Best Practices for Energy Efficient Chiller Plant Design, Operation and Controls

A GREENING HEALTH CARE RESEARCH PROJECT

SPONSORED BY:

We gratefully acknowledge the support and commitment of the 14 participating hospitals and the project sponsors.

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CLIMATE CHALLENGE NETWORK

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1 BACKGROUND

This research report provides the background to Greening Health Care's Best Practices Guide (the Guide) which is designed for use by hospital Facility Directors to help them direct their engineering consultants, service contractors, operators and controls companies in making their chiller plant performance the best it can be. The Guide is provided as a technical resource for Greening Health Care (GHC) members and is posted on the program website for use by all hospitals.

Ten acute care hospitals and four complex continuing care and other non-acute care hospitals (acknowledged in Table 1 below) took part in the research, providing technical input and review as well as information on their existing systems and operations. They total more than 11 million ft2 of building area and almost 235 million kWh of annual electricity use.

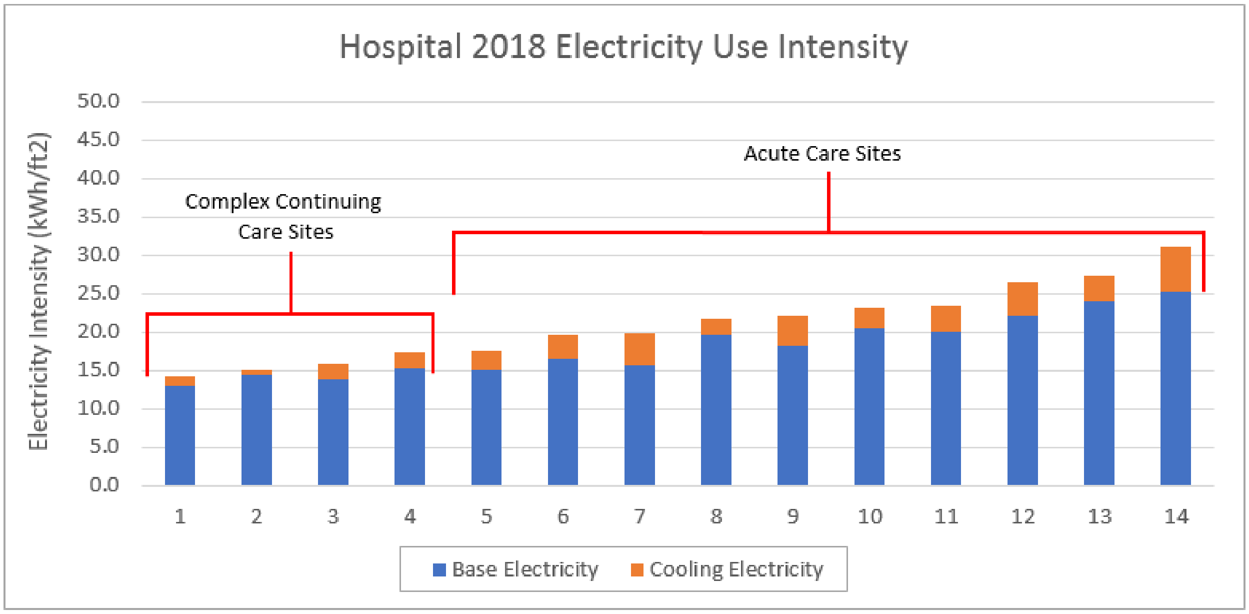
Table 1 Research Participant List

Hospital	Hospital Type	Building Area ft2	2018 Total Electricity kWh
Baycrest, Toronto ON	Continuing Care	988,700	14,979,536
Providence, Toronto ON	Continuing Care	647,605	9,212,081
Ontario Shores, Whitby ON	Continuing Care	540,696	8,630,282
Runnymede Healthcare, Toronto ON	Continuing Care	179,070	3,117,046
Huntsville District Memorial, ON	Rural Acute Care	135,336	2,647,600
Orillia Soldiers' Memorial, ON	Rural Acute Care	429,204	11,744,009
AHS - Wetaskiwin Hospital, AB	Rural Acute Care	236,055	7,359,518
Humber River Hospital, Toronto ON	City Acute Care	1,826,209	39,705,650
THP - Queensway Health Centre, Toronto ON	City Acute Care	484,440	8,545,999
North York General Hospital, Toronto ON	City Acute Care	755,508	17,562,307
Oakville Trafalgar Memorial, ON	City Acute Care	1,701,876	39,687,931
THP - Mississauga Hospital, ON	City Acute Care	968,856	21,373,734
THP - Credit Valley Hospital, Mississauga ON	City Acute Care	859,956	22,880,487
Kingston General Hospital, ON	City Acute Care	1,369,380	27,069,154
Totals:		**11,122,891**	**234,515,333**

Utility company and industry sponsors also played active roles, contributing technical knowledge and funding towards the work. Findings were presented to and reviewed with member hospitals at the Greening Health Care spring 2019 workshop and webinar, obtaining broader input to the project.

There is a wide range of electricity use intensity between them as shown in Figure 1. Some of this variance is attributed to cooling plant performance, but the larger part is associated with differences in building system (predominantly air handling system) loads. Acute care hospitals have predictably higher intensities overall, with some using 50% more electricity per ft2 than others.

Figure 1 Electricity Use Intensity



Getting the best practical efficiency from hospital cooling plants can lead to significant energy, utility cost and peak demand savings. Over the years, GHC member hospitals have implemented many chiller plant retrofits, replacements and controls upgrades which have produced significant electricity savings, notably North York General, Runnymede, West Park, Baycrest and CAMH. Interval metering and trend log analysis at these hospitals has allowed direct comparison of performance against each other and over time, providing a rich body of data from which best design, operational and control practices have been learned, shared with and applied by other hospitals. This experience has informed the measures contained in the Guide.

2 DATA COLLECTION AND ANALYSIS

2.1 Database

This research has created a large Database (the Database) of energy use, hospital types and building areas for the participating sites, together with information on plant configurations and capacities and operational data, including temperature set-points, water treatment and operating logs. The structure and content of the Database are presented in Appendix A. Not all information was available for all sites, and some changed during the course of the project as some participating hospitals replaced chillers and made adjustments to improve performance.

Best practices were developed from Greening Health Care experience and the knowledge and discussions among the project participants and reinforced where correlations between electricity use intensity and plant characteristics were identified. In general, such correlations were hard to find, but we expect more definitive results to emerge as plant upgrades and operational improvements are implemented over time and we are able to isolate the resulting savings.

The Database will be expanded and updated over time as the current participants make improvements and complete and update their information profiles, and as more hospitals join the research. Ten hospitals provided complete data and are included in Table 2 below.

The Database is ordered from the lowest to the highest cooling electricity use per square foot (ft2) of hospital area (see Section 2.2 for discussion of cooling electricity use and targets). This ordering aims to help identify the common characteristics of more and less cooling-efficient hospitals, and to help find correlations to support the identified best practices. For each best practice, the number of hospitals reporting they use it is provided for the Continuing/Non-Acute Care (C) and Acute Care (A) sites together with the total number of hospitals reporting on that best practice (in parentheses). Where correlations were found between a best practice and cooling electricity efficiency in the Database, this is indicated in each section of the Guide.

Founded in 2004, **Greening Health Care** is the largest program of its kind in North America, helping hospitals work together to lower their energy costs, raise their environmental performance and contribute to the health and well-being of their communities. Members manage data, assess their performance and track savings through an online energy information system. They share knowledge and best practices in workshops, webinars and networking to help plan, implement and verify improvements. This is a program of Climate Challenge Network with technical direction by Enerlife Consulting.

The summary of plant and equipment capacities from the Database is shown in Table 2, with the most efficient hospitals to the left.

Table 2 Summary of Plant and Equipment Capacities

System Metrics	NYGH	THP M-Site	THP Admin	Runnymede	Ontario Shores	Huntsville	Orillia Soldiers	KGH	South Muskoka	AHS – Wetaskiwin (Note 1)
Chiller Capacity Tons/1000ft2	2.48	2.95	2.40	2.51	3.20	2.47	2.86	3.18	3.76	2.45
Cooling Tower HP/1000ft2	0.24	0.21	0.12	0.17	0.16	0.25	0.39	0.38	0.35	0.22
Cooling Tower HP/ton	0.10	0.07	0.05	0.07	0.05	0.10	0.14	0.12	0.09	0.09
Cooling pumps HP/1000ft2	0.15	0.05	0.12	0.08	0.10	0.25	0.17	0.12	0.35	0.18
Pumps HP/ton	0.32	0.28	0.20	0.18	0.20	0.18	0.28	0.15	0.35	0.42

Note 1: Alberta Health Services facility metrics normalized based on peak CDD

Observations drawn from Table 2 include:

- a general correlation between the more efficient hospitals and lower Tons/1000ft2 and corresponding cooling tower HP/1000ft2 suggesting plant right-sizing contributes to efficiency; and
- a wide range (up to 7:1) of pumping power densities highlighting the magnitude of pumping energy and the importance of careful design and control.

2.2 Cooling Electricity and Water Use and Targets

Electricity consumption for the 14 hospitals is weather normalized to Toronto, Ontario and displayed in Figure 2. Cooling electricity is separated out by regression analysis of monthly billing data against cooling degree days (CDD), and ranges from 0.8 kWh/ft2 to 6.0 kWh/ft2. Cooling electricity ranges from 5.3% to almost 20% of total electricity use.

Cooling electricity targets are standards set at the top-quartile benchmark for each hospital type based on all hospitals of that type in the Greening Health Care energy information system. Two hospitals are already below that standard and their targets are reset down to their actuals. Cooling electricity savings potential for the whole group averages 26.9% and totals nearly 8 GWh per year.

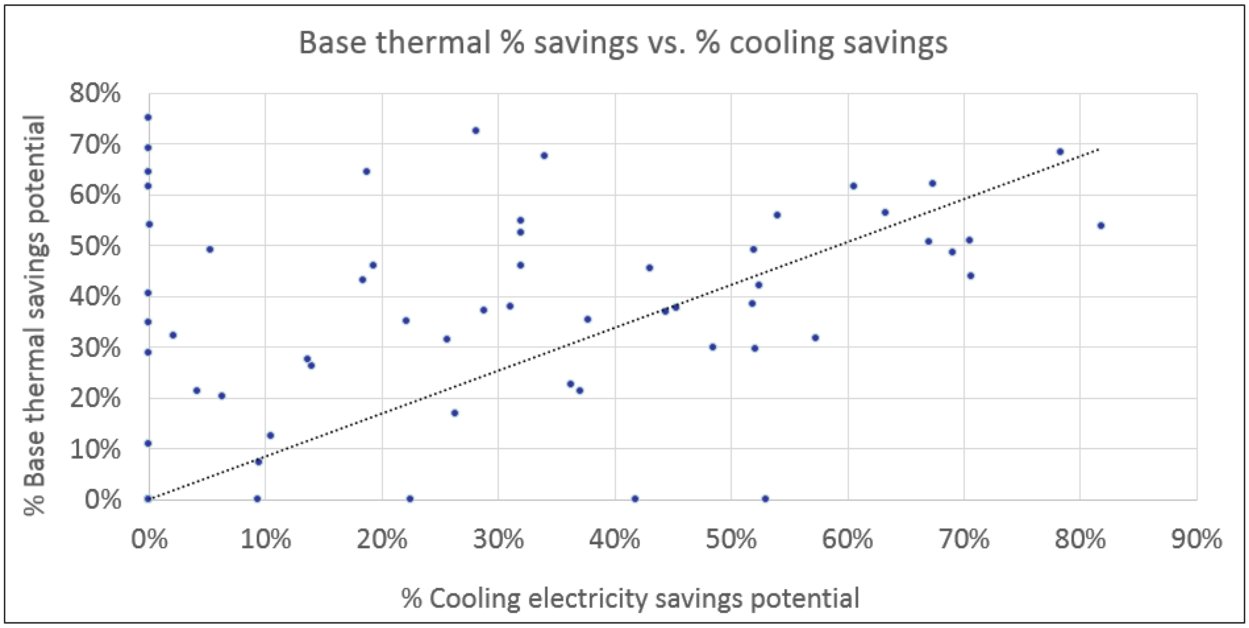
Table 3 Electricity Consumption and Cooling Savings Potential

Hospital	2018 Electricity kWh	2018 Cooling Electricity kWh	% Cooling Electricity	Cooling Electric 2018 kWh/ft2	Cooling Electric Target kWh/ft2	Savings %	Cooling Savings kWh
Baycrest	14,979,536	800,596	5.3%	0.8	0.8	0.0%	0
Providence	9,212,081	787,100	8.5%	1.2	1.2	0.3%	2,068
Ontario Shores	8,630,282	1,072,189	12.4%	2.2	1.2	47.4%	563,275
Runnymede Healthcare Centre	3,117,046	367,983	11.8%	2.1	1.2	43.8%	161,011
Humber River Hospital	39,705,650	3,715,628	9.4%	2.0	2.0	0.0%	0
THP - Queensway Health Centre	8,545,999	1,151,169	13.5%	2.6	2.2	17.7%	227,768
North York General Hospital	17,562,307	1,908,099	10.9%	2.8	2.7	5.5%	116,387
Oakville Trafalgar Memorial	39,687,931	4,918,056	12.4%	3.2	2.6	19.1%	1,047,599
THP - Mississauga Hospital	21,373,734	3,420,114	16.0%	3.9	2.7	32.1%	1,218,721
Huntsville District Memorial	2,647,600	378,183	14.3%	3.1	2.7	14.6%	61,395
Orillia Soldiers' Memorial	11,744,009	1,301,954	11.1%	3.4	2.7	21.3%	309,111
THP - Credit Valley Hospital	22,880,487	3,463,556	15.1%	4.4	2.7	39.6%	1,498,180
Kingston General Hospital	27,069,154	4,989,176	18.4%	4.1	2.6	35.6%	1,981,193
AHS - Wetaskiwin Hospital	7,359,518	1,412,423	19.2%	6.0	2.7	55.5%	784,156
Totals:	**234,515,333**	**29,686,227**	**12.7%**			**26.9%**	**7,970,862**

This savings potential is primarily attributed to inefficiencies in either or both of cooling loads (mostly air handling systems) and the cooling plant. The relationship of cooling electricity and base (year-round) thermal (natural gas and steam) is of interest due to the prevalence of ventilation reheat for space temperature and humidity control in hospitals which in turn adds substantially to cooling loads. Greening Health Care assigns equivalent top-quartile targets for base thermal, and Figure 2 charts cooling electricity against base thermal target savings.

Results show the expected positive correlation between the two, where higher base thermal is associated with higher cooling electricity use. The points above the regression line (high base thermal savings relative to cooling electric) indicate heating plant inefficiency while those below the line suggest cooling plant inefficiency.

Figure 2 Cooling Electricity Against Base Thermal



The research also examined additional water consumption during the summer months above the year-round use which is attributed to cooling tower makeup and in some cases to grounds watering. Further information on metered irrigation water will be included in future research. Cooling water targets are top quartile standards for different hospital types. Cooling water use, targets and annual savings potential is shown in Table 4. Zeros are shown where monthly billing data was inconsistent and precluded meaningful regression analysis. The data serve to highlight a handful of hospitals where further investigation is indicated.

Table 4 Water Consumption and Targets

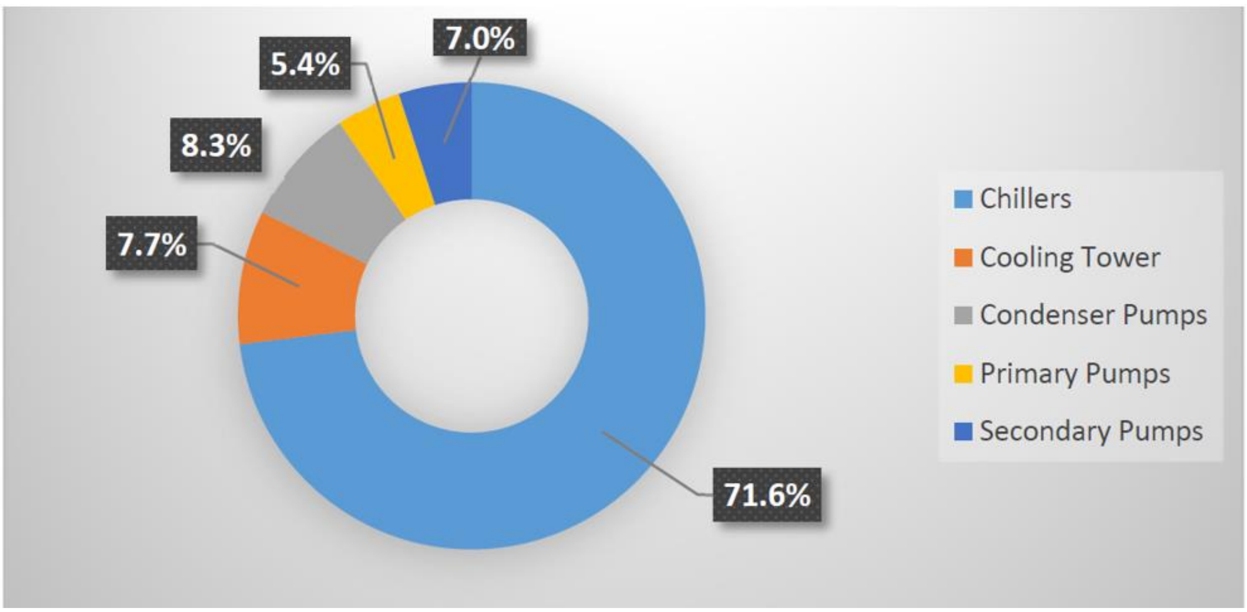
Hospital	2018 Total Water litres/ft2	2018 Cooling Water litres/ft2	Cooling % of total	2018 Cooling Target litres/ft2	% Savings Potential	Savings m3
Baycrest	165.3	27.2	16.4%	14.1	48.0%	12,879
Providence	139.0	4.0	2.9%	4.0	0.0%	0
Ontario Shores	134.8	0.0	0.0%	0.0	0.0%	0
Runnymede Healthcare Centre	132.7	26.0	19.6%	15.7	39.7%	1,849
Huntsville District Memorial	182.3	16.2	8.9%	16.2	0.0%	0
Orillia Soldiers' Memorial	281.1	39.4	39.4%	27.5	30.3%	5,118
AHS - Wetaskiwin Hospital	255.8	0.0	0.0%	0.0	0.0%	0
Humber River Hospital	124.9	25.0	20.0%	25.0	0.0%	0
THP - Queensway Health Centre	164.2	21.3	13.0%	21.3	0.0%	0
North York General Hospital	113.6	0.0	0.0%	0.0	0.0%	0
Oakville Trafalgar Memorial	146.7	19.6	13.4%	19.6	0.0%	0
THP - Mississauga Hospital	192.5	23.2	12.1%	23.2	0.0%	0
THP - Credit Valley Hospital	225.7	61.9	27.4%	27.5	55.6%	29,605
Kingston General Hospital	171.3	31.8	18.6%	27.5	13.7%	5,986
Totals						**55,437**

Two of the hospitals feature heat recovery chillers which operate year-round, recycling heat generated within the hospital to supplement the heating systems and offset gas or purchased steam use. They are flagged separately since their energy use profiles are quite different, with higher base electricity, lower cooling electricity and reduced base thermal consumption.

2.3 Cooling Plant Electricity Breakdown

The electricity use breakdown for Kingston General Hospital which provided more detailed trend log and load measurement data is shown in Figure 3 and can be considered representative of hospitals with centrifugal chiller plants without heat recovery chillers.

Figure 3 Electricity Use Breakdown



3 BEST PRACTICES – CHILLER PLANT DESIGN, RETROFITS AND EXPANSION

Every cooling plant is different, and users of the Guide are advised to consult their mechanical engineer and their chiller and water treatment service providers when evaluating and implementing these best practices.

3.1 Chiller selection

Conduct an energy efficient load analysis and right-size the new plant to required loads. Consider shoulder season cooling requirements with a chiller and auxiliaries sized for efficient low load operation.

Choose the most efficient new machines available which will typically be fitted with magnetic bearings and variable frequency drives (VFDs).

Include prescriptive performance data kilowatts per ton (KW/Ton) requirements in equipment specification. The numbers should be determined in discussions with your mechanical engineer and equipment manufacturers using life-cycle cost analysis. The starting point is the ASHRAE 90.1 latest standard. Prescriptive performance requirements allow comparison of different options and are used to verify actual performance during commissioning and ongoing performance from periodic testing (Section 4.1).

	Non-Acute	Acute
# of hospitals with VFD chillers	3 (5)	4 (7)
	# of hospitals reporting having the measure (total # of hospitals reporting on the measure)	

3.2 Pumping

When replacing a chiller plant, always test and replace/right-size pumps as necessary.

Right-size primary and secondary pumps to required loads. Apply variable frequency drives (VFDs) to all pumps. Note than an oversized pump with flow balanced using a VFD operates at lower efficiency, is limited when operating at low flow conditions and may have to be replaced.

Install 2-way rather than 3-way control valves on the secondary loops. Specify smart (energy) control valves for replacements or new installations.

	Non-Acute	Acute
# of hospitals with VFD pumping	2 (5)	5 (7)
	# of hospitals reporting having the measure (total # of hospitals reporting on the measure)	

3.3 Cooling towers

When replacing a chiller plant, always test and replace/refurbish cooling towers as necessary. Testing measures the approach temperature relative to ambient dewpoint – when it is too high this is indicative of poor cooling tower performance (inefficient heat rejection). Chemical treatment is very important since scale build-up reduces heat rejection capacity. Sometimes baffles need to be replaced but chemical cleaning may be a better option since replacement is quite costly.

Choose the most efficient cooling tower type available, matched to the chillers and equipped with fan motor VFDs. Review cooling tower fans and pumps to confirm actual operating loads for right sizing the cooling tower.

Consider replacing closed loop fluid cooler serving building 24/7 cooling load with heat recovery chiller to maximize heat recovery.

	Non-Acute	Acute
# of hospitals with VFD cooling tower fans	3 (4)	4 (7)
	# of hospitals reporting having the measure (total # of hospitals reporting on the measure)	

3.4 Winter operation and heat recovery chiller applications

Install heat recovery chiller(s), right sized to available heat loads and shoulder season demand. Integrate with chilled water and heating systems.

Avoid cooling tower winterization and winter operation in favour of heat recovery.

	Non-Acute	Acute
# of hospitals with heat recover chiller(s)	0 (3)	2 (7)
	# of hospitals reporting having the measure (total # of hospitals reporting on the measure)	

4 BEST PRACTICES – OPERATIONS AND CONTROLS

Every cooling plant is different, and users of the Guide are advised to consult their mechanical engineer and their chiller and water treatment service providers when evaluating and implementing these best practices.

4.1 Chiller testing and maintenance

Test part load performance kW/TR across the full operating range every 5 years. Chart the relative efficiencies of each machine to identify its most efficient "sweet spot". Compare results to previous test reports to monitor performance trends over time.

Implement maintenance recommendations from the testing contractor for improving efficiency.

	Non-Acute	Acute
# of hospitals with chiller testing in past 5 years	2 (4)	2 (8)
	# of hospitals reporting having the measure (total # of hospitals reporting on the measure)	

4.2 Chiller sequencing

Program chiller sequencing based on maximizing operation in the most efficient ranges. Use trend logs to verify intended operation.

	Non-Acute	Acute
# of hospitals with smart chiller sequencing	3 (3)	1 (1)

4.3 Supply water temperature controls

Dynamically reset chilled water supply temperature based on building demand (typically control valve position on critical air handling systems).

Dynamically reset condenser water temperature to optimize chiller efficiency and cooling tower fan energy.

Set up and monitor trend logs to verify intended operation.

	Non-Acute	Acute
# of hospitals with dynamic water temperature control	2 (3)	2 (7)
	# of hospitals reporting having the measure (total # of hospitals reporting on the measure)	

4.4 Pump controls

Test and rebalance to achieve design supply/return water temperature differentials with main balancing valves fully open.

Program VFD speeds to maximize temperature differentials while maintaining required pressures and flow rates with dynamic feedback from system control valve positions.

Set up and monitor trend logs to verify intended operation.

	Non-Acute	Acute
# of hospitals with pump testing and rebalancing	0 (0)	2 (2)
	# of hospitals reporting having the measure (total # of hospitals reporting on the measure)	

4.5 Water treatment & operation logs

Install and monitor makeup water meter.

Monitor condenser and chilled water Percent in Control continuously (electronic) or through daily operator readings supplemented by service contractor reports. Record results over time to identify performance trends.

Implement electronic operating log capable of trending parameters and flagging out-of-range conditions for remedial action. These systems are available from water treatment service providers. Train operators to make full use of this capability.

	Non-Acute	Acute
# of hospitals reporting Percent in Control	2 (2)	2 (2)
	# of hospitals reporting having the measure (total # of hospitals reporting on the measure)	

4.6 Cooling tower maintenance

Test and inspect cooling towers to ensure proper flow distribution and heat transfer.

Implement maintenance recommendations from the testing contractor for improving efficiency.

Set up and monitor trend logs to verify intended operation.

	Non-Acute	Acute
# of hospitals with cooling tower testing in past 5 years	0 (0)	2 (2)
	# of hospitals reporting having the measure (total # of hospitals reporting on the measure)	

4.7 Building automation systems & controls

Set up of trend logs (15 min interval) for key chiller plant points with readily accessible archiving for a minimum of 2 years' worth of data.

Develop the interface between the BMS and facility operations to ensure the system provides fully effective support to front-line staff including:

- Logging of manual overrides and corrective action taken to remove and prevent recurrence
- Accurate and complete user interface screen displays
- Staff training in and comfort with the system

	Non-Acute	Acute
# of hospitals with trend logs set up and archived	0 (3)	1 (4)
	# of hospitals reporting having the measure (total # of hospitals reporting on the measure)	

5 CHILLER PLANT EFFICIENCY CASE STUDY

5.1 Runnymede Healthcare Centre

Runnymede Healthcare Centre has undergone several controls improvements to its cooling plant and HAVC system over the past three years to achieve significant savings.

Controls improvements:

1. Originally lead chiller is enabled manually and lag chiller often cycled on and off in short durations. In 2012 added Outdoor Air Temperature (OAT) enable for lead chiller, and increased Supply Air Temperature (SAT) in Air Handling Units (AHUs) from 13C design to 16C to 18C

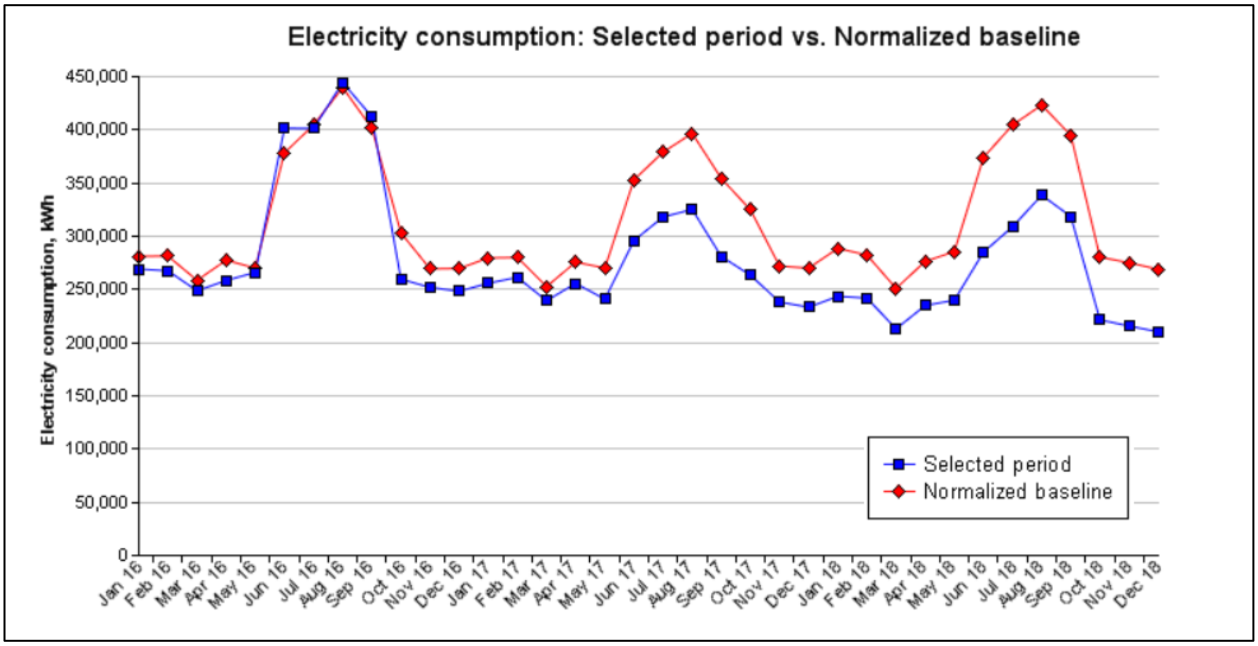
2. Since 2017 the chillers were being controlled manually while watching closely to satisfy space temperature & relative humidity requirements:

    - Limiting chiller VFD to <70%
    - Supply water temperature reset while watching AHUs' return air temperature and relative humidity: loop temperature increased to 7.5 to 8C while space is still satisfied on mild days
    - Supply air temperature reset on AHUs to delay lag chiller coming on as much as possible
    - Closely monitoring operation and found in Sept-Oct 2017 the chiller wasn't shutting off at night and was corrected
    - Forecasting and controlling chiller operation by the "feels like" in weather forecast and decide on whether lag chiller needs to be enabled
3. Controls Automation:
    - Investigating installing accurate outdoor relative humidity sensors and connecting to local weather stations for predictive control based on forecast as well as enthalpy
    - The chiller controls are currently all manual. Resets and limits can be programmed to function automatically

    - Currently the fluid coolers are programmed to turn on automatically whenever the chillers are off. There are periods when the chillers are not needed for space cooling but there's enough capacity in the loop to handle equipment cooling loads. The fluid coolers can be programmed to run based on load conditions
4. Load Reduction:
    - The patient areas are served by 100% outside air systems with thermal wheels and on average are supplying 5.6 air changes per hour. It can be reduced to 4 to further reduce cooling loads
    - The radiant heating loop circulates year-round, but the radiant panels do not need heating in summer (reheat is handled in the Variable Air Volume (VAV) boxes). This loop can be turned off to further reduce cooling loads

The electricity savings from measures implemented in the past three years are shown in the monthly savings report in Figure 4. The total percentage of electricity reduction in the selected 2018 period compared with the 2015 normalized baseline was 19.3%. This was equal to 733,608 kWh and approximately $110,000.

Figure 4 Runnymede Electricity Savings Report



Even with the recent success in energy reduction at the hospital, they still have electricity and thermal savings potential of 27.9% to reach the program target, as outlined by component in Figure 5.

Figure 5 Energy Targets and Savings Potential

Electricity (kWh/ft2)				Thermal (ekWh/ft2)				Total Energy (ekWh/ft2)		Savings Potential	
Base		Cooling		Base		Heating					
Actual	Target	Actual	Target	Actual	Target	Actual	Target	Actual	Target	%	Cost
15.4	14.1	2.1	1.2	17.7	7.8	11.5	10.5	46.6	33.6	27.9%	$118,856

APPENDIX A: DATABASE CONTENTS

Chiller	# of cooling plants
	Plant operation
	# of chillers
	Years installed
	Type
	Cooling source
	Maximum tonnage
	Chiller Capacity Tons/ft2
	VFD
	Season
	Hot gas bypass
	Water makeup meter
	Design kW/ton
Cooling Tower	# of cooling towers
	Cooling tower fan HP
	HP/ft2
	HP/ton
	# of cooling tower fans
	year installed
	year of major refurbishment (n)
	Type
	# of cells
	Staging
	Season
	Water makeup meter
	Drained in winter
Pumps	Primary CHW pump total HP
	Primary CHW pump duty HP
	Cooling pumps HP/1000ft2
	HP/ton
	Duty pumps HP/ton
	Duty pumps HP/1000ft2
	# of primary CHW pumps
	VFD
	Season
	Primary condenser pump total HP
	Primary condenser pump duty HP
	# of primary condenser pumps
	VFD
	Secondary CHW pump total HP
	Secondary CHW pump duty HP
	# of secondary CHW pumps
	VFD

Operations	Test reports for pumps and chillers
	Operating logs (new)
	Trends
	2017 Trends
	CHWT setpoint
	Current kW/ton
	Valves
	Limiting factor for SWT
	Reheat in summer
Water	Water treatment company
	Tower procedure
	Water treatment issue
	Automated water control
	% in control
	Filter
	Type of filter
Other	Upgrades

APPENDIX B: CHILLER PLANT DESIGN, RETROFIT AND EXPANSION BEST PRACTICES GUIDE CHECKLIST

Action		Already Implemented	Planned	Consider	Reject/ NA	Details
#	NAME					
	Plant design, retrofit and expansions					
3.1	**Chiller Selection**					
3.1.1	Match load, right size for seasonal performance and choose most efficient machine					
3.1.2	Use prescriptive performance data to select new chiller plant equipment					
3.2	**Pumping**					
3.2.1	Add VFD's, right-size pumps to match load					
3.2.2	Control valve - 2-way to 3-way conversion, use energy valves as applicable					
3.3	**Cooling Tower**					
3.3.1	Test performance and refurbish before replacement					
3.3.2	Replace end of life fluid cooler with HRC					
3.3.3	New selection - review trends and test data for right sizing & use prescriptive performance data for selection					
3.4	**Winter operations and heat recovery chiller applications**					
3.4.1	Add new heat recovery chiller and avoid cooling tower winterization and winter operations					

APPENDIX C: CHILLER PLANT OPERATION AND CONTROLS BEST PRACTICES GUIDE CHECKLIST

Action		Already Implemented	Planned	Consider	Reject/ NA	Details
#	NAME					
	Plant operation and control					
4.1	**Chiller testing and maintenance**					
4.1.1	Test chiller part-load efficiencies and compare every 5 years					
4.2	**Chiller sequencing**					
4.2.1	Minimize total plant power and use trend logs to verify the performance					
4.3	**Supply water temperature controls**					
4.3.1	Use cooling control valves feedback to reset SWT & use trend logs to confirm perform					
4.4	**Pump controls**					
4.4	Rebalance distribution with VFD's and program pump control based on control valve positions					
4.5	**Water treatment and operating logs**					
4.5.1	Install make up water meter					
4.5.2	Monitor percent in control (electronic or manually) on daily basis & train operations staff to identify anomalies					
4.6	**Cooling tower maintenance**					
4.6.1	Inspect, test performance (every 5 years) and refurbish as recommended.					
4.6.2	Set up trend logs to verify performance					
4.7	**Building automation and controls**					
4.7.1	Set up trend logs (15min interval) for key chiller plant points and with readily archiving available for 2 years					