

High Performance Industrial Laboratory: A Design Case Study

Workshop:

**“Modernizing Canadian Laboratories – A Sustainable Future for
Science and Technology”**

Sponsored by:

Real Property Institute of Canada

Mike Lubun

Sustainable Buildings & Communities

Natural Resources Canada

June 22, 2010

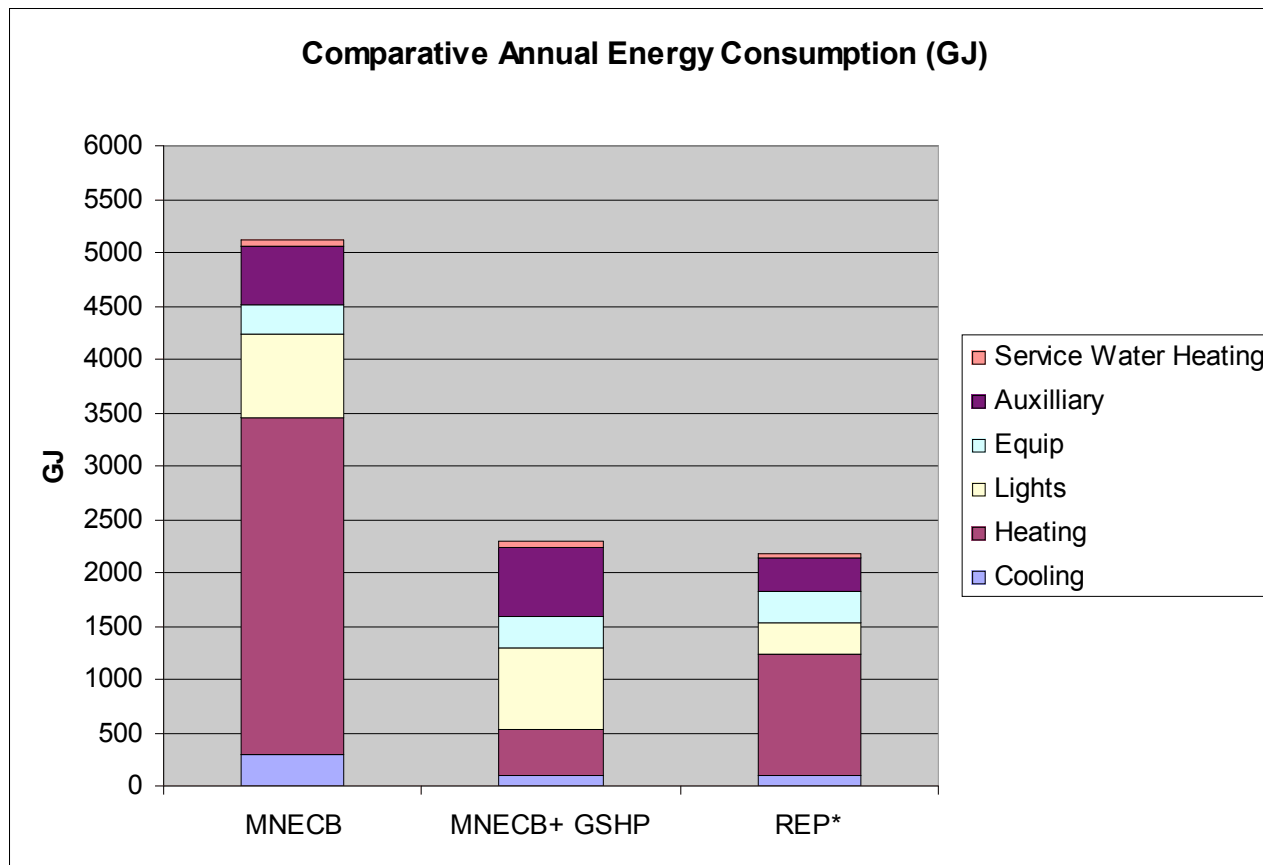
NRCan Materials Testing Laboratory Hamilton Re-location

Conceptual Design Simulation: Screening Tool

- Industrial-type laboratory
 - 2 storey office with high-bay heavy industrial and regular height light industrial.
- Generic warehouse/light industrial building with front office model 7,841.6 m² total;
 - Office + special support areas: 2,267.5 m²
 - Labs + industrial areas 5,574.1 m²
- Three scenarios developed for planning assessment
 1. MNECB reference building developed;
 2. MNECB reference using ground-source heat pump central system for heating, air tempering and cooling;
 3. High performance building tuned for minimal electrical consumption and renewable energy deployment – Renewable Energy Platform building (REP).

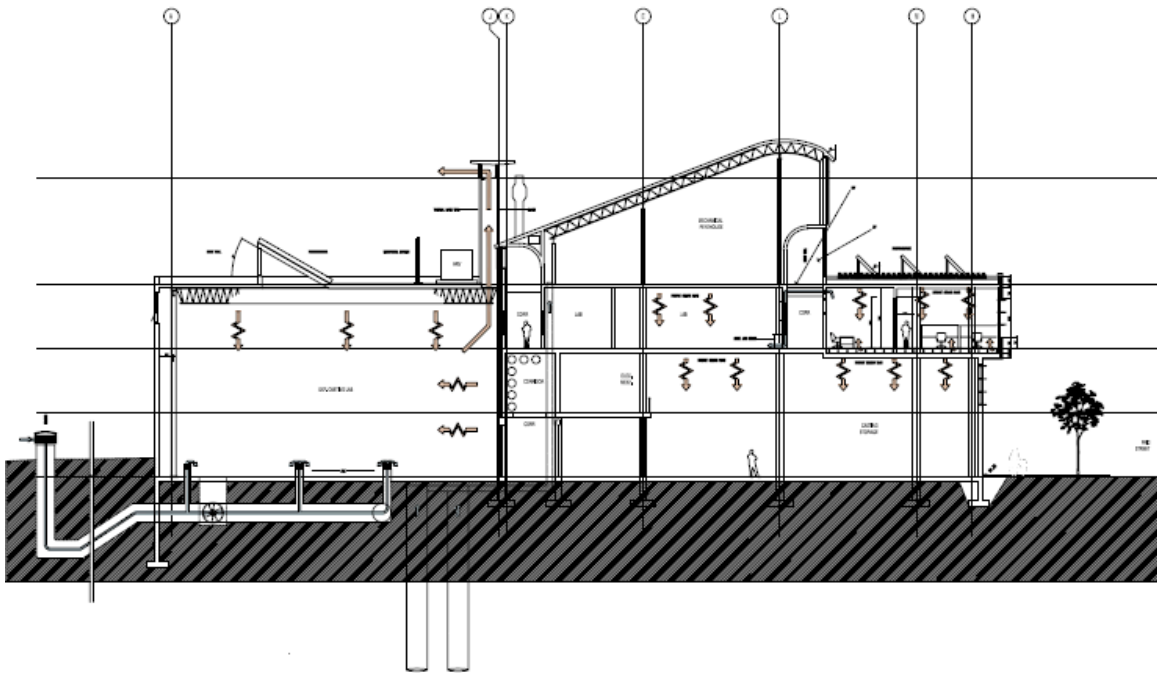
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Conceptual Design Simulation: Screening Tool Performance Assessment



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Preliminary Design Simulation: EE4



Screening Tool: Nov. 2006: 7,841.6 m²

Preliminary Design: Nov. 2007: 12,952 m²

Floor Plate: length: 205.8 m

width: 527 m

3 storeys: 15.5 m ab/gr, 4.25 m b/gr

EE4 Model:

65 thermal zones

167 spaces (each room represented as a space)

16 air handlers

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EE4 Envelope Assessment

Increasing Roof RSI from RSI 3.52 (R20) on a 6316 m² roof

Design RSI	Base RSI	Energy Savings (ekWh)	Energy Savings (\$/yr)	% Savings over MNECB	Mechanical Re-sizing Savings (%) (kW)	Net Present Value (\$)	25 yr Life Cycle Cost With Mech Savings (\$)
RSI 4.57 (R26)	RSI 3.52 (R20)	6528	920	52.3	1% (11 kW)	34371	-14949
RSI 5.31 (R30)	RSI 3.52 (R20)	10490	1490	52.4	2% (20 kW)	56796	-22328
RSI 5.64 (R32)	RSI 3.52 (R20)	11643	1672	52.6	2% (22 kW)	66470	-69741
RSI 7.05 (R40)	RSI 3.52 (R20)	25648	3476	52.9	2.5% (27 kW)	117144	-150347
RSI 7.05 (R48)	RSI 3.52 (R20)	35389	4794	53.3	3% (32 kW)	165700	-221212

Assumptions:

Construction Costing: \$1/ m2 of roof area per imperial R-value of added insulation

Mechanical Savings: \$300 / kW of reduced equipment (plant, pumps, terminals)

Finance/Discount Rate: 4.5% per annum compounded annually

Energy Escalation Rate: 8% per annum

A negative Life Cycle Cost means energy + mechanical savings exceed insulation investment

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EE4 Envelope Assessment

Increasing Wall RSI from RSI 2.82 (R16) on a 6100 m² wall

Design RSI	Base RSI	Energy Savings (ekWh)	Energy Savings (\$/yr)	% Savings over MNECB	Mechanical Re-sizing Savings (%) (kW)	Net Present Value (\$)	25 yr Life Cycle Cost With Mech Savings (\$)
RSI 3.52 (R20)	RSI 2.82 (R16)	4076	581	52.5	0.5% (7 kW)	22158	-8687
RSI 4.24 (R24)	RSI 2.82 (R16)	7224	1035	52.6	1.0% (10 kW)	45547	-5346
RSI 4.93 (R28)	RSI 2.82 (R16)	8933	1276	52.7	1.5% (16 kW)	68088	13311
RSI 5.31 (R30)	RSI 2.82 (R16)	9739	1392	52.7	1.6% (17 kW)	79960	23996
RSI 6.34 (R36)	RSI 2.82 (R16)	10678	1508	52.8	2% (21 kW)	115331	73866

Assumptions:

Construction Costing: \$1 / m² wall area per each imperial R-value of added insulation

Mechanical Savings: \$300 / kW of reduced equipment (plant, pumps, terminals)

Finance/Discount Rate: 4.5% per annum compounded annually

Energy Escalation Rate: 8% per annum

A negative Life Cycle Cost means energy + mechanical savings exceed insulation investment

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EE4 Envelope Assessment

Reducing Glazing in Lab areas (originally 660 m²) with a 30%

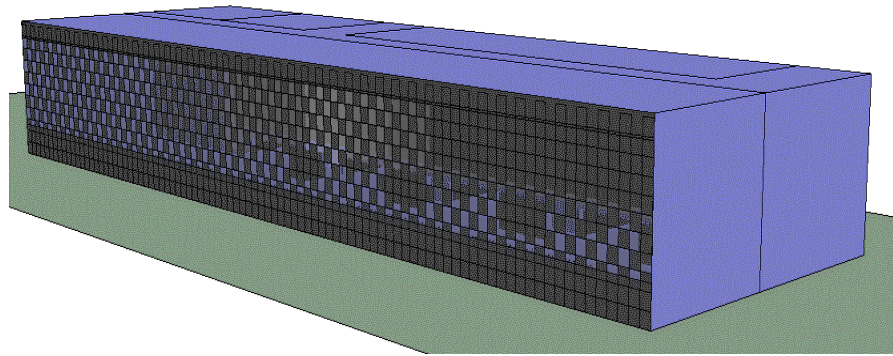
Design Lab FWR	MNECB Lab FWR	Energy Savings (ekWh)	Energy Savings (\$/yr)	% Savings over MNECB	Mechanical Re-sizing Savings (%) (kW)	Net Present Value (\$)	25 yr Life Cycle Cost With Mech Savings (\$)
30%	30%	-	-	52.6			
20%	20%	9211	1121	52.1	1.0% (10 kW)	139726	-23809
10%	10%	13889	1690	51.9	1.5% (19 kW)	279877	-465765

Assumptions: Construction Costing: \$ 650/m² of window (installed), \$420/m² of RSI 3.52 wall (installed)
 Finance/Discount Rate: 4.5% per annum compounded annually
 Energy Escalation Rate:8% per annum compounded annually

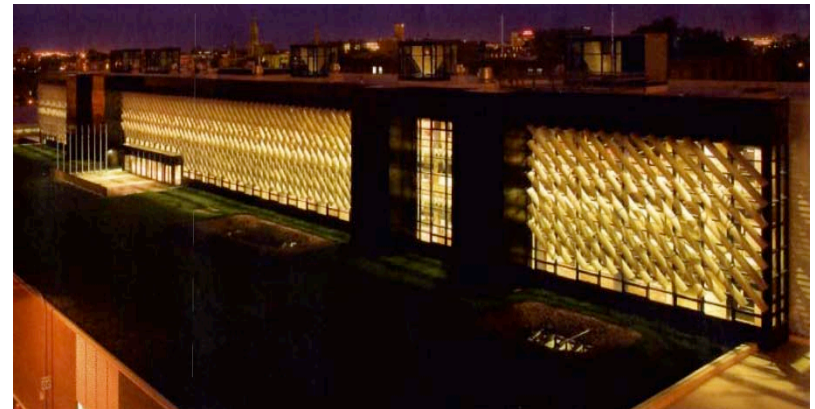
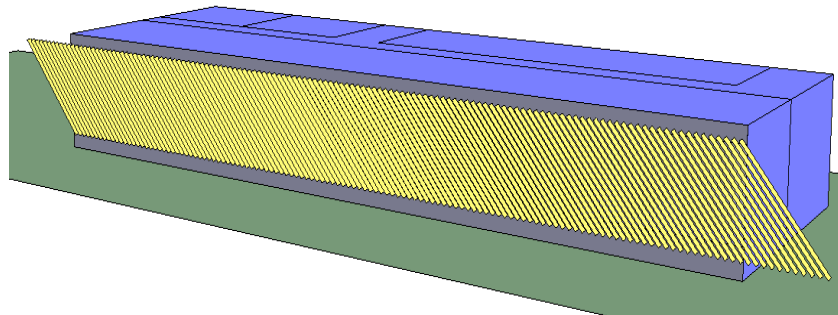
Note: reducing lab fenestration to wall ratio (FWR) also affected natural lighting which is partially reflected in the reduced energy savings by going to a 10% FWR from 20% FWR

West Façade: Shading Evaluation

Perforated Mesh

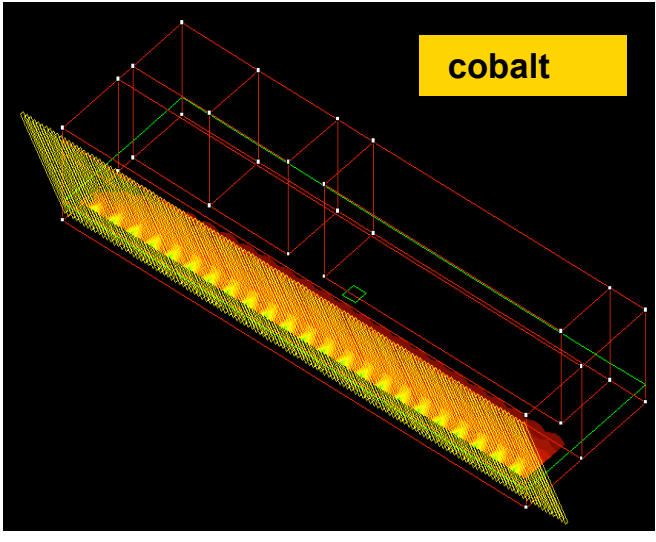
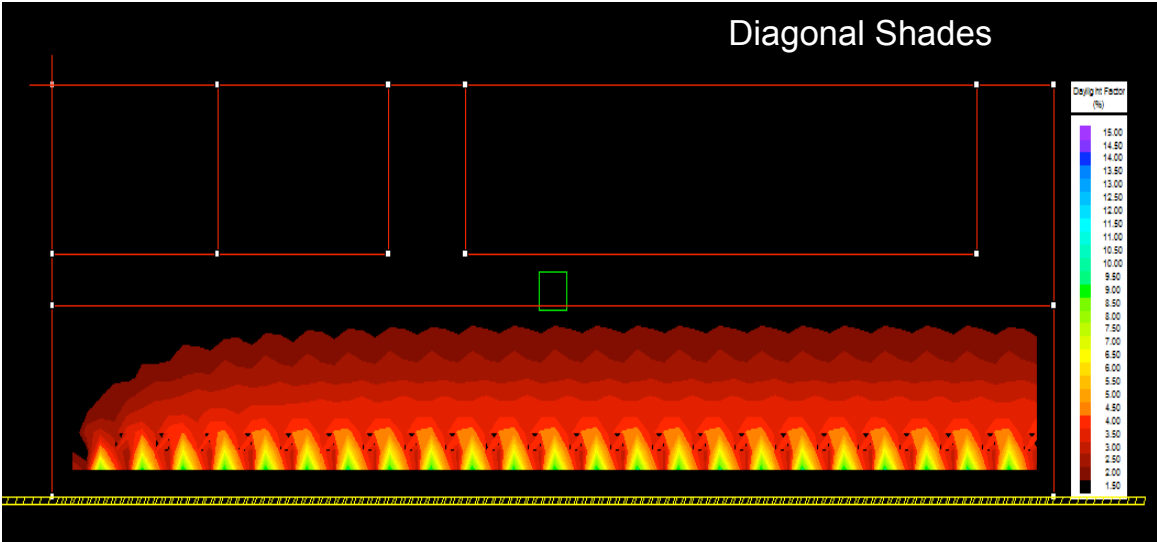
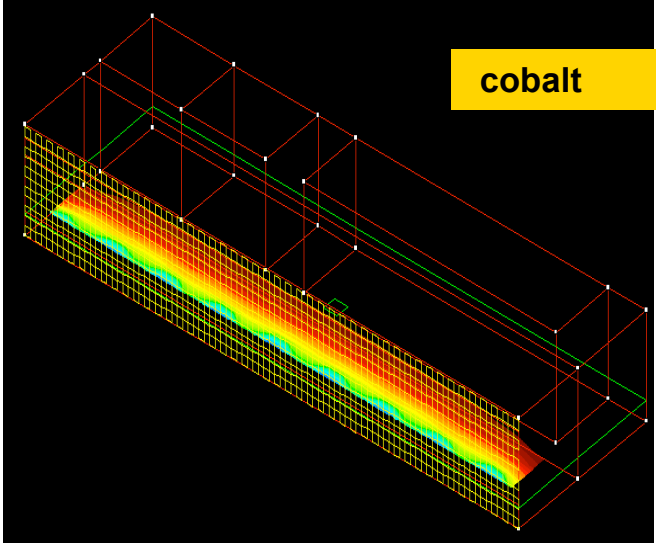
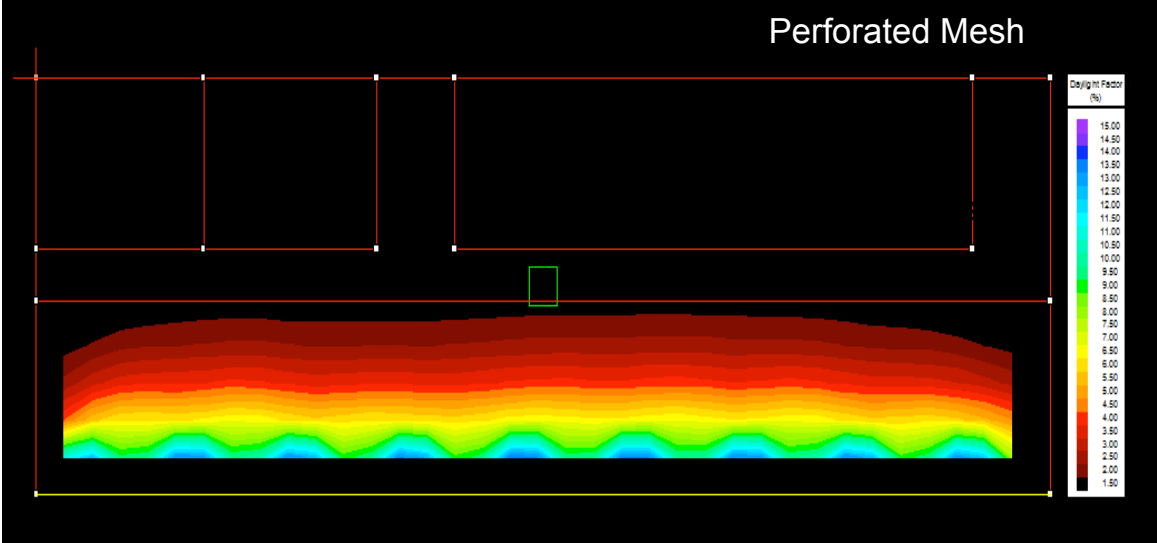


Diagonal Shading



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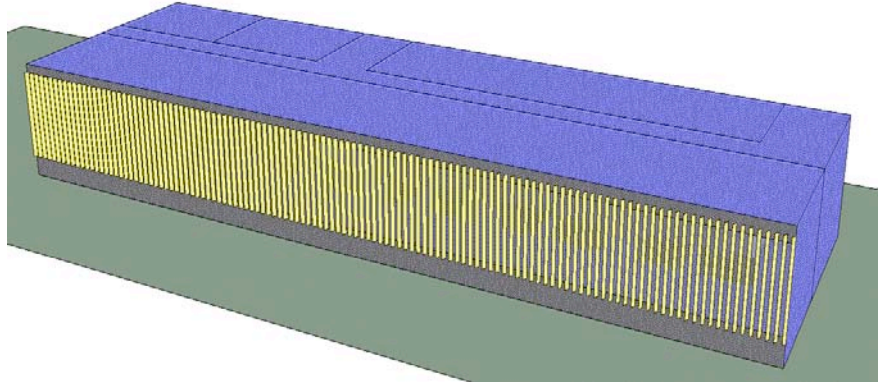
West Façade: Shading Evaluation



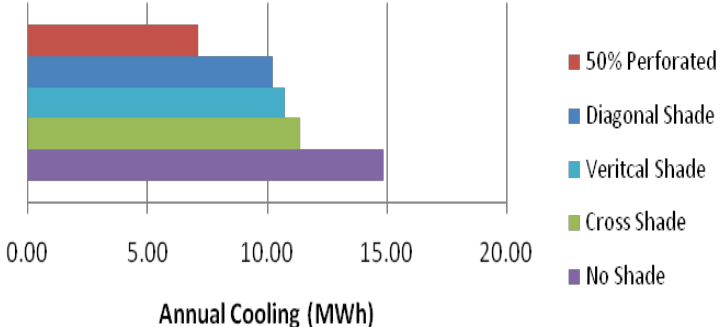
West Facade

Results for 50% Heat Mirror (SHGC=0.38) plus Okalux

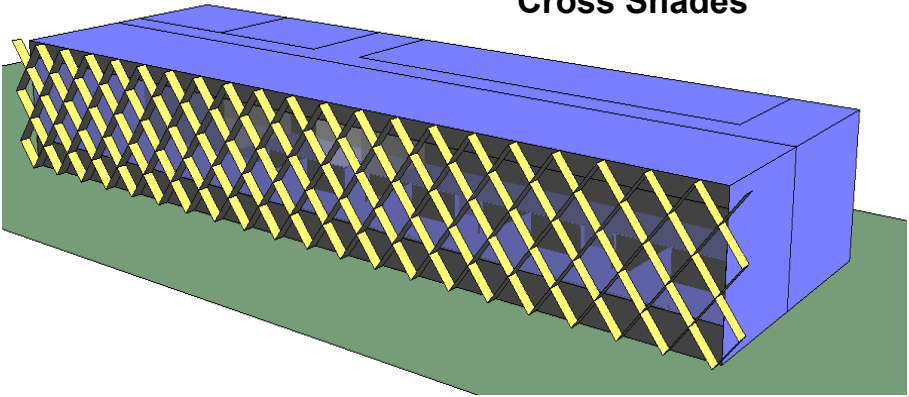
Vertical Shading



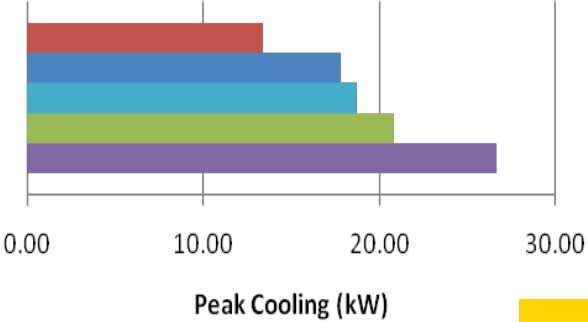
Annual Cooling for Shading Options



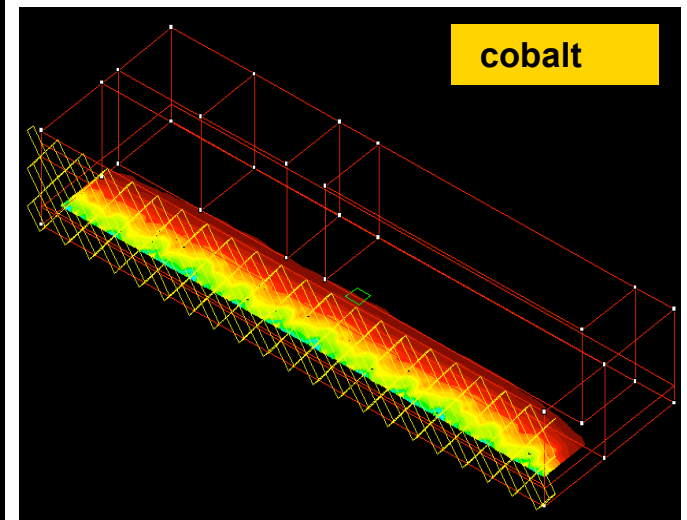
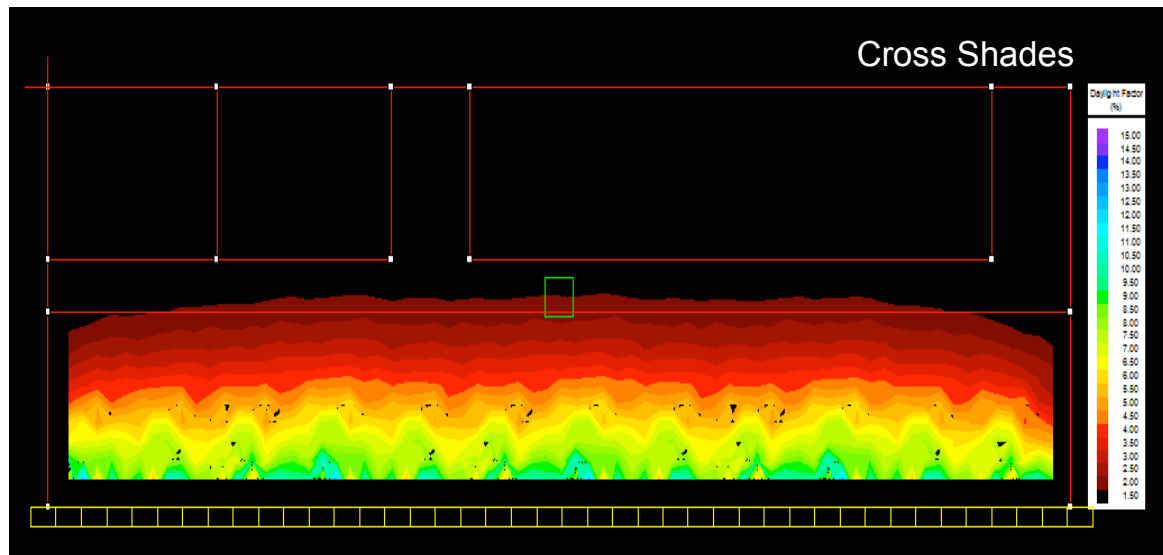
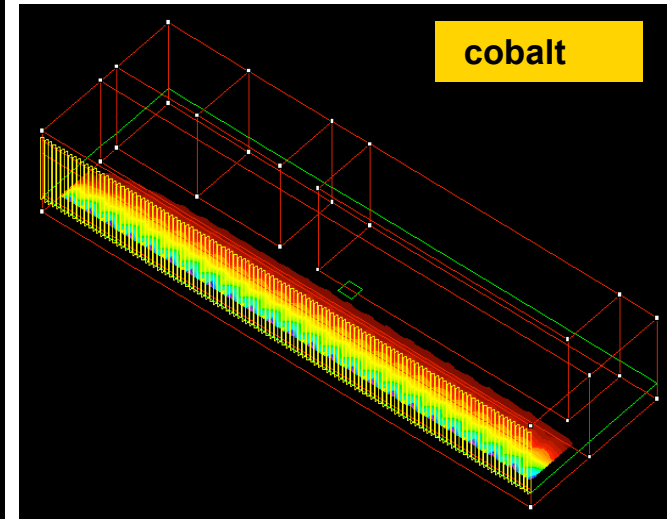
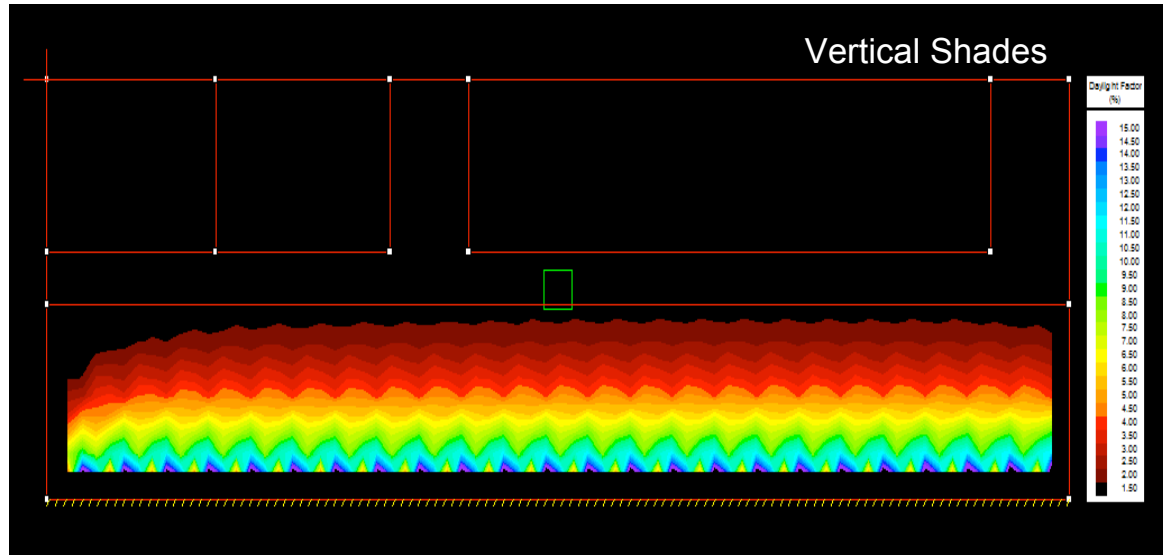
Cross Shades



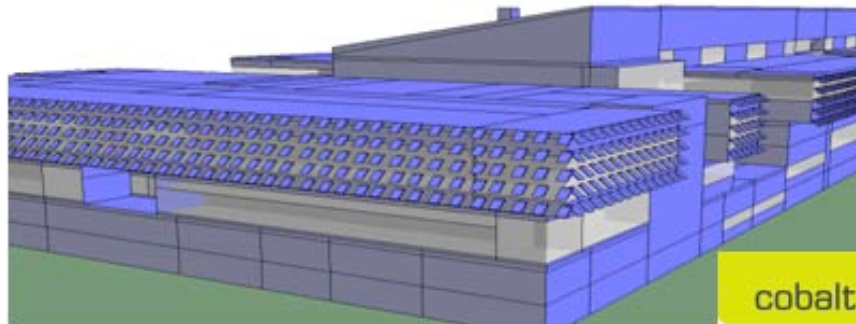
Peak Cooling for Shading Options



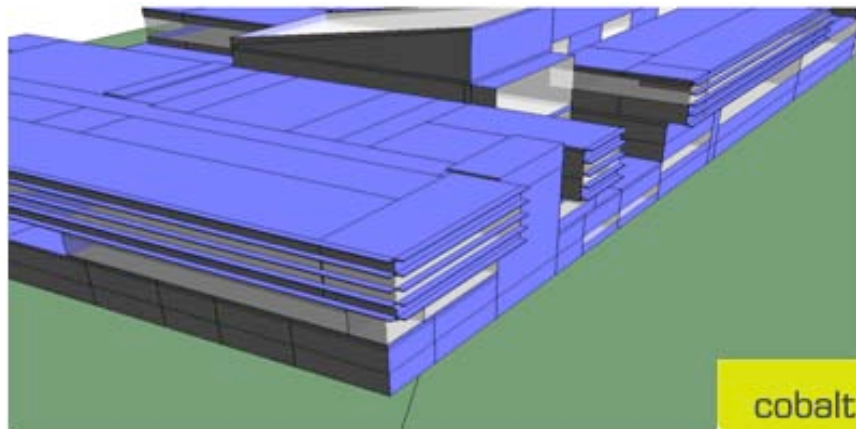
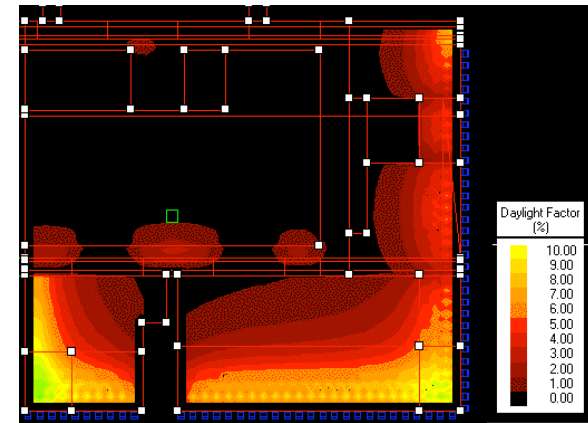
West Façade: Radiance Assessment



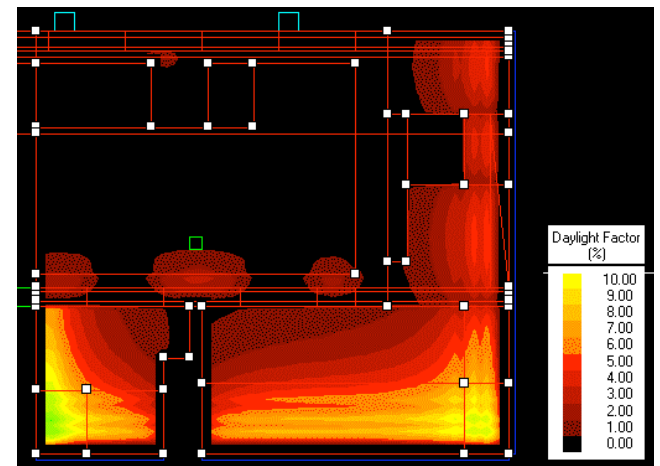
South East Corner: Daylighting



Angled Perforated Shades



Horizontal Shades

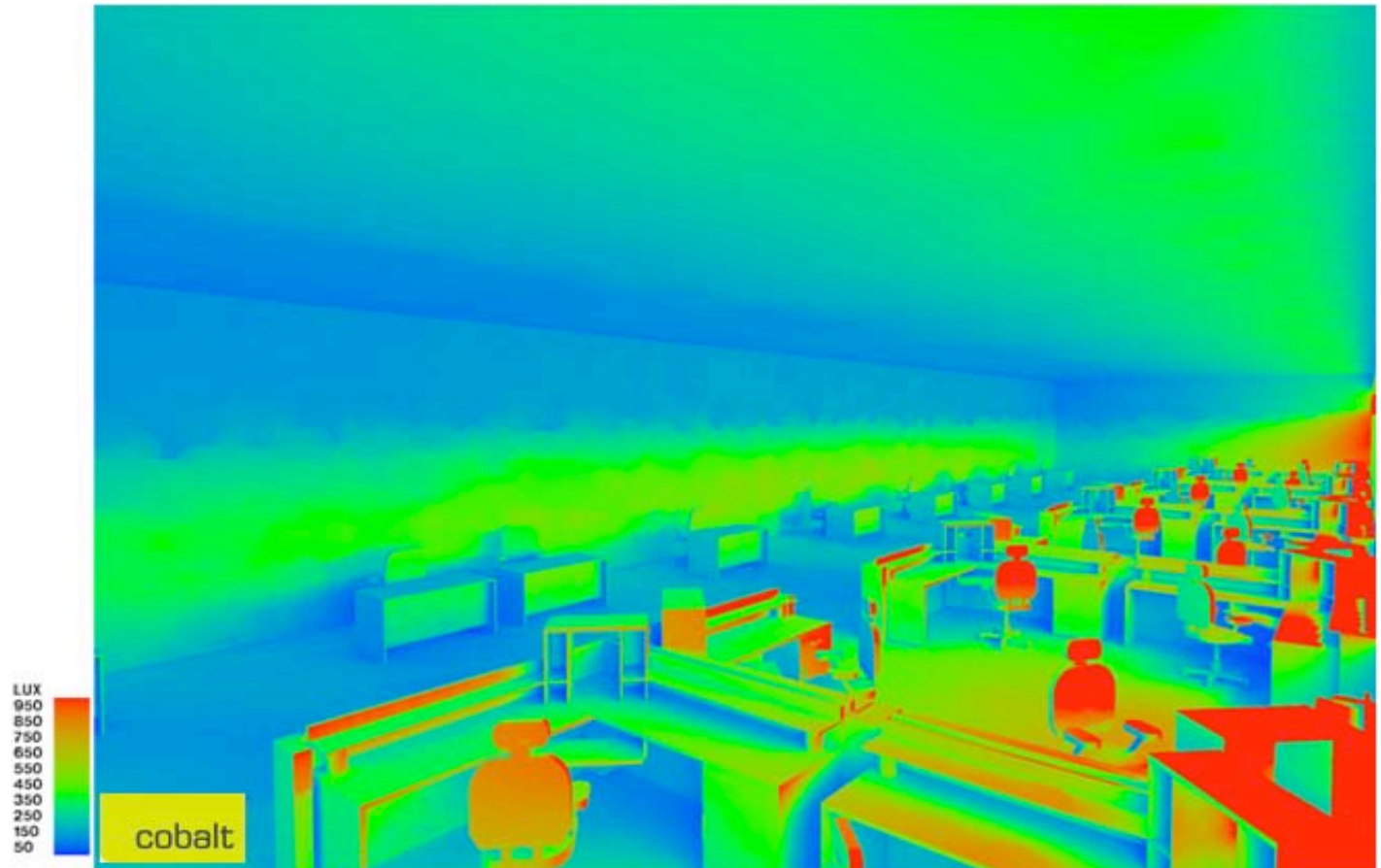


VE Image of Radiance Model of Office Spaces



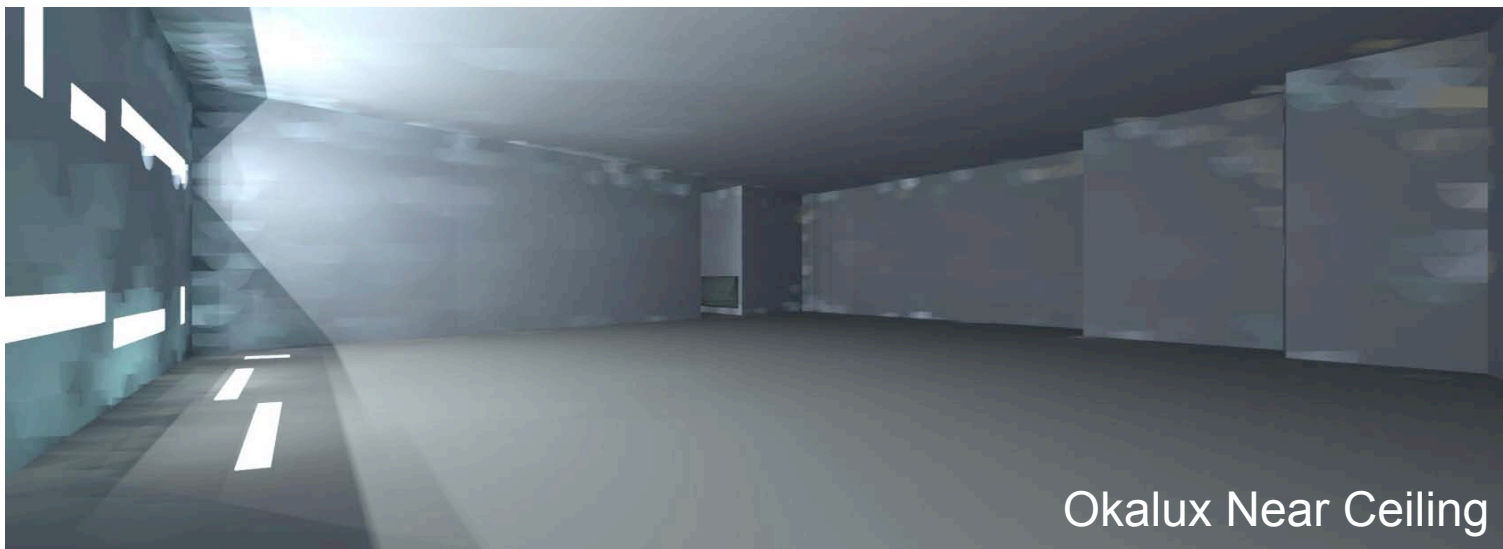
Note: specific time of day, specific day/yr

VE Image of Radiance Model of Office Spaces: Surface Illuminance



Note: specific time of day, specific day/yr

Okalux in High-Bay - South



cobalt

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EE4 Ventilation Assessment

Multiple Air Handling Systems

Design Option	Measure Energy Savings (ekWh)	Measure Energy Savings (\$/yr)	Cumulative Savings (ekWh)	Cumulative Savings (\$/yr)	Savings over MNECB (%)
Base Case: 6 AHUs with high performance envelope, low lighting levels, GSHP/boiler plant					57.2
Measure 1: added 50% enthalpy wheel to office areas (36% of building floor space)	41,454	1,873	41,454	1,873	57.6
Measure 2: added lab glycol run-around loop for 60% of labs where this is possible	231,507	11,590	265,603	13,467	59.8
Measure 3: added earth tube ventilation air preheating for 2 large process labs	83,178	4,057	306,312	15,747	60.2
Measure 4: added demand control ventilation to all non-lab spaces	51,667	3,414	335,609	18,331	60.7
Measure 5: added Solarwall (465 m ²) to penthouse southern wall	183,900	9,195	473,459	23,672	61.8

Note: Sum of individual measures (591,706 ekWh/yr) does not equal cumulative savings (473,459 ekWh/yr) due to modelling consideration of measure interactions

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EE4 Heating/Cooling Plant Assessment

Design Option: LEED Silver Building to LEED Platinum Building and assessing different heating and cooling plant options to achieve a 70% savings over MNECB * Reference case changed from natural gas to all-electric	Measure Energy Savings (ekWh)	Measure Energy Savings (\$/yr)	Savings over MNECB (%)
Base Case: LEED Silver: 2 sequenced 425 kW modulating gas boilers (85%); 750 kW Centrifugal air-cooled chiller (COP=4.0), variable speed pumps at 100 kPa head			32.9
Option 1: LEED Platinum envelope, lighting and air handling systems, plant equals LEED Silver	663,632	39,273	42.3
Option 2: LEED Platinum envelope, lighting and air handling systems, Condensing Boiler (92%), Centrifugal air-cooled Chiller (COP= 4.0)	822,968	44,806	44.0
Option 3: LEED Platinum envelope, lighting and air handling systems, Condensing Boiler (92%) Absorption Chiller (COP = 1.2)	281,289	24,507	37.9
Option 4: LEED Platinum envelope, lighting and air handling systems, Condensing Boiler (92%) Double Effect Adsorption Chiller (COP = 0.75)	133,587	21,275	36.9
Option 5: LEED Platinum envelope, lighting and air handling systems, Condensing Boiler (92%)/Ground Source Heat Pump Combination (COP=5.0), pump head increased	2,297,460 *	316,276 *	60.7 *
Option 6: LEED Platinum envelope, lighting and air handling systems, Ground Source Heat Pump with underground thermal storage (COP=5.0), pump head increased	2,334,725 *	312,526 *	60.1 *

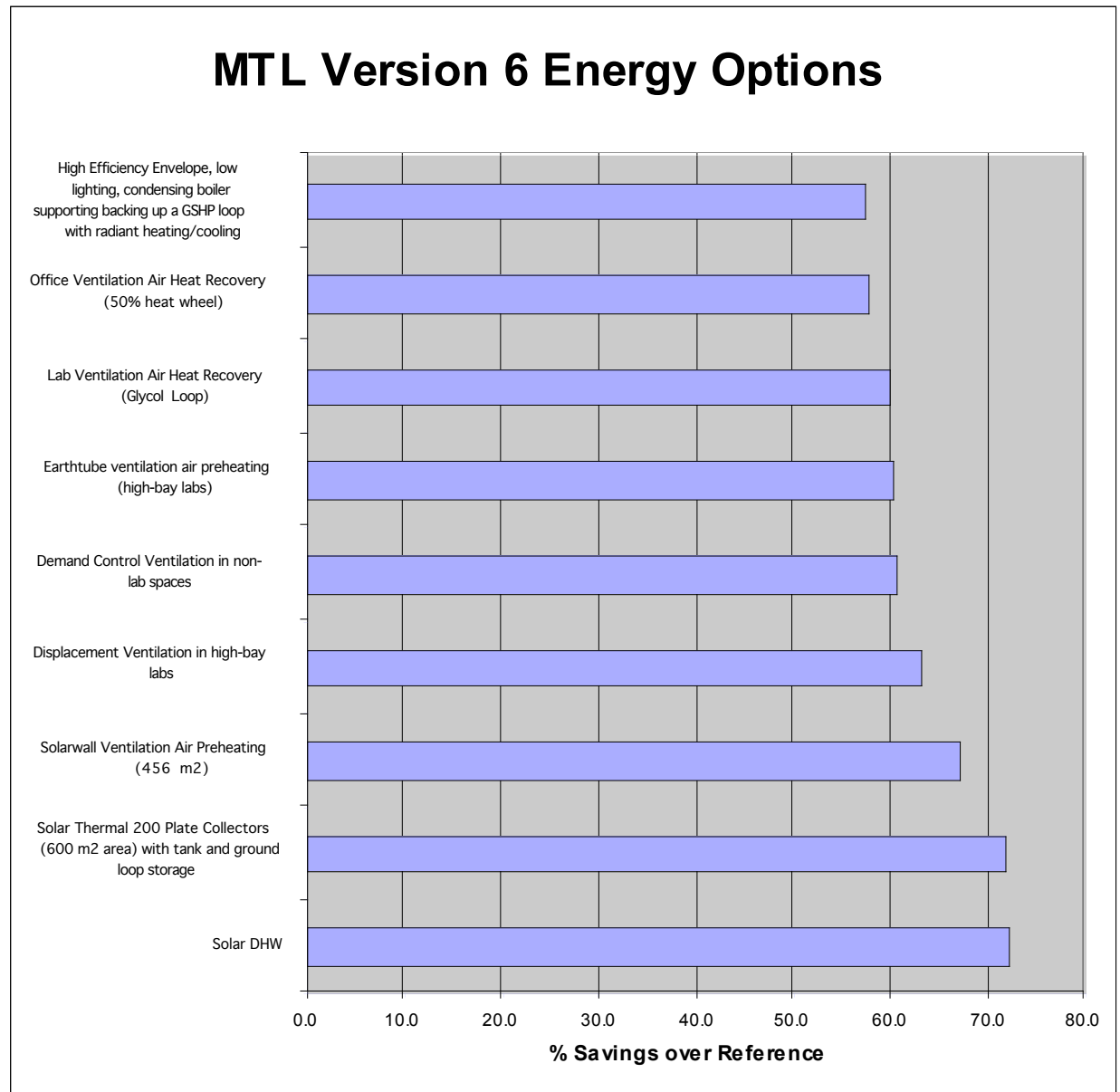
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EE4 Heating/Cooling Plant Assessment with Solar Thermal Assist to Meet 20% Renewable Target

Design Option: LEED Platinum Building contained a 20% renewable total energy target which could be met by solar thermal and solar PV Renewable targets created for each plant option and solar thermal collectors and storage developed to meet those targets (options 3 & 4 use a gas reference, options 5 & 6 use an electric reference)	Solar Thermal Target (ekWh)	Solar Thermal Value (\$/yr)	Total Measure Energy Savings (\$/yr)	Savings over MNECB (%)
Option 3: LEED Platinum envelope, lighting and air handling systems, Condensing Boiler (92%) Absorption Chiller (COP = 1.2), 756 m ² evacuated tube solar collectors (258 Viessman collectors) and 80,000 Litre storage tank	435,787	52,477	179,418	53.6
Option 4: LEED Platinum envelope, lighting and air handling systems, Condensing Boiler (92%) Double Effect Adsorption Chiller (COP = 0.75) 1184 m ² flat plate solar collectors (400 collectors) and 133,000 Litre storage tank	479,843	57,582	181,291	54.1
Option 5: LEED Platinum envelope, lighting and air handling systems, Condensing Boiler (92%)/Ground Source Heat Pump Combination (COP=5.0), 592 m ² flat plate solar collectors (200 collectors) and 40,000 Litre storage tank with minimal ground loop recharging	316,473	20,601	354,418	68.1
Option 6: LEED Platinum envelope, lighting and air handling systems, Ground Source Heat Pump with underground thermal storage (COP=5.0), 592 m ² flat plate solar collectors (200 collectors) and total borehole ground loop recharging	312,735	37,666	371,040	71.2

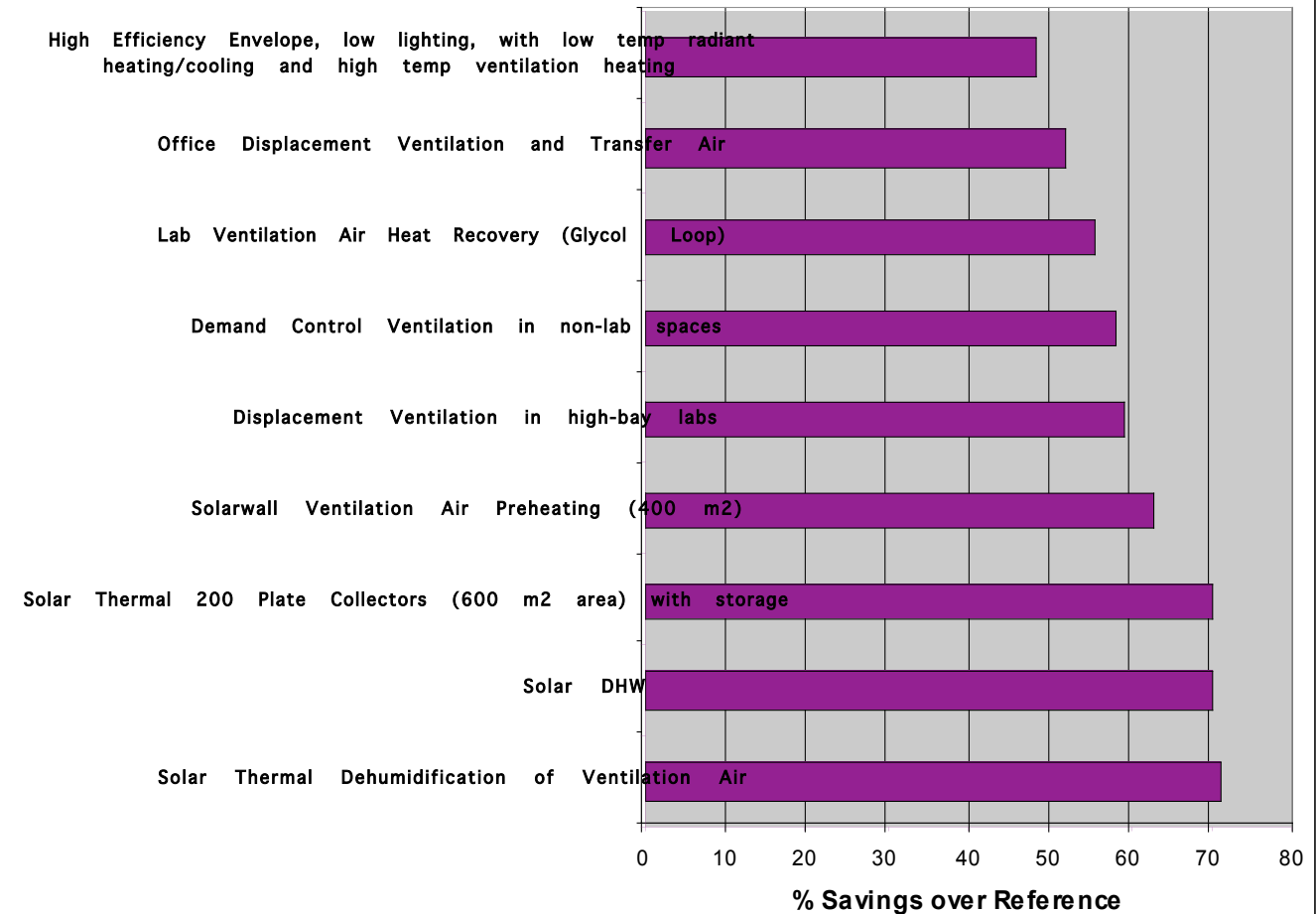
EE4 Design Assessment

- Envelope options considered first (load reductions);
- lighting considered as a second priority as lighting affects heating and cooling loads;
- ventilation loads and systems considered next as these affect heating and cooling loads;
- service hot water load reductions;
- balance of mechanical systems (heating & cooling plant, pumps, service hot water) then considered (optimal sizing and operation of efficient equipment);
- once all loads reduced, improved equipment selected and optimally sized for function then apply renewables



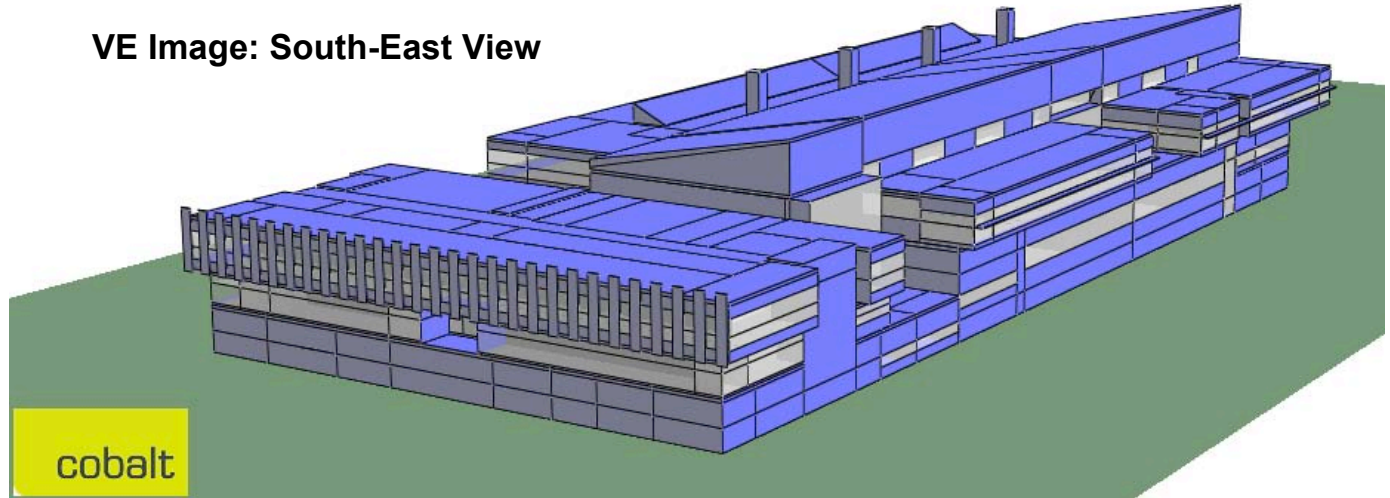
MTL Version 12 Energy Options

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- balance of mechanical systems (heating & cooling plant, pumps, service hot water) then considered (optimal sizing and operation of efficient equipment);
- once all loads reduced, improved equipment selected and optimally sized for function then apply renewables
- renewables: solar thermal providing space heating priority and dehumidification in cooling season

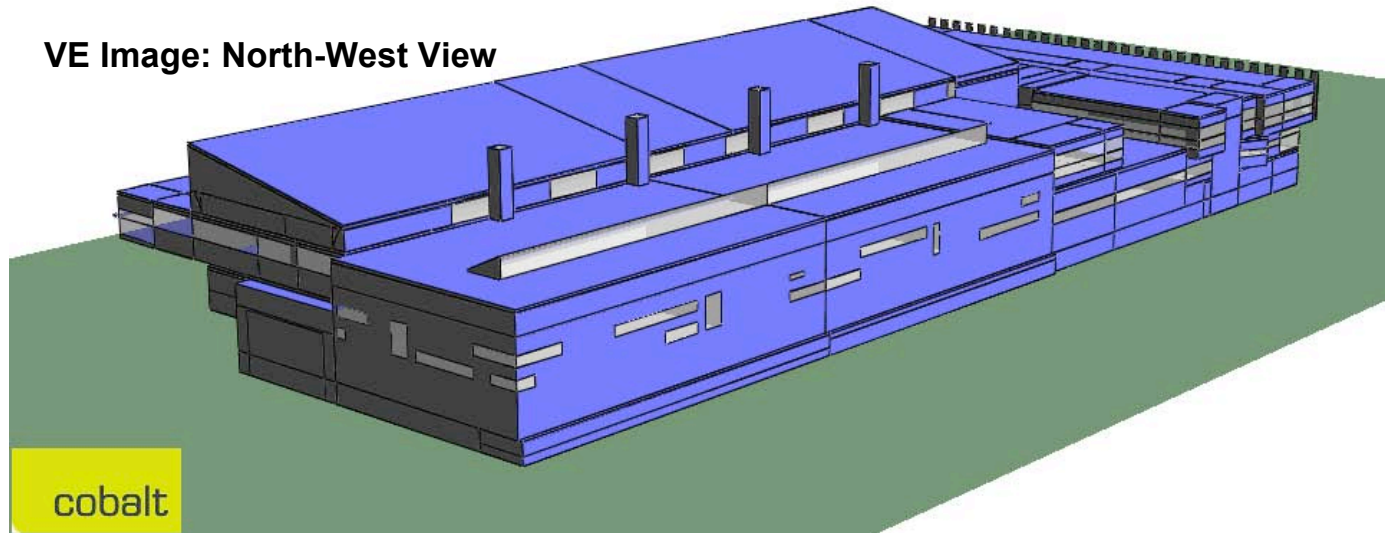


Tendered Design

VE Image: South-East View



VE Image: North-West View



2009 Tender Design Features

Envelope:

- Exterior Walls: RSI 3.7 (effective)
- Exterior Roofs: RSI 5.64 (effective)
- Glazing: U-value 0.74 (heat mirror) (mesh shading)

Lighting:

- 60% reduction in installed fixtures compared to MNECB
- Extensive daylight harvesting

Ventilation:

- Displacement ventilation within majority of spaces
- Office and common space exhaust air is used as fume hood and process supply air
- Solarwall ventilation air preheating
- Exhaust air heat recovery via glycol loops on majority of 75% of exhaust air

2009 Tender Design Features

Space Heating:

- Radiant heating with high thermal mass used throughout
- Solar thermal provides 80% space heating (use of variable supply temps and short term storage via four 2500 Litre storage tanks)
- Ventilation air heating: solarwall + solar thermal + exhaust heat recovery + DES
- Connection to district energy system (GSHP borehole + condensing boilers)

Space Cooling:

- Radiant cooling using chilled ceilings
- Connection to district energy system (GSHP borehole)

Other Features:

- Total rainwater harvesting
- Green Roof
- Process heat recovery (equipment rejection heat added to radiant loop)
- Advanced controls (fume hoods, pumps, fans, reset strategies)
- Solar domestic hot water heating

Integrated Design Process Team

- Client: McMaster Innovation Park
- Tenant: Natural Resources Canada, Material Testing Laboratory
- Architect: Diamond and Schmitt Architects Incorporated
- Structural: Read Jones Christofferson Ltd.
- Mech/Elec: Cobalt Engineering
- Sustainable: Cobalt Engineering
- Cost Consultant: cm2r Inc.
- Commissioning: CFMS West
- IDP Facilitation: Natural Resources Canada, CanmetEnergy
- Simulation: Natural Resources Canada, CanmetEnergy

Other consultants invited to IDP meetings as required

Thank you

