Beyond Design: Verifying Zero Through Operations

Mohawk College's Joyce Centre for Partnership and Innovation

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October 10, 2019

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Post Secondary Institutions Strategic Infrastructure Fund (S.I.F.)

- Initiated in Spring 2016
- Mohawk College - Total Project Value: $54.25M

$ 4.25 M	Renovations to E-Wing
$50.00 M	New Building
$20M	Grant Received

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Post Secondary Institutions Strategic Infrastructure Fund (S.I.F.)

Project Value: $50M ($47M Construction)

Estimated Building Size: 90,000 SF

Estimated Unit Cost: $525/SF (rounded)

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JCPI Final Costing Detail

- **Final Cost (Construction): $47,610,000**
- **Final Area: 96,700 square feet**
- **Final Unit Cost: $492/sq.ft.**

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Building Type (Altus Group)	$/Sq. Ft. – GTA (Altus Group)	
Universities & Colleges Teaching/Lecture Hall	395 - 520	
Universities & Colleges Laboratories (L1 & 2)	510 - 670	
Joyce Centre for Partnership and Innovation (Adjusted for Altus Cost Index of 1.04)	473	

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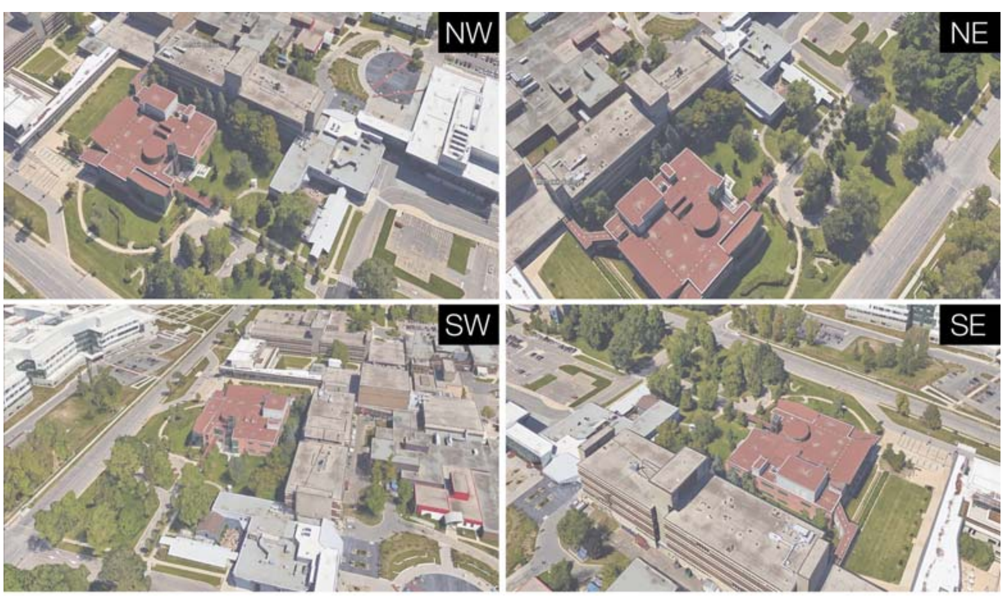

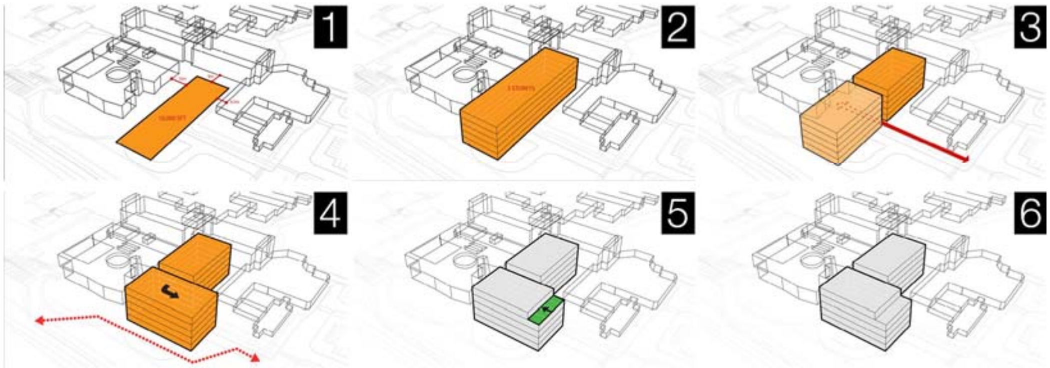

MASSING STUDIES

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Campus Perspective

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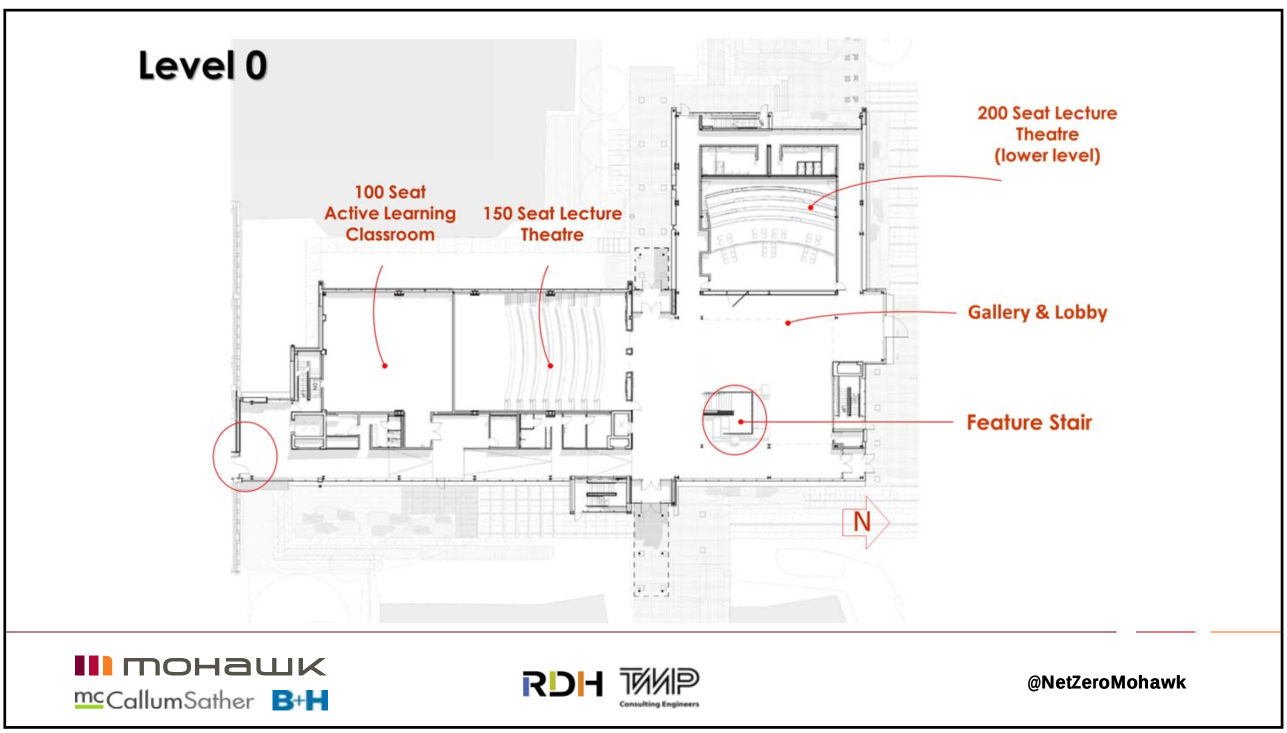
THE JOYCE CENTRE
FOR PARTNERSHIP & INNOVATION


Level 0
200 Seat Lecture Theatre (lower level)
100 Seat Active Learning Classroom
150 Seat Lecture Theatre
Gallery & Lobby
Feature Stair
N
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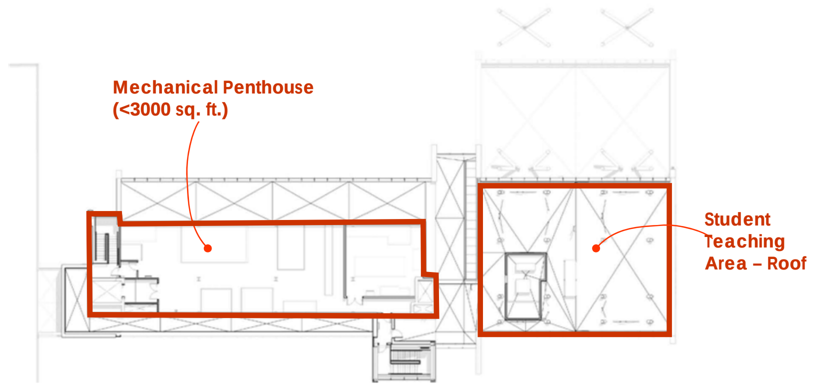
Penthouse



Plan to Achieve Net Zero and Challenges

- Energy Targets & Model
- Building Envelope Design
- Mechanical Systems
- Solar PV and Solar Thermal Systems
- Measurement & Verification
- Change in Culture

Any project can be Net Zero

Provided you have enough $$$

Or modest expectations for:
- Comfort
- Environmental Quality
- Amenities
- Etc.

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Energy Targets – Design Meeting #1

75 ekWh/m²-yr (24.2 kBtu/ft²-yr)

CIEBUS College/University Average: 211 ekWh/m²-yr (68.1 kBtu/ft²-yr)

R10 window + wall

Ontario SB-10 Climate Zone 5 Requirement: R4.7

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Energy Targets – Design Meeting #1

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R10 window + wall

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Design Meeting #2 "Energy Model"

End Use	Radiant Heating / Cooling + GHSP	Radiant Heating / Cooling + GHSP + Solar Thermal	Water Source VRF + GHSP	Water Source VRF + GHSP + Solar Thermal	Water Source VRF + Boiler / CT	Water Source VRF + Boiler / CT + Solar Thermal	Air Source VRF Heating / Cooling
Lighting	10.7	10.7	10.7	10.7	10.7	10.7	10.7
Misc. Equipment	19.3	19.3	19.3	19.3	19.3	19.3	19.3
Space Heating	17.1	8.6	13.7	9.6	13.0	13.0	21.4
Space Cooling	8.0	8.0	6.4	6.4	6.4	6.4	8.7
Pumps and Aux	9.6	11.0	6.7	8.2	3.4	4.8	0.0
Fans	7.5	7.5	11.3	11.3	11.3	11.3	11.3
DHW	4.5	2.3	4.5	2.3	4.5	2.25	4.5
Boiler	0.0	0.0	0.0	0.0	19.5	9.7	0.0
Total (ekWh/m²)	**76.7**	**67.3**	**72.5**	**67.6**	**88.0**	**77.4**	**75.9**
Rank (lowest to highest)	5	1	3	2	7	6	4
Net Solar Thermal Effect (ekWh/m²)		-9.4		-4.9		-10.6	
Total ekWh	578,000	508,000	547,000	510,000	664,000	584,000	573,000
Annual Energy Cost	$ 69,360	$ 60,960	$ 65,640	$ 61,200	$ 65,760	$ 63,120	$ 68,760
Size of PV Array (kWp)	525	462	497	464	604	531	521
Size of PV Array (m²)	4,379	3,848	4,144	3,864	5,030	4,424	4,341
Flat Roof Area (m²)	8,758	7,697	8,288	7,727	10,061	8,848	8,682
Cost of PV	$ 1,320,000	$ 1,160,000	$ 1,250,000	$ 1,160,000	$ 1,510,000	$ 1,330,000	$ 1,310,000
NREL Recommended O&M / year	$ 9,900	$ 8,700	$ 9,375	$ 8,700	$ 11,325	$ 9,975	$ 9,825
Linear m of Borehole	4,400	4,400	4,400	4,400			
# of 500' boreholes	29	29	29	29			
m² Area of Field using 6 m spacing	1,039	1,039	1,039	1,039			
Cost of Borehole	$ 440,000	$ 440,000	$ 440,000	$ 440,000			

At 8,600 m² and 5 storeys, our roof area is estimated at **1,720m²**

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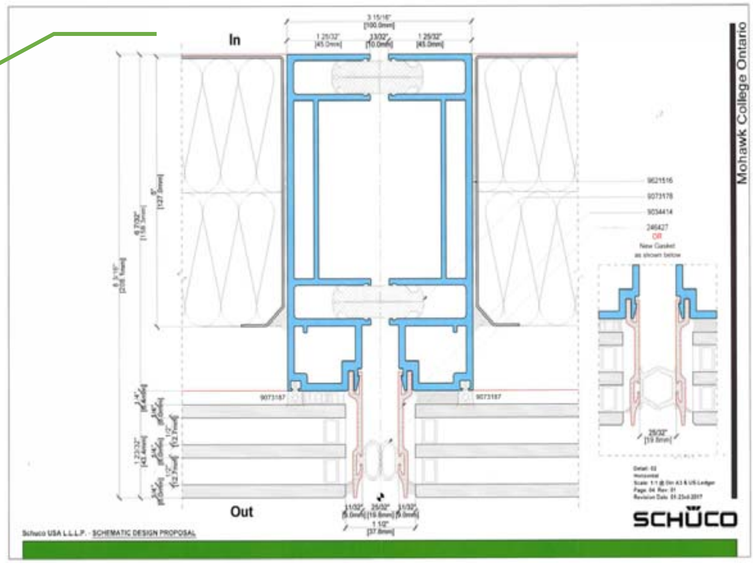
cavity insulation not shown

Unique Thermally Broken Curtain Wall to reduce thermal flanking at spandrel to vision transitions



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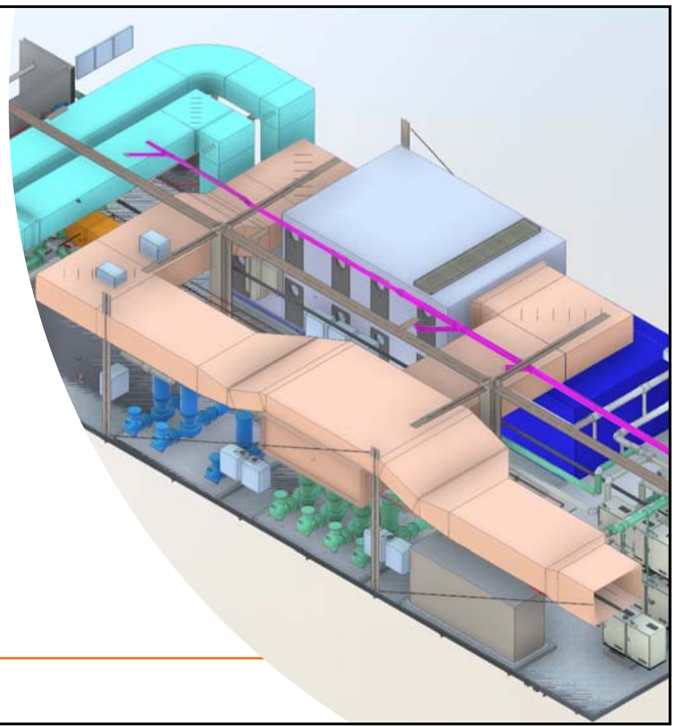
HVAC Systems Used

- Heat Pump system –Water Cooled VRF
- Geothermal field
- Dedicated outdoor air system (DOAS)
- Solar thermal for preheating DHW
- Heat pump "templifier" for aux DHW heating



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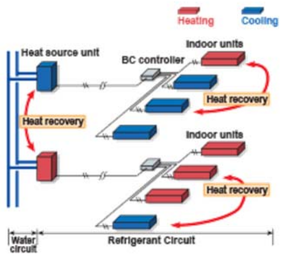
Water Cooled Geothermal VRF System

- Central geothermal condenser loop
- Heat recovery between heads on a circuit and between compressors
- Daikin VRF System



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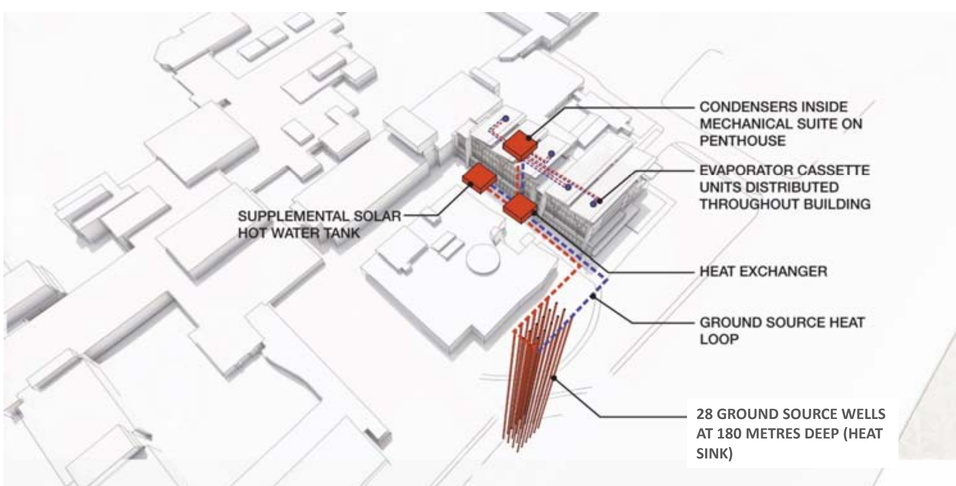
Mechanical Systems



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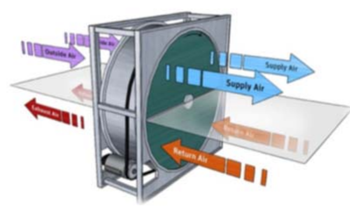
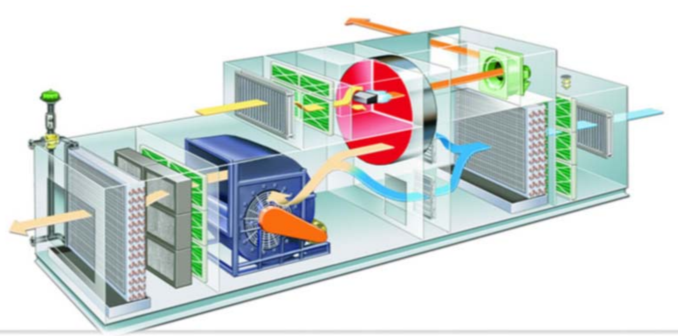
Heating Water System

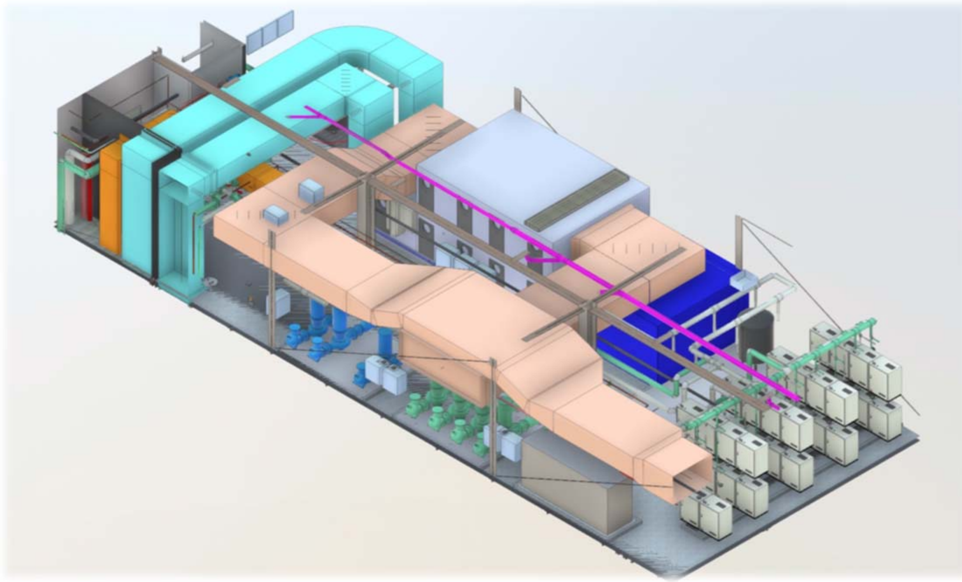
- Entrance heat and remote terminal heat
- Backup for DHW solar thermal

DOAS System

- Central dedicated outdoor air system
- Local VAV boxes for demand based ventilation
- Carefully placed ventilation connection to fan coils
- Heat Recovery Wheel







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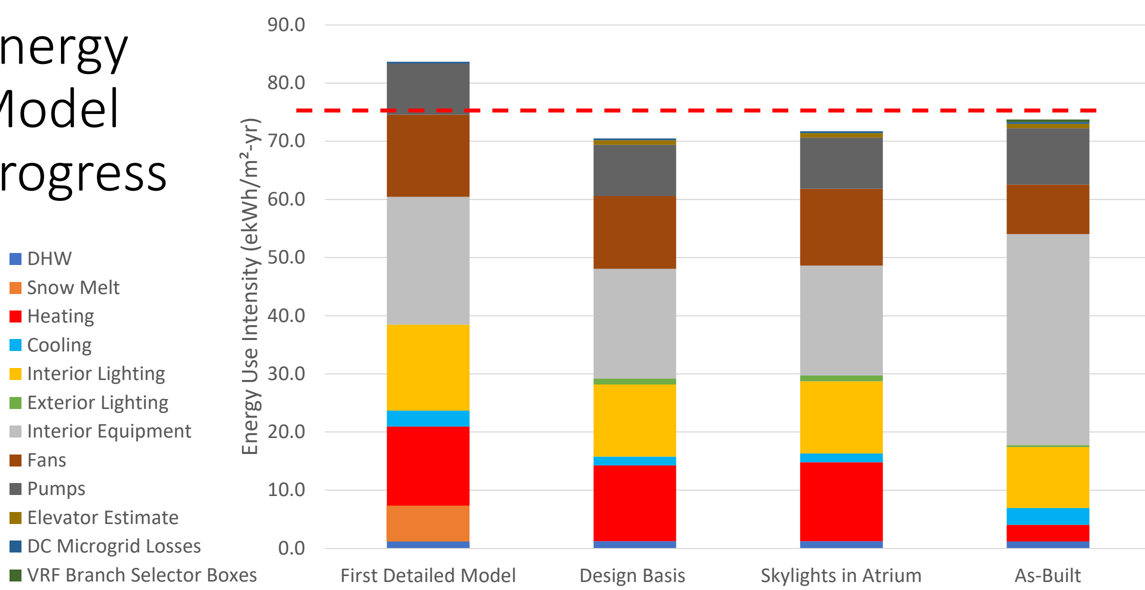
Energy Model Progress



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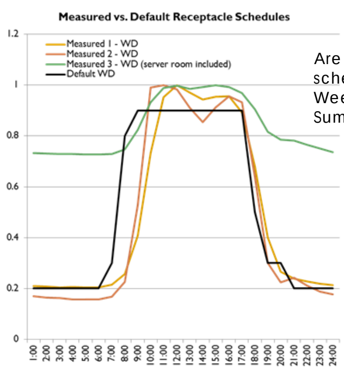
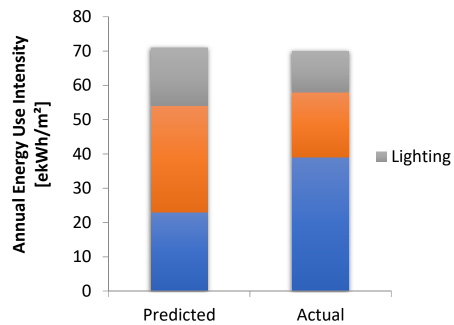
Build experience, question your assumptions and MEASURE



Are my operating schedules realistic?
Weekday / Weekend
Summer / Winter



"One accurate measurement is worth a thousand expert opinions" – Admiral Grace Murray Hopper (Dec 9 1906 to Jan 1 1992)

PROCESS OF ESTIMATING RECEPTACLE/PROCESS LOADS AND SCHEDULE

Review Program and Spaces → Create Table and Categorize Likely Receptacle Loads → Measure Loads with Surrogates

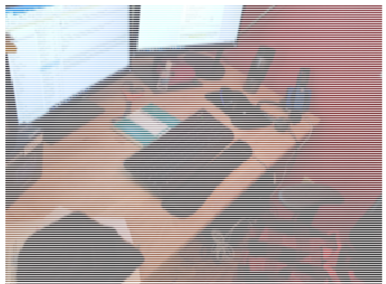
Review Schedule Assumptions with Client → Compare with Expectations → Refine Assumptions

Re-Review with Client

Measure Loads with Surrogate

Gaming Computer: Avg ~215 W

~35 W (charging)
~18 W (charged)



Avg ~63 W

75kWh/mo
Avg 104 W

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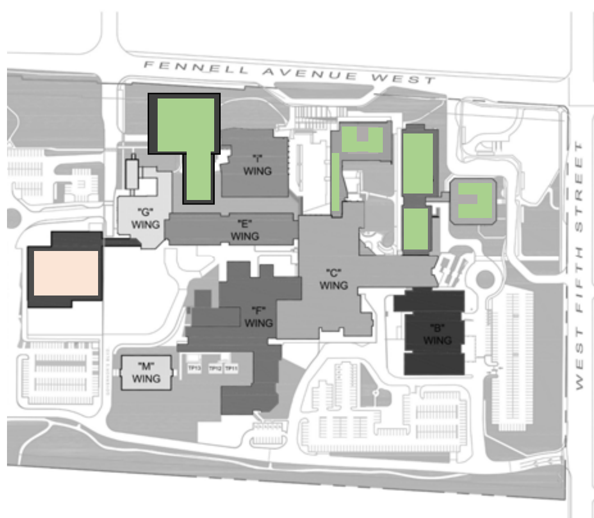
PV array

PV ARRAY MODULES	
JCPI	594
H-WING	360
A-WING	702
J-WING	324
TOTAL	1980



PV array   Back up option

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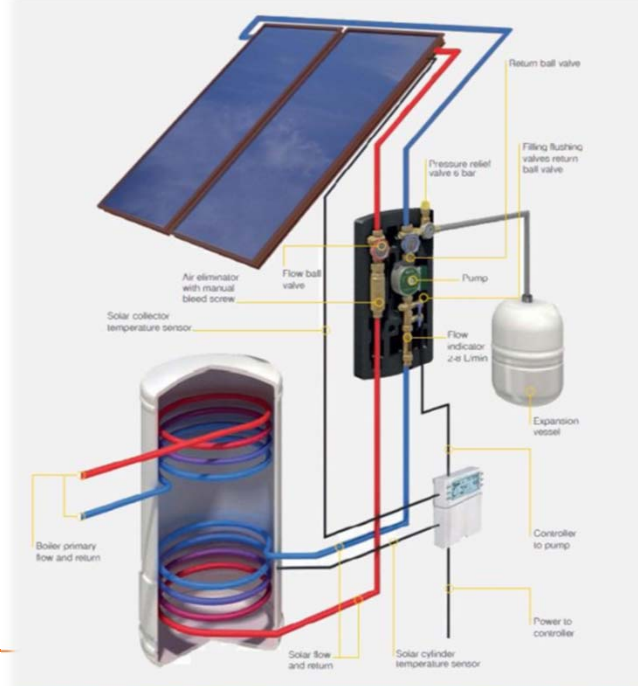
Solar Thermal

- Used to generate DHW and to augment condenser water loop heating
- Safeties for low load/no load conditions
- Viessmann panels, tanks and controls



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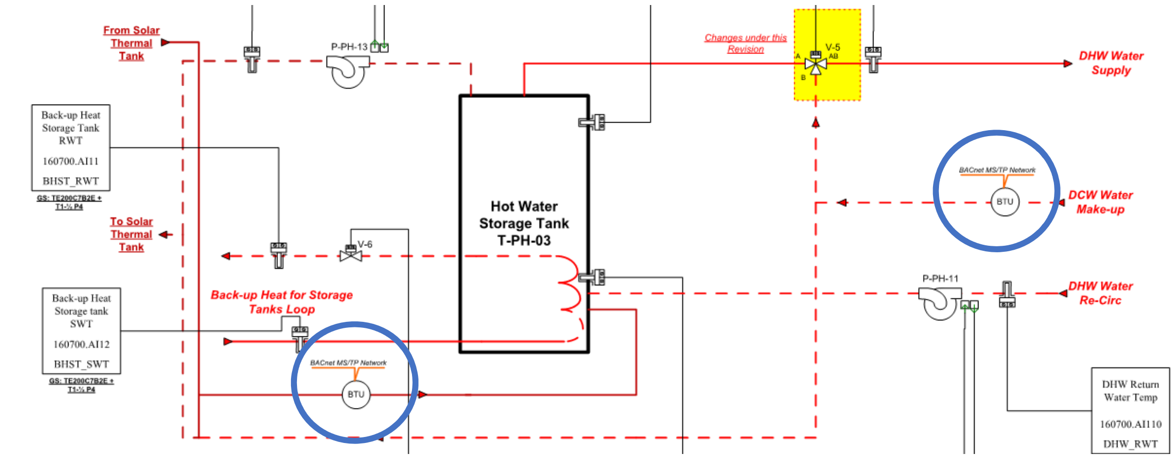
CaGBC Zero Carbon Design Certification

- Embodied Carbon:
  - 482 kg CO2eq / m² (96 lb CO2eq/sqft)
- Operating Carbon:
  - -17.7 kg/m²-year (-3.5 lb CO2eq/sqft)

Performance Monitoring - Is It Working?

- Motivation
  - Living Lab
  - Course Integration

- Design
  - 48 electrical submeter points
  - 3 BTU Meters
  - 3 Flow Meters (Rainwater Harvesting)
- Challenges
  - VRF heat output



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First Year of Operation

- September 15 2018 to September 15 2019
- **Top floor not fully occupied**
- Whole building and PV generations reporting
  - Some weeks missing in the continuous monitoring
  - Check meters work just fine!
- Submetering challenges – only a few months of data
- Calibrated energy model to be complete in early 2020
- Have identified further operating savings
  - Lighting controls
  - Temperature setbacks

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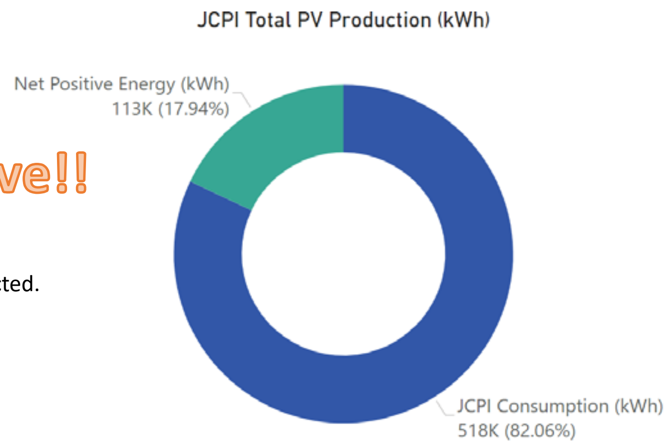
Whole Building Measured Results



We are Net Positive!!

Building Consumption 20% less than expected.

PV Production is 2% less than expected

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Monthly Analysis

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To Do: With a year of submeter data...

- Full Circle Energy Modelling
  - Weather
  - Schedules
  - Receptacle Loads
- Calibration (ASHRAE Guideline 14)
- Troubleshoot and Share

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Changing the Culture

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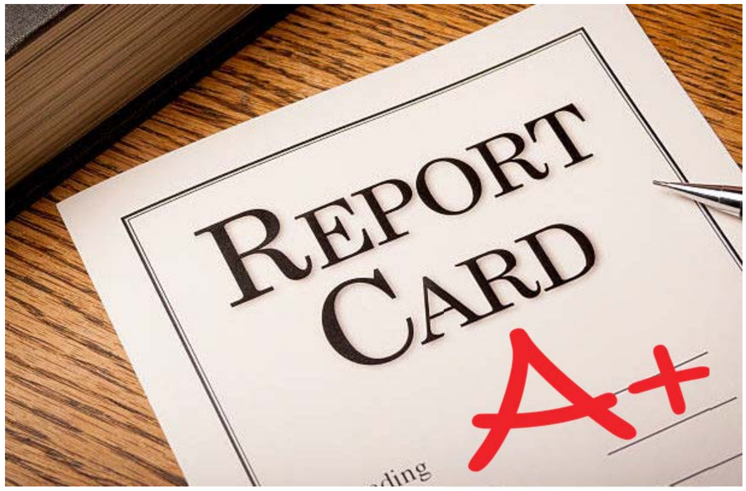
Building performance will translate to grades



Project Successes

Process:

- Establishing the Energy Budget

Technology:

- Integrating proven technologies with innovative high performance building envelope

Impacts: Net Zero Targets Achievable

- Net Zero Energy
- Net Zero Carbon

Project Challenges

- Commissioning Net Zero
- Metering Software
- Skilled Labour Trades Understanding & Awareness
- Staff Training
- Staff & Student Culture

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Thank you!
Questions?

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