WOOD PELLET
ASSOCIATION OF CANADA

SHAW RENEWABLES

NOVA SCOTIA
Public Works

Wood Pellet Feasibility Study

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March 18, 2021

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EXECUTIVE SUMMARY

Nova Scotia Department of Public Works wants to eliminate the use of furnace oil from all the buildings under their portfolio to reduce emissions. As a result, this study looks at alternative fuel sources which are greener than furnace oil including electrification, wood pellets and wood chips. A life cycle cost analysis has been conducted for each of the alternative fuel system types.

In addition, Nova Scotia's Environmental Goals and Climate Change Reduction Act has a goal to decrease greenhouse gas emissions across Government-owned buildings by 75% by the year 2035 and with heating and domestic hot water accounting for close to 50% of the energy use in commercial and institutional buildings in Atlantic Canada, eliminating furnace oil is essential to achieve 2035 target.

The buildings under Public Works' portfolio were categorized based upon their annual fuel consumption and a building from each category was selected as a representative of the category:

- <7,000L
- 7,000-30,000L
- 30,000-50,000L
- 50,000-100,000L
- 100,000L+

The life cycle economics analysis results showed that:

- For the buildings with an annual oil consumption of less than 30,000L, wood pellets are the most economical alternative system
- For the building with an annual oil consumption of more than 100,000L, wood chips are the most economical alternative system
- For the buildings with an annual oil consumption of between 30,000L to 100,000L, the results vary based upon the closeness of the site to Local Pellet Producers which will lead to lower wood pellet delivery cost and the ability of the building to hold a pellet boiler in the existing boiler room which will lead to lower initial cost
- For the location which shows both pellet and chips as the economical alternative system between 30,000L to 100,000L oil consumption category, they will be subjected to availability of the wood chips close to the site and the quality of the chips delivered

The table below shows the most economical alternative system for the different annual oil consumption categories. It shows results if the building was at a different site and if the building could hold the new pellet boiler in the existing boiler room or not.

<table>
<tr><th></th><th colspan="10">Annual Oil Consumption</th></tr>
<tr><th></th><th colspan="2"><7,000L</th><th colspan="2">7,000-30,000L</th><th colspan="2">30,000-50,000L</th><th colspan="2">50,000-100,000L</th><th colspan="2">100,000L+</th></tr>
<tr><th>Pellet Boiler Location / Site</th><th>Need new mech. shed</th><th>Use existing boiler room</th><th>Need new mech. shed</th><th>Use existing boiler room</th><th>Need new mech. shed</th><th>Use existing boiler room</th><th>Need new mech. shed</th><th>Use existing boiler room</th><th>Need new mech. shed</th><th>Use existing boiler room</th></tr>
<tr><td>Digby</td><td>Elec. Boiler</td><td>Wood pellet</td><td colspan="2">Wood pellet</td><td colspan="2">Wood pellet or Chips</td><td>Wood Chips</td><td>Wood pellet or Chips</td><td colspan="2">Wood Chips</td></tr>
<tr><td>Noel</td><td colspan="2">Wood pellet</td><td colspan="2">Wood pellet</td><td colspan="2">Wood pellet</td><td colspan="2">Wood pellet or Chips</td><td colspan="2">Wood Chips</td></tr>
<tr><td>Kentville</td><td colspan="2">Wood pellet</td><td colspan="2">Wood pellet</td><td>Wood pellet or Chips</td><td>Wood pellet</td><td colspan="2">Wood pellet or Chips</td><td colspan="2">Wood Chips</td></tr>
<tr><td>Port Hawkesbury</td><td>Elec. Boiler</td><td>Wood pellet</td><td colspan="2">Wood pellet</td><td colspan="2">Wood pellet or Chips</td><td>Wood Chips</td><td>Wood pellet or Chips</td><td colspan="2">Wood Chips</td></tr>
</table>

The other advantages of switching to wood pellet or wood chip fuel systems are:

- Negligible inventory GHG emissions and already meets the 75% GHG emissions reduction in all government buildings target in year 2022
- Locally sourced hence helps in supporting the local economy
- Fuel cost is unaffected by carbon cost under Cap & Trade and Federal Carbon Tax program
- Will not be impacted by the forthcoming federal Clean Electricity Standard which may further increase electricity cost projections used in this study
- Fuel cost stability and Local pellet producers capacity to serve all DPW’s sites

1 Introduction

Nova Scotia Department of Public Works wants to eliminate use of furnace oil from all the buildings under their portfolio to reduce emissions and this study looks at the alternate fuel options available and provides a qualitative and quantitative review of the advantages and logistics of converting the existing furnace oil systems with the alternate fuel sources.

Nova Scotia's Environmental Goals and Climate Change Reduction Act [1] has a goal to decrease greenhouse gas emissions across Government-owned buildings by 75% by the year 2035 and with heating and domestic hot water accounting for close to 50% of the energy use in commercial and institutional buildings in Atlantic Canada, eliminating furnace oil is essential to achieve this 2035 target.

The Department of Public Works building portfolio has more than 100 buildings under their portfolio which use furnace oil for heating. For this study purposes, the buildings were categorized based upon their annual fuel consumption and a building from each category was selected as a representative of the category. The categories are as follows:

- <7,000L
- 7,000-30,000L
- 30,000-50,000L
- 50,000-100,000L
- 100,000L+

For each building selected, this study compares the first cost, energy cost (including carbon cost) and carbon emissions over a period of 25 years for the alternative systems as listed below:

- Option 1: Wood Pellets
- Option 2: Wood Chips (only analyzed in larger fuel use building categories)
- Option 3: Electric Boiler
- Option 4: Air-to-water heat pump with electric boiler
- Option 5: Business as usual – Furnace oil

[1] https://nslegislature.ca/legc/bills/64th_1st/1st_read/b057.htm

2 EXISTING SYSTEMS

2.1 DIGBY LOCKUP - <7,000L

The building is located at 127 Queen St., Digby, NS and is heated by an oil-fired boiler located in the basement rated at 264MBH (77 kW). The boiler provides 200°F supply water to baseboard heaters. Holding cells are heated by an electric duct heater and by a heat pump located in the guard area. Domestic hot water is provided by an electric hot water tank. The furnace oil tank is located indoors.

Figure 2-2 - Digby Lockup

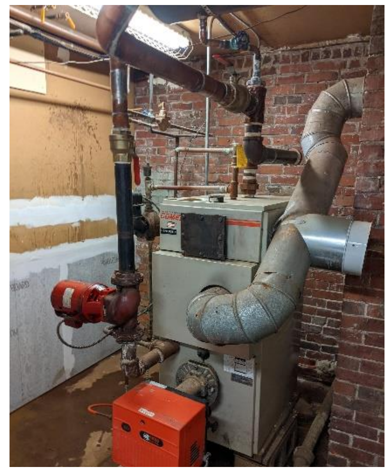

Figure 2-1 - Digby Lockup Boiler room

2.2 NOEL 5-BAY GARAGE - 7,000-30,000L

This is a 5 Bay Garage facility located in Noel, NS and is heated by an oil-fired boiler rated at 600 MBH (176 kW) gross output located in a small boiler room. The boiler supplies 160°F water to force flow heaters. Domestic hot water is supplied by a 46-gallon electric water heater. The boiler room entrance is from one of the bays which has access to the outdoors. The oil tank is located underground outside of the building and close to the boiler room.

Figure 2-4 - Noel 5-Bay Garage

Figure 2-3 - Noel 5-Bay Garage Boiler room

2.3 PORT HAWKESBURY PROVINCIAL BUILDING - 30,000-50,000L

The Port Hawkesbury Provincial Building is located at 218 MacSween St., Port Hawkesbury, NS and utilizes two oil-fired boilers units with a gross output of 1,729 MBH (507kW) each supplying 200°F water to baseboard heaters and radiant panels. VRF air-source heat pumps also serve the ground and 4th floor providing heating and cooling. Domestic hot water is supplied by a 76-gallon indirect fired water heater tank and by a 60-gallon electric water heater tank in the summers when the boiler units are shut down. The boiler room is in the basement and doesn't have direct access to the outdoors. The oil tank is located outside of the building, close to the boiler room.

Figure 2-5 - Port Hawkesbury Provincial Building

Figure 2-6 - Port Hawkesbury Provincial Bld. Boilers

2.4 KENTVILLE JUSTICE CENTRE - 50,000-100,000L

The Kentville Justice Centre is located at 87 Cornwallis St., Kentville, NS and is heated by two oil-fired boilers rated at 1,339 MBH (390 kW) each which supply 190°F water to baseboard heaters and AHU coils. Domestic hot water is supplied by a 50-gallon oil-fired water heater. The boiler room is at ground level and has direct access to the driveway to the rear parking lot. The furnace oil tank is located outside the building and at some distance from the boiler room.

Figure 2-7 - Kentville Justice Centre

Figure 2-8 - Kentville Boiler room

2.5 Port Hawkesbury Justice Centre – 100,000L+

The Port Hawkesbury Justice Centre is located at 15 Kennedy St., Port Hawkesbury, NS. The building is heated by two oil-fired boilers rated at 1,420 MBH (412 kW) each supplying 200°F water to baseboard heaters, unit heaters and AHU coils. Domestic hot water is supplied by a 119-gallon indirect fired water heater tank and by a 60-gallon propane hot water tank in the summer when the boilers are shut down. The boiler room is located in the basement next to the hallway that leads to the rear parking lot of the building. Furnace oil and propane tanks are located in the rear side of the building next to the parking lot.

Figure 2-10 - Port Hawkesbury Justice Centre

Figure 2-9 - Port Hawkesbury Justice Centre Boiler room

3 Proposed Retrofit Heating Systems

3.1.1 Wood Pellet System

3.1.1.1 Pellet Storage and Handling

Wood pellets can be either stored outdoors in a large galvanized steel silo or indoors in a silo made of polyester fabric interwoven with metal threads. Typical outdoor silo capacities range from 25 m^3 to 55 m^3 (16 tonnes to 35 tonnes) and indoor silo capacities range from 3 m^3 to 14 m^3(2 tonnes to 19 tonnes).

Indoor storage must be in a dry ventilated space with capability to cool the wood pellets to avoid possible mould growth.

Wood pellets are delivered by truck and are pneumatically blown into the storage silo. Delivery frequency can vary from weeks to months during the heating season depending on the usage rate of pellets and storage system size. The silos are normally sized so that they store a minimum of 1 week's worth of requirements at full boiler output.

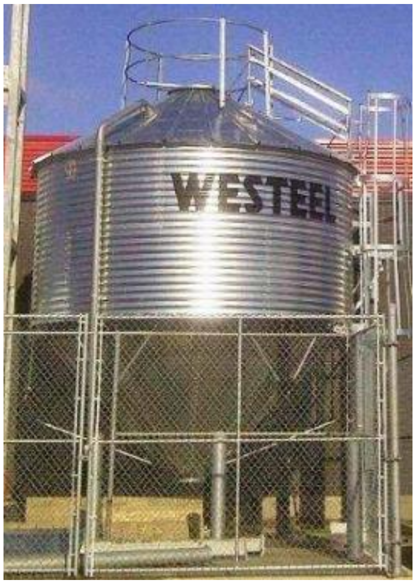

Figure 3-2 – Outdoor Wood Pellet Silo

Figure 3-1 - Indoor Wood Pellet Silo

Handling the fuel involves moving the wood pellets from the silo to the combustion chamber of the boiler. Fully automated handling systems use auger conveyors to accomplish this task and due to the limited length of the auger conveyor, the pellet silo must be located close to the boiler. Figure 3-3 shows an auger conveyor penetrating an exterior wall to transport wood pellets from a storage silo to the boiler.

Figure 3-3 - Wood Pellet Auger Conveyor

3.1.1.2 Combustion Chamber and Heat Exchanger (Boiler)

The handling system moves the wood pellets/chips into the combustion chamber and places them on a moving grate, upon which it is burned. The moving grate system evenly distributes the fuel above the fire bed. Moving grate systems also convey the fuel through different zones of under-fire airflow and move the resultant ash to the end of the combustion chamber.

The combustion chamber burns wood under controlled conditions, utilizing control systems which regulate the inflow of air in response to the heating demand. To ensure best efficiency on a continuous burn, some cleaning and maintenance is required. Quality biomass (wood chip or wood pellet) boilers are designed with easy maintenance features built in.

Heat produced in the combustion chamber is transferred to the building heating system via a heat exchanger. Both water and steam can be used as the heat transfer medium.

Figure 3-4 - Wood Pellet/Chips Boiler

3.1.1.3 Buffer Tank

A buffer tank is a large insulated tank which is used to store large quantities of hot water at a constant temperature. A buffer tank allows for a boiler to operate longer at peak load where it operates most efficiently and also operate for its minimum runtime under periods of low load. Incorporating a buffer tank into a biomass heating system serves to improve performance and extend the working life of the boiler.

Figure 3-5 - Buffer Tank

3.1.1.4 Ash Removal and Storage

Burning wood pellets produce less than 1% of the burned volume in ash and wood chips produce less than 3% for a moisture content of 35%. The combustion chamber is equipped with a de-ashing system which collects ash from the boiler and deposits it into a container for storage and ultimate removal from site. Ash can be reused as fertilizer or recycled in some industrial applications.

Figure 3-6 - Biomass Boiler with Ash Removal System

3.1.2 WOOD CHIP SYSTEM

A wood chip boiler system is similar to a wood pellet boiler system except for the fuel storage and fuel handling system. Due to its exhaust being a bit dirtier than pellets, it can also require a cyclone dust extractor.

3.1.2.1 Chip Storage and Handling

Wood chips are normally stored in underground bins but they can also be stored at the same level as the boiler. The storage bin is sized to hold more than the volume of the delivery truck to allow the operator to order a delivery before the bin is empty – these trucks normally do not have scales so they need to offload a full truck load at the site.

Wood chips have higher moisture content and can freeze easily on the floor of the storage bin. To avoid this and have a hassle-free fuel delivery system, it is recommended to use a walking floor (scraper floor) system to move chips to the auger conveyor and recess the bin underground to reduce the opportunity for freezing conditions. The other chips delivery system used is the spring agitator system which rotates around a central axis and pushes fuel on to the auger.

Fuel delivery depends upon the bin location. For a below grade storage bin the wood chips can be directly discharged from the truck without requiring any other mechanical system and for other storage locations chips are pneumatically blown into the bin. Figure 3-7 & Figure 3-8 show the wood chips storage location with reference to boiler location.

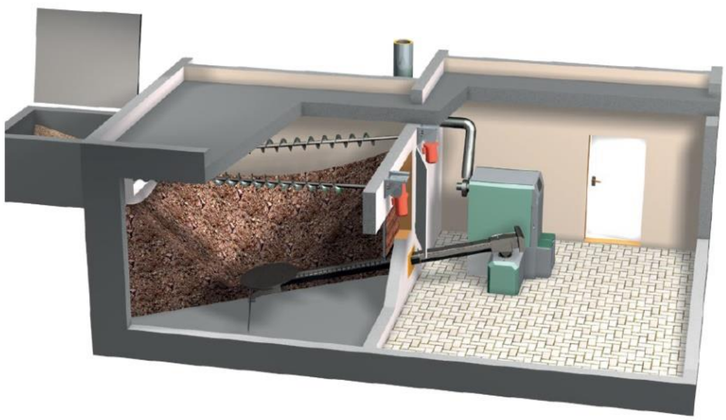

Figure 3-7 –Wood Chips supply system - Spring agitator

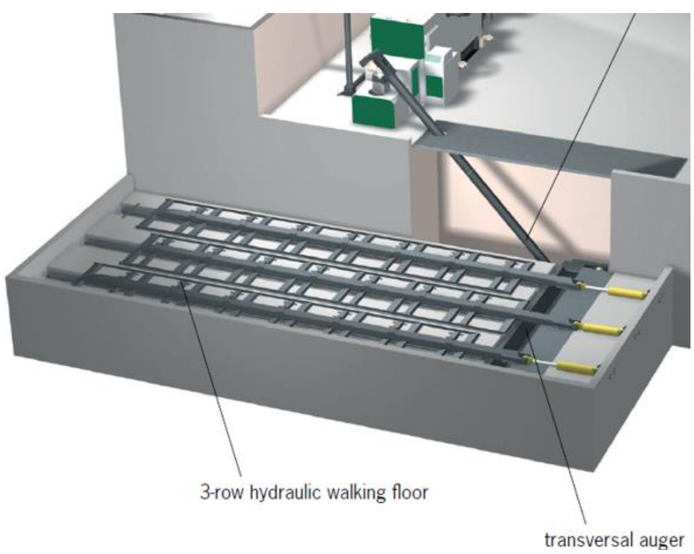

Figure 3-8 –Wood Chips supply system - Walking floor

3.1.2.2 *Cyclone Dust Extractor*

A cyclone is used to separate dust particles from the exhaust stream off the boiler before released out in the air. The flue gas is brought in a twisted motion inside the cyclone leading to the generation of centrifugal forces on the flue gas which leads to the separation of dust which drops into an ash storage bin.

Figure 3-9 - Cyclone Dust Extractor

3.1.3 Air to Water Heat Pump

An air-to-water heat pump extracts heat from the outside air through a refrigerant circuit. The system is installed outdoors at grade and uses glycol and a heat exchanger to transfer heat to the water supplied to the building.

Figure 3-10 - Typical Air to Water Heat Pump unit

Since heat pumps draw heat from the outside air, they require a backup system to assist when there isn't enough heat available in the outside air to heat the water to the required temperature. Figure 3-11 shows a typical air to water heat pump's delivered hot water temperature and the hot water temperature requirements of the buildings under study at various outdoor temperature ranges. It can be seen that at an outside temperature of 40°F, the hot water temperature requirement of the building and the hot water temperature delivered by the heat pump overlaps; this is referred to as the balance point temperature. If the outdoor temperature is below the balance point temperature, the heat pump requires a backup heating system to provide the required hot water temperature. The backup system could be a booster heat pump or an electric boiler. As heat pumps are expensive, adding a booster heat pump will increase the initial investment even higher. If a booster heat pump is used as a backup system, it is advised to improve the building envelope to allow them to serve a large portion of the annual heating load to achieve savings in the reduced energy cost.

Heat pump COP is also reduced as the outdoor air temperature falls, with higher COP at higher outdoor temperature and lower COP at lower outdoor temperature.

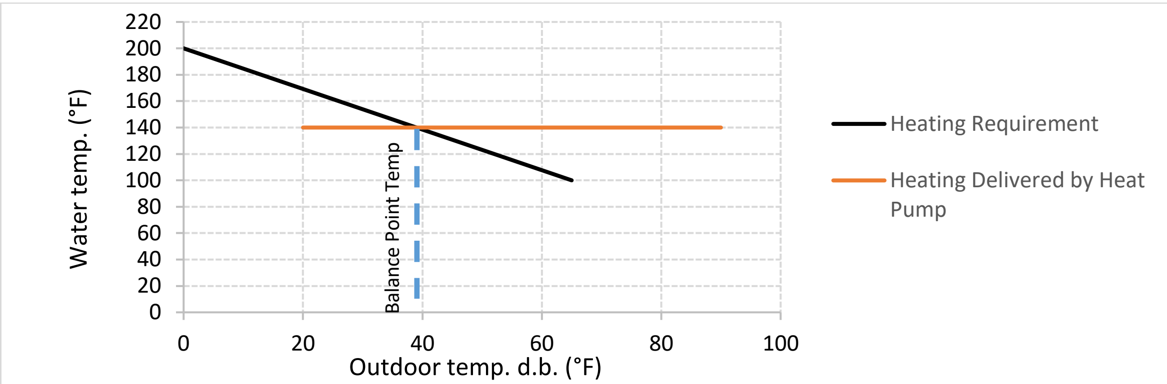

Figure 3-11 - Heat Pump operating range

3.1.4 Electric Boiler

An Electric boiler heats the water using resistance elements within the boiler. Water is passed over the elements and is heated in the process.

Figure 3-12 - Electric Boiler

3.2 Space Requirements

The space requirements for each proposed system will vary based upon the boiler heating capacity. Smaller buildings will normally only have one source of heat (boiler or heat pump) while larger buildings will normally have two heating sources for redundancy. We have allowed for 100% backup capacity for Heat Pumps and 66%

backup for Biomass boilers for redundancy in this study and can be adjusted later. For comparison purposes, the footprints of 500kW capacity boiler systems are displayed in Table 3-1. This table is only for preliminary sizing purposes and final system sizes must be determined through detailed design. The table does not include equipment clearances or piping and considers the pellet system can be placed in the existing boiler room.

Wood Pellet + Elec. Boiler System		Wood Chip + Elec. Boiler System	Oil Only System	Air to Water HP + Elec. Boiler System	Elec. Boiler System
Interior Components Biomass Boiler 8m^2 Elec. Boiler 2m^2 Ash Storage 1m^2 Buffer Tank 3m^2 **Exterior Components** Wood Pellet Storage 8m^2	**Room height req.** 2.8m (9.2ft)	Mechanical Shed (all Component) 97m^2	Oil Boiler (2 qty) 3m^2 Oil Tank 4m^2	Elec. Boiler 2m^2 Heat Pump 14m^2	Elec. Boiler (2 qty) 4m^2
Total: 22m^2		**Total:** 97m^2	7m^2	16m^2	4m^2

Table 3-1 - Footprint Comparison

For those cases where a wood pellet boiler cannot be installed in the existing boiler room for one of the reasons listed below, an outdoor mechanical shed/container would be required:

- Pellet boiler cannot be installed into the boiler room due to boiler room size or narrow hallways leading to the boiler room
- Wood pellet silo cannot be set up outdoors near the boiler room which is required in order to be accessible by a delivery truck

It should be noted that the wood chip heating systems in these buildings require construction of a new outdoor mechanical shed as it requires underground storage accessible by a delivery truck and boiler setup adjacent to the storage. This makes its footprint significantly larger and may not be a suitable option for sites with limited site space available.

4 Proposed Boiler Capacities & Design Philosophy

4.1 Boiler Capacities

Table 4-1 shows the existing boiler capacities against annual oil consumption data. It can be seen from the table that with increasing oil consumption, the system capacities in some buildings do not increase in the same trend and hence system capacities need to be re-evaluated. For example, Port Hawkesbury Provincial building has the third largest annual oil consumption (39,644 L) but has the largest boiler capacity.

Site		Existing System Capacity	Historic Oil Consumption
Digby lock-up	<7,000L	77 kW	7,157 L/yr
Noel 5-Bay garage	7,000-30,000L	176 kW	27,443 L/yr
Port Hawkesbury Provincial Bldg.	30,000-50,000L	2 X 507 kW	39,644 L/yr
Kentville Justice Centre	50,000-100,000L	2 X 390 kW	79,077 L/yr
Port Hawkesbury Justice Centre	100,000L+	2 X 420 kW	129,517 L/yr

Table 4-1 - Existing System Capacity & Oil Consumption

Proposed system capacities were calculated using existing mechanical drawings for each site to calculate the actual heating demands in the building (using the pump flow rates and design temperature difference) and the results are shown in the table below.

Site		Proposed System Capacity
Digby lock-up	<7,000L	77 kW
Noel 5-Bay garage	7,000-30,000L	176 kW
Port Hawkesbury Provincial Bldg.	30,000-50,000L	300 kW
Kentville Justice Centre	50,000-100,000L	300 kW
Port Hawkesbury Justice Centre	100,000L+	540 kW

Table 4-2 - Proposed System Capacity

4.2 System Sizing Philosophy

The approach taken in designing the proposed system is as follows:

- Wood Pellet/Chips boilers are sized at 100% capacity to meet the heating demand and are equipped with a 66% electric boiler backup system for the buildings with higher annual oil consumption
- Electric boilers and Furnace oil boilers are sized at 100% capacity and for the buildings with higher annual oil consumption, two boilers are used, sized at 66% capacity each
- Heat pumps are sized at 100% capacity and as explained in section 3.1.3 of this report, they require a backup system when the outdoor temperature drops below 40°F. The backup system could be a booster Heat Pump or an electric boiler at 100% capacity. Since heat pumps have higher initial cost, we have selected electric boiler as a backup system to keep the initial investment low

System	Digby lock-up	Noel 5-Bay garage	Port Hawkesbury Provincial Bldg.	Kentville Justice Centre	Port Hawkesbury Justice Centre
	<7,000L	7,000-30,000L	30,000-50,000L	50,000-100,000L	100,000L+
Wood Pellet/Chips	One boiler @ 100%	One boiler @ 100%	One boiler @ 100% & One backup Elec boiler @ 66%		
Elec Boiler	One boiler @ 100%	One boiler @ 100%	Two boilers @ 66%		
Air to Water HP	Heat Pump @ 100% & One backup Elec boiler @ 100%				
#2 Furnace Oil	One boiler @ 100%	One boiler @ 100%	Two boilers @ 66%		

Table 4-3 - Proposed System Design Philosophy

5 Proposed System Preliminary Design

This section details the selected systems and electrical requirements for all the proposed options for each site. This is only a preliminary design and will require further in-depth site study before implementation.

Assumptions made while selecting systems are as follows:

- Wood pellet storage bins are sized as per the requirement at the site and not at full load capacity of the delivery truck. It is assumed that small delivery can be made by the pellet supplier
- Wood chip system requires construction of an outdoor mechanical shed which has a much larger footprint. It is assumed that site has space available for the construction and that it can be accessed by delivery truck
- Locally sourced wood chips are available close to the sites under study

5.1 Digby Lockup - <7,000L

5.1.1 Option 1 - Wood Pellet System

This option utilizes two MESys 36kW boilers to provide the required heating capacity for the building. Due to the lower ceiling height in the boiler room, two boilers are used instead of one at this location. A single 80kW boiler requires a minimum ceiling height of 7’7” and the available ceiling height in the boiler room is only 7’5”.

The existing boiler room walls need to be expanded to house the proposed boilers and the buffer tank. The wood pellet silo will be placed in the adjacent room where the oil tank is currently located.

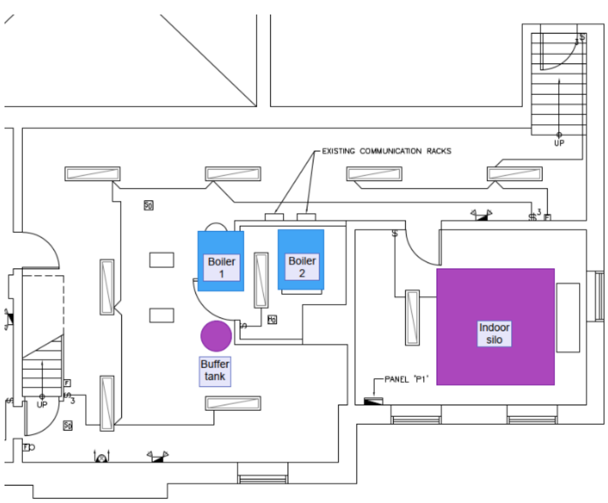

Figure 5-1 - Digby Lock-Up - Wood Pellet Boiler

5.1.2 Option 2 – Wood Chip Boiler

A wood chip boiler is not considered for this site due to higher capital investment.

5.1.3 Option 3 – Electric Boiler

This option utilizes two Thermolec B40, 40 kW boilers which will be placed in the existing boiler room.

Electrical requirements for the system are as follows:

- Electric Boiler – 240V/1Ph, two pole 125amp breakers for each boiler

To meet this increased electrical demand, electrical upgrades will be required.

5.1.4 Option 4 – Air To Water Heat Pump

This option utilizes an Aermec NRK 0550, 100kW air to water heat pump and two Thermolec B40, 40kW electric boilers. The heat pump will be installed outdoors as shown in the image and the electric boilers will be installed in the existing boiler room.

Electrical requirements for the system are as follows:

- Heat Pump - 460V/3Ph, 100amp
- Electric Boiler – 240V/1Ph, two 125amp breaker switches for each boiler

The building currently has a 240V/1Ph service and to meet this increased voltage and current requirement the electrical service must be upgraded.

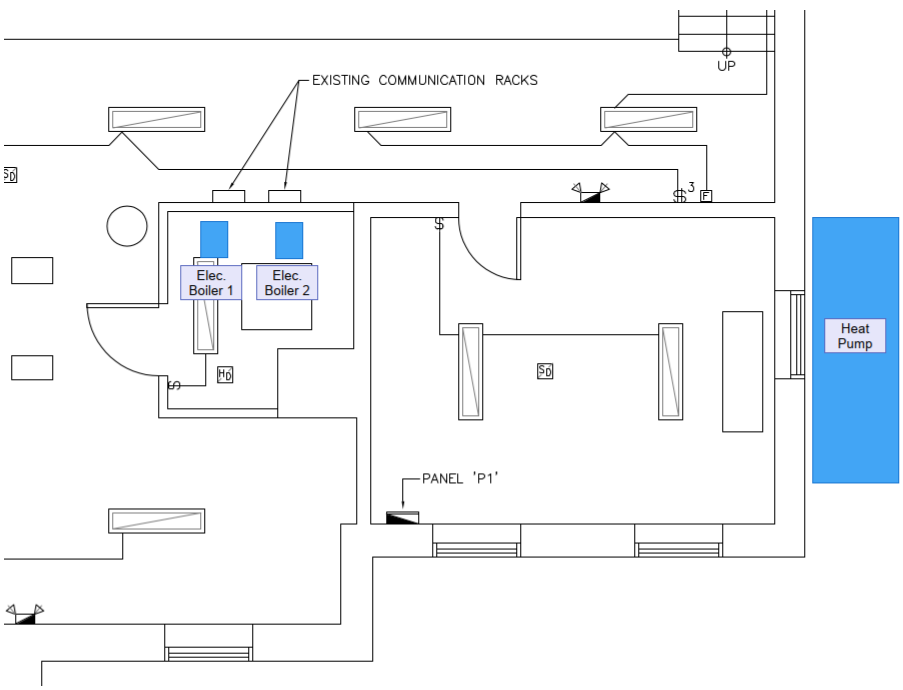

Figure 5-2 - Digby Lock-Up - Heat Pump & Elec. Boiler

5.1.5 Option 5 – Furnace Oil

In this option, a new De Dietrich GT 226, 77kW furnace oil-fired boiler is required as the existing boiler would not last for the 25-year life of the analysis for heating and similarly the replacement of the existing oil tank with a new one would be required.

5.2 Noel 5-Bay garage - 7,000-30,000L

5.2.1 Option 1 - Wood Pellet System

This option utilizes a Herz Firematic 200kW boiler to provide the required heating capacity for the building. The existing boiler room length needs to be expanded to hold the buffer tanks inside. A wood pellet silo will be placed outside close to the parking area for easy access for fuel delivery.

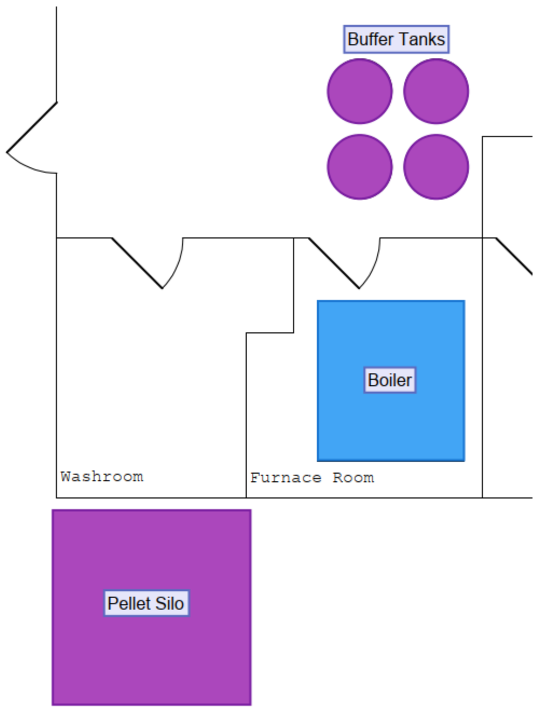

Figure 5-3 - Noel - Wood Pellet Boiler

5.2.2 Option 2 – Wood Chip Boiler

This option also utilizes a HERZ Firematic 200kW boiler which can also accept wood chips as a fuel source. Since this system requires underground wood chips storage where a delivery truck can secure and unload wood chips in the underground silo, it will be placed outside of the existing building and requires construction of a new mechanical room. This new mechanical room will hold a wood chip boiler and underground silo.

5.2.3 Option 3 – Electric Boiler

This option utilizes a Cleaver-Brooks WB-122, 180 kW electric boiler and will be placed in the existing boiler room.

The electrical requirements for the system are as follows:

- Electric Boiler – 600V/3Ph, 174amp

The existing building has 120/3Ph supply and will require an electrical upgrade to meet this increased current and voltage demand.

5.2.4 Option 4 – Air To Water Heat Pump

This option utilizes an Aermec NRB-H 900, 225kW air to water heat pump and Cleaver-Brooks WB-122, 180 kW boiler. The heat pump will be installed outdoors behind the mechanical room and the electric boiler inside the existing boiler room.

The electrical requirements for the system are as follows:

- Heat Pump – 600V/3Ph, 117amp
- Electric Boiler – 600V/3Ph, 174amp

The existing building has 120/3Ph supply and will require an electrical upgrade to meet this increased current and voltage demand.

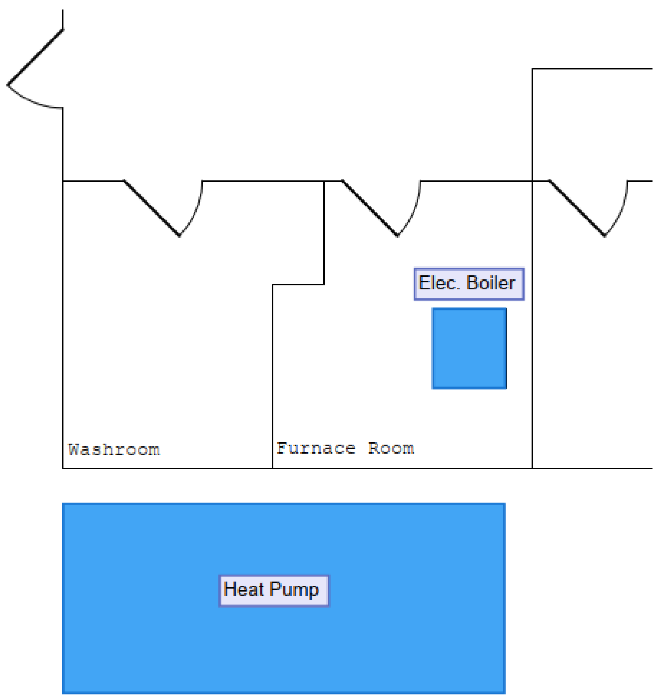

Figure 5-4 - Noel - Heat Pump & Electric Boiler

5.2.5 OPTION 5 – FURNACE OIL

This option utilizes De Dietrich GT 335, 176kW furnace oil boiler for heating and replacement of the existing underground oil tank with a new above ground oil tank.

5.3 PORT HAWKESBURY PROVINCIAL BUILDING. - 30,000-50,000L

5.3.1 OPTION 1 - WOOD PELLET SYSTEM

This option utilizes a Herz Firematic 350kW boiler to provide the required heating capacity for the building and a Cleaver-Brooks WB-122, 198kW electric boiler as a backup. The existing boiler room has no direct access to the outside and the corridor to the boiler room is not wide enough to maneuver the new biomass boiler into the room. Hence, this site requires the construction of an outdoor mechanical room to hold a biomass boiler and buffer tanks. The new mechanical room can be built on the green belt where the oil tank is currently located. The electrical backup boiler will be placed in the existing boiler room.

The electrical requirements for the system are as follows:

- Electric Boiler – 600V/3Ph, 278amp

The existing building has 600/3Ph supply and will require an electrical upgrade to meet this increased current demand.

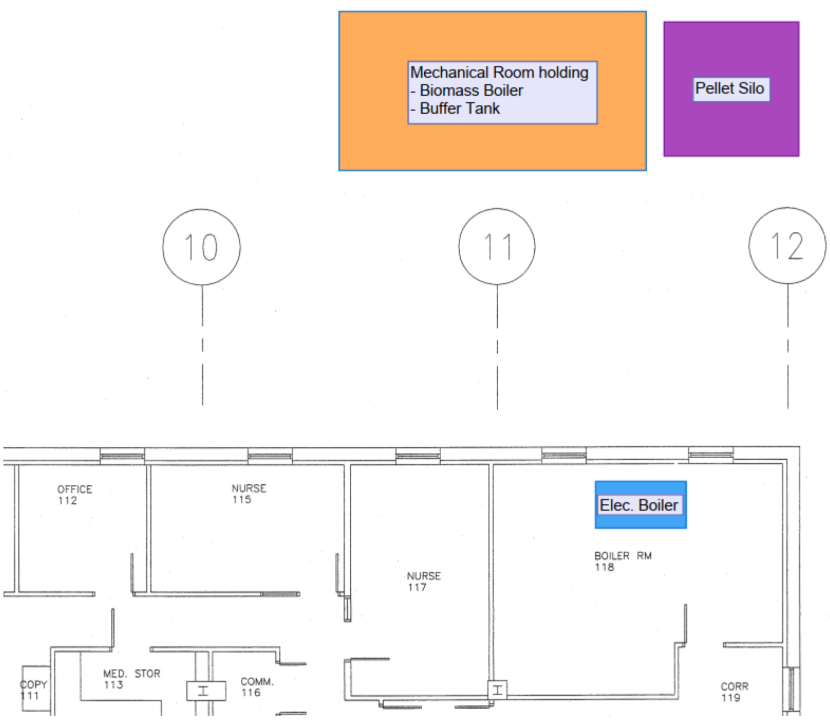

Figure 5-5 - Port Hawkesbury Provincial Bldg. - Wood Pellet Boiler

5.3.2 Option 2 – Wood Chip Boiler

This option also utilizes a HERZ Firematic 350kW boiler which can also accept wood chips as a fuel source and a Cleaver-Brooks WB-122, 198kW electric boiler as a backup.

The biomass boiler and the underground wood chips storage will be placed in a new mechanical room which will be constructed on the green belt where the oil tank is currently located. The backup electric boiler will be placed in the existing boiler room.

The electrical requirements and upgrades required are similar to the wood pellet option.

5.3.3 Option 3 – Electric Boiler

This option utilizes two Cleaver-Brooks WB-122, 216kW boilers and will be placed in the existing boiler room.

The electrical requirements for the system are as follows:

- Electric Boiler – 600V/3Ph, 209amp for each boiler

The existing building has 600/3Ph supply and will require an electrical upgrade to meet this increased current demand.

5.3.4 Option 4 – Air To Water Heat Pump

The Heat Pump option for this building is not being considered, as this building currently contains heat pump systems for heating levels 1 and 4 of the building and increasing capacities of the existing system makes sense instead of adding another heat pump.

5.3.5 Option 5 – Furnace Oil

This option utilizes two De Dietrich GT 336, 230kW furnace oil boilers for heating and replacement of the existing oil tank with a new one.

5.4 Kentville Justice Centre - 50,000-100,000L

5.4.1 Option 1 - Wood Pellet System

This option utilizes a Herz Firematic 350kW boiler to provide the required heating capacity for the building and a Cleaver-Brooks WB-122, 198kW electric boiler as a backup. New boilers will be placed in the existing boiler room which has direct access to the outdoors and the pellet silo will be located outside the boiler room adjacent to the chiller.

The electrical requirements for the system are as follows:

- Electric Boiler – 600V/3Ph, 278amp

The existing building has 600V/3Ph supply and will require an electrical upgrade to meet this increased amperage.

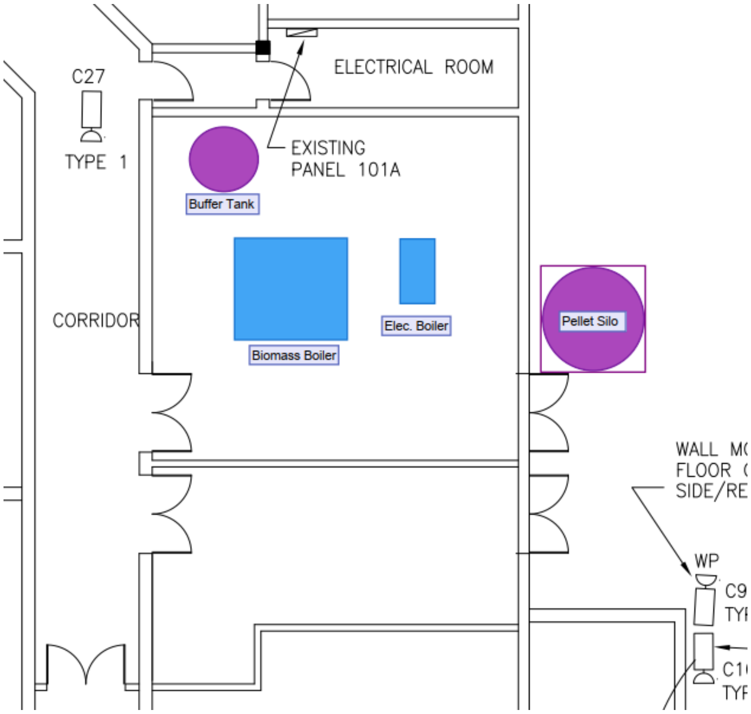

Figure 5-6 - Kentville Justice Centre - Wood Pellet Boiler

5.4.2 Option 2 – Wood Chip Boiler

This option also utilizes a HERZ Firematic 350kW boiler which can also accept wood chips as a fuel source and a Cleaver-Brooks WB-122, 198kW electric boiler as a backup.

The biomass boiler and the underground wood chips storage will be placed in a new mechanical room which will be constructed on the green belt where the oil tank is currently located. The backup electric boiler will be placed in the existing boiler room.

The electrical requirements and upgrades required are similar to the wood pellet option.

5.4.3 Option 3 – Electric Boiler

This option utilizes two Cleaver-Brooks WB-122, 216kW boilers.

The electrical requirements for the system are as follows:

- Electric Boiler – 600V/3Ph, 209amp for each boiler

The existing building has 600V/3Ph supply and will require an electrical upgrade to meet this increased amperage.

5.4.4 Option 4 – Air To Water Heat Pump

This option utilizes an Aermec NRB 1400, 360kW air to water heat pump and a Cleaver-Brooks WB-122, 288kW electric boiler. Due to the lack of space, the heat pump cannot be placed outside the boiler room and therefore will be placed at a distance closer to the existing oil tank and the electric boiler will be placed in the existing boiler room.

The electrical requirements for the system are as follows:

- Heat Pump – 600V/3Ph, 202amp
- Electric Boiler – 600V/3Ph, 278amp

The existing building has 600/3Ph supply and will require an electrical upgrade to meet this increased amperage.

Figure 5-7 - Kentville Justice Centre - Heat Pump

5.4.5 Option 5 – Furnace Oil

This option utilizes two De Dietrich GT 336, 230kW furnace oil boilers for heating and replacement of the existing oil tank with a new one.

5.5 Port Hawkesbury Justice Centre – 100,000L+

5.5.1 Option 1 - Wood Pellet System

This option utilizes a Herz Firematic 500kW boiler to provide the required heating capacity for the building and a Cleaver-Brooks WB-201, 360kW electric boiler as a backup. Since there is no nearby location for the placement of a wood pellet silo outdoors close to the boiler room, which is one of the design requirements, the wood pellet boiler needs to be placed outdoors and requires construction of a new mechanical room. The new mechanical room will be constructed in the rear parking lot of the building where a delivery truck can drive in to fill the wood pellet silo. The electric boiler will be placed in the existing boiler room.

The electrical requirements for the system are as follows:

- Electric Boiler – 600V/3Ph, 486amp

The existing building has 600V/3Ph supply and will require an electrical upgrade to meet this increased amperage.

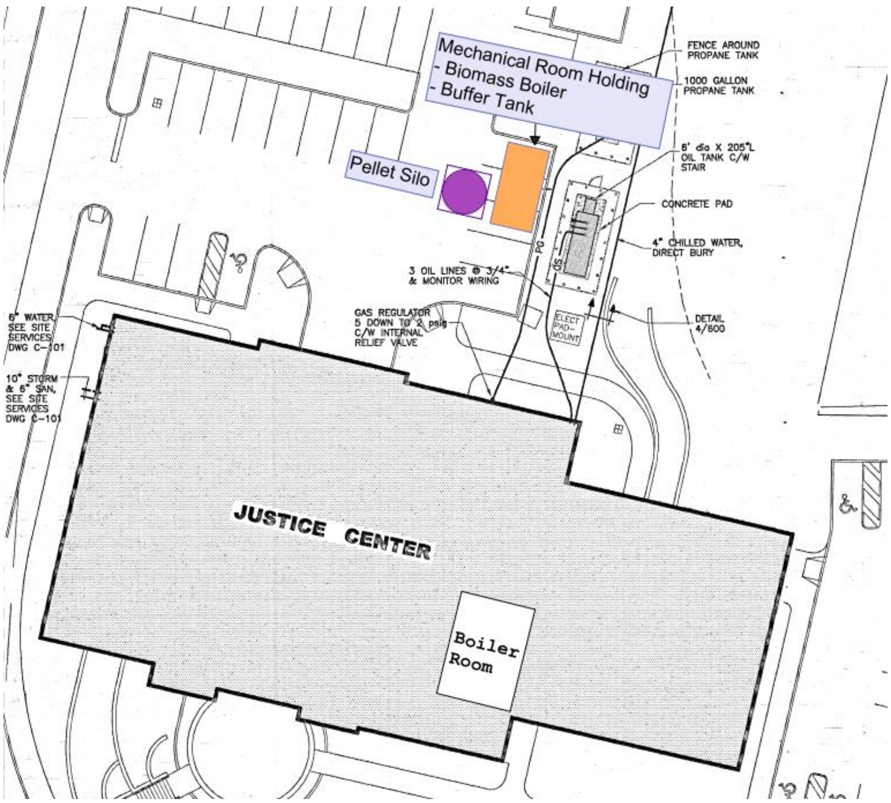

Figure 5-8 - Port Hawkesbury Justice Centre – Wood Pellet Boiler

5.5.2 OPTION 2 – WOOD CHIP BOILER

This option also utilizes a HERZ Firematic 500kW boiler which can also accept wood chips as a fuel source and a Cleaver-Brooks WB-201, 360kW electric boiler as a backup.

The biomass boiler and the underground wood chips storage will be placed in a new mechanical room which will be constructed in the rear parking lot of the building where a delivery truck can drive in and deliver wood chips. The backup electric boiler will be placed in the existing boiler room.

The electrical requirements and upgrades required are similar to the wood pellet option.

5.5.3 Option 3 – Electric Boiler

This option utilizes two Cleaver-Brooks WB-201, 432kW boilers.

The electrical requirements for the system are as follows:

- Electric Boiler – 600V/3Ph, 417amp for each boiler

The existing building has 600V/3Ph supply and will require an electrical upgrade to meet this increased amperage.

5.5.4 Option 4 – Air To Water Heat Pump

This option utilizes two Aermec NRB 1400, 360kW air to water heat pumps and a Cleaver-Brooks WB-202, 504kW electric boiler. The heat pumps will be placed near the existing oil tank and the electric boiler will be placed in the existing boiler room.

The electrical requirements for the system are as follows:

- Heat Pump – 600V/3Ph, 202amp for each heat pump
- Electric Boiler – 600V/3Ph, 486amp

The existing building has 600/3Ph supply and will require an electrical upgrade to meet this increased amperage.

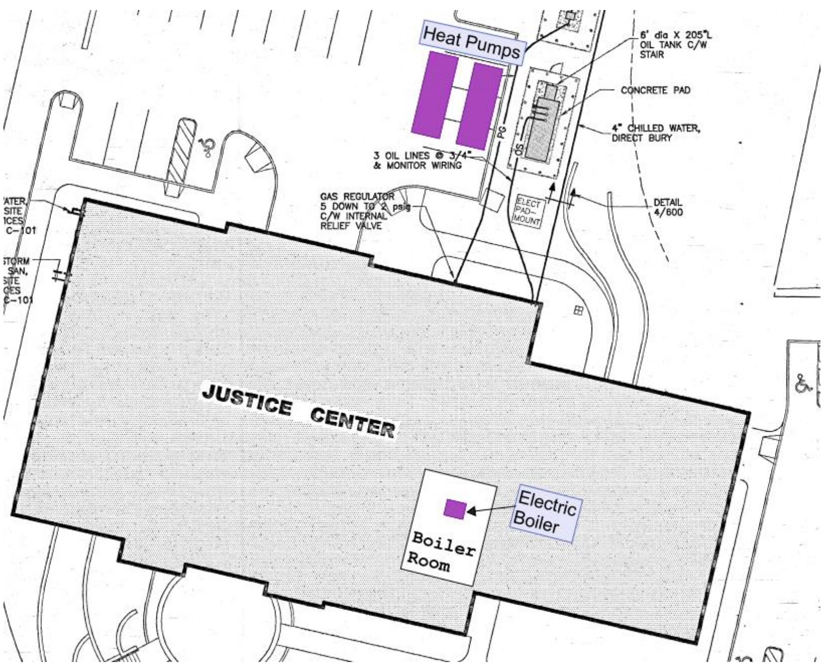

Figure 5-9 - Port Hawkesbury Justice Centre - Heat Pump & Elec. Boiler

5.5.5 Option 5 – Furnace Oil

This option utilizes two De Dietrich GT 339, 420kW furnace oil boilers for heating and replacement of the existing oil tank with a new one.

6 Energy & Emissions

6.1 Unit Costs of Fuel Options

To make a useful comparison between each of the proposed options the most recent fuel costs were used for analysis:

- The price of furnace oil was taken from SAP data shared for the sites under study by the Department of Public Works for the month of October and November 2021 and was noted at $0.82/L
- Electricity pricing was taken from the NS Power IRP study scenario 3.1C [2] which is being used in this study as the chosen path for grid decarbonization and phases out coal plants by 2030 - $0.163/kWh for 2022.
  It is to be noted that the forthcoming federal Clean Electricity Standard which requires all electricity to be zero emission by 2035 will not be achievable by scenario 3.1C and will require further investments which may result in higher electricity prices
  IRP Scenario 3.1C electricity prices for the next 25 years can be found under Appendix C
- 8% moisture content wood pellets are considered for this study at a price of $222/tonne from Local pellet producers. The delivery price varies depending on the delivery location and the effective total fuel price for each location is shown in Table 6-1
- 35% moisture content air-dried pulpwood chip are considered for this study at a price of $110/tonne including delivery assuming that locally source wood chips are available close to the sites under study

Fuel Type	$/Tonne	$/ltr	$/kWh	$/GJ
#2 Furnace oil	-	$0.82	$0.076	$21.13
Wood Pellet	$222	-	$0.047	$12.98
Electricity	-	-	$0.163	$45.28
Wood Chips (35% moisture content)	$110	-	$0.035	$9.82

Pellet Fuel Cost including delivery		
Site	Pellets- $/kWh	Pellets - $/GJ
Digby	$0.058	$16.171
Noel	$0.051	$14.137
Kentville	$0.056	$15.643
Port Hawkesbury	$0.058	$16.171

Table 6-1 - Fuel cost in utility units and per kWh for comparison

[2] Page 191, https://irp.nspower.ca/files/key-documents/NS-Power-IRP-Appendices-A-N.pdf

6.2 Energy Intensity & Fuel Savings

Historical oil consumption data was used to calculate fuel savings for the proposed fuel types. Oil has an energy intensity of 10.78 kWh/L and with the existing boiler's average efficiency of 75% the useful energy delivered reduces to 8.1 kWh/L. Using this energy intensity, total annual heating energy delivered for each site was calculated.

Site		Annual Oil Consumption	Delivered Heating Energy
		Ltr/yr	kWh/yr
Digby lock-up	<7,000L	7,157	57,852
Noel 5-Bay garage	7,000-30,000L	27,443	221,831
Port Hawkesbury Provincial Bldg.	30,000-50,000L	39,644	320,457
Kentville Justice Centre	50,000-100,000L	79,077	639,206
Port Hawkesbury Justice Centre	100,000L+	129,517	1,046,927

Table 6-2 - Annual Heating Energy Demand for Each Site

This delivered heating energy is the energy which each alternative fuel type must deliver with the new proposed system types. By dividing this delivered heating energy by proposed system average efficiencies as listed in Table 6-3, the fuel consumption for each option was calculated and was multiplied by the unit fuel cost mentioned in section 6.1.1 to calculate the total annual fuel cost.

System	Eff/COP	Operating capability
Wood Pellet	85%	N/A
Wood Chips	85%	N/A
Electricity	100%	N/A
Air to Water HP	2.3 COP	Only down to 40°F
#2 Furnace Oil	80%	N/A

Table 6-3 - Proposed system efficiencies and capabilities

The energy intensity of wood chips and pellets depends upon the moisture content in them. With increase in moisture content, the energy intensity goes down. It is to be noted that the wood pellets manufactured by Local pellet producers are EN*plus*-A1 certified, which is derived from CSA-ISO 17225-2 standard, which defines the quality standard for wood pellets. Wood chips quality standard that a chip manufacturer can follow in Canada is CSA-ISO 17225-4, but unlike pellets there is yet no certification available in Canada for wood chips.

For this study 8% moisture content wood pellets and 35% moisture content wood chips are considered, and their energy intensity and other properties were noted from EU Biomass Trade Centres - Wood Fuel Handbook[3] and are also listed under Appendix D.

[3] https://forestry.msuextension.org/wood-burning/pellets/WOOD_FUELS_HANDBOOK_BTC_EN.pdf

Air to water heat pumps are not operable when the outside temp is below 40°F and require electric boiler backup as explained in section 3.1.3 of this report. Bin data analysis was used to estimate what percentage of the annual heating will be provided by heat pump and electric boiler respectively. The Bin data analysis sorts the annual Heating degree days (HDD) into bins of different temperature ranges. Each bin contains the number of average HDD for the specific outside temperature range. From the data it was found that 73% of the annual HDD fall below 40°F outdoor air temperature range and will require backup electric boiler for providing heat and the remaining 27% of the annual heat will be provided by heat pump.

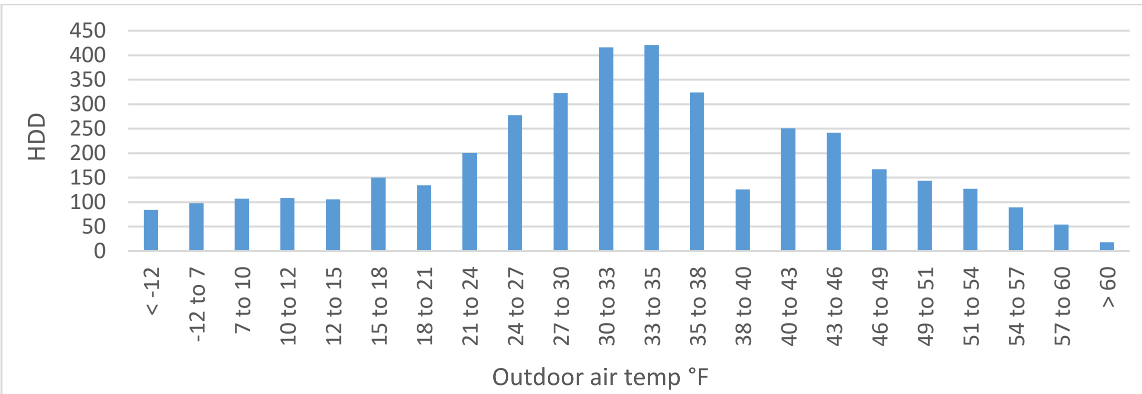

Figure 6-1 - Historic HDD bins for Halifax

Heat pump's COP also varies with the outdoor air temperature and to calculate its effective COP, another bin data analysis was done in which heat pump's COP for different temperature ranges from the product specification sheet were used and the average number of hours falling under those temperature range bins were used to calculate the effective COP.

Assumptions made while calculating energy cost:

- 35% moisture content wood chips are considered. As wood chips are not certified in Canada, the moisture content may vary and be higher in real life leading to higher energy costs

System	Digby lock-up	Noel 5-Bay garage	Port Hawkesbury Provincial Bldg.	Kentville Justice Centre	Port Hawkesbury Justice Centre
	<7,000L	7,000-30,000L	30,000-50,000L	50,000-100,000L	100,000L+
Wood Pellet	$3,962	$13,282	$21,947	$42,348	$71,702
Wood Chips (35% moisture content)	N/A	$9,231	$13,335	$26,598	$43,564
Elec Boiler	$9,430	$36,158	$52,235	$104,191	$170,649
Air to Water HP	$7,965	$30,540	N/A	$88,001	$144,133
#2 Furnace Oil	$5,502	$21,097	$30,476	$60,790	$99,566

Table 6-4 – First year fuel cost of proposed system

6.3 Carbon Emissions

Table 6-5 shows the GHG emissions for each fuel type and the equivalent net CO_2 emissions per unit of energy for the year 2022 and it can be noted that wood pellets are the cleanest of all options. GHG emissions are inventory only.

Fuel	g CO_2/kWh	g eCH_4/kWh	g eN_2O/kWh	g CO_2e/kWh
Wood Pellet	0.00	0.021	0.015	4.9
Wood Chips (35% moisture content)	0.00	0.032	0.023	7.5
Electricity	-	-	-	369.7
#2 Furnace oil	255.43	0.002	0.003	256.4

Table 6-5 - Emissions per unit energy per fuel type in 2022

Inventory emission values for all fuel types except for electricity were noted from the Emission Factors sheet[4] used to estimate Canada's annual greenhouse gas inventory. CO_2 emissions from biomass are reported under the Land Use, Land Use Change and Forestry (LULUCF) and are hence not reported during combustion and are therefore noted as zero. Electricity emissions were noted from the NS Power IRP report for scenario 3.1C[5] and are listed under Appendix C.

To calculate emissions over the life cycle of 25 years as shown in Table 6-6 & Figure 6-2, following assumption were made:

- Electricity emissions listed for the next 25 years under scenario 3.1C are considered and any deviation from this will vary the results
- 35% moisture content wood chips are considered and if the moisture content increases the emissions will go up due to their lower energy intensity

System	Digby lock-up	Noel 5-Bay garage	Port Hawkesbury Provincial Bldg.	Kentville Justice Centre	Port Hawkesbury Justice Centre
	<7,000L	7,000-30,000L	30,000-50,000L	50,000-100,000L	100,000L+
	CO_2e emissions over 25 yrs.				
Wood Pellet	8 tons	32 tons	46 tons	92 tons	151 tons
Wood Chips	N/A	49 tons	71 tons	141 tons	231 tons
Elec Boiler	199 tons	763 tons	1,102 tons	2,197 tons	3,599 tons
Air to Water HP	168 tons	644 tons	N/A	1,856 tons	3,040 tons
#2 Furnace Oil	463 tons	1,777 tons	2,567 tons	5,121 tons	8,387 tons

Table 6-6 – Total emissions over 25 yrs.

[4] https://donnees.ec.gc.ca/data/substances/monitor/canada-s-official-greenhouse-gas-inventory/Emission_Factors.pdf
[5] Page 266, https://irp.nspower.ca/files/key-documents/NS-Power-IRP-Appendices-A-N.pdf

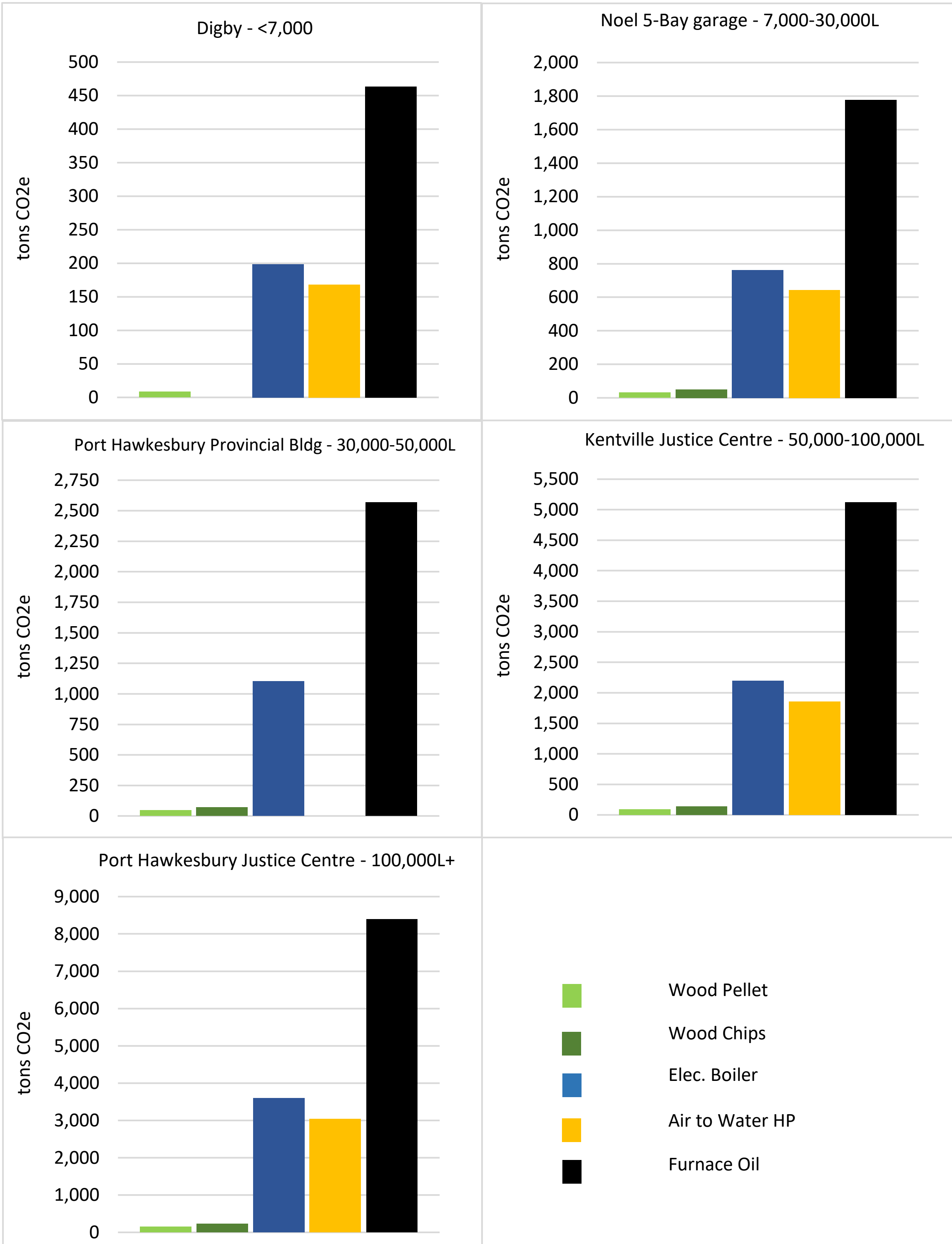

Figure 6-2 - Total emission over 25 years

Figure 6-3 shows a comparison between the emissions from the alternative systems in 2035 against a dashed line representing the 75% reduction in emissions from the business as usual: furnace oil, which is a requirement under the Environmental Goals and Climate Change Reduction Act[6].

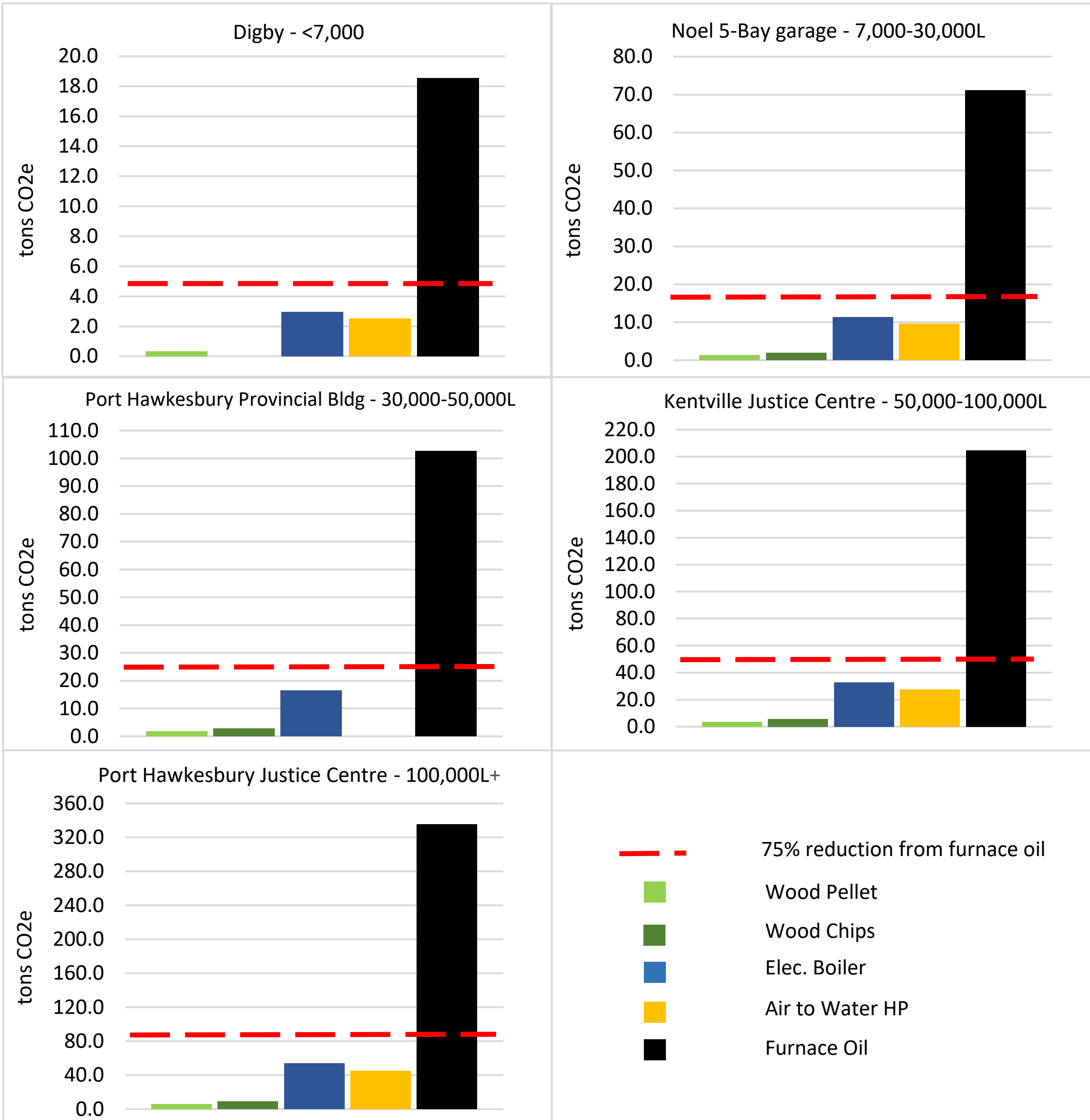

Figure 6-3 - 2035 emissions vs 75% emissions reduction target

[6] https://nslegislature.ca/legc/bills/64th_1st/1st_read/b057.htm

6.4 Carbon Cost

To meet national emissions reduction goals, the federal government started imposing a tax on carbon starting in 2018. Current carbon emission tax is at $40 per tonne for the year 2021 and will reach $170 per tonne in 2030. Nova Scotia opted to use Cap & Trade program which currently meets the minimum requirement of the Federal Carbon tax program. The price per tonne CO_2 is the same as other provinces but only a portion of emissions are priced, unlike in provinces such as Ontario and Alberta, where all consumer and commercial emissions are priced.

Impact on fuel price due to carbon emission as per Cap & Trade program[7] is shown below:

- CO_2 emissions from the combustion of biomass are reported under the LULUCF category and are also exempt under the Cap & Trade program and are hence zero. Other GHG emissions generated during combustion such as Methane (CH_4) and nitrous oxide (N_2O) emissions are reported but are not included in calculation of total emissions[8], making biomass exempt from rate impact due to emissions
- Heating oil is impacted by $0.013/L or $0.335/GJ starting in year 2018[7]
- NS Power IRP 3.1C scenario, which is being used in this study as the chosen path for grid decarbonization has projected grid emissions below the allowed cap[9] starting in year 2022 and hence will not have a rate impact

To calculate the carbon cost for the life cycle of 25-years, the following assumptions were made:

- The Nova Scotia Cap & Trade program's impact on fuel price due to emissions listed above will raise at the same rate as the federal carbon tax program
- After 2030 federal carbon tax program is not yet known and is considered to raise $6.5 per tonne per year to reach $300 per tonne in year 2050. This approach is noted from the CaGBC Decarbonizing Canada's Large Buildings study[10]

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[7] Page 24, https://climatechange.novascotia.ca/sites/default/files/Nova-Scotia-Cap-and-Trade-Regulatory-Framework.pdf
[8] Page 11 Notes, https://publications.gc.ca/collections/collection_2021/eccc/En4-423-1-2021-eng.pdf
[9] Page 239, https://irp.nspower.ca/files/key-documents/NS-Power-IRP-Appendices-A-N.pdf
[10] https://www.cagbc.org/cagbcdocs/advocacy/2021_CaGBC_Decarbonizing_Canadas_Large_Buildings_LAS.pdf

Table 6-7 shows the present value of fuel cost including carbon cost for a life cycle of 25 years with an energy escalation rate of 0% and a discount rate of 5%. The table clearly shows that switching to biomass will significantly reduce life cycle fuel cost.

System	Digby lock-up	Noel 5-Bay garage	Port Hawkesbury Provincial Bldg.	Kentville Justice Centre	Port Hawkesbury Justice Centre
	<7,000L	7,000-30,000L	30,000-50,000L	50,000-100,000L	100,000L+
	Fuel and carbon cost over 25 yrs.				
Wood Pellet	$55,843	$187,201	$309,326	$596,854	$1,010,561
Wood Chips	N/A	$130,097	$187,939	$374,875	$613,991
Elec Boiler	$144,754	$555,049	$801,825	$1,599,375	$2,619,545
Air to Water HP	$122,262	$468,805	N/A	$1,350,862	$2,212,516
#2 Furnace Oil	$81,516	$312,567	$451,534	$900,661	$1,475,152

Table 6-7 - Lifecycle fuel and carbon cost for proposed system

7 LIFE CYCLE COST ANALYSIS

Life-cycle costing (LCC) has been performed in accordance with ASTM Standard E917-05: Practice for Measuring Life-Cycle Costs for Buildings and Building Systems. A constant dollar analysis was performed thus allowing the impact of inflation for each of the options to be excluded.

Assumptions made for LCC analysis are as follows:

- Study Period: 25 years
- Discount rate of 5% chosen for the analysis
- Three scenarios are studied under LCC
    1. **Scenario 1: Base case**
       Annual energy escalation rate (EER) of 0% before inflation is considered for all fuel types, except for electricity, which has an annual average energy escalation rate of 0.8% according to NS Power IRP 3.1C scenario
    2. **Scenario 2: Sensitivity analysis case 1**
       Biomass does not require to invest in infrastructure for decarbonization like grid energy and has stable historic fuel prices hence is considered to have an EER of 0% and electricity, which requires investments for grid decarbonization has an EER of 2%. Furnace oil has an EER of 2% to account for volatility of fuel oil prices
    3. **Scenario 3: Sensitivity analysis case 2**
       Scenario 2 EER with Higher future carbon cost. Adaptation of federal carbon tax program in Nova Scotia

- Fuel cost and carbon cost used are as listed under section 6.1 and 6.4 respectively
- Annual Maintenance and Replacement Costs were obtained from RS Means Facilities Maintenance *& Repair costs data book, 2014. Reed Construction Data*
- System component costs that were not arranged from supplier such as piping, chimney, pumps, oil tank, RS Means Mechanical Cost Data book, 2019 was used
- Coal plant annual maintenance and replacement costs from RS Means Facilities Maintenance *& Repair costs data book, 2014* are used to represent Biomass boilers
- Maintenance cost for wood pellets and wood chips are considered to be equal
- Any replacement or major repair costs scheduled to occur in year 25 were not included in this analysis. All equipment is assumed to last the full 25 years except heat pumps which are replaced in year 20 and electric boiler in year 15.
- Oil tanks are considered to be at the end of their life and are replaced for all sites under furnace oil option
- Life cycle and repair frequencies were determined from the RS Means Facilities Maintenance & Repair costs data book, 2014, with additional information obtained from the ASHRAE: Service Life and Maintenance Cost Database
- As the RS Means costs were tabulated in 2014, an adjustment factor was added to the material costs to reflect the current value of the Canadian dollar
- Salvage value was obtained by multiplying the fraction of remaining life by initial cost
- Options requiring electrical upgrades at site are considered to cost $50,000
- Initial capital cost covers the following list of components:

Components	Pellets	Chips	Electric Boiler	Air to Water HP	Furnace Oil
Boiler	✓	✓	✓	✓	✓
Back up electric boiler *(For sites with higher boiler capacities, 300kW+)*	✓	✓	✓	✓	
Buffer tank	✓	✓			
Pump	✓	✓	✓	✓	
Silo	✓				
Walking floor		✓			
Chimney	✓	✓			
New piping	✓	✓	✓	✓	
Automation and control	✓	✓	✓	✓	
Outdoor mechanical shed *(For sites requiring outdoor installation)*	✓	✓			
Removal of existing boiler & oil tank	✓	✓	✓	✓	✓

New Oil tank					✓
Miscellaneous	✓	✓	✓	✓	✓
Electrical upgrades	✓	✓	✓	✓	

Table 7-1 - Components covered under Initial cost

- Following overheads were added to the initial cost
  - I. Contractor’s overhead - 10%
  - II. Contractor’s profit - 5%
  - III. Design allowance - 5%
  - IV. Design fee - 5%

A comparison of the proposed retrofit heating systems LCC - Scenario 1: Base case in terms of present value is shown on next page under each site heading and a detailed cost breakdown can be found in Appendix A.

LCC-Scenario 2 and 3 charts can be found under Appendix B.

7.1 Digby Lockup - <7,000L

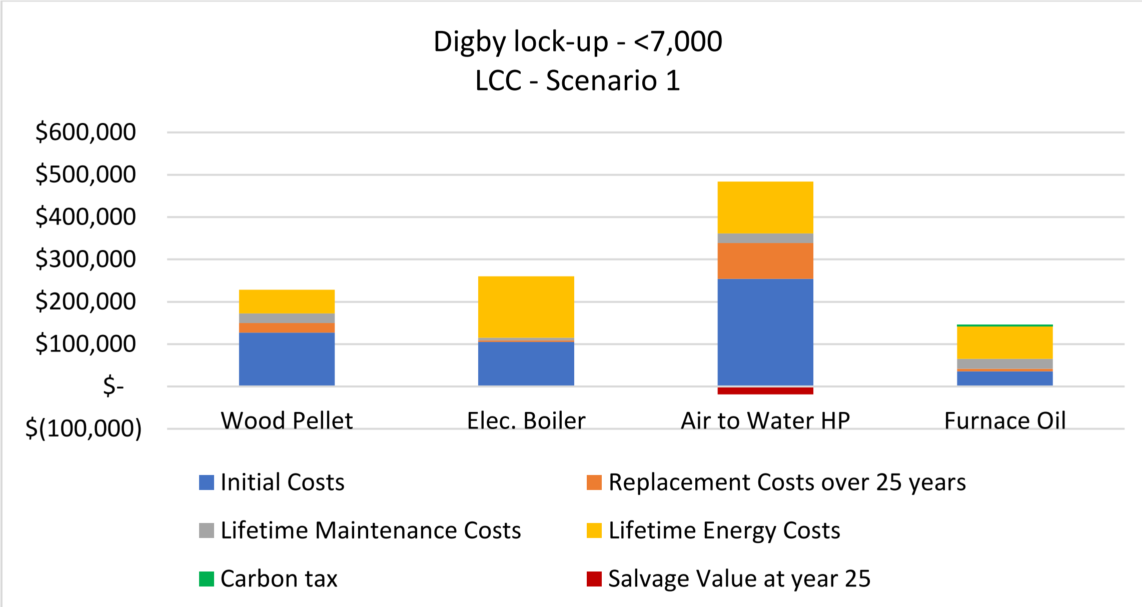


Figure 7-1 - LCC breakdown, Digby lockup <7,000L

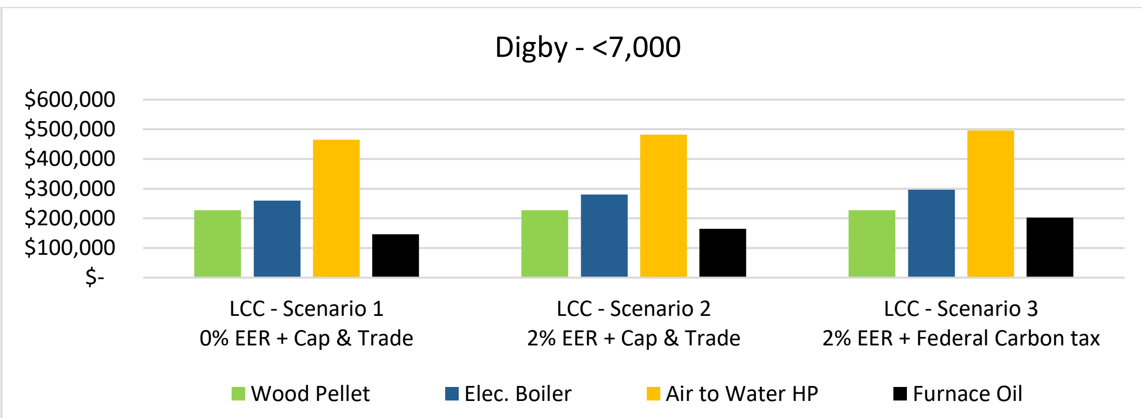


Figure 7-2 - LCC scenarios comparison - Digby lockup <7,000L

From the above figures it can be seen for buildings with an annual oil consumption of less than 7,000L, that switching off the furnace oil doesn't make a strong financial case unless LCC-Scenario 3 is considered. But to reduce the building's GHG emissions, a change from furnace oil will be required and the next most economical fuel source to it is wood pellets, which is also the greenest of all the fuel types under consideration.

7.2 NOEL 5-BAY GARAGE - 7,000-30,000L

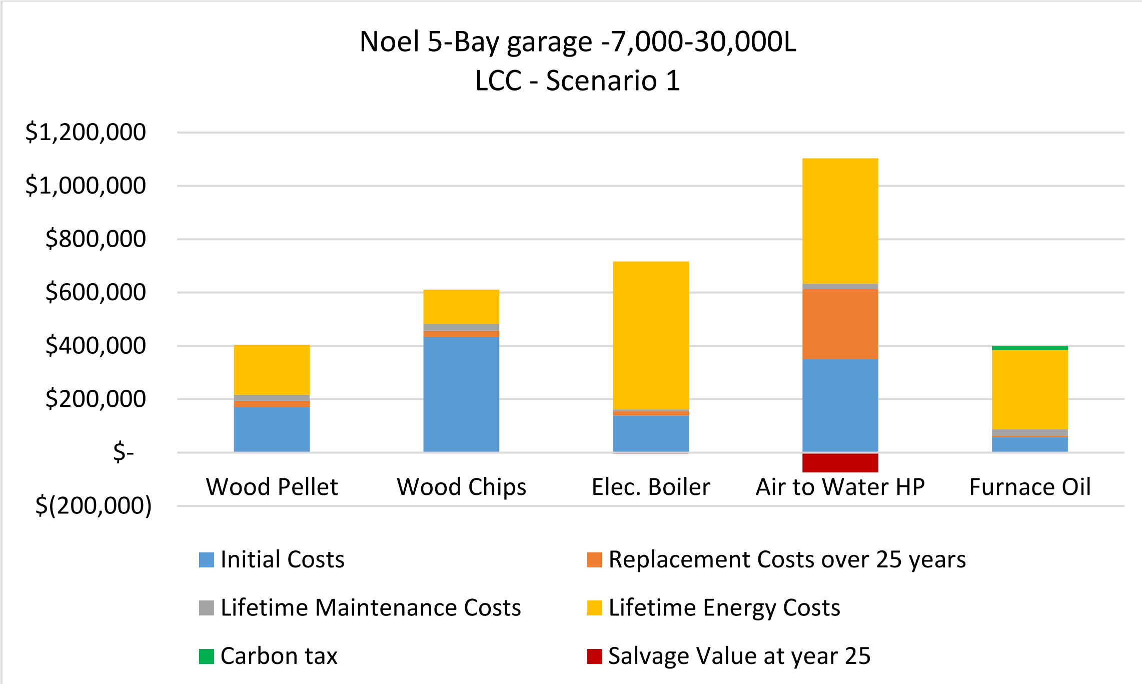


Figure 7-3 - LCC breakdown, Noel 5-Bay garage - 7,000-30,000L

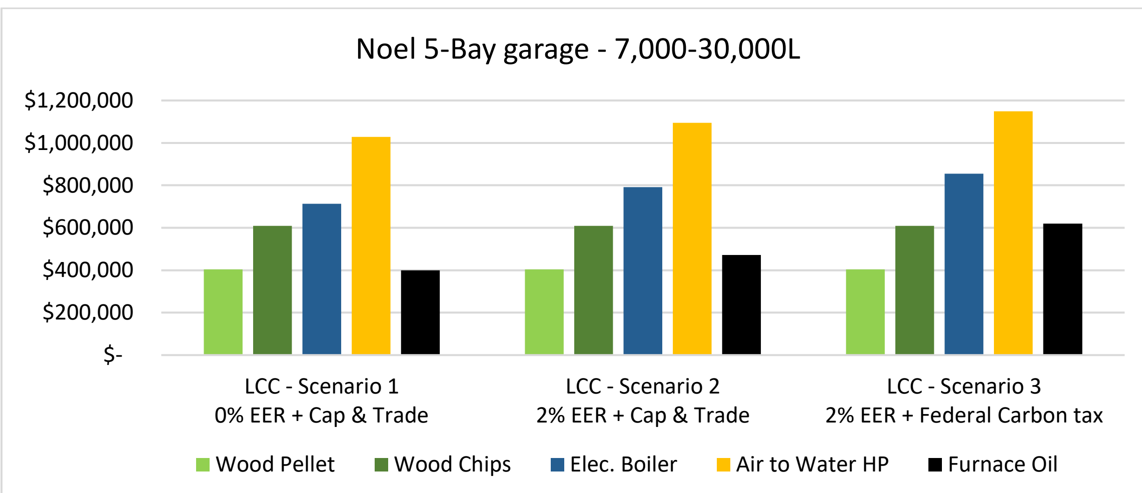


Figure 7-4 - LCC scenario comparison, Noel 5-Bay garage - 7,000-30,000L

For the buildings with an annual oil consumption between 7,000L – 30,000L, wood pellet is the most economical and green alternative system followed by wood chips. The gap between wood pellets and chips is more than 40%. Under LCC scenario 3 when a federal carbon tax is introduced, it can be noted that furnace oil will be most affected by it.

7.3 Port Hawkesbury Provincial Building - 30,000-50,000L

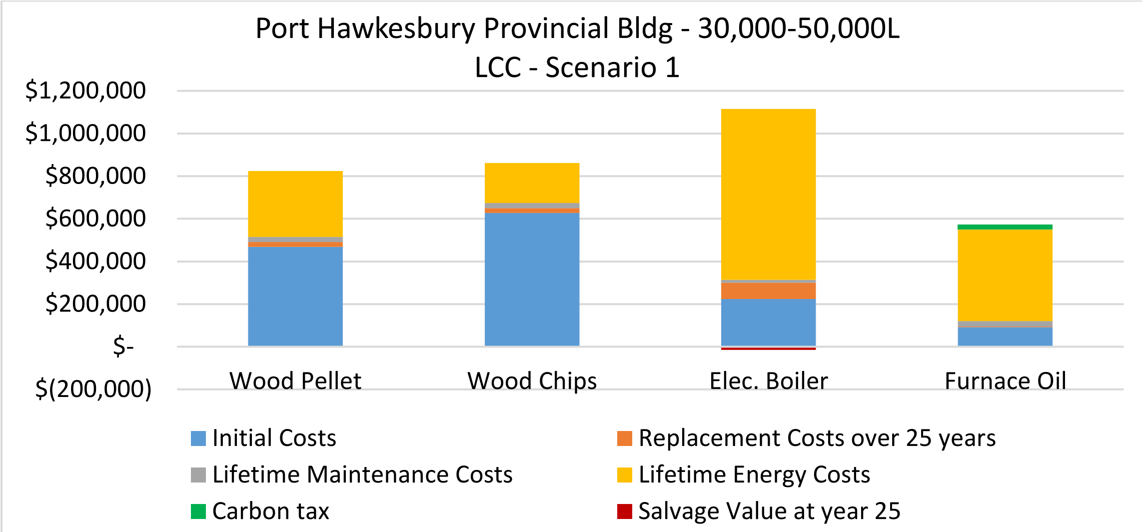


Figure 7-5 - LCC breakdown, Port Hawkesbury Provincial Bldg - 30,000-50,000L

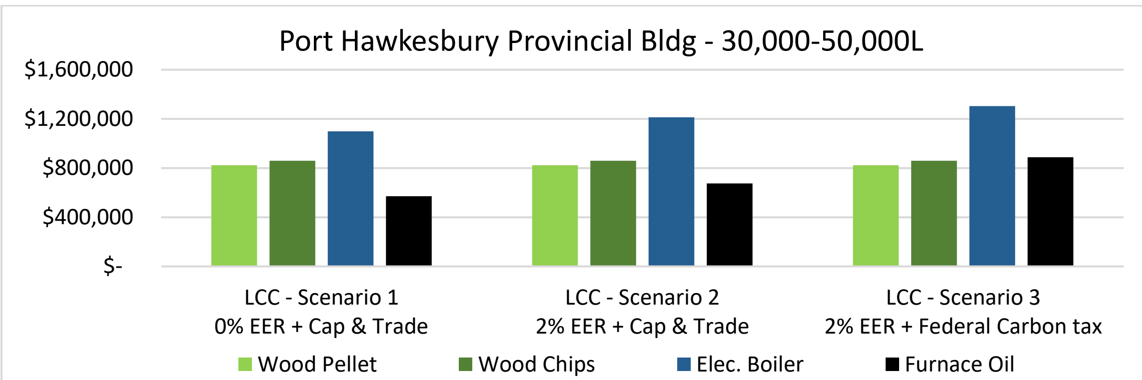


Figure 7-6 - LCC scenario comparison, Port Hawkesbury Provincial Bldg - 30,000-50,000L

The LCC of wood pellets and chips boiler looks similar for the buildings with an annual oil consumption of 30,000L – 50,000L and this is because the site under study doesn't allow placement of wood pellet boiler in the existing boiler room and requires construction of an outdoor mechanical shed, leading to higher initial cost. If it could be avoided the cost of wood pellet system will decrease significantly and the gap between pellets and chip system will increase to 15% making pellets as the most economical alternative system. Under LCC scenario 3 when a federal carbon tax is introduced, it can be noted that furnace oil even though being the most economical fuel source under scenario 1 will be most affected by it, whereas biomass fuels are unaffected by higher carbon costs.

7.4 KENTVILLE JUSTICE CENTRE - 50,000-100,000L

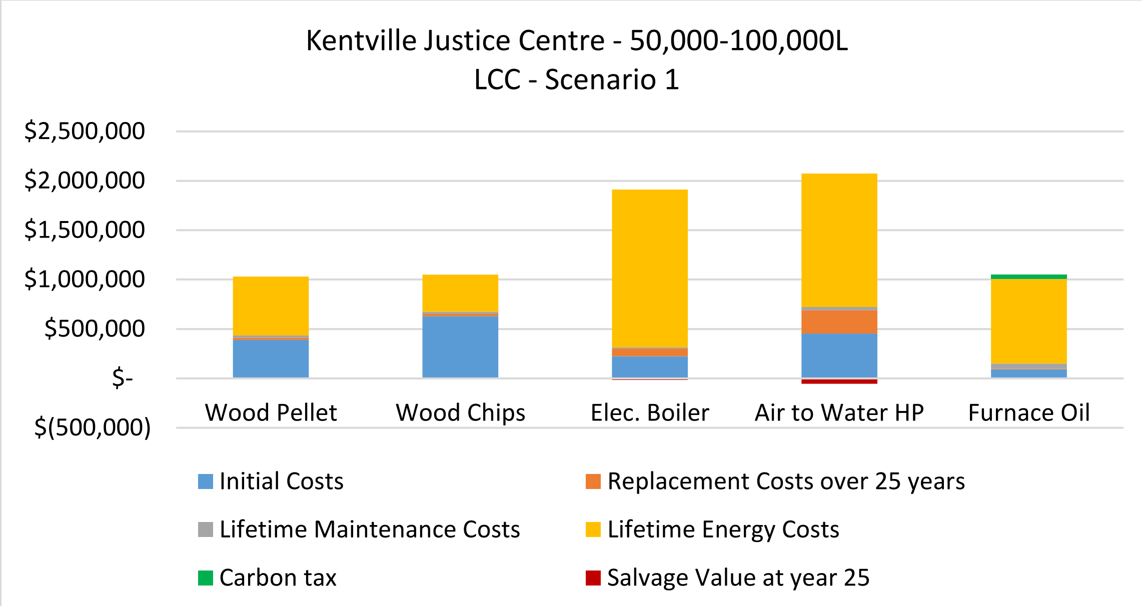


Figure 7-7 - LCC breakdown, Kentville Justice Centre - 50,000-100,000L

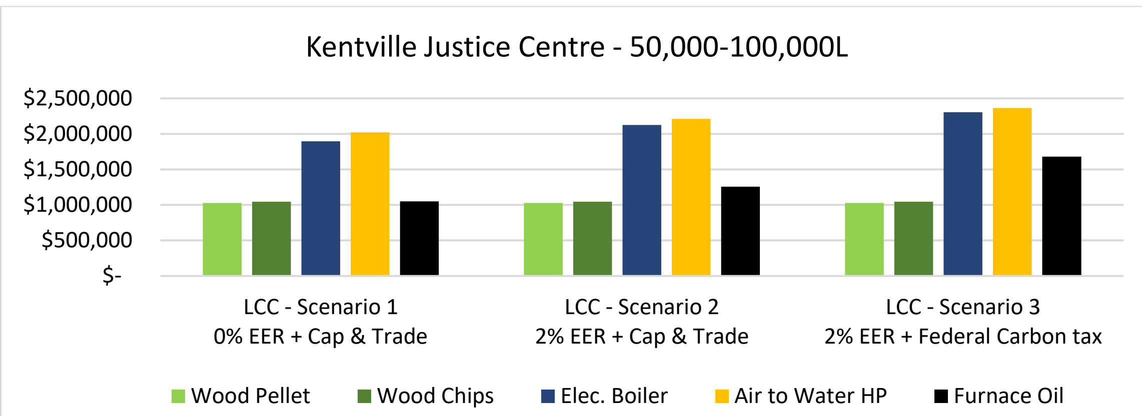


Figure 7-8 - LCC scenario comparison, Kentville Justice Centre - 50,000-100,000L

Unlike Port Hawkesbury Provincial Building, this building allows installation of wood pellet boiler in the existing boiler room and eliminates the requirement of an outdoor mechanical shed. Even with higher initial cost due to construction of an outdoor mechanical shed, the wood chips system LCC is similar to that of the wood pellet system. This is because wood chips are the most economical fuel source and as annual fuel consumption increases, life cycle fuel cost savings increase, provided the moisture content of the wood chips considered for this study is maintained. As there is no clear winner in this case, it will be subjected to factors such as the individual building design, availability of wood chips close to the site, wood chips quality and closeness of the site to Local ellet producer which will lead to lower wood pellet cost.

7.5 Port Hawkesbury Justice Centre - 100,000L+

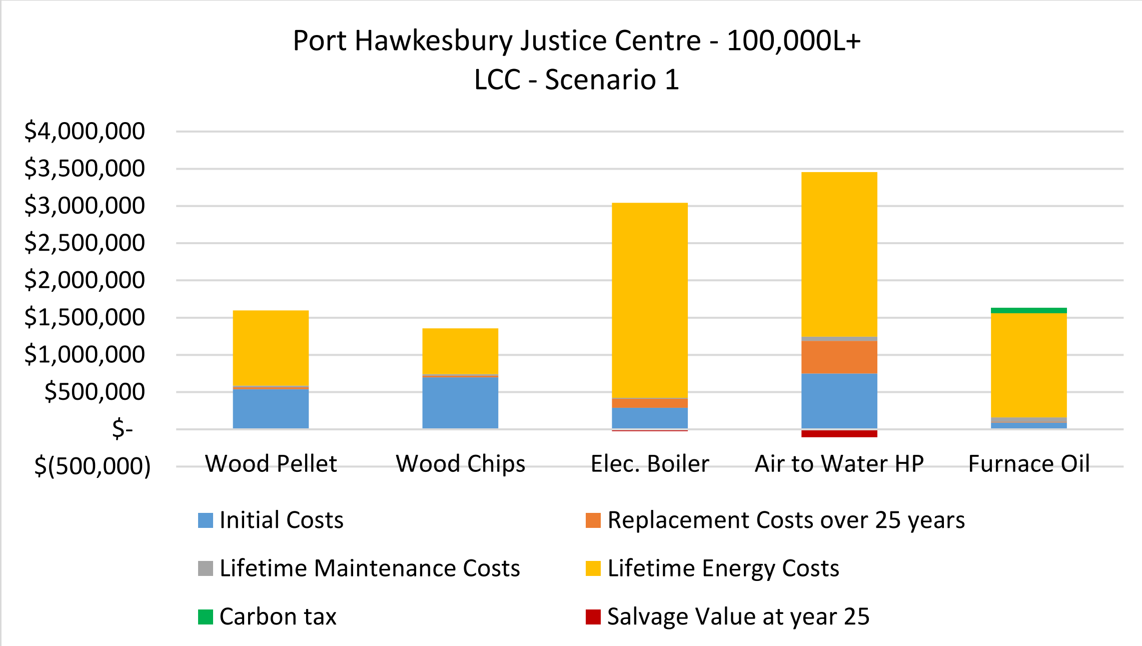


Figure 7-9 - LCC breakdown, Port Hawkesbury Justice Centre - 100,000L+

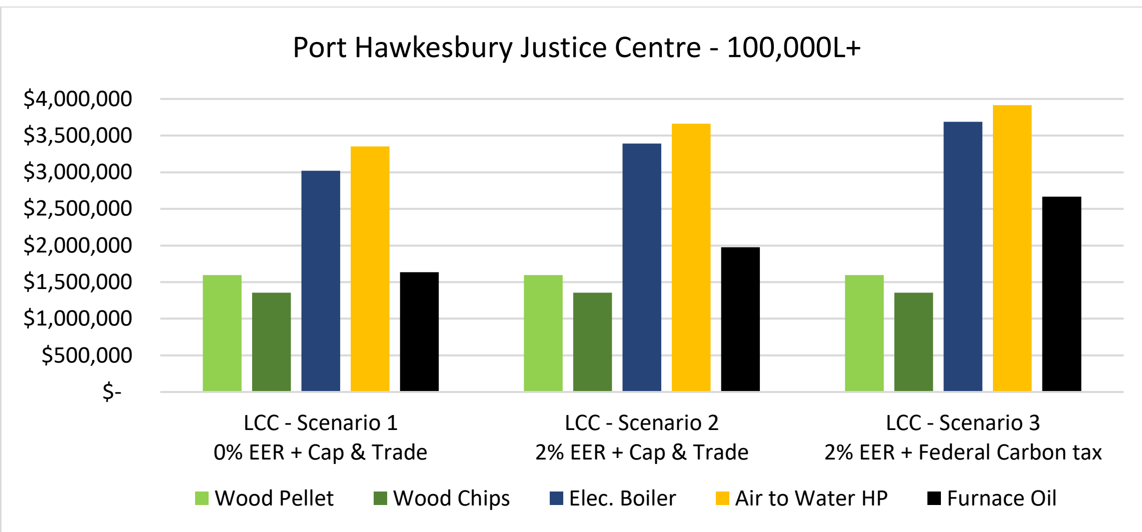


Figure 7-10 - LCC scenarios comparison, Port Hawkesbury Justice Centre - 100,000L+

Wood chips being the least expensive fuel source becomes the most economical alternative system for the buildings with annual fuel consumption higher than 100,000L. The difference between the LCC of wood chips and pellets for this category increases to 15%.

8 CONCLUSION

As per Nova Scotia's Environmental Goals and Climate Reduction Act, the GHG emissions across all government-owned buildings must be reduced by 75% by the year 2035. With close to 50% of energy use in commercial and institutional buildings in Atlantic Canada being from space and domestic hot water heating, switching to a biomass fuel source will help to achieve the 75% target easily as they are the cleanest fuel source with negligible emissions.

Biomass (Wood pellets and chips) options are the only options which currently meet the 75% GHG emissions reduction target and as the grid decarbonizes as per the IRP Scenario 3.1C, other alternative grid dependent systems will also meet the 75% GHG emissions reduction by year 2035 target. But if we look at the cumulative emission by 2035, only the biomass options meet the 75% GHG emissions reduction target. Another important thing to note is that, unlike grid-dependent options, biomass options' carbon intensity is independent of any variable. Any deviation from the IRP Scenario 3.1C decarbonization path due to the forthcoming federal Clean Electricity Standard or other market factor will impact projected grid emissions and electricity costs, whereas biomass options are cleaner and have no carbon costs, so do not require upgrade investments to decarbonize like electricity gird and hence biomass is anticipated to have more stable rates.

The life cycle cost financial analysis showed that biomass (wood pellet and wood chips) heating systems are the most economical alternative heating system over the life cycle period of 25 years.

As delivery pricing of wood pellets varies depending on the distance of the site from the pellet plant, it will influence the LCC results. The other factor affecting the LCC results is the ability of the existing building to accommodate the pellet boiler in the existing boiler room, resulting in lower initial costs.

The table on the next page shows the most economical alternative system for the different annual oil consumption categories. It demonstrates consideration for different site locations and if the building could hold the new pellet boiler in the existing boiler room or not.

	Annual Oil Consumption									
	<7,000L		7,000-30,000L		30,000-50,000L		50,000-100,000L		100,000L+	
Pellet Boiler Location / Site	Need new mech. shed	Use existing boiler room	Need new mech. shed	Use existing boiler room	Need new mech. shed	Use existing boiler room	Need new mech. shed	Use existing boiler room	Need new mech. shed	Use existing boiler room
Digby	Elec. Boiler	Wood pellet	Wood pellet		Wood pellet or Chips		Wood Chips	Wood pellet or Chips	Wood Chips	
Noel	Wood pellet		Wood pellet		Wood pellet		Wood pellet or Chips		Wood Chips	
Kentville	Wood pellet		Wood pellet		Wood pellet or Chips	Wood pellet	Wood pellet or Chips		Wood Chips	
Port Hawkesbury	Elec. Boiler	Wood pellet	Wood pellet		Wood pellet or Chips		Wood Chips	Wood pellet or Chips	Wood Chips	

Table 8-1 - LCC analysis summary for various furnace oil consumption categories

From the table above following conclusion can be made:

- For the buildings with an annual oil consumption of less than 30,000L, wood pellets are the most economical alternative system
- For the building with an annual oil consumption of more than 100,000L, wood chips are the most economical alternative system
- For the building with an annual oil consumption of between 30,000L to 100,000L, the results vary based upon the site and the ability of the building to hold pellet boiler in the existing boiler room.
  For the location which shows both pellet and chips as the economical alternative system, they will be subjected to availability of the wood chips close to the site and the quality of the chips delivered

Additional benefits of wood pellet as a fuel source:

- Least GHG emissions
- Supports local jobs
- Fuel cost stability and multiple pellet supplier availability in Maritimes with plant capacities higher than the DPW’s sites annual oil consumption

- Shaw Resources, Hardwood Lands, NS 50,000 tonne
- Shaw Resources, Belledune, NB 100,000 tonne
- Groupe Savoie, Saint-Quentin, NB 90,000 tonne
- Grand River pellets, NB 100,000 tonne
- GNTI, NS 100,000 tonne

APPENDIX A

Scenario 1: Base Case Life cycle cost (LCC) analysis

Assumptions

- 25-year lifecycle, 5% discount rate
- Wood Pellets 0% EER
- Wood Chips 0% EER
- Electricity 0.8% EER
- Oil 0% EER
- Cap & Trade

Digby Lockup - <7,000L

	Heating System				
	Wood Pellet	**Wood Chips**	**Elec. Boiler**	**Air to Water HP**	**Furnace Oil**
Initial Costs	$ 126,809	$ -	$ 105,607	$ 254,309	$ 35,505
Replacement Costs over 25 years	$ 22,724	$ -	$ 3,400	$ 84,148	$ 6,047
Lifetime Maintenance Costs	$ 23,358	$ -	$ 6,451	$ 23,002	$ 23,448
Lifetime Energy Costs	$ 55,843	$ -	$ 144,754	$ 122,262	$ 77,544
Carbon cost	$ -	$ -	$ -	$ -	$ 3,972
Salvage Value at year 25	$ (1,591)	$ -	$ (624)	$ (18,787)	$ (795)
Total Lifecycle Costs	**$ 227,143**	**$ -**	**$ 259,589**	**$ 464,934**	**$ 145,721**

Noel 5-Bay Garage - 7,000-30,000L

	Heating System				
	Wood Pellet	**Wood Chips**	**Elec. Boiler**	**Air to Water HP**	**Furnace Oil**
Initial Costs	$ 171,698	$ 434,961	$ 138,800	$ 351,542	$ 59,041
Replacement Costs over 25 years	$ 22,724	$ 22,724	$ 16,494	$ 261,429	$ 3,118
Lifetime Maintenance Costs	$ 23,358	$ 23,358	$ 6,451	$ 21,371	$ 25,672
Lifetime Energy Costs	$ 187,201	$ 130,097	$ 555,049	$ 468,805	$ 297,337
Carbon cost	$ -	$ -	$ -	$ -	$ 15,229
Salvage Value at year 25	$ (1,591)	$ (1,591)	$ (3,276)	$ (74,241)	$ (289)
Total Lifecycle Costs	**$ 403,390**	**$ 609,549**	**$ 713,518**	**$ 1,028,906**	**$ 400,109**

Port Hawkesbury Provincial Building - 30,000-50,000L

	Heating System				
	Wood Pellet	Wood Chips	Elec. Boiler	Air to Water HP	Furnace Oil
Initial Costs	$ 468,092	$ 627,751	$ 224,073	$ -	$ 91,002
Replacement Costs over 25 years	$ 22,724	$ 22,724	$ 76,491	$ -	$ 3,118
Lifetime Maintenance Costs	$ 23,358	$ 23,358	$ 12,902	$ -	$ 25,672
Lifetime Energy Costs	$ 309,326	$ 187,939	$ 801,825	$ -	$ 429,534
Carbon cost	$ -	$ -	$ -	$ -	$ 22,000
Salvage Value at year 25	$ (1,591)	$ (1,591)	$ (15,366)	$ -	$ (289)
Total Lifecycle Costs	**$ 821,909**	**$ 860,180**	**$ 1,099,925**	**$ -**	**$ 571,038**

Kentville Justice Centre - 50,000-100,000L

	Heating System				
	Wood Pellet	Wood Chips	Elec. Boiler	Air to Water HP	Furnace Oil
Initial Costs	$ 388,082	$ 627,751	$ 224,073	$ 453,971	$ 91,002
Replacement Costs over 25 years	$ 22,724	$ 22,724	$ 76,491	$ 236,152	$ 5,957
Lifetime Maintenance Costs	$ 23,358	$ 23,358	$ 12,902	$ 34,273	$ 51,254
Lifetime Energy Costs	$ 596,854	$ 374,875	$ 1,599,375	$ 1,350,862	$ 856,777
Carbon cost	$ -	$ -	$ -	$ -	$ 43,884
Salvage Value at year 25	$ (1,591)	$ (1,591)	$ (15,366)	$ (55,719)	$ (530)
Total Lifecycle Costs	**$ 1,029,427**	**$ 1,047,117**	**$ 1,897,475**	**$2,019,538**	**$ 1,048,343**

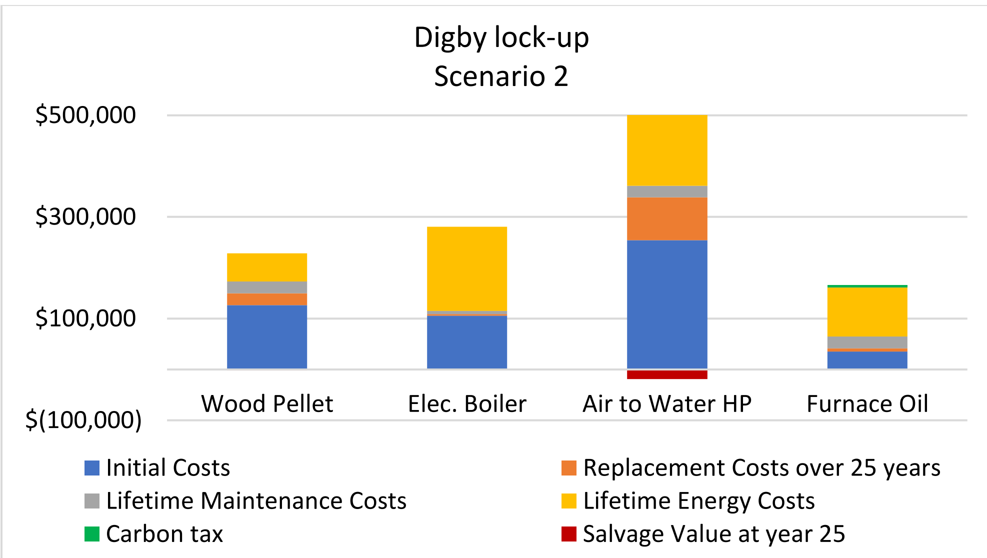
Port Hawkesbury Justice Centre – 100,000L+

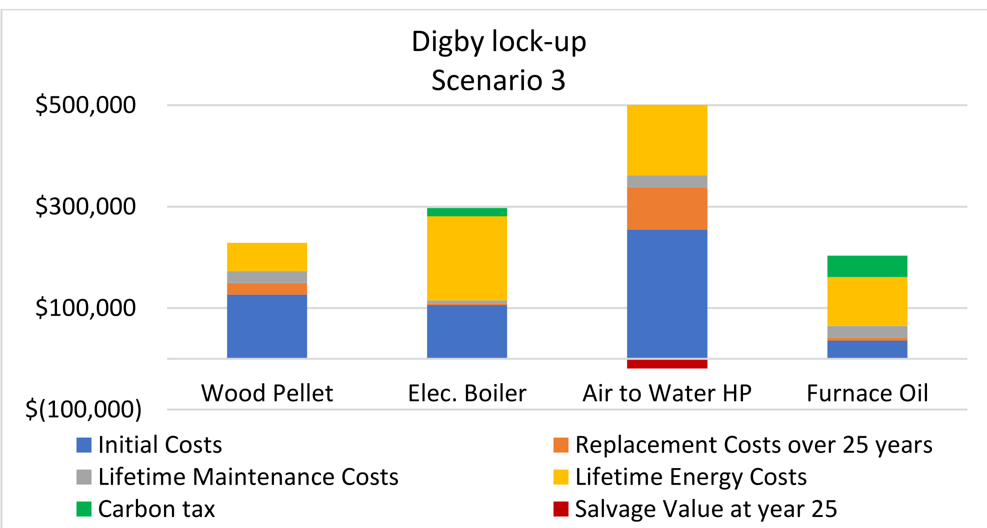
	Heating System				
	Wood Pellet	Wood Chips	Elec. Boiler	Air to Water HP	Furnace Oil
Initial Costs	$ 540,929	$ 696,626	$ 289,446	$ 748,031	$ 92,367
Replacement Costs over 25 years	$ 22,724	$ 22,724	$ 122,572	$ 441,895	$ 9,180
Lifetime Maintenance Costs	$ 23,358	$ 23,358	$ 12,902	$ 53,182	$ 57,928
Lifetime Energy Costs	$ 1,010,561	$ 613,991	$ 2,619,545	$ 2,212,516	$ 1,403,277
Carbon cost	$ -	$ -	$ -	$ -	$ 71,875
Salvage Value at year 25	$ (1,591)	$ (1,591)	$ (24,702)	$ (105,408)	$ (1,084)
Total Lifecycle Costs	**$1,595,980**	**$ 1,355,109**	**$ 3,019,764**	**$3,350,216**	**$ 1,633,543**

Appendix B

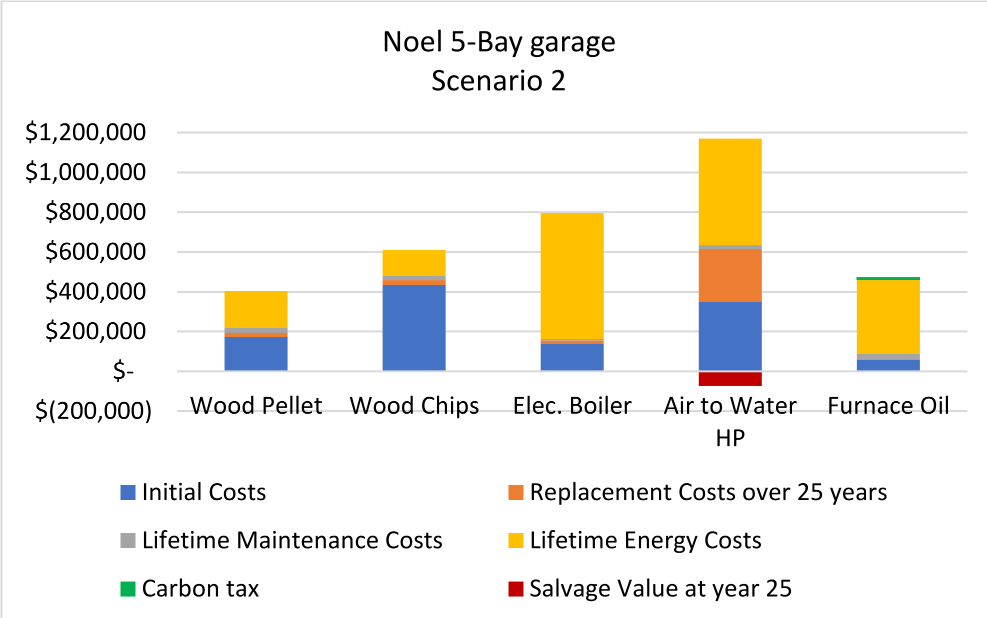
LCC - Scenarios	Scenario 1 Assumptions	Scenario 2 Assumptions	Scenario 3 Assumptions
	25-year lifecycle, 5% discount rate		
Wood Pellets	0% EER	0% EER	0% EER
Wood Chips	0% EER	0% EER	0% EER
Electricity	0.8% EER	2% EER	2% EER
Oil	0% EER	2% EER	2% EER
Tax Program	Cap & Trade Program	Cap & Trade Program	Federal Carbon Tax

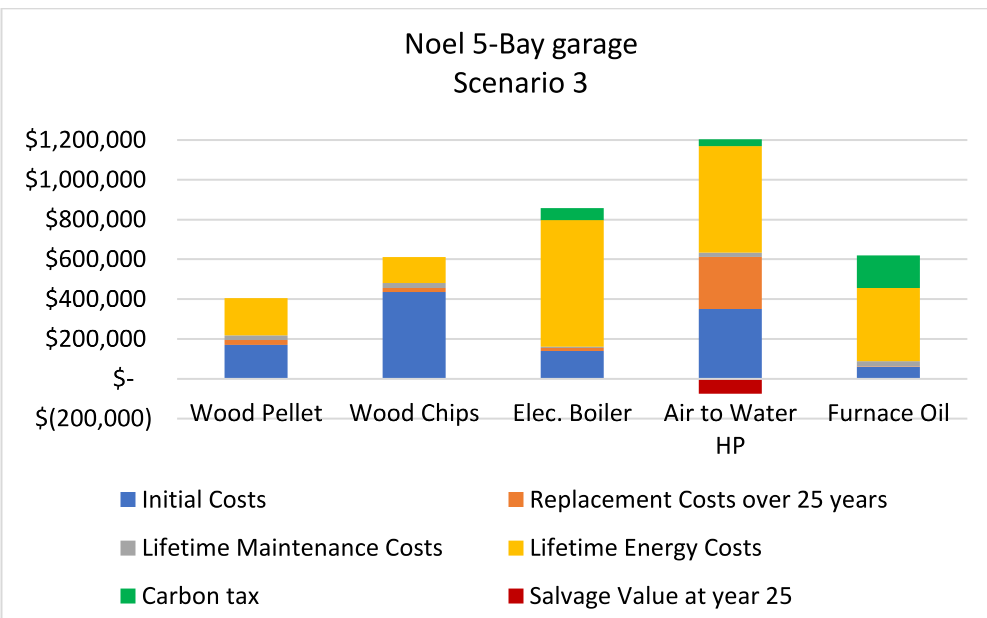
Digby Lockup - <7,000L



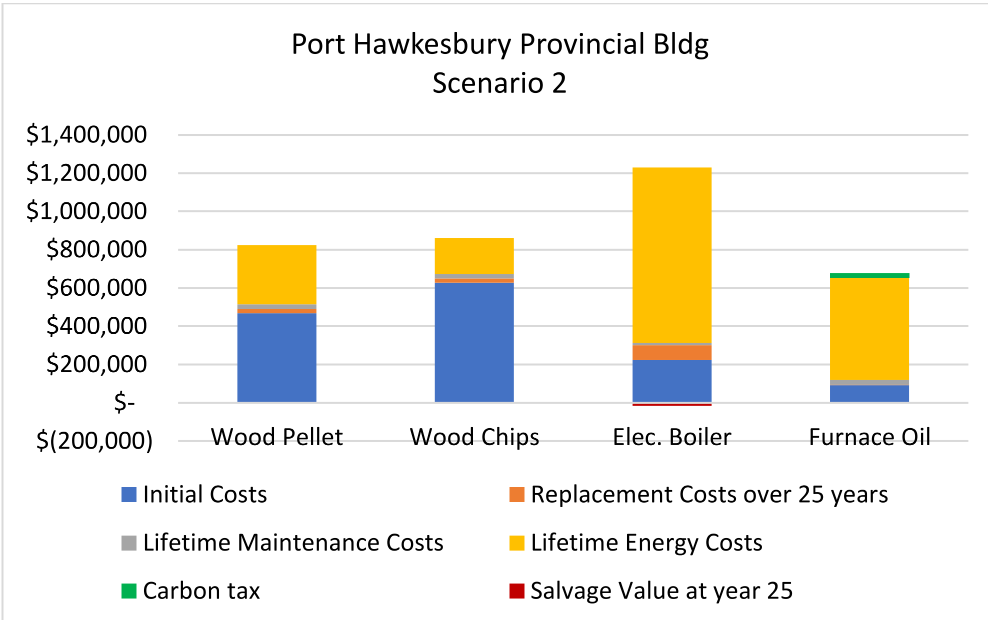


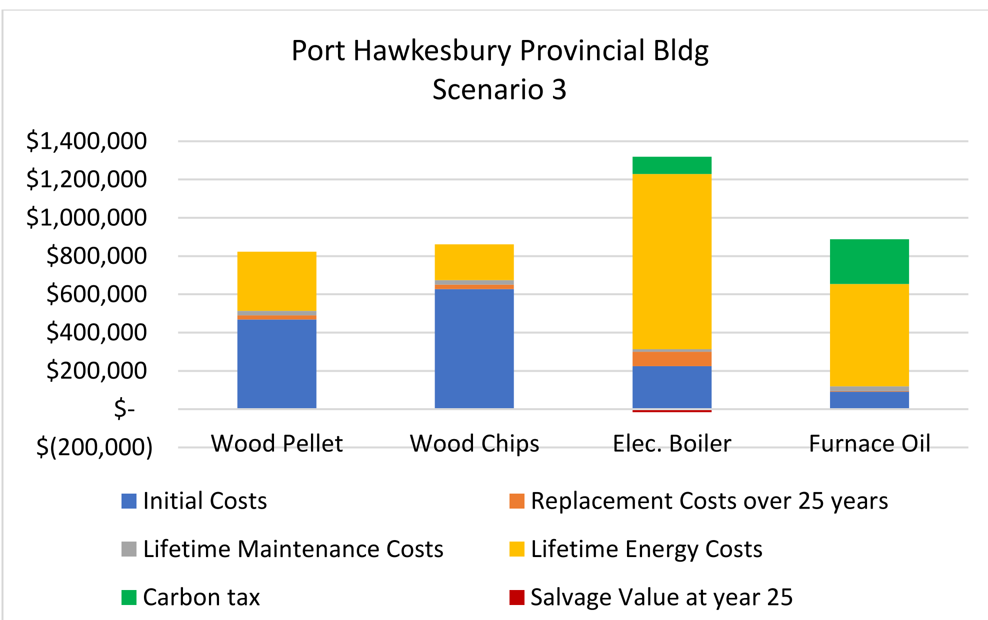
Noel 5-Bay Garage - 7,000-30,000L



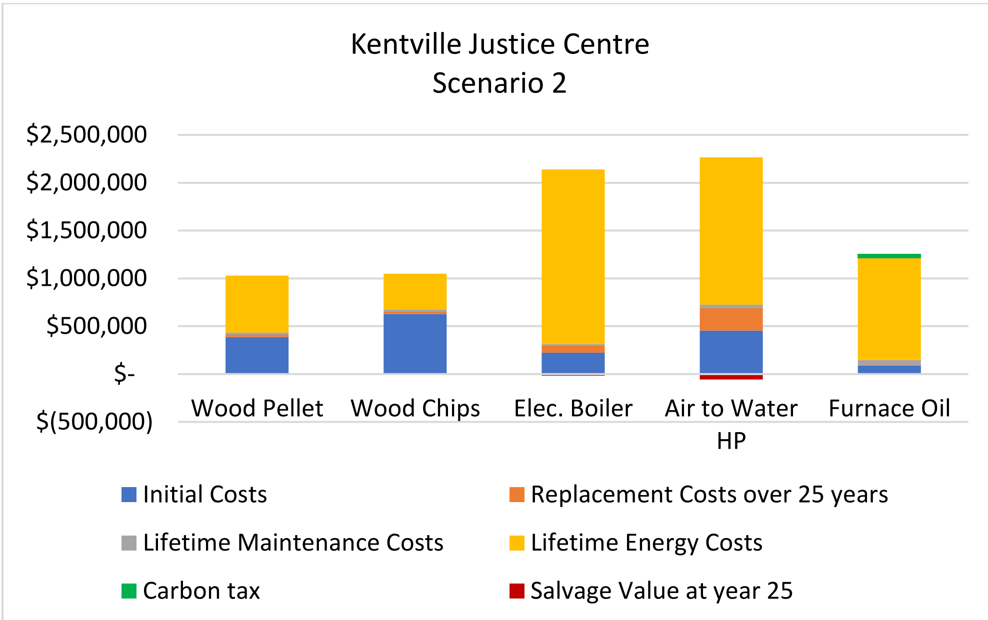


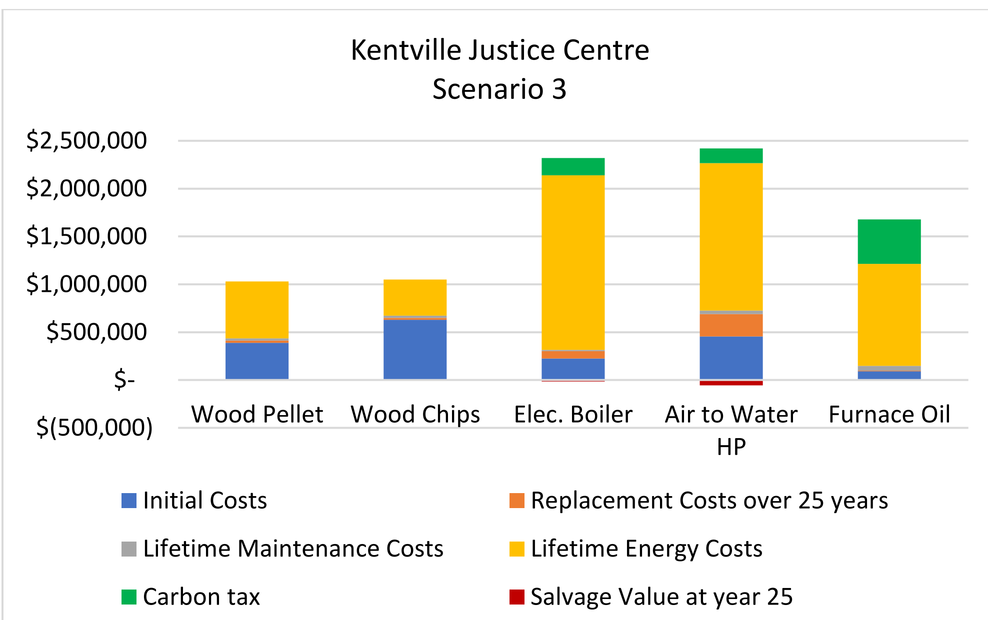
Port Hawkesbury Provincial Building - 30,000-50,000L



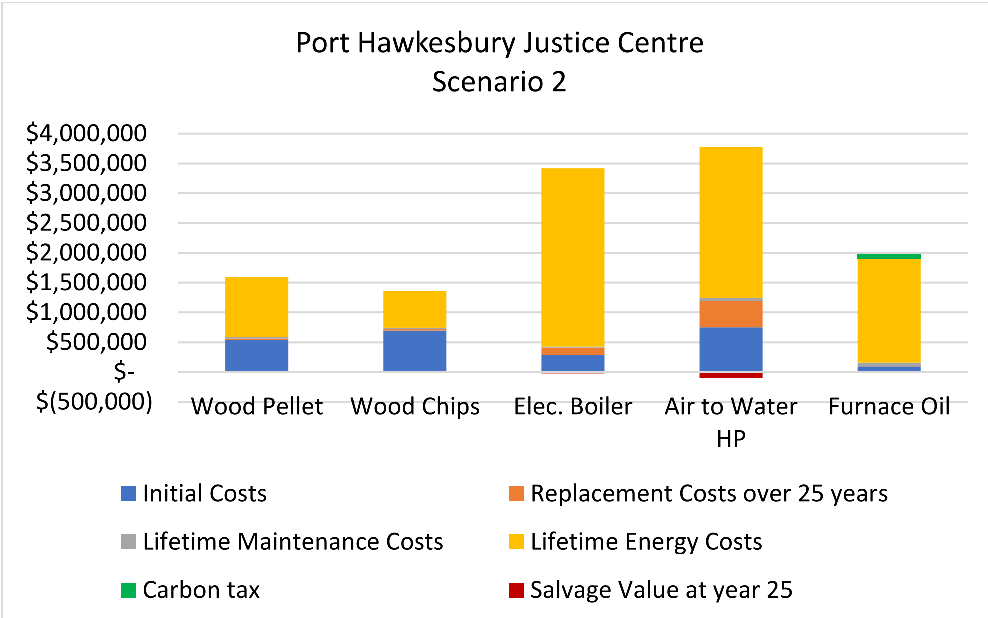


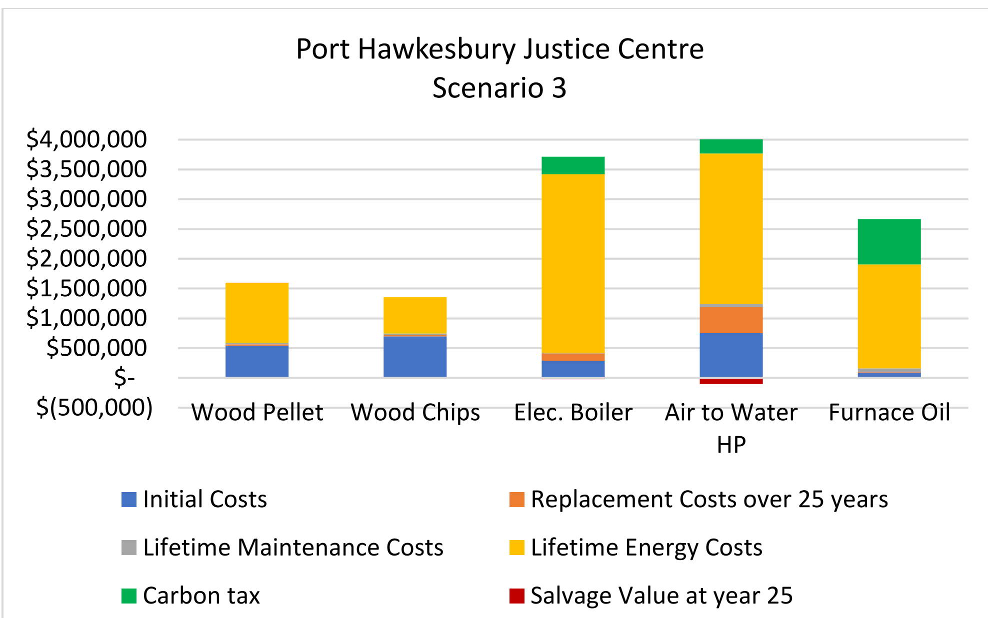
Kentville Justice Centre - 50,000-100,000L





Port Hawkesbury Justice Centre – 100,000L+





APPENDIX C

NS Power IRP- Scenario 3.1C projected generation, emissions, and rate values from the report[11].

The report shows projections up to 2045 and 2046 is considered to have same values as 2045.

Year	Load GWh	CO_2 Emissions Million Tones	CO_2 g/kWh	Rate cents/kWh
2022	11,332	4.19	369.7	16.30
2023	11,337	4.22	372.5	15.91
2024	11,385	4.26	373.8	16.05
2025	11,383	3.62	317.8	16.34
2026	11,381	3.85	338.4	16.26
2027	11,387	3.54	310.8	16.38
2028	11,405	3.58	314.0	16.53
2029	11,380	1.96	172.4	17.63
2030	11,349	0.57	50.0	18.20
2031	11,363	0.57	50.1	18.06
2032	11,414	0.58	50.6	17.94
2033	11,438	0.58	50.7	18.17
2034	11,499	0.59	51.0	18.30
2035	11,567	0.59	51.3	18.31
2036	11,664	0.61	52.0	18.37
2037	11,730	0.62	52.8	18.36
2038	11,812	0.63	53.3	18.49
2039	11,901	0.65	54.3	18.62
2040	11,989	0.66	55.1	18.55
2041	12,043	0.67	55.4	18.84
2042	12,125	0.67	55.3	18.74
2043	12,205	0.69	56.1	18.97
2044	12,274	0.61	49.7	19.18
2045	12,360	0.50	40.5	19.16
2046	12,360	0.50	40.5	19.16

[11] https://irp.nspower.ca/files/key-documents/E3_NS-Power_2020_IRP_Report_final_Nov-27-2020.pdf

APPENDIX D

Wood chips and pellets properties used for the study. Values noted from EU Biomass Trade Centres - Wood Fuel Handbook[12].

Wood Pellets

Moisture Content	8%	
Density	650	kg/m3
Heating Value (NCV)	4.8	kWh/kg

Wood Chips

Moisture Content	35%	
Density	242	kg/m3
Heating Value (NCV)	3.1	kWh/kg

[12] https://forestry.msuextension.org/wood-burning/pellets/WOOD_FUELS_HANDBOOK_BTC_EN.pdf