City of Richmond

Report to Committee

To:	General Purposes Committee	**Date:**	June 30, 2022
From:	Peter Russell, MCIP RPP Director, Sustainability and District Energy	**File:**	10-6125-07-02/2022-Vol 01
Re:	**Technical and Economic Considerations for Rooftop Solar Energy Systems for New Buildings**		

Staff Recommendation

That as described in the report titled "Technical and Economic Considerations for Rooftop Solar Energy Systems for New Buildings" dated June 30, 2022, from the Director, Sustainability and District Energy, staff proceed with engaging local builders and developers as part of identifying regulatory and incentive pathways to advance building electrification and on-site low carbon energy systems, including rooftop solar PV systems, and report back.

Peter Russell, MCIP RPP
Director, Sustainability and District Energy
(604-276-4130)

Att. 1

REPORT CONCURRENCE		
ROUTED TO:	**CONCURRENCE**	**CONCURRENCE OF GENERAL MANAGER**
Building Approvals	☑	
Development Applications	☑	
Policy Planning	☑	
SENIOR STAFF REPORT REVIEW	**INITIALS:**	**APPROVED BY CAO**

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Staff Report

Origin

At the Planning Committee meeting of December 18, 2018, City Council resolved that:

> *"Staff examine the potential of a comprehensive policy on solar panels, in particular including options for incentives, and the environmental and economic impacts, and report back."*

At the Council Meeting of June 8, 2020, City Council resolved that:

> *"Staff examine the requirements for increasing the capacity for electric vehicle charging stations for non-residential projects, including a review of rooftop solar panels and rooftop agricultural uses, and report back."*

This report responds to the request for staff to conduct a review of rooftop solar panels. Proposed EV charging infrastructure requirements for non-residential buildings will be covered in a forthcoming report.

This report supports Council's Strategic Plan 2018-2022 Strategy #2 A Sustainable and Environmentally Conscious City:

> *Environmentally conscious decision-making that demonstrates leadership in implementing innovative, sustainable practices and supports the City's unique biodiversity and island ecology.*

> *2.1 Continued leadership in addressing climate change and promoting circular economic principles.*

This report supports the implementation of the City's Community Energy and Emissions Plan 2050, and OCP emission reduction policies through:

Strategic Direction 3: <u>Carbon Neutral New Buildings</u>

Actions:

- ☑ Advance implementation of low carbon energy systems in new construction
- ☑ Raise awareness of the benefits of building electrification
- ☑ Encourage cost-effective on-site renewable energy generation in new construction

Analysis

This report presents key findings from technical and economic analysis of rooftop solar photovoltaic (PV) energy systems for new residential, commercial office and industrial buildings, representing the first phase of work on the above referrals. A subsequent report on policy options will be completed following engagement with building design and construction stakeholders in the fall of 2022, subject to Council approval to proceed with the second phase of work.

Background on Solar-Friendly Richmond Framework

On January 28, 2016, Council endorsed a high-level policy approach for utilizing solar energy systems on both City facilities and private buildings within the *Solar-Friendly Richmond Framework*. The report provided conclusions on the applicability of three solar technologies:

- **Solar photovoltaic (PV) systems** (panels producing electricity supplying energy to the building and/or electric grid); and
- **Solar hot water systems** (panels producing thermal energy for domestic hot water use and heating swimming pools); and
- **Solar air heating** (a solar collector is used to pre-heat air, which then provides supplemental heating to conditioned building space).

The staff report noted that solar PV systems have applicability to a wide range of buildings, particularly given continued reduction in the market costs of solar panels and supportive equipment such as PV array racking, wiring, charge controllers and inverters. Staff further note that there are a number of firms in BC with experience designing and installing rooftop PV arrays in a range of sizes and roof configurations.

The City installed a rooftop solar array at Brighouse Fire Hall No. 1 in 2018. This building hosts 136 PV panel array that produces approximately 60,000 kWh of electric power annually. Excess power not used is sent directly to BC Hydro's electrical grid, and is credited against the building's electricity bill through a standard net-metering arrangement.

City Policy Direction on Building Energy Efficiency, Decarbonisation and Electrification

Community GHG emissions from the operation of buildings represent a significant proportion (41%) of annual citywide emissions, and actions to reduce these emissions are included in the Community Energy and Emissions Plan 2050. Council policy is for all new applicable buildings to meet the top performance level of the BC Energy Step Code (Step Code) at Building Permit by 2027. The Step Code is the primary regulatory tool to achieve more energy efficient new construction, with the top performance level of the Step Code considered 'net zero energy ready'.

In BC, building electrification has been identified as the main pathway to achieve major reductions in emission from buildings. BC's low emission electrical grid provides opportunities to quickly shift from high carbon fuel sources to near zero carbon sources of energy. This entails a large scale transition toward low-carbon mechanical systems, such as high efficiency electric heat pumps for space heating / cooling and domestic hot water, or connecting the building to low-carbon district energy within areas of Richmond being served by these systems.

Solar PV Costs and Grid Parity in BC

Rooftop PV systems can help offset annual electrical demand in buildings, and pairing a sufficiently sized onsite solar PV array on an energy efficient, all-electric building can make it possible to achieve net zero energy and net zero emission performance on an annual basis.

The total cost of solar PV includes the following components:

Hard Costs

- Solar module (i.e., the panel)
- Other hardware (inverters, charge controller, racking / mounting system)
- Financing cost and installer profit

Soft costs

- Permitting, inspection and interconnection (electrical permits, building permits, utility interconnection fee)
- Labour

Implementation of solar PV systems worldwide is accelerating rapidly. Continuous improvements in PV panel manufacturing and generation output, in tandem with decreasing production and installation costs, result in a steep and continuous decline in the cost of panels between 2008 and 2020, as per North American trend analysis done by the US National Renewable Energy Laboratory. As prices have declined, PV panels have become more efficient in converting sunlight to electrical energy (kWh per panel). Improvements to other hardware components, noted above, have further reduced system costs. As a result, solar PV systems have become a low cost power generation technology in many parts of the world. The only change in this 12-year trend has been a modest increase in costs in 2021 (since reaching the lowest price point in 2020) due to economic and supply chain disruptions of the past two years.

Greater Vancouver has lower total annual hours of sunshine than most urban regions in North America. BC also has some of the lowest grid electricity prices in North America. Another factor historically limiting solar energy projects in BC has been less generous incentives for solar energy relative to those available in the United States, although this situation has recently improved. As a result, local solar projects may still have longer payback periods than their counterparts in other areas of America. However, due to the declining cost of PV panels and related components in recent years, solar PV systems are becoming more economically viable in coastal BC.

Staff estimate that the total installed cost of a solar PV array would need to be no more than $2.00 per Watt to be fully cost competitive with grid-supplied electricity at residential rates. Based upon a review of the engineering study prepared for City staff, as well as costing information provided by solar installers, staff estimate that the current cost per Watt installed for greater Vancouver would range between $2.75 and $2.25 per Watt, with larger arrays benefitting from economies of scale.

Interconnection to the BC Electrical Grid

Rooftop solar PV systems within BC Hydro's service area typically connect to the provincial electrical distribution grid via the utility's Net Metering Program. This program has been set up for residential and commercial customers with an onsite solar PV system. Net metering allows a building to draw energy from the electrical grid as needed, but also send excess energy to the grid when generating more kilowatts than the building uses. In effect, local generation offsets a portion of the building's electrical consumption, allowing it to receive a credit on their utility bill (excess generation is credited by BC Hydro to the account at a rate of 9.99 cents per kWh).

BC Hydro also sets a maximum generation limit for 'simple net metering' projects up to 27 kW in size, rated at 425 Watts / panel); and up to 100 kW for 'complex net metering projects, rated at 425 Watts / panel) under BC Hydro's Net Metering Program.

Technical and Economic Analysis – Methodology

To complete the first phase of this project, detailed energy modelling was conducted to predict the level of energy used in a building constructed to a mid level and top level of the BC Energy Step Code, and the Passive House standard. Staff sought to assess the modelled physical size of a PV array, annual generation potential, and estimated total cost of rooftop mounted PV in eleven representative new building archetypes in Richmond.

For purposes of this analysis, each building type, except for industrial, was modelled at three performance levels:

1) Mid level of BC Energy Step Code;
2) Top level of BC Energy Step Code; and,
3) Certified Passive House standard.

Scenario (1) reflects modelled energy demand in a mid-Step Code building, establishing a baseline for comparison. Scenarios (2) and (3) are at the highest levels of building energy efficiency, referred to as 'net zero energy ready' performance.

To establish consistent and comparable benchmarks that could inform future policy measures and/or regulatory requirements, energy modelling was conducted for each building archetype using software from the US National Renewable Energy Laboratory (PV Watts Calculator) and Photovoltaic Geographic Information System (PVGIS) by the European Commission. Using these tools, determination was made of array size (number of panels), area of roof coverage, power generation potential and capital cost of an onsite PV system that could offset all, or a portion of, annual grid electricity use for each building type, under the following scenarios:

a) Offset 100% of the building's total annual energy requirement;
b) Offset the building's annual internal and external electrical lighting load;
c) Offset the building's annual external electrical lighting load only;
d) Offset total modelled annual cooling load only; and,
e) Offset 10% of modelled annual load (kWh/year) for Level 2 electric vehicle charging.

See Attachment 1 for tables showing modelled solar PV offset potential for each building type, and at the three levels of building energy efficiency noted above.

Key Findings

Analysis indicates that for smaller residential buildings (single-detached, duplexes and townhouses) there is sufficient roof space for solar PV to significantly offset electrical energy demand in these buildings, particularly as they reach the highest levels building energy efficiency (i.e., top level of the BC Energy Step Code or Passive House standard), and with comparatively fewer PV panels than what would be required at the mid level of the Step Code.

For larger multi-unit residential, commercial and industrial buildings, analysis indicated that there is sufficient roof space for solar PV to provide 100% of annual external lighting load in both hotels and mid-rise residential apartment buildings. External lighting loads are more significant in larger buildings, as they have parkades with 24-hour lighting requirements. For both mid rise and taller multi-unit residential buildings, the model assumes all resident parking stalls have Level 2 charging capability, as per the City's Zoning Bylaw requirement. For mid rise residential buildings, up to 25% of annual EV charging loads could be offset by an onsite PV array, and up to 10% can be offset in a taller multi-unit residential building.

Smaller buildings offer relatively greater potential than larger buildings to offset electricity loads with an onsite solar PV array. This is a reflection of building form factor, where small buildings have more roof area relative to total floor area. For large buildings (other than industrial warehouses), roof area is much smaller relative to total floor area, so the potential to completely offset annual electrical load is more limited. Staff also note that the other factor limiting array size in larger buildings is BC Hydro's cap of 100 kW for net metering projects, which means a maximum array size of 224 to 235 PV panels based upon annual productivity of 430 to 445 kWh per panel.

With respect to integrating onsite solar PV in a building that is also served by low-carbon district energy, both systems would be entirely compatible. The thermal energy delivered by district energy would complement the electrical energy supplied to the building through a combination of onsite solar PV and connection to the BC electrical grid.

<u>Phase 2: Opportunities for Solar PV to Support Building Electrification and Decarbonisation</u>

With Phase 1 analysis completed, staff are requesting Council approval to proceed to the next stage of this work, which would explore policy and regulatory approaches, identify potential incentives, and understand market drivers by answering the following questions:

- **Advancing Net Zero Energy buildings:** What role could onsite solar PV have in supporting the transition toward low energy buildings (top level of the Step Code and Passive House)?
- **Building decarbonisation and electrification:** What are the opportunities for onsite solar to help drive the transition to electric heat pumps for building heating and cooling? Are there 'niche' roles for onsite solar to improve the business case for electrification (e.g., avoiding higher Tier 2 electricity rates in high-demand buildings)?
- **Enhancing energy and climate resiliency:** Do onsite solar PV systems have a role in advancing building resiliency in Richmond? Can they play a role in offsetting a portion of rising grid electricity demand due to electrification of buildings and vehicles?
- **Use of rooftop space and south-facing walls in larger multi-unit residential buildings:** What are the potential friction points in potentially situating a solar PV array within an outdoor residential amenity space or green roof? Could we eventually see building integrated photovoltaic panels (BIPs) in vertical cladding elements in BC?

Staff will engage with building design and construction community, solar PV system installers, affordable housing providers and other subject area experts to further refine the conclusions reached in Phase 1. Three workshops will be convened to facilitate dialogue and exchange ideas on technical and economic considerations, including exploration of opportunities and potential directions with respect to policy, regulation, and incentives. With Council approval, staff will conduct a three-part engagement process that will begin in fall 2022, as shown in Table 1.

Table 1 – Proposed Industry Dialogues on Opportunities and Directions

Explore Ideas and Cost Factors Workshop 1	**Options and Trade-Offs** Workshop 2	**Proposed Approaches** Workshop 3	**Council Review**
Review results from Phase 1 analysis and explore opportunities for each building type	Deep dive into opportunities and gather feedback on how they could drive building electrification	Identify preferred approaches for proposed policy, incentive and regulatory measures	Present engagement results and recommended approach for Council consideration

With Council approval, staff will proceed with Phase 2 of this work in fall 2022, and report back with options for consideration.

Financial Impact

None.

Conclusion

Staff have completed analysis of technical and economic considerations for rooftop solar PV systems for new buildings, with modelling of solar PV offset potential completed for ten building archetypes, and at mid- and high-levels of building energy efficiency. A second phase of work is proposed for Council consideration, beginning in fall 2022. This would engage the building design and construction community in exploration of opportunities and options that would inform proposed policy, regulatory, and incentive drivers for building electrification and decarbonisation, including the role of onsite solar PV systems in supporting these objectives.

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Att. 1: Solar PV Offset Potential for Modelled New Building Archetypes in Richmond

Solar PV Offset Potential for Modelled New Building Archetypes in Richmond

Modelled Archetypes and Building Characteristics Summary

Archetype	Roof Type	Floor Area (m^2)	Building Height (m)	Total Roof Area (m^2)	Dwelling Units
Single-Detached Home	45-degree slope	202	9	176	1
Single-Detached Home	flat roof	285	9	120	1
Single-Detached Home	low-angle roof	286	9	150	1
Duplex	45-degree slope	234	8	162	2
Townhouse [1]	flat roof	438	10	350	3
Mid-Rise MURB [2]	flat roof	14,326	25	2,360	160
14 floor MURB [2]	flat roof	29,830	47	895	361
14 floor Hotel [2]	flat roof	7,295	47	660	100
10 floor Office [2]	flat roof	6,151	35	1,200	-
Light Industrial	flat roof	8,286	16	2,870	-
Large Industrial	flat roof	46,542	15	16,124	-

(1) Townhouse archetype is a 15-unit complex, with a 3-unit building being modelled.

(2) Assumes mixed-use building with ground floor retail / restaurant uses, utilizing 381 m^2 of floor area.

Solar PV Offset Potential for Modelled New Building Archetypes in Richmond

Single-Detached Home (45-degree roof)

Single-Detached Home (45-degree roof)										
Target Scenario	Electrical Load (kWh/year)	Max Solar Capacity (kWp)	Per Panel Productivity (kWh/year)	Solar Output (kWh/year)	% of Target	# of Panels	% of Roof Covered	Cost	Payback Period	IRR
Mid Level Step Code										
Offset 100% Annual Electrical Load (kWh/year)	19,277	17.4	479	19,647	102%	41	62%	$47,919	23	0.98%
Offset Internal and External Lighting	3,317	3.0	479	3,354	101%	7	8%	$8,181	23	0.98%
Offset External Lighting Load Only	1,253	1.3	479	1,438	115%	3	3%	$3,506	23	0.98%
Offset Annual Cooling Load	5,656	5.1	479	5,750	102%	12	14%	$14,025	23	0.98%
Top Level Step Code										
Offset 100% Annual Electrical Load (kWh/year)	15,237	13.6	479	15,334	101%	32	36%	$37,400	23	0.98%
Offset Annual Cooling Load	2,545	2.6	479	2,875	113%	6	7%	$7,013	23	0.98%
Passive House Standard										
Offset 100% Annual Electrical Load (kWh/year)	14,043	12.8	479	14,376	102%	30	34%	$35,063	23	0.98%
Offset Internal and External Lighting	2,654	2.6	479	2,875	108%	6	7%	$7,013	23	0.98%
Offset External Lighting Load Only	1,002	1.3	479	1,438	143%	3	3%	$3,506	23	0.98%
Offset Annual Cooling Load	2,262	2.1	479	2,396	106%	5	6%	$5,844	23	0.98%
EV Charging Load										
Offset 10% Annual EV Charging Load (kWh/year)	422	0.4	479	479	114%	1	1%	$1,169	23	0.98%
Offset 100% Annual EV Charging Load (kWh/year)	4,220	4.0	479	4,790	114%	10	10%	$11,690	23	0.98%

Modelled building energy loads that could be entirely offset with an onsite solar PV array.

Notes to modelling results table:

- Due to the roof angle in the single-detached sample provided by City staff, 62% of roof coverage is the maximum amount PV array coverage that can be installed on this sample home (or 41 panels) in a home achieving Step 3 of the BC Energy Step Code. The array size drops to 32 panels at Step Code level 5, and 30 panels at a Passive House level of energy efficiency.
- All modelled electrical loads for this home can be fully offset with an onsite solar PV array at the sizes indicated.

Solar PV Offset Potential for Modelled New Building Archetypes in Richmond

Single-Detached Home (flat roof)

Single-Detached Home (flat roof)										
Target Scenario	Electrical Load (kWh/year)	Max Solar Capacity (kWp)	Per Panel Productivity (kWh/year)	Solar Output (kWh/year)	% of Target	# of Panels	% of Roof Covered	Cost	Payback Period	IRR
Mid Level Step Code										
Offset 100% Annual Electrical Load (kWh/year)	25,466	14.0	442	14,589	57%	33	83%	$37,166	22	0.43%
Offset Internal and External Lighting	4,683	4.7	442	4,863	104%	11	28%	$11,660	22	0.43%
Offset External Lighting Load Only	1,770	2.1	442	2,210	125%	5	13%	$5,300	22	0.43%
Offset Annual Cooling Load	7,980	8.1	442	8,400	105%	19	48%	$20,140	22	0.43%
Top Level Step Code										
Offset 100% Annual Electrical Load (kWh/year)	19,766	14.0	442	14,589	74%	33	83%	$37,166	22	0.43%
Offset Annual Cooling Load	3,591	3.8	442	3,979	111%	9	23%	$9,540	22	0.43%
Passive House Standard										
Offset 100% Annual Electrical Load (kWh/year)	18,081	14.0	442	14,589	81%	33	83%	$37,166	22	0.43%
Offset Internal and External Lighting	3,746	3.8	442	3,979	106%	9	23%	$9,540	22	0.43%
Offset External Lighting Load Only	1,416	1.7	442	1,768	125%	4	10%	$4,240	22	0.43%
Offset Annual Cooling Load	3,192	3.4	442	3,537	111%	8	20%	$8,480	22	0.43%
EV Charging Load										
Offset 10% Annual EV Charging Load (kWh/year)	422	0.4	442	442	105%	1	3%	$1,060	22	0.43%
Offset 100% Annual EV Charging Load (kWh/year)	4,220	4.0	442	4,420	105%	10	27%	$10,600	22	0.43%

Modelled building energy loads that could be entirely offset with an onsite solar PV array.

Notes to modelling results table:

- Due to the configuration of the roof in the sample provided by City staff, some areas of the roof are not large enough to house PV panels, or are shaded by taller parts of the roof.
- Overall, the maximum PV array roof coverage on this sample home is 83% of the available portion of the roof (or 33 panels), in a home achieving Step 3 of the BC Energy Step Code.
- With the exception of 100% of annual electrical load, all other modelled electrical loads can be fully offset by an onsite PV array.

Solar PV Offset Potential for Modelled New Building Archetypes in Richmond

Single-Detached Home (low angle roof)

Target Scenario	Electrical Load (kWh/year)	Max Solar Capacity (kWp)	Per Panel Productivity (kWh/year)	Solar Output (kWh/year)	% of Target	# of Panels	% of Roof Covered	Cost	Payback Period	IRR
Mid Level Step Code										
Offset 100% Annual Electrical Load (kWh/year)	25,541	21.3	446	22,282	87%	50	70%	$58,438	22	0.65%
Offset Internal and External Lighting	4,698	4.7	446	4,902	104%	11	15%	$12,100	22	0.65%
Offset External Lighting Load Only	1,775	1.7	446	1,783	100%	4	5%	$4,400	22	0.65%
Offset Annual Cooling Load	8,008	7.7	446	8,022	100%	18	24%	$19,800	22	0.65%
Top Level Step Code										
Offset 100% Annual Electrical Load (kWh/year)	19,821	19.1	446	20,054	112%	45	60%	$52,594	22	0.65%
Offset Annual Cooling Load	3,604	3.8	446	4,011	111%	9	12%	$9,900	22	0.65%
Passive House Standard										
Offset 100% Annual Electrical Load (kWh/year)	18,129	17.4	446	18,271	101%	41	54%	$47,919	22	0.65%
Offset Internal and External Lighting	3,758	3.8	446	4,011	107%	9	12%	$10,519	22	0.65%
Offset External Lighting Load Only	1,420	1.7	446	1,783	126%	4	5%	$4,400	22	0.65%
Offset Annual Cooling Load	3,203	3.4	446	3,565	111%	8	11%	$8,800	22	0.65%
EV Charging Load										
Offset 10% Annual EV Charging Load (kWh/year)	422	0.4	446	446	106%	1	1%	$1,100	22	0.65%
Offset 100% Annual EV Charging Load (kWh/year)	4,220	4.0	446	4,460	106%	10	10%	$11,000	22	0.65%

Modelled building energy loads that could be entirely offset with an onsite solar PV array.

Notes to modelling results table:

- Due to the configuration of the roof in the sample provided by City staff, 70% of roof coverage (50 panels) is the maximum array size that can be installed on this single-detached home achieving Step 3 of the BC Energy Step Code.
- With the exception of offsetting 100% of electrical load at Step Code level 3, all other modeled electrical loads can be fully offset with an onsite solar PV array.

Solar PV Offset Potential for Modelled New Building Archetypes in Richmond

Duplex (flat roof)

Duplex Home (flat roof)										
Target Scenario	Electrical Load (kWh/year)	Max Solar Capacity (kWp)	Per Panel Productivity (kWh/year)	Solar Output (kWh/year)	% of Target	# of Panels	% of Roof Covered	Cost	Payback Period	IRR
Mid Level Step Code										
Offset 100% Annual Electrical Load (kWh/year)	25,893	21.3	478	23,889	92%	50	62%	$58,438	22	0.96%
Offset Internal and External Lighting	3,031	3.0	478	3,344	110%	7	9%	$8,181	22	0.96%
Offset External Lighting Load Only	637	0.9	478	956	150%	2	2%	$2,338	22	0.96%
Offset Annual Cooling Load	6,558	6.0	478	6,689	102%	14	17%	$16,363	22	0.96%
Top Level Step Code										
Offset 100% Annual Electrical Load (kWh/year)	21,209	19.1	478	21,500	101%	45	56%	$52,594	22	0.96%
Offset Annual Cooling Load	2,951	3.0	478	3,344	113%	7	9%	$8,181	22	0.96%
Passive House Standard										
Offset 100% Annual Electrical Load (kWh/year)	19,824	17.9	478	20,067	101%	42	52%	$49,088	22	0.96%
Offset Internal and External Lighting	2,424	2.6	478	2,867	118%	6	7%	$7,013	22	0.96%
Offset External Lighting Load Only	510	0.9	478	956	187%	2	2%	$2,338	22	0.96%
Offset Annual Cooling Load	2,623	2.6	478	2,867	109%	6	7%	$7,013	22	0.96%
EV Charging Load										
Offset 10% Annual EV Charging Load (kWh/year)	843	0.9	478	956	113%	2	2%	$2,338	22	0.96%
Offset 100% Annual EV Charging Load (kWh/year)	8,430	9.0	478	9,560	113%	20	20%	$23,380	22	0.65%

Modelled building energy loads that could be entirely offset with an onsite solar PV array.

Notes to modelling results table:

- Due to the configuration of the roof in the sample duplex provided by the City, 62% of roof coverage (or 50 panels) is the maximum array size that can be installed in this duplex achieving Step 3 of the BC Energy Step Code.
- With the exception of offsetting 100% of electrical load at Step Code level 3, all other modeled electrical loads can be fully offset with an onsite solar PV array.

Solar PV Offset Potential for Modelled New Building Archetypes in Richmond

Townhouse (3 units, flat roof)

Townhouse (3 units, flat roof)										
Target Scenario	Electrical Load (kWh/year)	Max Solar Capacity (kWp)	Per Panel Productivity (kWh/year)	Solar Output (kWh/year)	% of Target	# of Panels	% of Roof Covered	Cost	Payback Period	IRR
Mid Level Step Code										
Offset 100% Annual Electrical Load (kWh/year)	60,067	38	442	39,785	66%	90	77%	$101,363	22	0.84%
Offset Internal and External Lighting	5,424	5.5	442	6,189	114%	13	11%	$14,641	22	0.84%
Offset External Lighting Load Only	946	1.3	442	1,326	140%	3	3%	$3,379	22	0.84%
Offset Annual Cooling Load	12,268	11.9	442	12,378	101%	28	24%	$31,535	22	0.84%
Top Level Step Code										
Offset 100% Annual Electrical Load (kWh/year)	51,304	38.3	442	39,785	78%	90	77%	$101,363	22	0.84%
Offset Annual Cooling Load	5,520	5.5	442	5,747	104%	13	11%	$14,641	22	0.84%
Passive House Standard										
Offset 100% Annual Electrical Load (kWh/year)	48,713	38.3	442	39,785	82%	90	77%	$101,363	22	0.84%
Offset Internal and External Lighting	4,339	4.3	442	4,421	102%	10	9%	$11,263	22	0.84%
Offset External Lighting Load Only	757	0.9	442	884	117%	2	2%	$2,253	22	0.84%
Offset Annual Cooling Load	4,907	5.1	442	5,305	108%	12	10%	$13,515	22	0.84%
EV Charging Load										
Offset 10% Annual EV Charging Load (kWh/year)	2,740	2.8	442	2,878	105%	7	6%	$7,420	22	0.84%
Offset 100% Annual EV Charging Load (kWh/year)	27,400	28.0	442	28,780	105%	21	18%	$22,260	22	0.84%

Modelled building energy loads that could be entirely offset with an onsite solar PV array.

Notes to modelling results table:

- Due to roof configuration and various rooftop equipment on the sample townhouse development, 77% of roof coverage (or 90 panels) is the maximum sized PV array that can be installed in a 3-unit townhouse project achieving Step 3 of the BC Energy Step Code.
- With the exception of offsetting 100% of electrical load in these townhouses, all other modeled electrical loads can be fully offset with an onsite solar PV array.

Solar PV Offset Potential for Modelled New Building Archetypes in Richmond

Mid-Rise MURB (6 floors, flat roof)

Mid-Rise MURB (6 floors, flat roof)										
Target Scenario	Electrical Load (kWh/year)	Max Solar Capacity (kWp)	Per Panel Productivity (kWh/year)	Solar Output (kWh/year)	% of Target	# of Panels	% of Roof Covered	Cost	Payback Period	IRR
Mid Level Step Code										
Offset 100% Annual Electrical Load (kWh/year)	2,479,816	100	432	101,500	4%	235	32%	$235,000	22	1.38%
Offset Internal and External Lighting	215,358	100	432	101,500	47%	235	32%	$235,000	22	1.38%
Offset External Lighting Load Only	68,949	68	432	69,106	100%	160	20%	$159,800	22	1.38%
Offset Annual Cooling Load	401,118	100	432	101,500	25%	235	32%	$235,000	22	1.38%
Top Level Step Code										
Offset 100% Annual Electrical Load (kWh/year)	2,193,303	100	432	101,500	5%	235	32%	$235,000	22	1.38%
Offset Annual Cooling Load	180,503	100	432	101,500	56%	235	32%	$235,000	22	1.38%
Passive House Standard										
Offset 100% Annual Electrical Load (kWh/year)	1,535,569	100	432	101,500	7%	235	32%	$235,000	22	1.38%
Offset Internal and External Lighting	172,286	100	432	101,500	59%	235	32%	$235,000	22	1.38%
Offset External Lighting Load Only	55,160	54	432	55,285	100%	128	16%	$127,840	22	1.38%
Offset Annual Cooling Load	160,447	100	432	101,500	63%	235	32%	$235,000	22	1.38%
EV Charging Load										
Offset 10% Annual EV Charging Load (kWh/year)	33,720	34	432	34,104	101%	84	11%	$78,960	22	1.38%
Offset 25% Annual EV Charging Load (kWh/year)	84,300	85	432	85,260	101%	210	28%	$197,400	22	1.38%

Modelled building energy loads that could be entirely offset with an onsite solar PV array.

Notes to modelling results table:

- BC Hydro's net metering program limits onsite power generation to a maximum system size of 100kWp. The solar modelling results reflect that cap (which translates to 235 panels for this mid-rise residential building, at the rated panel efficiency).
- The mid-rise residential archetype has relatively large external lighting loads due to 24/7 parking garage lighting operation.
- 100% of external lighting load from this building can be fully offset with on onsite PV array.
- Up to 25% of total annual EV charging load in this building can be fully offset with on onsite PV array.

Solar PV Offset Potential for Modelled New Building Archetypes in Richmond

Tall MURB (14 floors, flat roof)

Target Scenario	Electrical Load (kWh/year)	Max Solar Capacity (kWp)	Per Panel Productivity (kWh/year)	Solar Output (kWh/year)	% of Target	# of Panels	% of Roof Covered	Cost	Payback Period	IRR
Mid Level Step Code										
Offset 100% Annual Electrical Load (kWh/year)	4,693,919	100	431	101,339	2%	235	79%	$235,000	22	1.37%
Offset Internal and External Lighting	728,516	100	431	101,339	14%	235	79%	$235,000	22	1.37%
Offset External Lighting Load Only	222,040	100	431	101,339	46%	235	79%	$235,000	22	1.37%
Offset Annual Cooling Load	835,239	100	431	101,339	12%	235	79%	$235,000	22	1.37%
Top Level Step Code										
Offset 100% Annual Electrical Load (kWh/year)	4,680,943	100	431	101,339	2%	235	79%	$235,000	22	1.37%
Offset Annual Cooling Load	375,857	100	431	101,339	27%	235	79%	$235,000	22	1.37%
Passive House Standard										
Offset 100% Annual Electrical Load (kWh/year)	3,311,360	100	431	101,339	3%	235	79%	$235,000	22	1.37%
Offset Internal and External Lighting	582,813	100	431	101,339	17%	235	79%	$235,000	22	1.37%
Offset External Lighting Load Only	177,632	100	431	101,339	57%	235	79%	$235,000	22	1.37%
Offset Annual Cooling Load	334,096	100	431	101,339	30%	235	79%	$235,000	22	1.37%
EV Charging Load										
Offset 10% Annual EV Charging Load (kWh/year)	81,602	81	431	81,934	100%	190	64%	$189,763	22	1.37%

Modelled building energy loads that could be entirely offset with an onsite solar PV array.

Notes to modelling results table:

- BC Hydro's net metering program limits onsite power generation to a maximum system size of 100kWp. The solar modelling results reflect this cap (which translates to 235 panels for this mid-rise residential building, at the rated panel efficiency).
- The tall multi-unit residential building archetype has significantly larger external lighting loads due to 24/7 parking garage lighting operation.
- Up to 10% of total annual EV charging load in this building can be fully offset with on onsite PV array (190 panels).

Solar PV Offset Potential for Modelled New Building Archetypes in Richmond

Hotel (14 floors, flat roof)

Hotel (14 floors, flat roof)										
Target Scenario	Electrical Load (kWh/year)	Max Solar Capacity (kWp)	Per Panel Productivity (kWh/year)	Solar Output (kWh/year)	% of Target	# of Panels	% of Roof Covered	Cost	Payback Period	IRR
Mid Level Step Code										
Offset 100% Annual Electrical Load (kWh/year)	948,402	84	429	84,939	9%	198	90%	$197,753	22	1.53%
Offset Internal and External Lighting	102,168	84	429	84,939	83%	198	90%	$197,753	22	1.53%
Offset External Lighting Load Only	24,813	25	429	24,881	100%	58	26%	$57,928	22	1.53%
Offset Annual Cooling Load	204,271	84	429	84,939	42%	198	90%	$197,753	22	1.53%
Top Level Step Code										
Offset 100% Annual Electrical Load (kWh/year)	875,448	84	429	84,939	10%	198	90%	$197,753	22	1.53%
Offset Annual Cooling Load	91,922	84	429	84,939	92%	198	90%	$197,753	22	1.53%
Passive House Standard										
Offset 100% Annual Electrical Load (kWh/year)	437,724	84	429	84,939	19%	198	90%	$197,753	22	1.53%
Offset Internal and External Lighting	97,205	84	429	84,939	87%	198	90%	$197,753	22	1.53%
Offset External Lighting Load Only	19,851	20	429	20,162	102%	47	21%	$46,941	22	1.53%
Offset Annual Cooling Load	81,708	81	429	81,936	100%	191	87%	$190,761	22	1.53%

Modelled building energy loads that could be entirely offset with an onsite solar PV array.

Notes to modelling results table:

- BC Hydro's net metering program limits onsite power generation to a maximum system size of 100kWp. The solar modelling results reflect this cap.
- Due to some rooftop space being occupied by mechanical equipment (HVAC) and elevator access, 90% of rooftop area is the maximum coverage for a solar PV array (198 panels) for this sample hotel.
- Hotels have relatively larger external lighting loads due to 24/7 parking garage lighting operation.
- 100% of external lighting load from this building can be fully offset with on onsite PV array (190 panels).
- EV charging load was not modelled for hotels, as the City has not yet established by-law requirements on minimum Level 2 charging capability in non-residential buildings. This analysis will be covered in a subsequent report.

Solar PV Offset Potential for Modelled New Building Archetypes in Richmond

Office (10 floors, flat roof)

Office (10 floors, flat roof)										
Target Scenario	Electrical Load (kWh/year)	Max Solar Capacity (kWp)	Per Panel Productivity (kWh/year)	Solar Output (kWh/year)	% of Target	# of Panels	% of Roof Covered	Cost	Payback Period	IRR
Mid Level Step Code										
Offset 100% Annual Electrical Load (kWh/year)	1,045,736	100	431	101,339	10%	235	59%	$235,000	22	1.37%
Offset Internal and External Lighting	160,815	100	431	101,339	63%	235	59%	$235,000	22	1.37%
Offset External Lighting Load Only	25,423	25	431	25,443	100%	59	15%	$58,926	22	1.37%
Offset Annual Cooling Load	172,239	100	431	101,339	59%	235	59%	$235,000	22	1.37%
Top Level Step Code										
Offset 100% Annual Electrical Load (kWh/year)	615,139	100	431	101,339	16%	235	59%	$235,000	22	1.37%
Offset Annual Cooling Load	77,508	77	431	77,621	100%	180	45%	$179,775	22	1.37%
Passive House Standard										
Offset 100% Annual Electrical Load (kWh/year)	3,311,360	100	431	101,339	27%	235	59%	$235,000	22	1.37%
Offset Internal and External Lighting	133,297	100	431	101,339	76%	235	59%	$235,000	22	1.37%
Offset External Lighting Load Only	24,983	25	431	25,011	100%	58	15%	$57,928	22	1.37%
Offset Annual Cooling Load	68,896	68	431	68,997	100%	160	40%	$159,800	22	1.37%

Modelled building energy loads that could be entirely offset with an onsite solar PV array.

Notes to modelling results table:

- BC Hydro's net metering program limits onsite power generation to a maximum system size of 100kWp. The solar modelling results reflect this cap. Therefore, 59% of rooftop area is the maximum coverage for a solar PV array (235 panels) for this archetype.
- The Office archetype has comparatively lower external lighting loads than mid-rise and taller MURBs, due to the common practice of turning off lighting when businesses do not require it (assumed run time is based on Vancouver Energy Modelling Guidelines and National Energy Code for Buildings).
- EV charging load was not modelled for commercial office buildings, as the City has not yet established by-law requirements on minimum Level 2 charging capability in non-residential buildings. This analysis will be covered in a subsequent report.

Solar PV Offset Potential for Modelled New Building Archetypes in Richmond

Light Industrial Warehouse (flat roof)

Light Industrial Warehouse (flat roof)										
Target Scenario	Electrical Load (kWh/year)	Max Solar Capacity (kWp)	Per Panel Productivity (kWh/year)	Solar Output (kWh/year)	% of Target	# of Panels	% of Roof Covered	Cost	Payback Period	IRR
20% more energy efficient than current BC Building Code										
Offset 100% Annual Electrical Load (kWh/year)	1,034,711	100	431	101,373	10%	235	25%	$225,000	20	1.91%
Offset Internal and External Lighting	205,448	100	431	101,373	49%	235	25%	$225,000	20	1.91%
Offset External Lighting Load Only	4,394	4.7	431	4,745	108%	11	1%	$10,519	20	1.91%
Offset Annual Cooling Load	139,205	100	431	101,373	73%	235	25%	$225,000	20	1.91%
70% more energy efficient than current BC Building Code										
Offset 100% Annual Electrical Load (kWh/year)	415,980	100	431	101,373	24%	235	25%	$225,000	20	1.91%
Offset Annual Cooling Load	92,803	92	431	93,177	100%	216	23%	$206,550	20	1.91%

Modelled building energy loads that could be entirely offset with an onsite solar PV array.

Notes to modelling results table:

- BC Hydro's net metering program limits onsite power generation to a maximum system size of 100kWp (235 panels covering 25% of available rooftop space). The above solar modelling results reflect this cap.
- EV charging load was not modelled for industrial buildings, as the City has not yet established by-law requirements on minimum Level 2 charging capability in non-residential buildings. This analysis will be covered in a subsequent report.
- Currently, the BC Energy Step Code does not cover industrial warehouse uses, so energy performance scenarios were set at 20% and 70% better than current (2018) BC Building Code requirements.
- For this study, light industrial warehouse buildings were not modelled at a Passive House level of energy performance.

Solar PV Offset Potential for Modelled New Building Archetypes in Richmond

Large Industrial Warehouse (flat roof)

Large Industrial Warehouse (flat roof)										
Target Scenario	Electrical Load (kWh/year)	Max Solar Capacity (kWp)	Per Panel Productivity (kWh/year)	Solar Output (kWh/year)	% of Target	# of Panels	% of Roof Covered	Cost	Payback Period	IRR
20% more energy efficient than current BC Building Code										
Offset 100% Annual Electrical Load (kWh/year)	5,799,596	100	431	101,373	2%	235	3%	$225,000	20	1.91%
Offset Internal and External Lighting	1,150,728	100	431	101,373	9%	235	3%	$225,000	20	1.91%
Offset External Lighting Load Only	23,613	23.4	431	23,726	100%	55	1%	$52,594	20	1.91%
Offset Annual Cooling Load	780,386	100	431	101,373	13%	235	3%	$225,000	20	1.91%
70% more energy efficient than current BC Building Code										
Offset 100% Annual Electrical Load (kWh/year)	2,331,899	100	431	101,373	4%	235	3%	$225,000	20	1.91%
Offset Annual Cooling Load	520,257	100	431	101,373	19%	235	3%	$225,000	20	1.91%

Modelled building energy loads that could be entirely offset with an onsite solar PV array.

Notes to modelling results table:

- BC Hydro's net metering program limits onsite power generation to a maximum system size of 100kWp (235 panels covering 3% of available rooftop space). The above solar modelling results reflect this cap.
- EV charging load was not modelled for industrial buildings, as the City has not yet established by-law requirements on minimum Level 2 charging capability in non-residential buildings. This analysis will be covered in a subsequent report.
- Currently, the BC Energy Step Code does not cover industrial warehouse uses, so energy performance scenarios were set at 20% and 70% better than current (2018) BC Building Code requirements.
- For this study, large industrial buildings were not modelled at a Passive House level of energy performance.