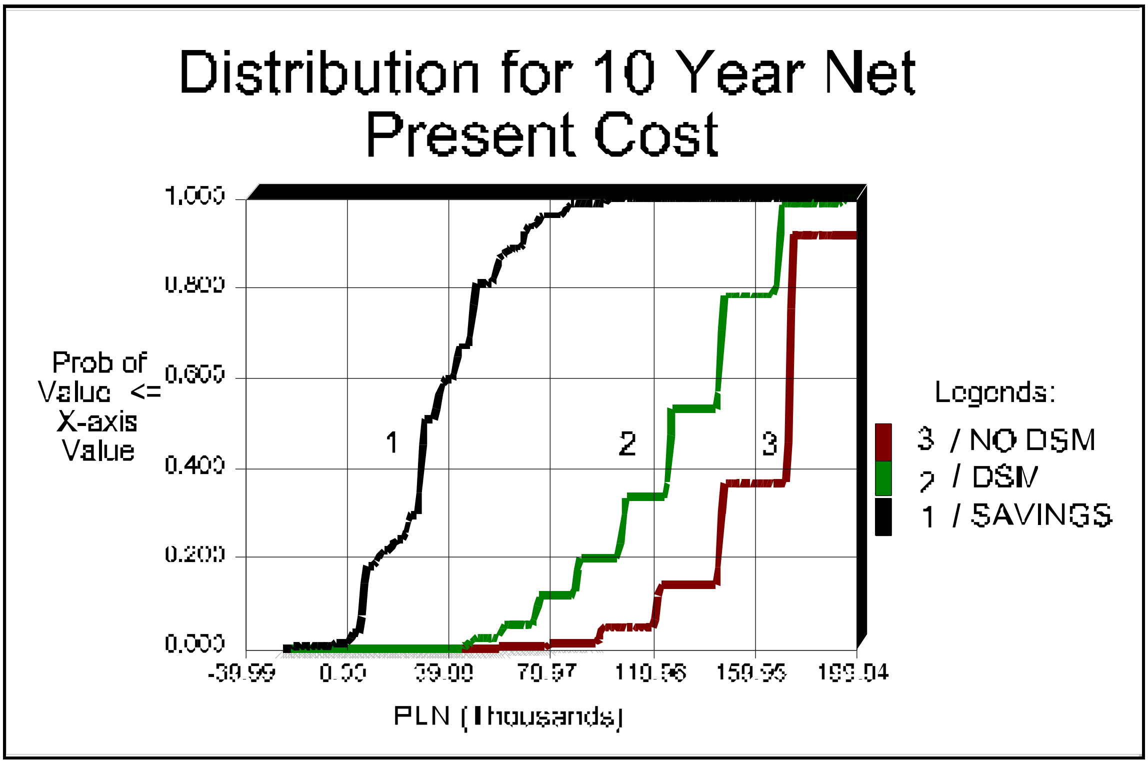

Figure 2. *Cumulative Probability Curves Over a 10-Year Period*

Statistics for the distributions plotted in Figures 1 and 2, as well as distributions for the same analysis using a 5-year analysis horizon, are summarized in Table 4. Table 4 also provides statistics for the probability distributions of the years in which the first (#1) and second (#2) grid upgrades are required for each scenario.

Table 4. ***Summary Statistics for Model Runs with the PELP DSM Pilot***

Net Present Costs	Name	Min.	Mean	Max.	Std. Dev.
	5 Year/No DSM	0	83,680	123,347	26,307
	5 Year/DSM	27,559	43,840	95,380	19,120
	5 Year/Savings	-27,715	39,840	95,652	21,221
	10 Year/No DSM	41,524	160,187	199,936	26,600
	10 Year/DSM	44,990	126,922	191,214	34,203
	10 Year/Savings	-25,654	33,265	112,196	22,598
Year of Upgrade	Upgrade #1/No DSM	1	2	8	1
	Upgrade #1/DSM	3	6	16	2
	Upgrade #2/No DSM	11	NA	>20	NA
	Upgrade #2/DSM	12	NA	>20	NA

As clearly shown in the above statistics, it is highly probable that a DSM strategy results in lower net present costs than a No DSM strategy for the P4 site.

A sensitivity analysis of these model runs, which tested the possibility that all critical model inputs had been substantially overestimated in favour of the DSM scenario, indicated that for a five-year analysis horizon, DSM still substantially outperforms the No DSM strategy. For the ten-year horizon, however, the No DSM strategy slightly outperforms the DSM strategy.

Model runs were also completed for a set of DSM programs, including the DSM pilot and two hypothetical programs that were developed partly from the load research on other residential end uses. These runs were completed to test the longer-term benefits of using DSM in a DU utility framework. For the runs done on the DSM pilot by itself, the DSM scenario outperformed the No DSM scenario and more generally indicated a substantial opportunity for cost effectively deferring distribution system upgrades by implementing DSM programs.

This analysis only considered the cost of deferring investments at a low point on the grid and did not include the substantial value of deferring investments at higher points on the grid. The value of deferring investments at higher points on the grid, as well as deferring investments in generation resources, can become quite large if DSM programs are more widely implemented in the service territory of Torun ZE. This preliminary look at the value of implementing these types of programs over a longer time period should encourage Polish distribution system planners to consider a more through evaluation of the opportunity.

8 - POSSIBLE EXTENSIONS TO OTHER END-USE AREAS

As mentioned in the beginning, the project’s features and successes can be replicated for other electricity end-uses, in particular electric motors. The PELP project demonstrates that a subsidy at the manufacturer level can result in dramatic cost savings. Combined with an education and information campaign, consumers can realise the benefits of investing in an energy efficient product in order to reduce electricity bills. The short-term subsidy will not help introduce customers to a new project, but could lower costs over the long term by increasing demand.

Electric motors and transformers consume a large fraction of electricity in Poland. According to, the consumption in the industrial sector alone amounts to 35 TWh/y, which contributed to about 56% of the total consumption in 1996 (72.4 TWh). If one assumes (Wlodek 1995) that the identified savings potential in the replacement of the existing motor stock in the range of 3 to 120 kW with modern energy-efficient motors is about 3.3 TWh/y, then the decrease of the associated CO_2 emissions into the atmosphere would constitute a significant contribution to Poland’s greenhouse gas emission reduction declared at Kyoto.

In the case of electric motors, an essential factor is economic benefits, which are seldom realised by industrial decision-makers responsible for purchases of electrical equipment. The energy-efficient motors are more expensive than traditional ones, notably due to the high copper content (HCC), which reduces energy losses. Nevertheless, usually the dominant decision-making factor is minimisation of investment costs only and many choose the option of the lowest initial cost. However, in order to minimise the total cost planning for the purchases of new electrical motors, one should take into account both the purchase cost and the total exploitation costs over the lifetime of the investment. It is very important to realise that the latter costs typically exceed the price of a new motor by a factor of 100 (Wlodek 1995). These observations may lead one to apply the experience of PELP to electrical motors (for brevity let us dub this idea PEMP = Polish Efficient Motor Project).

Despite obvious differences, PEMP would have a number of common features with PELP:
1. convergence of global environmental goals (CO_2 emission reduction)
2. possibility to cost-effectively defer the investments of the electricity supply grid (Gula et al. 1998);
3. economic benefits for the electricity user;
4. the need for an intensive educational and informational campaign;
5. existence in Poland of production capacity of efficient motors (which are presently exported to Western countries) with limited domestic demand (as with the situation of CFLs manufactured in Poland before PELP); and
6. the need for a market push by a temporary reduction of price to increase the demand.

The most essential lesson is that a market push provided by a temporary subsidy provided at the „factory gate” to the manufacturers is an economically effective mechanism that substantially reduces the retail prices due to reduction of wholesaler and retailers mark-ups and VAT. Due to the above-mentioned environmental benefits, it is worth considering to make interested in PEMP the grant sources like those that provided funding for PELP.

9 - REFERENCES:

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