Harbour Centre – Data Centre Heat Recovery Chiller Case Study

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Building Name/Address	Harbour Centre, 555 W. Hastings St. Vancouver, BC
Building's Asset Class	Office (with data centre)
Building Size	~74,847 sq.m (~805,650 sq.ft.)
Year Built	1978
Building Owner & Manager	Polaris Realty
Engineering Consultant	Anthony Jones & Associates Inc.

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Introduction

Many engineering and contracting firms are now familiar with heat recovery retrofits. While this case study provides project specifics, it is also intended to help property managers identify heat recovery opportunities and to understand why heat recovery systems provide deeper environmental benefits than many other retrofit approaches. This case study contains a mix of technical project descriptions, as well as basic principles of operation and application.

Context

Our sun produces energy which flows to the earth and is transformed into food energy by plants through photosynthesis. Most animals harvest their food energy from living plants or from other animals that have eaten the plants. Humans, however, are different. Not only do we get our life-sustaining energy from plants and other animals, but also we have learned to harvest stored energy from fossil fuels which are essentially prehistoric uneaten plants. This harvesting has led to the agricultural and industrial revolutions and has upset the natural balance of energy flow. All of our activities, accelerated by harvesting fossil fuel energy, release carbon dioxide into the atmosphere accelerating climate change. Reducing fossil fuel consumption by implementing energy conservation measures, helps to partially mitigate this problem.

Many energy conservation measures merely reduce the amount of energy consumed and greenhouse gasses produced by improving efficiency or through basic fuel switching. Heat recovery systems on the other hand, recycle 'used' heat. This can produce a far greater reduction in energy and greenhouse gasses than many other energy conservation measures because 'new' heat does not need to be produced.

In order to successfully implement a heat recovery retrofit, the opportunities must first be identified. Following is a technical description of this application.

Project Summary

Existing Building Systems

This 528,620 square foot complex located at 555 West Hasting Street, Vancouver B.C. is comprised of a 28 story office tower, an adjacent heritage building, a two level shopping mall, a revolving restaurant, a large data centre and parkade facilities.

The HVAC system is comprised of variable air volume (VAV) air handling systems for the tower and most of the heritage building. These systems make use of free cooling from outdoor air when operating conditions permits. The supply air is cooled by chilled water coils when free cooling is inadequate. Hot water coils heat the supply air when heating is required. The VAV system reduces air volume as the cooling load decreases. This also reduces unnecessary reheat of the supply air. The envelope heat losses of the tower are handled by perimeter radiation units. This overall design is one of the more efficient air handler configurations, but its heating is powered by fossil fuel consumption.

The shopping mall has 100% outdoor air units primarily for make-up air, and constant volume mixed air handling systems.

The heating water required by the air handling systems and perimeter radiation is produced by two shell and tube heat exchanger plants which get their heating energy from steam. The steam is generated off site by combustion of fossil fuel. The heating water temperature is reset between 50 C to 75 C based on outdoor air temperature conditions and trimmed by space load conditions. The top of the observed heating water temperature range was within the capabilities of some heat recovery systems, so further investigation for a heat recovery opportunity was warranted at Harbour Centre.

There is a new mechanical room located on P1 which contains two 950 ton centrifugal chillers and associated cooling plant equipment. The cooling plant extracts heat from the data centre 24 hours per day and provides comfort cooling when natural ventilation is inadequate to meet the cooling loads. The cooling system has redundant capacity for the data centre and comfort cooling. The cooling tower system, required for rejecting the waste heat, is located on the low-rise roof. The mechanical room on the P2 level contains an additional backup centrifugal chiller as well as one of the two steam powered hot water heating plants.

Data Centre

Data centres perform many important tasks which power our economic, health care, scientific and communications systems to name a few. Performing these tasks requires a lot of electrical energy and this energy ends up in the form of heat which is often wasted to the atmosphere by the heat rejection systems. The data centre in this facility provided an attractive heat source for implementing a heat recovery retrofit due to the abundance of heat energy available during the heating season.

Heat Sources for Heat Recovery

The data centre at Harbour Centre provides a large, reliable source of heat to be recycled. Buildings without data centres also produce heat that can be recycled, particularly those buildings with simultaneous heating and cooling loads. The heat rejected from the cooling systems can be immediately recycled into the heating systems if the heating and cooling loads occur simultaneously. Buildings that do not have simultaneous heating and cooling loads can still be retrofit with heat recovery systems which harvest heat from the ventilation exhaust air or even from the surrounding environment. Some ground source geo-exchange systems can recover heat from the cooling systems during the summer and store the heat in the ground until it is needed for heating in the winter. The viability and economics of a project vary depending on the application, but all heat recovery possibilities are worth exploring even if only on a cursory basis, because opportunities to recycle heat are all around us including in our own homes.

Heating and Cooling Load Analysis

Effective sizing of the heat recovery plant optimizes the capital investment, maximizes the installed system utilization (average percent load) and finds an effective match of available waste heat recovery with heating requirements. Too large a capital investment results in a larger than required underutilized machine and higher construction and maintenance costs. Too little capital investment results in untapped opportunity. A modular system design, such as was implemented at Harbour Centre allows for a right-sized initial capital investment with the opportunity to add capacity as desired based on measured results and changing future conditions.

Recovered heat needs to flow to a heating load, otherwise it is wasted, and this results in increased, instead of decreased, energy usage. Unfortunately, this does happen from time to time when systems are improperly commissioned or inadequately maintained. This is worth examining for existing and proposed systems. When recovering heat from cooling systems, it important to evaluate to what extent the cooling loads and heating loads occur simultaneously, providing a good match both in terms of capacity as well as timing.

Project Description

At Harbour Centre, to provide an accurate picture of the timing and magnitude of the loads, a year's worth of 15-minute trend data was analyzed. The 15-minute intervals were grouped by hour of the day for each month for graphical analysis, but calculations were performed on each individual time interval.

Heating demand peaks occur on cold morning system start up. It was necessary to compare several proposed capacities to each interval heating load to help optimize heat recovery plant size. At Harbour Centre, the data centre provided a reliable year-round source of heat exceeding the heating requirement.

Figure 1, below, shows the minimum, maximum and average steam demand that occurred for each hourly bin for each month (about 120, 15-minute samples per hourly bin). Any interval load in excess of the model heat recovery system output is partially serviced by the steam plant. Any load at or below the heat recovery system output is be fully serviced by the heat recovery plant. Transient peak loads under which are under a half hour duration are likely accommodated by the thermal mass of the heating system so actual satisfied loads are probably higher than calculated.

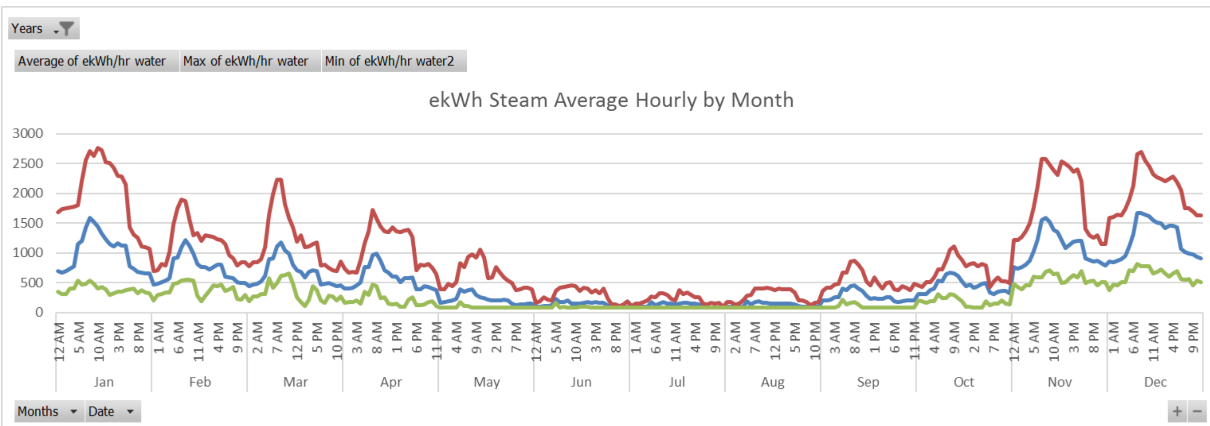

Figure 1

Figure 2 shows the totalized steam use for each hourly bin in each month, and the totalized load met by a modelled 140 ton heat recovery unit. The blue line is the satisfied load.

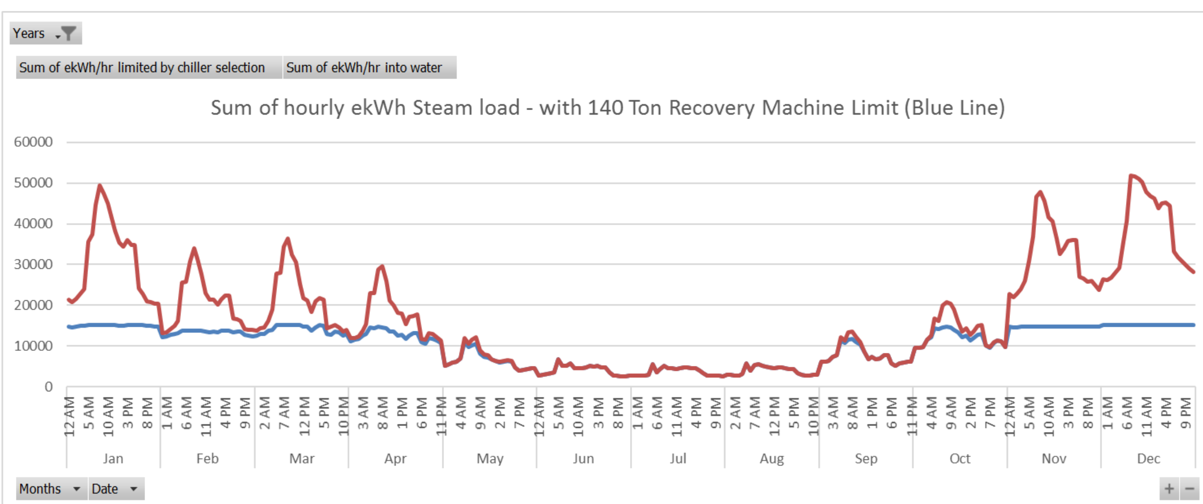

Figure 2

Figure 3 shows the totalized steam use for each hourly bin in each month, and the totalized load met by a modelled 300 ton heat recovery unit. The blue line is the satisfied load.

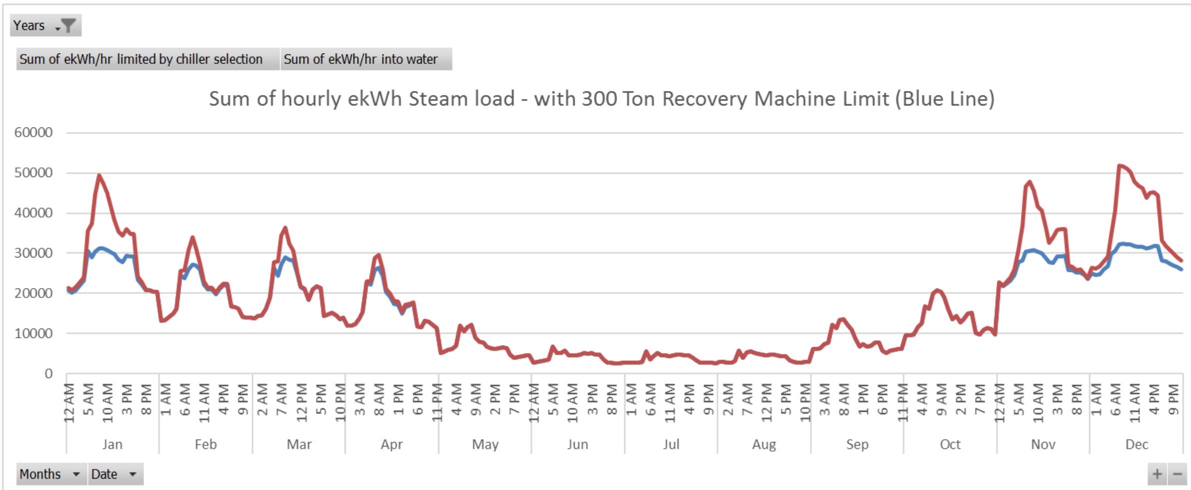

Figure 3

Design

A modular 140-ton heat recovery chiller was selected to recover heat from the chiller plant condenser water outlet. The thermal lift provided by the heat recovery plant was sufficient to satisfy the heating water temperature requirements of the terminal loads under almost all operating conditions. This is not to say that it handles the full load under peak load conditions, but that the temperature of the heating water delivered by the heat recovery system is high enough to contribute effectively to meeting the heating load under full load conditions.

The heat recovery plant is hydronically decoupled from the condenser water to satisfy the design requirements of the heat recovery chiller without affecting the primary system operation. Variable speed pumps on the condenser and evaporator sides of the heat recovery plant maintain design flow rates for the unit while providing efficient pumping operation. The heated water produced by the heat recovery plant is injected back into the heating water return. For hourly periods where peak heating loads exceed the capacity of the heat recovery chiller, the temperature is topped up by the steam heat exchangers.

Installation Challenges

The cooling tower is an open loop system and therefore it is subject to accumulation of dirt and debris in the fluid stream feeding the evaporator side of the heat recovery unit. This fouling would reduce efficiency and could also cause damage to the machine. To mitigate this issue a side stream filter is added to maintain cleanliness of the condenser water. This measure is also beneficial to maintaining efficiency of the chiller plant.

Measured Results

Savings were estimated at 2,962,967 ekWh of steam. Actual savings achieved were higher at 3,166,196 ekWh. The offsetting electrical usage to run the heat recovery system was 871,461 kWh for a net ekWh reduction of 2,294,735 ekWh. The 12-month trailing steam consumption during the M&V period was 3,157,853 ekWh compared to the 3-year average of 6,324,040 ekWh. The greenhouse gas reduction was 559 CO_2e/yr.

Measure Description	Estimated Savings	Actual Saving	% Saved
Steam Savings	2,962,967 ekWh	3,166,196 ekWh	50%
GHG Reduction		559 CO_2e yr.	48%

Additional realized benefits

It should also be noted that the reduced heat rejection also results in major water savings for the cooling tower, about one million gallons each year in this case.

COVID Variables

The period for which savings were measured included extended equipment operation resulting from implemented ASHRAE COVID ventilation recommendations. These included additional air purge operation as well as increased daytime ventilation rates. This added ventilation air had to be heated in cold weather, while a lack of internal heat gains from occupants, plug and lighting loads also increased the heating requirement. Overall, despite these load increases, the savings were achieved. There may be unaccounted for decreases in consumption resulting from COVID so it will be beneficial to review when societal conditions have fully stabilized.

Future Recommendations

There is an additional heating hydronic loop that can be serviced by connecting the two separate heating loops or installing a separate heat recovery unit which Polaris is currently reviewing in conjunction with further sustainability measures.

Data centres in general could be viewed as heat recycling opportunities, not just for the facility in which they are housed but also for the communities within which they could be connected through community energy sharing infrastructure. This would afford interesting opportunities city-wide.

Conclusion

After the installation of the heat recovery system at Harbour Centre, the steam consumption dropped by 50% with similar greenhouse gas reductions. This was possible because instead of wasting the data centre heat to the atmosphere through cooling tower operation, the heat is recycled into the heating systems. This offloaded the need to burn fossil fuel to generate new heat.

Careful evaluation of simultaneous heating and cooling loads is necessary to help optimize the heat recovery plant size and build a strong business case for a project. It is also very important to ensure that the heat recovery design will meet the temperature requirements of the heating loads.

Heat recovery opportunities exist where a waste heat source is located near a heating load. The waste heat source can be a data centre, a simultaneous cooling load, an exhaust air stream or the building environment. Thermal storage system such as some ground source geo-exchange systems can even store heat energy for use in the next season while community infrastructure can share heat between buildings. The opportunities are all around us.

Heat recovery systems, like all systems, need to be properly commissioned and maintained. It is important to conintuously check on existing systems because they can silently drift into inefficient operation if improperly controlled, so review your existing systems, but also look for new opportunities!