Prospecting for Gold with the HVAC Applications Matrix

Irfan Rehmanji, BC Hydro
Jack Callahan and Tyler Dillavou, Bonneville Power Administration
Jay Madden, Southern California Edison
Jonathan Livingston, Livingston Energy Innovations, LLC

ABSTRACT

North American energy utilities and other organizations that promote energy efficiency (EE) can benefit from technology and market opportunity assessments to support decision-making for optimal program design and marketing. Because comprehensive assessments that cover a wide range of existing and emerging technologies can be costly and time-consuming, they may be delayed until later stages of program development or deferred completely. A simple assessment approach that isolates a subset of technology and market criteria can help prioritize opportunities before the start of program design and marketing.

In 2010, BC Hydro developed the Lighting Applications Matrix, a simplified framework for better decision-making around alternative lighting energy saving options in commercial-use buildings. By accounting for building stock characteristics, this tool enabled identification and prioritization of technology and market opportunities that could form the basis for lighting program design and marketing. Further, projected market and regulatory trends included in the Lighting Applications Matrix generated insight into the timing and likely conservation value of rebate programs, building codes, and product standards.

Based on the success of the Lighting Applications Matrix, Bonneville Power Administration and Southern California Edison joined BC Hydro in adapting this approach for heating, ventilation, and air conditioning (HVAC). This paper describes the framework and methods used to develop the HVAC Applications Matrix and presents sample results for each of the utilities. It also suggests areas for future improvement, including options for applying the framework to other utility regions and energy efficiency measures.

Background

To create viable portfolios of energy saving measures, energy utilities are constantly prospecting for gold — those EE products and services that generate the most benefit for customers and the greatest cost-effective impacts from rebate program spending. Standard practice calls for commissioning comprehensive, multi-year, and costly energy efficiency market potential studies that point program managers to promising opportunities at a macro level. For instance, a broad EE market potential report may cost hundreds of thousands of dollars to complete. Efforts in the Pacific Northwest to develop spreadsheet-based energy savings and supply curve models have led to layers of complexity and multi-year efforts to approach desired levels of precision. However, the EE industry lacks a systematic, easy-to-use, and rapid process to guide creation of targeted, high-impact programs for specific markets.

Facing this challenge, BC Hydro developed a novel solution: the Lighting Applications Matrix. The Lighting Matrix uses the capabilities of a spreadsheet to mash up[1] two different types of information: estimates of electricity consumed by lighting equipment currently used in commercial buildings and expected energy savings by applying emerging EE lighting technologies. This mash up identifies combinations of measures and types of customers in BC Hydro's service area that offer important program opportunities over the next few years. Although this method is less rigorous than a comprehensive assessment of market potential, it offers advantages in ease-of-use, cost savings, and customization to a topic of interest. BC Hydro is applying its findings from the Lighting Applications Matrix to design upcoming lighting programs and marketing efforts.

Encouraged by this success, BC Hydro recruited Bonneville Power Administration (BPA) and Southern California Edison (SCE) as project partners with extensive complementary experience in design and implementation of EE programs. The three utility partners, with support from Livingston Energy Innovations, developed an approach based on the Lighting Matrix to evaluate opportunities for heating, ventilation, and air conditioning (HVAC) technologies.

The resulting easy-to-use tool has proven valuable in helping the partner utilities identify technologies and markets with the greatest potential to provide cost-effective energy savings. And by deliberately aiming to provide relative rankings of the most promising combinations of system types, space types, and market sub-segments rather than quantitative estimates of their impact, the partners were able to design and construct the fully-operational Matrix with fewer than 50 person-days of labor, including all development, review, and coordination activities.

This paper presents the objectives of the HAVC Applications Matrix project, the methods and data used to create the Matrix, and the resulting Matrix structure. It also presents example results for each of the utilities. Finally, the paper discusses the next steps for this project, including potential collaborations with other utilities to review the Matrix data sources and assumptions and apply the Matrix to their markets.

Objectives

The HVAC Applications Matrix project set out to achieve several key objectives. Foremost, the partners sought to develop a simple and powerful method to target high impact HVAC measures for application in commercial-use buildings. A second objective was to demonstrate that the methods used to develop BC Hydro's Lighting Applications Matrix could be adapted to identify opportunities for other technologies and markets.

To achieve these two objectives, the utility partners pooled their collective knowledge, experience, and ideas, with input from external experts and reviewers, to develop a more robust and flexible tool than any of their organizations might create on their own. This approach allowed the utility partners to achieve relatively high confidence levels for their consensus assumptions about expected energy performance and savings with various HVAC system applications, increasing the predictive accuracy of the HVAC Matrix and its results.

This section and the following one summarize Matrix development and architecture, as shown in Figure 1 on page 4**.**

[1] "Mash up" is used in this paper in the sense of http://en.wikipedia.org/wiki/Mashup_(web_application_hybrid) , which includes the concept that "The main characteristics of the mashup are combination, visualization, and aggregation. It is important to make existing data more useful, moreover for personal and professional use."

Approach

To create the HVAC Applications Matrix, the utility partners followed a process similar to that used in developing the BC Hydro Lighting Applications Matrix. The team worked in a collaborative fashion, holding several day-long workshops and web-enabled virtual meetings to develop and refine the tool. The terms defined on this page appear throughout this section and the following one:

HVAC System. HVAC equipment categories with shared design elements. For instance, Central System describes centralized equipment that use water or steam to deliver heated or cooled air throughout a building. Each System type includes sub-systems such as pumps, compressors, fans, and controls.

Sub-system components and systems were assigned two baseline conditions, *As Found* and *Current Code*. *As Found* represents the typical or average level of efficiency of equipment currently in use, consistent with standard practice typical at the time of installation. *Current Code* represents a level of efficiency consistent with governing state, provincial, national and/or international energy codes.

Measure. A replacement technology, improved practice, or combination of both that is expected to increase energy efficiency in one or more sub-systems within an HVAC system. *Measure bundles* were defined as groups of measures that apply to one or more sub-system components and that create synergistic efficiency benefits to optimize system performance.

Measures were assigned to three categories. *Enhanced Retrofit* represents a commonly chosen option to increase efficiency levels above current building code requirements. *Best Practice* represents the best available equipment and system installation practices for deep energy reductions. *Advanced Technologies* represents emerging technologies and practices that are used in no more than 2 percent of buildings today, and that may become standard practice in 10 or more years.

Sub-sector. A building type categorized by occupancy or purpose. Examples of sub-sectors are large office buildings (more than 100,000 square feet of conditioned floor area) and hospitals.

Space type. An occupancy type or HVAC function within a sub-sector. For example, retail sales area and warehouse area are two space types within the Retail Food sub-sector.

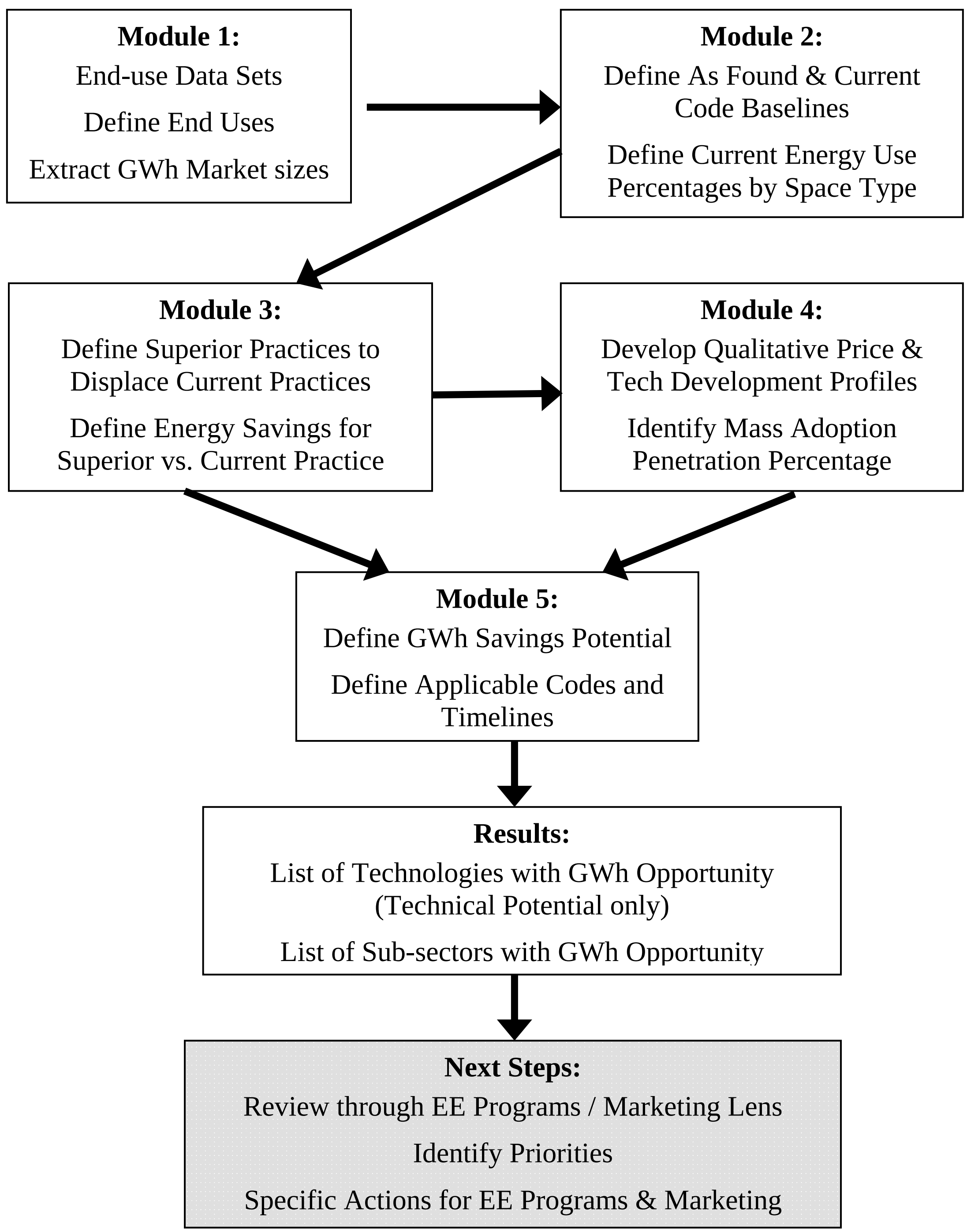
Data Collection

The team used standard, large-scale energy end-use studies for each utility as sources for annual HVAC electricity use by market sub-sector:

- *California Commercial End-Use Survey (CEUS)*, a comprehensive study of commercial sector energy use, served as the principal data source for the SCE service area.
- *BC Hydro 2007 Conservation Potential Review* builds on modeled electricity use data by subsector in for a base year of 2006 to develop estimates of future electricity conservation potential. The base year consumption data served as the principal source for the BC Hydro service area.

- *Sixth Northwest Conservation and Electric Power Plan*, which synthesizes data from studies of electricity use in the Pacific Northwest and forecasts 20 years' regional power system supply and demand, served as principal data source for the BPA service area.
- *2009 Northwest Commercial Building Stock Assessment*, which updates a previous study of the physical and energy-use characteristics of commercial facilities in the Pacific Northwest, served as a building stock data source for the BPA service area.

Figure 1. Modular View of HVAC Applications Matrix Development



Development of Assumptions

To develop and agree on key assumptions, the team convened a group of utility HVAC engineers, energy efficiency program managers, and in-house codes and standards (C&S) experts. Outside experts from the Northwest Power and Conservation Council, Western Cooling Efficiency Center, and PECI were also consulted. Characteristics of HVAC systems and measures were determined based on review and discussion of expert opinions, codes and standards, and trends in technology and market activity. Based on these discussions, the team decided to focus exclusively on the commercial retrofit market, given its size relative to the commercial new construction market and the residential market in general. However, the Matrix design will allow future addition of commercial new construction and residential options.

Estimates of electricity use by space type were developed in consultation with HVAC engineers familiar with the current building stock, the factors that determine appropriate HVAC system types for a specific application, and their expected energy performance. The potential electricity savings of measure bundles – relative to the *As Found* and *Current Code* baselines – resulted from consultation with the same engineers and with EE program experts familiar with the energy-savings impacts of equipment retrofits.

Matrix Architecture

The HVAC Applications Matrix is an Excel workbook made up of tabbed worksheets addressing the following successive steps in the mash-up process: data collection, assumption development, analysis and graphical display of results. The section below describes these worksheets and their contents.

Market Data Worksheets

Three identically formatted Market Data Worksheets present detailed estimates of current electricity use for HVAC systems in each utility's service area. Electricity use is estimated by sub-sector, space type, and by three primary HVAC equipment functions: space cooling, space heating, and fans and pumps. Each worksheet then summarizes annual energy use by space type for all HVAC systems as well as for electric heating only and exhaust only systems (Figure 2).

Figure 2. Excerpt from BC Hydro Market Data Worksheet: Annual Energy Use by Space Type

Estimated Sub-Sector Space Type GWh/yr						
Combined Sub-Sector	Combined Total	Space Type	Space Type Ratio Assumptions (Expert Opinion only)	Annual GWh Market Size	Annual GWh Heat Only	Annual GWh Exhaust Only
Large Office Buildings	445.1	Cubicles, Private Offices, and Meeting Rooms	90%	400.6	327.06	305.37
		Data Closet / Server Room	10%	44.5	36.34	33.93
Medium Office Buildings	129.8	Cubicles, Private Offices, and Meeting Rooms	95%	123.3	98.23	88.73
		Data Closet / Server Room	5%	6.5	5.17	4.67

A Market Data Summary Worksheet compiles data from the three utility-specific Market Data Worksheets to show, by space type for each utility, total annual HVAC electricity use and the proportion used by heat-only systems and exhaust-only (ventilation) systems (Figure 3).

Figure 3. Excerpt from the Market Data Summary Worksheet: Annual Energy Use by Sub-Sector and HVAC System Type (Electric Heating Only)

Estimated Sub-Sector Space Type GWh/yr					Estimated Sub-Sector Space Type GWh/yr - Electric Heating Only		
Combined Sub-Sector	Space Type	BC Hydro Annual GWh Market Size	BPA Annual GWh Market Size	SCE Annual GWh Market Size	BC Hydro Annual GWh Market Size	BPA Annual GWh Market Size	SCE Annual GWh Market Size
Large Office Buildings	Cubicles, Private Offices, and Meeting Rooms	400.59	876.31	487.79	327.06	541.22	220.85
	Data Closet / Server Room	44.51	97.37	54.20	36.34	60.14	24.54
Medium Office Buildings	Cubicles, Private Offices, and Meeting Rooms	123.31	330.89	1045.39	98.23	205.87	473.30
	Data Closet / Server Room	6.49	17.42	55.02	5.17	10.84	24.91

System Worksheets

Seven identically formatted System Worksheets detail the baseline and superior practice conditions for each of the system types used in the Matrix (Table 1).

Table 1. System Types in the HVAC Applications Matrix

Name	Description	Capacity	Common Applications
Package Terminal Air Conditioner/Package Terminal Heat Pump (PTAC_PTHP)	Unitary ductless air-cooled units	Up to 2 tons or 24,000 Btu/hr	Hotels/motels
Split System	Air handling units with a direct expansion (DX) cooling coil served by a separate air-cooled condensing unit and ducted air distribution	1–50 ton	Small-to-medium commercial occupancies, typically single story
Packaged Unit	Air conditioning or heat pump units with an integral DX cooling system and electric or gas-fired heating units; most are air-cooled and use ducted air distribution. Includes rooftop units (RTUs).	1.5–100 ton	Low-rise commercial occupancies
Electric Heating Only	Heat source assumed to be electric baseboards, cadet heaters, unit heater, furnace, cable ceiling heat, or any radiant heat; no mechanical cooling	N/A	Small commercial occupancies with no AC load and where natural gas is not supplied for space heating

Table 1. System Types in the HVAC Applications Matrix (cont'd.)

Exhaust Only (including ventilation)	Dedicated, high cubic feet per minute (CFM) ventilation and possibly gas heating with an air handling unit	N/A	Kitchen ventilation hoods, laboratory fume hoods
Central System	Water-cooled units that provide cooling only and use chilled water in conjunction with steam or hot water from boilers for thermal distribution; air handling units and fan coil units provide air distribution	100 to several thousand tons	High-rise commercial occupancies, hospitals, universities and other campus-type settings
Computer Room Air Conditioner (CRAC)	Generally air- or water-cooled units designed for high reliability and minimal downtime; generally use ductless air distribution	8–30 ton	Server rooms of 1,000 ft^2 and up

The System Worksheets list complementary and competing measures, organized by HVAC sub-system (Figure 4). Utility HVAC engineers, energy efficiency program managers, and outside experts developed consensus estimates of percent electricity savings for measure bundles across all sub-systems at various levels of superior practice compared to baselines.

Figure 4. Excerpts from HVAC Sub-system Measure Bundles for Packaged Units - Baseline and Enhanced Retrofit Cases Shown

	Bundle Name	System	Compressor	Thermal Rejection
"As Found"			reciprocating or scroll compressor	air cooled condenser
Current Code			reciprocating or scroll compressor	air cooled condenser
Enhanced Retrofit		Integrated Economizer	VFD, multi-speed or digital scroll compressor, electronically commutated motor	Larger condenser

System Worksheets also display the assumptions for efficiency improvements for measures bundles relative to *As Found* and *Current Code* baselines, as well as graphical representations of projected technology pricing and development trends (Figure 5).

Figure 5. Graphical Representations of Technology Pricing and Development Trends

Pricing & Technology Development Legend - implies market ready and price point competitive to incumbent technologies.

Constant (no price change)	⇨⇨⇨	Emerging Technology stage	⇨⇨⇨
Gradual decline	⬂⬂⬂	Program stage	⇨⇨⇨
Aggressive decline (hockey stick)	⇩⇩⇩	Code stage	⇨⇨⇨

Results Worksheets

Two identically formatted Results Worksheets present the Matrix analysis results. The *As Found* Results Worksheet calculates the technical potential for *Current Code* and *Enhanced Retrofit* measure bundles relative to the *As Found* baseline. Competing measure bundles estimated to produce comparable savings percentages are summarized in each level of superior practice, and competing measure bundles that enable significantly higher or lower savings percentages are included in an appropriately higher or lower level of superior practice.

Technical potential is displayed by sub-sector and space type for each utility's service area. Expected price and technology development trends are represented graphically, and key dates for and potential impacts of planned future changes in building codes and regulations are listed (Figure 6).

Figure 6. Excerpt from *As Found* Results Worksheet for BC Hydro

Commercial Sub-Sector (CPR 2007 and other sources)	Space Type	"As Found" Baseline System Type	Superior Practice (<5 yr horizon)	Price & Technology Development (See legend)			Annual GWh Market Size	Annual GWh Savings Potential
			System Details	1-3 yrs	4-6 yrs	7-10 yrs		
Large Office Buildings	Cubicles, Private Offices, and Meeting Rooms	Packaged Unit	Current Code	⇨⇨⇨	⇨⇨⇨	⇨⇨⇨	401	12
			Enhanced Retrofit	⇨⇨⇨	⇘⇘⇘	⇨⇨⇨		42
		Central System	Current Code	⇨⇨⇨	⇨⇨⇨	⇨⇨⇨		18
			Enhanced Retrofit	⇘⇘⇘	⇘⇘⇘	⇨⇨⇨		45
	Data Closet / Server Room	Packaged Unit	Current Code	⇨⇨⇨	⇨⇨⇨	⇨⇨⇨	45	0.3
			Enhanced Retrofit	⇨⇨⇨	⇘⇘⇘	⇨⇨⇨		1.2
		CRAC	Current Code	⇨⇨⇨	⇨⇨⇨	⇨⇨⇨		0.0
			Enhanced Retrofit	⇘⇘⇘	⇘⇘⇘	⇨⇨⇨		5.8
		Central System	Current Code	⇨⇨⇨	⇨⇨⇨	⇨⇨⇨		0.7
			Enhanced Retrofit	⇘⇘⇘	⇘⇘⇘	⇨⇨⇨		1.7

The *Current Code* Results Worksheet provides the same information for *Enhanced Retrofit* and *Best Practice* measure bundles relative to the higher-efficiency *Current Code* baseline.

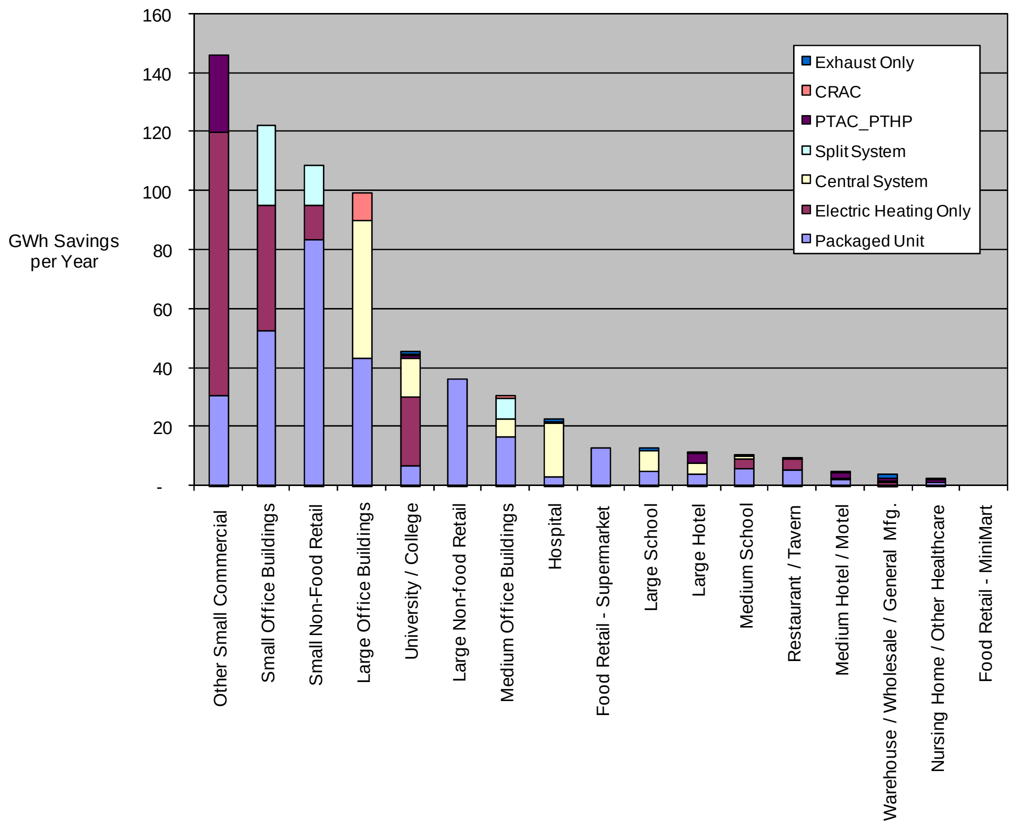
The comprehensive listing of combinations of efficiency levels, market sub-sectors, space types, and annual savings potential in each Results Worksheet provided support for selection of appropriate near-term and mid-term EE program market interventions. By referring to price and technology development trends, planned changes in building codes and regulations, and Annual GWh savings potential values in the Results Worksheets, users can spot potential incremental or transformational market trends that may occur in future years.

Results

In addition to data collection, analysis, and synthesis, the HVAC Applications Matrix uses the pivot table and pivot chart functions of Excel for data mining, additional synthesis, graphical representation, and prioritization of findings. Figures 7, 8, and 9 display estimates for each utility partner's service area of the technical potential for *Enhanced Retrofit* measure bundles relative to the *As Found* baseline.

These charts illustrate the value for EE program design and marketing of targeting opportunities with the greatest potential and provide justification for moving ahead with the most promising measures and programs quickly. Like the Matrix approach that they build upon, the pivot charts provide a systematic, easy-to-use, and rapid process for exploring the Matrix data sets and developing "what if" scenarios for program planning and targeting.

Figure 7. Technical Energy Savings Potential in BC Hydro's Area by Retrofitting Current HVAC Systems with Measures at the Enhanced Retrofit Efficiency Level



Results for BC Hydro shown in Figure 7 indicate a significant opportunity available by concentrating on small commercial buildings (offices and others), small retail businesses (other than food), and large office buildings. Buildings without mechanical cooling and those with packaged units represent an additional high priority area for BC Hydro to target. Common sense confirms that small commercial businesses are hard to reach and may not be able to fund energy efficiency upgrades. Electric-only heating and packaged units are notoriously inefficient.

Following a multi-day charrette involving Program Managers and Engineering Team Leads, BC Hydro identified its top three HVAC Market Transformation priorities for the Commercial Sector. The team also identified barriers and developed a 3-year action plan to address each priority; e.g. targeted pilot or showcase projects, further market studies focused on the specific sector, trades and alliance support etc.

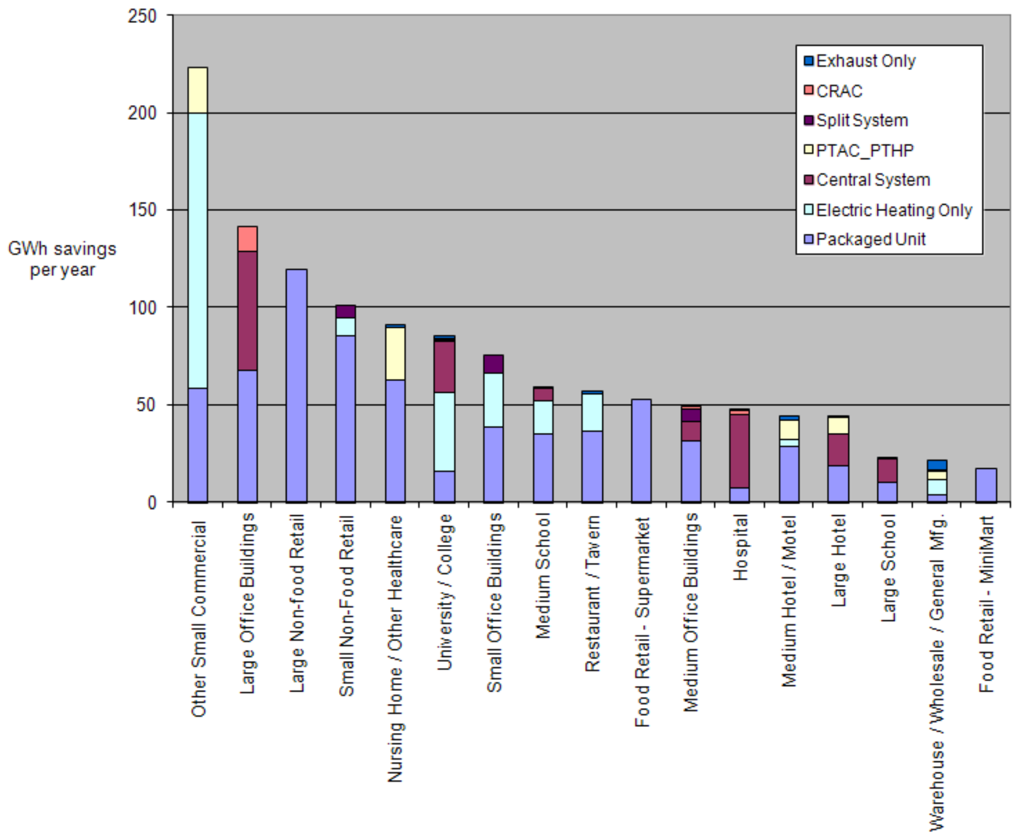
The top three priority areas are:

- Large/Medium/Small Non-Food Retail (big box stores, malls etc): Packaged Roof Top Units - 120 GWh technical savings potential
- Large/Medium/Small Office Buildings: Packaged Roof Top Units - 113 GWh technical savings potential

- Large/Medium Office Buildings, Hospitals, Universities: Central Systems (chillers and boilers) - 78 GWh technical savings potential.

Prior to the development and application of the HVAC Matrix, BC Hydro Program Managers had an awareness of Roof Top Units as an opportunity area, but did not appreciate the scale of this opportunity and the optimal subsectors for targeting. Also, the HVAC Matrix results provide Program Managers with the justification to scale back or drop marketing efforts in other areas identified as relatively less significant.

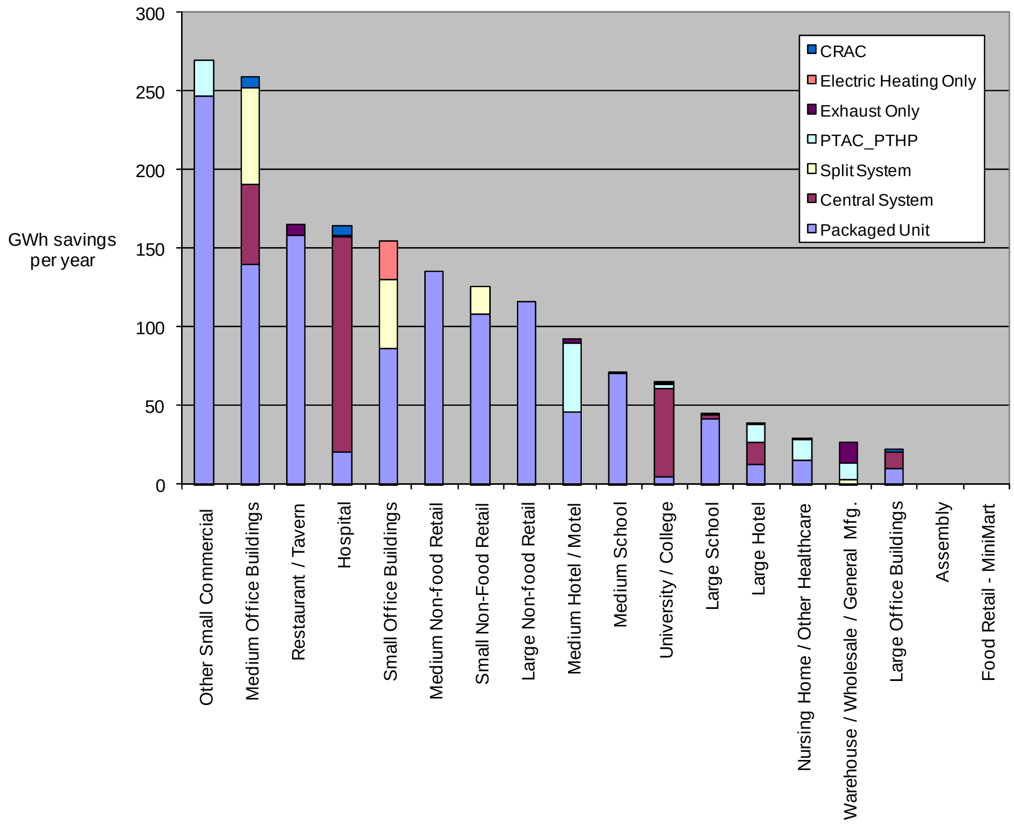
Figure 8. Technical Energy Savings Potential in BPA's Area by Retrofitting Current HVAC Systems with Measures at the Enhanced Retrofit Efficiency Level



Results for BPA shown in Figure 8 highlight the opportunity for a measure bundle that improves efficiency of electricity use by packaged rooftop HVAC units. This common equipment type often provides year-round ventilation and space conditioning. Along with unitary electric heaters, packaged units meet much of the need for heating in the Pacific Northwest, a major component of regional peak demand. With renewed attention to this opportunity, BPA is currently assessing incentives for retrofitting packaged units with advanced controls, variable-frequency drive fans, and integrated economizers. As indicated by our analysis, likely targets for these programs include owners and operators of small commercial buildings, offices, and retail businesses.

Electric heating is a second, large opportunity identified by this approach. BPA is actively developing tactical options around advanced heat pump technology, including cold-climate designs, inverter-driven compressors, and variable refrigerant flow systems with heat recovery. In the past, BPA had focused effort on development of measures to target packaged terminal heat pumps (PTAC_PTHP). This analysis suggests that those efforts may be better applied to higher priority technologies in the future.

Figure 9. Technical Energy Savings Potential in SCE's Area by Retrofitting Current HVAC Systems with Measures at the Enhanced Retrofit Efficiency Level



Based on the results shown in Figure 9, SCE stands to benefit from programs to apply energy efficiency measures to packaged AC units in multiple sub-sectors, notably restaurants, retail outlets, and other small commercial facilities. 70% of the potential energy savings for commercial HVAC systems are in packaged AC units, versus only 15% potential in central plant systems.

Newer packaged AC units are available with variable speed supply fans and variable speed compressors. Retrofit packages that convert existing AC units to variable fan speed operation are currently being evaluated in the field. Measures that evaporatively pre-cool incoming condenser air are also being studied on actual operating AC units.

Regional differences in HVAC systems surfaced in the study results. Whereas electric heating is a major load in the Northwest, low heating demand and regulatory restrictions makes this system almost non-existent in the California market.

Conclusions and Areas for Future Improvement

As stated in the Objectives section above, the goal of the matrix was to identify priority opportunity areas for HVAC programs, with the understanding that the HVAC Matrix can provide a starting point for deeper technology market assessments and potential studies. To do this, the HVAC Matrix relies heavily on existing energy consumption data and on expert consensus assumptions. The confidence level in assumptions for HVAC use by space type, distribution of system types by application, and expected savings is relatively high because HVAC Matrix development combined input from several utilities and from outside experts and reviewers. The authors do not expect the HVAC Matrix end results to achieve uniformly high levels of quantitative accuracy. However they have found that the HVAC Matrix provides a robust and flexible tool for ranking EE program targets, easily incorporating new data. Thus the it allows for continuously improvement by users, unlike many conventional market studies.

To pursue continuous improvement and to enhance its value for wide range of decision makers within a utility, the HVAC Matrix functionality can be augmented and refined. The authors envision several steps to improve its accuracy, value, and range of application. One step is to further review, refine, and augment the consensus assumptions. For example, the authors plan to work with codes and standards experts to provide more specifics around the timing and levels of future codes and standards requirements that will affect the onset and termination of EE programs.

Additional priorities include developing HVAC Matrix capabilities for automatic pivot table and chart generation enabling more flexible queries and better display of results, creating a data entry form to facilitate inclusion of new and emerging technologies, and incorporating macros to automate Matrix functionality.

The structure and granularity of primary data sources varies considerably by utility and region. The Matrix architecture described in this paper may benefit from modifications to better utilize available data sets and focus on areas of particular interest for EE programs, such as electricity consumption for exhaust-only systems where applicable. It is hoped that if successful, the Matrix approach for planning and program design may guide the criteria for future building and energy end-use data collection and modeling efforts.

The utility partners that developed the HVAC Matrix welcome input from and involvement of additional collaborators to validate our assumptions, enhance the Matrix architecture and usability, adapt this approach to other utility service areas, and expand the Matrix concept to additional EE technology and market opportunities.

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