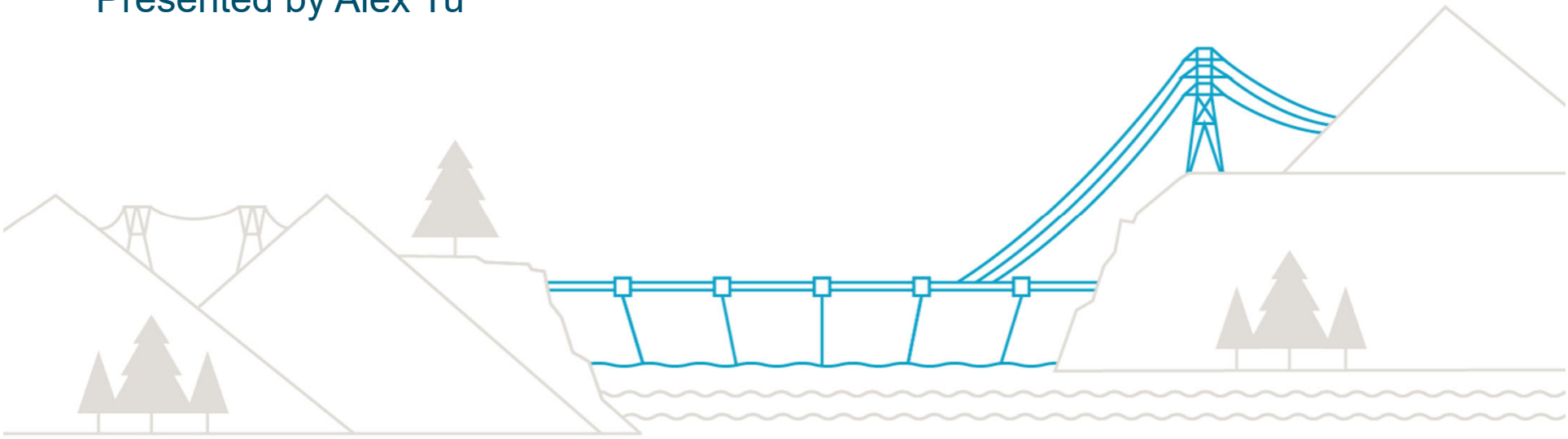
Resource Options Engagement
Solar Technical Potential

Presented by Alex Tu



November 12, 2019

BC Hydro
Power smart

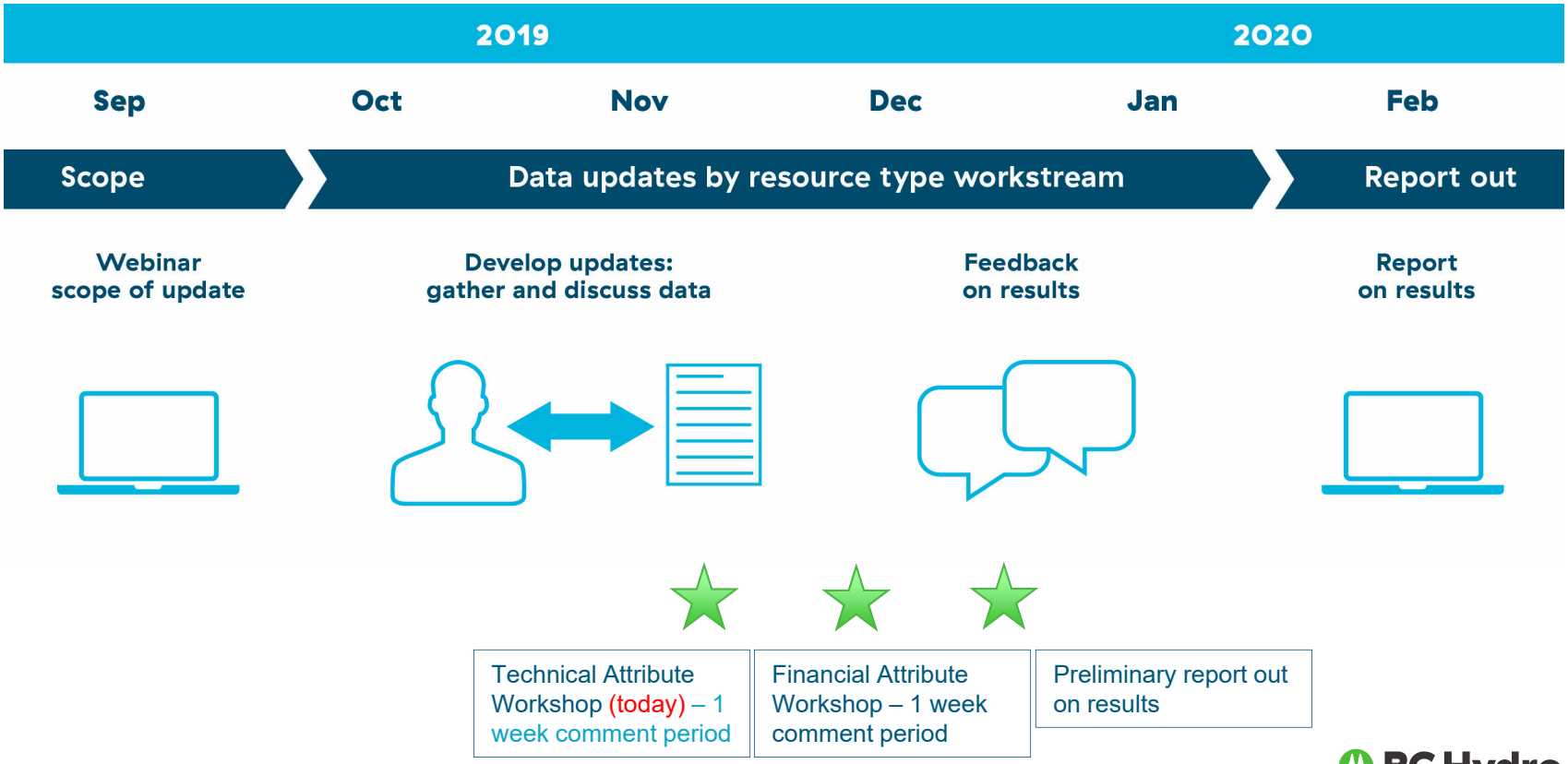
Purpose and Agenda

Receive input from technical experts on the assumptions that underpin BC Hydro's view of the solar resource potential in BC

1. What is the Resource Option Inventory
2. Draft assumptions to estimate size and location of solar resources in BC
    - Utility Scale
    - Urban Scale
    - Customer Scale
3. Summary of input assumptions for discussion

Resource Option Engagement Schedule

For Solar – two proposed engagement sessions to solicit input on technical assumptions and financial assumptions



BC Hydro
Power smart

What is the Resource Option (RO) Inventory

What it is

- A reasonably comprehensive listing of potential supply options in BC
- A high-level representation of each option's technical, financial, social and environmental attributes to allow apples-to-apples comparisons

What it is NOT

- A detailed estimate of what a specific project will cost or produce
- A prelude to any specific energy acquisition program

What are the relevant attributes?

Attributes describe each option, and are consistent across all resource types

Technical Attributes (examples)

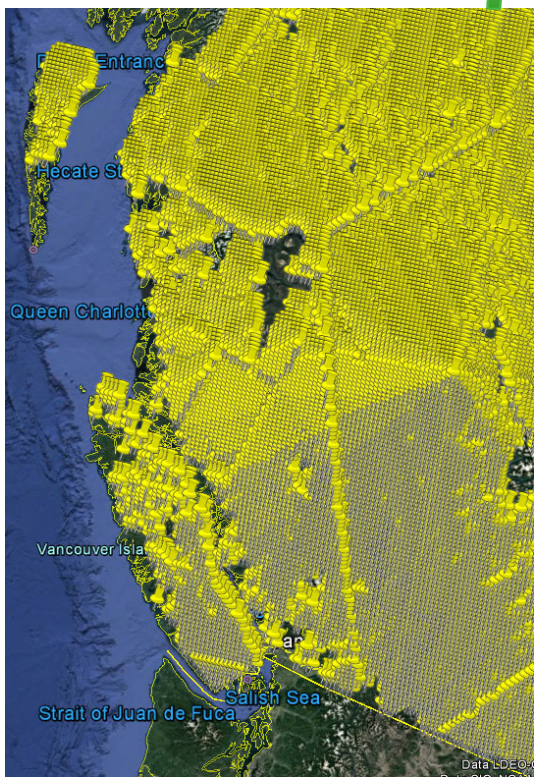
- Location (Latitude & Longitude)
- Installed Capacity (MW AC)
- Average Annual Energy (GWh/yr)
- Monthly Average Energy (% of annual energy)
- Facility Footprint (hectares)

Financial Attributes (examples)

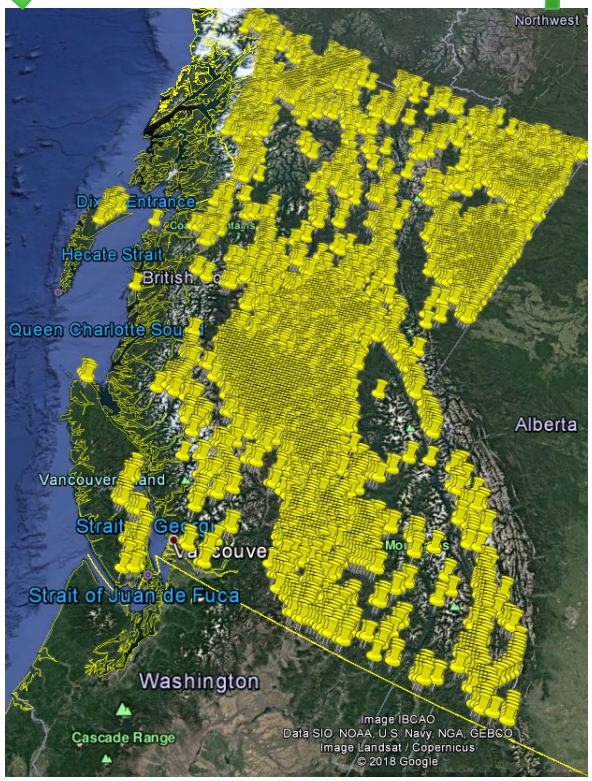
- Overnight Capital Cost
  - Construction Cost
  - Equipment Cost
  - Other Development Costs
- Planning Life
- Project Lead Time
- Fixed OMA (k$/yr)
- Variable OMA ($/MWh)

Proposed approach to Solar Technical Attributes (Utility scale)

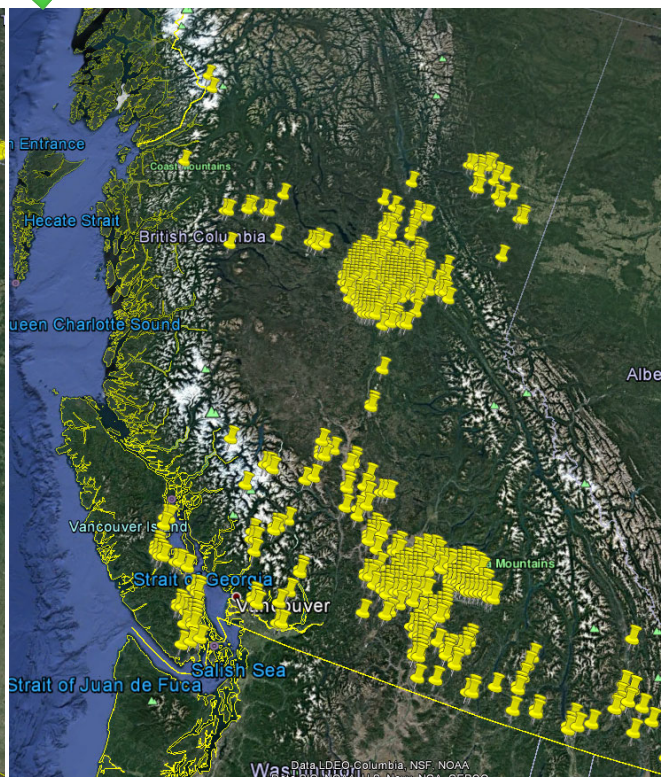
Apply a series of exclusion filters to identify areas (polygons) where solar could be developed



Unconstrained – Exclude only water, parks and built areas



Less than 5% slope, not light forest



At least 15 MW, and within 50 miles of transmission

BC Hydro
Power smart

Proposed approach to Solar Technical Attributes (Utility Scale)

For each polygon, use some basic rules of thumb to maximally build out solar facility

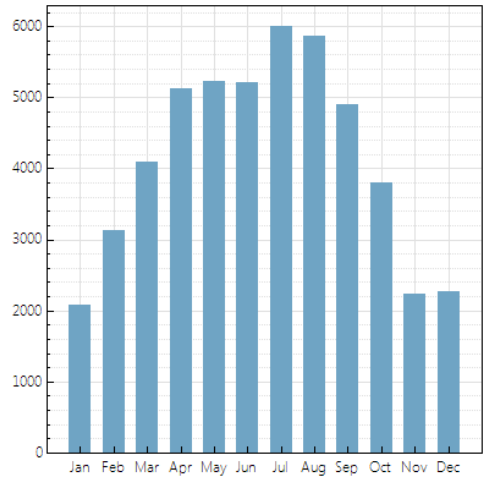
Proposed Assumptions (from NREL)

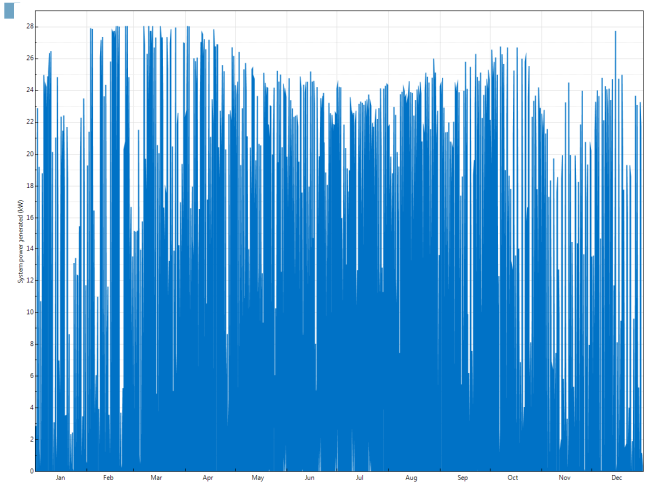
- 32 MW (DC) per available sq km
- Multicrystaline PV panels
- Single axis tracker, tilt at latitude
- 1.3 DC-AC overbuild ratio
- 14% total losses in system (2% soiling, 3% shading, 2% light induced losses in year 1, 4% losses in mismatch and wiring, 3% losses from inavailability)
- Hourly generation over a “typical weather” year calculated based on simulation of 20 years of NSRDB solar insolation data using NREL System Advisory Model (SAM) tool

Proposed approach to Solar Technical Attributes (Utility Scale)

These basic rules suggest ~500 sites, sized up to 1000 MW, with net capacity factors between 12 – 17% (DC)

Capacity (MW DC)	Distance to Transmission (mi)	Net Capacity Factor	Latitude	Longitude	Area (km2)
102.9024	29.04804751	0.143779482	56.15537999	-130.1513321	3.2157
32.9184	19.34228003	0.146968398	55.9553877	-129.8060704	1.0287
36.0288	11.21569992	0.140014307	56.12971381	-122.3992852	1.1259
34.2144	10.10695913	0.140088659	56.14350778	-122.3075969	1.0692
118.4544	11.47726785	0.13988249	56.17095865	-122.1240687	3.7017
77.2416	18.65814629	0.139291148	56.24664329	-121.9661628	2.4138
69.984	16.24143698	0.139614278	56.19822645	-121.9403394	2.187
47.4336	21.27403466	0.139367835	56.26022543	-121.8741408	1.4823
310.2624	8.544320667	0.139183501	56.12258581	-122.0981316	9.6957
44.064	23.71062378	0.139281477	56.14187886	-121.6133669	1.377





Sample output from 36 MW DC (27.7 MW AC) project in Osoyoos

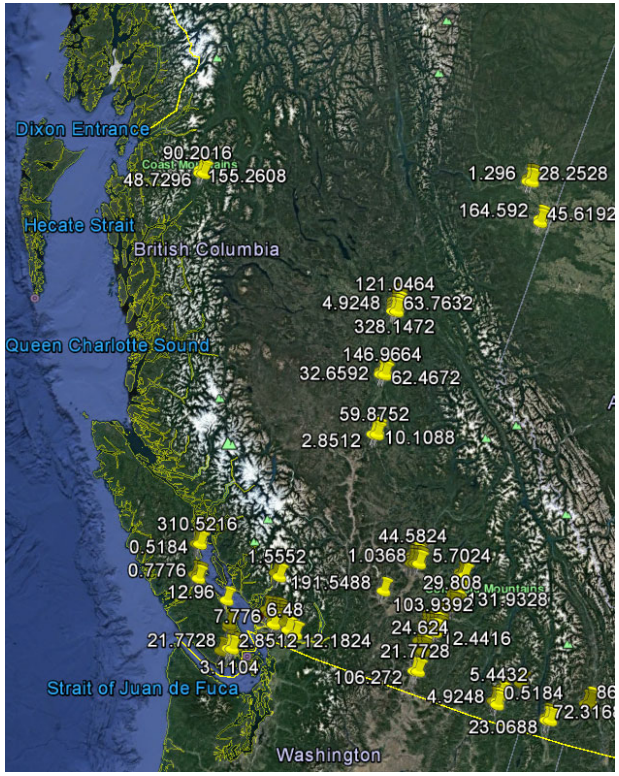
BC Hydro
Power smart

Discussion on Utility Scale Approach

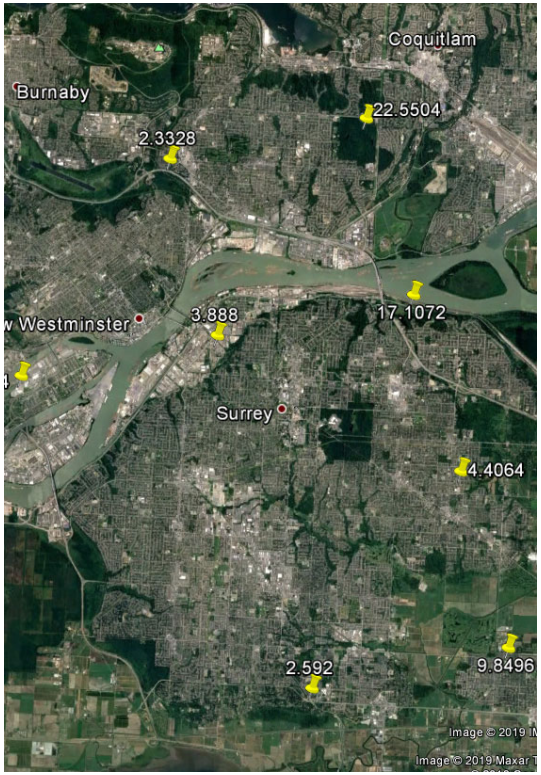
BC Hydro
Power smart

Proposed Approach to Solar Technical Attributes (Urban Scale)

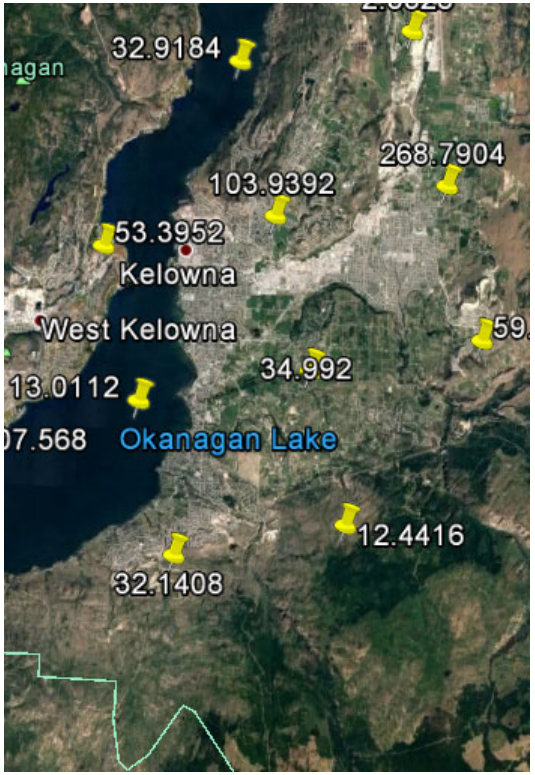
A similar GIS-Based exclusion process, highlighting development potential in urban greenspace



Province wide Urban



Greater Vancouver



Kelowna

BC Hydro
Power smart

Proposed approach to Solar Technical Attributes (Urban Scale)

Same basic rules of thumb to maximally build out solar facility

Proposed Assumptions (from NREL)

- 32 MW (DC) per available sq km
- Multicrystalline silicon PV panels
- South facing, single axis tracker
- 1.3 DC-AC overbuild ratio
- 14% total losses in system
- Net Capacity factor calculated based on simulation of 20 years of NSRDB solar insolation data

Proposed approach to Solar Technical Attributes (Urban Scale)

These basic rules suggest ~100 sites of different sizes with net capacity factors between 11 – 15% (DC)

Capacity (MW)	Net Capacity Factor	Latitude	Longitude	Area (km2)
227.8368	0.137864594	56.24773841	-120.8766033	7.1199
189.4752	0.138280557	56.26076302	-120.7842892	5.9211
1.296	0.138879552	56.19916829	-120.8518375	0.0405
28.2528	0.138890748	56.21217654	-120.7596068	0.8829
155.2608	0.115812365	54.53325496	-128.6332594	4.8519
90.2016	0.115930304	54.48633776	-128.6021143	2.8188
48.7296	0.114767497	54.50311902	-128.515202	1.5228
164.592	0.138447105	55.76513824	-120.2409066	5.1435
45.6192	0.136628032	55.7166149	-120.216991	1.4256
3.888	0.139343154	53.97343935	-122.8880687	0.1215
4.6656	0.141193688	54.03508003	-122.8258437	0.1458

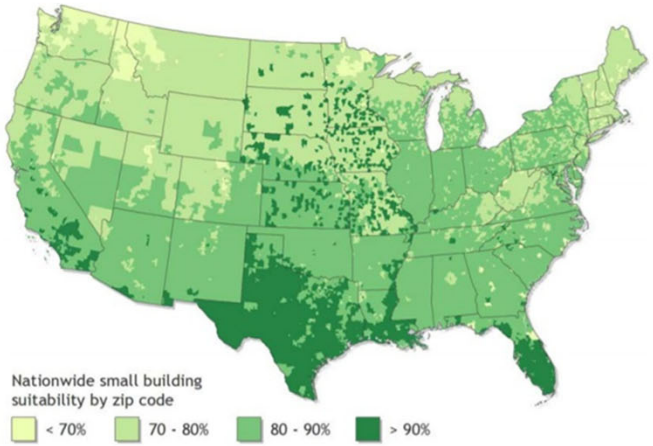
Discussion on Urban Scale Approach

BC Hydro
Power smart

Proposed approach to Solar Technical Attributes (Customer Scale)

Rooftop space, rather than greenspace, is the key factor

Approximately 1.1 TW of technical potential, mostly in small buildings (i.e. residential homes)



Building Class (Building Footprint)	Total Suitable Area (Billions of m^2)	Installed Capacity Potential (GW)	Annual Generation Potential (TWh/year)
Small (< 5,000 ft^2)	4.92	731	926
Medium (5,000–25,000 ft^2)	1.22	154	201
Large (> 25,000 ft^2)	1.99	232	305
All Buildings	**8.13**	**1,118**	**1,432**

- The average **small building** had 52 m^2 (8.3 kW) of developable area, and 79% were "suitable"
- The average **medium building** had 952 m^2 (152 kW), and 52% were suitable
- The average **large building** had 4,178 m^2 (668 kW), and 52% were suitable

Gagnon, P. et al. (2016). *Rooftop Solar Photovoltaic Technical Potential in the United States. A Detailed Assessment* NREL/TP--6A20-65298.

BC Hydro
Power smart

Proposed approach to Solar Technical Attributes (Customer Scale)

BC Residential rooftop capacity based on housing stock on rules of thumb from US analysis

Table 2-4: Base Year Housing Stocks (Residential Accounts)

Housing Type	Lower Mainland	Southern Interior	Vancouver Island	Northern BC	Total
Single Family Detached/Duplexes	494,034	126,887	238,854	98,476	**958,251**
Single Family Attached/Row	139,962	15,944	26,383	5,772	**188,061**
Apartments <= 4 stories	216,678	19,842	59,179	14,832	**310,531**
Apartments > 4 stories	158,724	4,221	17,195	1,465	**181,605**
Other Residential	19,726	32,432	27,450	26,259	**105,867**
Total	**1,029,124**	**199,326**	**369,061**	**146,804**	**1,744,315**

The number of apartment units represents individual apartment accounts and not single-buildings.
Source: Navigant analysis based on data provided by BC Hydro

Limitations on suitable residential rooftops

- Limited to Single Family Dwellings
- Assume US average for 'suitability' based on roof shape, shading, and orientation (79%)
- Limited to Owner-Occupied (76 of SFDs%)
- Suitable houses could host (on average) ~6 kW system (~400 sq feet roofspace)
  - **Total ~ 3.6 GW residential**

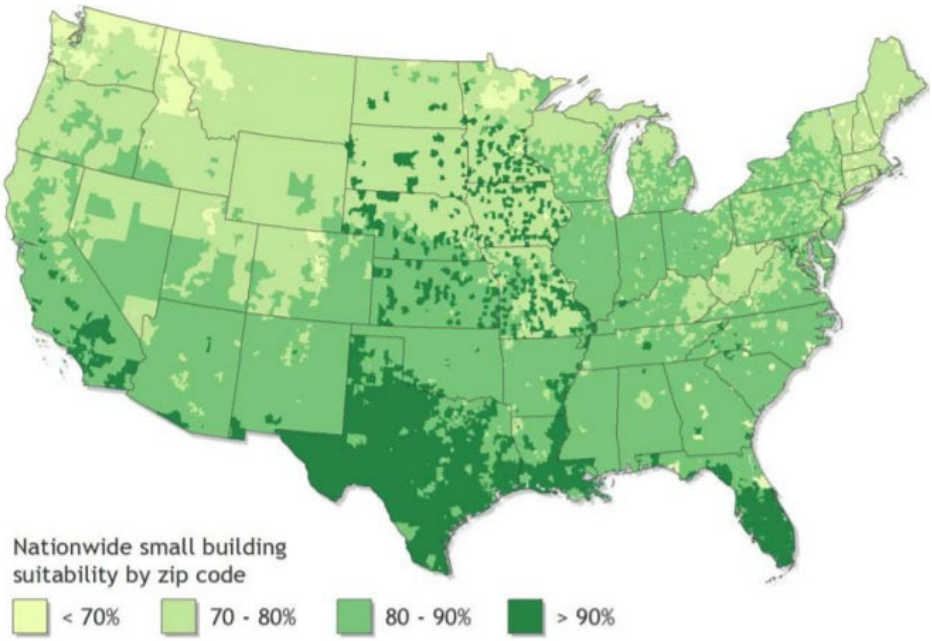
    (1.8 GW just in Lower Mainland)

Source: NREL

BC Hydro
Power smart

Proposed approach to Solar Technical Attributes (Customer Scale)

BC Commercial customer potential estimated based on customer type / building type



Source: NREL

Limitations on suitable commercial customer rooftops

- All Small General Service (SGS) customers included (eg restaurants, hotels, retail…)
- Estimate of total rooftop space for each SGS customer based on average sq foot area of different customer types
- 42% of all rooftop space is ‘suitable’ based on mid Navigant estimate
- Assume 67 square feet of ‘suitable’ rooftop space required per kW installed
    - **Total ~ 2.5 GW SGS rooftop potential**

BC Hydro Power smart

Proposed approach to Solar Technical Attributes (Customer Scale)

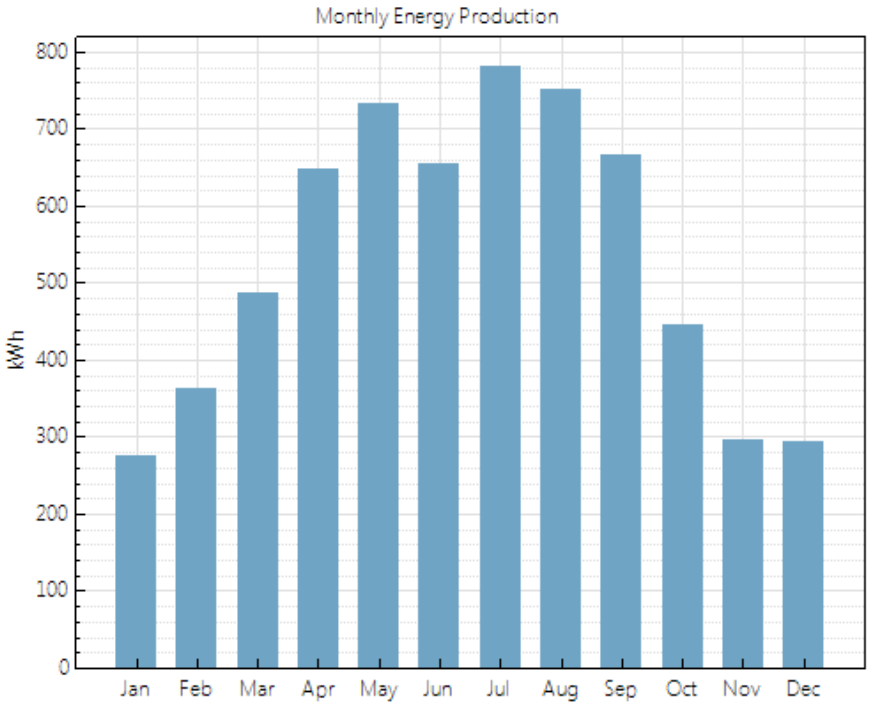
Same basic rules of thumb for rooftop solar systems

Proposed Assumptions

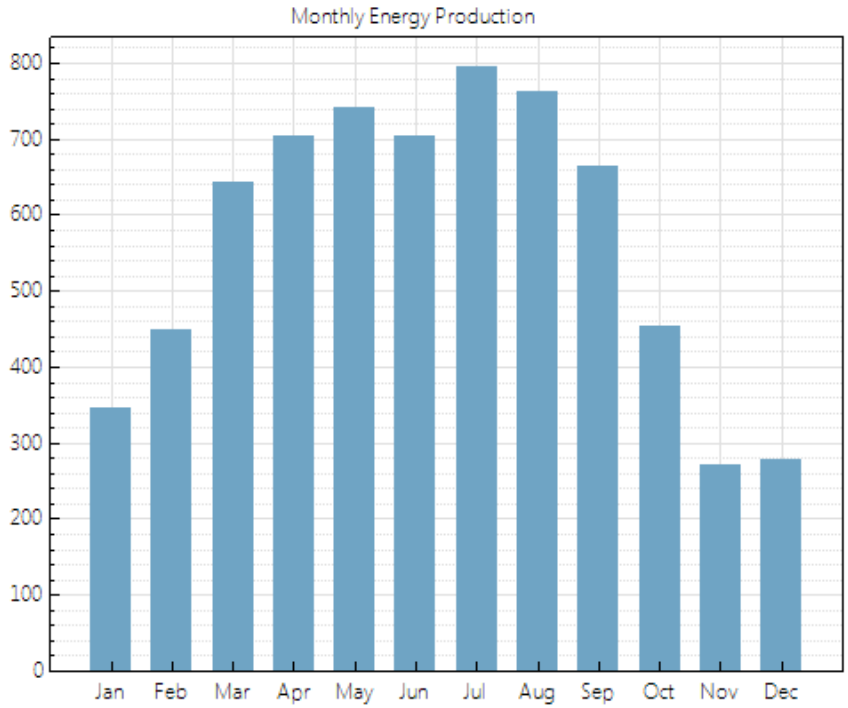
- Multicrystalline silicon PV panels
- 67 sq feet of suitable roofspace required per kW
- For residential: fixed rooftop
- For commercial: flat plate
- 1:1 DC-AC overbuild
- 14% total losses in system
- Representative energy generation calculate using PVWATTS model in each BCH region for residential configurations and commercial configurations

Proposed Approach to Solar Technical Attributes (Customer Scale)

Sample generation profiles of 6 kW rooftop systems in Vancouver and Kelowna



Vancouver



Kelowna

BC Hydro
Power smart

Discussion on Customer Scale Approach

BC Hydro
Power smart

Summary of Technical Input Assumptions

…For utility, urban and customer side solar

GIS Exclusion Criteria		Solar Facilities		Customer Solar Potential	
Slope	>5%	Density	32 MW / km2	Residential	
Land Use	Parks	Overbuild	1.3 DC-AC	Type	SFD only
Land Use	Forested	Tracking	Single Axis	Renters?	No
Land Use	Wetland	PV Panel	multicrystal	Density	160 W/m2
Land Use	Built env.	Losses	14%	Suitable homes	76% of total
Distance to Trans	< 50 miles	Solar resource	NDRSB typical year	System Size	6 kW average
Urban	Greenspace Only	Gen Profile	Based on NREL SAM	Gen Profile	Based on PVWatts


BC Hydro
Power smart