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Final Design Specification (FDS)

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Project Title	9 Boardwalk Drive - Reducing Utility Costs for Gas and Water
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Executive Summary

Ms. Fionnuala Martin, President of the Condominium Board at 9 Boardwalk Drive Toronto, ON, requires a design system that will ensure maximum gas and water efficiency for the condominium.

The design team developed the functional basis - modifying mass and energy- and the primary function: to modify the design such that mass and energy usage is efficient and controlled. Significant stakeholders include the Toronto City Council as well as government agencies such as Ontario Ministry of Energy, who are primarily interested in a system that can ensure energy and water efficiency in buildings. The designs were judged based on how they met the main objectives: percentage increase in efficiency, cost effectiveness and the length of payback period which were narrowed down using Pairwise Comparison. The constraints were developed using the existing *Building Code Act and Condominium Act* which detail the regulations concerning any changes to buildings in Ontario. The primary service environment is the location of the condominium: Toronto, Ontario, selected because of its moderate to extreme weather conditions, which will enable the design to function efficiently in all weather conditions. The design team generated fifty design ideas using Structured Brainstorming; the top ten design ideas were selected through a Multi-voting process. Five different alternative designs were then chosen using a Graphical Decision Matrix, in which the most important objectives (increased water/ gas energy efficiency and short payback period) were used to compare the designs. Through the Weighted Decision Matrix, the Proposed Conceptual Design (CDS) was selected. Based on feedback from Ms. Martin for the CDS, the design team restricted the proposed designs in the Final Design Specification to only include designs for the common elements of the condominium.

The final design includes designs for the common elements in the condominium, which the design team categorized into four major target areas: the garden, four common area washrooms, the water piping/supply room and the common living areas (including library, multi-purpose room, the exercise room and the windows of the condominium). The design system includes installing a drip water irrigation system, planting holly shrubs, spreading organic wheat straw on the soil of the grass, installing dual flush toilets, installing aerators and motion-sensor faucets,conducting a thermal audit to detect heat/air leaks in the building, installing thermally efficient windows, replacing furnace filters every 3 months, insulating exposed water pipes, regular water drainage from the hot water tanks. The major implementation requirements include pipe insulators for $4.64 per meter of piping and shrubs for fountains, which will require full initial payment, without the option of installments, though the client can carry out implementation in different areas of the condominium over a period of time before proceeding to the next area**.** Important tests that would need to be conducted are a 24 h simulated-use test and a calculation of the original cost of all systems vs. the cost of the updated version. The estimated payback period is 39 years and cost savings will be approximately $884 per year. The design team will develop a Final Presentation to present to Ms. Martin and the Board of the Condominium on April 26, 2016.

1.0-Project Requirements

The Condo Board of 9 Boardwalk Drive, Toronto has requested a design solution that will optimize gas and water usage and ensure maximum cost savings. The following sections detail the requirements of the design project:

1.1-Problem Statement

30% of the operation expenses of the condominium are spent on utilities, including water and gas, due to features such as barbeques, uneven heat/water distributions, and fireplaces. Statistically, condominiums usually pay 35% more energy per unit than buildings with social or non-profit ownership of housings [2,3]. The energy is often lost due to lack of insulation when delivering the heat/hot water to individual units. As a result, the demand for gas to generate more energy increases. In addition, the uneven distribution of heat generated by heat radiator is a likely cause for higher energy consumptions through electric heaters/fireplaces [4]. The water usage in the condominium has an estimated peak flow rate of about 132.5 litre/min in each unit [5,6] and an average of 15,000 m^3 of water consumption per year. Consequently, the utility cost of water usage is very high, about $3.40 per cubic metre of usage [7] resulting in approximately $48,000 in 2015. As inflation continues in Canada, the price per cubic metre of water will increase and cause higher budget for the condominium as the years progress.

The gap is the lack of monitoring systems and efficient method to control water and gas usage within the condominium. The client's need is to redesign the system for energy/water usage that would result in 30% efficiency compared to previous installment. The goal is to develop a design that will ensure a decrease in water/gas usage and thus reduced utility costs. The design shall provide immediate or long-term cost reduction with minimum initial cost, and must also comply with minimal barrier posed by the board condominium where .

1.2-Identification of Stakeholders

This section outlines the stakeholders' interests and impacts on the functions, objectives and constraints (FOC) of this project. (Appendix A).

Table 1-Stakeholders and Their Interests and Impacts on the Design

Stakeholders	**Interests**	**Impact on FOC**
City of Toronto	Legal: Compliance with provincial/municipal regulations [9] Economic: Efficient water supplying techniques [9]	F1,O1,C2,C6
Ontario Ministry of Energy	Environmental: Developing sustainable energy [10]	F1,O1
Ontario Ministry of the Environment and Climate Change	Environmental: Improving the environment quality. [11]	F6,F3,O1,C4
Ontario Ministry of Natural Resources and Forestry	Environmental: Natural resources conservation. [12]	F6,F3,O1,C4,C6
Non-Governmental Organizations focused on energy efficiency e.g. The Toronto Green Network	Environmental: Energy conservation [13]	F6,F3,O1,C4

1.3-Functions

The design team developed the following functions using Functional Decomposition and the Black-box Method for reducing the utility cost of water/gas in the condominium (Appendix B).

1.3.1-Functional Basis:
1. Modify mass and energy

1.3.2-Primary Functions:
The design should:
1. Increase efficiency - **F1**

1.3.3-Secondary Functions:
The design:
1. Detects mass/energy losses - **F2**
2. Prevents mass/energy losses - **F3**
3. Detects areas with highest mass/energy loss - **F4**

1.3.4-Unintended Functions:
The design:
1. May produce other forms of energy - **F5**

1.4-Objectives

The objectives outlined below were used to assess potential design solutions. The design team used Pairwise Comparison method to rank the objectives.They are listed in order of priority and will be compared to the existing system in the condominium. (Appendix C)

Table 2-Objectives and Measurable Goals

Objectives (The design should have:)	**Objective Goals**
O1: Increased efficiency	• 40% decrease in water/gas usage compared to current design in the common elements of the condominium.[14,15]
O2: Short Payback Period	• Maximum 10 years [18]
O3: Longer life-span	• Minimum 20 years. [14, 20, 21]
O4: Easy to operate	• Can be operated with little-to-no technical background [23, 24]
O5: Environmentally sustainable	• No harmful emissions.

1.5 Constraints

This section contains the constraints of the project, developed using Acts, Codes and Regulations in the province of Ontario regarding any modification to buildings (Appendix D).

Table 3-Constraints of the design and the corresponding metrics

Constraints	**Metrics** (Appendix D)
1. Have annual cost savings of 30%.	• Monthly bills from the prototype will be used to calculate the percentage cost savings
2. Safe to operate	• Alterations will be approved/assessed by authorities
3. Maintain drinking water safety.	• Test the drinking water under the *Safe Drinking Water Act* [25]
4. Lifespan longer than the payback period	• Minimum 10 years

1.6 Service Environment

This section considers the environmental factors at the location that will influence the design. The service environment is Toronto, Ontario, the location of the condominium. Toronto's extreme temperatures require a design that is both efficient and effective - ensuring that the design can function in all extreme conditions.

1.6.1-Physical Environment

This section outlines the details of the physical conditions/geographical data about the immediate building environment and of the general location.

Table 4-Physical Environment

General	- Ninety-eight units in the building. - Approximately 200 residents.
Climate (Appendix E) [1]	**Daily Average Temperature** [26] - Winter (November-March): -3 °C - 2.8 °C - Summer (May-August): 17.3 °C - 23.6 °C **Sunlight** [27] - Percentage of daylight hours: ii. Winter: 29.9% ii. Summer: 55.7% **Precipitation** [26, 28] - Average rainfall per month: 54.14mm - Average snowfall from October-April: 17.36 cm
Utilities (Appendix E)	All units have access to electricity, gas and water. Water/gas is not metered separately: **Gas** - The building is heated with gas-boilers. - Units on fourth floor and the penthouse have gas fireplaces. **Water** - Each unit has individual laundry/washing machine - Sinks and toilets in the common area washrooms - Two fountains in the garden (Appendix E)

1.7-Client Ethics and Values

Our Client, the Board of TSCC 1626 is very passionate about sustainability and energy conservation programs. The Board participates in an active recycling program and broadcasts energy conservation tips through its Concierge Plus communication website to educate the residents of the condominium. The Board is committed to high standards, maintaining an aesthetically pleasing environment at the condominium and respecting the environment through seeking environmentally sustainable design recommendations.

2.0-Detailed Design

The proposed design provides strategies for the common elements in the condominium, which the design team categorized into four major target areas: the garden, common area washrooms, the water piping/supply room and the common living areas (library, multi-purpose room, the exercise room and the windows of the condominium). Below is a detailed description of the components of the design and how they meet the objectives of the project, the Design for Efficiency (by reducing water and heat energy usage) and the client's needs. The cost of installation of the designs is approximately $225000 (the cost of labour is not included). See Appendix F and G for the detailed calculations.

2.0.1. Garden Area

Recommendation 1: Installing Drip Water Irrigation System

The system would use tubes to slowly drip water to the roots of plants. The advantage of this system is that the drip process keeps water loss at a minimum level and it can save up to 30- 50% of the water used in a sprinkler system [29].

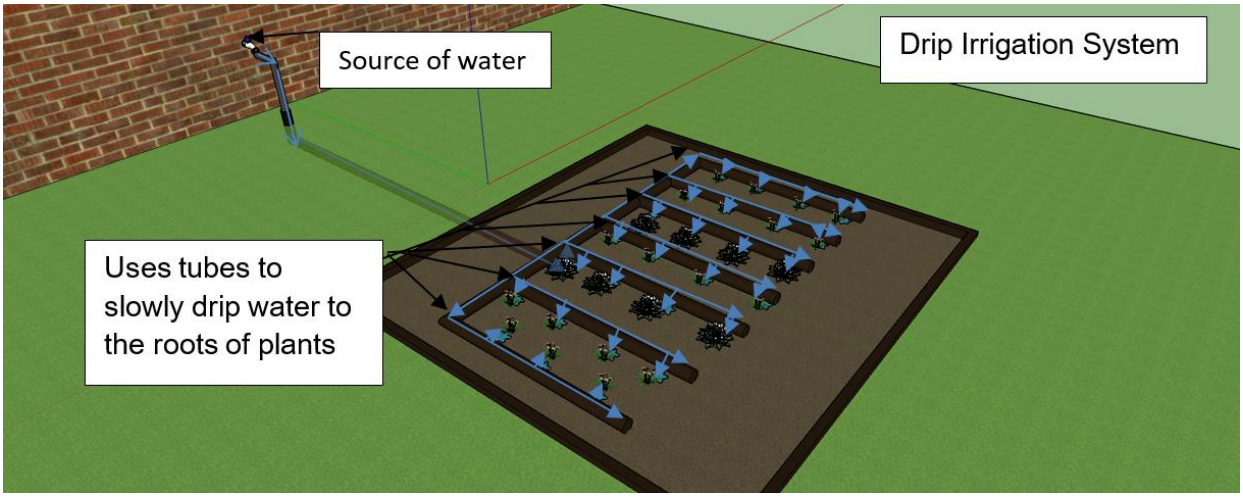


Figure 1-Image of the drip water irrigation system

Recommendation 2: Planting Shrubs

These shrubs near the fountain will shelter the fountain water from excessive evaporation by the sun [30]. This will reduce the amount of water wasted so that more water remains within the fountain system. As a result, less water will be required to be replaced.

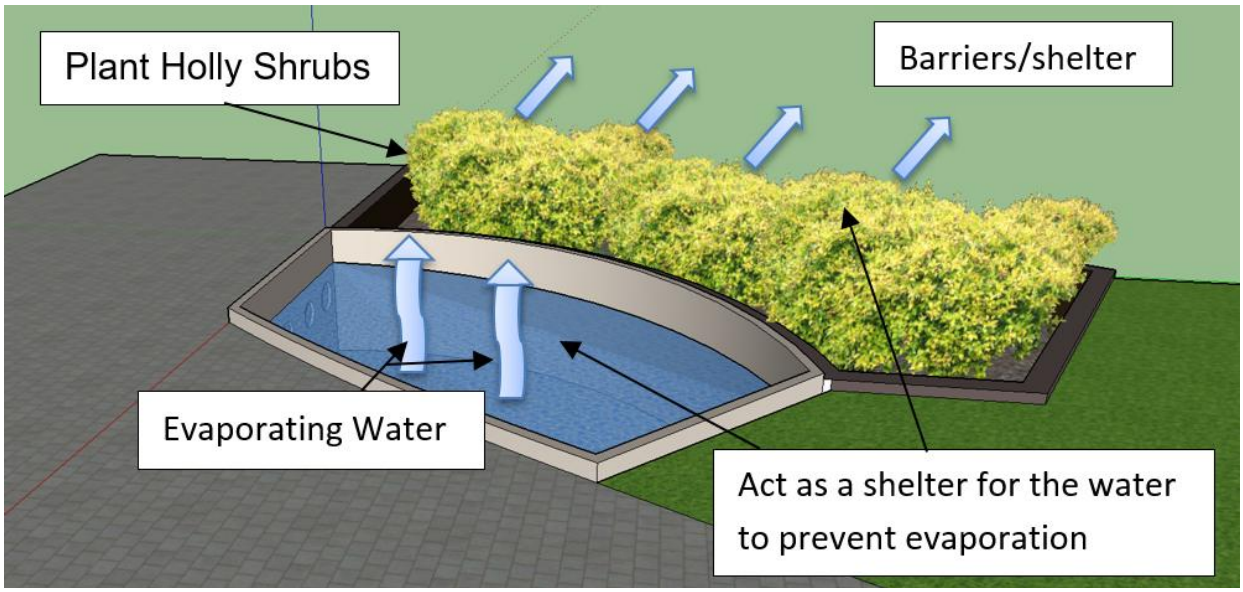


Figure 2-Image of the fountains sheltered by shrubs.

Recommendation 3: Spreading Organic Wheat Straw on Soil

To increase water retention in the grass, the design team also recommends placing organic wheat straw on top of the soil in the garden. A mixture of 7.5% wheat straw into soil can increase water retention in soil within 10 - 15 days. Putting wheat straw on the grass in the garden will decrease excessive loss of water from the grass, allowing water to be retained so that external watering is needed less frequently. Thus, it will provide water usage savings [31].

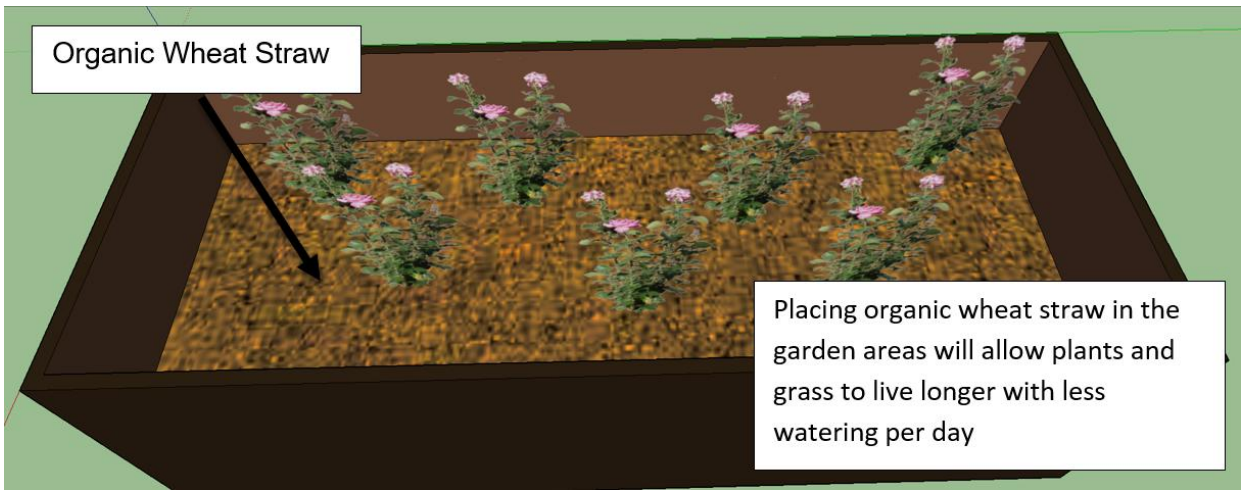


Figure 3-Image of organic wheat straw.

Table 5- Designs for Garden and Evaluation Against Objectives

Objectives	**Design Details**
O1	30%-50% reduction in water usage [29]
O2	The cost of the garden system is $6360 (Appendix F)
O3	Long life expectancy [32]
O4	Requires initial installation. Maintenance required is minimum
O5	No harmful emissions

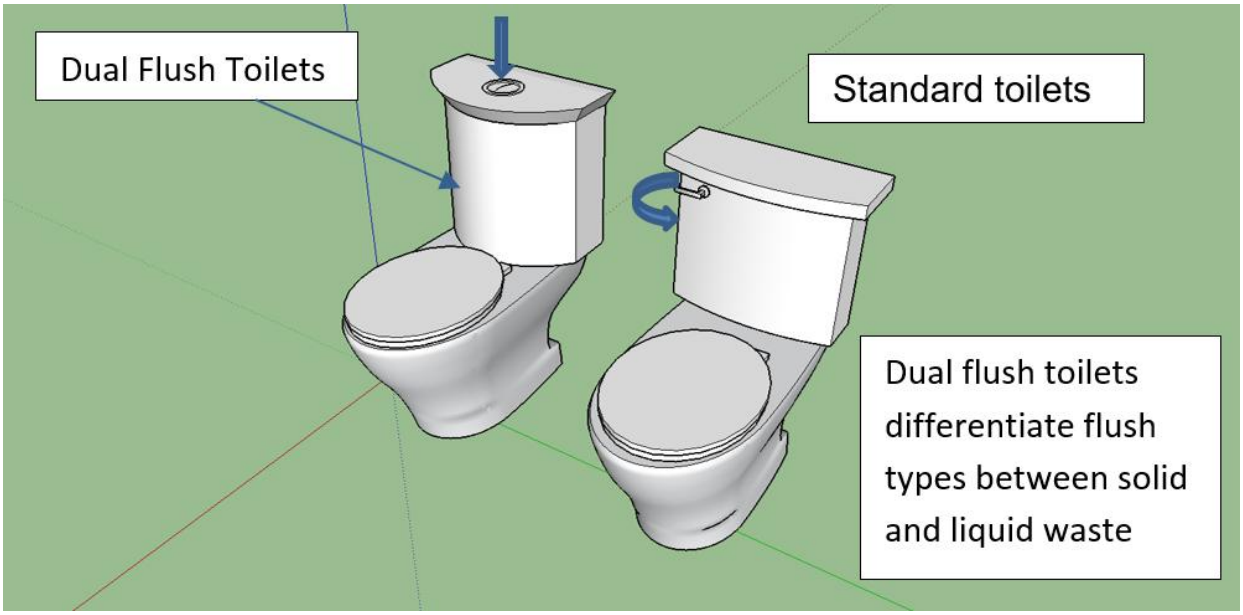
How the Designs for the Garden Area Meet the Client's Needs:

This design system for the garden area is effective and meets the client's needs as it reduces the amount of excess water lost due to evaporation, allows plants and grass to retain water for a longer amount of time and because of the drip irrigation system, it reduces the amount of water wasted when watering by supplying only the required amount of water. The design system has a long expected lifespan, requires only minimal maintenance after initial installation and does not release any harmful emissions into the environment.

2.0.2 Designs for the Common Area Washrooms:

Recommendation 1: Installing Dual Flush Toilets

The design team recommends installing Dual Flush Toilets in the common area washrooms. This design aims for reduction in water usage by targeting toilet flush systems. The dual flush toilets differentiate flush types between solid and liquid waste so that greater conservation can be achieved compared to standard toilets. The design consists of a toilet that allows users to choose between half flush for liquid waste and full-flush for solid waste. This design will have a 18% water reduction compared to the



standard toilets [33].

Figure 4-An image of the recommended dual flush systems and standard toilets currently installed in the condominium.

Recommendation 2: Installing Aerators and Automatic Motion-Sensor Faucets

Automatic motion-sensor faucets are programmed to release a small quantity of water when activated by the motion of the user's hands and will automatically stop running when they sense that the hands have been removed. The settings can also be programmed to provide warm water instead of hot or cold which will save energy. The automatic shut-off of the faucets has a lower risk of accidental sink overflow. Additionally, since the automatic faucets do not require users to turn off the faucets, taps will not be turned off improperly and leave the faucets dripping[34]. Aerators installed in the faucets reduce the water-flow by mixing water and air. As the aerator does not change water perception due to higher velocity, the user will not notice the reduced water flow.

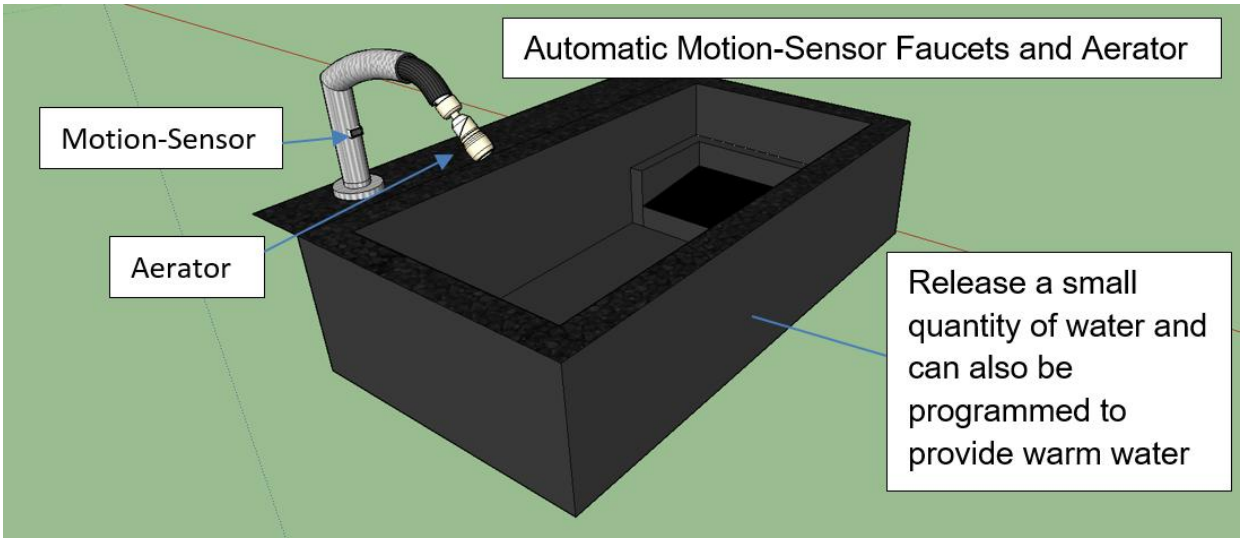


Figure 5-Image of the recommended changes to currently installed faucets.

Table 6-Designs for Washrooms and Evaluation Against Objectives

Objectives	**Design Details**
O1	Reduce water usage by 18% [33]
O2	The cost of this installation is $1383.86.
O3	Long Life expectancy
O4	Requires initial installation. Maintenance required is minimum
O5	No harmful emissions

How the Designs for the Common Area Washrooms Meet the Client's Needs:

This design system for the common area washrooms is very effective because it significantly lowers water usage. The dual-flush toilets use less water than standard toilets for liquid waste and motion-sensor faucets reduce water wastage originating out of sinks. The design also requires minimum maintenance after the initial installation and is easy to use.

2.0.3. Designs for the Common Living Areas:

Recommendation 1: Installing Thermally Efficient Windows

The team recommends that the windows in the common elements are coated with low-emissivity materials that are based on SnO_2 and anti-reflective coating on both sides [35,36,38]. This reflects intense sunlight during summers. In the winter, the windows allow more solar energy to pass through, therefore lowering the heating demand of the building. The estimated energy reduction is about 4% to the whole condominium [37].

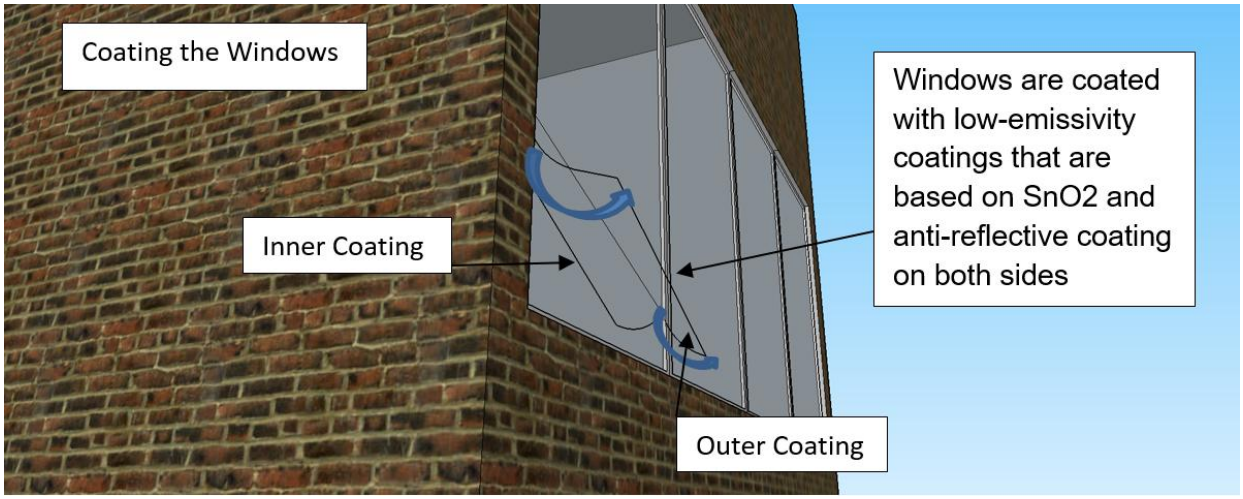


Figure 6-Image of reflective coating on the common element windows.

Recommendation 2: Replacing Furnace Filters

This design focuses on improving ventilation by replacing furnace filters every 3 months or as soon as they become dirty [39]. Clean furnace filters will have approximately 5% to 15% energy savings annually [40,41]. Another advantage is that they improve the air ventilation and contribute to dust reduction [41].

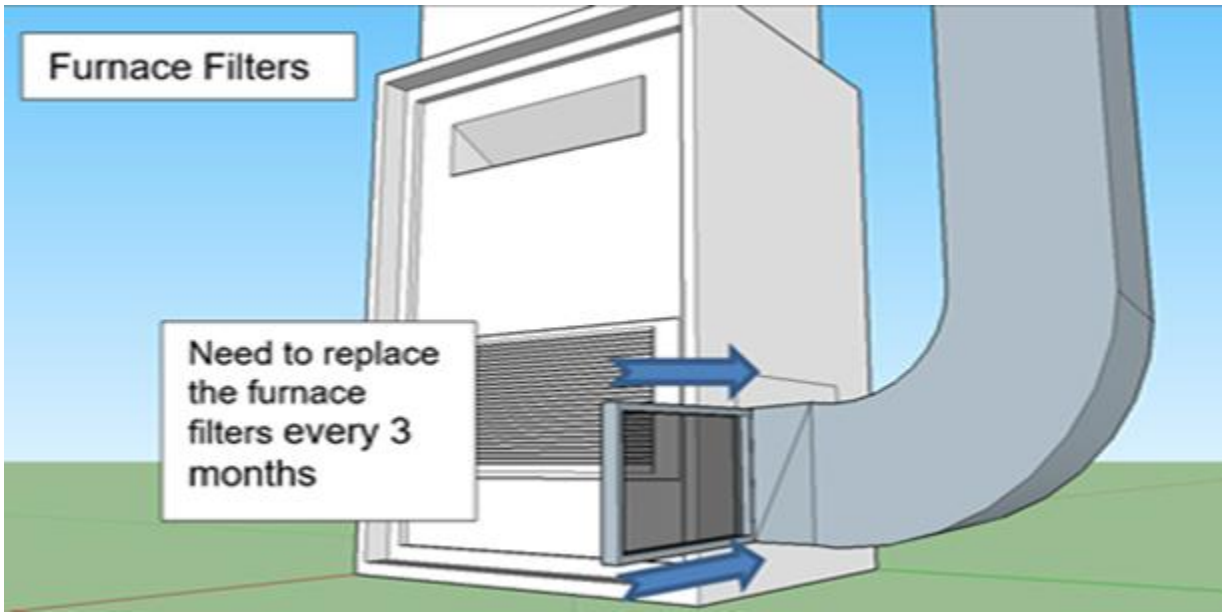


Figure 7 - Image of commonly used furnace filters.

Table 7-Designs for Common Areas and Evaluation Against Objectives

Objectives	Details
O1	9%-19% energy saving annually [37,40,41]
O2	The installation cost is $217000, which varies with number of windows. (Appendix F)
O3	Lifespan is over 20 years [42]
O4	Requires initial installation. Easy to operate. Minimum maintenance required.
O5	No harmful emissions

How the Designs for the Common Living Areas Meet the Client's Needs:

This design system is very effective because heat energy usage is lowered as more energy can be absorbed from the sun and the maintenance task also increases the efficiency of the heaters which will decrease the amount of heat wasted due to dirt build-up in the filters.

2.0.4. Designs for the Piping/Supply Room

The design will be preceded by conducting a thermal audit to determine if there are any air/heat leaks in the condominium.

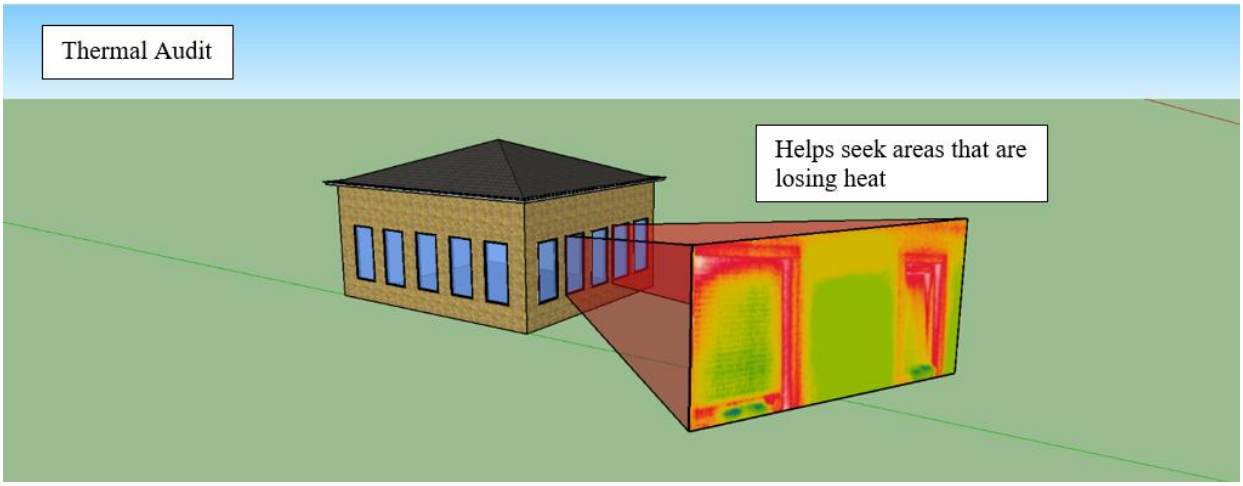


Figure 8-Image of a thermal audit being conducted.

Recommendation 1: Insulating Exposed Water Pipes

The team recommends insulating the exposed pipes that connect to the water heater/storage tanks and boilers with Armaflex Pipe Insulation. Currently, the exposed water pipes at the condominium are insulated by standard pipe insulation materials. Armaflex insulation is inexpensive and prevents energy loss while protecting the pipes from condensation and freezing at a higher rate that the current material. It has easy and quick installation and resists temperatures ranging from -183ºC-82 ºC.[43]

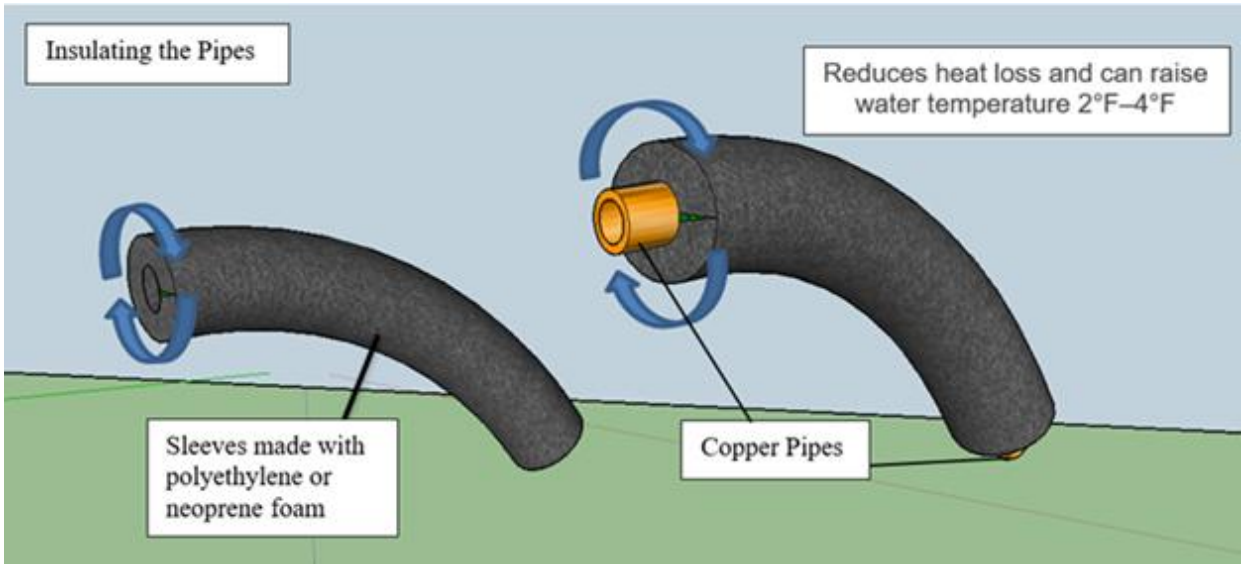


Figure 9-Image of Armaflex Self-Seal Rubber Insulation

Recommendation 2: Regular Water Drainage

Draining 0.95 L of water from each hot water tank removes sediments that obstruct heat transfer and lower the efficiency of the heaters [47].

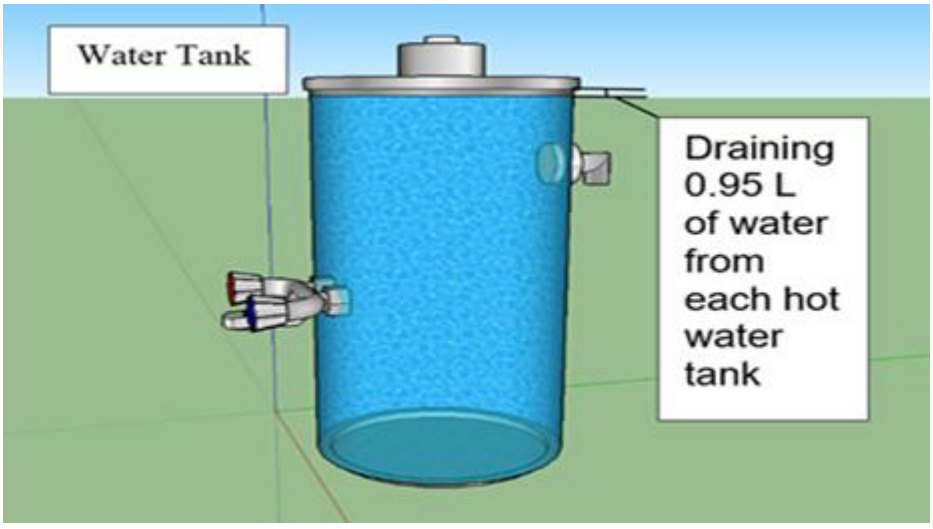


Figure 10-Image of a water tank.

Table 8-Designs for Piping/ Supply Room and Evaluation Against Objectives

Objectives	Detail
O1	Recommendation 1 raises the water temperature by 1-2 °C and reduces waiting time for hot water; this also helps the user to conserve water [46]. Recommendation 2 removes sediments that obstruct heat transfer and lowers the efficiency of the heaters [47]
O2	The estimated cost of the design is $185.6. (Appendix F) The payback period is 3 months.
O3	The lifespan will be over 20 years [45].
O4	No external operation required after initial installation
O5	No harmful emissions

How the Designs for the Piping/Supply Room Meet the Client's Needs:

The piping insulation causes water usage to be reduced because residents do not have to run water for long in the faucets/showerheads before receiving hot water. Energy loss is reduced as less heat escapes through the insulated pipes, and lowering the water heater temperature reduces standby heat and demand losses. The design has a short payback period and small initial cost.

2.1-Regulations, Standards, and Intellectual Property

The design team implemented regulations specified under the legislation and relevant standards. The design proposes the installation of commercially available products and thus any associated patents will not affect the client.

2.1.1 Regulations and Standards

This section outlines the regulations, codes and standards relevant to the design proposed by the design team. Table 9 provides details of these regulations, standards and the associated impacts.

Table 9-The regulations and standards relevant to the design

Name	Type	Description	Impact
Condominium Act 1998 [48] Section 89, 91, 93	Provincial Legislative Act	● Details the use of the Reserve Fund as well as requirements about condominium maintenance.	● The design proposes: i. changes only to the condominium which are under the Condo Board. ii.
Residential Tenancies Act - Maintenance Standards. [49] Sections 5, 7, 9, 11, 21	Ontario Regulation	● Details regulations with regards to: i. Preventing leakage and defects. ii. The minimum temperature of hot water must be at least 43°C. iii. Chimneys/flues/gas vents shall be kept clear of obstructions.	● The design ensures: i. Sealing of water pipelines to prevent water loss, ii. The recommended decrease in water temperature is as required by the regulation, iii. Regular replacement of air and furnace filters.
ISO 50002:2014 - Energy Audits -- Requirements with guidance for use. [50]	Standard	● Outlines the requirements for conducting an energy audit and how to analyze the results.	● The thermal audit should be conducted by an agency and/or inspector certified by ISO 50003:2014. [51]

2.2-Testing

This section outlines the tests that will be conducted to determine whether the final design meets the key objectives. Detailed test methods are included in Appendix J and K.

Table 10-Tests to be conducted

Objective	Proposed Test	Result Type
O1	• 24 h simulated-use test- CAN/CSA P.3-15. [52]	• Energy consumption comparison
O2	• Calculate the original cost of all systems (Appendix K) vs the cost of the updated version.	• Calculate payback period and savings
O3	• Flexometer Testing- ISO 4666-1:2010. [53]	• Fatigue-life above 10 years
O4	• Environmental Compliance Auditing- CSA Z773-03 (R2013). [54] • Water quality Test when using irrigation systems. - ISO 16075-3:2015[55]	• Audit report • Producing the best water quality from the drip irrigation system

2.3-Implementation Requirements

This section outlines the resources and effort needed from the client in order to implement the final design.

Table 11-Monetary Investments for Implementation

Item	Cost
Pipe Insulator	$4.64 per meter of piping [43]
Furnace Filter	$29.99 per furnace
Organic Garden Wheat	$60-$80 per metric ton
Short Shrubs	Around $18.00-$40.00 each varying in types [30]
Rain Bird SMRT-Y Moisture Sensor Kit	Around $200.00/ kit. [56]
Rain Bird Drip Irrigation Kit for 7 square meters	Average $45.00. [56]
Toilets (dual flush)	$192 per unit [57]
Motion-sensor faucets	$87.98 per unit [58]
Coated windows	$217 per set [59]
Window installation materials such as glues and etc.	$20 per window [60]

Table 12-Required Personnel for Implementation

Personnel	Description
Heat Auditor	Thermal Audit $218-544 per hour
Condo Maintenance Technician	Change furnace filter

Licensed Plumber	Install all plumbing related equipment $45-150 per hour [61]
Professional Irrigation Contractor	Install drip irrigation system $59-89 per hour
Window installation Person	Install windows $84.72 per window [62]

Table 13-Possible disruption during implementation

Water outage	Water is restricted for safety during plumbing work period

2.4-Life Cycle and Environmental Impact

This section identifies potential environmental impacts of the design and assesses the positive and negative aspects of the impacts, developed by the design team using a Life Cycle Assessment. The team considered four aspects of the life of the primary products involved in the design. [63]

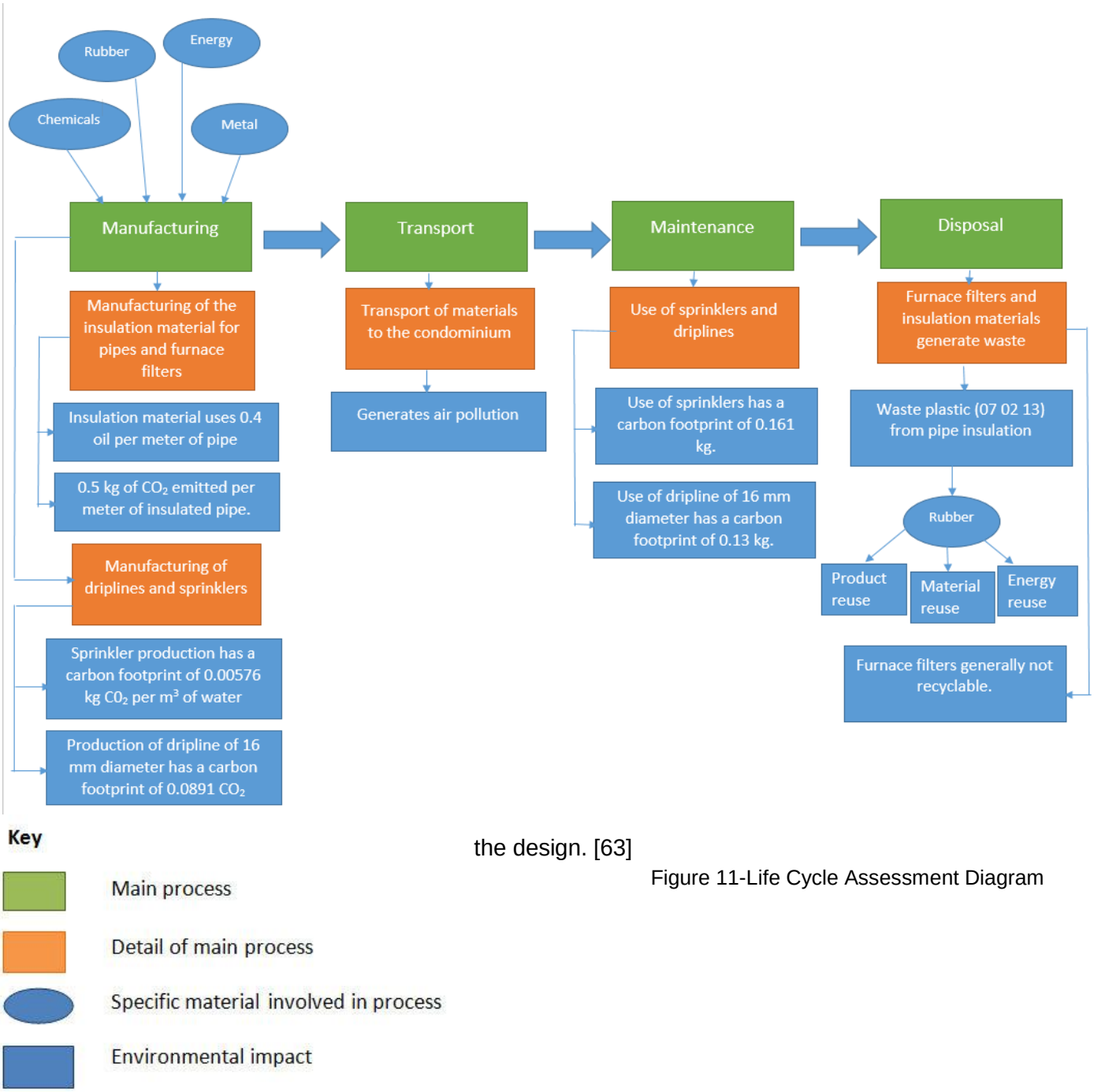


Figure 11-Life Cycle Assessment Diagram

Table 14-Positive Impacts of the Design

Positive Impacts	Source of Impact
• Reduces fossil-fuel consumption	• Insulation prevents excessive heat loss and increases energy efficiency.
• Reduces excessive loss of water.	• Installing a drip irrigation system • Insulating the pipes
• Does not require manufacturing and disposal of excessive materials.	• Minimum physical change.

Table 15-Negative Impacts of the Design

Negative Impacts	Source of Impact	Mitigation
• Waste disposal	• The disposal of the insulation material generates waste. • Regularly-replaced furnace filters.	• Selected material can be recycled. • Filter can be reused/cleaned.
• Air Pollution	• Transport of materials to the condominium.	• Coordinated logistics to reduce frequency of travel.
• Can have an adverse impact on the surrounding ecosystem.	• Organic Wheat placed on soil	• Applying non-harmful sprays to area. [64]
• Alkalization • Soil acidification	• From the drip-water system	• “ Allow for access to channels for maintenance in design.”[65] • Develop irrigation management infrastructure for maintaining irrigation and drainage systems. [65]

2.5-Human Factors

The design team analyzed the levels of human factor using Kim Vicente's Human-Tech Ladder concept, with a focus on the psychological level. The table below shows the 3 significant human factor for the design including physical, psychological, and political level.

Table 16-Human factors in 3 levels

Factor Level	**Impact/Addressing Method**
Physical	For Garden ● No manual control or adjustment for moisture-sensing sprinkler For Bathroom ● 2 buttons for dual flush/aerator for faucet ● Less turns necessary for desired perception of water flow for faucet and sinks
Psychological Level	For ventilation and Window/Heating ● More conscious of possible draft leakage ○ Residents can quickly detect draft leakage and report to property management ○ Room temperature are kept the same between days and nights For Piping Insulation ● Less wait time for desired water temperature ○ No longer need to waste water when waiting for hot water
Political	● Shall comply with Condominium Act Part 6 Section 98 for any modification.

2.6-Social Impact

An innovative utilities design could have a large impact on residential buildings. The community should strive to maximize energy/water usage. Inefficient systems cause water/energy and financial loss. A major benefit is the potential cost savings that could be achieved, which may result in other condominiums implementing this design. The negative impacts of the design will be lessened by ensuring that all requirements and regulations are met. The primary concern for stakeholders would be the design's impact on water/gas usage and how it affects energy-saving techniques.

Table 17-Social Impacts of the Design

Stakeholders	**Social Impact**
S1	• Improves the reliability of the design • Less use of water, causes less water to be provided
S2	• Prevention of thermal energy loss
S3	• Efficient ways of utilizing resources, reduces environment and climate change
S4	• Water conservation
S5	• Helping people live with better regards for the environment
Social Groups	**Social Impact**
Condominium residents	• Improve awareness of utility optimization in all the condominium common element and influence change in their individual units
Contractors and Plumbers	• CSA standards have to be taken into account • Qualified/licence in their profession
Gardeners	• Gardener adapts to drip irrigation system in place

2.7-Economics

This section contains the necessary costs (fixed/capital cost), operating, and disposal costs for the design. The costs for the design are all reasonable estimates taken from a range of appliances already on the market, varying on the quality displayed in the source. Cost specification included in Appendix H.

Table 18-Capital Cost of the Designs

Cost	**Amount (CAD dollars)**
Drip Irrigation system	● Consist of two parts: 1. Rain Bird SMRT-Y Moisture Sensor Kit $200 2. Drip Irrigation Kit [56] $45
Organic Garden Wheat Straw	$60 - $80 per metric ton
Holly Shrub	$20-$40[30]
Dual Flush Toilet	$200-$400 per toilet[57]
Aerator For Faucet/Showerhead	$3.00-$10.00 each (varying on type of material)[63]
Coated windows	$217 per set of windows[59]

Table 19-Variable Cost

Cost	**Amount (CAD dollars)**
Professional Plumber	● To install pipe insulation ● $45-150 per hour[58]
Pipe Insulator	$4.64 per meter of piping[43]
Heat Auditor	● Heat auditing the building. May use the thermal camera. ● $218-$544/hour
Professional Irrigation Contractor	$40 - $50 per hour[67]
Licensed Dual Flush Installation Cost	$212.00-$499.00 per toilet replacement [68]
Licensed Window	Install windows

Installation Technician	$84.72 per window[62]

Table 20-Operating Cost

Cost	Amount (CAD dollars)
Maintenance	• Constant monitoring for heat leakage and drafts and replacing plastic insulation • Material to block drafts • The minimal cost of maintenance is 1hr-1day for $100 to $1000 based on situations and pipe conditions.[69]

Table 21-Disposal Cost

Cost	Amount (CAD dollars)
Professional Plumber	$45-150 per hour
Disposal of Pipe Insulator	External cost required to dispose Recyclable Pipe Insulator, and Reusable Heat Furnaces and the price depends on material
Professional Irrigation Contractor	Around $59 - $89 per hour[70]
Garden Wheat/Holly	• Holly and Wheat are Bio-degradable. • No cost

Payback Period

Payback period equals the (utility cost / (cost saving - operating cost)) is 39 years (refer to Appendix L).

2.8-Conclusion

The proposed design recommends the implementation of various energy and water efficiency techniques currently prevalent. The installation of these components in the common elements of the condominium will result in an estimated 30% cost savings. The payback period of the design will be 39 years and an estimated cost savings of $884 per year. Utilizing optimum available products will further increase the savings at the condominium.

3.0-Reference List

[1] NHS Profile, 5350020.00 (2011) Statistics Canada [Online] Available: www.statcan.gc.ca.[Accessed: Feb 2nd 2016]

[2] Hill, D. , "*Analysis of the Annual Energy and Water Consumption of Apartment Buildings*", CMHC Database (Technical Series 01-142*)*, 1996.

[3] Water Usage Estimating Chart, Avid Water Systems, 2011.[Online] Available: http://avidwatersystems.com.

[4] Woodford C., "Gas Central Heating Boilers", 17th April 2015. [Online]. Available: http://www.explainthatstuff.com. [Accessed: 28-Jan-2016].

[5] Garg, S. P. , "*Rule of Thumb and Tips for Water Management for Apartment Buildings (3-4 Stories High)*", October 2010.

[6] Builder Insight, "Technical Maintenance Bulletin" [Online]

[7] City of Toronto, " 2016 Water Rates", 2015. [Online]. Available: www1.toronto.ca.

[8] Patil, K., Ghosh, A., Das, D., Vuppala, S. K., "*Integrated Water Consumption Monitoring Solution for Enterprises*", ICONIAAC 2014, Article 10, New York, 2014.

[9] City of Toronto | City of Toronto. [Online]. Available at: www1.toronto.ca. [Accessed: 28-Jan-2016]

[10] Ontario Ministry of Energy, "Home",. [Online]. Available at: http://www.energy.gov.on.ca/en/. [Accessed: 28-Jan-2016].

[11] "Ontario Ministry of the Environment and Climate Change,", July 2014. [Online]. Available at: https://www.ontario.ca/ministry-environment-and-climate-change. [Accessed: 28-Jan-2016].

[12] "Ministry of Natural Resources and Forestry," Ontario.ca, 2014. [Online]. Available at: https://www.ontario.ca/ministry-natural-resources-and-forestry. [Accessed: 28-Jan-2016]

[13] Toronto Green Network, 2016. [Online]. Available: http://www.weconserve.ca. [Accessed: 27- Jan- 2016].

[14] U.S. Environmental Protection Agency, "*Energy Efficiency in Water and Wastewater Facilities"*, 1st Edition., 2013, pp. 1-23.

[15] WaterWorld Magazine, "Water Utility Efficiency Priorities: What Are They?", 2016. [Online]. Available: http://www.waterworld.com. [Accessed: 28- Jan- 2016].

[16] ASHRAE HVAC Applications Handbook, "Service Water Heating,", 1st Edition, 2016, pp. 11-50.

[17] Rishel, J., "*Wire-to-Water Efficiency Of Pumping Systems*", ASHRAE Journal, pp. 40-44, 2016.

[18] U.S. Environmental Protection Agency, "*The Role of Energy Performance Contracting in Deployment of Nonresidential Solar Water Heating Systems"*, 1st Edition., 2013, pp. 5.

[19] Abrams, D. and Hiller, C., "*A Simple Software Program for Evaluating Energy Consumption and Operating Costs for Water Heaters"*, 1st Edition. 2016, pp. 2-4.

[20] Water Heater Repair Guide, "Water Heater Life Expectancy", 2016. [Online]. Available: http://www.water-heater-repair-guide.com. [Accessed: 28- Jan- 2016].

[21] Your Mechanic, "How Often Should the Fuel System Be Inspected?", 2015. [Online]. Available: https://www.yourmechanic.com. [Accessed: 10- Feb- 2016].

[22] Thiele, T., "*Programming Programmable Thermostats*", 2016. [Online]. Available: http://electrical.about.com. [Accessed: 31- Jan- 2016].
[23] ASHRAE, "*ASHRAE Equipment Life Expectancy Chart"*, 1st Edition. 2016.
[24] Water Heater Repair Guide, "*Water Heater Temperature - Water Heater Setting*", 2016. [Online]. Available: http://www.water-heater-repair-guide.com. [Accessed: 31- Jan- 2016].
[25] Government of Ontario, "Safe Drinking Water Act, *c. 32*",2002 [Online]. Available at: https://www.ontario.ca/laws/statute/02s32. [Accessed: 27-Jan-2016].
[26] Government of Canada, "Canadian Climate Normals", 2015. [Online]. Available: http://climate.weather.gc.ca. [Accessed: 26- Jan- 2016].
[27] Environment Canada, "Canadian Climate Normals 1981-2010 Station Data," 2015. [Online]. Available at: http://climate.weather.gc.ca. [Accessed: 26-Jan-2016].
[28] Toronto Weather Statistic, "Wind Speed over the Last 5 Years (quarterly data) for Toronto,". [Online]. Available at: http://toronto.weatherstats.ca/. [Accessed: 26-Jan-2016].
[29] S. van der Kooij, M. Zwarteveen, H. Boesveld and M. Kuper, "The efficiency of drip irrigation unpacked", *Agricultural Water Management*, vol. 123, pp. 103-110, 2013. [Online]. Available: http://www.sciencedirect.com.myaccess.library.utoronto.ca/science/article/pii/S0378377413000759.
[30] "Holly - Shrubs - Garden Plants & Flowers - Garden Center - The Home Depot", *Homedepot.com*, 2016. [Online]. Available: http://www.homedepot.com/b/Outdoors-Garden-Center-Garden-Plants-Flowers-Shrubs/Holly/N-5yc1vZc8r6Z1z0n71k. [Accessed: 24- Mar- 2016].
[31] "A Method to Reduce Water Evaporation from Soil Using the Absorbent Properties of Organic Wheat Straw", AMNH, 2016. [Online]. Available: http://www.amnh.org/learn-teach/young-naturalist-awards/winning-essays2/2014-winning-essays/a-method-to-reduce-water-evaporation-from-soil-using-the-absorbent-properties-of-organic-wheat-straw.
[32] "Drip Irrigation", *Colostate.edu*, 2016. [Online]. Available: http://www.colostate.edu/Dept/CoopExt/4dmg/Garden/drip.htm.
[33] L. Oliveira, O. Goncalves and C. Uchida, "Performance evaluation of dual-flush WC cistern in a multifamily building in Brazil", *Building Services Engineering Research and Technology*, vol. 30, no. 1, pp. 27-36, 2009.
[34] "Automatic Faucets for Water Conservation" [Online]. Available: http://sustainability-certification.com/automatic-faucets/
[35] J. Mohelnikova, "Materials for reflective coatings of window glass applications", *Construction and Building Materials*, vol. 23, no. 5, pp. 1993-1998, 2009. Available at: http://www.sciencedirect.com.myaccess.library.utoronto.ca/science/article/pii/S0950061808002596
[36] J. Mohelníková, "Infrared Reflective Coatings for Window Glazing", *Solid State Phenomena*, vol. 144, pp. 226-231, 2009. Available at: http://www.scientific.net.myaccess.library.utoronto.ca/SSP.144.226
[37] T. Rosencrantz, H. Bulowhube, B. Karlsson and A. Roos, "Increased solar energy and daylight utilisation using anti-reflective coatings in energy-efficient windows", *Solar Energy Materials and Solar Cells*, vol. 89, no. 2-3, pp. 249-260, 2005. Available at:

http://www.sciencedirect.com.myaccess.library.utoronto.ca/science/article/pii/S0927024805000759.

[38] K. Tonooka and N. Kikuchi, "Super-hydrophilic and solar-heat-reflective coatings for smart windows", *Thin Solid Films*, vol. 532, pp. 147-150, 2013. Available at: http://www.sciencedirect.com.myaccess.library.utoronto.ca/science/article/pii/S004060901201680X.

[39] "Heat & Cool Efficiently : ENERGY STAR", *Energystar.gov*, 2016. [Online]. Available: https://www.energystar.gov/index.cfm?c=heat_cool.pr_hvac

[40] "5 Reasons to Change Your Furnace Filter", *Angie's List | Find a Local Business, Ratings, Reviews, Deals*, 2013. [Online]. Available: https://www.angieslist.com/articles/5-reasons-change-your-furnace-filter.htm

[41] "Energy-saving tip: Clean furnace filters save energy dollars", *Montana State University*, 2016. [Online]. Available: http://www.montana.edu/news/3244/energy-saving-tip-clean-furnace-filters-save-energy-dollars.

[42] "Replacement windows: how many years can they last?", *Improvementcenter.com*, 2016. [Online]. Available: http://www.improvementcenter.com/windows/replacement-windows-how-many-years-they-last.html.

[43] Home Depot, "Armaflex Rubber Pipe Insulation," 2016. [Online].Available: https://www.homedepot.ca/en/home/p.armaflex-self-seal-78-inch--id-x-12-inch--wall-x-6-feet--rubber-pipe-insulation.1000502836.html.

[44] Home Advisor, "How much does it cost to hire a plumber," 2015 [Online].Available: http://www.homeadvisor.com/cost/plumbing/hire-a-plumber/

[45] "Armacell Product Catalogue," 2016 [Online]. Available:http://www.armacell.com/C1256AF100412A28/F/NT0148A7D6/$FILE/Armacell_UK&ROI_Product_Catalogue_Digital2013.pdf

[46] U.S. Department of Energy "Savings Project: Insulate Hot Water Pipes for Energy Savings," 2015. [Online]. Available: http://energy.gov/energysaver/projects/savings-project-insulate-hot-water-pipes-energy-savings

[47] U.S. Department of Energy, "Tips: Water Heating," 2015. [Online].Available: http://energy.gov/energysaver/tips-water-heating

[48] Government of Ontario, "*Condominium Act, c. 19*",1998. [Online]. Available at: https://www.ontario.ca. [Accessed: 27-Jan-2016].

[49] Government of Ontario, "*Residential Tenancies Act, 2006 Ontario Regulation 517/06 Maintenance Standards*" (Sections 7, 9, 11, 15, 21), 2006.

[50] ISO 50002:2014, Energy Audits - Requirements with guidance for us, ISO, London, UK, 2014.

[51] ISO 50003:2014, Energy Management Systems - Requirements for bodies providing audit and certification for energy management systems.

[52] CAN/CSA P.3-15, Testing method for measuring energy consumption and determining efficiencies of gas-fired and fuel oil-fired water heaters, 2004.[Online].Available at :https://subscriptions-techstreet-com.myaccess.library.utoronto.ca/products/695162

[53] ISO 4666-1:2010, Rubber, vulcanized - Determination of temperature rise and resistance to fatigue in flexometer testing - Part 1: Basic principles, 2010.[Online].Available at :https://subscriptions-techstreet-com.myaccess.library.utoronto.ca/products/583059.

[54] CSA Z773-03 (R2013),Environmental Compliance Auditing,2013.[Online].Available at :https://subscriptions-techstreet-com.myaccess.library.utoronto.ca/products/140618
[55] "Guidelines for treated wastewater use for irrigation projects - Part 3: Components of a reuse project for irrigation", ISO 2015, Switzerland, 2015.
[56] "Rain Bird SMRT-Y Soil Moisture Sensor Kit", *Rainbird.com*, 2016. [Online]. Available: http://www.rainbird.com/landscape/products/accessories/smrty.htm. [Accessed: 27- Mar- 2016].
[57] "Glacier Bay Dual Flush Two Piece All-In-One 1.60 Gal. Elongated Toilet in White | The Home Depot Canada", *Homedepot.ca*, 2016. [Online]. Available: https://www.homedepot.ca/en/home/p.dual-flush-two-piece-all-in-one-160-gal-elongated-toilet-in-white.1000669705.html.
[58] "iTouchless EZ Faucet - Touch-Free Automatic Sensor Faucet Adaptor | The Home Depot Canada", *Homedepot.ca*, 2016. [Online]. Available: https://www.homedepot.ca/en/home/p.ez-faucet---touch-free-automatic-sensor-faucet-adaptor.1000781554.html.
[59] "Jeld-Wen Windows & Doors 3500 SERIES Vinyl Slider Window 48 Inch x 48 Inch | The Home Depot Canada", *Homedepot.ca*, 2016. [Online]. Available: https://www.homedepot.ca/en/home/p.3500-series-vinyl-slider-window-48-inch-x-48-inch.1000526619.html.
[60] "Homewyse Calculator: Cost to Install Replacement Windows", *Homewyse*, 2016. [Online]. Available: http://www.homewyse.com/services/cost_to_install_replacement_windows.html.
[61] “How much does it cost to hire a plumber”, HomeAdvisor.[Online]. Available at: http://www.homeadvisor.com/cost/plumbing/hire-a-plumber/
[62] "Homewyse Calculator: Cost to Install Replacement Windows", *Homewyse*, 2016. [Online]. Available: http://www.homewyse.com/services/cost_to_install_replacement_windows.html.
[63] *Icid2015.sciencesconf.org*, 2016. [Online]. Available: http://icid2015.sciencesconf.org/65622/document. [Accessed: 28- Mar- 2016].
[64] "Keeping Squirrels Out of the Garden", *OUR ROOTS RUN DEEP.*, 2016. [Online]. Available: https://bonnieplants.com/library/keeping-squirrels-out-of-the-garden/. [Accessed: 28- Mar- 2016].
[65] "Chapter 4: Major impacts of irrigation and drainage projects", *Fao.org*, 2016. [Online]. Available: http://www.fao.org/docrep/v8350e/v8350e09.htm. [Accessed: 28- Mar- 2016].
[66] "Aerators & Adaptors - Plumbing Parts & Repair - The Home Depot", *Homedepot.com*, 2016. [Online]. Available: http://www.homedepot.com/b/Plumbing-Plumbing-Parts-Repair-Aerators-Adaptors/N-5yc1vZc68n?Ns=P_Smartsort|1. [Accessed: 24- Mar- 2016].
[67] "Irrigation services and pricing irrigation services", *Grounds-mag.com*, 2016. [Online]. Available: http://grounds-mag.com/mag/grounds_maintenance_dont_sell_yourself/. [Accessed: 28- Mar- 2016].
[68] "Learn how much it costs to Install a Toilet.", *Homeadvisor.com*, 2016. [Online]. Available: http://www.homeadvisor.com/cost/plumbing/install-a-toilet/. [Accessed: 28- Mar- 2016].
[69] J. Bousquin, "Caring for Your Plumbing System", *Houselogic*, 2010. [Online]. Available: http://www.houselogic.com/home-advice/plumbing/plumbing-system-maintenance/.

[Accessed: 28- Mar- 2016].
[70] "Homewyse Best Practices: Gardener - 2015 hiring guidelines, hourly costs and services.", *Homewyse*, 2016. [Online]. Available: http://www.homewyse.com/service_pros/irrigation_contractor.html. [Accessed: 24- Mar- 2016].
[71] “How much does it cost to hire a plumber”, HomeAdvisor.[Online]. Available at: http://www.homeadvisor.com/cost/plumbing/hire-a-plumber/
[72] S. Kavanaugh, “*Estimating demand and efficiency*”, ASHRAE, pp.37, 2003.
[73] Unf.edu, "Chapter 5 Cost Estimation", 2016. [Online]. Available: http://www.unf.edu/~dtanner/dtch/dt_ch5.htm.
[74] "Guidelines for treated wastewater use for irrigation projects - Part 3: Components of a reuse project for irrigation", ISO 2015, Switzerland, 2015.
[75] "Alkali", *TheFreeDictionary.com*, 2016. [Online]. Available: http://www.thefreedictionary.com/alkali.

Appendices

Appendix A

This appendix provides detailed explanation about the interests of the stakeholders to this project.

1. City of Toronto

The City of Toronto is responsible for Bylaws and it enforcement[9]. All of the regulations and the acts that the project must follow as mentioned in Appendix E will be enforced by the bylaw enforcement and investigations services units of the City of Toronto.

The City of Toronto is provider of drinking water in the Toronto area[9]. The water provider of the city has interest in this project since they control the distribution of drinking water and the quality of those drinking water.

2. Ontario Ministry of Energy

Although the Ontario Ministry of Energy focused mainly on the electrical energy, it also works on developing other forms of sustainable energy[10]. Thermal energy which is related to this project will be an interest of the Ontario Ministry of Energy.

3. Ontario Ministry of the Environment and Climate

The Ministry of the Environment and Climate Change will be interested in the environmental impact of this project[11].

4. Ontario Ministry of Natural Resources and Forestry

The Ministry of Natural Resources and Forestry will be interested in the water conservation aspect of this project[12].

5. NGOs focused on energy efficiency

An informal network of groups and businesses called The Toronto Green Network is focused on helping people living green[13]. Some of its members will be interested in this project.

Appendix B

The main design function is to reduce the use of water and gas usage, that will lower the total cost of the utilities. In order to achieve this the design team will have to control the amount of thermal energy being lost and introduce a more efficient system that will increase the efficiency of the utilities being used.

***Process:** The team decided to approach function generation by first carrying out the Black Box Method. The team used these to identify the functional basis and then used this basis to develop the primary and secondary functions.

Black Box Method (First Draft)

This is a method used to help develop the functions of the design. In this method we view the system as a black box (i.e. keep it solution independent) and then consider the inputs and outputs in terms of mass, energy and information.

Table 22: Functional Basis developed by the design team using Black Box Method.

Inputs	Outputs
Mass ❖ Used water **Energy** ❖ Thermal energy ❖ **Information** ❖ Detect mass and energy usage	**Mass** ❖ Reused mass (water) and Recycled mass (water) ❖ Purified mass (water) ❖ Filtered mass (water) **Energy** ❖ Generates thermal energy **Information** ❖ Detecting of the location where mass and energy.

Appendix C

This appendix details how the design team developed the objectives. The design team used brainstorming to come up with as many objectives as possible and then used Pairwise Comparison. A Pairwise Comparison table is a way of ranking the objectives of each of the alternate designs given in the Conceptual Design Specification (CDS). From this table, the design team selected the highest ranked objectives to use for the final design comparison.
The first draft of objectives that the design team developed is as follows:

1. Lightweight - (8)
2. Efficiency increase by (40-50)% - (1)
3. Easy to operate, use, control - (5)
4. Cost savings (40%) - (1)
5. Small payback period (less than ten years) - (4)
6. Reduction in emissions/ environmentally beneficial - (8)
7. Life span (minimum life span has to be double the payback period) - (1)
8. Low initial cost - (7)
9. Volume/dimensions - (10)
10. How much energy will it use (over an extend period of time/ least as possible) - (5)
11. Resistance to natural disasters - (11)

	Objective Number 1	Objective Number 2	Objective Number 3	Objective Number 4	Objective Number 5	Objective Number 6	Objective Number 7	Objective Number 8	Objective Number 9	Objective Number 10	Objective Number 11
Objective Number 1	X	1	1	1	1	0	1	1	0	1	0
Objective Number 2	0	X	0	0	0	0	1	0	0	0	0
Objective Number 3	0	1	X	1	1	0	1	1	0	0	0
Objective Number 4	0	1	0	X	0	0	0	0	0	0	0
Objective Number 5	0	1	0	1	X	0	1	0	0	0	0
Objective Number 6	1	1	1	1	1	X	1	0	0	1	0
Objective Number 7	0	0	0	1	0	0	X	0	0	0	0
Objective Number 8	0	1	0	1	1	1	1	X	0	1	0
Objective Number 9	1	1	1	1	1	1	1	1	X	1	0
Objective Number 10	0	1	1	1	1	0	1	0	0	X	0
Objective Number 11	1	1	1	1	1	1	1	1	1	1	X
Total	3	9	5	9	7	3	9	4	1	5	0

Figure 12: Objectives Pairwise Comparison Table developed by the design team.

Table 23: on which test we are going to use:

Objective	What test we are going to Use:
O1	ASHRAE-D-A502011SI-06242011[18] ASHRAE-D-6003-20010406. [19] ASHRAE-D-6003-20010406. [19]
O2	ASHRAE-D-7615-19991231. [21]
O3	ASHRAE Equipment Life Expectancy Chart [24]
O4	ASHRAE-D-A502011SI-06242011. [18]
O5	ASHRAE-D-28004-20060511

Appendix D

This appendix includes details about the metrics in the Section 1.5 - Constraints. Laws and regulations related to this project will also be included.

Constraints

1. Have annual cost savings of 30%.
2. Safe to operate
3. Maintain drinking water safety.
4. Lifespan longer than the payback period
5. Not impact the residents in the condominium

Table 24: Details on Metrics

Metric	Details
Assessment of Cost Savings	i. Monthly bills from each prototype will be used in the following calculations: [(New monthly utility for water/gas - Old utility costs)/(Old utility cost)] x 100% Note: If the design is separate for each unit, the total cost savings will be 98* (cost saving for each individual unit).
Compliance with the regulations and laws	Authorities such as the City of Toronto will be assessing the alterations to the building according to specific laws related to condo and building. ● **Building Code Act, 1992, S.O. 1992, c. 23** [67] Section 3. Enforcement by municipalities 4. Provincial enforcement ● **Condominium Act, 1998, S.O. 1998, c. 19** [68] Section 76. Status Certificate 91. Alteration by Declaration 97. Changes made by corporation
C1	The design will undergo a Life Cycle Assessment to make sure that it does not have a negative impact on the environment. The LCA will be conducted under the guideline of ISO 14042:2000, “Environmental management - Life cycle assessment - Life cycle impact assessment”.[73]
C5	The design shall not impact the living experience of the residents in the condo. The design will get approved by the condo board to ensure the living experience will not be affected.

C3	The drinking water from the design will be tested under the: *Safe Drinking Water Act, 2002, S.O. 2002, c. 32[29].* The test will use PART VII of the act which is the "Drinking Water Testing". ● **Safe Drinking Water Act, 2002, S.O. 2002, c. 32:** PART VII Drinking Water Testing [29]
C4	The minimum lifespan is related to the Objectives Section which indicates that the maximum payback period will be ten years, therefore, the design has to have a lifespan of ten years.

Table 25: Additional Regulations

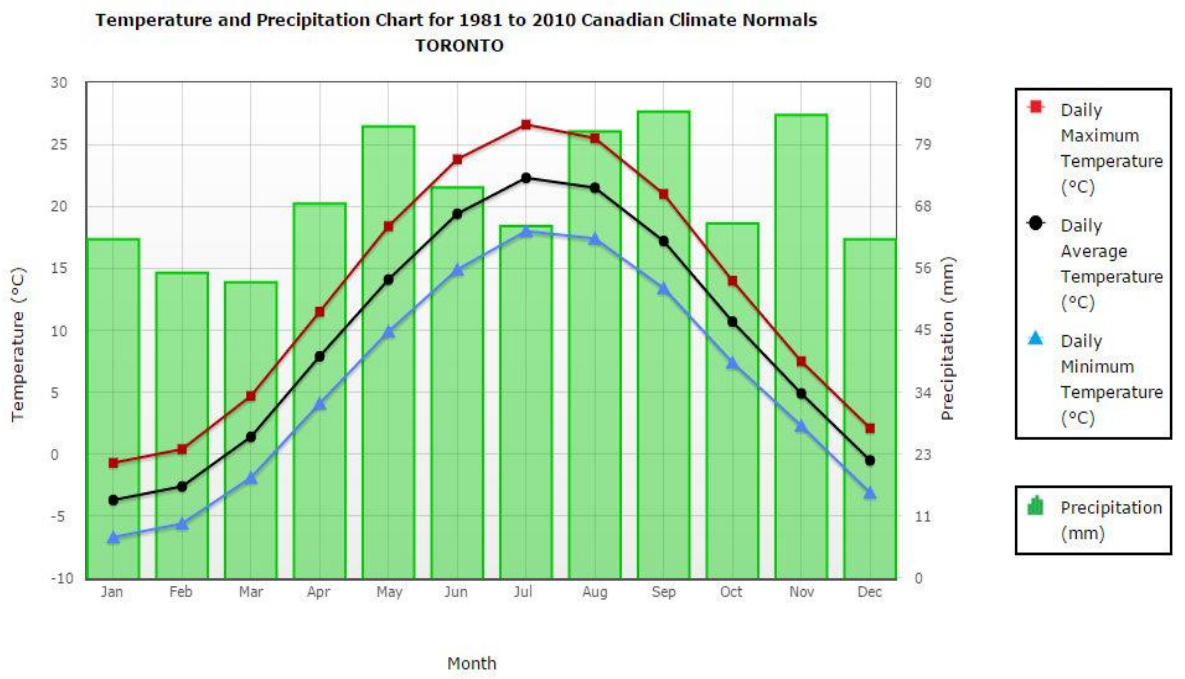
1. Water Heating	● **A50 -- Service Water Heating (SI)** [17] **ASHRAE-D-A502011SI-06242011** Section 50.1 System planning ➔ Energy Sources Section 50.2 Water heating equipment ➔ Gas-Fired Systems ➔ Oil-Fired Systems ➔ Electric Section 50.11/12 Hot Water Requirements and Storage Equipment Sizing ➔ Load Diversity ➔ Residential ➔ Commercial and Institutional
2. Water Efficiency of Pumping Systems	● **Wire-to-Water Efficiency of Pumping Systems**[18] ➔ Wire-To-Water Efficiency Analysis ➔ System Analysis
3. Equipment Life Expectancy	**ASHRAE Equipment Life Expectancy chart**[23]

	➔ Unit heaters: ➔ Gas or electric ➔ Hot water or steam
4. Evaluating Energy Consumption and Operating Costs for Water Heaters	**A Simple Software Program for Evaluating Energy Consumption and Operating Costs for Water Heaters:** [20] • **ASHRAE-D-7615-19991231** ➔ Calculation Methodology ➔ Assumptions and Limitations ➔ Specific Considerations for Heat Pump Water Heaters ➔ Energy Factor Rating Conditions ➔ User interface
5. Environmental Impacts of Surface Water Heat Pump Systems	**ENERGY AND EMISSIONS ANALYSIS[40]:** • **ASHRAE-D-28004-20060511**

Appendix E

This Appendix includes charts and tables used for climate-related calculations conducted for the Service Environment (Section 1.6) and further includes the details of the calculations. All calculations were done using Historical Climate Normals for Toronto from 1981

to 2010.



1981 to 2010 Canadian Climate Normals station data

Precipitation

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Rainfall (mm)	29.1	29.7	33.6	61.1	82.0	70.9	63.9	81.1	84.7	64.3	75.4	38.2	714.0
Snowfall (cm)	37.2	27.0	19.8	5.0	0.0	0.0	0.0	0.0	0.0	0.1	8.3	24.1	121.5
Precipitation (mm)	61.5	55.4	53.7	68.0	82.0	70.9	63.9	81.1	84.7	64.4	84.1	61.5	831.1

1981 to 2010 Canadian Climate Normals station data

Bright Sunshine

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Total Hours	85.9	111.3	161.0	180.0	227.7	259.6	279.6	245.6	194.4	154.3	88.9	78.1	2066.3
Days with measurable	21.2	21.3	25.1	26.4	28.3	28.2	30.1	29.5	27.2	27.4	20.6	19.7	304.8
% of possible daylight hours	29.7	37.7	43.6	44.8	50.0	56.3	59.8	56.7	51.7	45.1	30.5	28.0	44.5

Figure 13: Tables From: Canadian Climate Normals 1981-2010 Station Data [27]

1. Temperature Calculations

- **Winter**

  i. Maximum Average Temperature = (-0.7 + 0.4 + 4.7 + 7.5 + 2.1)/5 = 2.8 °C

  ii. Minimum Average Temperature = (-6.7 - 5.6 -1.9 +2.3 -3.1)/5 = -3 °C

- **Summer**
  i. Maximum Average Temperature: (18.4 + 23.8 + 26.6 + 25.5)/4 = 23.575 °C
  ii. Minimum Average Temperature = (14.9 +18.9+18+17.4)/4 = 17.3 °C

2. Sunlight

i. Percentage of possible daylight hours (per month):

- **Summers:** (50.0+ 56.3+ 59.8+ 56.7)/4 = 55.7 %
- **Winters**: (9.7+ 37.7+ 43.6 + 30.5+ 28.0)/5 = 29.9 %

3. Precipitation Calculations

- **Rainfall**
  i. Average rainfall per month throughout the year:
  (29.1+29.7+ 33.6+61.1+ 82.0+70.9+63.9 + 81.1+ 84.7 +64.3 +75.4+38.2)/12 = 54.14 mm
- **Snowfall**
  i. Average snowfall per month throughout winter (October to April):
  (37.2 + 27.0 +19.8+5.0+0.1+ 8.3+ 24.1)/7 = 17.36 cm

*Note: No snowfall between May to September.

4. Wind

i. Quarterly

- 2010: 17.66 km/hr
- 2011: (17.91+16.41+14.14+15.49)/4 = 15.9875 km/hr
- 2012: (16.77+15.24+12.54+14.69)/4 = 14.81 km/hr
- 2013: (16.79+15.62+13.72+16.74)/4 = 15.7175 km/hr
- 2014: (19.19+15.99 +14.21+17.25)/4 = 16.66 km/hr
- 2015: (19.14+15.98+13.67+16.53)/4 = 16.33 km/hr
- 2016: 18.12 km/hr

ii. Yearly

Per year (over 7 years):

(17.66 + 15.9875 + 14.81+15.7175+16.66+16.33+18.12)/7 = 16.4693 ~ 16.50 km/hr

Appendix F

This Appendix includes details of the individual elements of the detailed design.

Total Cost for Garden Area: $6360
Total Cost for Washroom Area: $1383.86
Total Cost for Common Living Area: $217000
Total Cost for Piping/Supply Room: $185.6
Total Cost: $224929.46

Table 26: Cost calculation for Garden Area

Item	Cost
100 Shrubs	$18*100=$1800
1 metric ton of organic wheat	$60
100 drip irrigation kit	$45*100=$4500

Table 27: Cost calculation for Washroom Area

Item	Cost
4 dual-flush toilets	$192*4=$768
7 motion-sensor faucets	$87.98*7=$615.86

Table 28: Cost calculation for Common Living Area

Item	Cost
Approximately 1000 set of windows	$217*1000=$217000

Table 29: Cost calculation for Piping/Supply Room

Item	Cost
Approximately 40m of insulation material	$4.64*40=$185.6

Appendix G

As a result of client feedback, the team reopened the requirements and design space, in order to brainstorm for better solutions. As a preliminary step, the design team identified the barriers /constraints that would affect the solutions.

1. The design cannot target the individual units, only common elements.
2. The design can only affect usage, not cost.
3. The design should only affect aspects of the condominium that the Board has control over.

4. The Reserve Fund cannot be used until a funding cycle comes along.
5. Not every objects (e.g pipes) are accessible.
6. The design should not depend on individual users.
7. Political Barriers e.g. Regulations

Appendix H

This Appendix indicate the cost calculation for the Preliminary Economic

Pipe Insulator:

- The pipe insulator varies depend on the radius and thickness and type of insulation. All pipe insulator sold from this source is sold in 6 feet.

Approximately $2.70 to $11.51 per 6ft of Pipe insulator
taking Average gives: $7.1/ft [71]

Appendix I

This appendix underlines methods of calculations/predictions for are proposed conceptual design.

Increased efficiency:

Using the ASHRAE-D-17339-20030701 standard to measure efficiency. This is a standard is for water pumps and The following calculations have been taken from the "Estimating and Demand Efficiency" Journal:

Figure 3: Taken from [72]

"

Values for pump and motor efficiencies are entered. Equation 3 is used to convert the pump pressure, flow rate, and efficiency to motor output power in horsepower and then to motor input in kW based on motor efficiency. " [72]

$$\frac{\mathrm{kW}_{CHW\ Pump}}{\mathrm{ton}} = \left[\frac{\Delta h(\mathrm{ft\ H_2O}) \times 2.4\ \mathrm{gpm/ton}}{\eta_{Pump} \times 3{,}960}\right] \mathrm{hp} \times \frac{0.746\ \mathrm{kW/hp}}{\eta_{Motor}} \quad (3)$$

Figure 14: Taken from [72]

"

The chilled water pump heat also should be deducted, although it is often a minor contribution. If it is located outside the conditioned space, Equation 4 should be multiplied by the pump motor efficiency to assign the motor losses to ventilation air rather than to the building load."[72]

$$\frac{q_{CHW\ Pump}}{\mathrm{ton}} = \frac{\mathrm{kW/ton}_{Pump} \times 3{,}412\ \mathrm{Btu/kWh}}{12{,}000\ \mathrm{Btu/ton-hr}} = \mathrm{ton/ton} \quad (4)$$

Figure 15: Taken from [72]

Cost efficiency:

Cost:

The way that Cost efficiency will be measured is by using the *Account Analysis Method.* The following calculations have been taken from http://www.unf.edu/~dtanner/dtch/dt_ch5.htm:

"

The account analysis approach requires that each individual cost is examined, and based on judgment is categorized as a fixed or variable cost. Then all variable costs are totaled.

Total variable costs = Variable cost per unit

Number of units produced and sold

"[73]

Savings:
The way that savings will be measured is by using the Efficiency ratio. The following calculations have been taken from http://www.unf.edu/~dtanner/dtch/dt_ch5.htm :
" Efficiency Ratio = Expenses* / Revenue
(*not including interest expense)"

Appendix J

This section includes the detailed test methods for the preliminary test plan.

- Test procedure for 24 h simulated-use test- CAN/CSA P.3-15
  Section 5

- Test procedure for flexometer test-ISO 4666-1:2010
  Section 7

- Test procedure for Environmental Compliance Auditing-CSA Z773-03 (R2013)
  Section 7 and 8

- Test procedure for Guidelines for treated wastewater use for irrigation projects -ISO 16075-3:2015
  Section 7.3

This is a chart taken from the Guidelines for treated wastewater use for irrigation projects -ISO 16075-3:2015

"**Figure 16:** Water quality chart

Definitions of the suitability of water quality to the irrigation system according to clogging potential, pH, and redox potential

Water quality[a]	Parameter		
	Clogging potential – (1)[b]	pH (2)	Redox – (3)[c]
	Time		mV
Good	Longer than 7 min	<7,2	Between 300 and 500
Medium	Between 3 min and 6 min	Between 7,2 and 8,0	Between 250 and 300 and between 500 and 600
Low	Shorter than 3 min	>8,0	<250 and >600

[a] These levels are suitable for water to maintain the irrigation system rather than for irrigation water specified elsewhere in this guide.

[b] The Clogging Potential Meter (CPM) tests using a 150 µm mesh.

[c] The redox potential has been chosen as an index of the organic substances found in the water. A chlorine requirement test is not possible for continuous measurement since the instrument for such test is extremely costly and can be installed only in large irrigation systems. The redox has been chosen to be part of the monitor system as a default, although it is not an accurate index for organic material. It will be mentioned in the guide that if chlorination efficiency should be tested, a continuous chlorine meter will be used

"[74]. This is how we will test the water quality resulting from the drip irrigation system. Low is equal to 1 medium is equal to 2 and good is equal to 3, based on these results we can implement a treatment method.

This is a chart taken from Guidelines for treated wastewater use for irrigation projects -ISO 16075-3:2015:

" **Figure 17:** Comparing water quality results

Details of the recommended treatments by water quality parameter level

Treatment model	Water quality index level		
	Clogging potential	PH	Redox
1	1	1	1
4	2	1	1
6, 4	3	1	1
3	1	2	1
6	2	2	1
7, 6	3	2	1
3	1	3	1
5	2	3	1
7	3	3	1
2	1	1	2
2	2	1	2
4	3	1	2
3	1	2	2
4, 5	2	2	2
6	3	2	2
3	1	3	2
6	2	3	2
7	3	3	2
2	1	1	3
4	2	1	3
6	3	1	3
5	1	2	3
4	2	2	3
6	3	2	3
5	1	3	3
7	2	3	3
7	3	3	3

”[74]

All treatment methods are in “Guidelines for treated wastewater use for irrigation projects- section 7.3.3.2.1”[74]

Appendix K

This section outlines what the client has given to us.

- Utility usage
    - Water Consumption
    - Gas Consumption
    - Hydro Consumption

- Excel spreadsheet
    - Water Data
    - Gas Consumption
    - Gas Data
    - Hydro Consumption
    - Hydro Data

- Gas Budget
    - Projected cost
    - Actual cost

Figure 18: Gas budget over 7 years interval

2016 BUDGET	71,713
2015 PROJECTED	78,481
2014 ACTUAL	82,497
2013 ACTUAL	71,868
2012 ACTUAL	76,874
2011 ACTUAL	108,165
2010 ACTUAL	97,420

- Water Budget
    - Projected Cost
    - Actual Cost

Figure 19: Water budget over 7 years interval.

2016 BUDGET	60,851
2015 PROJECTED	48,023
2014 ACTUAL	48,915
2013 ACTUAL	43,611
2012 ACTUAL	39,844
2011 ACTUAL	20,194
2010 ACTUAL	36,665 (possible included waste disposal charges)

- Email of our question answered

Appendix L

This section outlines the calculation methods used when calculating costs, savings and payback period.

Table 30: Efficiency of individual strategy.

Ideas for Design	Savings
Garden	50%(WATER)
Bathroom	18%(WATER)
Living Area	19%(GAS)

Table 31: Usage distribution between residence/common elements.

TOTAL USAGE FOR THE BUILDING	PERCENTAGE UTILITIES BEING USED
Residence	97%
Common Area	3%

Table 32: Usage distribution between each design attribute.

USEAGE FOR THE COMMON AREAS	PERCENTAGE UTILITIES BEING USED
Garden	50% (WATER)
Bathroom	50%(WATER)
Living Area	100%(GAS)

Average gas consumption in last 5 years: $87,364.80 (See Appendix K for the data)
87364.8*0.19*0.03 = $497.98

Average water consumption in last 5 years: $37,845.80 (See Appendix K for the data)
37845.80*((50+18)/2)*0.03=$386.03

Total savings per year by common elements: $884.01

Payback period equals the (utility cost / (cost saving - operating cost))

- Payback period is 39 years
- Utility cost is about 21254 dollars
- Cost Savings is about 884 dollars
- Operating cost about 333 dollars

Glossary of Terms

The following definitions are mainly taken from *'Designing Engineers: An Introductory Text'* by Susan McCahan, Philip Anderson, Mark Kortschot, Peter E. Weiss and Kimberly A Woodhouse.

1. **Aerator**: a mechanism within faucet/showerhead that will expand the volume and velocity of the flow by inputting air into the water flow.
2. **Alkalization**: To become an alkali(**"**Any of various soluble mineral salts found in natural water and arid soils"[75]).
3. **Black-box Method**: a method used to discover functions of a design by connecting the components going into a design to the components that result from the design. We think of the design as a black box and think of the inputs and outputs to it.
4. **Capital Costs**: purchases necessary to initiate the project. Ex. Equipment, Tools etc.
5. **Demand Losses:** heat losses caused by consumption from water demand or use.
6. **Disposal Cost**: the cost associated with disposing after the life span of the project. The cost may include recycling, reusing, extraction, dismantling etc. Also known as Final cost.
7. **FOCs:** Functions, Objectives, Constraints.
8. **Final Design specification (FDS)**: this report deals with the details of the design solution, usually including detailed drawings, or schematics and the embodiment of the design (sketches or renderings of the technology). It may include economic, environmental, or other types of analysis of the design solution. This type of report is usually developed near or at the end of a design project. Along with the detailed drawings, it may be the last deliverable for the client.
9. **Functional Basis**: a technique for dissecting an engineering design problem and understanding it from a functional perspective. Writing the function of the design in terms of mass, energy and information.
10. **Functional Decomposition**: splitting up the functions of a design into a set of sub-functions in order to analyze each separately. This can include identifying several primary functions or identifying a set of secondary functions that together enable a primary function.
11. **Gap**: the hole in the reality that this project will fulfill. Something that is missing or lacking with current method/technology
12. **Goal**: a characteristic of a solution that is to be met by mentioning in the problem statement.

13. **Graphical Decision Matrix**: this decision-making process compares ideas on the bases of two different (and highest ranking) objectives.
14. **Heat Traps:** valves or sections of pipe that are installed on cold and hot water outlet pipes on water heaters
15. **Human Factor**: the possible effect by the design operation
16. **Life-Cycle Assessment**: a rigorous method for analyzing the production, operating and end-of-life environmental costs for a technology in terms of mass and energy.
17. **Need**: problems that the project MUST meet in order to be functional and fulfill the goal.
18. **Operating Cost**: the ongoing cost from start to the end of the project lifespan
19. **Pairwise Comparison**: a simple method for ranking a list. A pairwise comparison simplifies the task by breaking a complex decision up into a set of more simple decisions; each decision compares just one item to one another on the list.
20. **Physical Level**: in reference to Human Factors, is a level that explains the physical effect on people according to a range of physical characteristics.
21. **Political Level**: in reference to Human Factors, is a level that explains the effect on cultural or societal level.
22. **Psychological Level**: in reference to Human Factors, is a level that explains the psychological effect on people according to a range of psychological characteristics.
23. **Service Environment**: the description of the environment in which the technology will operate.
24. **Standby Heat Losses:** heat lost from the water heater into the surrounding basement area.
25. **Unintended Functions**: functions of the design solution that were not deliberately enabled.
26. **Variable cost**: depends on the activity of the project and the quantity of the work required.
27. **Weighted Decision Matrix**: this decision-making process involves assigning weights (percentages) for each objective on the basis of their importance. Each design is then given a weight that corresponds to how well the design meets each objective.