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# NTED™: An Innovative Design Using Nested Thermal Envelopes to Achieve Significant Reductions in Energy Use

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## ABSTRACT

*There is a need to reduce and eventually eliminate our reliance on nonrenewable energy sources. Although renewable energy technologies are promising, current sources cannot fulfill the increasing demands of industrialized countries. As a result, renewable solutions must involve significant reductions in energy consumption. A preliminary review of the energy supply mix in Ontario, Canada, reveals that renewable energy could meet home energy needs through a 75% reduction in demand. This paper presents a method of home construction that can achieve this energy goal. Known as Nested Thermal Envelope Design™ (NTED™), this method is an innovative concept that optimizes building heat gains and losses through the use of nested thermal envelopes. The design incorporates one insulated building inside another to control heat, air, and moisture transfer. A three-season perimeter area acts as a thermal buffer and heat recovery zone, while a core area is conditioned year-round as required. This study compares a low-energy R-2000 home to an NTED™ house located in Toronto, Canada. Research conducted to optimize the design as well as investigate the impact of occupant behavior on total energy use is presented. Study areas include (a) building orientation, (b) insulation levels, and (c) operating modes with building occupants. Results show that NTED™ is capable of meeting and even exceeding the target 75% energy reduction.*

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## INTRODUCTION

Today we realize a critical need to reduce and eventually eliminate our reliance on nonrenewable energy sources not only because of dwindling fuel supplies but also to reduce greenhouse gas emissions and our resulting contribution to climate change. Many current trends in sustainable building construction are harkening back to times before intensive energy use where concepts such as site orientation, cross ventilation, solar shading, and landscaping played key roles in achieving home comfort.

Nested Thermal Envelope Design™ (NTED™) is a concept that will allow occupants to achieve improved thermal comfort and drastic reductions in energy use through flexible space use provided by dual thermal zones. This proposed construction method incorporates many of the early passive design principles and improves upon a novel design

developed in the 1970s known as the Thermal Envelope House (Chown 1982).

The NTED™ system (Figure 1) employs one insulated building inside another to control heat, air, and moisture transfer. The interior, or core, area serves as the main living space operated at the desired living conditions year round. The perimeter area, typically operated for three-season occupation and with the ability to be conditioned to the living conditions setpoint if desired, acts as a thermal buffer and heat recovery zone helping to mitigate losses from the core. Conservative early modeling studies with an NTED™ home located in Toronto, Canada, have shown that reductions of up to 74% in heating energy use are possible (Pressnail et al. 2009).

The intent of this research is to create a robust NTED™ simulation model to both increase the accuracy of the results as well as begin to optimize the design. An additional objective

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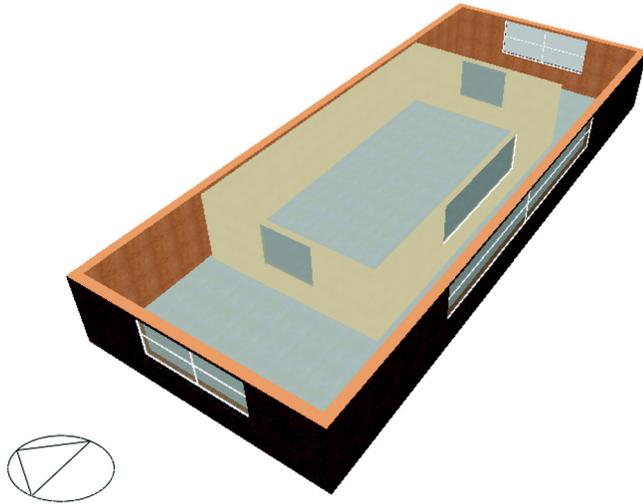


Figure 1 NTED™ example building configuration.

is to study various operating modes with building occupants to model the working performance of the design.

### NTED™ Design Details

An NTED™ house consists of an insulated interior envelope defined as the *core* area that contains the primary living spaces, including the bedrooms, kitchen, bathroom, and family room. Surrounding the core is an insulated exterior envelope termed the *perimeter* area that includes secondary living spaces such as a dining room and additional, or spare, bedrooms. The exterior envelope is constructed in a manner typical of residential construction with structural and finishing elements, operable windows, insulation, an air barrier, and a vapor retarding system. The interior envelope differs somewhat from typical partition walls in that it also contains insulation, operable windows, an air barrier, and a vapor retarding system.

Throughout most of the year, when temperatures are moderate, occupants inhabit the entire building using a single temperature setpoint. This operation is referred to as *Traditional* mode. During times of extreme outdoor temperatures, inhabitants can choose to occupy only the core and condition this space to a comfortable temperature. In this case, the perimeter is maintained at an intermediate setpoint between the core and exterior temperatures, referred to as *Gemini* mode. Essentially, this mode creates a thermal buffer around the core, helping to reduce heat transfer between both the core and perimeter and the perimeter and exterior due to smaller thermal gradients across each envelope. In addition, heat losses are reduced in Gemini mode due to a decreased surface area of the conditioned space as well as reduced effects of gross air movement from wind as the exterior envelope shields the interior envelope.

One of the most significant efficiency increases in Gemini mode occurs due to the fact that core heating energy is

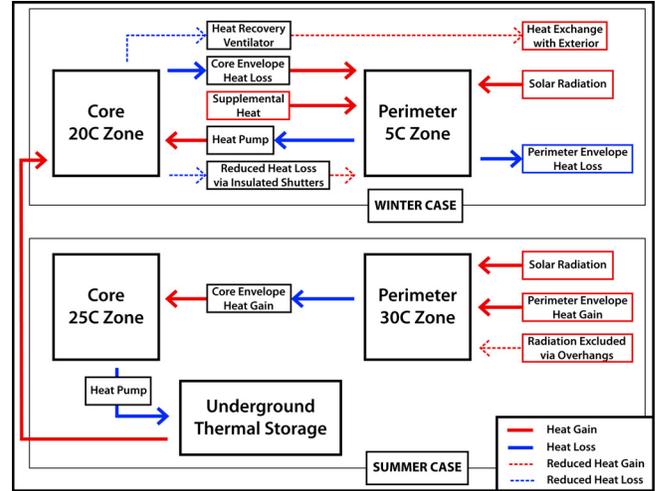


Figure 2 NTED™ seasonal heat flows.

obtained through the use of a heat pump operating between the core and perimeter spaces. Due to the intermediate perimeter temperature, the heat pump evaporator can see temperatures of 5°C (41°F) or greater, allowing operation at a coefficient of performance (COP) of 3 or more. This heat pump recovers both core heat losses and solar heat gains admitted through the perimeter glazing as it operates to heat the core living space.

The NTED™ system incorporates additional energy-saving devices such as a heat recovery ventilator and insulated shutters. The heat recovery ventilator is a key component of the HVAC system, ensuring living spaces are adequately ventilated while minimizing energy use. In addition, passive devices such as insulated shutters may be installed on the core windows. This location has a significant advantage over traditional externally applied insulated shutters. In this case, the shutters are easily accessible and less subject to freezing, thus encouraging regular use by occupants.

A final proposed energy-saving concept in the NTED™ system is the use of an underground thermal storage bed. During the summer, excess heat removed from the core by the air-conditioning system can be fed to the thermal storage area. In the winter, this heat would be made available to help offset the required heating energy. Figure 2 provides a schematic diagram of the NTED™ systems and their intended functions throughout the year.

A significant advantage of the NTED™ concept is its adaptability. In fact, NTED™ can be applied to virtually all building types, including new and retrofit residential construction and commercial as well as multi-unit residential applications. Simply stated, the perimeter zone can expand or contract to accommodate the spatial constraints of most applications. As a result, the NTED™ system has the potential to make a significant contribution to reducing the energy use required for building conditioning.

There are several considerations that must be addressed for the NTED™ concept to gain wide acceptance. These can be categorized under lifestyle, architectural, and technical headings. From a lifestyle perspective, while the proposed solution offers great potential for energy savings, it requires an adjustment to current typical living conditions. Occupants must understand that in times of extreme temperatures and/or when energy prices are high, living in a smaller area can result in significant energy savings. Architecturally, challenges exist to ensure that the buildings are attractive, are functional, and do not feel like a box inside a box—allowing light penetration and natural airflow through core windows is an important factor in this regard. Finally, technically, achieving an effective balance between incremental costs for envelope and HVAC upgrades while designing a flexible system that can accommodate both single-zone (whole-building) temperature and ventilation settings as well as multi-zone operation is key. While operational savings have the potential to be significant, initial costs and material use should be minimized to ensure a sustainable design.

### Existing Low-Energy Residential Designs

A brief summary of current and historical cold-weather, low-energy house concepts provides an understanding of the design progression as well as a basis for comparison of NTED™ system performance.

Alpha House, built in Ontario, Canada, by John Hix in 1979 (Lane-Moore 2007), is an example of a modified Thermal Envelope House. The original Thermal Envelope House design was developed in the United States in the 1970s and uses nested thermal envelopes on four of six sides. Successful operation relies heavily on southern exposure and, as a result, building orientation and solar access are critical.

R-2000 is a long-standing program from Natural Resources Canada that requires homes to meet energy use targets through insulation, airtightness, and ventilation measures. Certified homes are approximately 30% more energy efficient than traditional building code homes (NRCan 2009). The program, requiring licensed builders and an involved certification process, has resulted in more than 10,000 homes having been certified during the 20-year program.

Low-energy advanced home building has been ongoing in Canada since the oil crisis of the 1970s. Lstiburek (2008) summarizes Canadian efforts to design and construct low-energy housing. Rob Dumont of the National Research Council has figured prominently in these efforts. Dumont designed and built a very-low-energy home in the mid 1990s as part of the advanced house program. Results showed that the incremental cost of building a home in Saskatoon that reduced energy by a factor of 5 compared to a home built to the building code was less than \$20,000. Very thick walls and increased airtightness were some of the key measures used to achieve this result.

The EnerGuide program intends that new homes are constructed using techniques that will result in approximately 30% less energy use than those built to standard building codes. Homes are rated on a scale of 0–100 and must achieve a score above 80 to be labeled an EnerGuide home (NRCan 2010).

The Royal Architectural Institute of Canada (RAIC) has endorsed The 2030 Challenge. This program is built around a series of targets for new and renovated buildings that aim to reduce fossil fuel use and greenhouse gas emissions by 60% in 2010 up to 100% by 2030 (RAIC 2009).

NTED™ is an extension of the Alpha House concept. A double envelope is applied on all sides of the core, with living spaces on east, south, and west sides. In addition, while Alpha House relies on a fan-driven convective loop for heat transfer between the core and perimeter, NTED™ employs a heat pump to maximize recovery of core heat losses and perimeter solar heat gains. For the purposes of this research, NTED™ design performance is being evaluated by comparison to the benchmark low-energy home construction guideline in Ontario—the R-2000 standard (NRCan 2009).

### PHASE 1 PRELIMINARY RESEARCH: INITIAL ENERGY SAVINGS CALCULATIONS

Initial energy modeling (Pressnail et al. 2009) was performed considering heating loads in Toronto, Canada. At the time of this work, energy simulation program limitations did not allow modeling of nested envelopes with a heat pump operating between zones. As a result, a heating degree-day calculation in conjunction with results from HOT2000, Version 10.31, a whole-house energy analysis program published by Natural Resources Canada (NRCan 2008), was used to estimate the heating energy use.

The modeled home was a single-story building with a perimeter envelope of 14.5 × 9.5 m (48 × 31 ft) and a core envelope of 8 × 6.5 m (26 × 21 ft). In Gemini mode, the home was operated with a 20°C (68°F) core temperature setpoint and a perimeter setpoint equal to the greater of 5°C (41°F) or the average monthly exterior temperature. In Traditional mode, the entire building was operated at 20°C (68°F) to represent a home built to R-2000 standards. The work compared the heating energy use for the two operating modes.

The results showed a savings of 74% in heating energy for the building operated in Gemini mode compared to Traditional mode. Adjusting for the change in area from 138 to 52 m<sup>2</sup> (1485 to 560 ft<sup>2</sup>) when heating the entire house compared to the core only, this represented a 31% savings per unit of habitable area. Because energy costs are a factor in home operation, savings were also calculated on a cost basis, as shown in Figure 3. The difference in cost between electricity, assuming \$0.08/kWh (Gemini mode), and natural gas, assuming \$0.40 m<sup>3</sup> (Traditional mode), results in the Gemini mode dollar savings being less than the previously described energy savings.

## PHASE 2 CURRENT RESEARCH: DETAILED MODEL DEVELOPMENT AND DESIGN OPTIMIZATION

Upon completion of the preliminary research phase, further work was proposed involving creation of a more accurate energy model. This research involved two key components. The first was the development of a model to allow simulation of the desired HVAC configuration using a sub-hourly energy modeling program. The second involved a study of the effects of building geometry, construction, and occupant behavior on building energy use. In keeping with the preliminary research, these studies also focused on the heating season with the building located in Toronto, Canada. Figure 4 shows the NTED™ heat flow diagram highlighting the elements covered by this research phase.

### Energy Simulation Software Modification

EnergyPlus, a building energy simulation program from the U.S. Department of Energy (DOE 2009), was the modeling

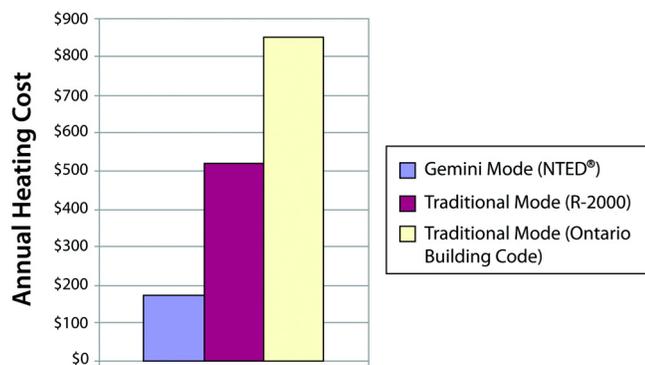


Figure 3 Heating season cost comparison for varied operating modes and construction types.

tool chosen for this phase of the research work. While EnergyPlus version 4.0 was able to model several key aspects of the NTED™ concept, including nested thermal envelopes, a limitation existed in that the heat pump model functioned between a specified zone and the building exterior, considered to be an unlimited heat source/sink. As a result, modification of the EnergyPlus source code was required to allow the heat pump to operate between two zones in a building. This was an important element, allowing an appropriate cooling load to be applied to the heat source zone, thus reflecting heat being removed from the zone. Figure 5b shows the result of the code modification in the context of the NTED™ project. In the case of core heating, the heat pump applies a cooling load to the perimeter zone through the evaporator component and a heating load is

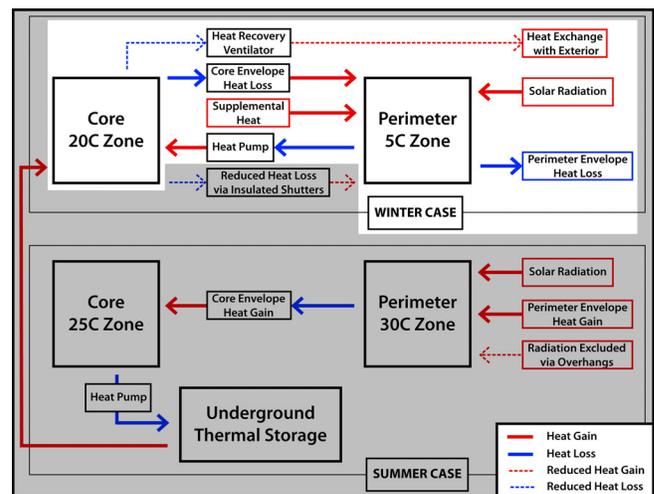


Figure 4 NTED™ current study area.

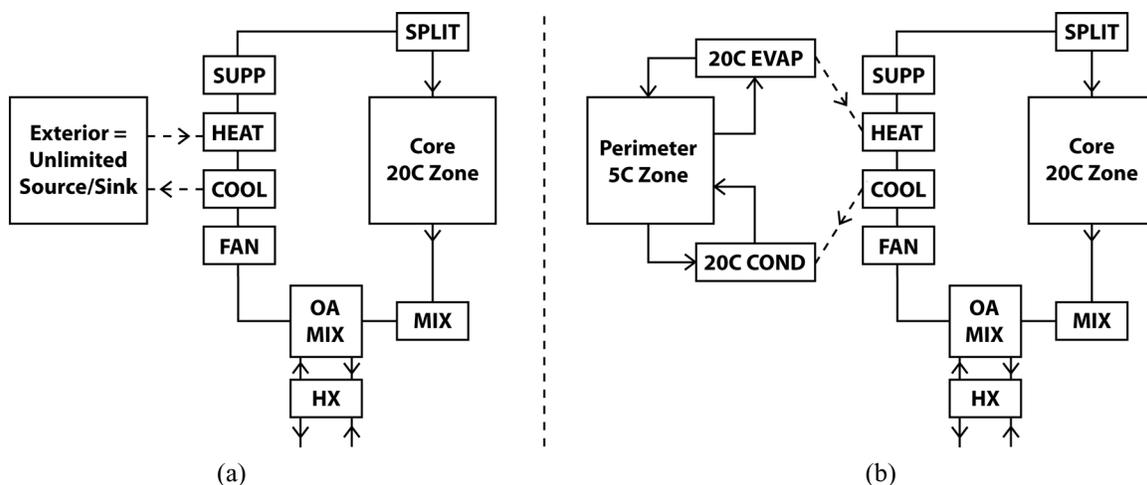


Figure 5 (a) EnergyPlus air-source heat pump components and (b) modified EnergyPlus interzone air-source heat pump.

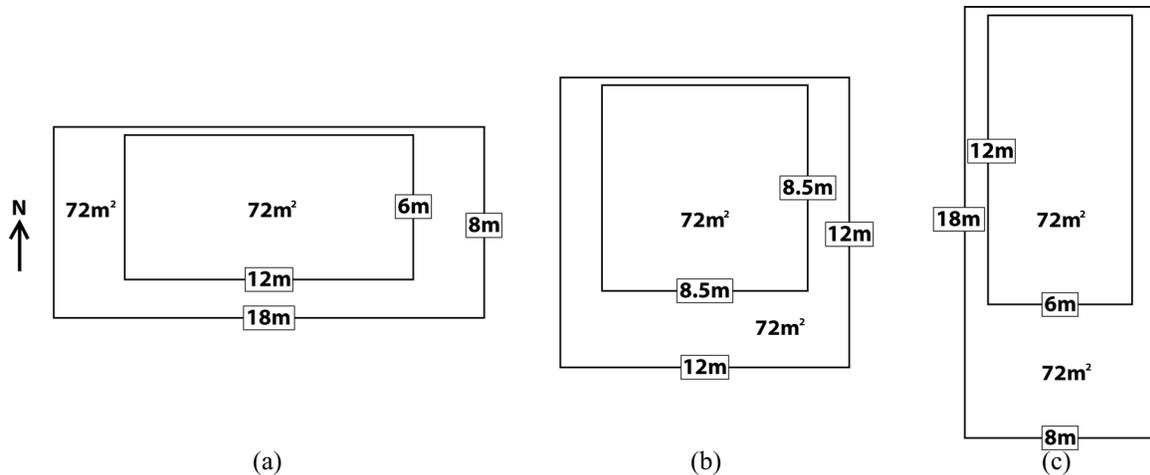


Figure 6 (a) Baseline, (b) Square, and (c) 90° Baseline building configurations.

Table 1. NTED™ Building Parameters for Energy Modeling

Perimeter Area	Perimeter Ceiling Height	Perimeter South Glazing	Perimeter East/West Glazing	Core Area	Core Ceiling Height	Core South Glazing	Core East/West Glazing	North Wall Cavity
72 m <sup>2</sup> (775 ft <sup>2</sup> )	3 m (10 ft)	20%	15%	72 m <sup>2</sup> (775 ft <sup>2</sup> )	2.5 m (8 ft)	20%	20%	0.15 m (6 in.)

Table 2. Traditional Mode Operating Conditions

Core Temperature Setpoint	Perimeter Temperature Setpoint	Whole-Building HVAC	Whole-Building Ventilation
20°C (68°F)	20°C (68°F)	forced-air gas furnace	heat recovery ventilator

Table 3. Gemini Mode Operating Conditions

Core Temperature Setpoint	Core Heating	Core Ventilation	Perimeter Temperature Setpoint	Perimeter Heating	Perimeter Ventilation
20°C (68°F)	air-source heat pump	heat recovery ventilator	5°C (41°F)	electric baseboard	n/a (non-occupied)

applied to the core through the condenser component. Verification of the respective heating and cooling loads was carried out to ensure that the model applies the expected loads to the perimeter zone.

### Building Configuration Setup

Data from the Natural Resources Canada Survey of Home Energy Use (NRCAN 2005) was used to update the zone areas for this modeling phase. The core and perimeter sizes were selected based on the typical heated dwelling area in Ontario and the second largest category of heated dwelling area in Canada, respectively. The goal was to establish a representative model that accurately reflects the founding NTED™ principles—a conservative dwelling designed to achieve a high level of energy efficiency, hence possessing a moderate floor

area. The model single-story building has a gross area of 144 m<sup>2</sup> (1550 ft<sup>2</sup>) with core and perimeter areas of 72 m<sup>2</sup> (775 ft<sup>2</sup>).

The base NTED™ building is shown in Figure 6a (Baseline). The impact of building orientation was investigated by modifying the proportions while maintaining the core and perimeter areas as shown in Figure 6b (Square) and Figure 6c (90° Baseline).

Table 1 shows the relative proportions and dimensions of key core and perimeter elements, consistent for each building configuration in Figures 6a, 6b, and 6c. It should be noted that there is no glazing on either the core or perimeter north elevations.

Two operating modes and corresponding HVAC configurations were used for simulation purposes, as outlined in Table 2 for Traditional mode (representative of a typical R-2000 home) and Table 3 for Gemini mode. The building is assumed to be reasonably airtight with an infiltration rate of

1.5 ach at a 50 Pa (0.0005 bar) pressure difference. This rate was chosen according to the R-2000 standard to ensure comparison accuracy between operating modes. A mechanical ventilation rate of 0.6 ach was established for the core assuming two bedrooms, one bathroom, a kitchen, and a living room. The occupied perimeter requires a ventilation rate of 0.25 ach assuming the area contains a dining room and two additional bedrooms. These rates were based on *CAN/CSA F326-M91, Residential Mechanical Ventilation Systems* (CSA 1991).

A variety of wall constructions were investigated to see the effect of varying the core and perimeter insulation levels. Table 4 shows the insulation values and the effective thermal resistance of the stud-insulation cavity assuming an on-center stud spacing of 0.400 m (16 in.).

### Simulation Parameters

The simulation matrix for energy use comparison, shown in Table 5, is divided into three main categories—geometry, wall construction, and occupant behavior. The geometry category involves the two operating modes (1–2) with the standard R-2000 insulation levels (9) simulated against each of the house orientations (3–5). The wall construction variations involved the Gemini mode (2) in Baseline orientation (3) simulated against all of the insulation thickness combinations (6–11). Because the building is operated at a single temperature setpoint in Traditional mode (1), the Baseline orientation (3) was simulated only against the perimeter insulation levels (8, 9, 10). The geometry and wall construction simulations

were completed without occupants to determine how the building configuration affects heating energy use.

The occupant behavior category involved the Baseline geometry (3) and R-2000 wall construction (9) simulated against each of the occupant behavior variations (12–14). The occupant schedule was based on three people with full occupation at night, no occupation during the day from Monday to Friday, and partial occupation (50%) on weekend days. Appliance and lighting loads were based on average Canadian household usage (NRCAN 2004). An appliance load of 3.81 W/m<sup>2</sup> (1.21 Btu/(h·ft<sup>2</sup>)) was applied to the core area, and a lighting load of 1.31 W/m<sup>2</sup> (0.42 Btu/(h·ft<sup>2</sup>)) was applied to the core and occupied perimeter areas. The Traditional-Occupied (12) and Gemini-Occupied (13) modes are as previously described, while the Moderate-Occupied (14) mode is based on weekday Gemini-Occupied with weekend and holiday Traditional-Occupied behaviors.

### EnergyPlus Simulation Results

Simulations resulting from the EnergyPlus model show larger heating energy differences when compared to the initial HOT2000 calculations, which were intended to be conservative. Table 6 shows the heating energy use, which demonstrates a savings of 85% when operating in Gemini versus Traditional mode. Taking into account the change in habitable area between the Gemini and Traditional operating modes, the Traditional heating energy use is 61 kWh/m<sup>2</sup> (19 MBtu/ft<sup>2</sup>) compared to 18 kWh/m<sup>2</sup> (6 MBtu/ft<sup>2</sup>) in Gemini mode, which is a savings of 70%.

**Table 4. Wall Construction Details**

Core Wall Designation	Perimeter Wall Designation	Insulation Thickness	Effective (Stud-Insulation) Thermal Resistance
C4	P4	0.089 m (3.5 in)	RSI 1.98 (R-11.23)
C6	P6	0.140 m (5.5 in)	RSI 3.11 (R-17.66)
C12	P12	0.292 m (11.5 in)	RSI 6.49 (R-36.84)

**Table 5. Simulation Matrix**

Operating Mode	Geometry	Wall Construction	Occupant Behavior
1. Traditional	3. Baseline	6. C4-P4	12. Traditional-Occupied
2. Gemini	4. Square 5. 90° Baseline	7. C4-P6	13. Gemini-Occupied
		8. C6-P4	14. Moderate-Occupied
		9. C6-P6	
		10. C6-P12	
		11. C12-P6	

**Table 6. Comparison to Preliminary Simulation Results**

Matrix Combination				Heating Energy Use
(i)	1. Traditional	3. Baseline	9. C6-P6	8841 kWh (30187 MBtu)
(ii)	2. Gemini	3. Baseline	9. C6-P6	1300 kWh (4439 MBtu)

This increase in efficiency can be attributed to the improved accuracy of the simulation tool and model details. For example, the sub-hourly EnergyPlus model is able to account for solar gains through the perimeter glazing. Also, the interzone heat pump operates based on equipment performance data and operating temperature conditions, which result in a COP varying from approximately 3.4 to 3.8. Of additional note is the fact that although the perimeter is equipped with electric baseboard heaters, core heat losses and perimeter solar heat gains are sufficient to maintain the perimeter above the setpoint temperature of 5°C (41°F) throughout the heating season even with the heat pump removing heat for delivery to the core. In other words, the supplementary baseboard heaters are not required to maintain the perimeter setpoint.

Table 7 shows the results of the geometry simulation component. Comparing the Baseline (i) and (ii) to the Square (iii) and (v) configurations shows a difference of 5% or less in heating energy requirement when operating in both Gemini and Traditional modes. A Baseline (i) and (ii) to 90° Baseline (iv) and (vi) configuration comparison shows less than a 10% difference in heating energy requirement in Gemini and Traditional modes. These results suggest that the building design is not highly sensitive to orientation, making it appropriate for urban and retrofit applications where solar access is limited and/or building orientation is predetermined.

Table 8 shows the results of the wall construction study. When comparing the Gemini operating modes it can be seen

that the perimeter insulation has a greater effect on reducing heating energy use than does core insulation. This is illustrated by the greater energy use in scenarios (xi) C6-P4 and (xiii) C12-P6 compared to the opposite configurations (x) C4-P6 and (xii) C6-P12. This difference can be anticipated due to the greater temperature difference between the perimeter and exterior than between the core and perimeter areas, the larger perimeter surface area compared to that of the core, as well as the impact of wind and pressure differences on the exterior envelope. Of additional interest from this phase is the impact of the perimeter insulation on each of the operating modes. Comparing the C6-P4 to C6-P12 cases for both the Traditional and Gemini modes shows a 27% decrease in energy use between the Traditional mode configurations (vii) and (viii) as compared to only a 17% decrease between the Gemini mode configurations (xi) and (xii). Again this difference is supported by the smaller temperature difference between the interior and exterior conditions and the reduced exposed surface area in Gemini versus Traditional modes. This suggests that the presence of the thermal buffer in the double-envelope Gemini configuration decreases the reliance on a highly insulated exterior envelope when compared to a typical single-envelope building operating with one thermal zone.

Table 9 shows the results of the occupant behavior study. These results are presented graphically in Figure 7, where it can be seen that the total heating season energy use approximately doubles with each subsequent operating mode change. That is, operating under Moderate conditions, where the build-

**Table 7. Geometry Simulation Results**

Matrix Combination				Heating Energy Use
(i)	1. Traditional	3. Baseline	9. C6-P6	8841 kWh (30187 MBtu)
(iii)	1. Traditional	4. Square	9. C6-P6	9055 kWh (30918 MBtu)
(iv)	1. Traditional	5. 90° Baseline	9. C6-P6	9490 kWh (32403 MBtu)
(ii)	2. Gemini	3. Baseline	9. C6-P6	1300 kWh (4439 MBtu)
(v)	2. Gemini	4. Square	9. C6-P6	1371 kWh (4681 MBtu)
(vi)	2. Gemini	5. 90° Baseline	9. C6-P6	1412 kWh (4821 MBtu)

**Table 8. Wall Construction Simulation Results**

Matrix Combination				Heating Energy Use
(vii)	1. Traditional	3. Baseline	8. C6-P4	10157 kWh (34680 MBtu)
(i)	1. Traditional	3. Baseline	9. C6-P6	8841 kWh (30187 MBtu)
(viii)	1. Traditional	3. Baseline	10. C6-P12	7380 kWh (25198 MBtu)
(ix)	2. Gemini	3. Baseline	6. C4-P4	1466 kWh (5006 MBtu)
(x)	2. Gemini	3. Baseline	7. C4-P6	1341 kWh (4579 MBtu)
(xi)	2. Gemini	3. Baseline	8. C6-P4	1430 kWh (4883 MBtu)
(ii)	2. Gemini	3. Baseline	9. C6-P6	1300 kWh (4439 MBtu)
(xii)	2. Gemini	3. Baseline	10. C6-P12	1183 kWh (4039 MBtu)
(xiii)	2. Gemini	3. Baseline	11. C12-P6	1259 kWh (4299 MBtu)

ing uses Gemini mode during the week and Traditional mode on weekends and holidays, almost doubles the energy use of the full Gemini mode base case. Full Traditional mode operation doubles the energy use from the Moderate case. In other words, the flexibility offered by the NTED™ design provides the potential for significant energy savings while allowing variable space use during the heating season.

**PHASE 3 FUTURE RESEARCH: CONSTRUCTION, MONITORING AND MODEL VALIDATION**

The next phase of work for the NTED™ project is to apply the concept to an existing residential building allowing both performance measurements and simulation model validation. The building, located in Toronto, Canada, is a University of Toronto property that will be inhabited and monitored by students to advance the NTED™ research agenda. Figure 8 shows the building exterior and a preliminary concept sketch of the proposed core (red) and perimeter (blue) areas.

**Consideration of Summer Cooling Case**

To this point, NTED™ research has focused on the winter heating case. This is to be anticipated with the building located in the heating-dominated climate of Toronto, Canada.

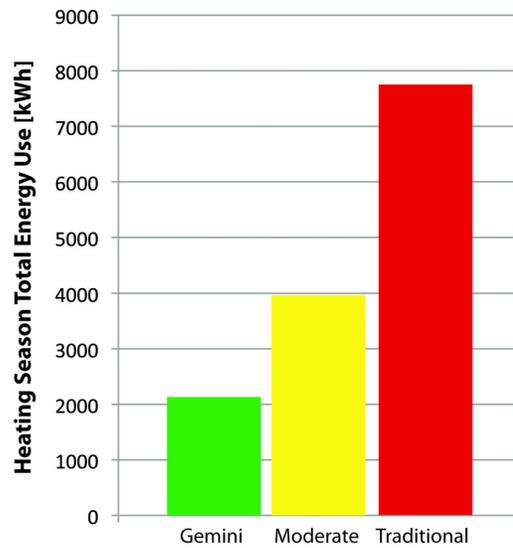
**Table 9. Occupant Behavior Simulation Results**

Matrix Combination			Heating Season Energy Use
(xiv)	3. Baseline	12. Traditional-Occupied	7734 kWh (26407 MBtu)
(xv)	3. Baseline	13. Gemini-Occupied	2186 kWh (7464 MBtu)
(xvi)	3. Baseline	14. Moderate-Occupied	3967 kWh (13545 MBtu)

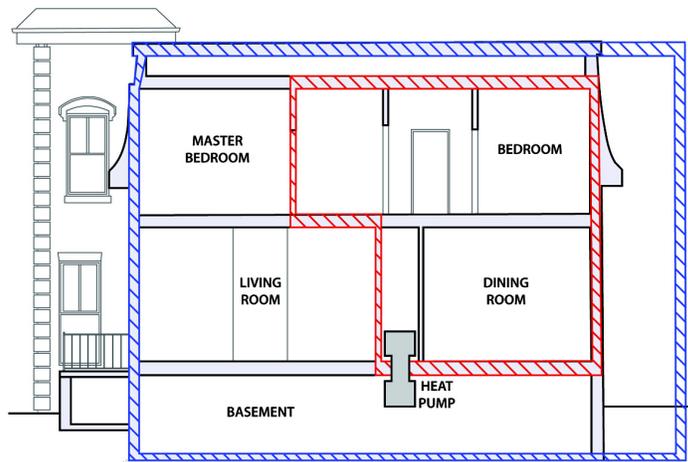
However, the significant seasonal variation of the climate in this location also warrants consideration of the summer season where cooling may be desired. Future modeling efforts can include modification to allow the EnergyPlus model to (1) expel excess heat from the core to the exterior, as is done with a traditional air conditioning unit (Figure 9a) or (2) direct the excess heat to an underground thermal storage area to offset the heating load during the winter months (Figure 9b). These modifications would help give a complete understanding of the energy saving benefits resulting from the NTED™ system.

**CONCLUSION**

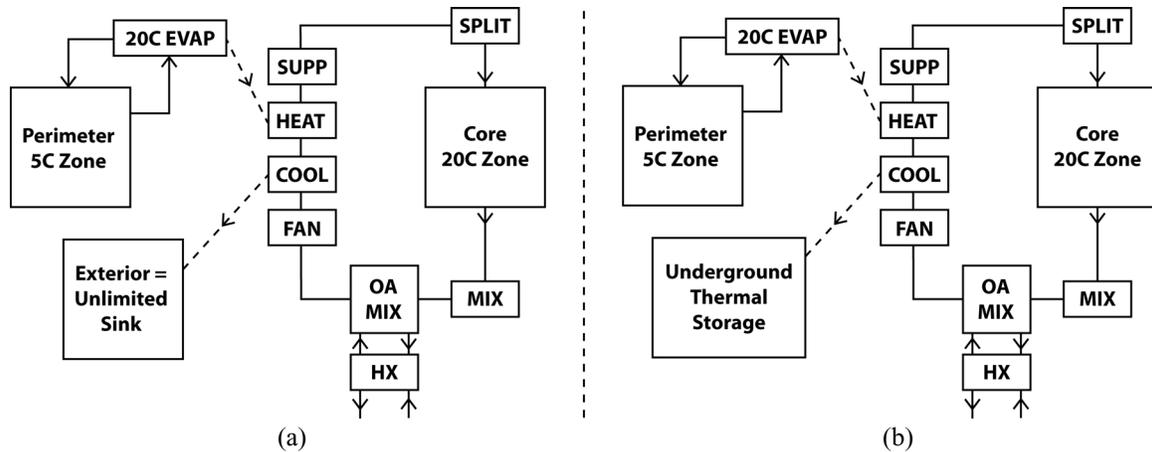
The NTED™ system has the potential to generate significant reductions in residential building conditioning energy



*Figure 7 Heating season energy use comparison for various operating modes of the occupied building.*



*Figure 8 Toronto, Ontario, house and initial design sketch for NTED™ retrofit.*



**Figure 9** (a) Interzone heat pump and exterior air-conditioning system and (b) interzone heat pump tied to an underground thermal storage bed.

use. Design flexibility allows NTED™ to be applied both to new and existing buildings, and the lack of reliance on southern exposure means that it is appropriate for the vast majority of building designs and lot configurations. Of additional benefit is the fact that conventional building methods reduce the barriers for adoption by contractors and building owners. As our culture of conservation develops, NTED™ provides building occupants with the flexibility to control their energy use through thermal zone and space use adjustments.

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## REFERENCES AND BIBLIOGRAPHY

- Chown, G.A. 1982. Thermal Envelope Houses. Building Practice Note, Division of Building Research, National Research Council of Canada, Ottawa, Canada.
- CSA. 1991. *CAN/CSA-F326-M91 (R2005), Residential Mechanical Ventilation Systems*. Mississauga, Ontario, Canada: Canadian Standards Association.
- Lane-Moore, L. 2007. The sun king: When it comes to passive solar design, architect John Hix rules. *The Barrie Examiner*, Fall, pp. 21–27.
- Lstiburek, J.W. 2008. Building America. *ASHRAE Journal* 50(12):60–64.
- NRCan. 2004. *Energy Use Data Handbook 1994 and 1998 to 2004*. <http://oee.nrcan.gc.ca/Publications/statistics/handbook06/pdf/handbook06.pdf>. Ottawa, Ontario, Canada: Natural Resources Canada.
- NRCan. 2005. Survey of Household Energy Use (SHEU) Summary Report. <http://oee.nrcan.gc.ca/publications/statistics/sheu-summary/trends.cfm?attr=0>. Ottawa, Ontario, Canada: Natural Resources Canada.
- NRCan. 2009. Office of Energy Efficiency R-2000 program. <http://oee.nrcan.gc.ca/residential/personal/new-homes/r-2000/About-r-2000.cfm>. Ottawa, Ontario, Canada: Natural Resources Canada.
- NRCan. 2010. Office of Energy Efficiency EnerGuide program. <http://oee.nrcan.gc.ca/residential/personal/new-homes/upgrade-packages/energuide-service.cfm?attr=0>. Ottawa, Ontario, Canada: Natural Resources Canada.
- Nested Thermal Envelope Design and NTED*, 2009 trademark Clevergreen Consulting Ltd.
- NRCan. 2008. HOT2000, Version 10.31. Ottawa, Ontario, Canada: Natural Resources Canada.
- Pressnail, K.D., R. Richman, and A.M. Kirsh. 2009. An innovative approach to low-energy building performance using nested thermal envelopes. *Proceedings of the National Building Envelope Conference (NBEC)*, Montreal, Canada.
- RAIC. 2009. The 2030 Challenge program. [www.raic.org/architecture\\_architects/green\\_architecture/2030\\_about\\_e.htm](http://www.raic.org/architecture_architects/green_architecture/2030_about_e.htm). Ottawa, Ontario, Canada: Royal Architectural Institute of Canada.
- DOE. 2009. EnergyPlus, Version 4.0. Washington, DC: U.S. Department of Energy.