The Top of the Annex NZE Townhomes

Presented by: Alan Fung

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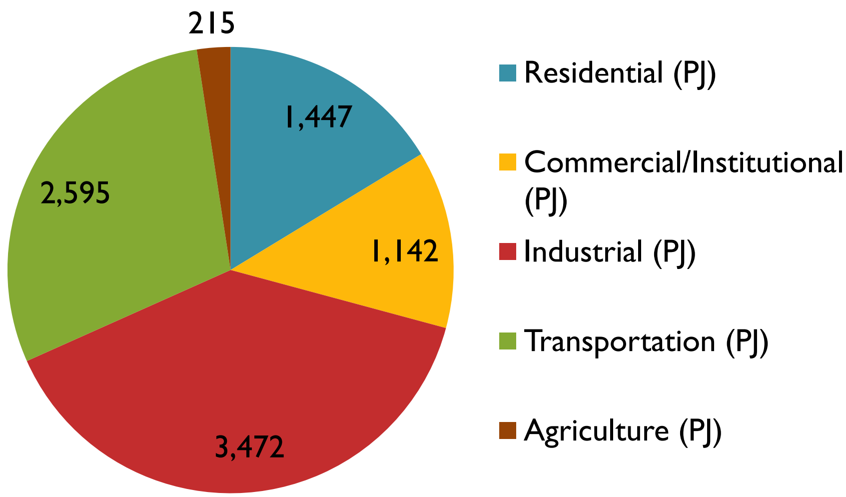
Outline

- Introduction
- SUI CMHC EQ Building Design
- SUI CMHC EQ Mechanical Equipment
- SUI CMHC EQ Analysis of Design

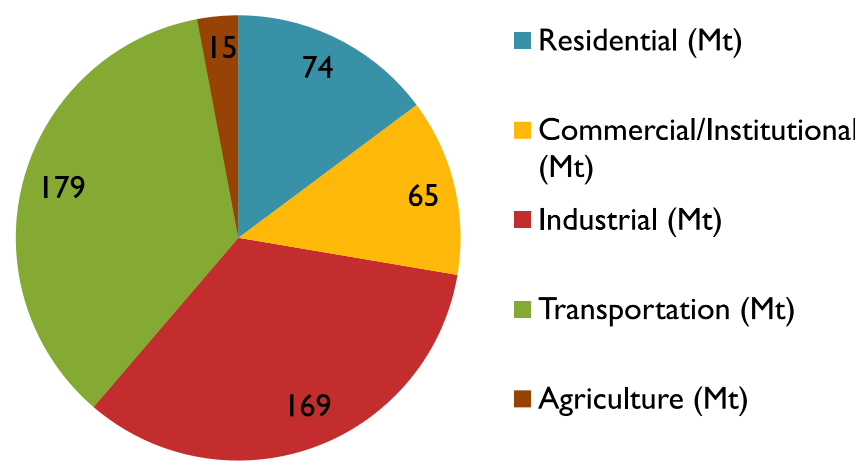
2007 Canadian End-use Energy Consumption and Greenhouse Gas Emission (NRCan, 2009)



Total: 8870 PJ

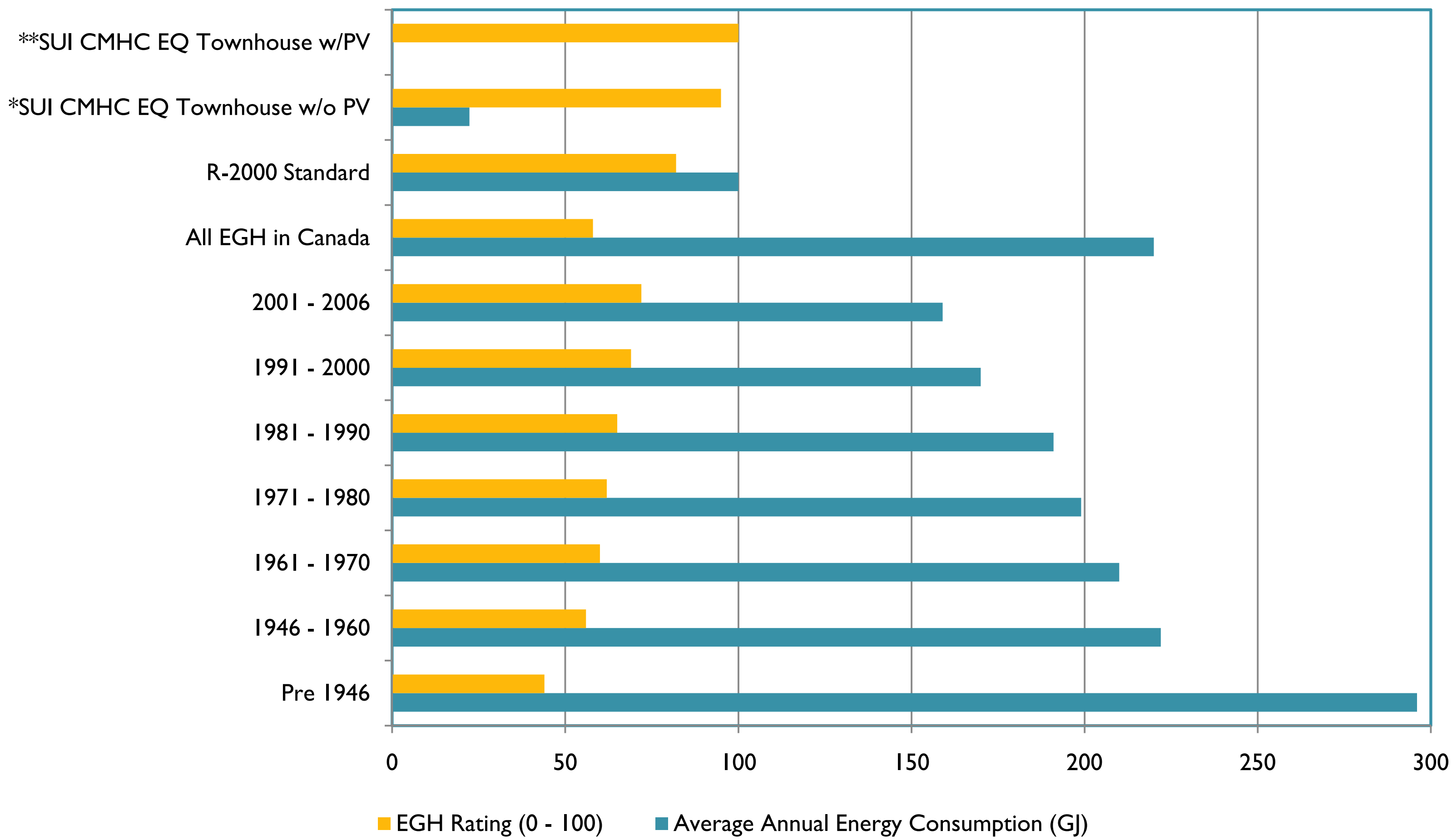
- 30% of total energy consumption from Building Sector
- 50% of total electricity consumption from Building Sector

- 28% of total GHG emission from Building Sector



Total: 502 Mt

Comparison of Energy Consumption for Different Houses (NRCan, 2007)



Main Reasons for Net-zero Energy Building (NZEB) R&D

- Ontario Green Energy and Economy Act
  - Energy conservation and renewable energies
  - Fit-in Tariff (up to $0.802/kWh for roof PV)
- NZEBs will be the standard in US and Europe by 2030
- Large life-cycle energy demand (and GHG emission) by buildings
- More…

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Project Team

- Building Developer:
  - 1420110 Ontario Ltd., Spero Bassil, President
- Construction Manager:
  - Mason Homes, Sean Mason
- Architect:
  - Ampas Architect, Lou Ampas, Eyad Boukli
- Structural Engineer:
  - Blackwell Bowick Engineering, David Bowick, Anthony Spick
- Mech + Elec Engineer:
  - Jain and Associates, Dinesh Jain, Essat Mitri

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Project Team

- Landscape Architect:
  - Martin Wade and Associates, Martin Wade, Nancy Charter
- Development & Marketing:
  - Orenda Developments Assoc., Alex Spiegel
- Solar Systems Energy Design:
  - Numerical Logics, Didier Thevenard
- IDP Facilitators:
  - The Fountainhead Design Group, Lawrence Morettin, Jordan Edmonds
- Sr. Planner (Midtown Toronto):
  - City of Toronto Planning Division, Barry Brooks

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Project Team

- Ryerson University, Faculty of Engineering, Architecture and Science:
  - Dr. Alan Fung (Mech Eng)
  - Dr. Mark Gorgolewski (Arch)
  - Dr. Ian McBurnie (Arch)
  - Dr. Miljana Horvat (Arch)
  - Dr. Wey Leong (Mech Eng)
  - Prof. Vera Straka (Arch)
  - Dr. Zaiyi Liao (Arch)

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Project Team

- Ryerson University, Students of Engineering, Architecture and Science:
  - David Correa Zuluaga (Arch)
  - Tura Cousins-Wilson (Arch)
  - Nicholas Discenza (Arch)
  - Farzin Masoumi Rad (Mech Eng)
  - Roxy Shiell (Arch)
  - Cristian Stefanescu (Mech Eng)
  - Humphrey Tse (Mech Eng)
  - Omar Siddiqui (Mech Eng)
  - Kun Tsai (Mech Eng)

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- Location:
  - 359 Davenport Road, Toronto, Ontario M5A 1K5
- Type of Housing:
  - Attached Freehold Common Element Condominium Townhomes
- Number of Units:
  - Three Units
- Orientation (solar PV):
  - 37° West of South

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- Site and Climate:
  - Altitude: 113 m
  - Latitude: 43°40`N
  - Longitude : 79°24` W
  - Average daily insolation Horizontal: 1.30 MWh/m^2
    Vertical: 0.99 MWh/m^2
  - Clearness Index (Kt) ~ 0.46
  - Average annual precipitation: 834 mm
  - Average annual wind speed: 4.0 m/s

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- Site and Climate:
  - ASHRAE Design Temperatures (ASHRAE Handbook, 2005)
  - 99% heating dry bulb: -16.7 °C (January)
  - 1% cooling dry bulb: 28.9 °C (July)
  - Degree-days (downtown Toronto)
  - Heating degree days (base 18°C) 3570
  - Cooling degree days (base 18°C) 359

Building Design

South West Rendering of the Top of the Annex Townhomes (www.sui-toronto.com)

Unit Characteristics:

- Heated Volume
  - 685 m^3 per unit
- Heated floor area
  - 210 m^2 per unit
- Ceiling area
  - 64.4 m^2 per unit
- Exposed wall area
  - 362 m^2 per unit
- Glazing area
  - North 23.2 m^2
  - South 33.6 m^2
  - East 26.5 m^2
  - West 30.3 m^2
- South glazing to floor ratio
  - 16 % (33.6/210 x 100%)
- Air tightness (targeted)
  - 0.5 ACH @ 50 Pa

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Building Design

South West Rendering of the Top of the Annex Townhomes (www.sui-toronto.com)

Thermal Characteristics

- Roof
  - RSI 13.6 m^2K/W (R-76)
- Above grade wall
  - RSI10.8 m^2K/W (R-60)
- Below grade wall
  - RSI10.8 m^2K/W (R-60)
- Window
  - RSI 0.71 m^2K/W (R- 4)
- Exposed floor
  - RSI12.0 m^2K/W (R-67)
- Below grade slab
  - RSI 3.6 m^2K/W (R-20)

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Building Design

Building Envelope - Exterior walls

- Gypsum Board Dry Wall, 13mm
- Polyethylene Vapor Retarder, 0.15mm
- (2x6) Wood Studs @600mm (24") O.C.
- Sprayed Polyisocyanurate closed cell foam139mm RSI-6.5 (R-37)
- OSB Structural Sheathing with STO Gold Coat 13mm
- Adhesive Straps 4mm
- Rigid Insulation - Extruded Polystyrene100mm RSI 3.48 (R-20)
- Air space 25mm
- Face Brick 100mm
- Overall RSI 10.8 m^2K/W (~R-60)

Building Design

Building Envelope - Roof assembly

- 19 x 19 mm
- 0.15 mm (6 mil) polyethylene vapour
- 294 mm pre-engineered I-joists
- Sprayed polyisocyanurate foam between joists
- OSB subfloor
- 50x50 mm (2x2 in) wood straps create air space for ventilating roof assembly and photovoltaic panels.
- Overall RSI 13.6 m^2K/W (R-76)

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Building Design

Building Envelope – Windows

- DG + 2 Heat Mirror 88
- Tint + Low-E .04
- 13 mm Argon filled space
- Fibreglass frame

- ER* = 0.49
- RSI = 0.71 m^2K/W

Building Design

Building Envelope – Thermal Mass

- Simulations conducted in TRNSYS to analyze the impact of using concrete slab as thermal mass.
- Winter and summer overheating big concerns for occupant comfort.
- 2 & 4 inch concrete slab used.
- 5-7% decrease in energy consumption as a result of incorporating a 2 inch concrete slab.
- Total number of hours where indoor temperatures exceed 26°C also reduced, thus increasing comfort

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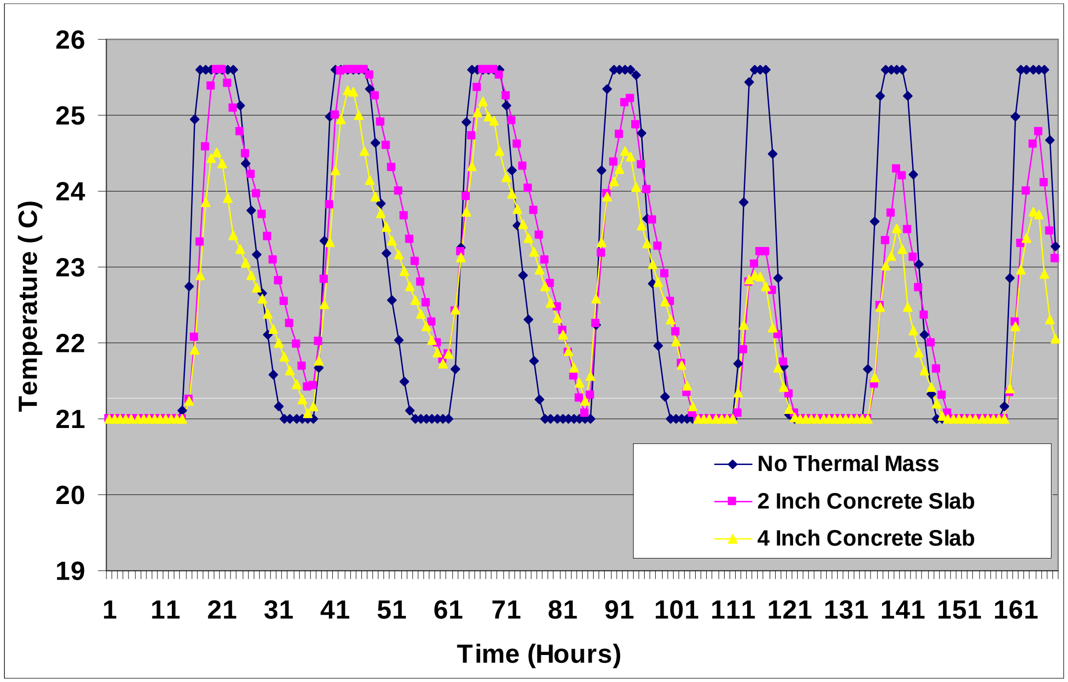
Building Design

Building Envelope – Thermal Mass



Temperature profile of the 3rd floor of the Net Zero Energy house during a typical winter week with varying thermal mass

Building Design

Building Envelope – Thermal Mass

Total number of hours during the winter season, the indoor temperature exceeds the heating set point, 21°C, or above

Part of the House	No Thermal Mass	2-Inch Concrete Slab	4-Inch Concrete Slab	20% Micronal PCM
Mezzanine	358 hours	299 hours	255 hours	237 hours
3rd Floor	1603 hours	1186 hours	1039 hours	998 hours
2nd Floor	653 hours	577 hours	523 hours	527 hours
1st Floor	477 hours	394 hours	368 hours	382 hours

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Mechanical Equipment

Space Heating and Cooling System

- Temperature set points are 21˚C for space heating and 24˚C for space cooling
- A ground source heat pump (GSHP) will be used for heating and cooling purposes
  - An ECONAR GeoSource 2000 GW/360/361 ground source heat pump for heating and cooling with 8.42 kW capacity
    - 4.2 COP heating efficiency and 4.9 COP cooling efficiency

Mechanical Equipment

Domestic Hot Water (DHW) System

- The reduced hot water draw was lowered from 225L/day (standard from CMHC) to100L/day
- It is reduced from 225L/day by utilizing:
  - Low flow shower heads (3.8L/min from 9.5L/min)
  - Lower hot water consumption from the chosen dishwasher (7.4L/day from 22L/day)
  - Lower hot water consumption from clothes washer (13.7L/day from 32L/day)

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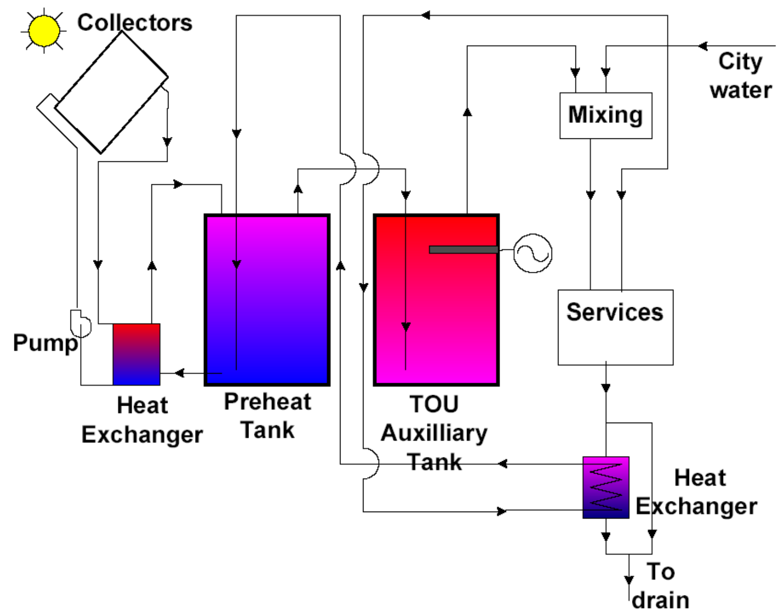
Mechanical Equipment

Solar DHW System

- Domestic hot water based on a solar hot-water system
- Maximized for year-round rather than winter production
- Thermodymanics SB64-9PV Solar DHW system for hot water energy delivered yearly is 1.41 MWh/yr (6m^2)
- Reduces annual energy consumption for DHW heating to 472 kWh



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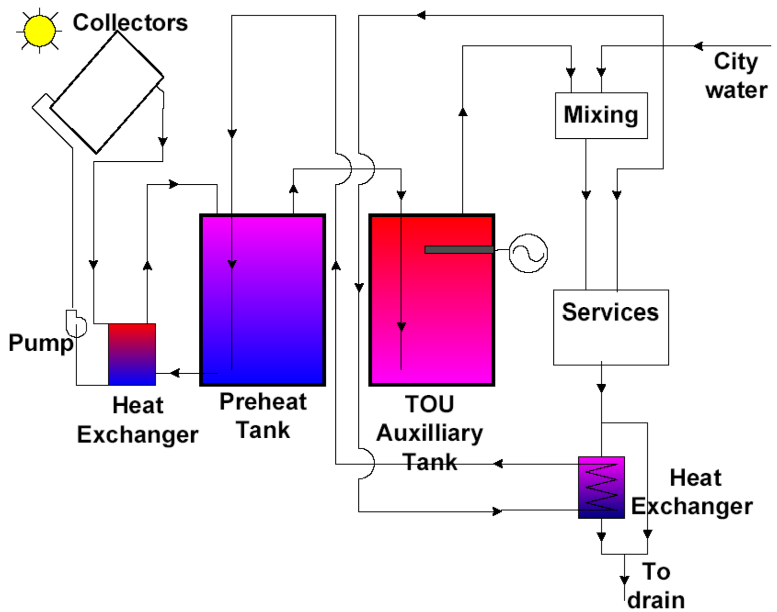
Mechanical Equipment

Solar DHW System

- The system consists of:
  - 2 solar thermal collectors
  - PV-powered circulation pump
  - External heat exchanger,
  - 454 L preheat tank
  - 50 L Time-of-Use (TOU) electric backup hot water tank w/ timer control*



Mechanical Equipment

Ventilation

- A dedicated high efficiency HRV, with high performance HEPPA and/or other similar filtering system
- Recirculation of the air in the house will be utilized to balance the temperatures of the rooms
- HRV – vanEE HRV 2000HE High Efficiency Heat Recovery Ventilator which is a 200 CFM - HRV Unit
- Mechanical ventilation rate: 65 L/s

Mechanical Equipment

Photovoltaic System

- The roof area available for solar devices is roughly 50 m^2. Of this, 6 m^2 are set aside for the thermal system and the remaining 44 m^2 with photovoltaic modules
- Sharp NT-185U1 PV modules for electricity with the array tilted at 20° and at an azimuth of 37° West of South (14.2 % module efficiency)
- Total system capacity 6.2 kW
- Annual energy production of the system is 7767 kWh/yr

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Mechanical Equipment

Major Appliances

Default

Refrigerator – 537 kWh/yr
Stove – 758 kWh/yr
Clothes Washer – 802 kWh/yr
Freezer – 573 kWh/yr
Dishwasher – 615 kWh/yr
*Dryer – 848 kWh/yr
Total - 3,285 kWh/yr

Specific

GE Monogram 48” – 592 kWh/yr
Frigidaire BFEF323C* – 438 kWh/yr
Whirlpool WFW8500SR – 152 kWh/yr
(combined with refrigerator)
Asko D3531 – 194 kWh/yr
Miele T9800 – 537 kWh/yr
Total - 1,376 kWh/yr

Reduction of proposed 3,285 kWh/year to 1,376 kWh/year

Instead of using both a refrigerator and freezer, we suggest to use a larger refrigerator/ freezer with a combined capacity of at least 25.5 ft^3

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Mechanical Equipment

Minor Appliances

- Energy consumption is highly variable on the ownership and discretionary usage of the number and type of equipment available
- Default consumption is 8 kWh/day or 2920kWh/year
- To reduce the consumption to 3 kWh/day is a reduction of 62.5%
- By reducing the standby losses of each appliance to 1W would decrease the losses due to standby by 68%
- By utilizing CFLs and LEDs, lighting loads can be reduced to 1kWh/day

Mechanical Equipment

*Control Strategy**

Building Automation System

- **Thermal control:**
  - -Shutters
  - -Hot-water for space heating
  - -Radiators
  - -Heat recovery ventilation
  - -Natural ventilation
  - -Solar shading
- **Lighting control:**
  - -Daylight
  - -Dimmable lighting fixtures
  - -Occupancy simulator
- **Solar control:**
  - - Solar hot-water collector
  - -PV
  - -Solar shading
- **Other services:**
  - - Domestic hot-water supply
  - -Smoke and flame detection
  - -Smoke control system
  - -Security

Analysis of Design

Base Case

- EnerGuide Home rating for the Base home is 84
- Consumes:
  - 1182 m^3/yr of natural gas
  - 9340 kWh/yr of electricity
- Annual Costs:
  - $577 for natural gas, at $0.488/$m^3$ (Enbridge Gas, 2007)
  - $962 for electricity, at $0.103/kWh (Toronto Hydro, 2008)
- Upgraded home (without the usage of a PV system) is 95. (>100 if PV is included.)

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Analysis of Design

Comparison Annual Energy Consumption HOT2000, RETScreen & TRNSYS 16 Results

Simulation Software	TRNSYS	RETScreen	HOT2000
Space Heating (kWh)	2845	-	1853
Space Cooling (kWh)	698	-	313
DHW (kWh)	472	630	-
Appliances & Lighting (kWh)	2835	-	2835
Total Consumption (kWh)	6850	630	5001
PV Generation (kWh)	7767	6600	-
NET Energy (kWh) (Generation – Consumption)	917	969	

Analysis of Design

Effect of Air Recirculation/Natural Ventilation on Annual Heating & Cooling Energy Requirements

Annual Energy Requirement (kWh)	
Without Recirculation	
Heating	Cooling
7837	1989
With Recirculation*	
Heating	Cooling
4550	955

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Analysis of Design

Effect of Air Recirculation/Natural Ventilation on Peak Heating & Cooling Loads

Peak Heating & Cooling Loads (kW)	
Without Recirculation	
Heating	Cooling
6.2	2.0
With Recirculation*	
Heating	Cooling
5.8	1.8

Analysis of Design

Effect of Air Recirculation/Natural Ventilation on Annual Heating & Cooling Energy Consumption w/ GSHP

Annual Space Heating and Cooling Energy Consumption using the GSHP (kWh)	
Without Recirculation	
Heating	Cooling
2845 (COP 2.75)	698 (COP 2.85)
With Recirculation*	
Heating	Cooling
1784 (COP 2.56)	340 (COP 2.80)

Analysis of Design

PV Generation and Income Analysis

Modules & Area	Total Annual Electricity Generation (kWh)	Income from exporting at TOU Rates* ($)	Income from exporting electricity at Flat Rate ($0.1053) ($)	Income from exporting electricity at OPA Standard Offer Rate ($0.42) ($)	Income from exporting electricity with Green Energy Act Feed-In Tariff Rate ($0.802) ($)
Sharp NT-185U1 44m^2	7767	899	818	3262	6229

**TOU Rate (Toronto Hydro, 2008)*

Analysis of Design

Energy Cost Analysis According to the Different Systems

	GSHP	Two Stage ASHP	Single Stage ASHP
Total House Consumption (kWh)	4501	5082	5304
Net Energy (Generation-Consumption) (kWh)	3266	2684	2463
Energy Cost with Flat Rate* ($)	474	535	559
Energy Cost with TOU Rate** ($)	453	497	515

**Flat Rate cost $0.1053/kWh (Toronto Hydro, 2008)*

***TOU Rate (Toronto Hydro, 2008)*

Analysis of Design

Energy Cost Savings (based on Net-Metering) & GHG Credits According to the Different Heating Systems

	GSHP	Two Stage ASHP	Single Stage ASHP
Annual Energy Cost Savings Due to PV at Flat Rate* Cost ($)	344	283	259
Annual Energy Cost Savings Due to PV at TOU Rate** Cost ($)	445	401	383
Annual GHG Credits at Flat Rate Factor (0.222 kg/kWh) (kg of CO_{2eq})	725	596	547
Annual GHG Credits at TOU Factors (kg of CO_{2eq})	859	749	676

**Flat Rate cost $0.1053/kWh (Toronto Hydro, 2008)*

***TOU Rate (Toronto Hydro, 2008)*

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Analysis of Design

Under Green Energy Act Tariff Benefits

- At $0.802/kWh:
  - The 44m^2 PV system will provide $6229 annually
- After deducting costing for total household energy w/ GSHP system:
  - $5776 at TOU pricing
  - $5755 at Fixed Rate pricing

Analysis of Design

Green Energy Act Tariff Benefits

- Annual Energy Cost Savings from Base Case (w/ gas furnace & DHW heater and A/C) :
  - (577+962) – 474 = $1065
- Amount for payback using flat rate to allow for comparison:
  - $5755 + $1065 = $6820/year (net income)
- Therefore $6820 can be put towards paying back for the systems implemented in the Top of the Annex Townhome

Opportunities for Future R&D

- Improvement of PV efficiency and cost
- Micro-inverter and smart grid
- Better window and shading control
- Better integration and control of renewable energy/HVAC systems (BIPV/T system)
- Thermal storage (diurnal, medium and long-term)
- Adaptive predictive control of whole building (lighting/shading/HVAC/etc.) using weather forecast for load shifting/shaving
- Life-cycle based least cost upgrade paths to NZE status
- Mixed used community based energy systems
- High resolution spatio-temporal renewable energy mapping, modeling and forecasting for planning and dispatching
- Policy……

Acknowledgement

- ***Sustainable Urbanism Initiative (SUI) Team***
- ***Canada Mortgage and Housing Corporation (CMHC)***
- ***Solar Buildings Research Network (SBRN)***

THANK YOU

Quick Economic Analysis

- Base Conventional HVAC System (based on the best contractor price for high-volume builders):
  - Gas Furnace (90%) - $1,300
  - Gas DHW tank (EF = 0.6) - $1,100
  - A/C (SEER 14) - $2,000
  - Total - $4,400
- Net-zero Energy System (based on new, one of a kind unique system price):
  - PV (6.2 kWp) - $48,000
  - GSHP (2-ton) - $20,000
  - Solar DHW w/ TOU Tank & Powerpipe - $4,000
  - Total - $72,000
- Payback – ~10 years ($72,000 - $4,400)/$6,820