2150 LAKE SHORE ENERGY STRATEGY

2150 - 2194 - LAKE SHORE BOULEVARD WEST
23 PARK LAWN ROAD

TORONTO

CPPIB Park Lawn Canada Inc
FCR (Park Lawn) LP

ENERGY STRATEGY

1.1/ INTRODUCTION

This Energy Strategy has been prepared by Arup on behalf of the land owners, FCR (Park Lawn) LP and CPPIB Park Lawn Canada Inc., in support of an Official Plan Amendment application for the redevelopment of 2150-2194 Lake Shore Boulevard West and 23 Park Lawn Road ("the site" or "2150 Lake Shore"). This document is also intended to provide input into the City's Secondary Plan for the site and immediately adjacent lands.

The Energy Strategy explores possible strategies to address energy conservation including peak demand reduction, resilience to power disruptions and local integrated energy solutions to address the City's targets of carbon dioxide emissions reduction.

1.1.1 THE ENERGY CONTEXT

Grid electricity in Ontario is produced by nuclear power for approximately two thirds, hydro-power for almost one quarter and the remaining 14% by a mix of wind, natural gas, solar, biomass, geothermal and petroleum (see Figure 1). This makes Ontario's electricity have a very low carbon dioxide intensity, with a carbon factor of 0.04 kgCO2eq/kWh according to the National Inventory Report 1990-2016: Canada's 2018 Submission to the United Nations Framework Convention on Climate Change (2018) – about a fifth of the UK's electricity carbon intensity, as a reference.

A number of district energy systems have been developed in Toronto, highlighted in orange in Figure 2, and the city has identified 27 locations with potential to support new networks (yellow in Figure 2). There are 4 main district heating networks:

- University of Toronto Campus
- York University Keele Campus
- Enwave district network
- Regent Park district network

The closest exiting network to the site is the Enwave district network, which is about 10 km away from 2150 Lake Shore. This network comprises a steam system and a Deep Lake Water Cooling system using water from Lake Ontario and serving around 60 buildings including Toronto's City Hall.

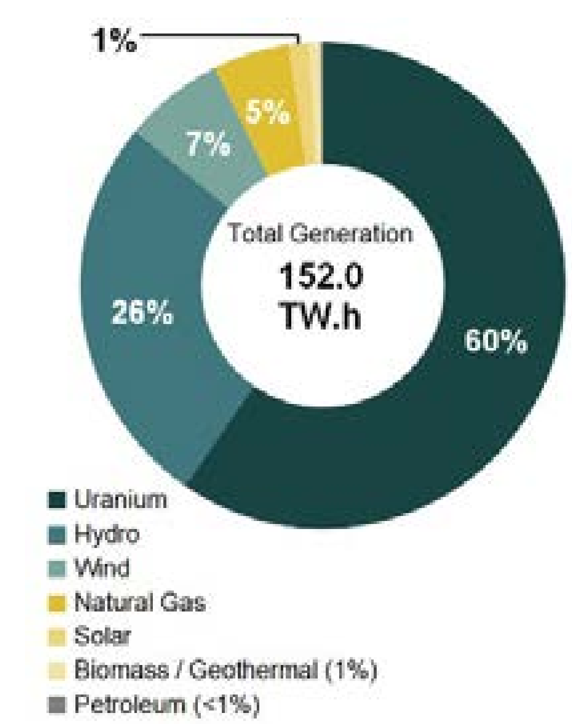

Figure 1 - Ontario's electricity generation by fuel (Canada's Energy Future, NEB, 2018).

1.1.2 CITY POLICIES

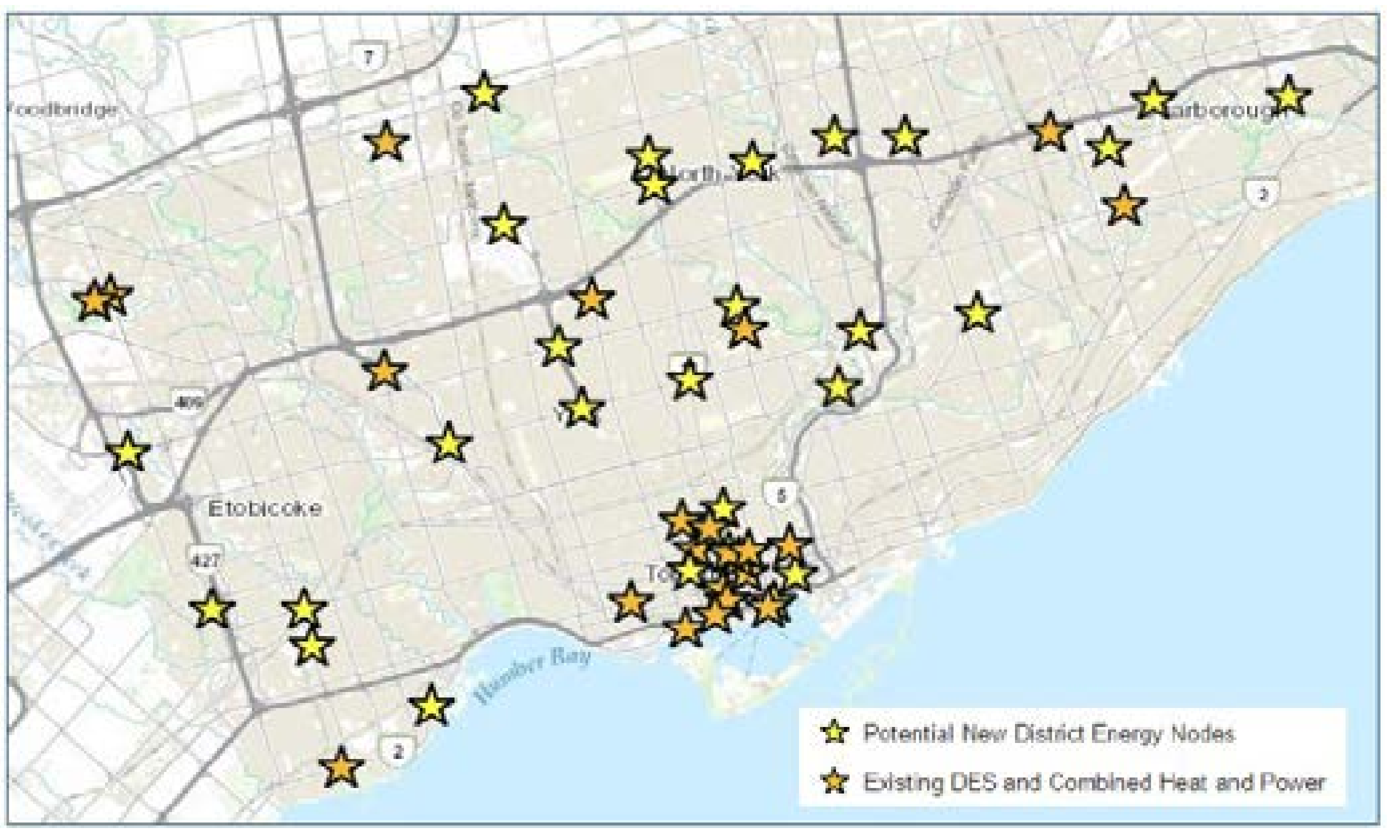

Figure 2 -Existing and potential new district energy nodes (source: Design Guideline for District Energy Ready Buildings V1.1 Oct 2016).

TransformTO

In 2007, Toronto adopted the Climate Change and Clean Air Action Plan, which outlined a number of actions to reduce the release of greenhouse gas (GHG) emissions and improve the City's air quality. Furthermore, in 2009 the City's Sustainable Energy Strategy was established which outlined specific targets for reducing electricity, conserving natural gas, and increasing renewable energy generation, as summarised in Figure 3.

In 2017, the Toronto City Council unanimously approved the current climate action strategy called TransformTO. It lays out a set of long-term, low-carbon goals and strategies to reduce local greenhouse gas emissions. Toronto's greenhouse gas (GHG) emissions reduction targets, based on 1990 levels, are:

- 30% reduction by 2020
- 65% reduction by 2030
- 80% reduction by 2050

The following standards are the key vehicles under TransformTO to achieve the GHG emission targets related to homes and buildings.

SOURCE	2020 TARGET	2050 TARGET
Electricity conservation	550 MW reduction	1050 MW reduction
Natural gas conservation	730 Mm^3 reduction	1650 Mm^3 reduction
Renewable energy generation	550 MW increase	1000 MW increase
Renewable thermal energy	90 Mm^3 of natural gas displaced	200 Mm^3 of natural gas displaced

Figure 3 -Targets from the City of Toronto's Sustainable Energy Strategy.

The Toronto Green Standards

The Toronto Green Standard (TGS) defines Toronto's sustainable design requirements for new private and city-owned developments. The third edition of the Toronto Green Standard (TGS-v3) – the latest version in issue at the time of writing – sets out a series of objectives for the city and provides a set of targets to which new developments should adhere.

There are currently four tiers under the TGS-v3. Tier 1 is the minimum requirement to obtain planning approval; Tiers 2 to 4 are higher level voluntary standards associated with financial incentives and verified post construction.

The TGS is expected to be updated to its requirement every three years, with the next tier becoming the new minimum requirement for planning approval.

Under the TGS, the section named to Energy/ GHG & Resilience for Mid to High-Rise Residential & all Non-Residential Development is relevant for the Masterplan Energy Strategy, which presents three main objectives:

- Reduce energy loads in buildings, encourage passive design strategies and provide protection during power disruptions
- Provide low carbon energy sources of supply
- Enable self-recovery during an emergency power disruption

The first criterion of this section is Energy Efficiency, which defines targets for new buildings to achieve the four Tiers.

The following metrics are set to measure the energy efficiency of the new buildings:

- Total Energy Use Intensity (EUI) – to encourage higher efficiency buildings and lower energy used by buildings hence utility costs
- Thermal Energy Demand Intensity (TEDI) – to encourage better building envelopes, improve occupant comfort and enhance resilience
- GHG Intensity (GHGI) – to encourage low-carbon fuel choices and reduce carbon dioxide emissions

Depending on the Tier the project aims for, target figures are set. The absolute pathway targets for each of these building types are summarised in Table 1.1.

	EUI (kWh/m²)				TEDI (kWh/m²)				GHGI ($kgCO_{2e}/m^2$)			
	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
Office	175	130	100	65	70	30	22	15	20	15	8	4
Retail	170	120	90	70	60	40	25	15	20	10	5	3
High-rise residential	170	135	100	75	70	50	30	15	20	15	10	5

Table 1.1 - Toronto Green Standards for offices, retail and high-rise residential buildings.

In addition to Energy Efficiency, the following requirements are set for Tier 2 and above:

- Renewable energy

- Solar readiness (Core): Ensure that buildings are designed to accommodate connections to solar PV or solar thermal technologies;

- On-Site Renewable Energy (Optional): Design on-site renewable energy systems to supply one of the following:

1. Minimum of 5 per cent of the building's annual energy consumption from one or a combination of acceptable renewable energy sources; OR

2. Minimum of 20 per cent of the building's annual energy consumption from geo-exchange.

- District Energy Systems

- District Energy Connection (Core): Design buildings to connect to a district energy system where one exists or is planned for development

- Operational Systems

- Benchmarking and Reporting (Core): Register the building on ENERGYSTAR® Portfolio Manager.

- Best Practice Commissioning (Core): Commission the project using best practice commissioning.

- Air Tightness Testing (Core): Conduct a whole-building Air Tightness Test to improve the quality and air tightness of the building envelope.

- Sub-metering (Optional):

1. Install thermal energy meters for each heating/cooling appliance in all residential units; OR

2. Install thermal energy meters for each individual tenant in multi-tenant commercial/ retail buildings

- Building Resilience

- Resilience Planning (Core): Complete the Resilience Checklist.

- Refuge Area and Back-Up Power Generation (Optional)

1.Residential: Provide a refuge area with heating, cooling, lighting, potable water, and power available; AND

2.Provide 72 hours of back-up power to the refuge area and essential building systems

Additional detailed guidance is provided for each criterion, including:

- Energy Strategy Terms of Reference
- Solar Ready Buildings Planning Guide
- Design Guideline for District Energy-ready Buildings

In particular, the Energy Strategy Terms of Reference provides guidance on the minimum requirements for Energy Strategies.

The Zero Emissions Buildings Framework (ZEB)

The Zero Emissions Buildings Framework (City of Toronto, 2017) was created to outline the future building performance requirement under TGS.

This framework provides a set of additional prescriptive requirements to ensure that modelled performance targets within buildings are fully realised in practice and set the future target for buildings to achieve net-zero carbon emissions.

The guidance also indicates typical envelope and system performance needed to achieve the desired TGS Tier for a number of archetypes, namely high-rise multi-unit residential buildings (MURB), low-rise MURB, commercial office and commercial retail. Table 3.2 shows the results from a study carried out to understand what design solutions can achieve the TGS tiers of performance for high-rise MURB, which is the prevailing archetype in 2150 Lake Shore development.

	TGS v3 Tier 1	TGS v3 Tier 2	TGS v3 Tier 3	TGS v3 Tier 4
Target EUI	170.00 kWh/m^2	135.00 kWh/m^2	100.00 kWh/m^2	75.00 kWh/m^2
Target TEDI	70.00 kWh/m^2	50.00 kWh/m^2	30.00 kWh/m^2	15.00 kWh/m^2
Target GHG	20.0 kg/s	15.0 kg/s	10.0 kg/s	5.0 kg/s
Achieved EUI	169.50 kWh/m^2	133.00 kWh/m^2	99.80 kWh/m^2	74.40 kWh/m^2
Achieved TEDI	70.60 kWh/m^2	42.20 kWh/m^2	29.00 kWh/m^2	9.40 kWh/m^2
Achieved GHG	22.6 kg/m^2	16.2 kg/m^2	9.0 kg/m^2	3.7 kg/m^2
WWR	40%	40%	40%	40%
Wall R-Value	10	10	10	20
Roof R-value	20	20	20	20
Win U-value	0.4	0.3	0.2	0.14
Infiltration Savings	Code	25%	50%	75%
Lighting Savings	30%	30%	50%	50%
Plug Savings	0%	10%	10%	20%
Fans	ECM	ECM	ECM	ECM
Heat Recovery	65%	75%	80%	85%
Vent. Effectiveness	0.8	0.8	1	1
Corridor Ventilation	30cfm/ste	15cfm/ste	15cfm/ste	0.3 l/(s.m^2)
Heating Plant	Condensing Boilers	Condensing Boilers	50% ASHP 50% Condensing Gas Boilers	90% ASHP Electric Boilers Top Up
Heating Plant Eff.	96%	96%	4.15, 96%	4.15, 100%
Cooling Plant	Water-cooled Screw Chillers	Water-cooled Screw Chillers	ASHP	ASHP
Cooling Plant COP	5.2	5.2	3.15	3.15
DHW Savings	20%	30%	40%	50%
Heating Gas	70.60 kWh/m^2	41.00 kWh/m^2	25.50 kWh/m^2	0.00 kWh/m^2
Heating Electricity	2.90 kWh/m^2	2.90 kWh/m^2	2.90 kWh/m^2	5.50 kWh/m^2
DHW Gas	35.60 kWh/m^2	31.10 kWh/m^2	4.90 kWh/m^2	0.00 kWh/m^2
DHW Electricity	0.00 kWh/m^2	0.00 kWh/m^2	3.30 kWh/m^2	5.70 kWh/m^2
Cooling Electricity	4.90 kWh/m^2	5.40 kWh/m^2	12.00 kWh/m^2	14.00 kWh/m^2

1.1.3 METHODOLOGY

Objectives

The 2150 Lake Shore masterplan seeks to be an exemplar, raising the benchmark for future developments. The masterplan concept has been developed based on an ambitious sustainability vision, delivered through tailored objectives and criteria that comprehensively address sustainable development at both the masterplan and building level.

The Sustainability Strategy for the masterplan consists of seven themes and contextualizes all the criteria to be adopted by design teams in the coming stages. 'Towards zero carbon' is the relevant theme for this Energy Strategy and sets the objective to achieve a near-zero carbon development by 2030.

Based on this, the current Energy Strategy explores possible solutions to achieve a near-zero carbon development, meaning targeting TGS v3 Tier 4 for all buildings in the development.

Additional general objectives for the Masterplan Energy Strategy are to:

- Minimise and offset, where possible, carbon dioxide emissions
- Preserve and improve, if possible, local area quality
- Limit urban heat island effect
- Increase resilience to climate change
- Provide reasonable energy bills for the occupants
- Achieve economically feasible solutions

Particularly, the carbon emissions offset will be pursued through solutions that:

- Minimise energy demand for the buildings
- Maximise the use of renewable and low carbon technologies for energy provision
- Assure capability of connecting to future district energy systems
- Avoid combustion activities on the site

The practical implications of a Tier 4 design have been evaluated as part of the concept masterplan design through a high-level comparative analysis of different possible options to estimate the environmental impacts of each option at concept stage.

Energy demand modelling

The study started from a demand modelling exercise to estimate the energy demand of the buildings that form the development to base the selection of the optimal energy supply solution.

Due to the early design stage, the demand model was based on Tier 4 energy demand benchmarks included in the Zero Emissions Buildings Framework (2017) and Arup's experience on similar projects to estimate the energy demand of the buildings. In particular, the thermal energy demand for all main archetypes was assumed at 15kWh/m^2, as per TGS v3 (see Table 1.3 below).

The energy demand of the site was then modelled on an hourly basis using hourly profiles from previous Arup projects and the CWEC weather file for Toronto. The model allowed to estimate the combined loads for the site and reduce the risk for overestimating the peaks. The estimated space heating, domestic hot water (DHW), cooling and electricity loads for the site during a typical year are showed in Table 3.4 and the following graphs.

It should be noted that the electricity loads shown refer only to lighting, plugs, pumps and fans (non-thermal use). The electricity loads for cooling and ventilation will vary depending on the selected solution, therefore were considered after selecting the preferred option.

Archetype	Tier 1	Tier 2	Tier 3	Tier 4
Office	70 kWh/m^2	30 kWh/m^2	22 kWh/m^2	15 kWh/m^2
High-rise MURB	70 kWh/m^2	50 kWh/m^2	30 kWh/m^2	15 kWh/m^2
Retail	60 kWh/m^2	40 kWh/m^2	25 kWh/m^2	15 kWh/m^2

Table 1.3 - TEDI targets by building type (source: TGS v3).

Load type	Peal load	Total annual demand
Space heating	14.2 MW	12.9 GWh
DHW	5.0 MW	11.9 GWh
Cooling	29.5 MW	16.9 GWh
Electricity (non-thermal)	9.1 MW	28.9 GWh

Table 1.4 - Energy demand for the development.

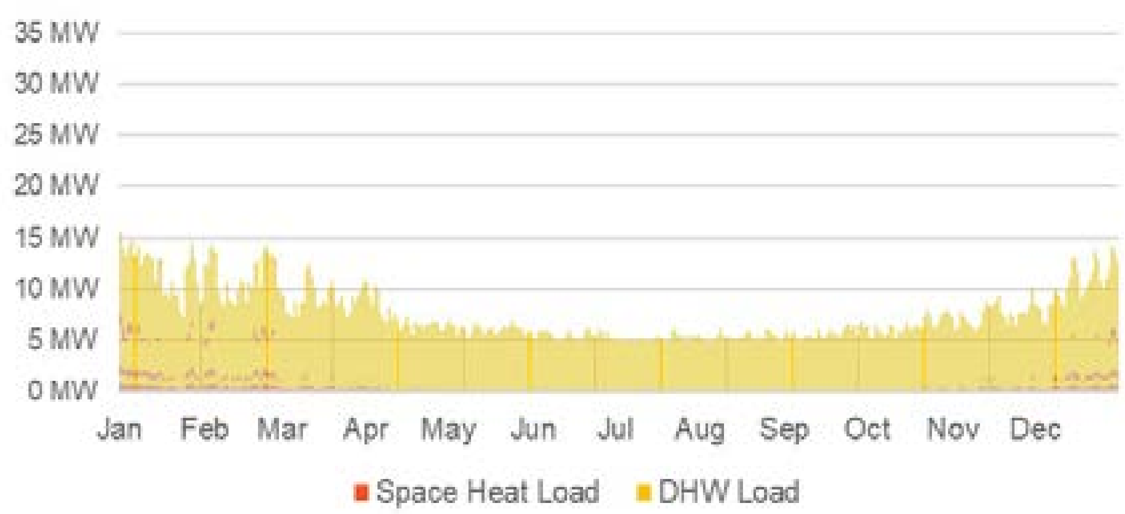

Figure 4 - Site heating loads (cumulative of space heating and DHW).

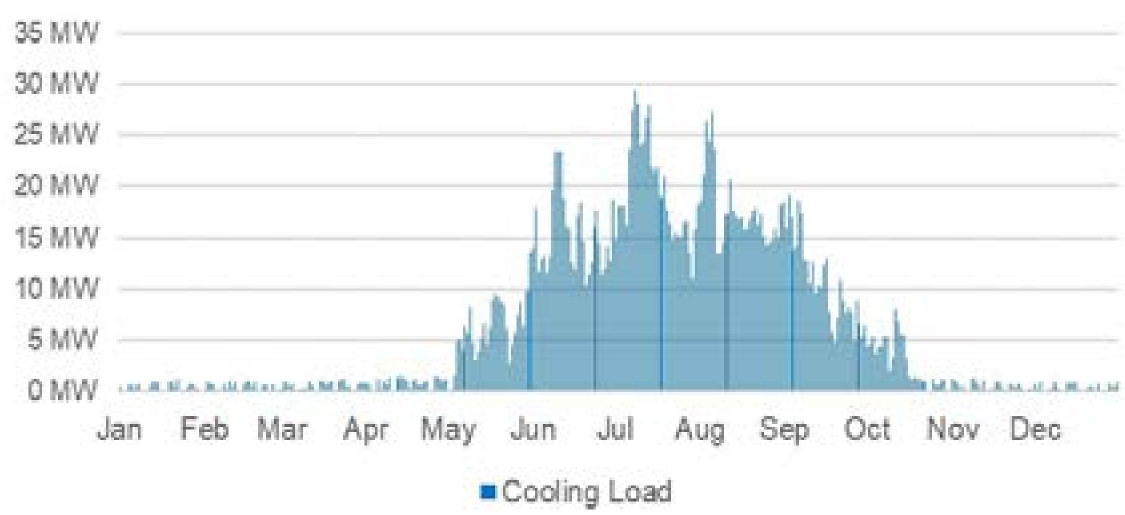

Figure 5 - Site cooling loads.

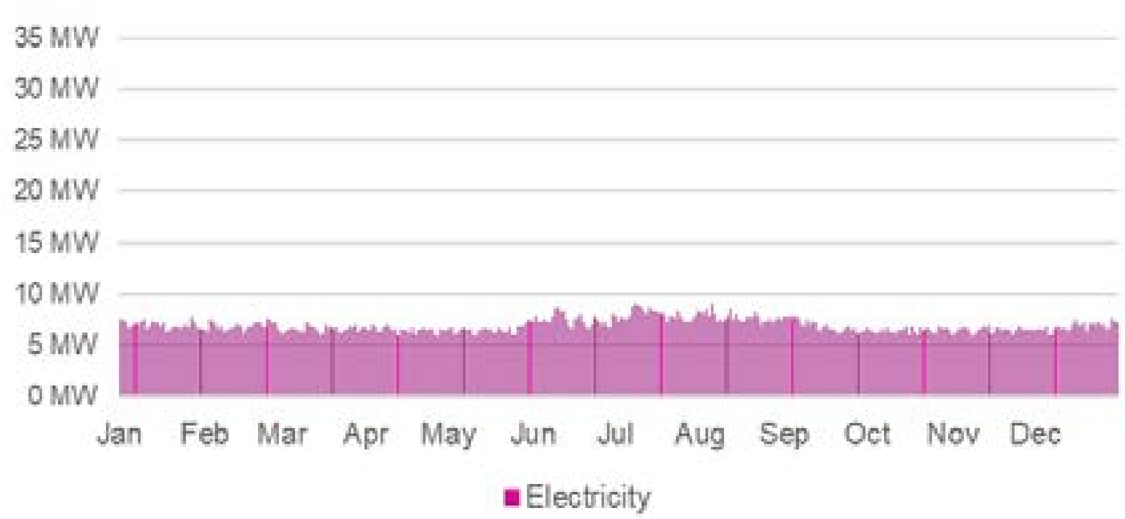

Figure 6 -Site electricity loads (non-thermal).

Energy supply modelling

A long list of possible energy supply solutions was explored for the site and these were considered in relation to qualitative considerations such as site conditions, fuel availability, air quality, environmental issues and compatibility with the energy demand profile of the site. Table 3.5 lists all the options considered and a summary of the pros and cons for each technology.

The qualitative analysis produced a short list of technologies that have been further investigated and compared through a quantitative analysis aimed at evaluating the implications of each solution in terms of reduction in carbon emissions and cost; these were:

- Ground source heat pumps (GSHPs)
- Air source heat pumps (ASHPs)
- Biomass boilers
- Water source heat pumps (WSHPs)

The quantitative comparative analysis of these options is included in the subsequent sections.

Table 1.5 - Long list of considered supply technologies

Supply technology	Pros	Cons	Short-listed
Gas fired boilers	Cheap option	High carbon dioxide emissions Combustion on site (air quality)	NO (Base case scenario)
Gas fired CHP plant	Usually a good financial return on investment Could supply the whole heating load	Very high carbon dioxide emissions Combustion on site (air quality)	NO
Ground source heat pumps	Very low carbon dioxide emissions No combustion on site	Cooling & heating demand need to be balanced throughout the year, therefore need to be sized on lowest base load Feasibility and number of boreholes to be checked Cannot cover the whole thermal load	YES
Water source heat pumps	Very low carbon dioxide emissions	Expensive option due to plant required and large pipe connection to the lake Viability of connection to the lake to be confirmed	YES
Air source heat pumps	Low carbon dioxide emissions if used at medium temperatures	Cannot work at very low outside air temperatures Cannot cover the whole thermal load	YES
Solar photovoltaic (PV) panels	Low carbon dioxide emissions	Roof space needed	YES
Solar thermal panels	Very low carbon dioxide emissions Cheap option	Roof space needed	YES
Biofuel (liquid) systems – heating only	Capable to cover the whole heating load Very low carbon dioxide emissions when correctly sourced Fuel versus food problem is not sourced correctly (reused vegetable oil instead of virgin etc.) Low capital cost but higher operation costs	Combustion on site (affects air quality) High NOx emissions Issues with transport of fuel Large fuel storage space required	NO
Biofuel systems – CHP / CCHP	Capable to cover the whole heating load Very low carbon Cheap option	High NOx emissions Issues with transport of fuel Big plant space required	NO
Wind turbines	Very cheap renewable electricity	Wind conditions not suitable Unlikely to find a suitable location considering building massing Small amount of electricity produced on a high-density plot	NO
Combined cycle gas turbine CCHP	High energy density (small footprint required)	Very high carbon dioxide emissions Still need electrical grid connection for resilience	NO
Open cycle gas turbine CCHP	High energy density (small footprint required)	Very wasteful Very high carbon dioxide emissions Still need electrical grid connection for resilience	NO
Anaerobic digestion	Very low carbon dioxide emissions	Plant produces a gas that needs to be burnt (combustion on site) Plant could be located off site by a food court etc. and piped to site Likely to provide insufficient energy for the site (heating and electricity)	NO
Fuel cells	CHP technology without combustion on site Improves air quality	Very expensive technology to buy and maintain	NO
Smart battery storage	Allows importing of electricity during low site demands to smooth peaks Can be used to reduce the carbon dioxide emissions of the site	An 'add on' technology that does not produce energy, it just stores it.	YES
Other solid fuel fired thermal only or CHP/ CCHP	When used with forest residue sourced virgin woodchip, a very low carbon dioxide emitting plant Uses forest waste to heat (and potentially power) the site.	Electrical generation plants can be wasteful Need to be operated and maintained daily (full time site presence may be required) Unlikely to represent return on investment without significant subsidies	NO

1.2/ REDUCING ENERGY DEMAND

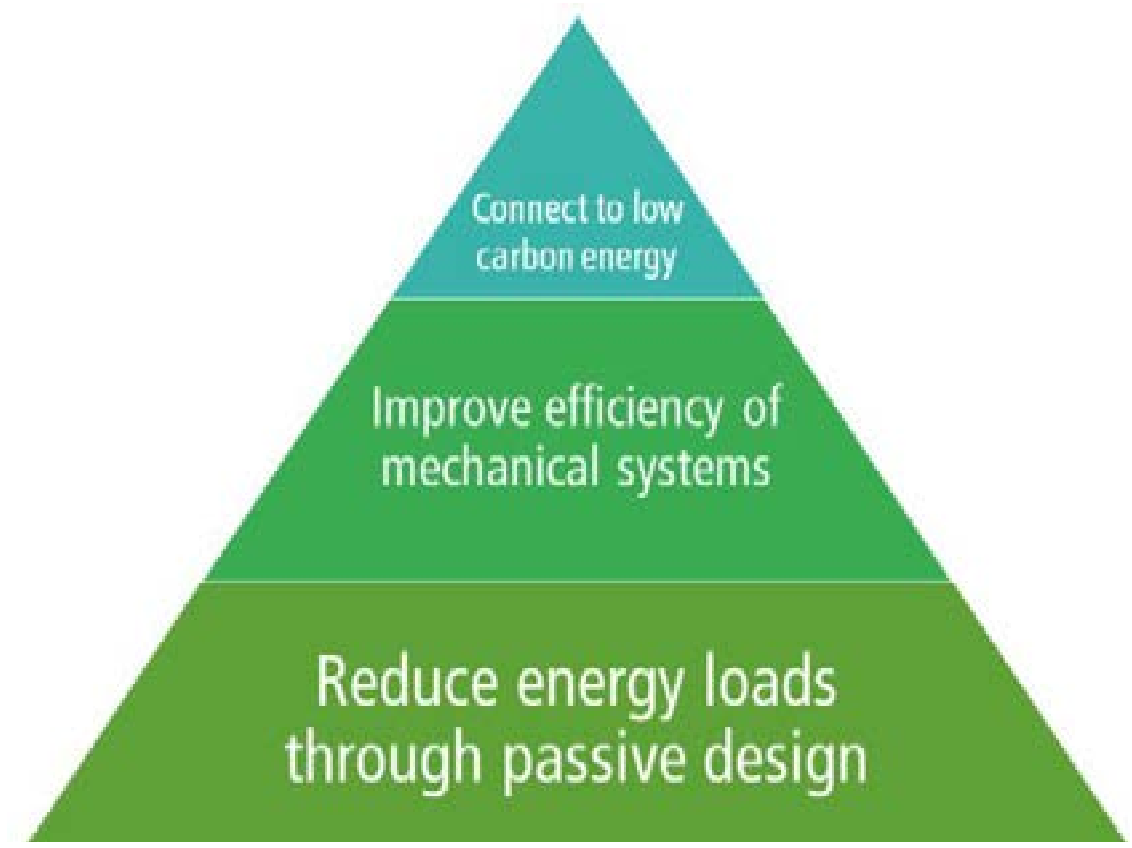

Figure 7 - Low-carbon building design hierarchy (Zero emissions buildings framework, 2017).

To achieve near-zero targets, the buildings will have to be designed to the highest level of performance to reduce energy demand and achieve the target TEDI and EUI. The Zero Emissions Buildings Framework suggests strategies to achieve low-carbon buildings design that are based on the low-carbon design hierarchy, namely:

1. Reduce energy loads through passive design
2. Improve efficiency of mechanical systems
3. Connect to low carbon energy

This means that passive strategies should be prioritized to minimise the demand for heating, cooling and lighting of the buildings first. The reduced demand should then be matched using high-efficiency systems which assure reduced primary energy demand. Then the remaining demand should be provided by renewable or low-carbon technologies as far as possible and the rest should be offset.

It is recommended that this approach is followed when designing the buildings in 2150 Lake Shore development; the following passive and active strategies should be considered at the next stage of design to achieve TGS Tier 4 TEDI and EUI targets.

1.2.1 # PASSIVE STRATEGIES

Passive strategies consist in design measures that optimise the use natural resources in the building to improve the internal comfort conditions without the use of any form of energy.

The use of passive strategies must be optimized throughout the year to balance the need for heating and cooling. The achievement of the optimal solution is dependent on a number of factors, such as use of the space, occupancy, orientation of the space, environmental shades and wind protection from other elements, etc.

Therefore, the possible passive strategies and their combination will have to be tested on a case by case basis to identify the optimal design configuration for each building and element.

Based on the local climate and the building typologies, the following passive strategies should be prioritised and investigated at the next stage of design:

- Optimise U values for the opaque and transparent building envelope elements to balance cooling and heating loads
- Optimise g values for windows to ensure high daylight levels, good amount of solar gains in winter, but limiting the cooling load in summer
- Minimise thermal bridges (e.g. using continuous façade insulation and thermal break balconies)
- Minimise airtightness to avoid unexpected heat loss and gain through infiltration
- Allow for human-controlled natural ventilation and design for wider ranges of comfort temperature
- Allow for cross ventilation in all spaces to maximise free cooling through natural ventilation
- Use exposed high thermal mass in walls and ceiling in living and office areas in combination with night-time ventilation
- Optimise the window ratio for each façade of the buildings in relation to the orientation and the environmental shades and obstructions
- Prefer the use of punched windows over curtain walls
- Optimise location and depth of balconies to block sun rays in summer and permit solar gains in winter
- Prefer external shading devices over internal to maximise the reduction in solar gains in summer (movable external shading devices ensure full flexibility during the year)
- Create openable greenhouses on South-facing balconies to pre-heat air in winter and allow free air flow in summer
- Create solar atria on the south side of the buildings with vertical compartments to limit excessive stack effect
- Optimise the location of space activities to take advantage of light and solar gains when the spaces are used

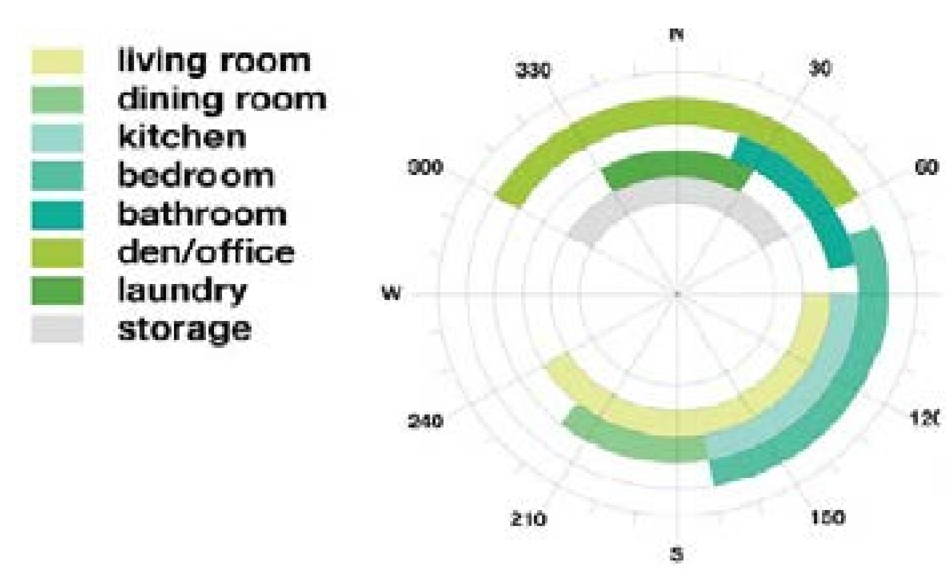

Figure 8 - Optimal location of space activities (source: Roadmap to Net Zero, 2017).

1.2.2 ACTIVE STRATEGIES

Active strategies consist in the selection of high-efficiency systems to provide the remaining building's energy need consuming the minimum primary energy possible

When selecting the building service systems for 2150 Lake Shore, the following selection should be prioritized:

- High efficiency heating and cooling generation systems (ENERGY STAR appliances) with heat recovery where possible

- Low temperature heating distribution systems

- Time & temperature zone control, occupancy demand-controlled ventilation, optimum start/stop and weather compensation to optimise plant performance

- High efficiency mechanical ventilation system with heat recovery

- Demand controlled ventilation with gas sensors and speed control to office areas

- Minimise Specific Fan Power of ventilation systems

- Utilise VAV system instead of CAV system and Demand controlled ventilation

- LED lighting and high efficiency lighting design

- Daylight and presence sensor to reduce lighting demand

- BMS system with automatic meter reading, energy monitoring and targeting facilities

1.3/ EFFICIENT AND LOW CARBON ENERGY SUPPLY

1.3.1 POSSIBLE TECHNOLOGIES

Once the energy loads for the building have been minimised through passive and active strategies, the remaining energy needed should be delivered using the most efficient and lowest-carbon solutions to ensure that the carbon emissions of the buildings are minimised and offset.

This section explores and compares a series of possible low-carbon energy technologies that were considered viable for 2150 Lake Shore.

Possible Technologies

As a result of the qualitative analysis presented in Table 1.5 a short list of technologies were selected as possible main strategies. These were then further investigated and compared through a quantitative analysis aimed at evaluating the implications of each solution in terms of reduction in carbon emissions and cost; these were:

- Ground source heat pumps (GSHPs)
- Air source heat pumps (ASHPs)
- Biomass boilers
- Water source heat pumps (WSHPs)

Ground Source Heat Pumps

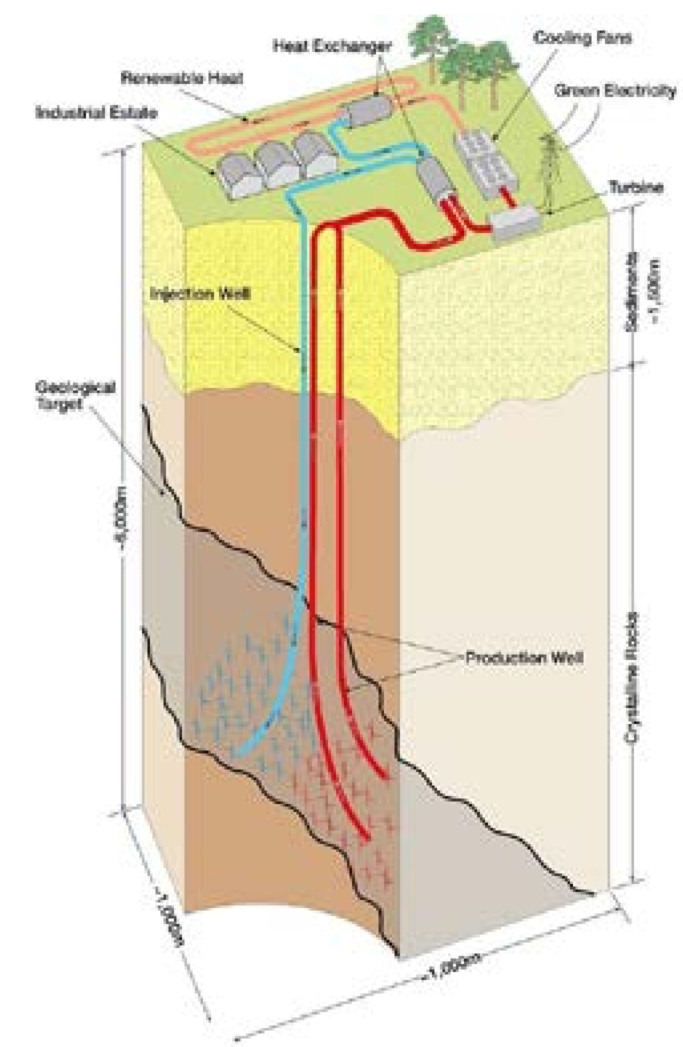

Figure 9- Geothermal system (open loop).

Ground Sourced Heat Pump (GSHP) systems use geo-thermal heat exchange to produce heating and cooling for buildings. They are generally used in conjunction with closed loop pipework systems installed either horizontally, approximately 2 metres below ground level, or vertically in bore holes with bore hole depths varying depending upon site ground conditions. Vertical pipe loops can often be accommodated within pile foundations to provide a more cost- and space-effective installation.

Ground-coupled heat pumps are not considered wholly renewable due to electrical energy required to generate heating/cooling, but when utilised can substantially reduce building carbon emissions thanks to the high efficiencies which lead to negligible use of primary energy compared to traditional systems.

GSHPs can generate cooling in summer, using the temperature of deep water in the ground, and heating in winter, which has to be produced at low temperature (in the order of 40-50°C) in order to keep high levels of efficiency.

The capacity of the system depends on the availability of soil to install boreholes and the system should be designed to balance the heat extracted from the ground in winter and the one injected back in summer.

Geo-exchange is an increasingly common low-carbon option in Ontario and does not present relevant feasibility issues, requiring little maintenance and low operational costs. However, the system has higher capital cost and operating energy cost compared to traditional natural gas-based systems.

This solution can be implemented on a block by block basis or on a centralised system, with the GSHP located in an energy centre and connected to the buildings to a district cooling and heating network. Both solutions have been considered in the comparative analysis, however the centralised solution does not present advantages in terms of economy of scale and increased efficiency, still involving higher capital cost and plant over-sizing issues.

A preliminary analysis has proven that the site's available ground area cannot yield sufficient geo-exchange capacity to provide the whole energy demand for the site due to the density of the development. Therefore, the system needs to be supplemented by gas-fired or electric boilers and chillers.

Air source heat pumps

Figure 10 - Air source heat pumps (source: Daikin UK website).

Air Source Heat Pump (ASHP) systems use the ambient air as the medium from which heat is extracted. Heat from the air is absorbed at low temperature into a fluid. This fluid then passes through a compressor where its temperature is increased and transfers its higher temperature heat to the heating and hot water circuits of the building.

The building design for heating would have to be adapted to cater for lower grade heat output from the ASHPs, typically 45°C maximum flow temperature, as oppose to conventional design, typically at 80°C flow temperature.

ASHPs operate very inefficiently at low external temperature conditions and typically cannot operate at temperatures below -5°C. For this reason, this option requires supplementary boilers or local immersion heaters in the apartments to meet the heating loads in winter.

ASHPs are a relatively simple system with no feasibility issues and very low maintenance required.

This solution is not effective on a centralised system due to the very low temperature of the heat generated which would lead to high distribution losses on a district heating network. Therefore, only a plot-by-plot solution has been considered in the comparative analysis.

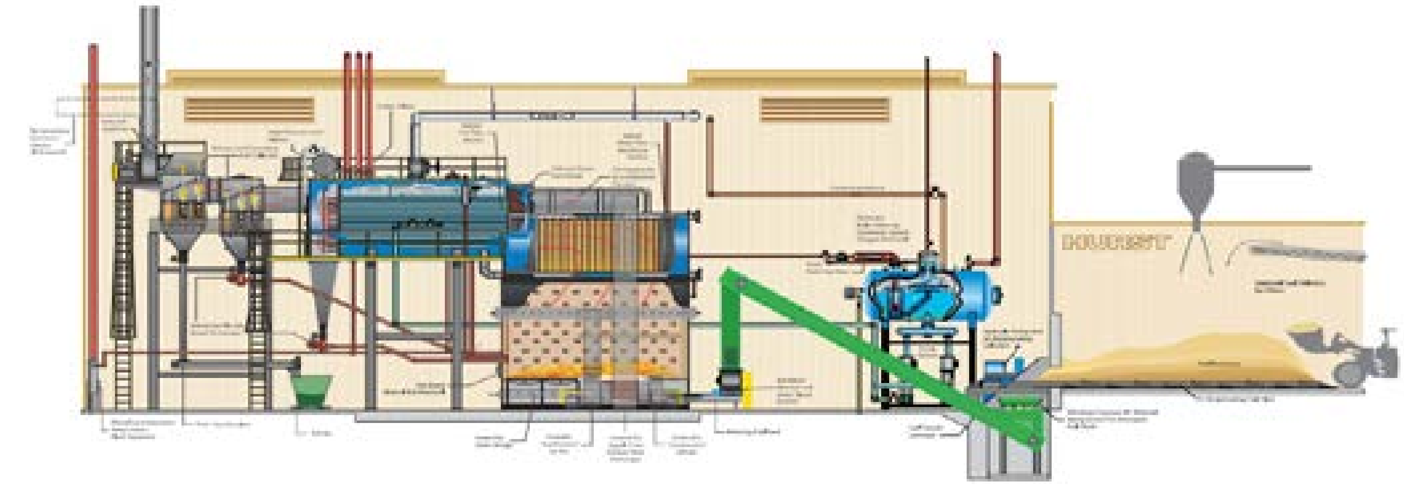

Figure 11 - Typical biomass boiler sketch (source: Hurst website).

Biomass boilers

Biomass boilers can be used to provide heating at high temperature to the buildings. Biomass is generally considered a renewable source since the material burnt into the boilers comes normally from sustainably managed forest that replant trees regularly; however, additional carbon emissions are involved in transporting and refining the material.

These systems present significant technical challenges and require many additional components, such as a storage facility, handling, delivery access, ash removal, thermal storage.

Fuel is normally delivered via trucks; therefore, careful consideration must be given to space requirements on site, vehicle turning radius and location of fuel store. Additionally, in urban environments, logistics and security of fuel delivery can also be an issue.

In addition, wood chips/pellets are usually housed indoor in order to avoid decay due to humidity and rain; thus, storage facilities would have to be built inside the energy centre, increasing the capital cost and reducing valuable floor area of the development.

Carbon dioxide intensity for biomass in Ontario is higher than the one of gas; additionally, biomass-fuelled heating systems can produce a large amount of NOx and so they have a negative impact on the local air quality and may cause problems with obtaining planning consent.

Water source heat pump

Water source heat pumps (WSHPs) are similar systems to ground source heat pump but use the water typically from a lake or a river as the medium for heat transfer. Lake-connected WSHPs can be deep or surface water system, depending on the depth at which the pipework is installed, with different issues related to permission and environmental impacts.

Deep lake water cooling is a non-viable solution for the site due to the lack of a water treatment plant nearby and the fact that the Humber Bay has a shallow water depth relatively to the water near Centre Island. The site is also located far away from downtown Toronto's deep lake water cooling system, thus the connection to the existing Enwave network is not viable.

An alternative option would be represented by Mimico Creek or Lake surface water, however in this case the temperature of the water can drop to near or below freezing point in winter being not effective for heat pump systems.

In addition, the use of surface or deep lake/creek water requires obtaining a certificate of approval from the Ministry of Environment, Conservation and Parks. Approval by MOECP is granted on a case-by-case basis and process requirement and timeline is not certain. Scientific studies, including but not limited to ecological, hydrological and hydrogeological study, are also required. Also, the connection to Mimico Creek or Lake Ontario requires easement in public right-of-way and/or private properties.

A preliminary analysis was carried out to estimate the potential to connect to the Mimico Creek; however, results have shown that the system would be capable to provide only a very small portion of the energy demand of the site; therefore, considered the difficult permission process and the financial implications related to such a system, this solution has been discarded.

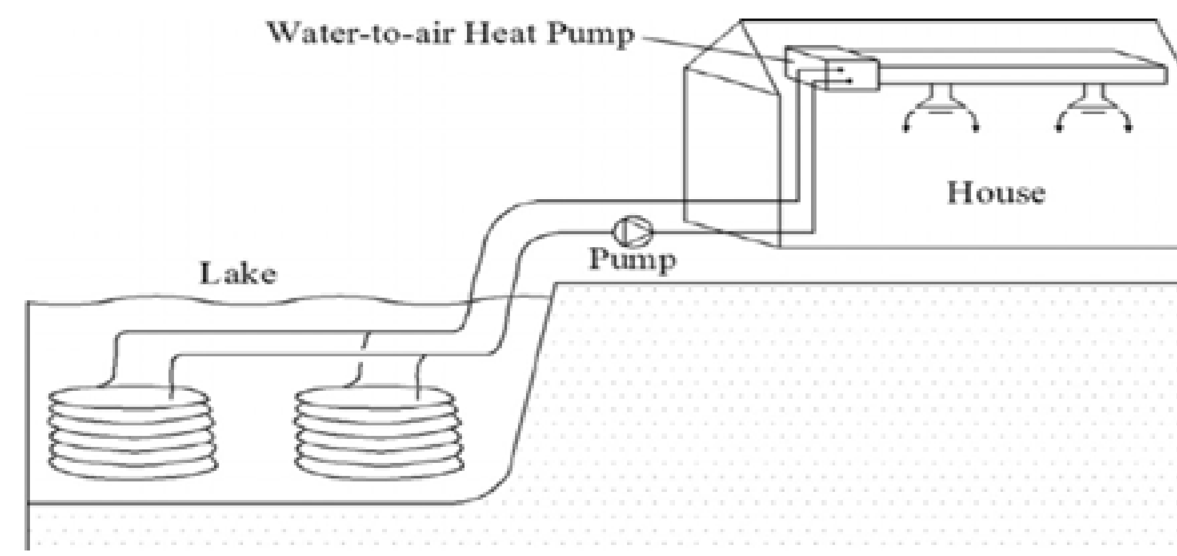

Figure 12 - Water source heat pump sketch (source: Journal of Renewable and Sustainable Energy, 2014).

Solar technologies

The use of solar technologies was also explored as an additional source of energy through renewable generation. These were considered compatible with any of the main technologies and therefore can be applied to any solution.

The potential of solar technologies has been explored through a solar analysis carried out using parametric modelling tools. The aim of the analysis was to define the optimal size and location of a solar system which could deal with the landscape requirement to have the lower level roof spaces free for green roofs and terraces.

Two scenarios were explored, the first one considering all roofs used for solar panels (Figure 13 and Figure 14) and the second applying solar panels only on the tallest roofs of each plot (Figure 15 and Figure 16).

The study showed that in the second scenario, 56% of the annual radiation was captured using only 28% of the roof area compared to scenario 1, meaning a much more effective system in terms of cost per tonne of CO_2 saved.

The second step of the analysis compared the carbon dioxide reductions related to solar photovoltaic panels to produce electricity and solar thermal panels to produce hot water.

The study considered horizontal panels located on 80% of the total roof available with effective area of 50% and efficiency equal to 15% for photovoltaic and 80% for solar thermal.

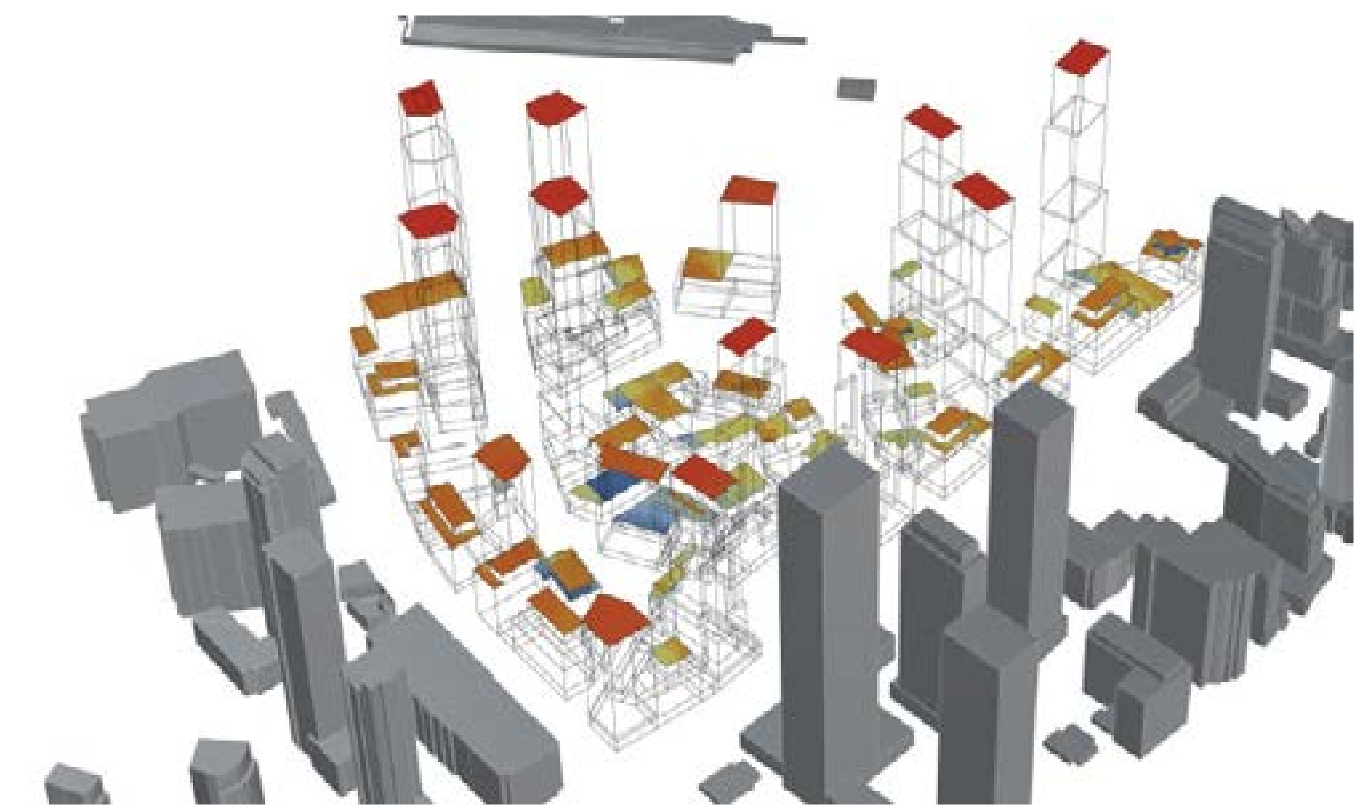

Figure 13 - Solar panel location and solar radiation in Scenario 1 – 3D view.

Figure 15 - Solar panel location and solar radiation in Scenario 2 – 3D view.

Figure 14 - Solar panel location and solar radiation in Scenario 1 – Plan view.

Figure 16 - Solar panel location and solar radiation in Scenario 2 – Plan view.

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The results of the solar analysis were then applied to the selected main energy solution (GSHP with electric boilers). Assuming that all the renewable energy generated can be used, the renewable energy produced was:

- 3.8 GWh from solar thermal (9.0% of the total energy demand for the site)
- 0.7 GWh for photovoltaic (1.7% of the total energy demand for the site)

The preliminary analysis, carried out on the annual solar energy available, showed that the solar panels have the potential to generate more thermal energy than the site heating demand covered by the electric boilers in the design option. A more detailed analysis at a later stage of design is recommended to optimise the size of the GSHP and the solar thermal system in terms of carbon dioxide reduction and costs.

It should also be taken into consideration that the integration of solar heating generation with the GSHP system can present issues in terms of constructability and pipework distribution, with cost and space implications particularly relevant for high-rise buildings.

1.3.2 COMPARATIVE ANALYSIS

In order to advise the best solution in terms of energy provision for the site, a number of supply options have been considered and evaluated in terms of environmental impacts, namely:

Ground Source Heat Pumps

Option 1A	Ground source heat pumps (GSHPs) providing heating and cool-ing coupled with gas-fired boilers and air-cooled chillers provid-ing cooling - by plot
Option 1B	Ground source heat pumps (GSHPs) providing heating and cool-ing coupled with electric boilers and air-cooled chillers providing cooling - by plot
Option 1C	Centralised ground source heat pumps (GSHPs) providing heat-ing and cooling coupled with electric immersion heaters in each apartment for DHW top-up and air-cooled chillers providing cooling by plot

Air Source Heat Pumps

Option 2A	Air source heat pumps (ASHPs) providing heating coupled with gas-fired boilers in the basement and air-cooled chillers provid-ing cooling - by plot
Option 2B	Air source heat pumps (ASHPs) providing heating coupled with gas-fired boilers on the roof and air-cooled chillers to provide cooling - by plot
Option 2C	Air source heat pumps (ASHPs) by plot providing heating cou-pled with electric immersion heaters in each apartment for DHW top-up and air-cooled chillers providing cooling by plot

Biomass

Option 3	Centralised biomass boiler to cover the heating base load coupled with centralised electric boilers and air-cooled chillers to provide cooling by plot

All the options were compared to a business-as-usual scenario (base case) involving gas-fired condensing boilers providing heating, and air-cooled chillers providing cooling on a plot-by-plot basis.

The Toronto Green Standards targets for Tier 4 were calculated for the whole site, area-weighting the targets for the different archetypes. The following Tier 4 site-wide targets were estimated:

- EUI = 75 kWh/m^2
- GHGI = 5.1 kgCO2/m^2

The model was built on the assumption that the buildings will be designed to achieve the Tier 4 TEDI targets, therefore this parameter – which is not influenced by the energy supply technologies – was taken out of the current analysis.

The following table and graphs show the results of the comparative analysis in terms of Tier 4 targets and annual carbon dioxide emissions.

Results show that all GSHP options – with gas-fired or centralised/decentralised electric boilers – can achieve Tier 4 of the Toronto Green Standard.

In terms of carbon emissions, though, the all-electric option (1B) achieves considerably better performances, with an additional 30% reduction over the hybrid solution (1A), meaning that it is the most carbon-effective solution.

Therefore, considered the aspiration of the project of achieving outstanding levels of sustainability with a near-zero carbon building design and the aim to avoid gas provision to site, Option 1B was considered the preferred option. The concept design for the masterplan has been therefore based on this energy supply solution.

Additional renewable technologies can be implemented to further improve the performance of the development and reduce the environmental impact of the site, such as solar photovoltaic and solar thermal panels. A high level solar analysis has been carried out for this purpose.

Also, the opportunities to implement smart energy storage systems shall be investigated at later stages of the design to further optimise the site energy system and improve the overall energy performance of the development, whilst reducing the peak electrical demands.

	Base case	Option 1A	Option 1B	Option 1C	Option 2A	Option 2B	Option 2C	Option 3
EUI	102.1 kWh/m²	72.5 kWh/m²	72.2 kWh/m²	73.4 kWh/m²	86.2 kWh/m²	85.3 kWh/m²	108.1 kWh/m²	102.1 kWh/m²
GHGI	11.1 kgCO2/m²	4.5 kgCO2/m²	3.6 kgCO2/m²	3.7 kgCO2/m²	7.3 kgCO2/m²	4.3 kgCO2/m²	16.9 kgCO2/m²	11.1 kgCO2/m²
Total CO2 emissions	6,550 tCO2/y	2,670 tCO2/y	2,130 tCO2/y	2,160 tCO2/y	4,280 tCO2/y	4,280 tCO2/y	2,510 tCO2/y	9,980 tCO2/y
Tier 4 achieved	✗	✓	✓	✓	✗	✗	✗	✗

Table 1.6 - Supply options summary.

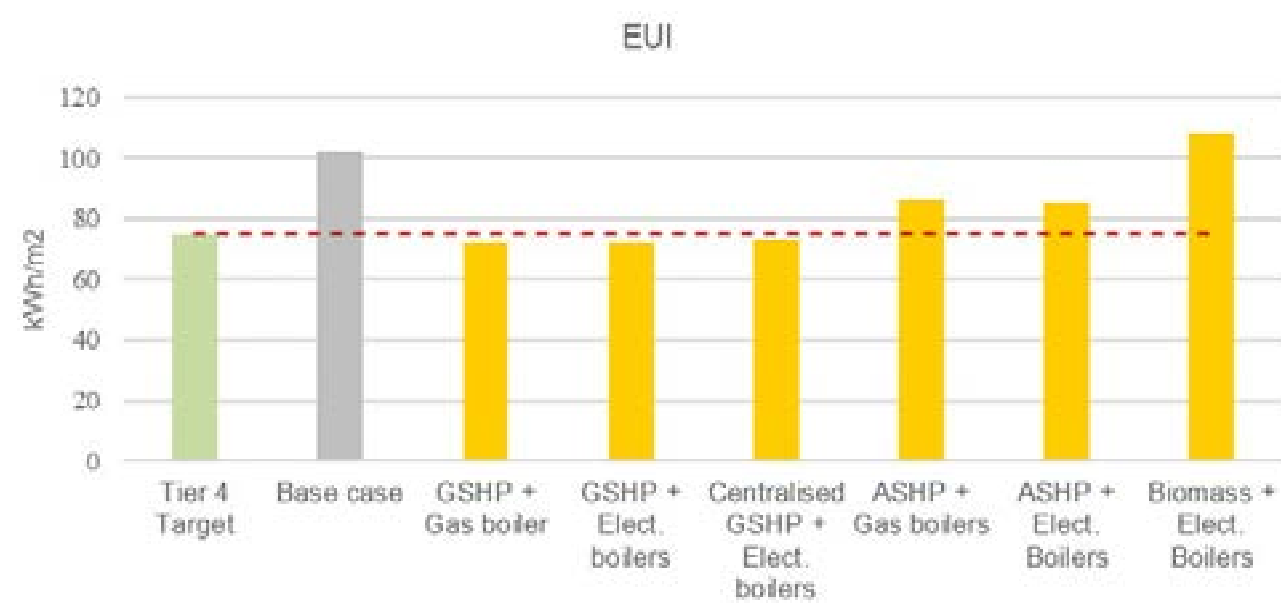

Figure 17 - Total Energy Use Intensity figures for the supply options.

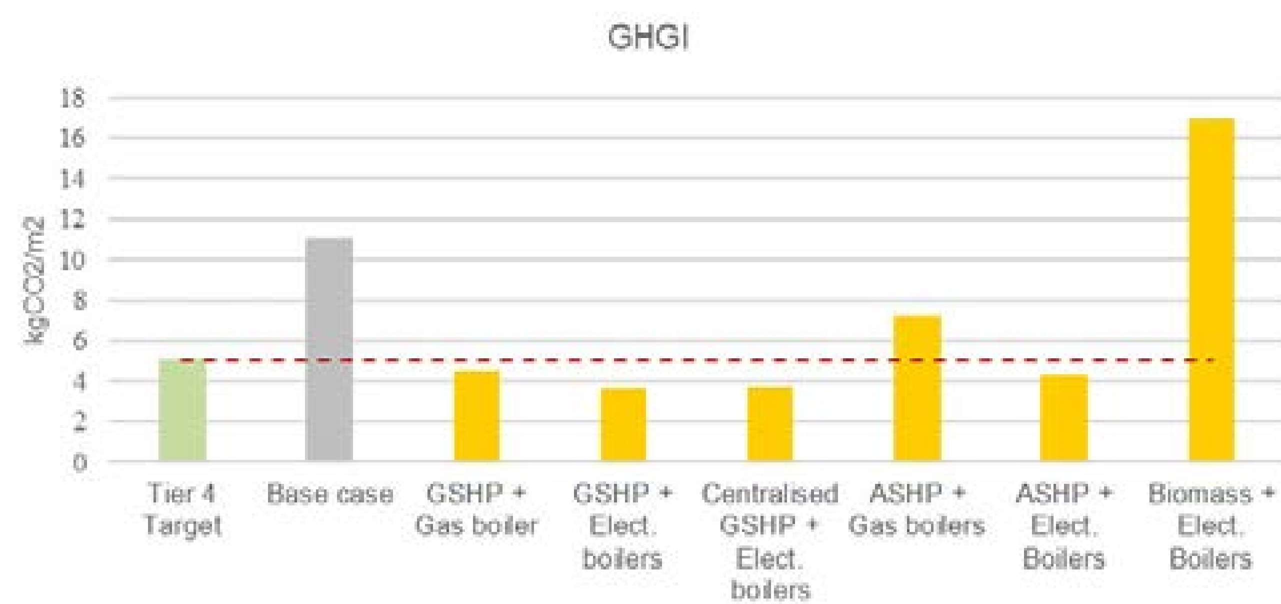

Figure 18 Greenhouse Gas Intensity figures for the supply options.

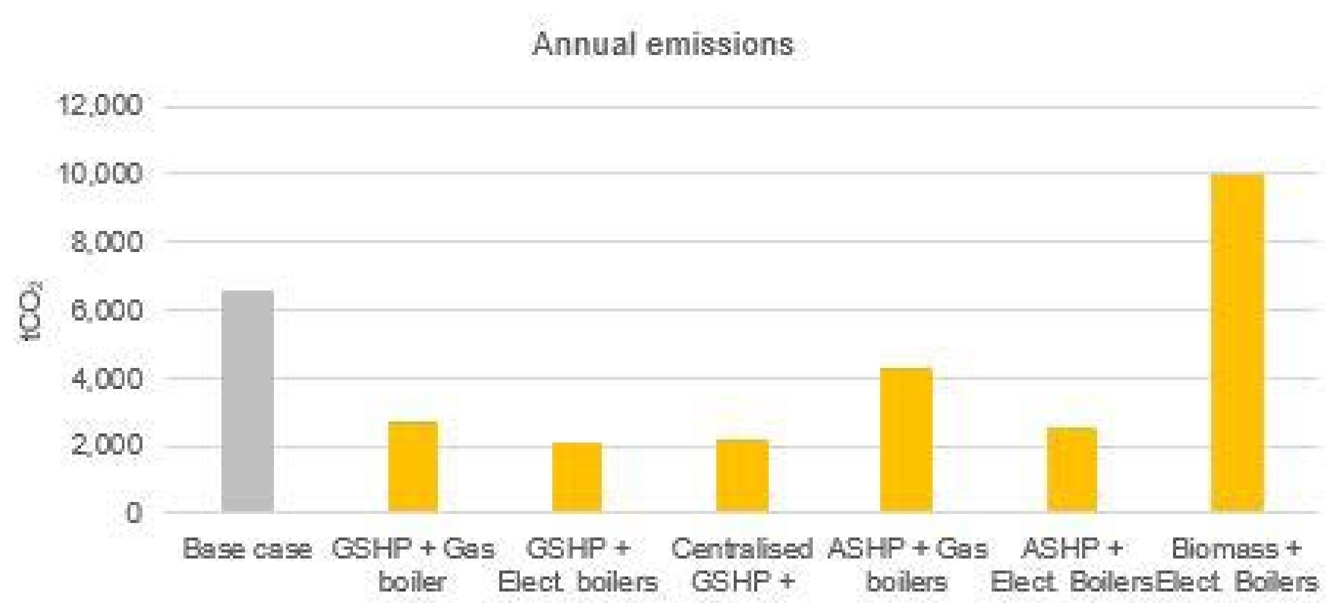

Figure 19 - Comparative annual carbon dioxide emissions for the supply options.

1.3.3 PREFERRED SOLUTION

Based on the comparative analysis, Option 1B (GSHP + Electric boiler) was selected as the proposed energy supply solution for the concept masterplan.

The strategy involves:

- Ground source heat pumps (GSHPs) to provide space heating, pre-heat for the DHW and cooling – by plot
- Electric boilers to top-up the DHW temperature and as a back-up solution – by plot
- Air-cooled chillers to top-up the cooling – by plot

The design of the GSHP was based on a study carried out by Arup to investigate the available capacity for geo-exchange and ensure annual heat balance with the ground.

Based on this, a GSHP providing 12 MW heating and 16 MW cooling capacity was considered for the whole site. For simplicity, at this stage, a proportion of this was assigned to each plot based on the total floor areas.

The assumed efficiencies of the system were:

- GSHP: SCOP in heating mode = 3.5; SCOP in cooling mode = 5.6;
- Electric boilers: 99% efficient
- Air-cooled chillers: Average EER = 6.7
- Buildings distribution losses: 6%

Results of the preliminary analysis show that the preferred solution has the potential to achieve the following targets:

- EUI = 72.6 kWh/m^2 (4% improvement over Tier 4 target)
- GHGI = 3.0 kgCO2/m^2 (29% improvement over Tier 4 target)
- Annual carbon dioxide emissions: 1,755 tCO2 (-4,420 tCO2/y compared to base case)

Additional solar energy generation can be combined with the main strategy. These should be designed based on a more detailed analysis at the next stage aimed at estimating the effective solar energy available on site through an hourly energy model.

Also, the use of smart batteries for energy storage is recommended to optimise the system and reduce the instantaneous peak electricity demands. The integration of batteries in the system shall be investigated as part of the next design stage.

1.4/ ENERGY RESILIENCE

According to the Resilient Design Institute, "Resilience" is the capacity to adapt to changing conditions and to maintain or regain functionality and vitality in the face of stress or disturbance.

Designing for resilience means, therefore, to account for future changes in climate, fuel availability and technologies when designing a building, allowing for enough capacity and flexibility to cope with increased loads and changes in the technologies available, as well as to respond to events of stress or disruption.

1.4.1 ADAPTABILITY TO FUTURE CHANGES

Figure 20 - Toronto's future weather figures (source: Toronto's Future Weather and Climate Driver Study, 2011).

The City of Toronto has carried out studies to understand the impact of climate change on Toronto's climate which were summarised in Toronto's Future Weather and Climate Driver Study, which provided a series of climate projections from 2040 to 2049. Key predictions for Toronto's future climate include:

- An increase in average summer temperatures by 3.8°C
- An increase in extreme daily minimum temperatures by 13°C
- An increase in the number of days above 20°C from 133 to 160
- An increase in the number of days above 0°C by 16%
- An increase in the number of "heat waves" from an average of 0.57 occurrences per year to 5 oc-currences per year
- An increase in the number of days requiring air conditioning
- A decrease in the number days requiring extra heating
- Slightly more precipitation overall, with the highest increases expected for the months of July (+80%) and August (+50%)
- A smaller number of storm events, but an increase in the amount of precipitation in these events

- A threefold increase in extreme daily rainfall in the month of June

While Toronto's climate has been traditionally a heating-driven climate, the presented scenario shows that the trend is toward a warmer and more humid climate; thus, it will be particularly important to design the buildings to reduce the need for cooling in the warm season.

Using a ground source heat pump system for thermal energy supply is in line with this objective, as it allows the generation of both heating and cooling from geothermal exchange. The detailed design of the system will have to ensure balance throughout the year between heat extracted and injected into the ground, also considering the future energy demands.

The selection of a decentralised scheme instead of a centralised one is also key to ensure future-proofing design to the scheme; in fact, a plot-by-plot system allows for greater flexibility compared to a centralised solution in case of a change of generation system or delivery temperature, as there is no district network to be adapted to the new system.

1.4.2 RESILIENCE TO POWER DISRUPTION

The Toronto Green Standards dictate requirements for additional resilience of power supplies to essential loads in multi-unit residential buildings (MURBs) in case of area-wide power outages. The backup power requirement is in addition to base requirements for emergency power necessary for life-safety. Table 1.7 illustrate the TGS requirements for both emergency and back-up power.

In addition, in the case of 2150 Lake Shore, the power back-up is a crucial point of the Energy Strategy considered that heating and cooling are provided 100% via electric sources.

A combination of the following can be considered towards securing power supply resilience of the site:

- Natural Gas / Diesel Generators
- Energy Storage Systems
- Secondary Utilities Supply

Back-up power supply is provided as standard via diesel or natural gas generators. Individual back-up generators can be located at basement levels serving one or multiple buildings. Using de-centralised topology allows for localised resilience to each building and avoids the requirement for large area reservations for multi-generator plant. The generator system can be designed to serve both emergency and back-up power requirements through a load management system that permits fast generator start-up (<15 seconds) to support critical loads and later gradual addition of essential loads.

Emergency Power Requirements	Back-up Power Requirements
Required for life-safety, emergency evacuation, fire-fighting and fire-fighting access	Required for safety and well-being of population during extended power outage
Supply to Critical systems – • Fire suppression (sprinkler systems) • Fire-fighting elevators • Smoke extraction systems • Emergency lighting	Supply to Essential systems – • Domestic water supply and treatment • Elevators • Heating • Basic telecommunications
Minimum duration: 2h	Minimum duration: 72h
To be designed to statutory laws and regulations	To be designed to non-statutory standards and guidance documents

Table 1.7 - Emergency and back-up power requirements from TGS.

The proposed Energy Strategy aims at avoiding natural gas use on site to keep carbon emissions to a minimum. Further analysis of space allowance and cost associated with fuel reserves versus dedicated gas distribution system is required to determine suitable technology to be used.

Energy storage is normally intended for peak load shaving under normal operation. During site-wide power outage the stored capacity can be used for supporting portion of the essential loads reducing the required sizes of back-up generators.

Another option to be investigated with Toronto Hydro is deriving supply from an alternative substation in the area, so a power failure can only affect a portion of the site. Critical and essential loads can be transferred to an alternative supply via automatic change-over devices and supported in case of emergencies. In combination with energy storage, this is the only option guaranteeing power resilience eliminating the reliance on fossil fuels.

1.5/ CONCLUSIONS AND NEXT STEPS

1.5.1 CONCLUSIONS

This Energy Strategy for 2150 Lake Shore explored viable solutions to achieve TGS v3 Tier 4 energy performance.

A number of passive and active design measures are suggested for the buildings to achieve Tier 4 TEDI targets. Then, a comparative analysis was carried out to identify the most effective solution to provide the remaining energy needed through low carbon energy supply technologies.

The initial proposed option is a block-by-block solution including:

- Ground source heat pumps (GSHPs) to provide space heating, pre-heat for the DHW and cooling
- Electric boilers to top-up the DHW temperature and as a back-up solution
- Air-cooled chillers to top-up the cooling

This solution has been modelled for the development and results show that it can achieve:

- EUI = 72.6 kWh/m^2 (1.5% improvement over Tier 4 Target)
- GHGI = 3.0 kgCO2/m^2 (41.2% improvement over Tier 4 Target)
- Annual carbon dioxide emissions: 1,755 tCO2 (-73% over base case)

The integration of solar technologies for renewable energy generation and smart batteries for energy storage shall be investigated as part of the next design stages.

1.5.2 NEXT STEPS

- Building design to maximise passive strategies to reduce energy demand
- Consultation with Toronto Hydro to ascertain location and capacity of existing power infrastructure
- Detailed solar analysis based on hourly modelling to evaluate effective solar energy available and investigate integration of solar system into the main plots' system
- Appointment of a cost consultant recommended to carry out detailed cost analysis on the selected options and assess the impact of variations such as centralised vs. decentralised solutions
- Energy back-up and energy storage solutions to be further investigated and sized to ensure resilience and reduce peak demands
- Cost benefit analysis of using diesel vs. natural gas generators for back-up power