Nova Scotia Provincial Housing Agency (NSPHA)

Solar Gardens and Fleet Vehicle Electrification for Affordable Housing in Halifax Regional Municipality

Pre-Feasibility Study - Final Report

NSCC Applied Energy Research Team

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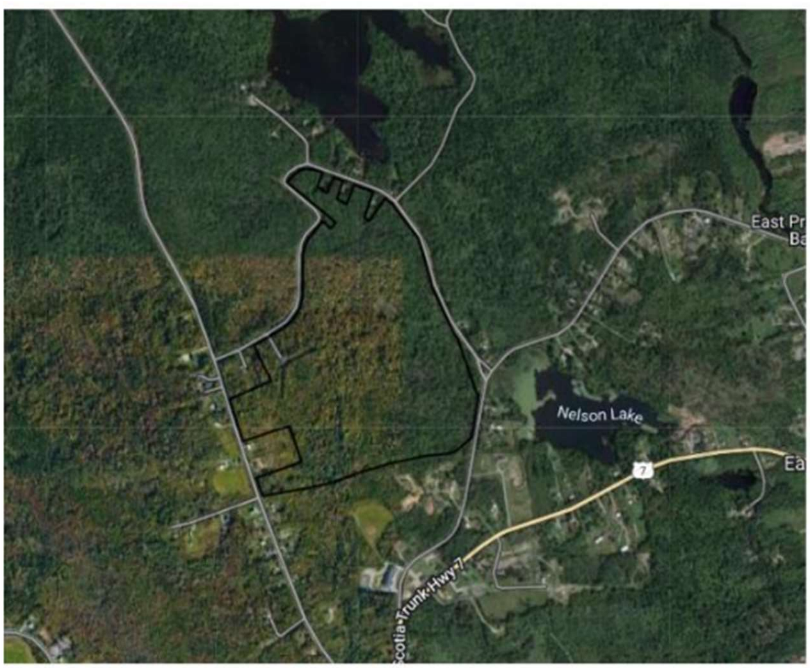

Design	Design 1
Module DC Nameplate	12.2 MW
Inverter AC Nameplate	9.77 MW Load Ratio: 1.25
Annual Production	16.35 GWh
Performance Ratio	86.1%
kWh/kWp	1,340.5

SITE 1: East Preston

With appreciation for the support of HCi3 for this work.

1. Background

This report summarizes the results of a study of the feasibility of community solar gardens and vehicle fleet electrification for affordable housing properties owned and managed by the Nova Scotia Provincial Housing Agency (NSPHA) in Halifax Regional Municipality (HRM). The NSPHA Metropolitan District provides affordable rental housing for over 6000 residents of HRM and has established a plan to decarbonize the energy supply for its building stock over the next 20 to 25 years.

In support of implementing the energy transition plan, in this project we have gathered data on electricity consumption of multi-unit residential properties to identify high and low consuming sites and estimate the required amount of solar photovoltaic generation capacity that would be needed to offset the electricity consumption of these properties. In addition, properties were assessed for their potential to produce solar electricity on-site. The gap between potential on-site solar energy production and the electricity consumption of these communities is proposed to be filled by community solar gardens to be installed on public properties in HRM.

A community solar garden, as defined here, is a solar electricity generation facility of medium to large scale for which the capital investment and productive benefits are shared among a group of people or organizations in a community. There is a new community solar program created by the Province of Nova Scotia that allows a proponent to install a solar garden, between 1 and 10 megawatts (MW) of capacity, that is supported by a group of subscribers who will purchase the electricity generated by the facility. A primary goal of community solar gardens is to facilitate more solar electricity production that is shared in a community, including participants who otherwise would not be able to install solar panels to offset their electricity consumption. In this case, NSPHA and its tenants represent a community with a goal of decarbonizing their energy supply, which may be facilitated by installing one or more solar gardens. The Nova Scotia Community Solar program is currently anticipated to launch in the summer/fall of 2023.

In this study, we estimate the size of community solar garden needed to offset the total electricity consumption of the multi-unit properties managed by the Metropolitan District, and we propose and assess a set of potential sites for community solar gardens for this purpose.

This work also includes research on vehicle fleet electrification, in which we collected data on the travel pattern of work vehicles employed by the Metropolitan District of NSPHA. The Metropolitan District operates a fleet of more than 40 work vehicles in HRM to service maintenance, repairs, and deliveries to their properties. As part of a long-term sustainability plan, the Agency is exploring a gradual transition to electric vehicles for its work fleet.

To support planning for a transition to electric vehicles, we collected data on daily travel distances and assessed the potential for electric vehicles to provide those services. For context, using an electric vehicle in Nova Scotia today results in a 30 to 50% reduction in greenhouse gas emissions per kilometer traveled, compared with providing the same service using a gasoline or diesel vehicle. This reduction will become greater over time as the emission intensity of electricity generation in Nova Scotia decreases.

2. Objectives

(1) To quantify the electricity consumption of all the NSPHA affordable housing properties in HRM that have greater than 10 units clustered together, such as apartment buildings and townhouses. There are 80 such properties in HRM, for a total of just over 3000 dwelling units. Examples in urban HRM include Mulgrave Park, Uniacke Square, and Greystone. For each property, we have collected data on electrical energy consumption to estimate the required capacity of solar arrays needed to supply this electricity.

(2) To identify locations in HRM that could be suitable for community solar gardens, including brownfield sites, parking lots, rooftops, or any other suitable sites. For each site, to assess the technical, economic, and social feasibility of siting a community solar garden there.

(3) To define a 5-year plan for investment and development of community solar gardens.

(4) To conduct a separate study of the vehicle fleet that the Metropolitan District of NSPHA operates in HRM and prepare an 8-year plan for its electrification, including analysis of vehicle and charging requirements.

3. Methodology

Electricity consumption:

Three years of data on electricity consumption at the various properties was provided by EfficiencyOne, consisting of electricity bill data compiled into clusters by property. This data contained no identifying information about the residents involved. This data was summed to provide a total for electricity consumption for each cluster, where distinct clusters were separated geographically by address.

Staff with NSPHA compiled data on the number and type of building assets operated by the Metropolitan District in HRM, along with estimates of their total electricity consumption based on the billing data recorded by NSPHA. These were used together with the data obtained through EfficiencyOne to estimate the total electricity consumption across the whole set of built assets in the Metropolitan District.

On-Site Solar Generation Potential

The potential for on-site solar electricity generation at the various properties was assessed using satellite imagery and Helioscope solar analysis software. The characteristics of each property were entered into Helioscope, and an estimate made of the capacity of solar photovoltaic panels that could be installed at the site, primarily on the roof. Helioscope also provided a robust estimate of the annual electricity production that could be expected at each site. This was then compared with electricity consumption to determine the ratio of self-generation that could be expected for each property.

Investigation of Potential Community Solar Garden Sites

Staff at NSPHA provided a list of provincially owned properties that could be considered as possible sites for community solar gardens. These properties are throughout Nova Scotia, and for the purpose of this study we focused on properties in HRM. On many of the properties, affordable housing developments are planned to be constructed. Through conversations with NSPHA staff, we learned which properties could potentially accommodate solar power generation facilities in addition to housing.

Assessment of Fleet Vehicle Electrification

To assess the potential to use electric vehicles for the NSPHA Metropolitan District work fleet, we installed GPS tracking devices in 30 of the approximately 40 vehicles in the work fleet. Most of these vehicles are cargo vans, with a few pickup trucks. With the tracker data, we found the distance travelled per day for each vehicle. Three tracked vehicles were eliminated from the analysis because they were not in use at the time and showed zero travel distance. For the remaining vehicles, we assessed the capability of currently available all-electric vehicles to meet the distance requirements and estimated the amount of charging infrastructure and electricity needed to operate the fleet using electric vehicles.

4. Results

4.1. Community Solar

4.1.1. Electricity Consumption – Summary statistics

Dataset 1:
The Public Housing Category in our data consists of dwelling units that are owned and operated by the NSPHA. Here are the findings based on the dataset provided by EfficiencyOne:

- 2287 dwelling units (including all clusters of ten or more units)
- 11,149 MWh of electricity consumed per year
- 4,875 kWh per dwelling unit per year

More detailed information on the electricity consumption at each cluster is available in a separate spreadsheet.

Note: This includes units that are heated electrically and units that are heated non-electrically (oil, natural gas, or propane). Therefore, the range of electricity consumption varies significantly between clusters and can be far from the average in either direction. However, the total is most relevant to the question of sizing a solar generation facility for the whole assembly of buildings.

Dataset 2:

Data collected separately by the NSPHA and stored in its own database gives an estimate of the total electricity consumption of NSPHA building stock in HRM (Table 1).

Table 1: Energy consumption of NSPHA building stock, based on utility bill analysis.

Building Type	Number of Assets	Number of Units	Real NSPHA Consumption, 2022 (MWh)	Assumed Tenant Consumption, 2022 (MWh)	Total Electrical Consumption (MWh)	Total Energy Consumption (eMWh)
CAMP (3 or more units)	231	3,664	11,679	11,003	22,682	68,011
LCAMP (less than 3 units)	176	198	3,711	-	3,711	4,513
Total	**407**	**3,862**	**15,379**	**11,003**	**26,393**	**72,524**

Definitions for Table 1:

Building Type: Anything with 3 or more units is considered a CAMP building, and any duplex or single-family homes are considered LCAMP buildings.

Number of Assets: Total number of buildings, defined by the boundaries of their envelope as well as their mechanical/electrical systems.

Number of Units: Total units within the buildings in the previous column.

Real NSPHA Consumption: The total electrical consumption recorded in the internal data management system, COGNOS. This record is prone to transcription errors due to manual entry by dozens of individuals and excludes any meters under tenants' names (a large part of CAMP energy consumption). This is often close but not exactly the same as what is recorded in the meter database.

Assumed Tenant Consumption: The estimated energy consumed by tenants that is not captured in COGNOS. Calculations were performed by a third-party contractor based on average energy use breakdown of residential dwellings.

Total Electrical Consumption: The total of the "real" and "assumed" consumption values.

Total Energy Consumption: The total estimated energy consumption of this set of buildings in their entirety. It includes electricity, fossil fuels used for heat or hot water, propane/diesel for generators, and the assumed tenant consumption. As the NSPHA aims to electrify the heating systems in its buildings, this represents potential future electrical consumption in the Metro District, although heat pump technology will decrease this total due to the higher efficiency of heat pumps.

Comparison of datasets:

Dataset 1 and dataset 2 are not based on exactly the same building stock, but they overlap substantially, and some conclusions can be drawn from comparing them particularly the CAMP units which are multi-unit buildings with three or more units.

Dataset 1: 4,875 kWh per dwelling unit per year (electricity only)
Dataset 2: 6,190 kWh per dwelling unit per year (electricity including assumed tenant usage)

Dataset 2, which is based on NSPHA records plus an assumption on tenant consumption, indicates 27%

higher electricity consumption per unit on average than Dataset 1, which is based on datasets from Nova Scotia Power that were provided through EfficiencyOne. These two sources do not cover exactly the same set of buildings, but this is a fairly significant difference.

Electrification Scenario:

In a future scenario that includes full electrification using heat pumps, assuming 300% seasonally averaged efficiency, the estimated total energy consumption across the whole fleet of buildings in HRM would be approximately 41,800 MWh per year, which is an average of 10,823 kWh per unit per year for all energy needs, nearly a doubling of electricity consumption. This illustrates that a large portion of the total energy used in this set of buildings is used for heating and hot water and is currently provided using non-electric means. Any future scenario will need to include energy efficiency improvements to manage the increasing load due to electrification of heating. Electric vehicles charged by tenants will also need to be part of future planning.

Future Energy Efficiency Plans:

NSPHA staff have indicated that the agency has an approved target to reduce total energy consumption in their buildings to 50% below 2005 levels by 2030, in keeping with overall provincial efficiency targets. According to the estimate above, a complete switch to heat pumps will lead to a reduction of approximately 57% from the current 2023 estimated total energy consumption, therefore the 50% reduction appears to be an achievable goal. As of this version of this report, we do not have the data on 2005 per-unit total energy consumption to use as a comparison. If we assume that the building stock hasn't changed substantially since 2005, then the total energy consumption estimate of 41,800 MWh per year (or lower) is likely to be a reasonable estimate of energy consumption for future scenarios, considering that electrification and building envelope upgrades will proceed simultaneously.

In the same time period, the Nova Scotia Housing Strategy (2023) commits the Province to building 222 additional units of publicly-owned housing by 2027. These units will have much lower per-unit energy consumption than the current building stock average. If we assume they will use 50% as much energy as the current average, they will only add about 1200 MWh per year to the total energy consumption, even if they were all built in HRM, which is unlikely to be the case.

> ***Given the above considerations, an approximate estimate of the amount of renewable electricity needed to be generated to offset the energy consumption of NSPHA public housing in HRM by the year 2030 is around 43,000 MWh per year.***

4.1.2. On-site solar energy potential

For the same set of buildings in the Public Housing Category (Dataset 1), based on Helioscope modelling, the estimated on-site solar energy generation potential for solar power systems designed to fit on the rooftops is:

- Total: 2102 MWh / year
- Annual production per dwelling unit: 919 kWh / unit per year
- This is 18.9% of the total electricity consumption that could be generated from on-site solar for this set of buildings.

- The remaining 81.1% represents 2773 MWh per year of clean electricity that would need to be generated elsewhere if the fleet of buildings in this study are to offset their current electricity consumption using solar energy.

4.1.3. Capacity requirement for Community Solar Garden

The analysis above provides a range of required quantities of solar electricity generation to meet a target of providing the total electricity consumption of the NSPHA public housing stock in HRM using solar energy. The quantity required depends on the definition of the goal, the number of participating dwelling units, and the ratio of on-site solar energy that will be generated. Considering these parameters, we present a set of scenarios based on specified assumptions.

To estimate the electrical capacity of solar required, we used the PVWatts solar calculator from the US National Renewable Energy Laboratory to estimate the annual electricity production from ground-mounted and 2-axis tracking solar arrays located in HRM:

- Ground-mounted, fixed array – facing due south and tilted 30 degrees up: 1249 MWh/MW.y
- Ground-mounted, 2-axis tracking array*: 1719 MWh/MW.y

*A 2-axis tracking array follows the sun throughout the day, increasing yield per installed MW by about 38%. However, capital costs are estimated to be around 25 - 30% higher, and maintenance costs are higher due to moving parts. Maintenance will need to be the responsibility of the plant owner/operator.

Scenario 1 – ***Minimum*** – Meet the electricity generation needs for the 2287 dwelling units in Dataset 1, minus the estimated 18.9% on-site generation potential.

Scenario 2 – Scaled – Meet the electricity generation needs implied by Dataset 1 but scaled from the 2287 dwelling units in that dataset to the 3862 units in the NSPHA dataset to represent the total public housing stock, minus the estimated 18.9% on-site generation potential.

Scenario 3 – Inclusive – Meet the total, larger electricity consumption from Dataset 2, including assumed tenant consumption, minus the estimated on-site solar generation potential.

Scenario 4 – Future 2030 – Meet the total projected ***energy*** consumption of the buildings in Dataset 2, after electrification using heat pumps, considering energy efficiency improvements, minus the estimated on-site solar generation potential.

Table 2: Capacity scenarios for off-site solar power generation.

	Scenario 1	**Scenario 2**	**Scenario 3**	**Scenario 4**
Number of dwelling units	2287	3862	3862	4084
Total electricity generation	11,149 MWh/y	18,827 MWh/y	26,393 MWh/y	43,000 MWh/y
On-site generation	2,107 MWh/y	3,558 MWh/y	4,988 MWh/y	5,192 MWh/y
Off-site generation	9,042 MWh/y	15,269 MWh/y	21,405 MWh/y	37,808 MWh/y
Capacity - fixed solar	7.24 MW	12.22 MW	17.14 MW	30.27 MW
Capacity - 2-axis tracker	5.26 MW	8.88 MW	12.45 MW	21.99 MW

These results indicate that the scale of off-site solar power generation needed to offset the energy consumption of provincial public housing in HRM could range between 5 and 30 MW, depending on the scenario and the type of solar power system chosen. The choice of a capacity within this range depends on the goal chosen for the solar energy investment. A fixed-array solar garden with a capacity of 17 MW, coupled with on-site solar electricity generation at all feasible buildings, is estimated to cover the current electricity consumption of the NSPHA public housing stock in HRM.

Capital Investment Estimate:

To estimate the capital investment required for a community solar garden, we used the new Mahone Bay Solar Garden as a case study. This solar power generation facility, completed by AREA and the Town of Mahone Bay in December 2023, has a generation capacity of 2.4 MW and a total cost of $5.8 million[1], yielding a normalized price of $2.42 per Watt, which includes a contingency fund. Based on this recent case study, the estimated investment required to develop a 10-MW community solar garden for NSPHA use would be approximately $24.2 million. A solar garden of this size would generate approximately 12,400 MWh of electricity per year for 25 years, with a value of about $2.1 million per year at current retail electricity prices.

Green Choice Program:

In addition to on-site and off-site solar power generation, the NSPHA also has an opportunity to sign up for the Nova Scotia Green Choice Program, to access renewable electricity, primarily wind power, from a third party. If NSPHA chooses to meet all its energy needs through that program, the maximum that we estimate would be needed as a subscription to meet all targets within HRM by 2030 and onward, is 43,000 MWh/y, (Scenario 4). This assumes a future scenario with full electrification, energy efficiency, and no on-site or off-site solar generation. At an average wind farm capacity factor of 35% for onshore wind farms in Nova Scotia[2], that would require contracting for the output of a wind farm of approximately 14 MW nameplate capacity.

It is likely to be beneficial to pursue a portion of all three renewable energy generation pathways – on-site solar, off-site solar, and the Green Choice Program.

4.1.4. Community Solar Garden Locations

Eleven potential locations in Nova Scotia for community solar gardens were identified, on provincial lands that are available to the Department of Municipal Affairs and Housing. Many of these properties are planned to be used for constructing affordable housing. Of the eleven starting properties, four were

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[1] Town of Mahone Bay, Minutes of Special Council Meeting, May 31, 2022. https://www.townofmahonebay.ca/uploads/1/3/0/6/130665195/2022-05-31_meeting_package_special_council.pdf

[2] Wind energy capacity factors: https://irp.nspower.ca/files/key-documents/presentations/Attachment-2-NSPI-E3-Supply-Options-Study.pdf

considered as unsuitable due to other uses for the property. Of the remaining seven properties, all or a portion could potentially be used for a community solar garden. Among these, two had the greatest combination of land availability, proximity to electrical infrastructure, and community development potential.

Table 3: Public lands considered in this study.

#	PID	Potential (MW capacity per acre)	Status	Candidate
1	**41057373**	0.20	Preston Area, lands could be allocated to housing development with room for solar	**Excellent**
2	**40188781**	0.20	Preston Area, lands could be allocated to housing development with room for solar	**Excellent**
3	45275039	0.19	Vaughan, Hartt Road	Good
4	15009970	0.20	Lake Fletcher Holland	Potential
5	15202153	0.20	Westmount Murphy Road	Potential
6	40699787/ 40695801	0.21	Combination of two parcels adjacent to one another. Future use TBD	Potential
7	40695801	0.21	Sackville Rossing Drive, Future use TBD	Potential

Detailed assessments of solar potential using Helioscope solar planning software were performed for Properties 1 and 2, in the Preston area. These results are shown below.

NOTES:

- Assessments are based on fixed solar PV arrays with standard conditions, oriented south at thirty degrees pitch angle from the horizontal, in rows spaced to minimize inter-row shading. These represent industry standard installation conditions.
- Solar arrays did not use the entire land area, leaving space for housing development.
- The average solar capacity on the land ranged from 0.19 to 0.21 MW per acre. If other parcels of land are considered, that figure can be used to estimate the capacity that can be fit on the parcel. This is approximately 5 MW or capacity per acre, which is within the norms for solar farms.
- At open land locations within HRM, solar farms designed similarly to these proposed examples can be expected to produce approximately 1300 MWh per year per MW of installed (DC) capacity.

SITE 1: East Preston, Lake Eagle Drive – PID 41057373 * Recommended

Key details:

Total land area: 87 acres

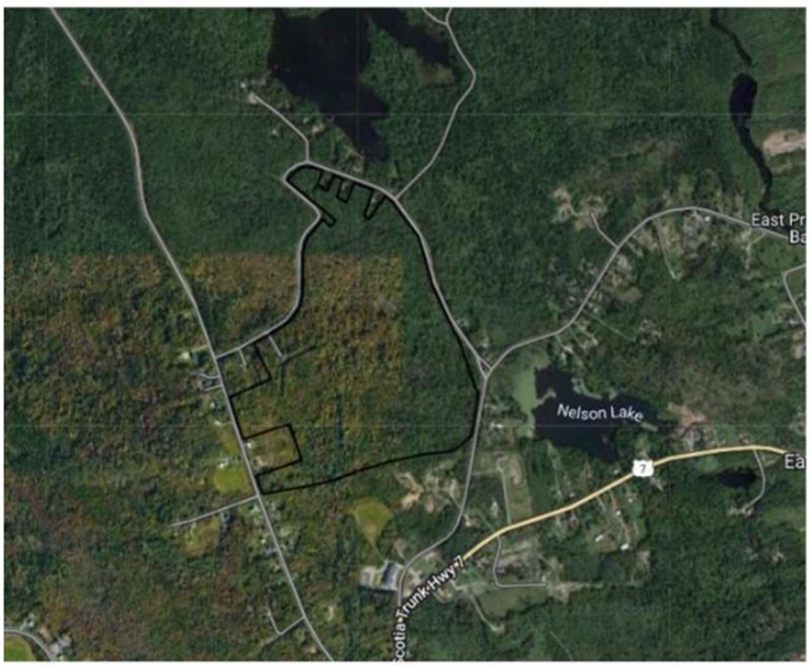
Present state of land: Forest regeneration

Future use: Potential affordable housing and/or housing land trust in proximity to East Preston Recreation Centre. Portion could be made available for solar power generation in conjunction with housing.

Estimated land area for solar: 61 acres

Estimated solar capacity: 12.2 MW DC

Estimated annual electricity production: 16,350 MWh



Design	Design 1
Module DC Nameplate	12.2 MW
Inverter AC Nameplate	9.77 MW Load Ratio: 1.25
Annual Production	16.35 GWh
Performance Ratio	86.1%
kWh/kWp	1,340.5

SITE 1: East Preston

SITE 2: North Preston, Upper Governor Street – PID 40188781 * Excellent Potential

Key details:

Total land area: 294 acres

Present state of land: Forest

Future use: Potential affordable housing and/or housing land trust a short distance from North Preston. Portion could be made available for solar power generation in conjunction with housing.

Estimated land area for solar: 56 acres

Estimated solar capacity: 11.2 MW DC

Estimated annual electricity production: 14,810 MWh

Design	Design 1
Module DC Nameplate	11.2 MW
Inverter AC Nameplate	8.97 MW Load Ratio: 1.25
Annual Production	14.81 GWh
Performance Ratio	85.2%
kWh/kWp	1,322.7

SITE 2: North Preston

SITE 4: Lake Fletcher Holland Road – PID 40118580 * Potential smaller pilot project

Key details:

Total land area: 45.25 acres

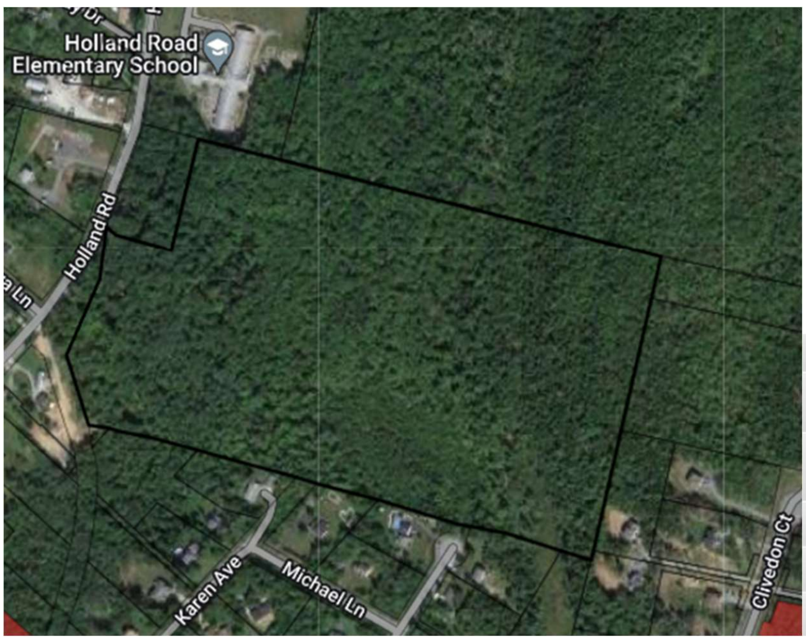
Present state of land: Forest regeneration.

Future use: Potential affordable housing development. A small portion could be made available for solar power generation in conjunction with housing.

Maximum land area for solar: 40 acres (6.38 acres for 1 MW DC pilot project.)

Estimated maximum solar capacity: 7.05 MW DC (Proposed 1 MW DC pilot project.)

Estimated annual electricity production: 16,350 MWh/year (2,329 MWh/year for 1 MW)



Design	Design 1
Module DC Nameplate	7.05 MW
Inverter AC Nameplate	5.65 MW Load Ratio: 1.25
Annual Production	9.332 GWh
Performance Ratio	84.5%
kWh/kWp	1,323.5

SITE 4: Fletcher's Lake, Holland Road

4.1.5. – Summary of Community Solar Gardens

There is sufficient space for community solar gardens of 10 MW or more on various public lands that are available in combination with housing. Three that we assessed have good to excellent potential. Of these, we have shown detailed assessments of two properties in the Preston area that have capacity to host solar gardens of over 10 MW in size, while leaving space for housing development as well. We have also suggested a site in Fletcher's Lake for a potential pilot project of 1 MW.

Our top recommendation from among the properties investigated is the property on Eagle Lake Drive in East Preston (PID: 41057373). This 87-acre property has space for a 12 MW solar garden, while still allowing 20 acres of space near the roadways for dense housing development such as small apartment buildings and townhouses. It is near the East Preston Recreation Centre, which has a 3-phase electrical distribution line just 420 metres from the proposed solar garden site, that will likely serve as a connection point. The location of this property within a historically underserved African Nova Scotian community also presents great opportunities to enhance equity and economic development by involving local community members, organizations, and contractors in the planning, design, construction and operations.

4.2. Vehicle Fleet Electrification

4.2.1. Fleet Description

The NSPHA fleet in HRM includes approximately 40 vehicles, most of which are cargo vans, with some pickup trucks. They range in model year from #### to #### and are parked at # different depots around HRM when they are not in use. The locations of the parking areas are described below.

Table 4: Locations of depots and vehicles

Location Name	Address	Vehicles tracked at location
Halifax Bayers West	6701 Chisholm Avenue, Halifax	#34 #41 #48 #49 #70
Halifax Mulgrave Park	89 Connor Lane, Halifax	#29 #45 #52 #57
Dartmouth	15 Green Road, Dartmouth	#47, #50, #59, #60, #67 and R27987 (license plate)
Sunrise Manor, Halifax	2457 Creighton Street, Halifax	#30 #31 #51 #66
Greystone, Halifax	2 Indigo Walk, Halifax	#35 #42 #43 #63 #65
Forest Hills	20 Circassion Drive, Dartmouth	#36 #38 #44 #55 #58

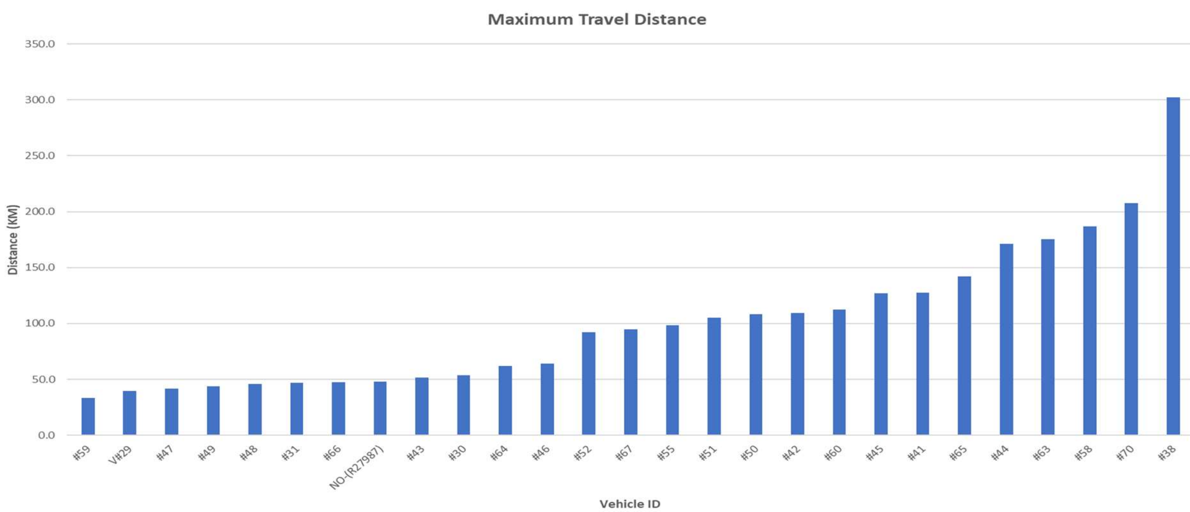
4.2.2. Vehicle Travel Pattern

Of the 30 vehicles tracked in this study, three were removed from analysis because they did not make enough trips during the tracking period, between August 16 and September 6, 2023. The sampled vehicles represent approximately 67% of the total work fleet of the NSPHA in HRM. At each depot, vehicles were chosen in consultation with the depot managers with the intention of tracking the most-used vehicles and avoiding those that are used little. The travel patterns of the 27 vehicles that were analyzed are described below.

Maximum Daily Travel Distance

A key question for the study was to measure the maximum daily travel distance for each vehicle, to determine whether the electric vehicles currently available on the market can provide the required range without having to be charged in the middle of the working day. As Figure # shows, the maximum daily distance varied from 40 km to a little over 300 km, with 92% of vehicles (25/27) having a maximum daily distance less than 200 km, and only a single vehicle with a maximum daily distance greater than 300 km.

Figure 1: Maximum Daily Travel Distance (km) by Vehicle



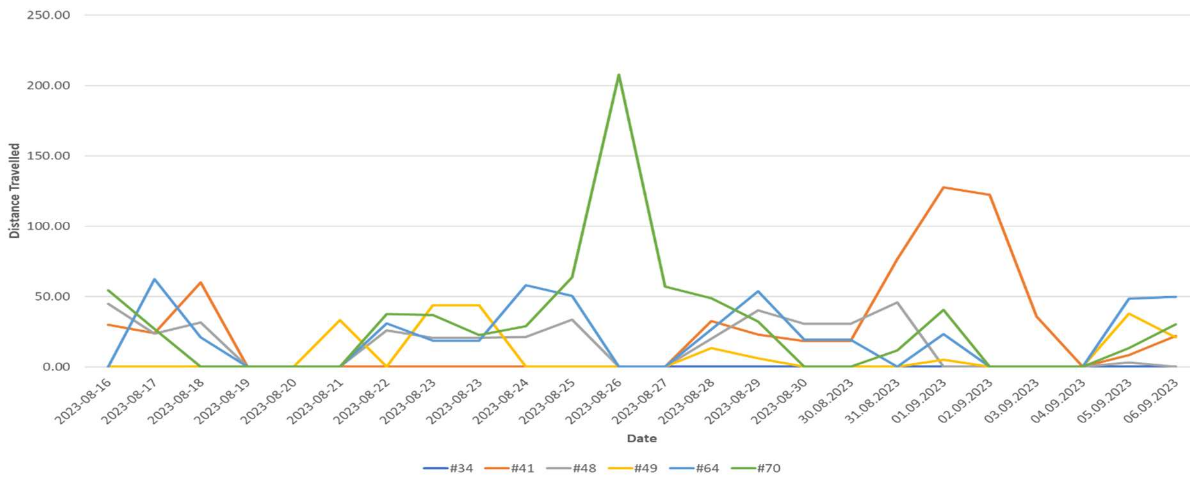
Summary of Maximum Daily Distances:

- Vehicle numbers (e.g. #59) refer to the NSPHA vehicle numbers. In one case, the license plate number was the only number recorded (R27987).
- Over the three-week period, most vehicles were on the road each weekday, and most were parked between 5:00 pm and 6:00 am. There were some trips on weekends for some vehicles.
- Three vehicles (#35, #36, #57) were removed from the analysis due to low trip numbers.
- 92% of vehicles studied had a maximum travel distance less than 200 KM, which is within a typical range of available 2022 electric cargo vans.
- Vehicle #38 had a maximum travel distance of ~305 km.
- Vehicle #38 had a total of 15 trips with an average daily distance of 145.6 km and a maximum of about 305 km.
- Average distance per trip for all other vehicles, excluding Vehicle #38, ranged between 70 and 136 km.

Daily travel pattern by depot:

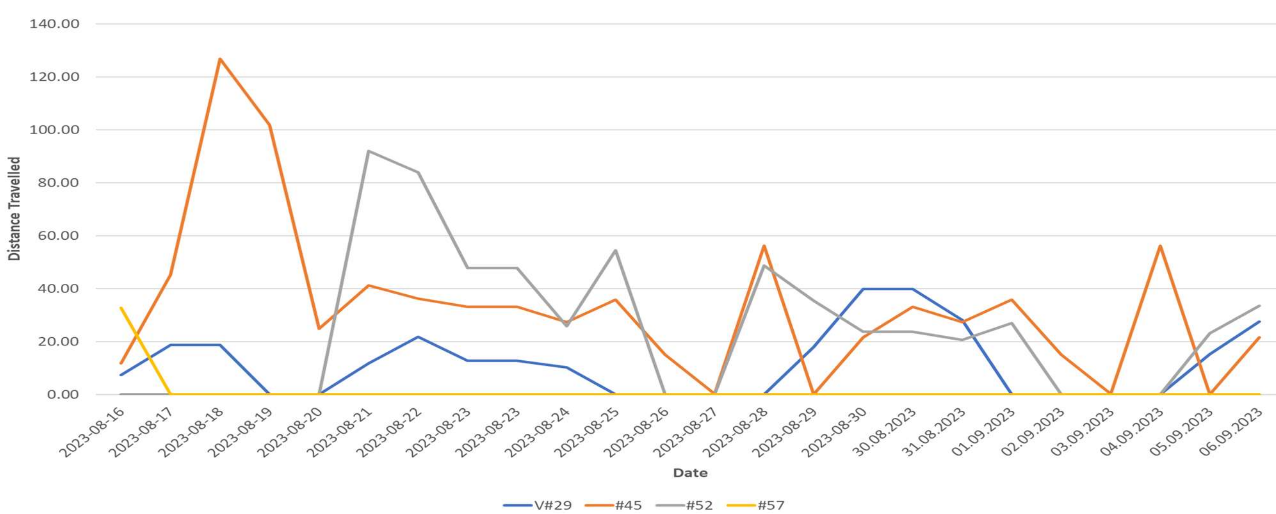
For each depot, the chart below shows the pattern of daily distance travelled for the vehicles that we tracked at that depot.

Depot 1: Halifax Bayers West – 6701 Chisholm Avenue



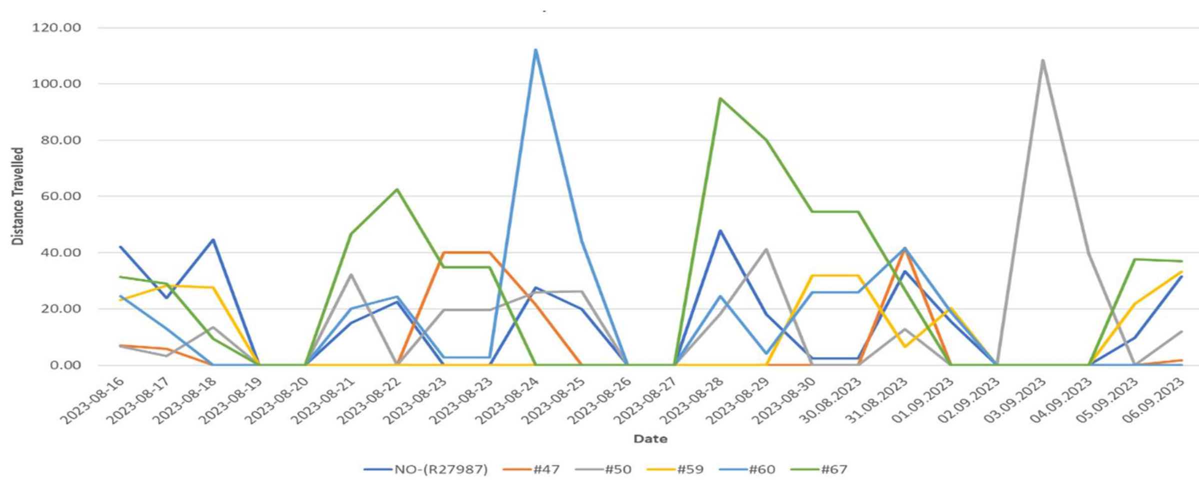
- Six vehicles were studied at the Chisholm Avenue depot, but only 5 had trips during the period.
- Vehicle #34 was removed from analysis because it had zero trips in the period.
- Maximum distance in one day = 207 km (Vehicle #70). Average daily distance across all vehicles = 20 km/day.
- Vehicles operated 8 to 15 trips during the 3-week study period, including some travel on weekends.

Depot 2: Halifax Mulgrave Park – 89 Connor Lane



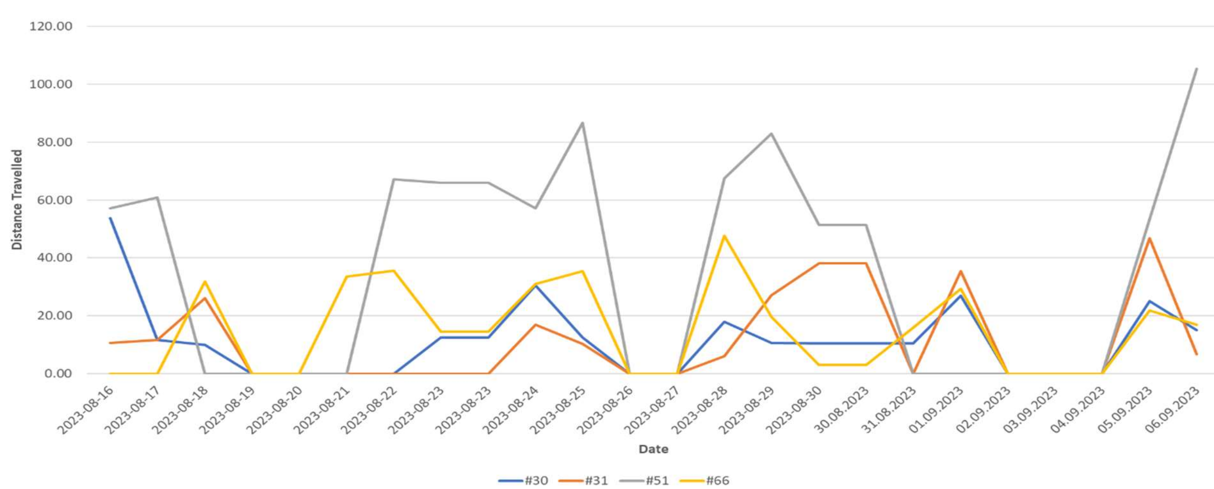
- Four vehicles were studied at the Connor Lane depot, but only 3 had sufficient trips during the period.
- Vehicle #57 was removed from analysis because it had only one trip in the period.
- Maximum distance in one day = 126 km (Vehicle #45). Average daily distance across all vehicles = 17.8 km/day.
- Vehicles operated 14 to 22 trips during the 3-week study period, including some travel on weekends.

Depot 3: Dartmouth – 15 Green Road



- Six vehicles were studied at the Green Road depot.
- Maximum distance in one day = 112 km (Vehicle #60). Average daily distance across all vehicles = 14.8 km/day.
- Vehicles operated 7 to 15 trips during the 3-week study period.
- Vehicle #59 had 12 consecutive days w/ no operation.

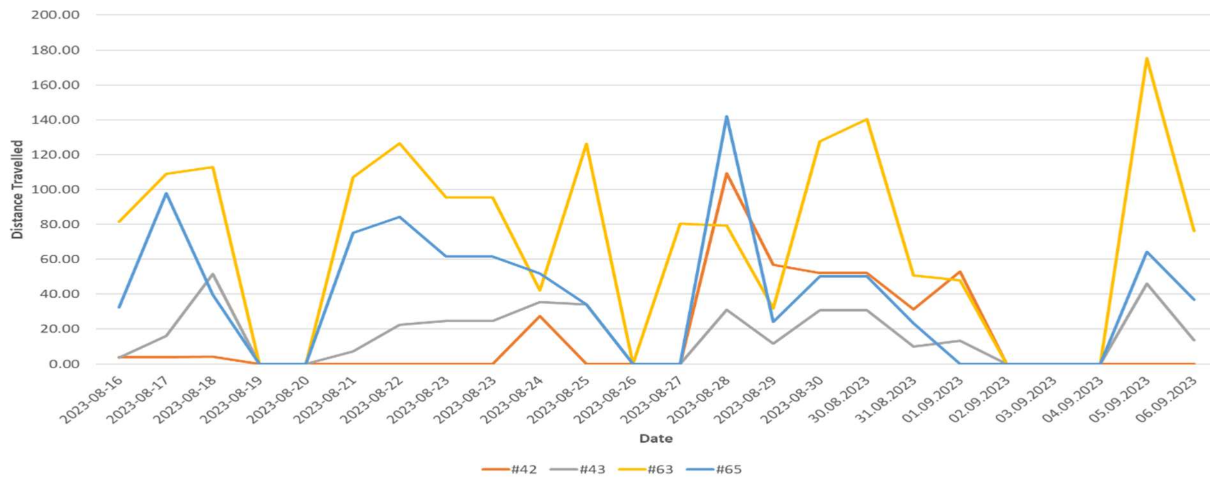
Depot 4: Halifax – Sunrise Manor – 2457 Creighton Street



- Four vehicles were studied at the Sunrise Manor depot.

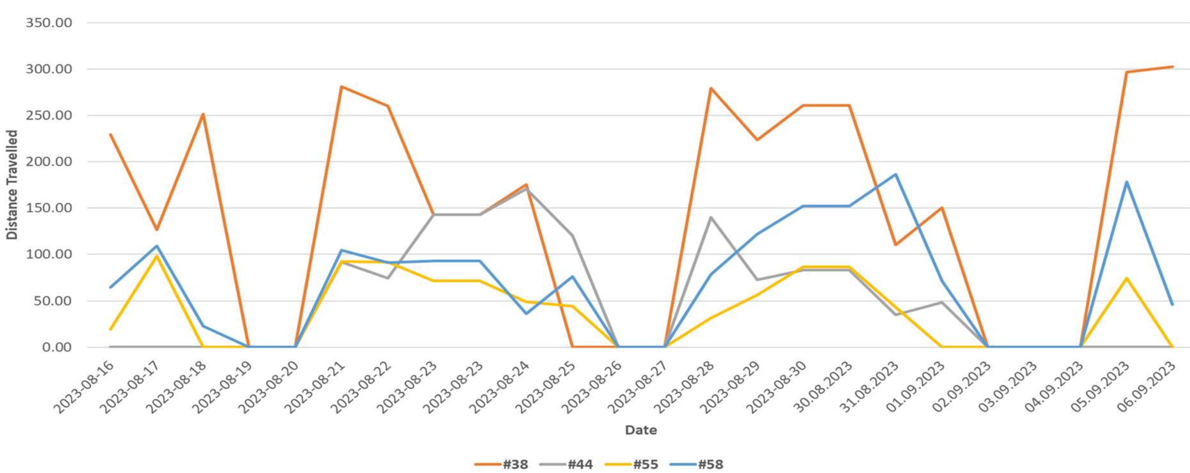
- Maximum distance in one day = 105 km (Vehicle #51). Note – this is the interoffice mail and parcel delivery vehicle.
- Average daily distance across all vehicles = 17.8 km/day.
- Vehicles operated 12 to 15 trips during the 3-week study period, with no travel on weekends.

Depot 5: Greystone – 2 Indigo Walk, Halifax



- Five vehicles were tracked at the Chisholm Avenue depot, but only 4 had trips during the period.
- Vehicle #35 was removed from analysis because it had zero trips in the period.
- Maximum distance in one day = 175 km (Vehicle #63). Average daily distance across all vehicles = 35.8 km/day.
- Vehicles operated 10 to 18 trips during the 3-week study period, including a small amount of travel on weekends.

Depot 6: Forest Hills – 20 Circassion Drive, Dartmouth



- Five vehicles were tracked at the Circassion Drive depot, but only 4 had sufficient trips during the period.

- Vehicle #36 was removed from analysis because it had only two trips in the period.
- Average daily distance ranged from 3 km to 146 km.
- Maximum distance in one day = 302 km (Vehicle #38).
- Vehicle #38 had uniquely high usage within the whole fleet, covering an average of 146 km/day over 16 trips.
- Vehicles operated 12 to 17 trips during the 3-week study period, with no weekend operations.

4.2.3. Key Findings

Summarized here are the key findings from our study of the fleet vehicle travel patterns:

- 377 trips in total were measured.
- 67% of trips were less than 50 km.
- 84% of trips were less than 100 km.
- 97% of trips were less than 200 km.
- 28 out of 30 vehicles monitored had a maximum travel distance less than 200 km, which is the range of the most readily available electric work van in Canada in 2023 (Ford e-Transit van).
- Vehicle #38 has the longest travel distances by far, including 10 trips longer than 200 km and one trip of 302 km. This is because it is based in Forest Hills, Dartmouth at 20 Circassion Drive and travels for work at NSPHA buildings on the Eastern Shore, sometimes as far as Sheet Harbour. This vehicle's travel pattern can be supported by a longer-range EV or by working with HRM to install a Level 3 fast charger in Sheet Harbour as part of HRM's expansion of fast-charging infrastructure, co-funded by the federal government.
- Depot 6 (Circassion Drive) hosts several vehicles that travel medium to high distances, due to its coverage of Eastern Shore locations.

4.2.4. Suitable Electric Vehicles

As of the model years 2024/25, multiple brands of electric work vehicles that meet the operational requirements of the NSPHA fleet are listed for sale or lease in Canada or expected to be available soon.

Table 5: Examples of electric work vehicles listed or expected in Canada in 2024.

Make and Model	Vehicle Type	Range (km)	Price (CAD$)	NOTES
Ford e-Transit	Cargo Van	203	$75,000	HRM bought in 2023.
RAM ProMaster Electric	Cargo Van	260	$75,000	Available late 2024.
Mercedes e-Sprinter	Cargo Van	308	$98,000	Available 2024
GM Brightdrop Zevo 600	Cargo Van	400	$136,000	Available at 7Gen*
GM Brightdrop Zevo 400	Cargo Van	400	$136,000	Available at 7Gen*
GreenPower EV Star	Cargo Van	240	Price not found.	Available at 7Gen*
Lightning e-Motors ZEV3	Cargo Van	225 or 320	Price not found.	Available at 7Gen*
Ford F-150 Lightning	Pickup Truck	370 or 515	$70,000	Available
Rivian R1T	Pickup Truck	430	$109,000	Online ordering
Chevrolet Silverado EV WT	Pickup Truck	640	$105,000	Available late 2024

*7Gen is a Canadian company based in Vancouver that offers electric cargo vans on an all-inclusive lease that includes chargers, tracking and charging software, and support (https://7gen.com/electric-vans/).

Electric Autonomy Canada maintains a list of medium-duty electric vehicles available in Canada, to help fleet operators find the electric vehicles they are looking for. This list is updated regularly, as product offerings are increasing rapidly[3].

Transport Canada is currently offering a $10,000 incentive on the purchase price of zero-emission vehicles in this size category by organizations, including provincial governments, with a limit of up to 10 vehicles per calendar year.[4]

Summary:

There are various electric vehicles on the market in Canada today that serve the purposes and meet the current capacity and range requirements of the work vehicles in the NSPHA fleet, and several more becoming available over the coming year. The Ford e-Transit cargo van represents the most cost-effective choice among the current offerings. Although it has a shorter range at 203 km, 97% of daily travel by the NSPHA fleet vehicles is below that distance, which means that for nearly all trips the drivers will not need to stop to charge during their working day. They can simply plug the vehicle in when they stop work in the evening, and it will be fully charged before the start of the next working day.

For Vehicle #38, the one vehicle we assessed that frequently does trips of 300 km/day, the fleet managers can take one of two approaches – use a standard range vehicle such as a Ford e-Transit and work with HRM to install a Level 3 fast charger in Sheet Harbour, or purchase a longer range vehicle such as an extended range Ford e-Transit, GM Brightdrop Zevo 400, or Ford Lightning pickup truck. With a fast charger in Sheet Harbour, an electric work vehicle with 200 km range can provide the service that Vehicle #38 currently provides, given a 30-minute break for fast charging in the middle of the day. The pattern of all the other vehicles we studied in the fleet does not require any fast charging.

4.2.5. Charging Infrastructure

The primary charging infrastructure needed to electrify the NSPHA fleet will be Level 2 (6 kW to 12 kW) AC EV chargers at the depots where the fleet vehicles usually spend the night, with one charging plug to be installed for each electric vehicle stationed there. It is important for operations that each electric vehicle at a depot has a dedicated Level 2 charging plug, for simplicity of use. The staff member using the vehicle only needs to plug it in to its dedicated charger at the end of the working day and it will be fully charged before the next morning's shift.

[3] Electric Autonomy EV Listings: https://evfleets.electricautonomy.ca/ev-listings/
[4] Transport Canada, Incentives for Medium and Heavy-Duty Zero-Emission Vehicles: https://tc.canada.ca/en/road-transportation/innovative-technologies/zero-emission-vehicles/medium-heavy-duty-zero-emission-vehicles/incentives-medium-heavy-duty-zero-emission-vehicles

Charging at Level 2 at the depot during non-work hours will cover 97% of the trips that we recorded in our study. If there are some special cases where a vehicle regularly needs to spend the night at another location, such as a staff member's home or a different office, it is probably feasible to also install a Level 2 charger for that vehicle at its alternate location. Subject to further assessment based on the specific site, a single Level 2 charger installation at an existing home or office building can often be done for an affordable price. Importantly, dedicated and costly Level 3 chargers are not needed at any of the depots to service this fleet in its current usage pattern.

Table 6: Approximate number of Level 2 charging plugs needed at each depot to service the current number of vehicles if all are replaced with electric vehicles. May vary with changing fleet numbers. Also includes electrical capacity and consumption estimates.

Depot Name	**Address**	**# of Level 2 charging plugs**	**Min. Electrical capacity needed (kW)***	**Estimated Electricity used (kWh/year)**
Bayers West	6701 Chisholm Avenue, Halifax	7	6.5	16,863
Mulgrave Park	89 Connor Lane, Halifax	5	4.1	10,720
Dartmouth	15 Green Road, Dartmouth	7	4.8	12,479
Sunrise Manor	2457 Creighton Street, Halifax	5	4.1	10,720
Greystone	2 Indigo Walk, Halifax	6	9.9	25,873
Forest Hills	20 Circassion Drive, Dartmouth	6	25.0	64,561
	TOTAL	**36**	**N/A**	**141,216**

*Minimum electrical capacity (kW) is based on the amount of electricity needed per night to recharge after the previous day's average distance, as measured in this study. In practice, each Level 2 charging plug will be capable of providing between 3 kW and 12 kW to each vehicle. If sufficient electrical capacity is available at the site, all vehicles can charge more quickly than the minimum speed. If electrical capacity is limited to less than 6 kW per charger, charging can be managed with a load management system to keep the demand within the available capacity, as long as the minimum capacity stated above is available.

Recent experience in 2023 with Natural Resources Canada's Zero Emission Vehicle Incentive Program (ZEVIP) suggests a budgetary cost estimate of about $9,000 per charger installed. A level 2 charger itself, with the necessary capabilities, has a retail price between $700 and $1000, but the cost of civil works and installing the electrical supply line varies depending on the location and capacity of existing electrical services on the site.

In this study, we did not investigate the capacity of the existing electrical services at the depots to supply power for a full set of Level 2 chargers for every vehicle stationed there, in terms of the current (amps) available to use for charging at each depot today. Based on experience with installing multiple EV chargers at multi-unit residential buildings, it is possible that either an upgrade to an electrical service or the installation of a separate electrical service may be needed.

However, one way to avoid or minimize the cost of electrical service upgrades is to use an electric vehicle energy management system (EVEMS), which automatically shares the available electrical capacity between multiple charging plugs to ensure that all the vehicles are charged in the available time while minimizing total electrical demand at any given moment. These systems are employed in multi-unit residential buildings to enable EV charging within buildings that have a limited electrical capacity. The CSA group published a report[5] about EVEMS in 2019, and since that time these systems have begun to be employed in Canada, including in Nova Scotia. The more sophisticated EVEMS monitor total power demand at the facility in real time and adjust the output of the chargers to use the available capacity and share that capacity between the vehicles that are plugged in to charge. In this way, they can charge multiple electric vehicles simultaneously on a lower-capacity electrical service than would otherwise be required. Two examples of electric vehicle energy management systems deployed in Canada are SWTCH Control[6] and VariableGrid Varian PRO[7].

The following list gives examples of Level 2 chargers (Electric Vehicle Supply Equipment, or EVSE) that are widely used in Canada. Any of these, and others, could be considered for use at NSPHA depots.

- ChargePoint (HomeFlex)
- Grizzl-E – Smart EV Charger (United Chargers)
- SWTCH
- Flo CoRe+
- Wallbox (Pulsar)
- Enel X (JuiceBox)
- Emporia Energy
- Tesla (Wall Connector)
- Leviton

In seeking Level 2 EVSE, it is helpful to source equipment that is compatible with the Open Charge Point Protocol (OCPP), which is an application protocol for communication between chargers and networked control systems for allowing access to start charging (cards, apps, codes, etc.), billing for charging, and managing charging capacity. Many of the above chargers are compatible with OCCP.

4.2.6. Operational Cost Savings

Charging for the entire fleet, using all 100% electric vehicles travelling the average distances we measured in our study, would require an estimated 141,216 kWh of electricity, at an annual cost of just over $24,000 per year in electricity at a current price of $0.17/kWh. This is approximate, but for comparison, we estimate the gasoline cost to operate the fleet for the same distance using the existing gasoline-powered vehicles is approximately $102,000 per year, based on today’s average gasoline price

[5] Electric Vehicle Energy Management Systems, CSA Group Research, May 2019.
[6] https://swtchenergy.com/technology
[7] https://www.variablegrid.com/products

of $1.60 per litre[8]. Roughly speaking, a net savings of about $78,000 per year in fuel costs would be expected for the fleet, which is about a 76% reduction in fuel cost.

Further to this, scheduled maintenance costs on electric vehicles are expected to be, on average, between 20% and 60% lower than for equivalent gasoline-powered vehicles, due to fewer moving parts. An analysis of light duty vehicles in Germany found 20% lower maintenance costs, and another study predicted between 40% and 60% savings on maintenance.[9]

5. Recommendations

5.1. On-site solar

Solar power generation installed on-site at NSPHA buildings has an estimated potential to produce approximately 19% of the building stock's total current electricity consumption if fully built out. On-site solar represents a good investment in the long-term sustainability of the building stock, and has multiple advantages:

- On-site solar can be contracted and built in stages through multiple small projects.
- On-site solar makes use of existing electrical services with few or only minor upgrades.
- On-site solar makes additional use of existing land within the footprint of the built environment.
- Transmission requirements are minimal because much of the power is used in the same building where it is generated.
- Solar PV can be added to buildings in tandem with other upgrades such as roof repairs and major exterior renovations.
- The cost per Watt is not significantly different between large-scale and rooftop solar in Nova Scotia, with prices for both currently between $2.20 and $2.80 per Watt of DC capacity installed.

We recommend continuing to install solar power on-site when capital investment is available, on both new and existing buildings, especially at those key moments when major upgrades are being made for electrification and decarbonization of each building, such as major building envelope upgrades and heat pump installations.

5.2. Community Solar Garden

Our best estimate based on the available data is that, with on-site solar electricity generation built out to its full potential, offsetting current energy usage in NSPHA properties in HRM using community solar

[8] Nova Scotia Utility and Review Board, Gasoline & Diesel Prices Zone Map: https://nsuarb.novascotia.ca/mandates/gasoline-diesel-pricing/gasoline-prices-zone-map#/zone_1

[9] Cost of Electric Commercial Vans and Pickup Trucks in the U.S. Through 2040, **ICCT Working Paper 2022-01**, P. 9.

gardens would require construction of approximately 17 MW of fixed solar arrays. Looking forward to 2030, after considering electrification, expansion, and efficiency upgrades of properties, offsetting the total energy consumption of the NSPHA building stock in HRM using solar electricity alone would require approximately 30 MW of fixed solar arrays.

The Province of Nova Scotia's Shared Solar Program allows for community solar gardens of up to 10 MW in size. Considering that the NSPHA building stock in HRM could consume the output from 17 MW or more, our recommendation is to propose a 10 MW fixed-array community solar garden at a location within HRM, to stay within the program limits while producing a significant percentage from solar. Wind power procured through the Green Choice Program could be complementary to the solar power in helping achieve a complete decarbonization of the energy supply for the building stock.

An approximate budgetary estimate for the cost of a 10 MW solar PV array, based on the recent experience in Mahone Bay ($2.42 per Watt), is $24.2 million. There is a significant range of uncertainty in this figure, which could be reduced by seeking proposals or expressions of interest in the market.

Our top recommendation for a location is Site 1, in East Preston, which has ample land available for both a solar garden and affordable housing development and is near a 3-phase electrical distribution line. This land is also in a historically underserved neighbourhood that could benefit from the economic opportunities associated with a community solar garden. We know from communication with a local community organization that there is some interest in solar gardens in the area. For any proposed site, a more detailed site assessment and consultations with the local community and Mi'kmaq leaders will be needed.

To gain experience with managing community solar garden development, it may be helpful to consider a smaller pilot project. For example, at 1/10th the scale, a 1 MW pilot project would fit at any of the recommended sites, including Site 1 at East Preston. Another potentially useful site for a 1 MW pilot project would be Site 4 in Fletcher's Lake, next to the Holland Road School. This site also offers potential for educational opportunities with the school.

5.3. Green Choice Program

The Green Choice Program offers another source for the renewable electricity needed to meet the NSPHA's decarbonization targets and is worth considering as an option for all or part of the electricity needs for the building stock. We do not have access today to a price estimate for the electricity to be procured through the Green Choice Program, but it is known that this electricity will be comprised of wind power, which is considered zero-emission in this context, and which is often lower-cost than solar power in the Nova Scotia climate.

To consider a scenario, if the NSPHA builds out all available on-site solar and creates a 10-MW community solar garden, the estimated amount of electricity remaining to be provided by other renewable, zero-emission sources would be approximately 25,300 kWh/year in the 2030 full electrification scenario. This is roughly equivalent to the average output from an 8.15 MW capacity wind farm, assuming the average 35% capacity factor for wind farms installed on land in Nova Scotia. At the upper limit, if all the clean electricity for the NSPHA building stock in HRM is obtained through the Green Choice Program, approximately 43,000 MWh/year would need to be procured by 2030 in the full electrification scenario.

Although wind power through the Green Choice Program is likely to cost less per kilowatt-hour than solar power from the community garden, there are advantages to having a variety of sources of low-carbon electricity, in terms of availability of energy, diversification of supply, and local economic benefits. Based on this variety of benefits, we recommend pursuing all three renewable energy generation pathways – on-site solar, off-site solar, and the Green Choice Program, with a portion of the required clean electricity being supplied by each source.

5.4. Vehicle Fleet Electrification

Multiple electric vehicles are available now that meet the requirements for NSPHA fleet vehicles. The entire fleet is feasible for electrification, based on its current work requirements and travel patterns. With the necessary investment in fleet renewal and charging infrastructure, the NSPHA work fleet can be all-electric by the year 2030 or sooner.

We recommend that the NSPHA begin by procuring two electric cargo vans in 2024/2025, either through purchase or lease, and installing two charging stations at a depot to begin the electrification process. Any of the depots can be a good starting point, however we recommend starting with the Forest Hills depot on Circassion Drive because this depot has the vehicles that travel the longest distance, which will save the greatest quantity of emissions and produce the greatest fuel savings quickly. Appropriate vehicles include the Ford e-Transit, Ram ProMaster Electric, Mercedes e-Sprinter, GreenPower EV Star, or Lightning e-Motors ZEV3. The Ford F-150 Lightning is also a good choice for an electric pickup truck at the current time.

At each depot, the largest planning effort and investment will be the electrical infrastructure needed to bring power to the charging stations, to be located at the parking spaces of the vehicles. Civil and electrical works to install outdoor chargers should be planned for future expansion. For example, when ordering the installation of the first two chargers at a depot, all the electrical and civil infrastructure for the full build-out of chargers at that depot should be installed at the same time. If that depot requires seven chargers in the long-term, then one good strategy is to install all the wiring for a string of seven chargers, with junction boxes in place for future installation, and fully install and commission only the last two chargers at the end of the line. The remaining chargers can be added later at very little cost.

An electric vehicle energy management system (EVEMS) could be helpful to manage the charging of the vehicles while minimizing peak load and the amount of electrical capacity needed. Most Level 2 chargers available today can easily charge at a rate of 6, 7, or 9 kW, however our analysis shows that most of the vehicles travel short enough distances per day that they do not need to charge that quickly when charging overnight. An EVEMS will ensure that all vehicles charge at an appropriate rate, sharing the available electrical capacity.

Summary of fleet electrification recommendations:

- Choose one depot (recommended Forest Hills) for an EV pilot project in 2024/25 with two EVs and two charging plugs. Use this as an opportunity for everyone involved to learn about fleet electrification and develop the capacity to electrify the rest of the fleet.
- Have a detailed plan prepared for civil and electrical works for charging infrastructure at all six depots, including the number of chargers for full electrification, detailed location plans and cost estimates. Each depot will have its own set of requirements with respect to running electrical service to the chargers, depending on how far they are from the nearest electrical service. Include provision in this for an electric vehicle energy management system to reduce the need for extra electrical capacity.
- After the first depot has EV charging infrastructure installed, the process for installing charging infrastructure at the remaining five depots can proceed more quickly.
- Begin procurement of electric vehicles, starting with two electric cargo vans in 2024/25.
- Plan for procurement of 34 additional electric vehicles, an average of 9 vehicles per year, in the years 2026, 2027, 2028, and 2029. Budget approximately $80,000 per vehicle on average in 2024 dollars, minus the $10,000 per vehicle federal incentive as long as that remains available.
- Residents in the affordable housing units will also begin to seek charging opportunities for electric vehicles at these properties over this time period. We recommend adding planning for charging infrastructure for residents to each property over time, with a focus on those properties that are in the queue for electrification of their heating systems. Including consideration for future EV charging in the electrification plans can save on future upgrades.

6. Conclusion

The affordable housing provided by the NSPHA in HRM can be operated with renewable, low-carbon electricity, given the investment in energy efficiency, electrification of heating systems using heat pumps, and implementation and/or procurement of renewable electricity. On-site solar electricity generation, a shared community solar garden of 10 to 30 MW capacity, and wind power of up to 14 MW capacity are all complementary options for supplying the required amount of low-carbon electricity. We recommend continuing to install on-site solar electricity where it is advantageous, implementing a community solar garden of up to 10-MW capacity at a site in HRM, and taking advantage of the Green Choice Program for a portion of the required clean electricity.

For the fleet of work vehicles, we recommend a phased-in approach over the years 2024/25 to 2029, starting with a pilot project with two electric cargo vans in 2024/25 and moving to full electrification over the following four years. The vehicles can be procured in batches of up to ten per year to take advantage of the federal incentive of $10,000 per vehicle. The charging infrastructure needs to be planned in greater detail for each depot and is best implemented on a depot-by-depot basis. The full build-out of charging at each depot should be planned in advance to save on civil and electrical engineering costs, allowing sets of chargers to be added gradually to a pre-planned system of civil and electrical infrastructure as the number of electric work vehicles grows.

As work on this initiative moves forward, our research team has more data, site photos, and information that can be helpful to the detailed planning for charging infrastructure and solar facilities.