YELLOWKNIFE ECO-HOUSING PROJECT

FINAL REPORT

Prepared for the City of Yellowknife
December 2013

GUY ARCHITECTS
ingenuity + results

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EXECUTIVE SUMMARY

The Yellowknife Eco-Housing project is a multi-unit, mixed-use ‘walk-up’ building proposed for downtown Yellowknife that comprehensively advances environmental and performance metrics established by the City’s Eco-Housing Task Force. The four storey, mixed use development includes 24 residential units in addition to 5,000 square feet of street level commercial / retail space that contributes to a vibrant, livable community in support of City of Yellowknife *Smart Growth* objectives for its downtown.

The project is designed to exceed *all* of the key “performance indicators” established by the Eco-Housing Task Force, which include a unique combination of social, economic, and environmental indicators that define the project’s innovation agenda. *The project adopts a* “low energy / low tech” approach which seeks major reductions in energy consumption through the use of a ‘high performance’ building envelope that minimizes heating and eliminates cooling requirements and through the use of selective high-efficiency systems. This approach also responds to the Task Force ‘affordability’ indicators and the project’s private sector delivery model.

Organized in response to solar orientation, the ‘L’ shaped building wraps around an expansive south-facing terrace that serves as a central amenity space / community garden for residents. Built form is responsive to context and micro-climate opportunities in order to advance / optimize environmental performance for passive ventilation and solar harvesting opportunities. Parking and service access are provided from the rear laneway system and are screened from view from the public street by retail space and by the elevated terrace / community garden.

Designed to achieve ‘near carbon neutral’ objectives, Eco-Housing utilizes grid-based hydro-electrical power for space heating and plug loads, and on-site generated solar thermal to reduce domestic hot water heating loads. Overall energy use for the project is estimated at 50% below 1997 MNECB standards with an overall annual Energy Use Intensity of 91.75 kWh/m^2, which is an extraordinary achievement level for northern multi-unit housing internationally. Water conservation strategies include the exclusive use of ‘water reducing fixtures’, ‘on-demand’ water heaters, and rainwater harvesting from roof areas for the irrigation of garden plots.

Designed through a unique public partnership model, the project will be delivered through a market driven / developer model, with construction costs and unit affordability criteria determined through this process. The project uses a combination of site built and prefabricated construction techniques to advance affordability objectives. The project provides a range of opportunities for skill development, particularly in the area of testing and sealing of high-performance / low-infiltration building envelope construction, and solar thermal installation /commissioning.

Follow-up analysis of utility costs is planned. Additional analysis of proposed sustainability and energy conservation measures using actual tender costs would facilitate increased understanding of incremental costs, benefits, and ‘payback’ analysis of sustainability initiatives within the northern market.

1.0 INTRODUCTION

1.1 Project Description

The Yellowknife Eco-Housing project is a multi-unit, mixed-use ‘walk-up’ building proposed for downtown Yellowknife that comprehensively advances environmental and performance metrics established by the City’s Eco-Housing Task Force. The four storey, mixed use development includes 24 residential units in addition to 5,000 square feet of street level commercial/ retail space that contributes to a vibrant, livable community in support of City of Yellowknife *Smart Growth* objectives.

The project is designed to exceed all of the key “performance indicators” established by the Eco-Housing Task Force, as summarized in *Figure 1.* A “low energy / low tech” approach was developed in consultation with the Task Force - focusing upon energy conservation strategies achieved through the use of a ‘high performance’ building envelope that minimizes heating and eliminates cooling requirements. RSI 10.56 (R60) walls, RSI 14.08 (R80) roof, triple/quad glazed energy star windows, external shading, infiltration below 1.5 ach @ 50 Pa and through the use of selective high-efficiency mechanical systems: Heat Recovery Ventilators (HRV’s), drain water heat recovery, ENERGY STAR® appliances, Solar Domestic Hot Water (DHW), on-demand boilers. In response to the Task Force ‘affordability’ indicators and the project’s private sector delivery model, the project uses proven technology developed in other markets, minimizing risks. This extends to the use of prefabricated / modular building assemblies.

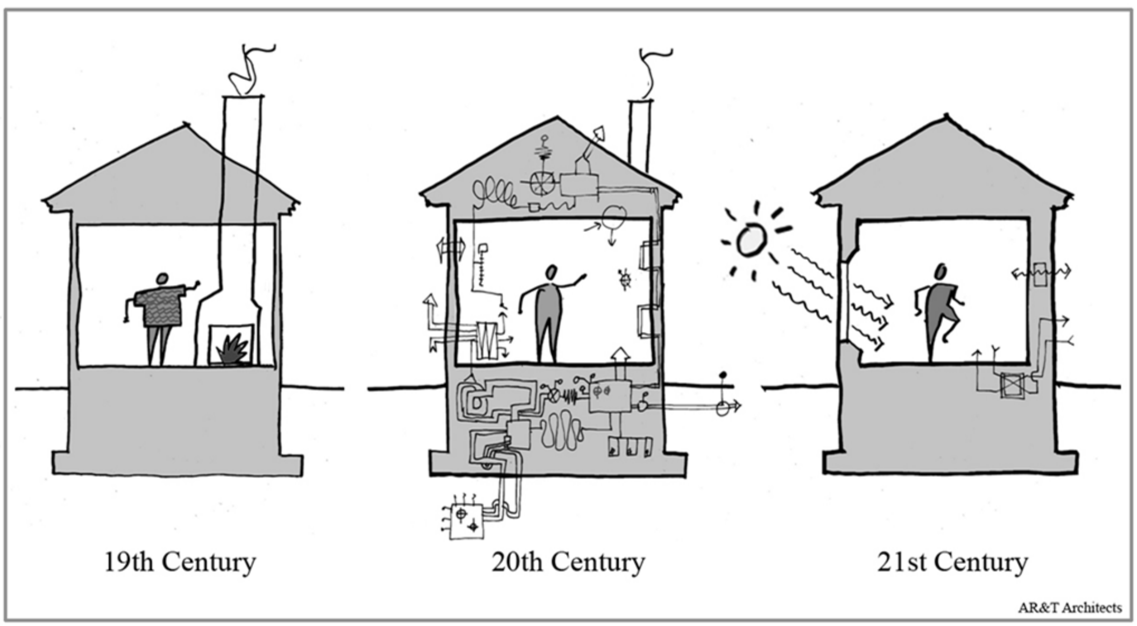


Figure 1 – Towards Simplicity – Low Energy/Low Tech

Designed to achieve ‘near carbon neutral’ objectives, Eco-Housing utilizes grid-based hydro-electrical power for space heating and plug loads, and on-site generated solar thermal to supplement electric on-demand domestic hot water boilers provided within each suite. No fossil burning fuels are proposed for any building system. Water conservation strategies include the exclusive use of ‘water reducing fixtures’, ‘on-demand’ water heaters, and rain-water harvesting from roof areas for the irrigation of garden plots.

Located two blocks from 50th Ave and 50th Street - the centre of town - the site provides residents a wide array of opportunities to 'live, work and play' in close proximity. It is proposed for a consolidated 100' x 150' parcel of land that fronts 48th Street on lots 3, 4 and 5 of Block 36, south-east of 51st Avenue adjacent to Boston Pizza Figure 2.

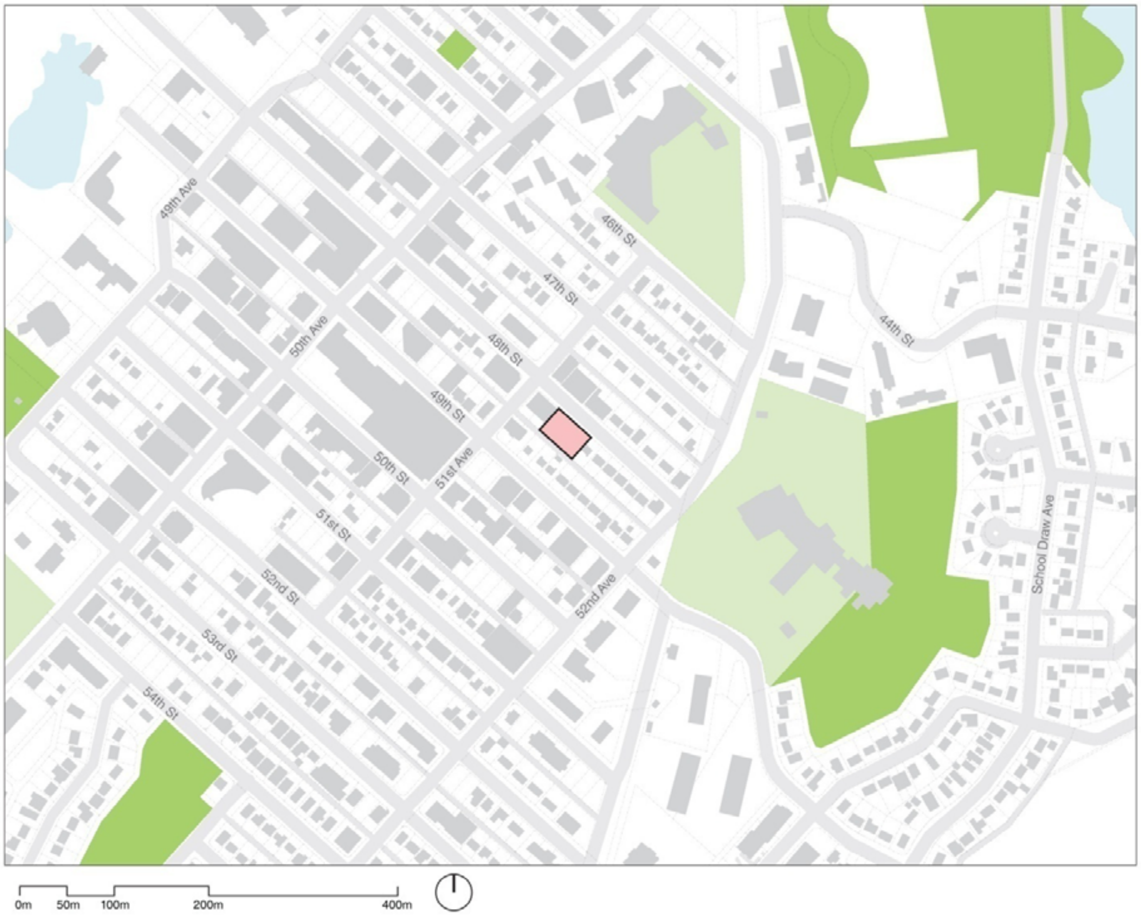


Figure 2 – Context Plan with Project Site

1.2 Responding to Climate and Community

Organized in response to solar orientation, the 'L' shaped building wraps around an expansive south-facing terrace that serves as a central amenity space / community garden for residents. Internally the building is organized to maximize responsiveness to context of the street, laneway, and to establish a micro-climate on the south courtyard to optimize building performance and passive solar opportunities. Parking and service access are provided from the rear laneway system and are screened from view from the public street by retail space and by the elevated terrace / community garden (Figure 3).

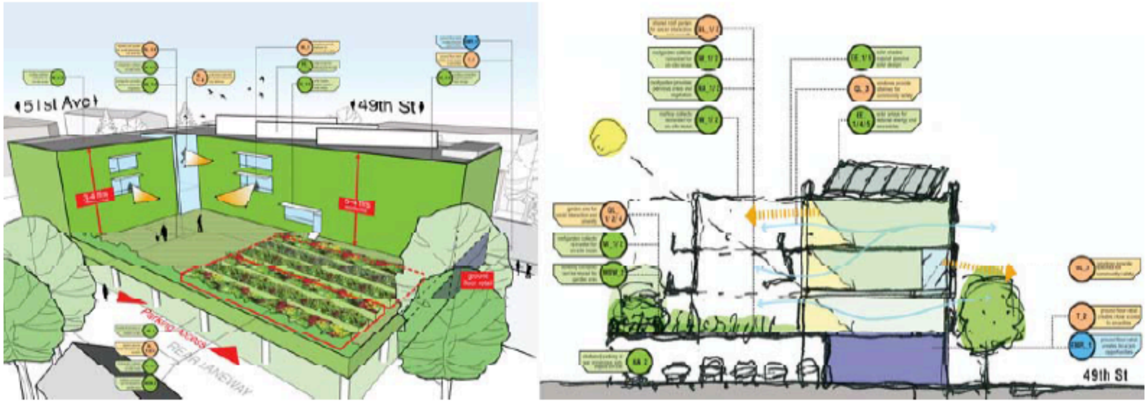


Figure 3 – Eco-Housing Concept Sketches

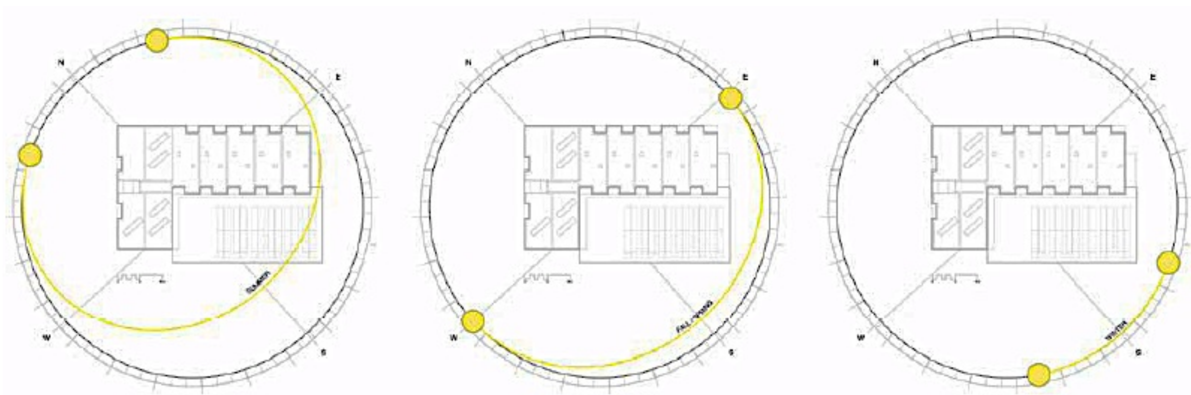


Figure 4 – Yellowknife Seasonal Sun Path – Summer, Fall/Spring, and Winter Equinox

The ‘L’ shaped configuration of the Eco-Housing building is oriented around an elevated south facing terrace, which provides opportunities for passive solar daylighting / heating and to develop favorable microclimate conditions for the terrace (Figure 4). Located above the parking area, the elevated terrace provides integrated opportunities for socialization and gardening in a secure, community focused setting. The terrace is protected from prevailing winds by the ‘L’ shaped form of the building and provides a shared outdoor amenity space for building residents, 6m^2. metre garden plots for each unit and private decks associated with units located at that level. The terrace is accessed by residential units, which literally ‘address’ the courtyard. Nearly 80% of units have direct interaction with the shared outdoor terrace from their units, which creates a strong sense of community life and neighborly interaction centered on the terrace.

The overall depth of the building is minimized to enable ‘through-units’. More than 90% of units (22 of 24) have exposures on two or more building faces, contributing to passive, ‘through-unit’ ventilation, daylighting strategies, as well as enhanced spatial interest, amenity and connectivity for residents with their community. On the third level, an indoor corridor provides access to remaining units - all of which are two level units. This configuration concentrates unit entrances on the same level, creating greater opportunities for interaction between neighbours, while greatly reducing the amount of uninhabited corridor space (Figure 5 and 6).

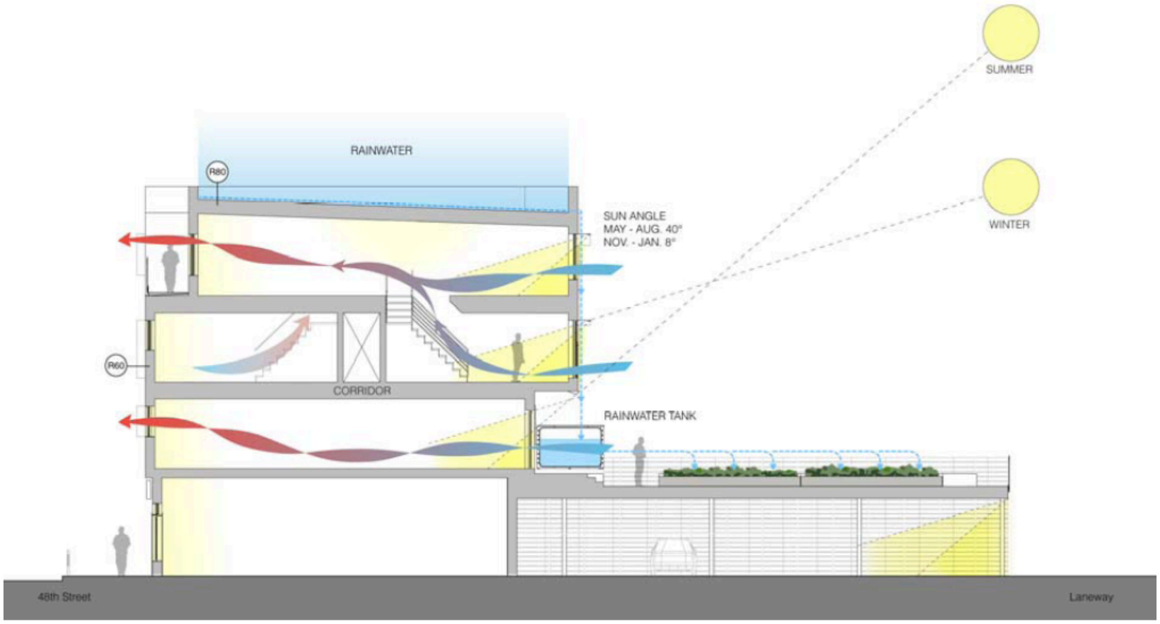


Figure 5 – "Thru-Units" and Two Storey Thru-Units

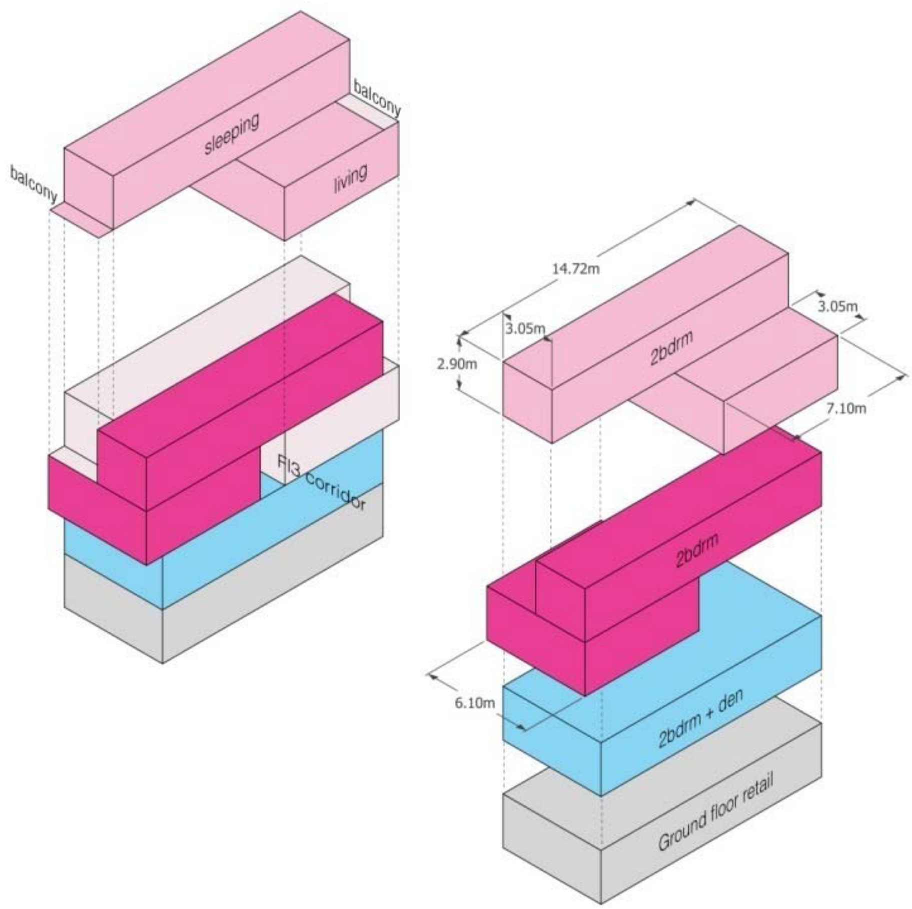


Figure 6 – "Thru-Units" and Two Storey Thru-Units

Together these integrated features result in an ultra compact building footprint that contributes to further economies including decreased operating and maintenance costs for common space, improved space utilization and corresponding reductions in construction/ costs. The resulting residential 'net to gross area ratio' of 1:12.5 in extremely efficient (Figure 7).

The overall building entrance is located on the northern-most corner of the site on 48th Street via a residential Lobby. The Lobby connects to residential parking areas accessed from the rear lane, secure indoor storage bicycle storage, waste disposal areas, and to the Main Stair, which provides access to all levels of the project.

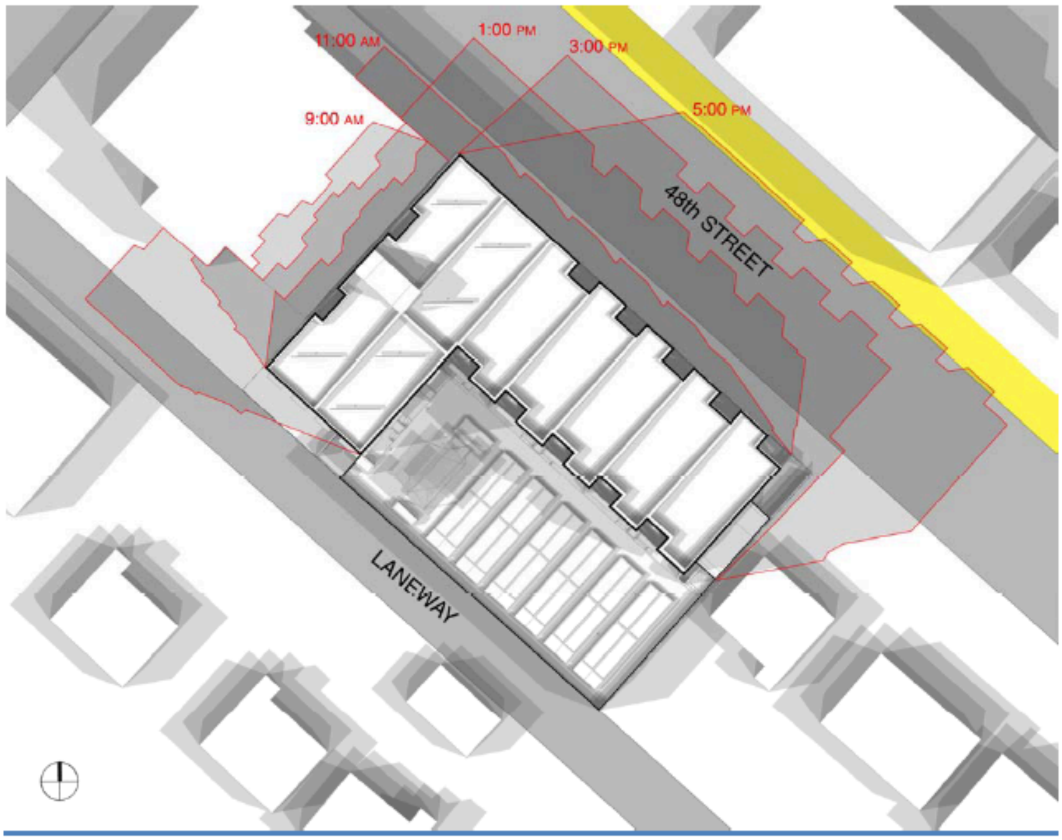
Figure 7 – Key Plan: ***blue-Commercial / light grey – M/E room / dark grey – Circulation / yellow – Residential***

1.3 Responding to Context – Activating the Street

The Eco-Housing project proposes the inclusion of active, street-level commercial and retail uses, which enable opportunities for employment within the immediate vicinity of the project, and serve to screen service functions (parking, loading and waste collection functions) to maximize streetscape continuity and pedestrian amenity. Parking areas are screened from upper level views by the second-level terrace while residential 'through-units' serve to maximize both 'eyes on the street' and the courtyard. The Building's massing and shadow study enables sunlight penetration to the opposing sidewalk on the opposite side of 48th Street's during summer months (Figure 8). In combination, these aspects of the building's design contribute to a land use intensification strategy to promote vibrant, pedestrian-friendly streetscapes that advances the City of Yellowknife's Smart Growth objectives.

Commercial / rental space will include 'green-standards" as part of leasehold improvements undertaken by commercial tenants to ensure improvements are consistent with Eco-Housing performance targets included in the Energy Modeling Report, refer to Appendix 1 Energy Model Summary. The decision to vertically stack retail and residential uses within a mixed use building format results in further energy savings and land use footprint reductions as compared to separately developed retail and commercial facilities. These inherent energy benefits are not however included in the performance results and 'benchmarking' methodology used for the Eco-Housing development. These savings represent additional energy reductions should the project's energy consumption be compared with two freestanding buildings with matching orientation and building envelope construction standards.

Figure 8 – Solar Study of Shadow Impacts on 48th Street and Sidewalk



1.4 Design Aspects

- 70% of units (18 of 24) contain more than 2 – 3 bedrooms
- More than 80% of units (20 of 24) have southern solar exposure
- 100% of units are provided with 6m outdoor garden plots on the shared outdoor terrace
- Nearly 80% of units (19 of 24) have direct interaction/overlook of shared outdoor terrace
- 60% of unit entries (14 of 24) are concentrated on the same level, nearly double that of a conventional layout, creating greater opportunities for interaction with neighbours, greatly reducing uninhabited corridor space, maintenance and conditioning requirements
- More than 90% of units (22 of 24) have exposures on two or more building faces, which contributes to passive, through-unit ventilation and daylighting strategies as well as spatial interest and enhanced comfort for the residents
- All units are accessed from only two levels of the project, creating compact and activated common areas.
- 48th Street and the adjacent south side laneway each have ë'eyes on the streetí' from 80% of residential units
- Secure, indoor bike storage is provided for 70% of units
- 24 Parking spaces are provided

1.5 Building Plans, Elevations

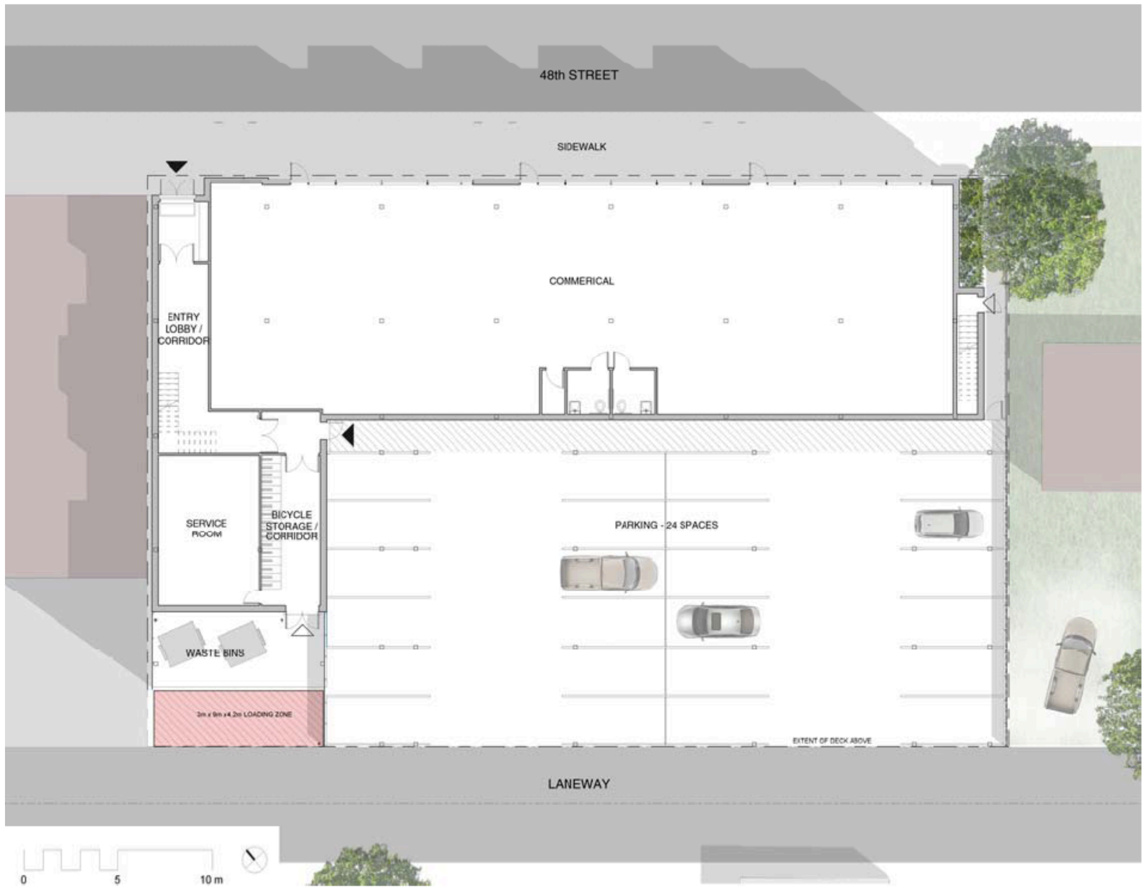


Figure 9a – Floor Plan 1

Figure 9b – North Elevation

Figure 10a – Floor Plan 2

Figure 10b – South Elevation

Figure 11a – Floor Plan 3

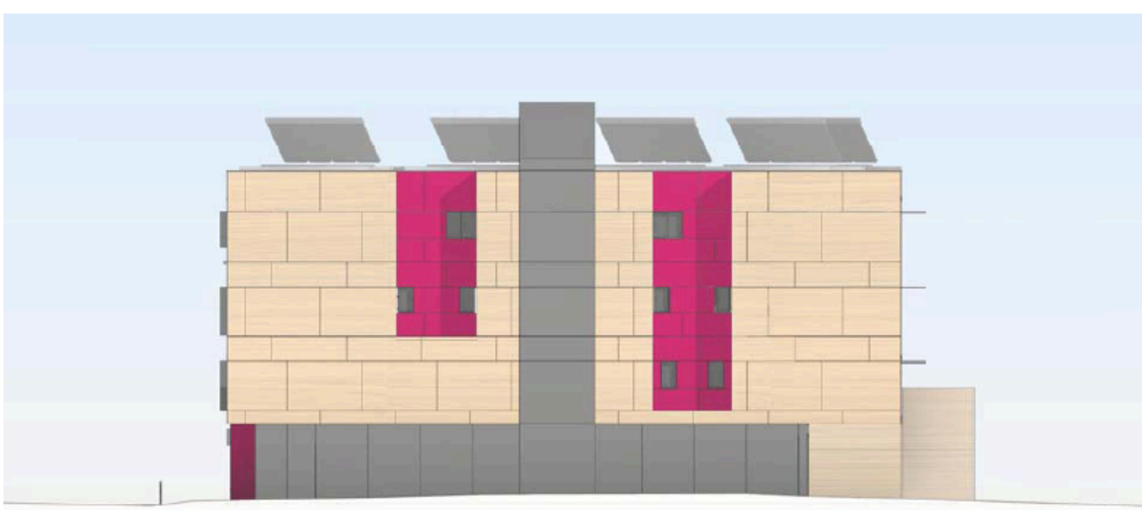


Figure 11b – West Elevation

Figure 12a – Floor Plan 4

Figure 12b – East Elevation

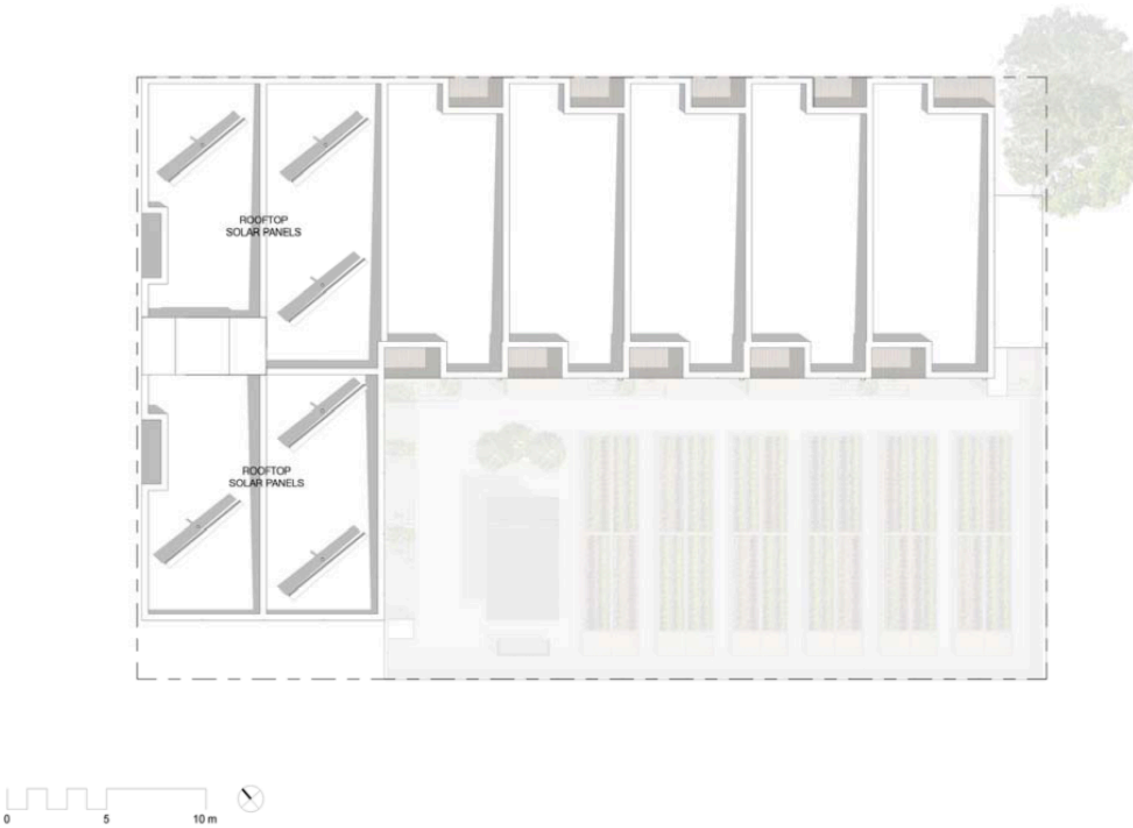


Figure 13 – Roof Plan

Figure 14 – Cross Section

2.0 RESPONDING TO ECO-HOUSING PERFORMANCE OBJECTIVES

2.1 Performance Targets

The Yellowknife Eco-Housing project is designed to address a series of performance targets outlined in the Yellowknife Eco-Housing Sustainability Framework created by The City of Yellowknife and various stakeholders established the terms of reference for this project. This consists of: 3 Legs; 12; Themes; 19 Goals and 34 Indicators. These project goals were developed by the Eco-Housing Task Force prior to the outset of this project through a public consultation process. These targets serve as the mandate for this project and define the project's innovation agenda. A summary of this framework is provided below (Figure 15 and 16). In some instances, "indicator" numbering is not consecutive due to the use of the Framework's numbering system developed in previous stages of the project. The City's Yellowknife Eco-Housing Design Workshop and City of Yellowknife Eco-Housing supplement this material further for Downtown Opportunity Analysis reports.

Figure 15 – Eco Housing Framework Pyramid

At outset of the project all performance and design criteria were extensively reviewed with the Yellowknife Task Force. In some instances clarification and amendment of targets were deemed necessary to both clarify intent and resolve potential conflicts. Amended targets were established in selective areas and were unanimously agreed upon by the Task Force on June 12, 2012, as summarized below:

Notable modifications to the existing Framework are summarized below:

- Agreement that EE-1 (reducing energy consumption by 50% of MNECB) was a higher priority than meeting energy target outlined in EE-2 (312 kWh/m^2).
- Agreement that EE-3 (district energy) was beyond team control but that building infrastructure that could accommodate future connection is desirable, rather than required. Having gone "electric" there is little capacity for district energy.
- Agreement that EE-4 (20% renewable energy target) includes local hydro-electric and wood pellets and is not restricted to on-site production to achieve target.
- Agreement that EE-5 (Net Zero) in reference to objectives for Green House Gas
- Emissions (GHGs) should refer to carbon emissions (i.e. Carbon Neutral).
- Agreement that MSW-2 (60% building waste diversion by residents) was beyond Team control but achievable and the team will design infrastructure to support this target.
- The proposed "green" shared amenity space over ground level parking was agreed to as an acceptable measure to address the targets or spirit of: NA-1 & NA-2 (related to protection of natural areas, impervious surfaces and active and continuous streetwall);
- QL to1-QL-3 (related to provision and use of common spaces, sense of neighbourliness and perception of safety in and around building).
- Housing goals HA-1 to HA-3 refer to tenure split, market / subsidized housing, and unit pricing. These targets were recognized to be beyond Design Team's control and are dependent upon involvement from a third party agency to own / operate rental units provided to the public.

- HA-4 (Universal Design) was deemed as being satisfied by other City projects and the inclusion of an elevator for the project was recognized to negatively impact overall affordability given the limited scale of the project (i.e. only 24 units). Universal access is obtainable only if paid for entirely by a ‘project partner’ so as not to impact unit cost and affordability.
- Targets DIV-1 to Div 4, relating to resident diversity, were acknowledged as being beyond the Design Team’s control.

Eco-Housing Performance Targets as confirmed and adopted by the Eco-Housing Task Force for this project are summarized in the following matrix:

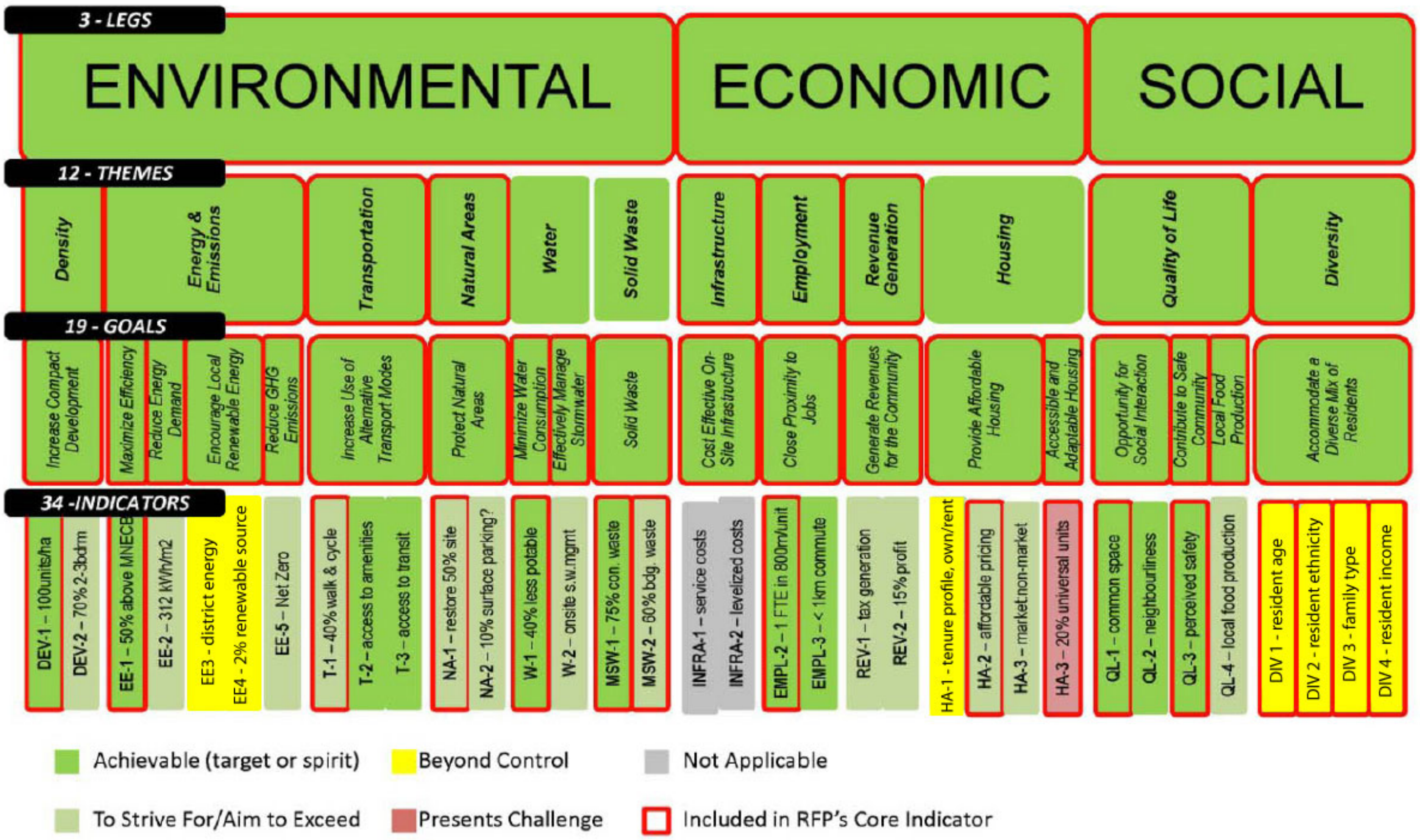


Figure 16 – Eco-Housing Objectives, Unanimous Task Force Agreement (2012-06-12)

Table 1 – Eco-Housing Objective and Performance Summary (2012-06-12)

LEG	THEME	GOAL	INDICATOR	ECO HOUSING FRAMEWORK TARGET	ESTIMATED PERFORMANCE***	ACHIEVMENT LEVEL
ENVIRONMENTAL	*Density*	*Increase Compact Development*	DEV-1	100 du/ha	120 du/ha	Exceeded
			DEV-2	70% of units contain 2-3 bedrooms	79% 2-3 bedrooms	Exceeded
	Energy & Emissions	*Maximize Energy Efficiency*	EE-1	Energy Performance 50% below MNECB 1997	50% below MNECB 1997	Exceeded
		Reduce Energy Demand	EE-2	312kWh/sqm	89.5kWh/sqm - over 70% reduction	Exceeded
		Encourage Local Renewable Energy	EE-3	Connected to district energy or 'ready'		N/A
			EE-4	20% from local renewable sources including wood pellet and hydroelectric	100% - excluding grid-supplied, emergency back-up	Exceeded
		Reduce Greenhouse Gas Emissions	EE-5	As per Task Force: Carbon Neutral	Carbon Neutral or Near Neutral - no fossil fuel burning sources are proposed for any building systems	Achieved
	Transportation	*Increase use of Alternative Transport*	T-1	40% of building residents walk and cycle	Bike space for 70% of units	Set to Achieve
			T-2	Access to amenities: schools and recreation within 800m, food and retail within 400m		Achieved
			T-3	Transit within 400m	Transit at end of street	Achieved
	Natural Areas	*Protect Natural Areas*	NA-1	Restore 50% of redevelopment sites excluding footprint, 20% of greenfield sites left undisturbed	N/A for this project by Task Force, but 1st and 2nd level greening strategies achieves	Intent
			NA-2	Portion of site area dedicated to ground level parking is less than 10%, including parking or garages unless they are beneath habitable building space	N/A for this project by Task Force, 2nd amenity deck over parking achieves, plus achieves intent for engaging streetscape	Intent
	Water	*Minimize Water Consumption*	W-1	Reduce potable water consumption by 40%	51.6% reduction	Exceeded
		Effectively Manage Stormwater	W-2	25% reduction of stormwater runoff (rate & quantity)	42% of rainwater is collected and re-used on-site	Exceeded
	Solid Waste	*Minimize Solid Waste*	MSW-1	Divert 75% of construction waste from landfill	Prefabricated or modular construction significantly reduces waste - Waste Management Plan in Tender Documents	Set to Achieve
			MSW-2	Divert 60% of building waste from landfill	On-site bins for separation of waste and recyclables and on-site composting	Set to Achieve

LEG	THEME	GOAL	INDICATOR	ECO HOUSING FRAMEWORK TARGET	ESTIMATED PERFORMANCE***	ACHIEVMENT LEVEL
ECONOMIC	*Infrastructure*	*Cost Effective On-site Infrastructure*	INFRA-1			N/A by Task Force
			INFRA-2			N/A by Task Force
	Employment	*Close Proximity to Jobs*	EMPL-2	1 full time job within 800m / unit		Achieved
			EMPL-3	Median distance residents travel to work is 1km		Set to Achieve
	Revenue Generation	*Generates revenue for the Community*	REV-1	Property tax revenue generated - no specific target		Achieved
			REV-2	15% return on investment for developer	Will be assessed once all project costs have been established.	Set to Achieve
	Housing	*Provide Affordable Housing*	HA-1	Tenure profile, 50% owner:50% tenant occupied		Set to Achieve
			HA-2	25% of rental units priced up to 80% of area median income, 15% of for sale units priced up to the area median income	It is anticipated with the range of unit size and cost that this target will be able to be achieved.	Strive For
			HA-3	20% of units are non-market or subsidized (4.8units)		Strive For*
		Accessible and Adaptable Housing	HA-4	Minimum of 20% of units are universally designed	Not a priority if compromises affordability as per Task Force	N/A by Task Force **

LEG	THEME	GOAL	INDICATOR	ECO HOUSING FRAMEWORK TARGET	ESTIMATED PERFORMANCE***	ACHIEVMENT LEVEL
SOCIAL	*Quality of Life*	*Opportunity for Social Interaction*	QL-1	Indoor and outdoor space provided for resident use	Large outdoor amenity deck provides significant common space for resident use	Achieved
			QL-2	Residents have familiarity with neighbours	Determine by survey at later date	Set to Achieve
		Contribute to a Safe Community	QL-3	Perceived safety in and around building	Determine by survey at later date	Set to Achieve
		Local Food Production	QL-4	Provide 6sqm of gardens for 50% of units	100% of units have option for 6sqm garden	Exceeded
	Diversity	*Accommodate a Diverse Mix of Residents*	DIV-1	A distribution of ages	Determine by survey at later date	Strive For
			DIV-2	A distribution of ethnic background	Determine by survey at later date	Strive For
			DIV-3	A distribution of household type	Determine by survey at later date	Strive For
			DIV-4	A distribution of income levels	Determine by survey at later date	Strive For

__Achievement Definitions__

Exceeded	*Predicted performance will exceed target*
Achieved	*Predicted performance achieves target*
Set to Achieve	*Design that fosters conditions for achievement, but beyond direct Design Team control*
Achieves Intent	*Does not achieve target directly, but achieves intent of goal*
Strive For	*Striving for but requires commitments/contributions outside of Design Team*

* *If a third party housing provider purchases, this is achievable, otherwise beyond control of private developer.*

** *No Elevator*

2.2 Forecasted Performance by "Indicator"

Each of the Eco-Housing performance indicators (i.e. Task Force requirements) are described below, together with forecast performance metrics for the current design. Supporting modeling information as well as specific technologies and products integrated into the project are included in the report's Appendices.

INDICATOR: **DEV-1** ACHIEVEMENT LEVEL: **EXCEEDED**
LEG: **ENVIRONMENTAL** THEME: **DENSITY**
GOAL: **INCREASE COMPACT DEVELOPMENT**
TARGET: 100 dwelling units (du) / developed hectare (ha)
PERFORMANCE: 120 du/ha
SUMMARY: Property area consists of three lots (50' x 100' each) totaling 0.139ha. Developed site area, measured to centerline of public road and laneway which service the property is 0.199ha. Development of 24 residential units results in density of 120 du/ha.

INDICATOR: **DEV-2** ACHIEVEMENT LEVEL: **EXCEEDED**
LEG: **ENVIRONMENTAL** THEME: **DENSITY**
GOAL: **INCREASE COMPACT DEVELOPMENT**
TARGET: 70% of units contain 2-3 bedrooms
PERFORMANCE: 79% of units contain 2-3bedrooms
SUMMARY: The proposed unit mix is as follows: (5) one bedroom units; (15) two bedroom units; (2) three bedroom units, and; (2) three-plus bedroom units which contain a room which can serve as either den or fourth bedroom. 79% of units contain 2-3 bedrooms.

INDICATOR: **EE-1** ACHIEVEMENT LEVEL: **EXCEEDED**
LEG: **ENVIRONMENTAL** THEME: **ENERGY AND EMISSIONS**
GOAL: **MAXIMIZE ENERGY EFFICIENCY**
TARGET: Energy performance 50% below MNECB 1997 requirements
PERFORMANCE: 50% reduction
SUMMARY: The reference building was estimated to have annual energy consumption of 183.5kWh/m2. The area-weighted average for energy consumption of the Eco-Housing project is 91.75kWh/m2. This achieves a 50% reduction over the 1997 MNECB reference building.

Please refer to the Energy Model information appended to the report (Appendix 1). Modeling is premised on a super energy efficient building envelope featuring high performance windows, air-to-air and drain-water heat recovery, and aggressive domestic hot water conservation measures, and ENERGY STAR® appliances. As noted in Dr. Kesik's Report Notes, modeling assumptions are conservative, based on tentative equipment selections and performance standards required to achieve meet Eco-Housing/ Task Force performance standards. Modeling metrics assume lower end efficiency for high performance equipment (lower end ENERGY STAR® Appliances, etc.), and moderately high levels of air tightness (1.5 ach @ 50 Pa / R 2000 standards) to both ensure 'worst case' scenarios for mechanical, appliances selections and envelope performance will result in project success and to enable flexibility in awarding contract to equipment suppliers through a competitive tendering process. Performance levels will increase with the provision of higher efficiency equipment and Light Emitting Diode (LED) lighting, which is recommended but not accounted for in the energy model. The project further proposes a strategy of individually metered suites to support both post-occupancy monitoring objectives, as well as the 2003 Survey of Household Energy Use (SHEU) Summary Report (Natural Resources Canada) findings that report "up to 68% difference in energy use among low-rise apartments between centrally versus individually metered suites". This modeling result is based upon a fleet averaging approach between various units and between retail and residential areas to arrive at an overall energy reduction outcome consistent with the overall reduction target below NMECB 1997.

INDICATOR: **EE-2** ACHIEVEMENT LEVEL: **EXCEEDED**
LEG: **ENVIRONMENTAL** THEME: **ENERGY AND EMISSIONS**
GOAL: **REDUCE ENERGY DEMAND**
TARGET: 312 kWh/m2
PERFORMANCE: 89.5 kWh/m2
SUMMARY: Energy Modeling information identifies overall energy consumption of the Eco-Housing project at 91.75kWh/m2. This exceeds the 'Reduce Energy Demand' target by over 70%. It should be noted the Eco-Housing Task Force identified this as a low priority target on the grounds the number included in the Framework was believed to
be too high and would require reexamination at a later date by the Task Force. In addition, achievement of this goal would be covered and exceeded by the achievement of EE-1.

INDICATOR: **EE-3** ACHIEVEMENT LEVEL: **N/A**
LEG: **ENVIRONMENTAL** THEME: **ENERGY AND EMISSIONS**
GOAL: **ENCOURAGE LOCAL RENEWABLE ENERGY**
TARGET: Building is connected to or 'ready for' district energy
SUMMARY: The development of a district energy geothermal system for the City of Yellowknife has not been established nor is it clear that this system will be implemented in the near/mid term. As a result, the Yellowknife Eco-Housing project is currently not designed with provision for tie-in systems.

INDICATOR: **EE-4** ACHIEVEMENT LEVEL: **EXCEEDED**
LEG: **ENVIRONMENTAL** THEME: **ENERGY AND EMISSIONS**
GOAL: BUILDING ENERGY SUPPLY FROM RENEWABLE SOURCES
TARGET: 20% of building and infrastructure energy from local, renewable sources (including wood pellets and hydroelectric)
PERFORMANCE: Nearly 100% from renewable sources
SUMMARY: The proposed Eco-Housing project relies solely on electricity for its energy needs both in terms of lighting, space and domestic water heating (supplemented by Solar HW). It is forecasted to obtain nearly 100% of energy supply from renewable sources given that the primary source of electricity in Yellowknife is from renewable hydroelectric. On-site renewable energy is also proposed in the form of roof-mounted solar thermal panels to reduce hot water energy loads by 50%.

INDICATOR: **EE-5** ACHIEVEMENT LEVEL: **ACHIEVED**
LEG: **ENVIRONMENTAL** THEME: **ENERGY AND EMISSIONS**
GOAL: **REDUCE GREENHOUSE GAS EMISSIONS FROM THE BUILDING**
TARGET: Stated as Net Zero in Framework – Task Force Unanimously adopted as Carbon Neutral in relation intention for reduced Green House Gas (GHG) emissions.
PERFORMANCE: Carbon Neutral (no GHG emissions).
SUMMARY: The Eco-Housing project is forecasted to obtain 100% of energy supply from local, renewable, hydroelectric for its lighting, space and water heating energy needs. The project is carbon neutral with the notable exception of back-up power that supplied by the City's diesel generation station in event of power disruption. This is a net zero building.

INDICATOR: **T-1** ACHIEVEMENT LEVEL: **SET TO ACHIEVE**
LEG: **ENVIRONMENTAL** THEME: **TRANSPORTATION**
GOAL: **INCREASE USE OF ALTERNATIVE MODES OF TRANSPORTATION**
TARGET: 40% of building residents walk and cycle
SUMMARY: It is anticipated that at least 70% of residents will be able to ride, walk or take public transportation to work, shop and obtain services required using these modes of transportation. Secure, indoor space for 17 bicycles has been included (Refer to Figure 17).

INDICATOR: **T-2** ACHIEVEMENT LEVEL: **ACHIEVED**
LEG: **ENVIRONMENTAL** THEME: **TRANSPORTATION**
GOAL: **INCREASE USE OF ALTERNATIVE MODES OF TRANSPORTATION**
TARGET: Access to Amenities: schools and recreation 800m, food and retail 400m.
SUMMARY: ***Figure 17*** – Context and Local Amenities, indicates a 400m or 5 minute walking radius from the site. This area encompasses most of Yellowknife's downtown retail area, 2 high schools, one elementary school 2 parks and wilderness preserve is accessible within this area. As this development wants to promote locally available services, the main floor of the development is commercial/retail space. This "mixed-use" approach is consistent with the City's "Smart Growth" plan and serves to keep the residential population and services in the downtown for rejuvenation of this area.

INDICATOR: **T-3** ACHIEVEMENT LEVEL: **ACHIEVED**
LEG: **ENVIRONMENTAL** THEME: **TRANSPORTATION**
GOAL: **INCREASE USE OF ALTERNATIVE MODES OF TRANSPORTATION**
TARGET: Access to transit within 400m.
SUMMARY: The project's central location provides access to transit stops North West of the site at 48th Street and 50th Avenue, as well as South East of it at 47th Street and 52nd Avenue. Both transit stops are within 400 m or a 5 min walk of the project.

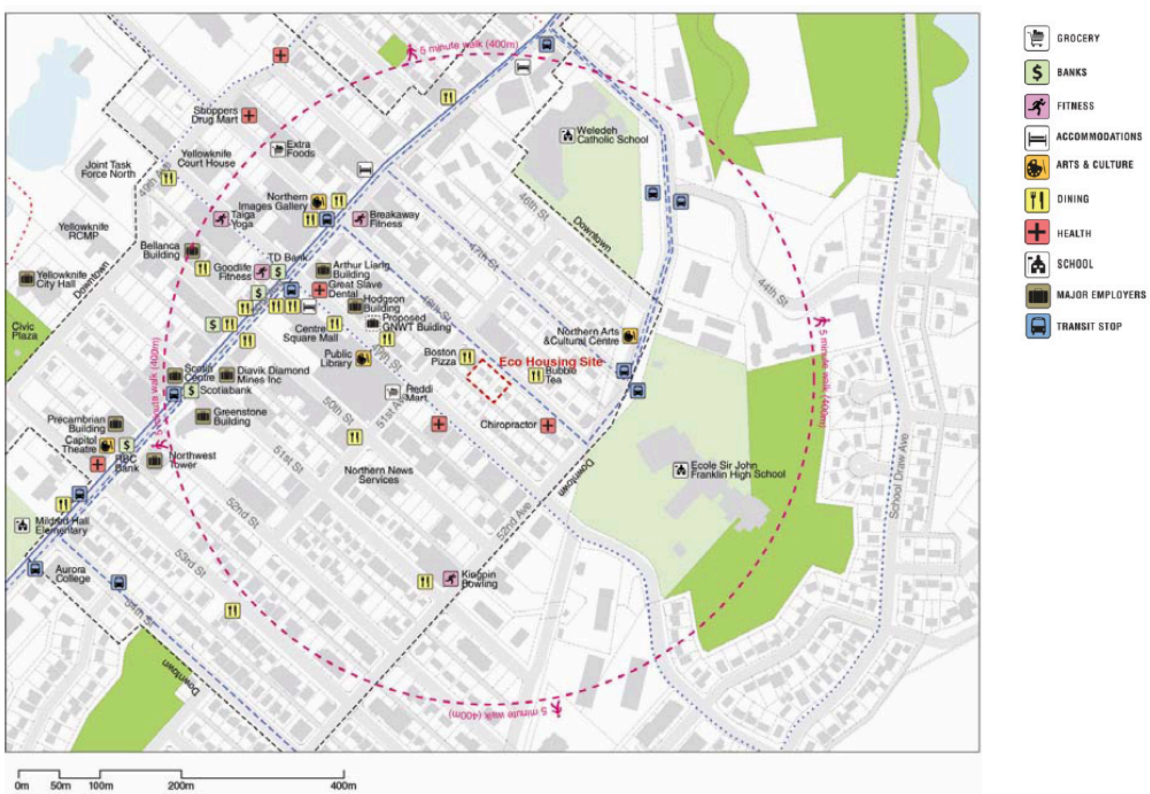


Figure 17 – Context and Local Amenities

INDICATOR: **NA-1** ACHIEVEMENT LEVEL: **INTENT**
LEG: **ENVIRONMENTAL** THEME: **NATURAL AREAS**
GOAL: **PROTECT NATURAL AREAS**
TARGET:

- Redevelopment Site: restore a minimum of 50% of the site area (excluding the building footprint) by replacing impervious surfaces with native or adaptive vegetation.
- Greenfield Site: 20% of land left undisturbed, for a residential density less than 98 units per hectare vs. 120 units per hectare without the terrace.

SUMMARY: The design incorporates a 2nd floor landscaped terrace, which will be used for community gardens and for general use by residents. The overall site area is 1,394 m^2 (15,000 ft^2), of which about 50% (600 m^2 / 6,500 ft^2) is occupied by the building footprint. The proposed terrace areas is 460 m^2 / 5,000 ft^2 in area or approx. 65% of remaining site area, of which about 33% is proposed for landscaping / community gardens. This is an urban site with parking at grade, parking can use asphalt paving or permeable paving.

INDICATOR: **NA-2** ACHIEVEMENT LEVEL: **INTENT**
LEG: **ENVIRONMENTAL** THEME: **NATURAL AREAS**
GOAL: **PROTECT NATURAL AREAS**
TARGET: The portion of the site area dedicated to ground level parking is less than 10% including, ground level parking and garages unless they are under habitable building space.
SUMMARY: While exceeding 10% of the ground floor area, parking for the project is concealed beneath the building by the outdoor terrace. The project achieves the described intent of this goal by locating parking "behind the building to create an engaging and safer pedestrian environment" as well as managing storm water on-site to reduce runoff impacts through rain water harvesting from roof areas. Further efforts at reducing parking would require the development of underground parking, which was deemed inconsistent with other complementary goals related to affordability.

INDICATOR: **W-1** ACHIEVEMENT LEVEL: **EXCEEDED**
LEG: **ENVIRONMENTAL** THEME: **WATER**
GOAL: **MINIMIZE WATER CONSUMPTION**
TARGET: Reduce potable water consumption by 40% of baseline.
PERFORMANCE: 51.6% reduction
SUMMARY: A baseline was established for typical water consumption without water conservation measures that was forecast to consume 17,100L/day. Performance was forecast utilizing standard water conserving fixtures as well as median water consumption for ENERGY STAR® appliances. In this scenario, forecasted daily water consumption for the Eco-Housing project amounts to 8,200L/day, based on the LEED baseline metric of about 240/day/person, resulting in a 48.4% reduction. Note these estimates did not include the commercial occupancy or contribution of irrigation conservation.

INDICATOR: **W-2** ACHIEVEMENT LEVEL: **EXCEEDED**
LEG: **ENVIRONMENTAL** THEME: **WATER**
GOAL: **EFFECTIVELY MANAGE STORWATER RUNOFF (RATE AND QUANTITY)**
TARGET: 25% reduction in the rate and quantity of storm water runoff
PERFORMANCE: 42% reduction in volume
SUMMARY: The potential volume of rainfall on the site was assessed to be 112,107L annually. Irrigation needs were assessed for the garden plots (6m^2 each x 24 plots) and the inclusion of an on-site rainwater harvesting system with a storage capacity of a 5,000 litres was identified which is predicted to save 47,211 litres of potable water annually. This will promote further water conservation reductions when used for irrigation requirements while diverting storm water from

municipal infrastructure. The storm water runoff is reduced by 42%.

INDICATOR: **MSW-1** ACHIEVEMENT LEVEL: **SET TO ACHIEVE**
LEG: **ENVIRONMENTAL** THEME: **SOLID WASTE**
GOAL: **MINIMIZE SOLID WASTE DISPOSAL**
TARGET: 75% diversion of construction waste from landfill.
SUMMARY: The project will be constructed off-site using factory-built modular construction; as a result, the amount of wastage going to the Yellowknife landfill will be negligible. This form of construction, in addition to a variety of other benefits, had long demonstrated its ability to reduce construction waste and recent reports suggest up to 90% reductions are achievable. Tender documents issued for the project will require Contractors and modular builders to prepare a waste diversion plan and to submit this plan for verification and compliance review. We also plan to work with the City of Yellowknife, to divert the demolition materials of the existing three residences on site to the construction salvage area.

INDICATOR: **MSW-2** ACHIEVEMENT LEVEL: **SET TO ACHIEVE**
LEG: **ENVIRONMENTAL** THEME: **SOLID WASTE**
GOAL: **MINIMIZE SOLID WASTE DISPOSAL**
TARGET: 60% diversion of building waste from landfill.
SUMMARY: The City of Yellowknife has a waste management system in place at the City's landfill whereby metal, wood, appliances, paints and tires are separated in stockpiles for potential salvage or recycle. The City provides blue-bins for cardboard, boxboard, aluminum cans and glass at several locations in town. These are well used as the City has instituted a 1-bag policy per household per week policy. The nearest blue-bin would be outside of the downtown area. Having said this, the local waste management service, Kavanaugh Brothers Ltd, provide dedicated dumpsters for cardboard and other recyclables. One of these could be put on site and emptied periodically to assist in the at-source division of the waste-stream into recyclables, compost and landfill. Post occupancy monitoring will verify achievement level.

INDICATOR: **INFRA-1** ACHIEVEMENT LEVEL: **N/A BY TASK FORCE**
LEG: **ECONOMIC** THEME: **INFRASTRUCTURE**
GOAL: **PROVIDE COST EFFECTIVE ON-SITE INFRASTRUCTURE SERVICE**
SUMMARY: Determined to be not applicable to this project by Task Force during consultation sessions, as there is currently no infrastructure tie-in, to adjacent properties.

INDICATOR: **INFRA-2** ACHIEVEMENT LEVEL: **N/A BY TASK FORCE**
LEG: **ECONOMIC** THEME: **INFRASTRUCTURE**
GOAL: **LEVELIZED COST TO PROVIDE HEAT FROM DISTRICT ENERGY**
SUMMARY: Determined to be not applicable to this project by Task Force during consultation sessions, as there is currently no district heating initiatives in the neighbourhood.

INDICATOR: **EMPL-2** ACHIEVEMENT LEVEL: **ACHIEVED**
LEG: **ECONOMIC** THEME: **EMPLOYMENT**
GOAL: **CLOSE PROXIMITY TO JOBS**
TARGET: 1 Full time job within 800m per unit.
SUMMARY: This project accommodates 465 sm (5,000 sf) of 'at grade' commercial space, which is intended to provide employment. As the site is located in the downtown area, all downtown services are located within an 800m radius (10 minute walk). This includes:

- 21 restaurants
- All Municipal, Territorial and Federal administrative offices
- Centralized health clinic
- Three school board offices
- 2 high school and 3 elementary schools
- Approx 80% of the professional services in Yellowknife

- Head Quarters for 2 diamond mines

The proximity to the largest employers in the community means that new hires to any of these organizations would find the location of the Yellowknife Eco-Housing project advantageous.

INDICATOR: **EMPL-3** ACHIEVEMENT LEVEL: **SET TO ACHIEVE**
LEG: **ECONOMIC** THEME: **EMPLOYMENT**
GOAL: **CLOSE PROXIMITY TO JOBS**
TARGET: Median distance residents' travel to work is 1km
SUMMARY: In light of the location of the main employers noted in EMPL-2, it is very likely that the workplace for most residence of the new development will be within the 1km of the site. Only those working in the industrial sector and the box-box chain stores, and out of town would require a longer commute.

INDICATOR: **REV-1** ACHIEVEMENT LEVEL: **SET TO ACHIEVE**
LEG: **ECONOMIC** THEME: **REVENUE GENERATION**
GOAL: **GENERATES REVENUES FOR THE COMMUNITY**
TARGET: Property tax revenue generated – no specific target.
SUMMARY: The development will provide 24 more residences to the downtown area. In addition to this, there will be more commercial space added as well. This densification of the CC district should reduce the per-capita expense of services and serve to revitalize the downtown area as more people bring more life and typically reduces the policing requirements as areas are monitored more frequently.

INDICATOR: **REV-2** ACHIEVEMENT LEVEL: **SET TO ACHIEVE**
LEG: **ECONOMIC** THEME: **REVENUE GENERATION**
GOAL: **GENERATES REVENUES FOR THE COMMUNITY**
TARGET: 10% reduction of the cost of living.
SUMMARY: As this is a mixed-use development there will be revenue for the tenants. In addition to this, there will be additional disposable income for residential occupants as transportation and utility costs will be dramatically reduced given the proximity to services and the efficiencies of the building envelope and systems. Target will be assessed once all project costs have been established.

INDICATOR: **HA-1** ACHIEVEMENT LEVEL: **BEYOND DESIGN TEAM CONTROL**
LEG: **ECONOMIC** THEME: **HOUSING**
GOAL: **PROVIDE AFFORDABLE HOUSING**
TARGET: 50% of units are owner-occupied and 50% of units are tenant-occupied to provide options for various household types.
SUMMARY: The current development will be stratified into a condominium development. There will be opportunity available for public housing providers such as the Yellowknife Housing Authority, NWT Housing Corporation or community organizations to purchase units. This provides an opportunity for assisted-housing providers to immediately meet a growing need to an area with the largest density of employment in the NWT. Depending on final price point which will be established once all costs have been established, it may be desirable for other landlords to purchase Yellowknife Eco-Housing units due to expected lower operational and maintenance costs. The final ratio of rentals to owner-occupied will be dependent on the market interest at time of sales.

INDICATOR: **HA-2** ACHIEVEMENT LEVEL: **STRIVE FOR**
LEG: **ECONOMIC** THEME: **HOUSING**
GOAL: **PROVIDE AFFORDABLE HOUSING**
TARGET: 25% of rental units priced up to 80% of area median income, 15% of for sale units priced up to the area median income.
SUMMARY: The Yellowknife Eco-Housings project will have a variety of unit sizes including 1

bedrooms. It is anticipated with the range of unit size and cost that this target will be able to be achieved. Further Cost/Purchase Price Analysis is required.

INDICATOR: **HA-3** ACHIEVEMENT LEVEL: **STRIVE FOR**
LEG: **ECONOMIC** THEME: **HOUSING**
GOAL: **PROVIDE AFFORDABLE HOUSING**
TARGET: 20% of units are non-market or subsidized.
SUMMARY: This would be achievable if public housing agencies were to buy into the project, as referenced in HA-1.

INDICATOR: **HA-4** ACHIEVEMENT LEVEL: **N/A BY TASK FORCE**
LEG: **ECONOMIC** THEME: **HOUSING**
GOAL: **PROVIDE ACCESSIBLE AND ADAPTABLE HOUSING**
TARGET: Minimum of 20% of units are universally designed.
SUMMARY: Determined by Task Force as not a priority due to impacts on affordability and project realization related to elevator requirements and general poor marketability of at grade units facing parking area. Desirable if third party partner is able to provide.

INDICATOR: **QL-1** ACHIEVEMENT LEVEL: **ACHIEVED**
LEG: **SOCIAL** THEME: **QUALITY OF LIFE**
GOAL: **PROVIDE OPPORTUNITY FOR SOCIAL INTERACTION**
TARGET: Indoor and outdoor space provided for resident use.
SUMMARY: An outdoor amenity terrace provides significant common space for residents of the Eco-Housing building. This terrace is planned to include garden plots for all the building's residents, a patio area beneath a shade structure and outdoor cooktop. In addition, private decks and balconies for nearly all of the building's units will extend onto or overlook the shared terrace providing great opportunity for interaction amongst neighbours. The goal of bringing the project affordably to market as well as the provision of 24 units on the tight site has made the provision of common indoor space unfeasible at this stage.

INDICATOR: **QL-2** ACHIEVEMENT LEVEL: **SET TO ACHIEVE**
LEG: **SOCIAL** THEME: **QUALITY OF LIFE**
GOAL: **FAMILIARITY WITH NEIGHBOURS**
TARGET: A high percent of households that have met or know their neighbours.
SUMMARY: A variety of features have been designed or included to create an environment that fosters familiarity with neighbours and a sense of community within the building. This includes a generous outdoor terrace, community gardens as well as ground floor commercial/retail spaces. Further, this has been done by through the building's circulation strategy which creates greater opportunities for interaction with one's neighbours such measures as

- locating bike storage on the path to the waste disposal area
- prioritizing a stairwell where residents are more likely to pass and interact with one another over an elevator
- by concentrating more unit entries on the same floor level through the elimination of a corridor that would have been included in a more conventional building layout.
- Front doors addressed from courtyard

While the resident's familiarly with their neighbours is beyond the design team's control, an environment that fosters achievement of this goal has been created. This will be verified using a post-occupancy survey based on suggested questions in the City's Eco-Housing Framework.

INDICATOR: **QL-3** ACHIEVEMENT LEVEL: **SET TO ACHIEVE**
LEG: **SOCIAL** THEME: **QUALITY OF LIFE**
GOAL: **PERCEIVED SAFETY IN AND AROUND THE BUILDING**
TARGET: Create a strong sense of perceived safety in and around the building
SUMMARY: Numerous building features will ensure a strong sense of perceived safety in and

around the Eco-Housing building. This includes:

- creating many ‘eyes-on-the-street’ with 48th Street and the site’s rear laneway overlooked by nearly 80% of the building’s units as a result of multiple exposure design of units and their organization within the building
- street level retail and an amenity terrace that overlooks the laneway and concentrates activity adjacent to neighborhood spaces
- concentrated unit entries along corridor (2x more than conventional) to reduce sensation of being ‘alone in a hallway’ due to higher likelihood of neighbor interaction
- motion sensor lighting in the parking area with clear walking paths

Levels of perceived safety will be verified using a post-occupancy survey based on suggested questions in the City’s Eco-Housing Framework.

INDICATOR: **QL-4**
ACHIEVEMENT LEVEL: **EXCEEDED**
LEG: **SOCIAL** THEME: **QUALITY OF LIFE**
GOAL: **LOCAL FOOD PRODUCTION**
TARGET: 50% of units have garden plots – benchmark of 6sqm of growing area.
SUMMARY: The Eco-Housing project incorporates a significant outdoor terrace above the parking on the second floor. Garden plots for the building’s residents are provided on this terrace. 6m^2 garden plots are planned for 100% of units at a later date.

INDICATOR: **DIV-1** ACHIEVEMENT LEVEL: **STRIVE FOR**
LEG: **SOCIAL** THEME: **HOUSING**
GOAL: Mix of residents by age
TARGET: Full spectrum of the population.
SUMMARY: As there is a mixture of unit types, there will be a price point for entry-level housing as well as a strong community centre on the terrace, which will attract older buyers looking for amenities to enhance lifestyle quality. The project does not have an elevator so those with disabilities would not be attracted to this development. It is felt that the young professionals and families to the empty nesters (the late 20’s-60yr range) will be the prime population group interested in these units.

INDICATOR: **DIV-2** ACHIEVEMENT LEVEL: **STRIVE FOR**
LEG: **SOCIAL** THEME: **HOUSING**
GOAL: Mix of residents by ethnicity
TARGET: Full spectrum of the population.
SUMMARY: As the project is located in the downtown area and Yellowknife, which is reported to be home to over 100 different cultures, it is felt that there will be a rich mix of ethnicities within the project. It is well know that the “inner-city schools, Mildred Hall and Weledeh, have an integrated, diversified cultural mix, it is anticipated that the same mix of population will be attracted to this project.

INDICATOR: **DIV-3** ACHIEVEMENT LEVEL: **STRIVE FOR**
LEG: **SOCIAL** THEME: **HOUSING**
GOAL: Mix of residents by household type, singles, couples, and families
TARGET: Full spectrum of the population.
SUMMARY: The Yellowknife Eco-Housing project has 1, 2 & 3br units in 5 configurations varying from 52sm (563sf) to 164sm (1750sf). This will attract a wide range of households, especially families as St Pats High School, Sir John High School, Mildred Hall elementary and Weledeh

elementary are within a 2 to 8 minute walk from the site.

INDICATOR: **DIV-4** ACHIEVEMENT LEVEL: **STRIVE FOR**
LEG: **SOCIAL** THEME: **HOUSING**
GOAL: Mix of residents by Income
TARGET: Full spectrum of the population.
SUMMARY: The Yellowknife Eco-Housing project has 1, 2 & 3br units in 5 configurations varying from 52sm (563sf) to 164sm (1750sf). It is anticipated that the price will attract the mid-income households as the development in the downtown area with higher land costs tend to drive up unit prices. To attract entry-level buyers, housing subsidy programs will have to be provided to attract a wider economic range to the project. Options to purchase parking will also impact "buy-in" costs.

3.0 APPROACH AND METHODOLGY

Eco-Housing's sustainability approach focuses, in the first instance, on proactive measures to reduce energy use intensity through the development of a high performance building envelope that minimizes heating and cooling loads via passive conservation measures. Active low energy and renewable systems are added incrementally to achieve performance standards. This approach was deemed best suited to address the holistic Eco-Housing Task Force performance objectives that extend to include broad social and affordability targets alongside prescriptive energy performance benchmarks.

3.1 Modeling and Validation

Design configuration and energy conservation measures were evaluated using HOT2000 energy modeling software with a separate performance assessment conducted on each individual suite. A separate eQuest model was developed for the retail space and a 'fleet averaging' approach was developed for the entire project to validate and confirm energy performance standards which meet or exceed mandated Task Force Targets. The federal CBIP Screening Tool for New Building Design was used to determine the baseline performance standard of 183.5 kWh/m^2 for a Yellowknife 'reference building' (*Refer to Appendix 1*). The corresponding overall Eco- Housing energy target was benchmarked at 50% below this amount or 91.75 kWh/m^2.

Although selective aspects of the building were analyzed from a cost-benefit perspective, results that did not achieve mandated energy reduction targets were rejected even if payback analysis suggested more favorable cost-benefit results for lower performing components (i.e. triple versus quad glazing – refer to *Appendix 3).* As well, actual costs from 'tender results' were not available at the time of this design stage analysis to enable determination of true market cost/benefits specific to Yellowknife. Future cost-benefit analysis, using itemized tender costs/benefits is recommended as a follow-up study.

A sensitivity analysis was performed to determine if additional, cost effective measures could be employed and nothing significant was identified. Increasing the thermal efficiency of the envelope has marginal benefits to the high overall effective RSI-value of the entire building. Air source heat pumps do not sustain a competitive coefficient of performance (COP) in the Yellowknife climate and improvements in heat recovery ventilation (HRV) efficiency does not deliver appreciable benefits. One area for improvement is LED lighting for exterior spaces, where heat loss is not beneficial for space heating, such as the parkade area, but this is not a significant energy saving measure in the overall context of the project.

Baseline energy modeling assumptions use conservative values regarding the efficiency of building technology which is expected to be competitively tendered and selected based upon real market conditions and multiple options for “similar products” (refer to appendix for performance assumptions). This approach extends to assumptions regarding air tightness at 1.5 air changes per hour @ 50 Pa. As such the design approach is not highly dependent upon unique products to achieve expected performance standards.

Quality control regarding the specification, final production selection procedures and installation of components that contribute towards achieving mandated performance targets is critical to achieving the design and performance standards validated in this report. This extends to include the validation and testing of completed assemblies in the field during the construction process and follow-up monitoring of utilities during the post- occupancy period.

4.0 ENERGY MODEL SUMMARY

The Eco-Housing project brief mandates an energy performance 50% below MNECB 1997 requirements. The combined residential/ commercial “reference building” was estimated to have annual energy consumption of 183.5kWh/m^2. The updated Energy Model forecasts performance at 50% reduction for the whole building with residential areas performing at 56.78% with an energy use intensity (EUI) of 79.3 kWh/m^2, and retail space performing at 22.28% better and EUI of 142.6 kWh/m^2. The area-weighted average for energy consumption of the Eco- Housing project is 91.75 kWh/m^2 achieving a 50% reduction over the 1997 MNECB ‘reference building’.

This project’s level of performance exceeds the Eco- Housing EE2 indicator for reducing energy demand. EE2 mandates a target of 312 kWh/m^2 and current performance is forecast at 88.3kWh/m^2. This greatly exceeds the ‘Reduce Energy Demand’ target by over 70%. It should be noted that the Eco- Housing Task Force identified this as a low priority target on the grounds that the number identified in the Framework was believed to be too high. In addition, achievement of this goal overlaps and exceeded by the achievement of EE-1.

Please refer to Appendix 1: Energy Model Summary

5.0 FUEL SOURCE / SPACE HEATING SYSTEM OVERVIEW REVIEW

At the request of the Eco-Housing Task Force a cost analysis was undertaken for various common heating system and fuel types used in the Yellowknife area. High level cost estimates (Class D) for centralized heating and utility rates provided by Williams Engineering are summarized in Table 2 – Heating Systems Cost Estimate. Estimated residential space heating loads for the Eco-Housing project are derived from the HOT2000 energy model.

All of the fossil fuel-based systems (oil and propane) compromise key goals for GHG reductions and carbon neutrality and are therefore unsuitable. As noted elsewhere in this report, electrical space heating has been proposed for the Eco-Housing development due to the availability of carbon neutral hydro-electric power throughout Yellowknife. From this simple comparative analysis it is apparent that the economic suitability of electric baseboard heating is dependent upon significant reductions in space heating loads and major upfront cost reductions for heating systems and other incremental construction costs. Payback opportunities associated with lower cost energy sources diminish in direct proportion to heating load reductions.

Table 2 - Heating Systems Class D Cost Estimates+

Space Heating System Type	Estimated Capital Cost	Baseline Cost	Annual Maintenance	Residential Heating Load(kWh)	Energy Rates ($/kWh)	Annual Avg. Costs
Wood Pellet Boiler	$299,988.00+	$183,154+	$2,759	*70,622*	*0.118*	*$11,092*
Oil	$210,538.00+	$93,754+	$920	*70,622*	*0.139*	*$10,736*
Propane	$210,588.00+	$93,754+	$920	*70,622*	*0.121*	*$9,465*
Electric Baseboard	$116,834.00	$0	$0	*70,622*	*0.269*	*$18,997*

+ Estimated Capital Costs identified are for mechanical system components only and do not include increased space/ construction costs for increased size of mechanical room, pellet storage, nor shaft / riser space. Total incremental costs are therefore higher than amounts identified customary costs above (est. $50,000). Due to the lot size limitations at the Eco-Housing project, accommodating this additional space produces significant planning and logistical considerations and the need for a basement level service space with 'area ways', access stair and structural premiums- generating incremental costs for service space beyond typical levels.

A direct comparison between carbon neutral space heating options - wood pellet and hydro-electric based electricity - reveals reduced annual operating costs estimated at $7,905 for the pellet system. Based upon simple payback using 'present value' rates, a 23-year period is required to offset upfront premium system costs of $183,154 for the pellet system. This payback timeline is consistent with typical mortgage periods, although the payback period would be further extended if incremental construction costs for service space needs for boilers and pellet storage areas were included. As well, this payback timeline approaches boiler 'service- life' limits. For other 'high performance' projects targeting carbon neutrality, this suggests wood pellets are a cost effective alternative to hydro-electric based heating only if incremental service space and related construction costs can be minimized. It also suggests that projects for greater scale/size than the Eco-Housing development wood pellet systems are increasingly viable as the 'plant' costs for the pellet boiler system would likely be only marginally more expensive on a larger project.

6.0 BUILDING PERFORMANCE FEATURES AND ATTRIBUTES

6.1 Building Envelope Construction

The design and construction of a high performance building envelope is critical to the project's energy conservation strategy and to enhancements for increased occupant comfort. This extends to include the provision of 'super insulated' walls, low levels of air infiltration, and advanced door/ window systems with solar control. Building envelope design standards used for this project are summarized below:

6.1.1 Insulation

RSI 10.56 (R60) walls and an RSI 14.08 (R80) roof utilizing a factory applied spray foam envelope that doubles as an air/vapour barrier, producing low infiltration rates. The energy model conservatively assumes 1.5 ach @ 50 Pa that reflects the R2000 standard; however, the proposed use of spray foam insulation is anticipated to bring the infiltration rates below these values and into the 1.0 to 0.8 ach @ 50 Pa range, and yield additional energy reductions above minimum standards. Outer wall construction is detailed to virtually eliminate thermal bridging and accommodate electrical wiring needs without compromise to the thermal and air barrier systems to create an effective building envelope.

6.1.2 Windows

Access to sunlight is a tremendous benefit to resident comfort, helping to minimizing impacts of seasonal affective disorder, daylighting, and to the passive solar energy contributions that add to the building's energy efficiency. All units are provided with comparably scaled window openings response to solar orientation and daylight opportunities using external fixed shading elements. The current design provides more than 80% of units (20 of 24) with exposure to southern sunlight and more than 90% of units (22 of 24) have exposures on two or more building faces to maximize opportunities for passive ventilation.

High performance triple and quad glazed windows using pultruded fiberglass frames have been reviewed. These products are ENERGY STAR® rated and have been assessed for energy performance by third-party testing. The design standard adopted for the project is based upon an effective U-Value of 0.95W/m^2 (R-6) consistent with manufacturing options for these products. At the request of the Eco-Housing Task Force a comparative cost benefit analysis of glazing types (double, triple and quad glazed units) was conducted in relationship to various energy sources for space heating (propane, wood pellets, oil and electricity) as included in an Appendix 2 and described below.

6.1.3 Window Cost Benefit Analysis

Please refer to the Appendix 1: Economic Cost-Benefit Analysis of Window Options.

The analysis (Appendix 2) outlines important methodology and assumption details regarding windows. The analysis considered life cycle differences between proposed electric baseboard and central boiler systems such as wood pellets, propane and oil as well as greenhouse gas emission implications. It did not consider "system effects, such as the reduction of equipment size due to lower heat losses, cooling, comfort or condensation potential" nor solar heat gains related to window choices. The analysis was based on the window layout of the proposed Eco-Housing project's design and upon pricing of fiberglass-framed windows with the characteristics outlined in Table 3 - Window Analysis: Characteristics of Options.

Table 3 – Window Analysis: Characteristics of Options

Option	Description	U-Value (W/m^2.k)	SHGC	VT
Base	Pultruded fiberglass frame (insulated) with double glazing, lowE, argon, insulating spacer.	1.59	0.63	0.67
Option 1	Pultruded fiberglass frame (insulated) with triple glazing, 2-LowE, krypton, insulating spacer.	1.16	0.56	0.58
Option 2	Pultruded fiberglass frame (insulated) with double glazing, LowE + Heat Mirror suspended film, krypton, stainless steel swiggle spacer.	1.14	0.31	0.51
Option 3	Pultruded fiberglass frame (insulated) with double glazing, LowE + 2 Heat Mirror suspended films, krypton, stainless steel swiggle spacer.	0.89	0.25	0.36
U-value is area weighted based on fixed and operable window areas. SHGC (solar heat gain coefficient) and VT (visible transmittance) is based on fixed on units. *Important Note: VT less than 0.40 appears as a noticeably tinted glass.*				

Summarizing the analysis, conclusions are as follows: "Given the cost premiums associated with Options 2 and 3, it appears the best value and daylighting quality is obtained from Option 1 - Pultruded fiberglass frame (insulated) with triple glazing, 2-LowE, krypton, insulating spacer." Notably, this option has lower thermal performance than originally anticipated and would decrease the building's predicted energy efficiency -whose target is to achieve the 50% better than MNECB goal of indicator EE1 -without employing additional measures.

Based upon the 25-year life cycle study, the average difference in cost between proposed electric baseboard and central boiler heating is \$838.75/m^2 more for a boiler. Based on total glazed area of the building, installation of central boiler heating “only makes financial sense if they can be installed at a marginal cost premium of \$183,016 inclusive of all equipment, piping, radiators, controls, individual meters and taxes” in addition to the cost implications associated with additional floor area requirements to house such a system. This differs from the \$93,754 baseline cost in Table 2, page 26 as the cost associated with additional floor space requirements have been added (60K) as has the annual maintenance costs (23K).

6.1.4 Doors

At the request of the Eco Housing Task Force the project team was asked to comment on the use of ‘combie’ / storm doors. The reported thermal differences between Fiberglass insulated doors vs Combie door (Fiberglass insulated doors with a second outer glass aluminum door) as noted below. The incremental benefit of this door type in the context of the Eco-Housing project was viewed as having marginal value to the overall performance level, adding capital and maintenance costs to the project.

Standard Fiberglass Door: Polyurethane insulated Fiberglass door alone is: R - 11.65

Combie Door: the above with an additional outside door is: R - 13.05

12% increase of R - 1.4

6.1.5 Window/ Door Selection – Fiberglass vs. PVC

Fiberglass windows have been selected for the Eco-housing project for their performance and environmental benefits.

Fiberglass is a composite structural material, comprised of glass fibers bound by a resin; acting together in concert, much like reinforcing bar and concrete, the material is extremely strong. Fiberglass is stronger and harder than other common frame materials – a function of its composite structure of glass fiber and resin. It is 8 times stronger than vinyl, 3.5 times stronger than wood composites and 20% stronger than aluminum. This contributes to increased resistance to deterioration, warping, corrosion or denting, thus giving it a longer lifespan.

Fiberglass has a low coefficient of expansion particularly compared to other frame materials like PVC. This means the fiberglass window frames expand and contract at rates similar to the insulated glass units, reducing the risk of seal failures. Varying expansion rates between window glazing and frame can cause air leakage, broken glazing seals, condensation and general failures in operable hardware and frames – all of which can severely reduce the performance of the window system and contribute to performance degradation. PVC frames expand and contract at a rate of nearly eight times that of glass. Given the extraordinary temperature range the building materials are exposed to in Yellowknife (-51.2 °C to 32.5 °C) this is an important consideration.

Fiberglass has superior thermal properties, achieving the highest Energy Rating (ER) of any frame material, as indicated by the National Resources Canada Consumer’s Guide. The ER is a rating of efficiency considering heat loss, heat gain, and resistance to air leakage – and fiberglass’ highest ER translates into better control of the interior environment and lower energy consumption. According to the US Department of Energy, it has the highest R-Value of any frame material.

In addition to fiberglass' high performance, its long life span and low embodied energy means a lower environmental impact. Fiberglass frames are extremely durable and expected to least for a building's lifetime. They are made from a plentiful natural material (silica sand) and produce minimal waste. Waste that is created can be recycled onto other products. Both glass fiber and resin manufacture is closed processes resulting in fewer emissions – fiberglass pultrusion has the lowest embodied energy consumption of any frame material (18MJ/kg vs. PVC which is 26 MJ/kg).

6.1.6 Solar Control

Air conditioning is atypical in Yellowknife. It is therefore critical for the success of the Eco-Housing project that air conditioning not be introduced to in order to maintain suitable interior conditions. To achieve this objective, low energy / passive concepts include the use of 'through' ventilation (refer to section 1.0) and the provision of fixed external shading for windows. While the high levels of insulation provided for the Eco-housing project help to dampen heat transfer to the interior during summer, this insulation also contains internal heating loads from appliances, lights and building occupants and other plug loads (TV's etc.), and solar loads through windows. In order to achieve both daylighting objectives and prevent the need for mechanical cooling of interior spaces, exterior solar shading devices are needed to reduce summer solar gain. Shading devices need to be configured to both restrict summer solar gain and permit solar gain during the winter and shoulder seasons.

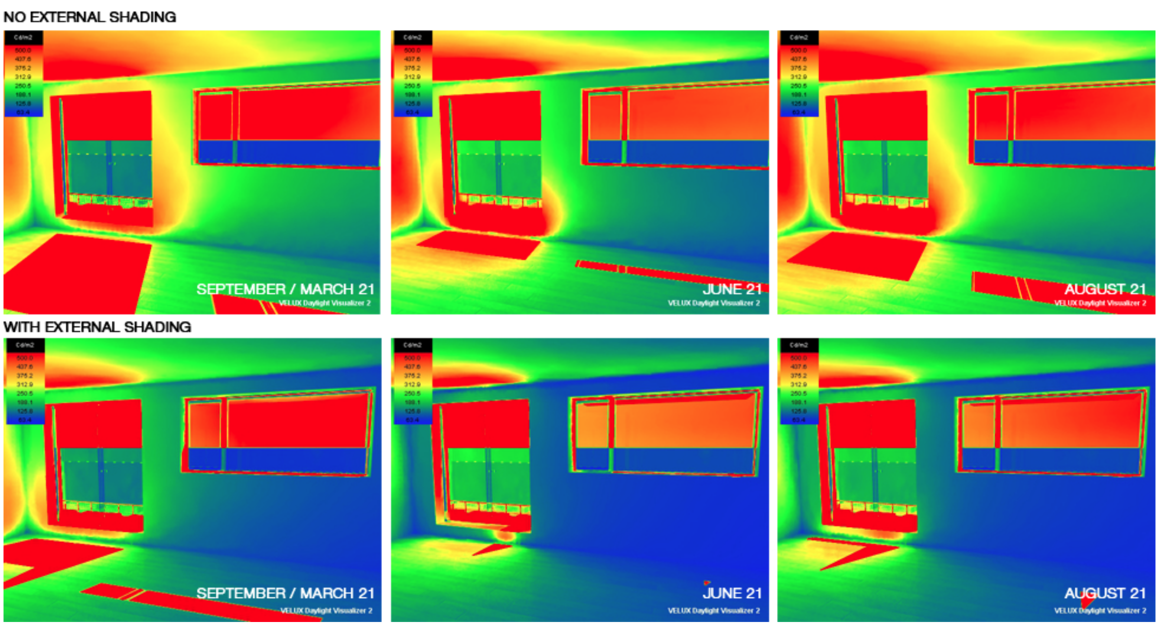


Figure 18 – External Horizontal Solar Control at Typical Type 'E' Unit - Facing towards Southern Terrace

Horizontal shading devices are deployed at southerly facing windows while vertical shades are used to restrict the entry of western sun, which occurs late in the day when ambient temperatures are highest. In Yellowknife, with its extended summer 'solar day' (up to 20 hours) this involves solar control of northern window openings. Vertical shades also serve as light reflectors for easterly morning light, to enhanced daylighting when the ambient early morning temperatures are lower.

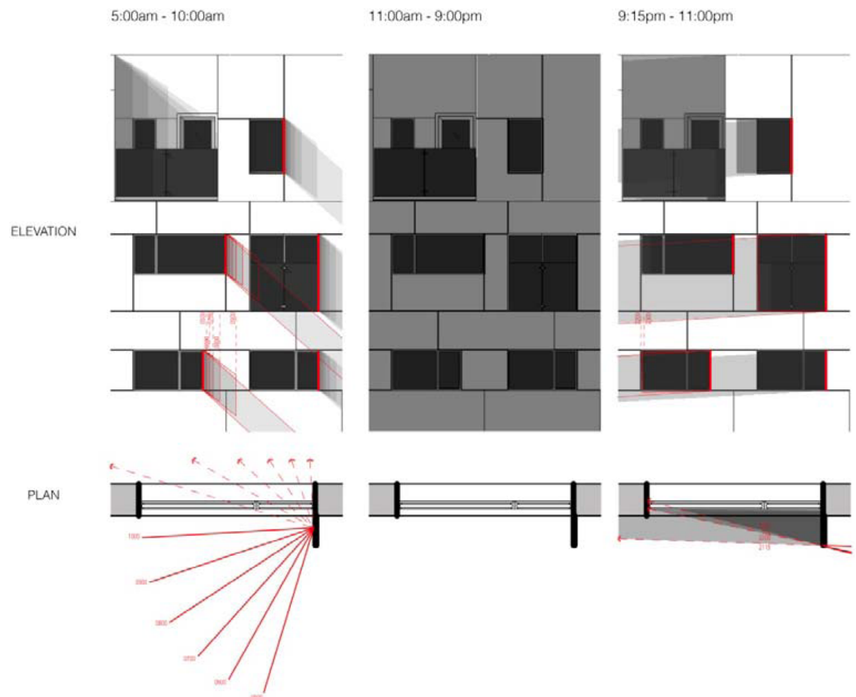


Figure 19 - Vertical Shade Devices Performance Study – N/E Elevation Summer Sun

6.2 Interior Systems and Features

6.2.1 Heat Recovery Ventilation

The Eco-Housing project employs both active and passive design strategies to improve 'controllability' of interior spaces by residents. "Through-units" promote passive / cross ventilation while double height units also utilize "stack effect" for passive ventilation and cooling during summer months. An active mechanical heat recovery ventilation system (HRV) delivers all of the ventilation needs during colder months, when people do not use operable windows. HRV's function as a heat exchanger to deliver outdoor ventilation air to interior habitable spaces while extracting heat from warm exhaust air to preheat incoming fresh air. Each residence is provided with an individual HRV unit to enable operational responsiveness specific to occupant behavior/ needs.

Yellowknife climate conditions generate several important design considerations regarding HRV performance and selection. Due to low winter outdoor temperatures, fresh air delivered through the heat exchanger will, at times, be provided to interior spaces at temperatures well below normal comfort levels and will rely upon the building heating system to elevate ventilation air up to set point temperatures. This can lead to drafty interior conditions. As well, lower outdoor temperatures can create conditions within the heat exchanger where core components 'freeze up' - compromising performance of the unit. To address these considerations HRV unit selection is limited to those with the capacity for integrated defrost cycles and controlled inline heating. Electricity consumed by the internal HRV heating element directly corresponds with reduced heating energy demands of interior space.

An HRV system with seasonal performance efficiency ranging between 69% and 88% is proposed and incorporated into the HOT2000 energy modeling simulation for the Eco-Housing project. The HRV system is proposed to address bathroom exhaust needs, however due to maintenance concerns regarding clogging and performance degradation, and anticipated biweekly filter changes, kitchen and laundry exhaust is designed to be directly ventilated to the exterior.

6.2.2 Lighting

LED type lighting is proposed throughout for lighting within units and common areas including; the entry lobby, corridors, stairwells, outdoor parking, and terrace. Sustainability considerations pertain mostly to extended bulb life / reduced maintenance operations and the avoidance of waste disposal concerns related to compact fluorescent lights which contain trace amounts of mercury. 'Waste' heat from electrical lighting contributes directly to reduced heating demand and to marginal increases in cooling loads when comparing LED versus compact fluorescent light sources. As the Eco-Housing project does not provide air conditioning, there is no direct energy conservation benefit derived from increased interior lighting efficiency. The inclusion of this feature is dependent upon project tender results, and energy modeling assumptions are based upon slightly low performing compact fluorescent lighting fixtures.

6.2.3 Programmable Thermostat

Programmable thermostats, which control baseboard heater and HRV functions, enable occupants to generate additional savings through controlled setback of temperature and ventilation based upon patterns of use and occupancy of the unit. These controls are dictated by 'user preferences' and have not been assumed within the Hot 2000 energy model estimate.

6.2.4 ENERGY STAR® Appliances

Energy efficiency of major appliances (refrigerator, dishwasher, clothes washers and dryers, and ranges) contribute to major reductions to electrical 'plug loads' and long term payback related investments in higher efficiency selections. Improved equipment efficiency also reduces internal heat generation and thermal loads, improving interior comfort conditions during the summer months. ENERGY STAR® qualified appliances have been identified for use throughout the Eco-Housing. The HOT2000 energy model conservatively assumes final appliance selections will be minimally complaint regarding 2013 ENERGY STAR® performance requirements.

For further information regarding ENERGY STAR® performance standards and payback calculations methodology refer to National Resource Canada's guide "Choosing and Using Appliances With EnerGuide"
https://oee.nrcan.gc.ca/sites/oee.nrcan.gc.ca/files/files/equipment/EnerGuideappliances.pdf

6.2.5 Drain Water Heat Recovery

Domestic hot water heating requirements will be reduced by heat recovery from shower drains. Heat recovery is achieved passively and "on demand" by routing incoming cold water piping around heated drain water lines, thereby preheating incoming cold water to reduce overall hot water use when showers are in use. Drain-Water Heat Recovery effectiveness of 30% has been assumed in the HOT2000 model. Tentative products selected for the Eco- Housing project are outlined in Appendix 4, including a payback analysis provided by the manufacture for the drain recovery system. Note estimated 'payback' period of 7.1 years may be longer than that outlined in the manufacturer's report due to higher local labour costs, and lower temperatures for incoming cold water. Final products selection and determination of installed costs will occur as part of the project's competitive tender/ bid process.

6.2.6 Solar Domestic Hot Water Heating

The overall 50% energy reduction target has also been applied to the project's remaining domestic hot water heating load that remains after water conservation strategies are applied (described later in this report). The total domestic hot water load water determined for the Eco-Housing project will have 50% of this heating load provided from renewable rooftop solar thermal collectors, with the remaining 50% provided through high performance on-demand electric boilers. The effective solar heating contribution of 32,000 kWh annually was determined.

A high efficiency Evacuated Tube Solar Collector system has been proposed. It is estimated that 5 banks of 4 collectors, facing south with a tilt of 60°, are needed to address this heating load (specifics are included in Appendix 4). Based on simulations, a solar fraction greater than 50% is achieved for each of three options considered. Options pertain to heat storage and heat rejection details in the event of power failure. 3,600-litre heat storage is expected to provide sufficient capacity to provide nearly 100% of the domestic water heating during the summer months. Solar heated water will be delivered through on-demand hot water heating, which will supplement heat as required in response to variable temperature of incoming heated water. Thermostatically controlled mixing values are needed to temper solar hot water to prevent scalding water being delivered at higher than intended temperatures.

Evacuated tube solar collector systems are supplied/ manufactured by a number of suitable companies including Enerworks, Viessmann, etc. The installation of this system is expected to contribute towards skills development in Yellowknife and that manufacturer support and training is anticipated regarding installation and commissioning activities for the system.

7.0 WATER CONSERVATION

The project has two water conservation performance objectives mandated by the Eco- Housing Framework. These objectives relate to potable water reductions and storm water runoff. As identified below, the forecasted performance of the Eco-Housing project exceeds both performance targets.

INDICATOR: W-1 **GOAL**: MINIMIZE WATER CONSUMPTION
TARGET: Reduce potable water consumption by 40% of baseline.
PERFORMANCE: 52% reduction

INDICATOR: W-2 **GOAL**: EFFECTIVELY MANAGE STORWATER RUNOFF
TARGET: 25% reduction in the rate and quantity of stormwater runoff
PERFORMANCE: 42% reduction in volume

Source: Yellowknife Eco Housing Project, In Progress Draft: Design Performance Report, October 30, 2012

Defining baseline measurements for potable water specific to Yellowknife patterns of water use and relevant to the project occupancy profile (i.e. multi-unit residential, unit size, number occupants per unit, shower/ water usage, etc.) is a complex activity that ultimately depends upon individual occupant behavior, which can vary widely. Baseline water consumption levels used to analyze water reduction goals for the Eco-Housing project adopt typical performance standards and methodologies used by the Canada Green Building Council's LEED 'New Construction' rating system and by other recognized third party agencies for appliance water performance standards.

Per capita domestic water use in Canada is graphically summarized in the following information from Environment Canada, which indicates daily domestic water consumption at about 340litres/person/ day. Recent studies suggest that Canadians are making headway in reducing water use. Homes with water meters installed are typically consuming far less - about 229L/person/day (SOURCE: Gov't of Canada http://www.ec.gc.ca/indicateurs-indicators/default.asp?lang=en&n=7E808512-1).

For the Eco-Housing project baseline water consumption, using LEED baseline metrics, is estimated at about 17,100L/day, which translates into a baseline of about 240L/day/person. Water conservation measures are applied to this baseline with Eco-Housing targeting water use at about 8,200L/day or 111L/person/day. ***Please refer to the Appendix 2: Water Conservation Forecast Tables.***

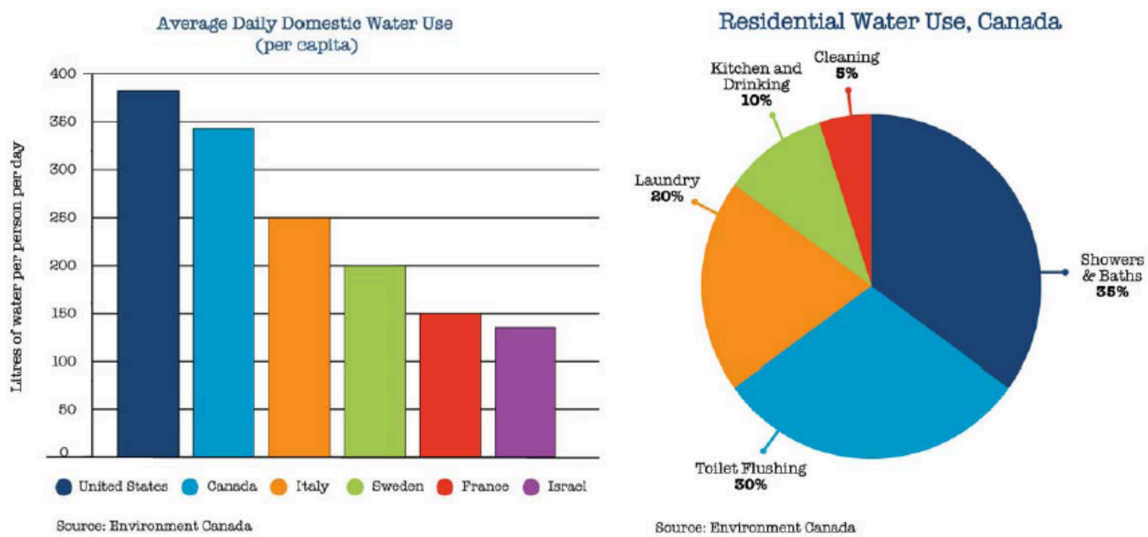


Figure 20 – Typical Baseline Domestic Water Consumption in Canada

7.1 High Performance Fixtures

Consistent with the overall approach, conservation and reduction strategies are sought and assessed before introducing additional systems or technologies. Initial determination of water reductions using low flow/ high efficiency plumbing fixtures for toilets, showers, laundry, faucets and dishwashers was determined to exceed mandated reduction targets of 40%. Refer to Appendix for Typical / Baseline Water Use Profile and Forecasted Water Use / Savings breakdowns by fixture type.

Performance standards for plumbing fixtures and standards are summarized below:

Shower Head:	4.7 LPM (0.0783 l/s)
Lavatory (aerator):	2.0 LPM (0.033 l/s)
Kitchen (aerator):	5.7 LPM (0.095 l/s)
Toilets:	3.0 LPF
Dishwasher:	13L/Load
Clothes Washer:	40.43 L/Load

Other approaches including grey water and rainwater harvesting were considered as additional measures as noted below. Tankless 'on-demand' boilers have been selected for use on the project primarily to reduce space requirements related to storage tanks.

Ultra Low Flow Toilets – A Comparison

A variety of fixture options were considered in relationship potential water savings/ performance and a 'simple payback' by fixture. This high level assessment indicates that the toilet with the lowest water consumption - the Water Matrix Ultra High Efficiency toilet at 3L/flush - is the most cost effective fixture with the shortest payback period based on water cost savings.

Table 4 – Fixture Summary

Fixture Summary						
	Toilet Make	**Designation**	**L/Flush**	**Cost**	**Premium**	**MaP Score**
Case 1	Glacier Bay	Typical/ Baseline	6	$ 97.00	-	1000g
Case 2	Glacier Bay	'High Efficiency'	4.8	$ 169.00	$ 72.00	800g
Case 3	Glacier Bay	'Dual Flush'	4.8	$ 149.00	$ 52.00	800g
Case 4	Water Matrix	'Ultra High Efficiency'	3	$ 175.00	$ 78.00	800g

Fixture Summary Method/Assumptions:

- *The Glacier Bay toilet costs have been sourced online from the Home Depot and Water Matrix pricing is provided by the manufacturer (2013) – tax not included.*
- *MaP Scores which measure waste removal have been provided on supplier websites. http://www.map-testing.com/map-search.html#result*
- *Cost per litre saved has been determined using the water saved from Case 1 and the cost to upgrade from it to Cases 2 – 4.*

Table 5 - Toilet Water Savings Analysis

Water Savings Analysis				
	Case 1: Base Case	**Case 2: High Efficiency**	**Case 3: Dual Flush**	**Case 4: Ultra-High Efficiency**
1 person daily consumption (L)	18	14.4	14.4	9
1 person annual consumption	6,570L / 6.57cu.m	5,256L / 5.26cu.m.	5,256L / 5.26cu.m.	3,285L / 3.29cu.m.
Annual Water Savings	-	1,314L / 1.31cu.m.	1,314L / 1.31cu.m.	3,285L / 3.29cu.m.
Annual Water Cost	$ 20.24	$ 16.19	$ 16.19	$ 10.12
Annual Cost Savings	n/a	$ 4.05	$ 4.05	$ 10.12

****Cost per Cubic Meter** $3.08 / cu.m.*

Water Savings Analysis Method/Assumptions:

- *The Glacier Bay 6L/f toilet is assumed as the base case.*
- *Usage based on 18L/day /person, at 6L/flush – derived from Eco- Housing Preliminary Forecast Water Use*
- *Dual Flush assumed to have average flush rate of 4.8L/f*
- *Water rate / cubic meter based on City of Yellowknife rates as provided by Williams Engineering*
- *Calculated based on one fixture / person with 3 times daily usage to assess 'worst case scenario' (i.e if toilet flush rates increase or number of people using each fixture increases above 1 payback period is reduced accordingly)*

Table 6 - Simple Payback per Fixture

Simple Payback per Fixture				
	Case 1: Base Case	Case 2: High Efficiency	Case 3: Dual Flush	Case 4: Ultra-High Efficiency
Capital Cost	$ 97.00	$ 169.00	$ 149.00	$ 175.00
Cost over Base Case	n/a	$ 72.00	$ 52.00	$ 78.00
Annual Savings	n/a	$ 4.05	$ 4.05	$ 10.12
Payback (years)	n/a	18	13	8

Simple Payback Method / Assumptions:

- *simple payback calculated on premium over base case / annual savings (toilet required to be installed regardless therefore labour not included)*
- *simple payback does not account for net present value, maintenance costs or applicable tax*
- *does not account for escalation in water rates which would improve payback*

7.2 Grey Water Reuse

Further water savings can be achieved by introducing a grey water recovery and reuse system, and could additionally contribute to the potential demonstration aspects of the project. Grey water systems are not currently approved for use in most municipalities nor are there any systems certified to CSA 128.3. Consistent with other aspects of the project, such a system would be implemented as a decentralized, in unit based, grey water system. This approach aims to simultaneously minimize condo fees and to link / increase awareness of individual habits and resource use.

The Sloan Aqus HMA 7000 is a decentralized grey water reuse product. Typically it is installed below the bathroom sink and cleans and filters sink drain water then stores it within its 5.5 gallon reservoir. When the toilet is flushed, 65% of the refill water is pumped from the Aqus reservoir and 35% comes from domestic cold water supply. The reservoir can supply three 6L flushes or six 3L flushes without replenishment. If the reservoir is empty, the tank will fill entirely from the domestic cold water, although more slowly. The unit is easily installed but is only compatible with toilets that flush by gravity precluding its use in conjunction with the Water Matrix toilet mentioned previously. The Aqus system uses a screen filter that must be emptied annually, (or as required) and 3 chlorine tablets which must be changed annually. These retail for $10-15/pack.

Figure 21 - Sloan Aqus Grey Water System

The following table provides high-level assessment of decentralized greywater (utilizing the Sloan Aqus system) in the Eco- Housing project that compares against the base case assumed in the previous section.

Table 7 - Fixture Summary with Grey Water Reuse

Fixture Cost Summary with Sloan Aqus Grey Water (G.W.) System Added						
	Toilet Make	**Designation**	**Potable L/Flush**	**Cost**	**Premium**	**MaP Score**
Base Case 1	Glacier Bay	Typical	6	$ 97.00	n/a	1000g
Case 5	Glacier Bay	Typical	2.1	$ 527.00	$ 430.00	1000g
Case 6	Glacier Bay	'High Efficiency'	1.68	$ 599.00	$ 502.00	800g
Case 7	Glacier Bay	'Dual Flush'	1.68	$ 579.00	$ 482.00	800g

<u>Fixture Summary Method/ Assumptions:</u>

- *The Glacier Bay toilet costs have been sourced online from the Home Depot – tax not included.*
- *Sloan Aqus 7000 Greywater System ($330 delivered) has been sourced from supplier and is assumed to require 1 hour of labour ($100/h) beyond toilet installation – tax not included.*
- *MaP Scores, which measure waste removal, have been obtained from supplier websites.*
- *Cost per litre saved has been determined using the water saved from Case 1 and the grey water test case premiums*
- *It is assumed that the full 65% savings on potable water through the system is realized for each flush. Analysis confirms that a deficit, which would reduce efficiency, would only result if flow rates were reduced below 0.04L/s. For high usage times in the morning and after school, it is anticipated that mainly potable water would be used.*

Table 8 - Grey Water Savings Analysis

Grey Water Savings Analysis				
	Case 1: Base Case (no G.W.)	Case 5: Typical with Aqus G.W.	Case 6: High Efficiency with Aqus G.W.	Case 7: Dual Flush with Aqus G.W.
1 person daily consumption (L)	18	6.3	5.04	5.04
1 person annual consumption	6,570L / 6.57cu.m.	2,300L / 2.30cu.m.	1,840L / 1.84cu.m.	1,840L / 1.84cu.m.
Annual Water Savings	-	4,270L / 4.27cu.m.	4,730L / 4.73cu.m.	4,730L / 4.73cu.m.
Annual Water Cost	$ 20.24	$ 7.08	$ 5.67	$ 5.67
Annual Cost Savings	n/a	$13.15	$ 14.57	$ 14.57

Water Savings Analysis Method/ Assumptions:

- *The Glacier Bay 6L/f toilet is assumed as the base case.*
- *Usage based on 18L/day /person, at 6L/flush – is derived from Eco- Housing Preliminary Forecast Water Use*
- *Dual Flush assumed to have average flush rate of 4.8L/f*
- *Water rate / cubic meter based on City of Yellowknife rates as provided by Williams Engineering*
- *Calculated based on one fixture / person (ie 1 person unit with 1 fixture, 2 person unit with 2 fixtures) to assess 'worst case scenario'*

Simple Grey Water 'Payback'

It would be misleading to present a simple payback analysis of the installation of a Sloan Aqus Grey Water reuse system that does not account for maintenance and operation costs (its use requires a 12V pump). Given the high level analysis and the observations, which follow, this has not been undertaken.

Annually, the Sloan Aqus system is anticipated to save $13-15 in water costs, which is negated by the required replacement of chlorine tablets, that cost $10-15 and would cancel out projected savings. If one were to account for price inflation of the tablets, pump electricity consumed, net present value of the purchase cost, price escalation of water rates as well as costs of potential repairs, one is very likely looking at a scenario that would be neutral, or could incur costs on an annual basis. This is not to diminish the merits of a system that is capable of reducing potable water consumption for toilet use to an impressive 1.68L/f, but rather suggests that the decision to implement such a system would be driven by more than cost benefit alone.

7.3 Rainwater Collection and Use

7.3.1 Rain Water Harvesting:

Harvested rainwater from rooftop areas will be collected in a 5,000L cistern located on the terrace level of the project. Collected rainwater will be used to irrigate garden plots through a gravity fed "hose bib" system. The inclusion of 5,000L of storage capacity has been assessed to satisfy weekly irrigation requirements as well as bridge normal dry spells. This harvesting of rainwater for irrigation yields the conservation of about 47,211L of potable water annually and the diversion of 42% of rainwater from municipal storm water infrastructure.

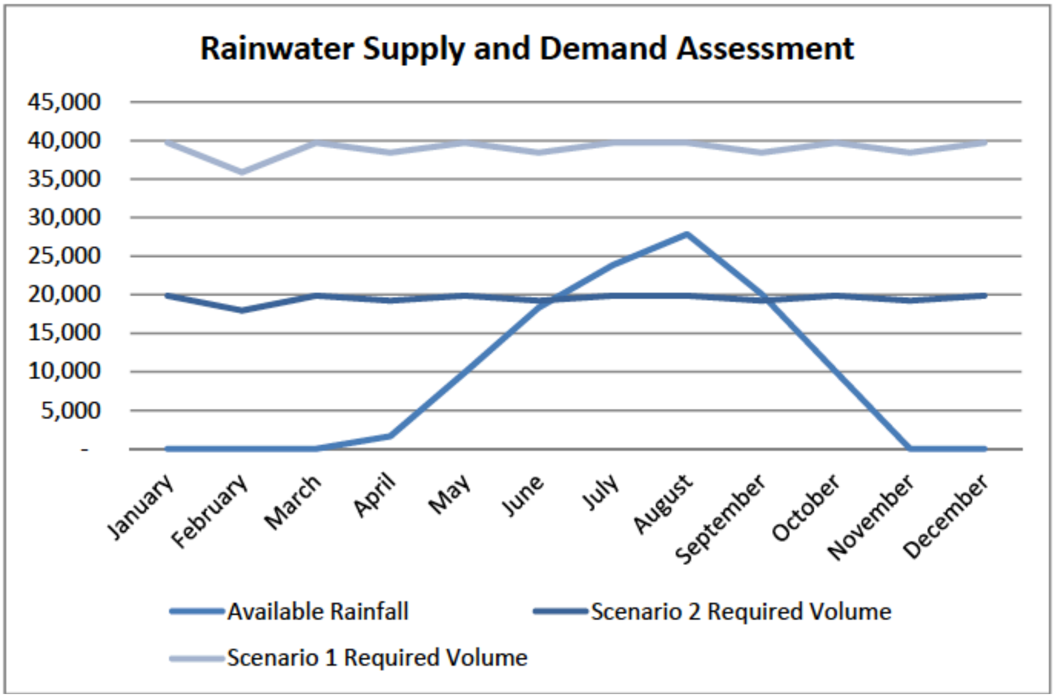


Figure 22 - Rainwater Supply and Demand Assessment

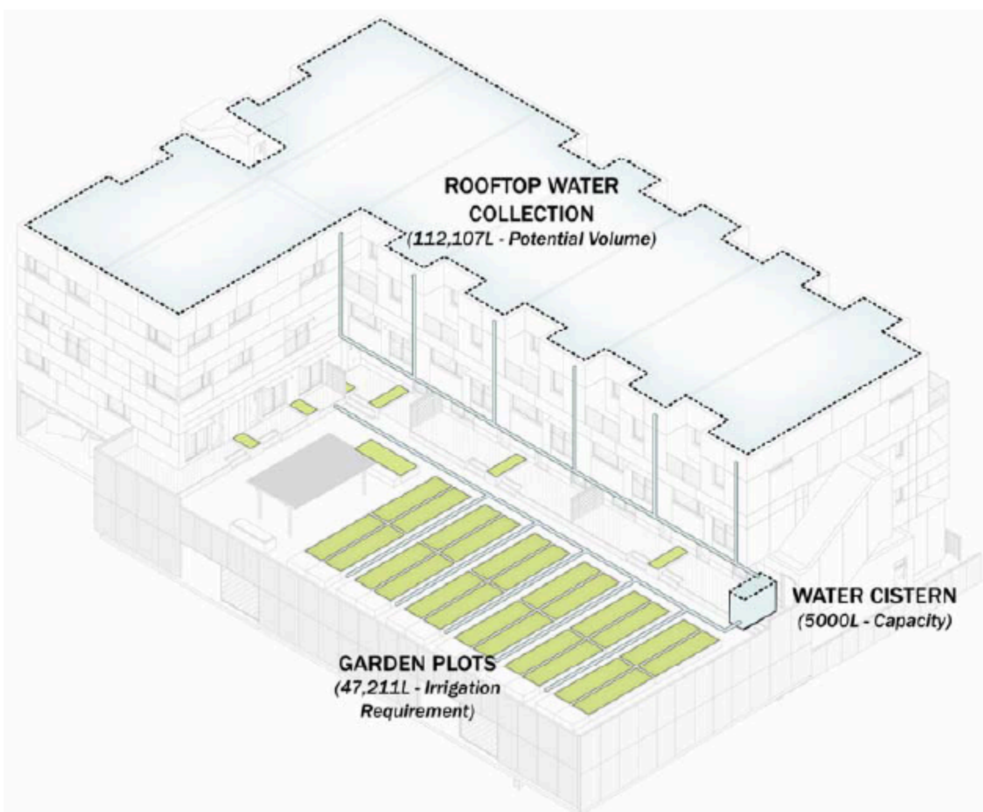


Figure 23 - Diagram of Rainwater Irrigation Concept

Rainwater harvesting to supply toilets is a potential alternative to both municipal, potable water supply and a grey water system. Such a system has been deemed impractical for a variety of reasons, the most significant one being that the seasonal availability of water is not well matched to year round water demands due to extended cold weather conditions. Instead, harvested rainwater will be allocated to satisfy irrigation requirements related to community garden plots where demand and supply are well matched.

Rationale for not supplying toilets with rainwater:

- Two scenarios were assessed: (Figure 23 - Rainwater Supply and Demand
- Assessment). Scenario 1, based on 6L/flush fixtures, and Scenario 2 based on 3L/flush fixtures. Forecasted harvested monthly rainfall would not be sufficient to offset demand in Scenario 1, and would only suffice for 3 months during Scenario 2.
- Even with a grey water reuse system (Sloan Aqus) employed in conjunction with rainwater harvesting - using the best case of 1.68L/f -a deficit would still occur.
- Williams Engineering has indicated that the use and collection of snow melt is not feasible.
- Both scenarios would require significant additional building infrastructure to treat and distribute collected rainwater through dedicated piping systems. This distribution system would also have additional electrical loads associated with it due to pumping and trace heating.
- Rainwater collection has currently been incorporated to support irrigation of terrace vegetation. We anticipate requirements of 47,211L annually. A 5,000L storage tank to support irrigation needs from May to August will be provided. Rainwater used for irrigation does not require treatment, only requires hand-powered pumps for garden distribution and is well tuned to periods of rainwater supply and irrigation demand. The rainwater's collection and use for on-site irrigation achieves a 42% reduction in storm water runoff, exceeding the mandated reduction of 25%. *(Refer to Appendix 2)*
- Rainwater collection could also be used to supply toilets.

7.4 Discussion: Cost Effective Water Conservation

The Team analyzed flow rates on all plumbing fixtures to investigate additional potential savings as well as confirm enough water was available from bathroom sinks to provide sufficient supply to a decentralized, grey water reuse (Sloan Aqus) system if it were to be included.

The examination highlights that an 'off the shelf' faucet aerator (0.031L/s – 0.5GPM) would save approximately 6,515L annually at a cost of roughly $5.00 while a similar 'off the shelf' low-flow showerhead would save approximately 7,008L annually at a cost of roughly $15.00 (both assumed as capital only due to minimal labour involved). These numbers represent reductions from the Forecast Water Use included in Appendix 1 of the *Yellowknife Eco- Housing Project, In Progress Draft: Design Performance Report*. See Appendix 3 product sheets for more details.

Comparatively, these savings exceed greatly the projected annual water savings associated with the best case (Case 6 or 7) forecasted performance of the decentralized, grey water reuse system (Sloan Aqus). Annually, approximately 4,730L are estimated to be saved by a grey water system at a premium of approximately $482.00 for each fixture.

Both faucet aerators or a grey water reuse system may be great options for achieving further reductions in water consumption either separately or in conjunction. In this case however the project exceeds its water performance goals and is intended to be delivered affordably. In this context, additional water savings from grey water reuse system are small and considerably more expensive when compared with other more cost effective means such as aerators.

Table 9 – Water Conservation Measures Analysis Summary

Water Conservation Measures Analysis Summary							
	Forecast Water Use: Some Conservation			Additional Conservation Measures			
	Shower	Lavatory	Toilet	Shower	Lavatory w/ aerator	Water Matrix Toilet	Toilet with G.W.
Per Use (L)			6			3	1.68
Flow Rate (L/s)	0.11	0.15		0.078	0.031		
Usage (sec)	600	30		600	30		
Total Volume (L)	66	4.5	6	46.8	0.93	3	1.68
Per person use/day	1	5	3	1	5	3	3
Per Day Water Use (L)	66	22.5	18	46.8	4.65	9	5.04
Per Year Water Use (L)	24,090	8,213	6,570	17,082	1,697	3,285	1,840
Savings From Base Case (L)	-	-	-	7,008	6,515	3,285	4,730
Premium	-	-	-	$ 10.00	$ 5.00	$ 78.00	$ 482.00
Annual Cost Savings	-	-	-	$21.58	$20.07	$ 10.12	$ 14.57

Method/ Assumptions:

- *Fixture Assumptions for Forecast Use from Appendix 1 of the Yellowknife Eco Housing Project, In Progress Draft: Design Performance Report*
- *Use assumptions unchanged from Appendix 1 of the Yellowknife Eco- Housing Project, In Progress Draft: Design Performance Report*
- *Flow rate fixtures sourced from www.ecofitt.ca*
- *Water Matrix Toilet and Sloan Aqus Grey Water system prices from supplier.*
- *Water rate / cubic meter based on City of Yellowknife rates as provided by Williams Engineering*

Figure 24 – Dual-Thread Needle Spray Bath And Kitchen Aerator – 2.0 LPM (0.5 GPM), $240, SKU: N3205N (Source: www.ecofitt.ca)

Figure 25 - Earth® Showerhead – 4.7 LMP (1.25 GPM) – $14.51, SKU: N2912CH (Source: www.ecofitt.ca)

This particular case illustrates that there are occasions when readily available technologies represent far greater savings than that of newer, 'innovative' or technologically intensive systems. While technological innovation can offer great benefit - especially in the context of water scarcity - higher performance can be achieved more affordably in some cases.

8.0 ALTERNATIVE FIRE SUPPRESSION SYSTEMS

The project team was asked by the Eco-Housing Task Force to review the suitability of alternative fire suppression systems such as foam fire suppression or mist fire suppression, as a way of diminishing reliance upon water and potential sustainability benefits (Williams Engineering's response):

Foam Fire Suppression – Generally used in places where hydrocarbon products and different alcohols are used/stored and kitchens where grease fires are possible. Not generally used in residential applications as they cost 2-4x a standard sprinkler system and require on-site storage of the concentrated foaming solution, which is injected into sprinkler system with mixing water.

Mist Fire suppression – Used in applications to minimize the amount of water damage to other zones when it is used. Generally cost 1.5-2x as much to install, as a common system but require a high-pressure pump to boost local water pressure to achieve atomization. Costs for pump depend on size of building.

"In regards to those two systems, they do not work with dry sprinkler sections for use in cold weather locations. So these systems would not work with sprinklers in the car parking and garbage storage areas specific to this project. These would need their own system if either of the two above were used. In both cases as soon as the dry suppression is expelled the foam or mist will quickly build up around the sprinkler head reducing its efficiency."

Regular sprinkler systems will cost ~\$2.95/ft^2 @ 1.5x in YK: ~\$4.50/ft^2 to install.

There is no "payback" on novel water saving fire suppression systems in a municipally connected building, because during normal operation of the building, standard fire suppression systems use no water. The planned operation is for the system to never be used, but always be ready in case it is needed. In case of a fire, low water use is not typically a priority (and fire water is not metered).

A downtown Yellowknife residential building is not a good test case for use of water saving fire suppression systems, as no water is stored on site for fire suppression. This would be completely a demonstration project with zero financial benefit or savings to the owner. Fire damage reduction is not a guaranteed payback item. Ideally there is never a fire in the building, so there is not a dependable economic argument for having a system that uses less water during a fire. Also, insurance companies typically pay for fire damage, and minimizing water damage from fire suppression is not easily quantifiable.

Buildings that are not connected to municipal services would be good candidates for exploration of fire suppression systems that use less water, as they must always keep a set amount of stored water on site for potential fire suppression. This type of system could result in space use savings (smaller tanks), and reduce capital costs if the building could be smaller based on housing a compressed foam system rather than housing large water storage tanks and/or reducing the requirement for electrical generation for pumping. None of these conditions apply to the current eco-housing project site. Any capital costs of a water saving fire suppression system would have to be incurred even in the case of no fire through the life of the building.

9.0 Project Delivery, Implementation, and Follow-up Monitoring

The project uses a combination of site built and prefabricated construction techniques to advance affordability objectives. Designed through a unique public partnership model, the project will be delivered through a market driven / developer model, with construction costs and unit affordability criteria determined through this process. Product selections contributing towards mandated Performance Indicators will be finalized through a competitive tendering process, using products that achieve performance criteria outlined in this report and as further defined by design and specification documentation prepared by the project's architecture and engineering team.

The project provides a range of opportunities for skill development, particularly in the area of testing and sealing of high-performance / low-infiltration building envelope construction, and solar thermal installation /commissioning. These skill development activities could be integrated within the program of 'field testing' that will occur during the construction process to ensure standards needed to achieve low energy / high performance design are realized in the completed project. Given the hybrid prefabrication and site build construction this will require both compliance verification testing in the manufacturing facility, and on site verification to address sealing and jointery considerations, related to infiltration testing.

Follow-up reporting and analysis of utility costs is planned as part of the scope of this study. Recommended follow-up studies include collection of itemized costing information of proposed sustainability and energy conservation measures using actual tender costs. This information would facilitate increased understanding of incremental costs and 'payback' for sustainability initiatives within the northern market. Other recommended studies include a 'lessons learned' review which could integrate cost /payback data using actual costs and actual utility rates (which are metered on a suite by suite basis). Assessing the Task Force's social and affordability indicators is another area recommended for follow-up study once the building is occupied and social patterns merge. This could be accomplished through simple online survey tools focused on occupant related issues, and/or issues addressing the broader stakeholder community.