ORION: A NEAR-ZERO EMISSIONS MULTI-UNIT RESIDENTIAL BUILDING IN PEMBERTON, B.C.

CASE STUDY

Orion is a multi-unit residential building in Pemberton, British Columbia. The project is expected to exceed the energy efficiency requirements set for its region and meet Step 4, the highest level of the BC Energy Step Code, while maintaining the construction cost below the market rate. This case study presents practical solutions and strategies implemented during design and construction to deliver an affordable, sustainable, low-carbon, healthy building in British Columbia's South Coast.

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PREPARED BY

zebx

UBC THE UNIVERSITY OF BRITISH COLUMBIA

VIDORRA DEVELOPMENTS

QUICK SUMMARY

INCREASED INSULATION

The exterior walls achieved an estimated overall performance of R48 using two layers of R24 insulation, batt insulation in the 2x6 walls and R24 as part of the EIFS wall system. The attic has R80 urethane foam insulation - **page 06**

INSULATED CONCRETE FORMS

in the foundation resist heat flow and moisture intrusion and contribute to the building's energy efficiency and occupants' comfort - **page 07**

THERMAL BRIDGING

is minimized by using a high-performance composite cladding system without mechanical fasteners and cantilevered glulam beams to support the balcony decks - **page 06**

LOWER PROJECT COST

by 12-34% than a similar residential building built to Step 1 of the BC Energy Step Code, due to implementing simple and cost-effective solutions that are streamlined on multiple similar projects by the same project team - **page 04**

EFFICIENT FENESTRATION

argon-filled, triple-glazed, low-E coated, Passive House certified windows provide efficient thermal performance and have a low solar heat gain coefficient to reduce the risk of overheating - **page 06**

MINIMAL HEATING

is provided by an integrated centralized system using air source heat pumps with variable refrigerant flow (VRF). The heating is distributed through the heat recovery ventilator for efficient space heating - **page 08**

ENERGY RECOVERY VENTILATORS

with an efficiency of 86% conserve energy by transferring heat from indoor air to preheat continuous incoming fresh air. There is a separate HRV system for the underground parkade - **page 08**

HEAT PUMP DOMESTIC HOT WATER

Single-pass heat pumps with CO_2 refrigerant increase the efficiency of the DHW system and reduce carbon emissions - **page 09**

EFFICIENT LIGHTING

is provided by LED light bulbs which are energy efficient and long-lasting and have motion sensors - **page 08**

EFFICIENT APPLIANCES

such as ductless condensing dryers reduce energy use and avoid airtightness and insulation penetrations - **page 08**

Credit:Vidorra Developments Ltd.

GENERAL OVERVIEW

Orion is designed and constructed with a focus on cost-effective energy conservation measures. The project's performance is expected to be equivalent to Step 4, which is the highest level of the BC Energy Step Code for Part 3 buildings.

Project Overview

Building Type	Multi-unit residential
Climate Zone	6 (3,000-3,999 Heating Degree Days)
Location	Pemberton, British Columbia
Gross Floor Area	4,827 m² / 51,962 ft²
Building Footprint	1,214 m² / 13,064 ft²
Building Height	11.5 m / 37.7 ft
Number of Floors & Suites	3 Stories + Parking garage 45 Units
Construction Period	May 2018 - March 2020
Occupation Date	March 2020

Project Team

Owner & Developer	Vidorra Developments Ltd.
Architect	Dennis Maguire
Structural Engineer	Chalten Engineering Ltd.
Mechanical & Electrical Engineer	SRC Engineering Consultants Ltd.
Envelope Consultant	Richard Kadulski Architect
Civil Engineer Consultant	RF Binne & Associates
Code Consultant	Evolution Building Science Ltd.
Sustainability Consultant	Innovation Building Group Ltd.

Project Context

In response to the global climate change crisis, in 2017 the Province of British Columbia enacted the BC Energy Step Code to improve the energy efficiency of newly constructed buildings and incrementally move toward net-zero energy ready buildings by 2032.

The Village of Pemberton enacted a bylaw in January 2020 that all new low-rise residential buildings (Part 9 of the B.C. Building Code) must meet Step 3 of BC Energy Step Code. However, at the time this case study was developed, there was no bylaw for higher Step Code requirements for mid-rise residential buildings (Part 3).

Orion is a three-story, multi-unit residential building (MURB) in Pemberton, B.C., with one level of underground parking. The energy performance is expected to be significantly better than the requirements set by the region's building authorities. The Orion project was only required to comply with Step 1, whereas the building is designed to meet Step 4 requirements, which is the highest step of the BC Energy Step Code.

This case study summarizes the design strategies and solutions implemented in this project to minimize energy use while keeping costs at the same level or below equivalent conventional code-compliant buildings.


Vidorra Developments Ltd.

Vidorra Developments Ltd.

PROCESS HIGHLIGHTS

Orion is designed with an envelope-first approach and offers a healthy and comfortable space for its residents. By focusing on cost-effective energy conservation measures, the team was able to keep the project's construction cost below the market rate.

Design Highlights

Orion has 45 residential units and underground parking. The building is designed with an envelope-first approach and incorporates a high-efficiency envelope to minimize the energy loads on the mechanical system. It is equipped with provisions to add on-site renewable energy generation in the future with wiring in place for photovoltaic panels on the roof.

In addition to high energy performance, the project adheres to industry best practices in building design and construction to ensure occupants' health, wellbeing, and comfort. The developer, Vidorra Developments, partnered with British Columbia-based universities to understand how to reduce the use of harmful materials and design healthy buildings.

Vidorra Developments uses The 9 Foundations of a Healthy Building framework by Harvard University to set the design and construction goals for their projects. The nine foundations are thermal health, air quality, ventilation, moisture, dust and pest, safety and security, water quality, lighting and views, and noise. Throughout the years, Vidorra Developments have streamlined solutions to achieve these healthy building goals and integrate them with other project goals, such as energy performance. The solutions used by the developer are presented in this case study.

Project Costs

According to the latest project costs report, the Orion project's costs are considerably lower than a typical project, while its energy and emissions performances are expected to be significantly better. Additionally, the project team was able to deliver the project with 5% less cost than the original budget.

The total project costs were $9.4M CAD, constituting $1.0M in soft costs that were used for consultants fees, project administration, permitting, marketing, and financing. Construction costs were $8.4M or $211 per square foot of the gross floor area (excluding parkade). According to Altus Group's 2019 Canadian Cost Guide, the construction of a similar wood-framed condo with one-level underground parking, built to Step 1 of the BC Energy Step Code is between $239-321/ft^2 CAD, which is 12-34% higher than Orion's construction costs.

One of the main reasons for the lower construction cost in Orion is that the designer, general contractor, developer, and most of the sub-contractors have worked together on a number of similar projects previously and have streamlined their collaboration processes and the building systems they use.

Orion's envelope is constructed with a highly insulated 2x6 stud wall on the inside and an exterior insulation and finish system (EIFS). It also has a liquid-applied vapour barrier (Credit: Vidorra Developments Ltd.).

ENERGY & CARBON PERFORMANCE

Orion's operational carbon emissions are minimized by reducing the energy demand and using renewable energy sources like hydro-generated electricity. The embodied carbon emissions are reduced by using locally sourced and low-carbon building materials.

Minimal Operational Carbon Emissions

Although the project team for Orion did not develop an energy model, the main design strategies were analyzed using the Building Pathfinder online tool. The total energy use intensity (TEUI) of the project is estimated to be between 60-70 kWh/m² per year and the thermal energy demand intensity (TEDI) close to 10 kWh/m² per year. This energy performance exceeds the requirements of Step 4 of the BC Energy Step Code.

In addition to minimizing energy use, the building is designed to have close to zero operational GHG emissions. The building's energy is fully supplied through electricity provided by BC Hydro, which is generated from 95% renewable sources. Additionally, Orion is ready to be zero-carbon operation, as the wiring for rooftop photovoltaic panels is already in place. According to a 2014 study by Intergovernmental Panel on Climate Change (IPCC), the GHG intensity of one kWh electricity produced by PV solar panels in British Columbia has about 50% less than the electricity supplied by the province's grid. Hence, the building's infrastructure will allow it to shift to on-site renewable energy sources in the future, when it is required by authorities or when it becomes financially feasible.

Low Embodied Carbon Emissions

Embodied carbon emissions are GHG emissions associated with the building materials throughout the building's life cycle, including production, transportation, installation, repair and replacement, and disposal.

The Orion project implemented three design strategies to reduce the embodied carbon emissions from its building materials. First, wood was used as the primary structural material because of its lower embodied carbon and it has a relatively low embodied carbon and has the potential to store carbon absorbed from the atmosphere during the growth of the trees. Second, most building materials used in the project are locally sourced from British Columbia, which reduces the GHG emissions associated with material transportation. Third, selecting long-lasting products that do not need to be replaced often, which reduces emissions associated with manufacturing and transporting replacement products.

Top left: Eight Sanden CO_2 air-to-water heat pumps are used as a primary source to heat the DHW for the building.
Top right: Wood is used as the main material for the structure and envelope to reduce the building's embodied carbon.
Bottom: DHW system uses a 27kW supplementary electric boiler for back-up. DHW system design incorporates highly insulated piping and an efficient monitoring and control system to prevent unintended heat losses.
(Credit: Vidorra Developments Ltd.)

HIGH-PERFORMANCE ENVELOPE

The project used a high-performance and airtight envelope that incorporates thick insulation, exterior insulation and finish system cladding, Passive House certified fenestration, thermal-bridge-free balconies, insulated concrete form foundation, and light-colored reflective roof covering.

The exterior walls of Orion have high thermal efficiency, with an effective thermal resistance of R48. The exterior wall assembly consists of wood-framed stud walls filled with R24 batt insulation and covered with an R24 Adex exterior insulation and finish system (EIFS) cladding.

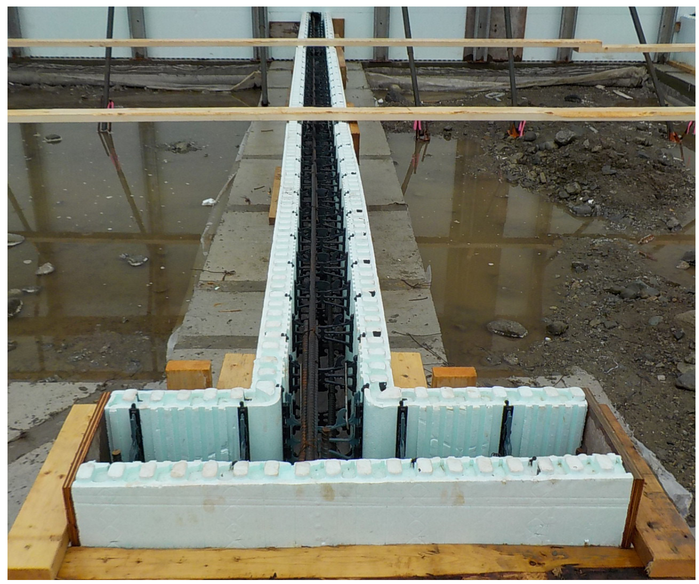
The EIFS cladding system has a simple on-site installation process, which also maintains the integrity of the air barrier layer. EIFS includes a liquid-applied, weather-resistant barrier, a continuous Expanded Polystyrene (EPS) insulation board with built-in drainage attached to the substrate with adhesives, and a reinforced base coat.

The Orion building uses Passive House certified, high-performance, argon-filled, triple-pane tilt and turn windows. The window glazing has low-E and a low solar heat gain coefficient to reduce the solar heat gain. To maximize the thermal performance and airtightness of the windows, they are installed in the middle of the wall panels, the EPS insulation is extended over the window frame to cover any gap between the window and wall, and the connection is double sealed with airtightness tape.

To prevent thermal bridging in the envelope through the suite balconies, the building features aluminum decks supported by cantilevered glulam beams as an alternative to self-standing structural brackets. The aluminum checkered plates used for the deck surfaces are durable materials requiring minimal maintenance.

A single layer, thermoplastic polyolefin (TPO) roofing membrane was installed on the roof. TPO is one of the most energy-efficient and cost-effective roofing solutions and is light-colored to reflect UV rays and heat, which helps keep the building cooler during the summer.

The building foundation is insulated concrete forms (ICF) with EPS insulation on both sides of the foundation forms. ICF is a durable, easy to install foundation system. The EPS not only works as the thermal barrier but also avoids accumulation of moisture and formation of mold in the underground parking.



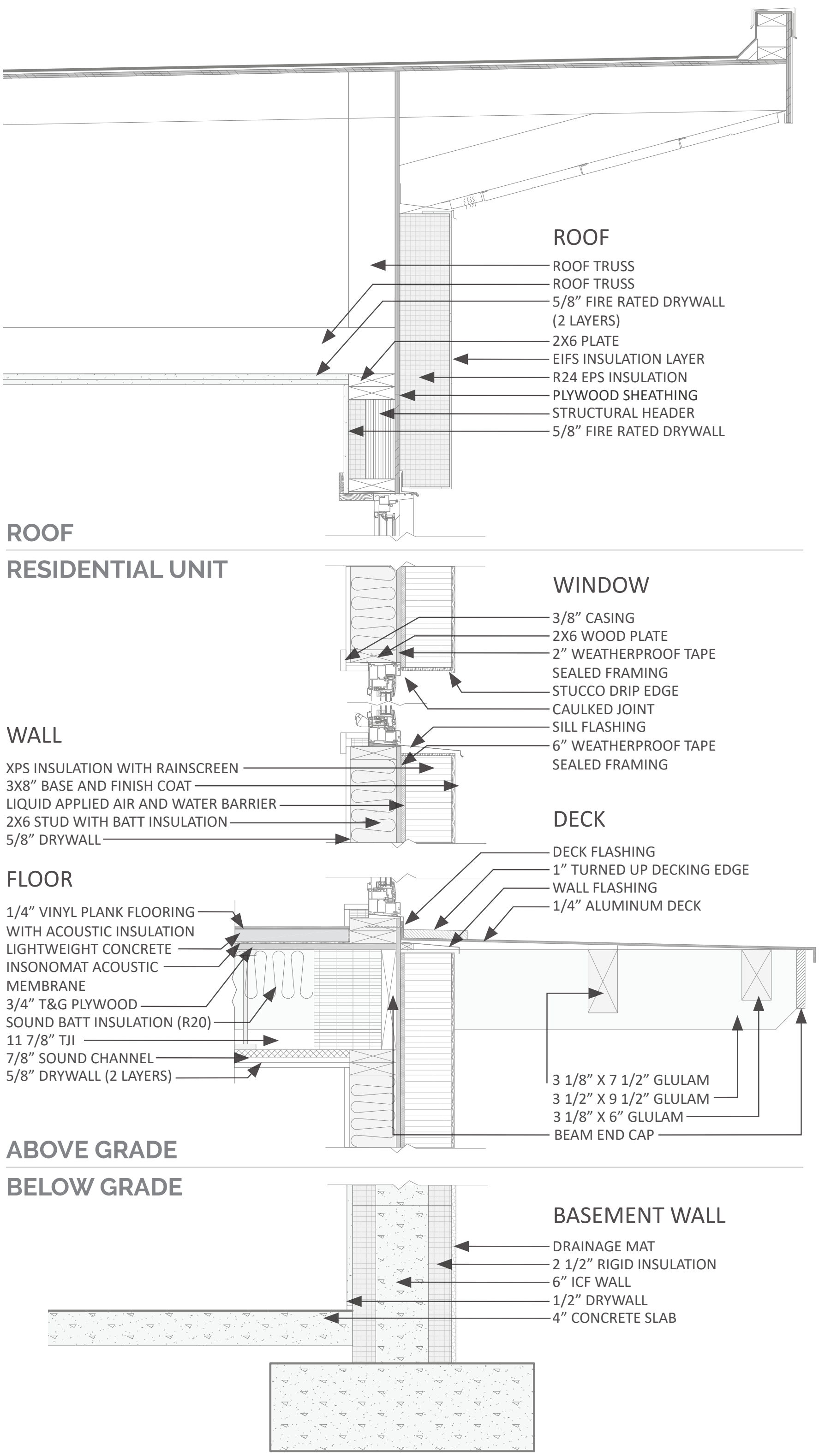
EPS insulation in the insulated concrete form (ICF) ready for pouring the concrete for the foundation (Credit: Vidorra Developments Ltd.)

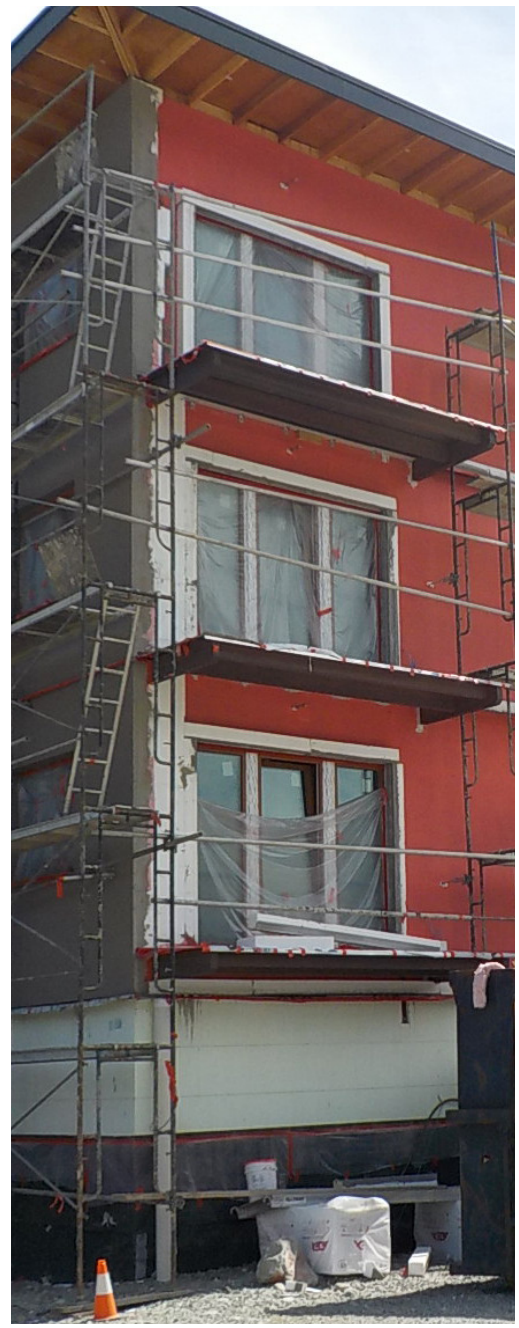
Thermal Performance of Exterior Components of Orion
(based on the information provided by Vidorra Developments Ltd.)

Envelope Component	Component Description	Thickness (cm/inch)	U-value (W/m²K)
Exterior Wall	2 x 6 stud wall with Batt insulation and covered with an Adex EIFS cladding system	34.5/13 ½	0.118 (R48)
Underground Parking Wall	ICF Foundation with EPS insulation on both sides	29/11 ½	0.258 (R22)
Floor Slab	TJI Joists floor assembly with Batt Insulation	40/16	0.283
Roof Slab	Roof trusses	Varies between 60-90/2-3'	0.081
Exterior Windows	Passive House certified windows Triple glazed, argon filled, Low-E coated	-	0.69-0.91
Exterior Doors	Passive House certified doors	-	0.79

ENVELOPE DETAILS

Orion was designed with an envelope-first approach in which an airtight and thermally-efficient envelope is designed to minimize the energy load of the building. The details are designed to minimize thermal bridges.





Right: Orion wall during construction, showing the liquid applied air and water barrier

Left: Orion wall section details

Stud wall construction with batt insulation, thermal-bridges-free construction, continuous airtightness membrane, and Passive House certified triple-glazed windows contributed to the envelope's high performance.

(Credit: Vidorra Developments Ltd.)

ENERGY EFFICIENCY STRATEGIES

The heating and ventilation systems were optimized by using an integrated centralized system with two outdoor air source heat pumps and an energy recovery ventilator. The use of LED lighting and efficient appliances also contribute to the energy efficiency of the building.

Orion has a centralized heating, ventilation, and air conditioning (HVAC) system which includes a Swegon Gold RX-35 energy recovery ventilator (ERV) unit with 86% efficiency. The ERV is connected to two Mitsubishi air source heat pumps with a variable refrigerant flow (VRF). The heat pumps allow the ERV to double its ventilation capacity and provide additional heating and cooling to respond to the peak demands.

The ERV has a bypass mode to flush the heat out and help cool the building in summers when the exterior temperature is lower than the inside temperature, especially at night time. The building also has a supplemental baseboard heating system with individual thermostat controls within each unit.

A real-time data monitoring system controls the HVAC system, which allows the building manager to optimize the performance of the central heat pump and ERV systems. This minimizes the need for the less-efficient baseboard electric heaters.

Energy-efficient appliances with minimal need for venting are selected to save energy and minimize envelope perforations that compromise the airtightness. For instance, ductless condensing dryers condense extracted moisture and discharge it down the drain, avoiding the need for exterior dryer vents in each unit. The kitchen hoods have recirculating fans that clean the exhaust air and release it back into the home. Additionally, the ERVs have an exhaust vent in the kitchen close to the range.

The building uses an Otis Next Gen2 energy efficient elevator that does not require a mechanical room and is less noisy in operation. Only LED lighting is used in the building as they are long-lasting, low-maintenance, and energy efficient. All exterior lights have motion sensors to decrease energy consumption and prevent light pollution.

Top: Central air-to-air heat pump with VRF technology integrated with high-efficiency ERV is used to meet the space heating, cooling, and ventilation requirements.
Bottom: Efficient appliances and LED lighting in the units (Credit: Vidorra Developments Ltd.)

DOMESTIC HOT WATER SYSTEM

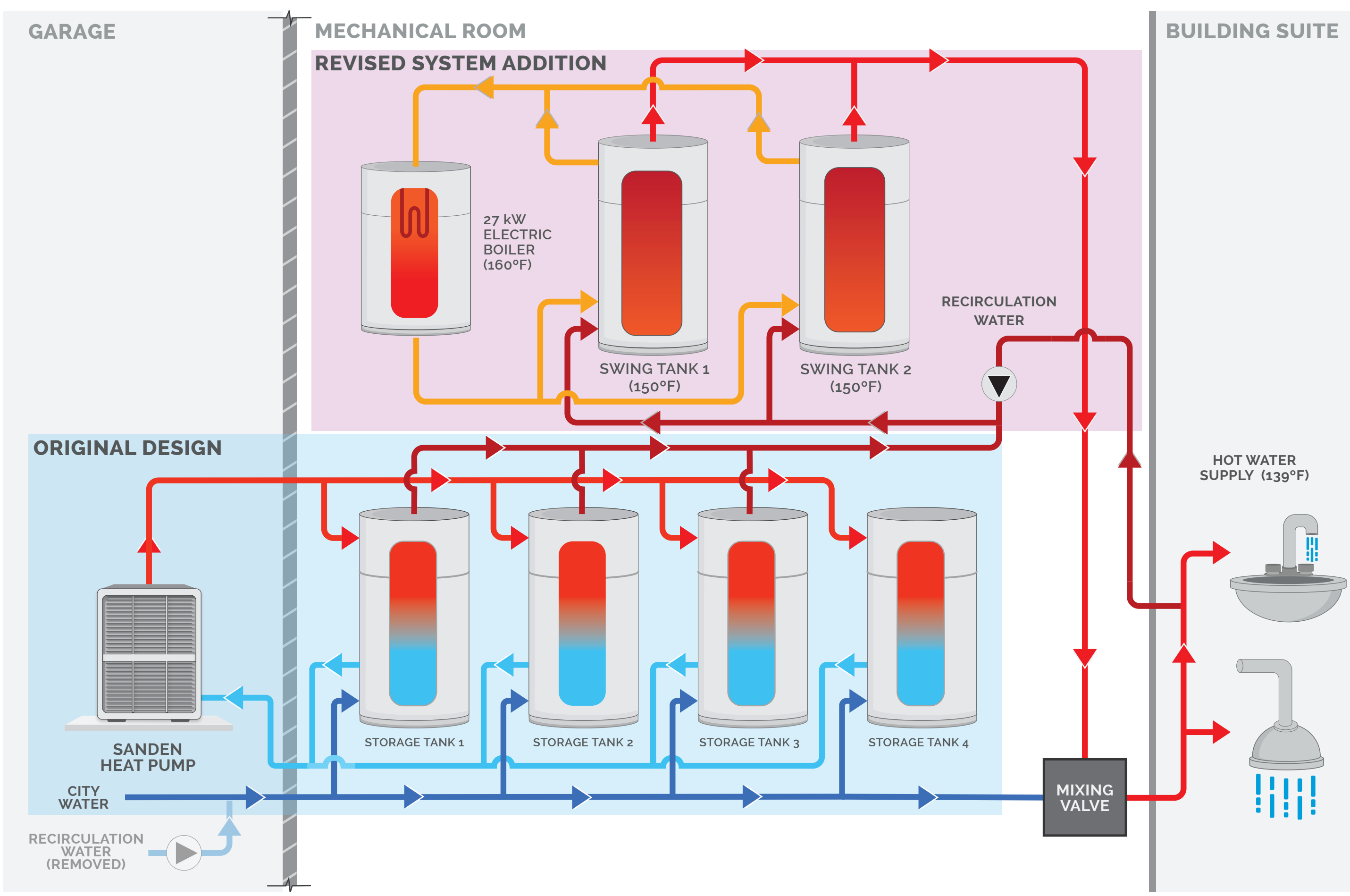
A heat pump system is used to heat domestic hot water more efficiently. To optimize the performance of the DHW system, separate swing tanks were added to store the hot water from the heat pumps, supply to the building demand, and collect the recirculated return water.

Domestic hot water (DHW) heating is provided by Sanden CO_2 air-to-water heat pumps that heat water in the storage tanks by transferring heat from outside air using CO_2 as a refrigerant. Using CO_2, instead of the more conventional HFC refrigerants reduces the potential GHG emissions in the case of a leak or at disposal.

Single-pass CO_2 heat-pump DHW systems are most efficient when receiving the coldest water possible directly from the municipal supply. The initial design of the DHW system configuration for the Orion project mixed the cold municipal water with the hot water produced by the heat pumps, and the recirculated water from the building in the storage tank. Mixing hot and cold water would have increased the water temperature the heat pumps would receive, which would have dropped the overall system efficiency. This issue was addressed by adding separate "swing tanks" that store the hot water from the heat pumps to supply to the building. The recirculated water was re-directed into the swing tanks and an electric boiler was added to provide supplemental heating when the temperature of the water from the heat pumps drops below 120˚F (49˚C).

A more efficient central DHW system configuration can be found in the ZEBx case study of "Batik Apartments: A Low-Carbon Central Domestic Hot Water System ", which is based on a report prepared by the project's DHW sytem design consultant, Ecotope Inc.

Schematic Design of Orion's DHW System (based on the information provided by Vidorra Developments Ltd.)
Bottom: Original Design: Cold municipal water is mixed with the recirculation water from the building and the heated water from the single-pass heat pumps, lowering the system efficiency.
Top: Revised Design: Swing tanks are added to supply hot water to the suits and collect recirculated water from them rather than mixing it with the cold city water in the storage tanks. An electric boiler is used to reheat water in the swing tank to the desired temperature.



GLOSSARY

Key terms, definitions, and abbreviations used in this case study arranged alphabetically.

Airtightness
The resistance to inward or outward air leakage through unintentional leakage points or areas in the building envelope. Airtightness is represented in units of ACH and is commonly tested using a blower door test.

Air Source Heat Pump
Air source heat pump transfers the heat between the outdoor and indoor air. It works by extracting the heat from the outside air and transfers it into the building. This heat can be released directly into the air stream or through the water pipes, based on the heating distribution system.

BC Energy Step Code
A voluntary provincial standard in British Columbia that provides an incremental and consistent approach to achieving more energy-efficient buildings that go beyond the basic requirements of the BC Building Code.

Variable Refrigerant Flow (VRF)
A technology that is based on transferring heat through refrigerant lines from an outdoor compressor to multiple indoor fan coil units. VRF systems vary the amount of refrigerant delivered to each indoor unit based on demand.

Embodied Carbon
The CO_2 emissions associated with the production of a building, including the extraction, manufacturing, and transportation of construction materials, as well as construction processes.

Energy Recovery Ventilator (ERV)
A mechanical device that can recover both heat and moisture, and helps to retain and control a comfortable humidity level within the space. This device is generally recommended when the typical outside air is usually dry.

Expanded Polystyrene (EPS)
A rigid and low-density insulating foam.

Exterior Insulation and Finish System (EIFS)
A multilayered exterior wall cladding system designed to provide high energy efficiency.

Heating Degree Days (HDD)
A measure of how cold the temperature was on a given day or during a number of days, usually less than 65˚F. The HDD of a specific location is directly proportional to the energy required to heat a building.

Heat Pump
A mechanical system that transfers thermal energy in the opposite natural direction of heat transfer from a colder space to a warmer space. Heat pumps are a more energy efficient alternative for space heating, cooling, and domestic hot water.

Insulated Concrete Form System (ICF)
Insulating Concrete Forms are cast-in-place concrete walls sandwiched between two layers of insulation material. The rigid thermal insulation layer increases the thermal resistance of concrete assemblies and minimizes thermal bridging.

Low-Emissivity (Low-E)
A surface condition that emits low levels of radiant thermal energy. Glass is highly thermally emissive, so to improve the thermal performance of windows, thin-film coatings with low-emissivity are applied to window glasses.

Passive House Standard
An internationally recognized certification program, developed by an independent research institute based in Germany. The program is intended to result in buildings with extremely low space heating and cooling needs and consequently lower environmental impacts, as well as comfortable indoor temperature and air quality.

GLOSSARY

Key terms, definitions, and abbreviations used in this case study arranged alphabetically.

Photovoltaic Panels
It is a device that transforms light energy into electricity. Usually, the photovoltaic system employs solar modules, each comprising a number of solar cells, which generate electrical power. These PV installations may be ground-mounted, rooftop mounted, or wall-mounted.

G-value or Solar Heat Gain Coefficient (SHGC)
Solar Heat Gain Coefficient or G-value is a measure that shows how well the glazing blocks the solar heat. It is expressed in values between 0 and 1, with the lower values corresponding to a better heating restriction. High solar heat gain can be beneficial in winters as it reduces the need for heating but causes overheating in summers.

Thermal Bridge
An area or a building component which has higher thermal conductivity than the surrounding materials, creating a path of least resistance for heat transfer. Thermal bridges in a building envelope result in significant heat loss and energy efficiency reduction.

Thermal Energy Demand Intensity (TEDI)
A metric of the modeled building's heating needs used in the BC Energy Step Code that is primarily influenced by the building enclosure insulation, airtightness, and ventilation system. A highly insulated, airtight enclosure, with heat recovery ventilation will achieve a lower TEDI value.

Thermoplastic Polyolefin (TPO) Roofing Membrane
A cost-effective and durable single-ply roofing membrane that covers the surface of the roof. They are available in light colors and offer the best solar radiant heat reflection properties.

Total Energy-Use Intensity (TEUI)
The total energy usage of the building that includes plug loads and lighting, auxiliary systems such as elevators, and miscellaneous equipment in addition to the HVAC and DHW systems.

Trus Joist I Joist (TJI)
A type of high-performance engineered I-joist with more dimensional stability used for making roofs and floors.

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Learn more at

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