Lessons Learned from LCE Projects

Summary of insights shared from BC Hydro Commercial Energy Manager Workshop, January 26, 2023

BC Hydro Power smart

Prism ENGINEERING

Overview

Purpose

To share lessons learned and best practices with the Commercial Energy Manager Community relating to heat pump and heat recovery chiller installations as these are the most common Low Carbon Electrification (LCE) opportunities for commercial buildings. The intent is to provide a practical document to help improve the quality of installations and performance of these systems by learning from others' experiences.

Background

A BC Hydro Commercial Energy Manager Workshop was held on Jan 26, 2023, hosted by Prism Engineering. Case studies from BCIT and SD42 were shared as well as recommendations from Prism's design team.

Selina Liu, BCIT presented on three separate projects at BCIT including a significant steam reduction resulting from a data centre heat recovery project (Downtown Campus) and lessons learned from a variable refrigerant flow (VRF) renovation project (Building NW06). Additionally, Selina presented on a project for a new building (Health Sciences Building) and the difficulties with commissioning a water to water heat pump with an air source heat pump, geo exchange loop and back-up boiler.

Alexandra Tudose, School District 42 - Maple Ridge - presented on challenges and trouble-shooting steps associated with installing new technology heat pumps in portable buildings.

Robert Greenwald presented on solutions to challenges at the various stages of the project from initiation to operations.

During the session, and through a pre workshop survey, Energy Managers shared both challenges and solutions regarding LCE projects in the chat. Post session, attendees from BC Hydro Engineering shared their feedback with Prism. This document summarizes all of the above learnings.

Acknowledgements

- Selina Liu (BCIT)
- Alexandra Tudose and Robbie Stewart (SD 42 Maple Ridge)
- Bjorn Richt (Island Health)
- Eric Snelling, Ari Spiegel and Tommy Yim (BC Hydro)
- Robert Greenwald, Energy and Mechanical Teams (Prism Engineering)

What is Low Carbon Electrification?

Replacing fossil fuel equipment with new equipment powered by low-carbon electricity; where the electrical energy is generated from processes or technologies with substantially lower CO_2 emissions than conventional fossil fuel power generation.

Format

Bullet (point form) is used throughout this document. The need for a fully flushed out "guide" was identified in the workshop; however, budget and timeline prevented the expansion of this workshop summary into a guide. Issues and challenges along with suggestions are presented.

Legend

ASHP- Air source heat pump

BAS – Building Automation System

COP – Coefficient of Performance

DOAS – Dedicated Outdoor Air System

HRC – Heat Recovery Chiller

HWST – Hot Water Supply Temperature

LCE – Low Carbon Electrification

MAU – Make Up Air Unit

OAT – Outdoor Air Temperature

SWT/RWT – Supply/Return Water Temperature.

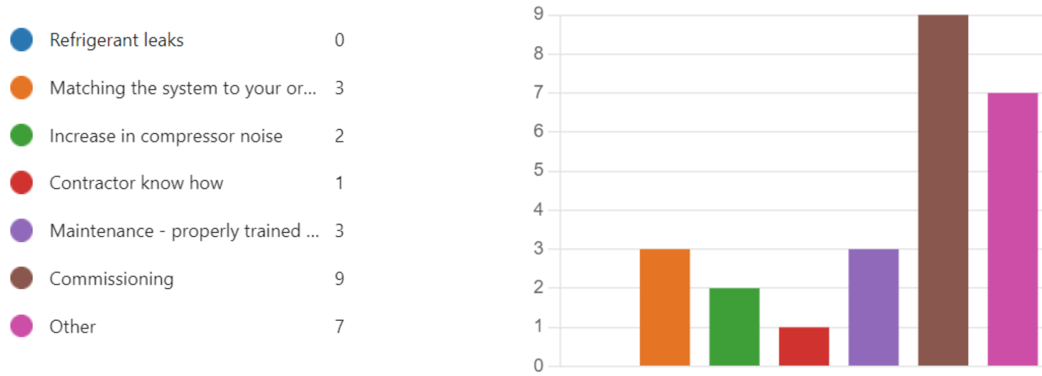
VFD – Variable Frequency Drive

Contents

What challenges are Energy Manager encountering?

EM Survey December 2022

What challenges have you encountered while implementing heat pump or chiller projects? (option given to select up to 3)



Study Phase

Challenges

STUDY PHASE	**Overestimated Savings**	• Savings are often overestimated in studies (overly optimistic engineering estimates)
		  ○ Studies may over-estimate COP, heat pump capacity at low temperature, and potential condenser leaving temperature.
		  ○ Studies may overly rely on manufactures published maximums (which are theoretical and do not include real world situation). For example, defrost cycles are often negated in the manufacturer claims of COP.
		  ○ In some cases actual results show reduced operating times for heat pump operation, more reliance on supplemental gas system, and higher than expected electrical consumption when operating.
		  ○ Inaccurate assumptions of design heating loads or available cooling loads (example: during the heating season for the HRCs)

Solutions

STUDY PHASE	**Data accuracy**	• Get real data to understand the actual loads wherever possible • Look at where and when the heating and cooling loads occur; make sure "loads" are clearly defined
	Heat pump integration	• Understand how heat pumps can be integrated into a hybrid plant that uses both natural gas and heat pumps, particularly in terms of temperature integration between the two systems.
	Control strategy	• Rethink the control strategy at the evaluation (study) stage instead of leaving it to the design
	Support	• "Hire a really good engineering firm to support you. Especially for school districts where teams are usually made up of 1 professional (maintenance, operations, sustainability)." (SD42) Alexandra Tudose

Design Phase

Challenges

DESIGN PHASE	**Sizing**	• Heat recovery loads may not be balanced in terms of time of coincidence and magnitude (i.e. there may be heat available for recovery when building does not need heating). Thermal storage may help in this case. • Heat pump (HP) sized for peak may not operate well at low load • Heat pumps cannot meet high building SWT. • RWT may be too high for heat pumps to operate. • HP MUA can't provide heating for makeup air at low OATs
	Hybrid and complex systems	• If not careful the design can be too complicated when multiple stages of heat source are used. One BCIT project (new design) integrated five different heat sources; they found that staging so many sources is complicated to program and commission. • Controls and commissioning issues: Island Health's HRC project had some control issues where it wasn't taking full advantage of available heat in the condenser loop during cooling season. • Issues with integrating HRCs into existing boiler systems. This needs to be addressed in the design: High temperature heating water systems may trip the safety features on the HRC compressors, which can lead to premature failure and decreased savings. • Island Health found challenges with the location of existing heating and cooling sources, and the large capital cost for large HRCs. Their recommended design solutions include using two HRC machines instead of one.
	Building electrical panel capacity availability	• electrical upgrade costs are significant (4 of 24 comments in chat specifically called this out as a key issue)

	Structural and space constraints	• One example noted there was not enough space to install the buffer tanks that would make the heat pumps operate in a more stable manner.
		• Maple Ridge Pitt Meadows School District 42, Portable Ventilation System Upgrade:
		  ○ Additional space was required for return air (key consideration when installing indoors), so closets that held the old furnaces had to be demolished.
		  ○ Structural upgrades were required because the new HPs were heavier than the existing furnaces.
		  ○ Overhead ductwork had to be new, and in-floor ductwork demolished.
		  ○ In the end, equipment cost was only half the entire project cost.

	Design expertise	• Availability of design expertise can be an issue
	Timelines	• projects need to move ahead quickly and may miss key details • equipment voltage may have a big impact on lead time (BCIT)

Solutions

DESIGN PHASE	**Sizing**	• Don’t oversize individual heat pumps, they may not work with low loads • Consider all indoor operating parameters • Real load data is required for proper design and sizing – BCIT found that real life data is important; they overestimated the electrical demand required and oversized the electrical connection in one project that could have been avoided with the use of prior data monitoring. • Equipment sizing is often cooling dominant – when designing decarbonization projects, often HP systems are sized for heating, but in practice, sizing is driven by cooling loads. • At BCIT: “We had our DOAS preheat lift the OAT up to 5°C, then the condensing unit does the rest.” • Consider fixed vs. variable capacity compressors – ASHP/HRC may be unable to achieve its rated max heating water supply temperature (HWST) for long because of fixed capacity compressors. Potential solutions include: variable capacity compressors (e.g., VFDs), larger buffer tanks, sizing heating loads for HWST < ASHP/HRC rated max HWST. • Design for resiliency – when designing a system, consider the building age when selecting design temperatures; if the building will be around after 2050, then consider climate change in design temperature selection and consider necessary building envelope upgrades.
	Equipment	• Don’t go cheap on terminal units as they may not provide optimal zone level control.
	Hybrid Plants	• Potential Solution: decouple high temperature loads from the main system and provide a smaller high temp heater dedicated to the high temp loop. This will allow the main loop temperature to remain within HP/HRC operable conditions.
	Controls and Commissioning	• Consider inconsistencies (possibly based in design problems) between building loop flow rate and/or temperature, and operating design parameters of an air source heat pump • “Make it commissionable at the design phase” Kesh Bandara | Township of Langley
	People	• At Island Health, they worked with the departments that had high loads (IT, medical imaging) to ensure their needs for legacy equipment was maintained
	Timelines	• Even if you phase the installation, don’t phase the design. Have a fully designed system in place.

Installation Phase

Challenges

INSTALLATION PHASE	**Equipment specific issues**	• Voltage difference between equipment ordered on same project (480 / 600 V) – BCIT NW06 Retrofit equipment voltage was different than voltage supplied to site. Same equipment types with correct voltages had significantly longer lead times. The solution was to install a transformer so that project timelines were met. • Equipment manufactured by different countries on same project – BCIT NW06 Retrofit had mismatched equipment resulting in pre-heat being forgotten. • Mitsubishi integration with Swagon units needs careful coordination.
	Condensate management	• Condensate management that can lead to safety issues (freezing water on walkways).
	Controls / Commissioning and BAS communication issues	• poor commissioning of heat pumps leads to future failures • challenges with integrating existing DDC with stand-alone controls of new heat pump / HRC • heat pump modules can be challenging to commission (Island Health) • In air handling units the outdoor air damper minimum position was too high for low temperature heat pump operation, in addition to heating and cooling dead band being too wide, and the factory compressor lockout temperature was too low (SD42).
	People "issues"	• Availability of installers • Contractor resistance to more 'complex' technologies • Limited personnel / resource capacity issue to manage project • More complex to commission
	Delays	• Long lead time for equipment • Permit delay • Concurrent projects at the same time
	Noise	• Compressor noise

Solutions

INSTALLATION PHASE	**Take extra time on first-time projects and allow for unknown issues and costs**	• "We re-adjusted the construction schedule early, aligning with optimum period for installation." • "Work closely with contractors & mechanical consultant." • "Continually being involved and checking back." • "Facilities can (reasonably) be protective of freezing heat pump equipment and are reluctant to run too low a temperature. We started at 6°C and have now eased them down to 3°C."
	Condensate Management	• More clearance required for outdoor units in cold climates to prevent improper condensate drainage. • Drip pan can be installed under the units to direct flow away from walkways
	Control Strategies	• OAT temperature switch over temperature for supplementary heating – it is recommended to revise the control strategy to sequence the boiler, so the heat pumps maintain their ability to provide first stage heating. Additionally, the sequence will be modified to properly control the heat pump stages to ensure they only operate well within their reliable operating range. • Select an appropriate heating / cooling dead band, and ensure minimum OA percentages are applied to AHUs. • Lowering the HWST will lower the HWRT and improve performance. Having the HW system off at night gives time for the HRC to preheat the system (BCIT). • "We need to rethink what has been working for conventional systems and program DDC systems considering the operational parameters of heat pumps and heat recovery chillers. This is especially important with Hybrid plants where boiler operation and setpoints can impact heat pumps use." Iram Green (Prism)
	Commissioning	• We should commission for heating, cooling and shoulder season operation (SD 42) • "Check voltage issues and spend lots of time commissioning....I have found SOO (sequence of operations) is very important to understand when adding ASHP to boiler loop" Mary Zuccaro (SD68 Nanaimo) • "Diligently reviewing system operation after project handoff phase, especially during seasonal change periods."
	Construction approach	• Consider using a phased approach for retrofits • Stage 1 – modify the existing system to operate at low temperatures: Operate at low temperature for a heating season to demonstrate the system is HP ready. Use this trial to obtain operational data for sizing HP. • Stage 2 – install heat pump, buffer tanks, and associated equipment.
	Noise	• Consider building a structure around the heat pump (of course you need to ensure airflow for heat exchange)

Operations & Maintenance

Challenges

OPERATIONS & MAINTENANCE	**Poor results**	• Higher than expected utility costs: "Systems not performing as intended with significantly higher than expected utility consumption". The impact of electrical demand charges can play a big part in this.
	Equipment Breakdown	• Higher maintenance costs, more frequent preventive maintenance by more qualified technicians may be required. • "Too many problems with our heat pumps from 2010-2018. They break down often, to the point that the natural gas backup becomes the primary with no immediate plan for repair due to repair costs." • Potential refrigerant leaks • Electrical boiler had two cracked elements due to air in the system
	Controls and HVAC Integration	• Don't know if they are operating properly: "I'm still unsure if we've completely resolved the issue regarding BAS integration." • Integration with different HVAC systems • Sensitivity to operating conditions, equipment / heat pump tripping due to low loop temperature • Limited support from BAS vendor • Network communications prevents alarms from coming through
	People	• Knowledge transfer, staff training, knowledge retention due to revolving door of refrigeration mechanics • Lack of clarity on roles during the warranty period
	Water quality	• Need condenser water system filtration • Open cooling towers allow silt into the system, risk of fouling brazed heat exchangers in modules (Island Health) • Water quality issues causing premature failure of electric heating boiler electrodes. This applies to any open loop system like a cooling tower as well.

Solutions

OPERATIONS & MAINTENANCE	**Continuous improvement**	• Need to analyse poor performance and learn from mistakes • Work through building automation issues and optimize system operations • Track energy performance

	Purchase quality equipment	• There are a range of manufacturers
		• It's important to get a quality system suited for your application
		    o Cold climate specific systems
		    o Part load performance
		    o Warranty and local support

	Seek to understand the source of the problem	• often requires decoupling higher temperature loads to ensure proper function (buffer or elec swing tanks)
	Water Treatment	• Sizing the water treatment (softener) is an important consideration from both technical and financial perspectives. • Include condenser water system filtration where necessary.
	People	• Gaps between DDC techs and Mechanical techs may need to be bridged. • Need to have properly trained trades to maintain the equipment • Provide adequate time for staff training during construction and commissioning phase – HVAC technicians are the first point of contact for teachers (SD42) • Involving the whole building operations team was a key to success for the BCIT DTC project.

Business Case

Challenges		
BUSINESS CASE	**CleanBC rebate is low**	• The incentive for the two BCIT retrofit projects from CleanBC was only 5% of the total actual project cost.
	Rate change	• BC Hydro rate changed after LCE upgrade, now with kW demand charge is a real issue
	Contractors	• "The controls contractor is often a sub of the mechanical who is the sub of the General Contractor, there must also be lots of mark up along the way!" (and potential for breakdown in the lines of communication).
	Project phasing	• For large electrification projects, as there may be multiple phases, costs typically go up (lack of adequate project funding leads to phasing of project which leads to higher costs).

Solutions		
BUSINESS CASE	**Cost anticipation**	• Plan for additional costs that may be needed: three other things in addition to the heat pump itself: structural, air distribution and electric power supply (SD42).
	Budget buffer	• Studies should allow for budget overruns as there are significant differences between total actual project costs vs estimated budget costs.
	Incentives	• Watch for changes to incentive programs https://www.betterbuildingsbc.ca/incentives/cleanbc-custom-program/

Follow up Requests

- Do a technology overview of various types of equipment and retrofit options.
- People complain about the efficiency of heat pumps as it gets cold so it would be good to compare the cost of running heat pumps near 0°C with lower COPs vs natural gas boilers.
- We have issues regarding BMS integration: would be nice to see the best practice from the industry.
- Develop a Best Practice Guide (for Commercial) for heat pump, HRC, and related LCE retrofits.

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This document was prepared by Prism Engineering Limited for the BC Hydro Commercial Energy Manager Program