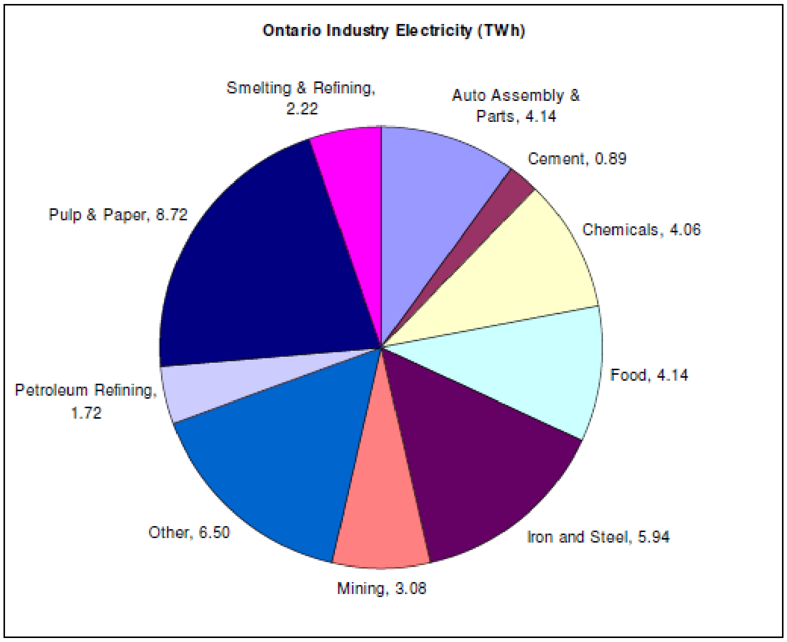
Enabling a Systems Optimization Strategy for Industrial Energy Efficiency

Andrew Smith, Ontario Power Authority
Parminder Sandhu, Willis Energy Services Ltd.
Sean Brady, Ontario Power Authority

ABSTRACT

In the province of Ontario, industrial customers account for approximately one third of total electricity energy consumption in the province and one quarter of coincident peak demand amounting to an expected 6,000 Mega-Watts (MW) of industrial peak demand by the end of 2010. A group of less than one-hundred large companies consume approximately half of the electricity energy in the Ontario industrial sector, primarily large industrials involved in resource extraction activities. The remaining industrial electricity consumption in Ontario is consumed by thousands of smaller entities across the province. A summary of Ontario industry electricity consumption is illustrated in figure 1 (Keyes et al., 2006, 9).

Figure 1. – Ontario Industrial Electricity (TWh)



This paper will discuss the research and analysis undertaken in the development of a holistic industrial energy efficiency strategy focused on enabling system-oriented electricity energy savings. The strategy suggests that significant savings can be enabled through a focus on capacity building in concert with system-oriented process optimization strategies.

Two key challenges in designing the strategy were 1) addressing the diversity of activities in the sector and; 2) addressing the low levels of capability and capacity in industrial conservation and demand management (CDM) resources due to the lack of a coordinated or resourced CDM electricity strategy in the sector for some time.

Introduction

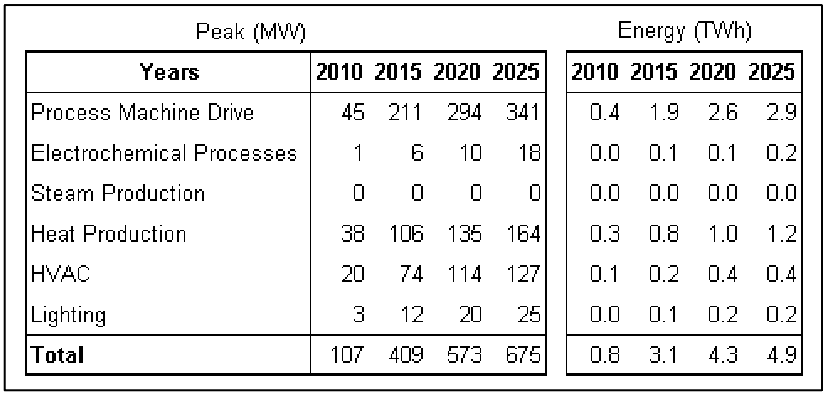
The Ontario Power Authority (OPA) was established under the Electricity Restructuring Act (2004) and began operations in January 2005. A not-for-profit corporation without share capital, the OPA is governed by an independent Board of Directors appointed by the Ontario Minister of Energy and Infrastructure, and its activities and programs are directed by a Chief Executive Officer. The OPA reports to the Ontario Legislative Assembly through the Ontario Minister of Energy and Infrastructure and is licensed and regulated by the Ontario Energy Board.

The OPA's mandate is to ensure an adequate, long term supply of electricity in Ontario. In pursuit of this mandate, activities are focused on the following three key areas:

- Building a conservation culture across Ontario;
- Ensuring the development of needed generation capacity;
- Long term power system planning;

The vision of the OPA is the development of a sustainable, competitive and reliable electricity system for the benefit of Ontario consumers (OPA, 2009). A key component of the OPA's activities is to deliver 6,300 MW of total peak demand reduction by the year 2025. In data submitted to the Ontario Energy Board as part of the power system planning process in 2008, the OPA identified an industrial energy efficiency target of 675 MW for 2025 as shown in figure 2 (OPA, 2008).

Figure 2. – Industrial Energy Efficiency Targets



	Peak (MW)				Energy (TWh)			
Years	**2010**	**2015**	**2020**	**2025**	**2010**	**2015**	**2020**	**2025**
Process Machine Drive	45	211	294	341	0.4	1.9	2.6	2.9
Electrochemical Processes	1	6	10	18	0.0	0.1	0.1	0.2
Steam Production	0	0	0	0	0.0	0.0	0.0	0.0
Heat Production	38	106	135	164	0.3	0.8	1.0	1.2
HVAC	20	74	114	127	0.1	0.2	0.4	0.4
Lighting	3	12	20	25	0.0	0.1	0.2	0.2
Total	107	409	573	675	0.8	3.1	4.3	4.9

In order to acquire these reductions in industrial electricity consumption, the industrial and Demand Response Group of the OPA's Conservation and Sector Development Division was tasked with researching the best methods and requirements for accessing industrial energy efficiency in the province of Ontario.

This paper summarizes some of the background research, analytical work, and stakeholder conversations that have formed the basis of the strategy development to this point. These activities indicate that the most effective strategy for capitalizing on industrial energy efficiency is to pursue in combination both: a) system optimization savings; and b) enabling efforts that increase the capability and capacity to provide systems focused solutions in industrial entities and their service providers.

Background

The Systems Approach

In industrial applications, electricity consuming devices are most commonly embedded into systems integral to the industrial process itself. Typical end uses include compressed air, pumping and fan systems. In the case of a pumping system, a prescriptive approach may focus on improving the efficiency of the individual components, such as replacing the pump motor with a more efficient version or replacing the pump impeller with a more efficient impeller for the operating conditions. The systems approach may instead look at the purpose of the pump system within the context of the broader industrial process. As Shipley and Elliott (2006) note "Whereas twenty years ago, simply replacing an inefficient standard model with a more efficient product may have provided improvement, today the least expensive opportunity may be how motor systems are managed".

By understanding the uses of the fluid being pumped within the system context and determining what duty cycles, flows, temperatures and pressures are actually required – as well as understanding the industrial process itself to determine key parameters that could be modified or optimized – it may be possible to substantially improve the efficiency of the entire pumping system through identification of particular design and operational requirements.

For example, Lovins, Lovins, and Hawken (1999) describe an engineer at Interface Corporation who realised that some simple design changes to a proposed pumping system being designed for installation in a factory at their new Shanghai facility would result in a 92% reduction in the required pumping horsepower. Furthermore, "His redesigned system cost less to build, involved no new technology, and worked better in all respects.".

Pursuing system optimization and improvements may require a higher degree of effort and technical expertise than a more prescriptive component-replacement approach. However, research suggests that the systems optimization approach will result in significant savings being delivered. McKane, Price, and de la Rue du Can (2007) assert that, "Optimizing industrial systems has a cost-effective improvement potential of 20% or more for motor systems and 10% or more for steam and process heating systems". Later in the same piece the authors state that "System optimization offers a way for companies to quickly realize cost, productivity, and operational benefits that can provide the reinforcement needed for management to proceed with the organizational changes required to fully integrate energy efficiency into daily operational practices."

Defining System Optimization Measures

The team at the OPA felt that to appropriately pursue system optimization activities, there was a need to understand in more depth the types of typical system optimization activities expected to occur in industry. The decision was made to focus the next stage of the strategy development on collection of data and the development of an analytical model of typical expected real-world system optimization approaches. The ultimate objective of this stage was to determine what kinds of capital, operational and implementation costs might be incurred in such applications, and the expected electricity savings that would be generated.

During the summer of 2007, the OPA contracted with Willis Energy Services Ltd. (Willis), Vancouver, Canada, to develop generic system level technical specifications and business case parameters for process optimization system improvements applicable to industrial entities in Ontario. Some suggested technology areas to be considered were listed in the initial Request for Proposals and included:

- Compressed air system optimization;
- Process cooling system optimization;
- Pumps/fans and blowers system optimization;
- Motors and drives system optimization;
- Monitoring and targeting of process energy consumption;
- Other - general process optimization including process control and instrumentation.

In the preliminary meetings with Willis, it was agreed that the analysis should focus on developing the following characteristics for each system optimization:

- The expected MW and MWh savings from each system improvement.
- Expected interaction effects (savings/increased usage) for each system improvement on consumption of other resources such as fossil fuels, water, etc.

Typical costs for installation were to include:

- Pre-project technical assessment costs;
- Capital requirements to install the base case versus the energy efficient case;
- Ongoing maintenance costs for the base case versus the energy efficient case.

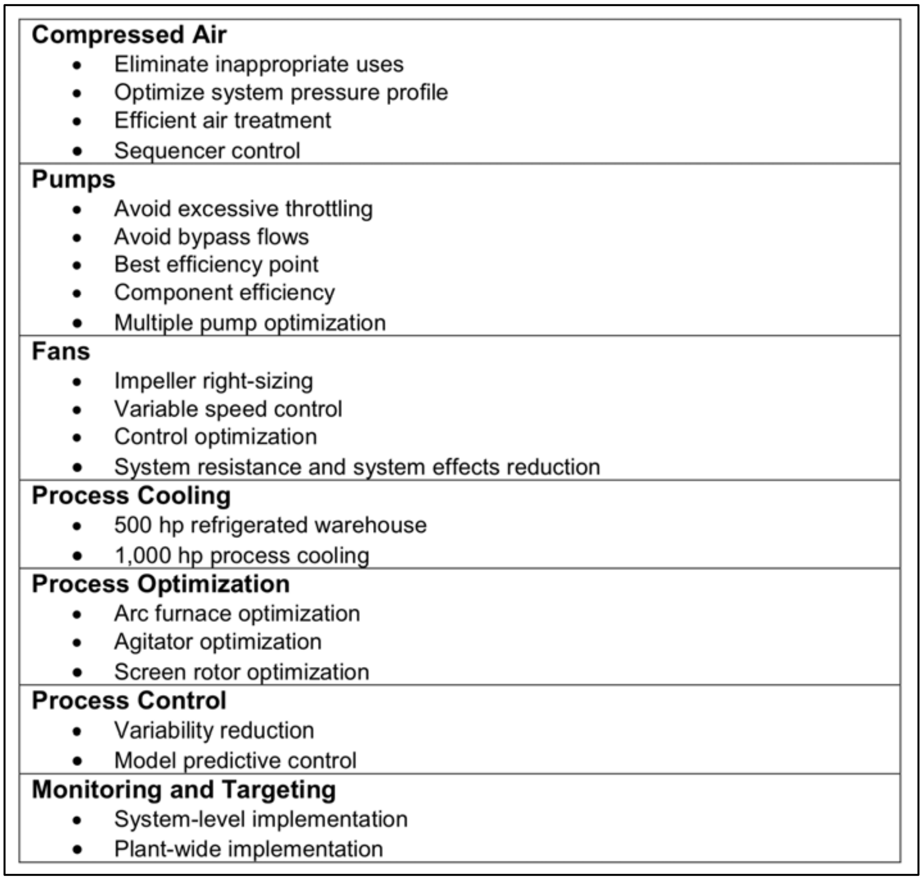
Measures were to be selected to ensure applicability to as many sub-sectors within the broader industrial sector as possible. A summary of the various end-use technologies and associated measures Willis provided to the OPA for further modeling are listed in figure 3 (OPA, 2007). The measures listed represent a total of forty-two individual measures. Process cooling comprises eleven measures applied in to the two different system configurations listed in the table under process cooling for a total of twenty-two process cooling measures. Twenty other measures make up the balance of the table. The applicability of each individual measure was also assessed for both small to medium-large and large facilities, and adjusted accordingly.

An assumption was also made that the system sizes would be adjusted relative to the expected size of the facility they may reside in. For example, in the case of a small compressed air system, the installed system size was assumed to be 250 horsepower (hp) whereas for a large compressed air system, the installed system size was assumed to be 1000 hp or more. Medium sized systems were assumed to have multiple small systems. Facilities were also classified as ‘small’ for those below 1 MW of maximum annual peak demand, and ‘large’ for those in excess of 1 MW maximum annual peak demand.

Another key assumption made by the team was that the system optimization approach would result in projects that bundled various system optimization measures together. For example, a system optimization project focused on compressed air may begin with the elimination of improper uses. With the overall system optimization objective in mind, it may then be optimal to revisit the system pressure profile and likely also include sequencer control adjustments. Some of the data evaluated is summarized by system optimization type in figure 4.

Finally, each system optimization measure was analyzed for the difference in impacts and costs that may occur as a result of an end-of-life replacement versus an early retirement strategy.

Figure 3 – System Optimization Measures



Compressed Air

- Eliminate inappropriate uses
- Optimize system pressure profile
- Efficient air treatment
- Sequencer control

Pumps

- Avoid excessive throttling
- Avoid bypass flows
- Best efficiency point
- Component efficiency
- Multiple pump optimization

Fans

- Impeller right-sizing
- Variable speed control
- Control optimization
- System resistance and system effects reduction

Process Cooling

- 500 hp refrigerated warehouse
- 1,000 hp process cooling

Process Optimization

- Arc furnace optimization
- Agitator optimization
- Screen rotor optimization

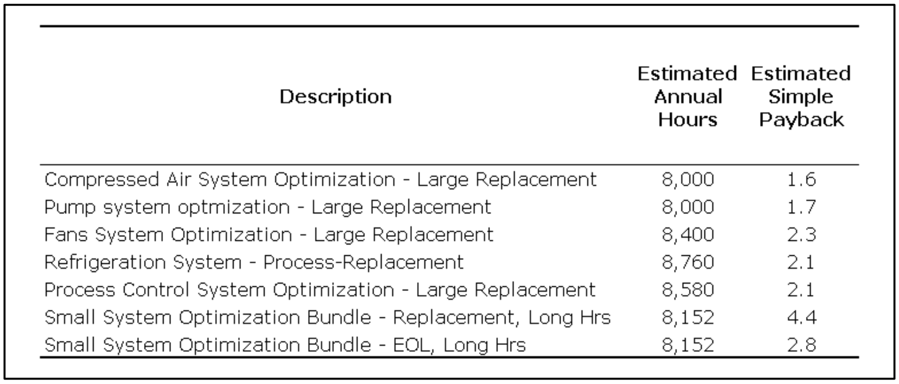
Process Control

- Variability reduction
- Model predictive control

Monitoring and Targeting

- System-level implementation
- Plant-wide implementation

Figure 4 – System Optimization Characterization



Description	Estimated Annual Hours	Estimated Simple Payback
Compressed Air System Optimization - Large Replacement	8,000	1.6
Pump system optmization - Large Replacement	8,000	1.7
Fans System Optimization - Large Replacement	8,400	2.3
Refrigeration System - Process-Replacement	8,760	2.1
Process Control System Optimization - Large Replacement	8,580	2.1
Small System Optimization Bundle - Replacement, Long Hrs	8,152	4.4
Small System Optimization Bundle - EOL, Long Hrs	8,152	2.8

Marketplace Capability and Capacity

In June 2007, the OPA hosted an industrial Energy Conservation Roundtable Discussion with thirteen stakeholders from across the industrial sector. Representatives from several industrial organizations participated in the session with a federal perspective provided by Natural Resources Canada. The half day session featured a formal presentation of the proposed concept for the Ontario industrial energy efficiency strategy; a group discussion on potential industrial energy efficiency strategies; a structured dialogue on technology, capability building and energy assessments; and a group exercise on technology and capability building measures.

Capability building measures were the most prominent consideration for the majority of stakeholders. Stakeholder interests included: support for raising awareness of energy and non-energy benefits; pooling their efforts together; and achieving executive level management buy-in. The discussion raised two specific challenges seen as key to their success in industrial energy efficiency. First, how to access credible industrial energy efficiency technical support, both from an external and internal perspective, and second, difficulty justifying the costs of sub-metering equipment often required to determine system optimization savings potential and impact. Sub-metering equipment is often fairly expensive and installation of sub-metering systems will not in itself produce energy savings. This creates a [circular] problem of not having the data to justify the investment in energy savings efforts but not having the energy savings to justify the expense of the sub-metering equipment required to attain the data.

The need to develop marketplace capabilities as identified in stakeholder consultations is also described by McKane, Price, and de la Rue du Can (2007) as follows: “Capacity-building training creates a cadre of highly skilled system optimization experts that can provide the necessary technical assistance for industrial facilities to identify and develop energy efficiency improvement projects…. After more than a decade of capacity-building, experts trained by the United States Department of Energy continue to identify millions of dollars in system optimisation improvement opportunities year after year. In 2005 alone, the Save Energy Now initiative documented 55 PJ in energy savings in the first 200 plant assessments, or $475 million in cost savings. Many of the recommended improvements had paybacks of less than 2 years.”.

Some specific measures that OPA stakeholder group believed could positively impact the issue of capability and capacity in the industrial energy efficiency marketplace include:

- Support for energy assessments and feasibility studies. Energy assessments allow a facility to get external expertise to evaluate the overall status of their energy consumption activities and provide some preliminary direction for improvement, while a feasibility study allows a technical expert to focus on studying and optimizing a particular system within the facility for energy efficiency. By making energy assessment and feasibility funding available to the technical community, it is hoped that more engineering firms would direct their efforts at these activities and assist in building marketplace capacity in these skilled areas.
- Directing training and awareness programs at system optimization efforts, focusing initially on opportunities in compressed air and pumping systems. By giving broad access to industry leading technical expertise, existing experts in the consulting and distribution/manufacturing roles would be given the opportunity to increase their own

knowledge, while the projects themselves would move forward as a result of these training and awareness sessions.

- Embedding energy efficiency into businesses through salary support for internal personnel focused on industrial energy efficiency. The focus here would be to assist larger industrial entities or groups of smaller industrials who are able to collaborate, to justify assigning a full-time resource to working on the development of an energy management plan for the organization or group of organizations. The advantage of supporting an internal resource is that this individual will have intimate knowledge of the industrial process at the facility; the business structure; the business culture; and values and priorities that an external consultant would have difficulty understanding during typical consulting assignments. By embedding the resource in the business structure, there is a higher likelihood that the concepts and ideas the resource raises would get incorporated into day to day business activities.
- Monitoring and targeting is an approach that allows an entity to measure and analyze their energy consumption on an ongoing and structured basis, while continuously improving their performance relative to their former activities. Traditionally, justifying the business case for monitoring and targeting hardware and software is challenging as the initial costs can be significant, with the actual results occurring only after implementation and significant effort has transpired. Financial support for monitoring and targeting efforts would allow business entities to justify funding for sub-metering efforts that would allow energy managers and technical experts to more readily identify and focus on potential energy management activities.

Although none of these activities on their own is particularly revolutionary, however the group felt that in the past these activities had not been integrated into a holistic approach that would allow the various components to leverage and maximize impact. This was felt to be the key learning from the stakeholder approach that the success of industrial energy efficiency requires as much effort to overcome capacity and capability in the marketplace to implement energy efficiency efforts as it does to overcome the financial barriers addressed through incentives for system optimization measures.

It is expected that in concert with an effective systems optimization approach, these capacity and capability building efforts will enable further savings that would not have occurred otherwise. As technical expertise is built through these enabling activities, the expectation is that many projects will be identified that make good business sense to pursue without any further need for direct support other than the enabling activities already described.

The Modeling Approach

Upon determination of the types of system optimizations to be considered, and with an expectation that significant savings can be enabled through capability building efforts, the next phase focused on by the team was how to model the strategy holistically. The objective of the modeling was to estimate expected incentive levels that may be required to incent the various system optimization measures identified in the first phase by Willis. The resultant model was used to estimate the expected electricity savings as well as the expected incentive levels and total funding requirements for budgeting. Some of the key assumptions included:

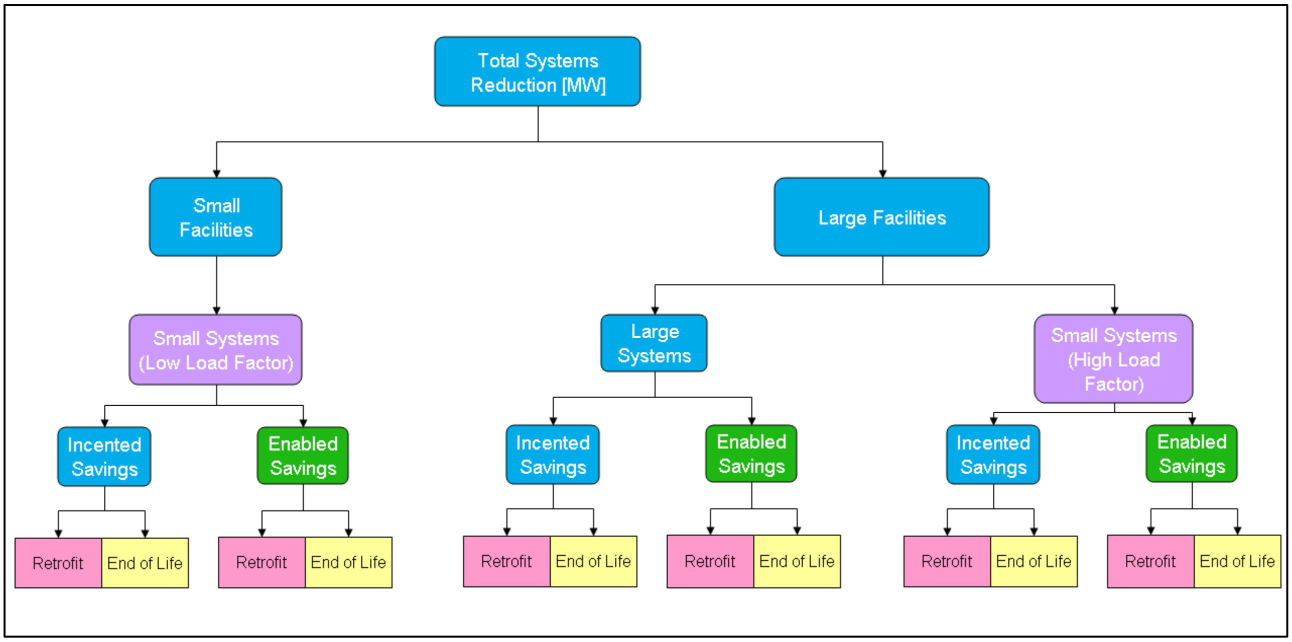
- The majority of the savings would be achieved in industrial installations from large facilities. This assumption is driven by the underlying logic that larger facilities will generally house larger electricity consuming systems, and so the systems would be expected to deliver higher absolute demand and energy savings at the same percentage savings rate as smaller systems. In addition, within the large facilities:

    - most of the savings generated would come from system optimization measures applied to large systems with high load factors, with some savings occurring from system optimization measures performed on small systems with high load factors. Larger facilities will generally have longer operating windows (more likely 24/7 types of operations), thus leading to high load factors for resident systems. Since the facilities are larger in scale, they would be assumed to contain more of the larger systems. However, the smaller systems resident in the facility would also be expected to run for longer periods of time each year.
    - Some of the savings would come purely through system optimization activity resulting directly from applications for energy incentives and some savings would occur as a result of enabling activities. For example, a manufacturing plant may apply for an energy incentive to optimize their compressed air system through application of a variable speed drive and also apply for an enabling incentive such as monitoring and targeting to work on improving their compressed air system's performance on a day to day basis. As a result of the monitoring and targeting incentive, they do in fact achieve direct energy savings that would not have occurred without this activity taking place.
    - The savings would further be affected if a system optimization measure was considered a replacement or retrofit or if it was occurring at the end of life of the original system. However, there are many other barriers to promoting replacement and retrofit of systems. Generally replacement and retrofit approaches will also incur higher costs and higher resistance from plant personnel who prefer not to see changes to their processes if at all possible. However only focusing on end of life retrofit instances will likely dramatically reduce the basket of potential opportunities as industrial systems generally have significant useful lives and are often extended far beyond the equipment manufacturer's expected or recommended lives.

- The remainder of the savings would come from small to medium facilities where the savings would all result from small system optimization projects with low load factors. Similar to the process applied to the large facilities, some savings were assumed to occur via enabling or incented activities, and further through either end of life replacement or in-place replacement assumptions within enabling or incented activities.

The logic model developed in this exercise is shown in figure 5 (OPA, 2007).

Figure 5 – Modeling Structure



Using the Model to Develop a Budget

The model described in the previous section then allowed the team to simulate various scenarios and determine key outputs in a timely fashion. Some of the key inputs include:

- The incentive level in cents per kilowatt-hour for incented savings. This incentive is applied to the first year of energy savings from each system optimization measure as identified by Willis and listed in figures 3 and 4;
- The minimum simple payback to which incentives would be applied. This parameter is used to limit the total absolute incentive to a maximum that would be required to reduce the simple payback of the undertaking to a minimum number of years. Simple payback here refers to the expected number of years it will take to recover all the installation costs associated with implementing the particular measure through savings generated as a result of the measure implementation;
- The percentage of projects expected to fall between small and large facilities where small facilities were designated as those less than one MW of maximum peak annual demand and large facilities as those with more than one MW of maximum peak annual demand;
- The all-in electricity price for each of small and large facilities. This was used in the calculation to determine the level of savings that would be generated from electricity cost savings as a result of the measure implementation;
- The percentage of projects in large facilities (greater than one MW of maximum peak annual demand) that would occur from large system optimizations versus small system optimizations;
- The percentage of projects that would occur as enabled projects versus incented. Enabled projects were modeled in the same manner as incented projects, merely without an incentive. In other words these are projects that would be expected to occur as a result of

the enabling activities of a holistic energy efficiency strategy and not purely through directly incenting energy efficiency projects. The energy savings generated through enabled project savings then become the justification for the cost-effectiveness of the various enabling activities such as energy assessments, feasibility studies, monitoring and targeting, etc;

- The percentage of projects expected to be end of life projects versus replacement or retrofit projects.

The model was implemented into an Excel spreadsheet. For each scenario, the model used the various inputs discussed and the system optimization measures listed in figures 3 and 4 to estimate the total number of system optimization projects required for ‘small’ and ‘large’ facilities as illustrated in figure 5. The key outputs of each model run included:

- Total number of projects required;
- Total energy savings generated;
- Total expected customer costs;
- Total required incentive costs.

The model also performed a total resource cost analysis using the model outputs. The mode output was critical in being used to determine the cost-effectiveness sensitivity of various scenarios and the likelihood of meeting various levels of energy efficiency. The model also allows for a logical methodology to assign enabled activities to actual savings.

Conclusion

This paper has summarized the background research, analytical work, and stakeholder dialogue that have formed the basis of a holistic system optimization industrial energy efficiency strategy to this point.

The effort has resulted in a proposed new methodology for systematically and holistically approaching the budgeting and electricity savings analysis of both system optimization measures and enabling activities in the context of a broad industrial energy efficiency strategy.

The new methodology has highlighted an approach to modeling energy savings and costs that may be incurred in the implementation of a holistic system optimization industrial energy efficiency strategy. Some of the key modeling approaches include allocation of energy savings and costs to different sized systems and plants, and allocation of energy savings to different types of energy efficiency efforts – directly incented system optimization measures and indirectly incented enabled system optimization measures.

The OPA believes that this approach is fundamental to the successful implementation of any industrial energy efficiency strategies. However, the OPA recognizes that there will still remain many uncertainties about the success of this approach. One key challenge will be to track, measure and verify enabled energy system optimization costs and savings since in many of these cases the projects may occur in absence of any interaction with a particular customer. Other barriers to the success of the strategy include no direct effort to target executive level leadership recognition and buy-in. Research and the stakeholder group identified executive level leadership as a key barrier to successful industrial energy efficiency activities. Another significant barrier to the success of the strategy will be the ability to enrol enough appropriate technical resources to support the overall effort who have a high level of expertise to effectively lead and implement challenging system optimization efforts.

References

Keyes et al. 2006. "Market profile and conservation opportunity assessment for large industrial operations in Ontario." http://www.conservationbureau.on.ca/Storage/14/1907_Market_Profile_and_Conservation_Opportunity_Assessment_For_Large_Industrial_Operations_in_Ontario.pdf

Lovins, A., Lovins, L., and Hawken, P. 1999. "A Road Map for Natural Capitalism." *Harvard Business Review on Green Business Strategy,* (2007).

McKane, A., Price, L., and de la Rue du Can, S., 2008. "Policies for Promoting Industrial Energy Efficiency in Developing Countries and Transition Economies." http://www.unido.org/fileadmin/media/documents/pdf/Energy_Environment/ind_energy_efficiencyEbookv2.pdf

Ontario Power Authority. 2006. http://www.powerauthority.on.ca/Storage/23/1870_IPSP-June13%2C2006.pdf

Ontario Power Authority. 2007. Technical Analysis and Total Resource Cost Model for an Industrial Custom Incentive Strategy for Ontario.

Ontario Power Authority. 2008. http://www.powerauthority.on.ca/Storage/53/4869_D-4_Att_4_corrected_071019.pdf

Ontario Power Authority. 2009. http://www.powerauthority.on.ca/Page.asp?PageID=861&SiteNodeID=118

Shipley, A., and Elliott, R., 2006. Report Number IE061. American Council for an Energy-Efficient Economy.