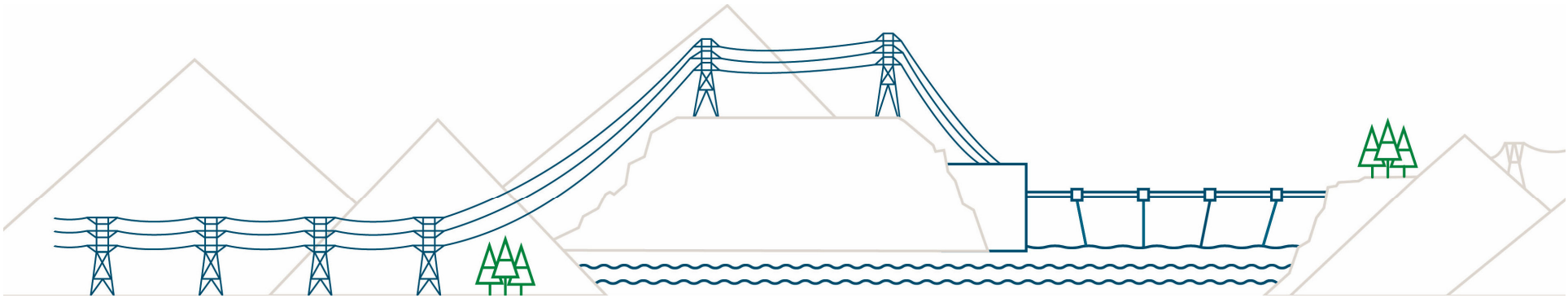
Resource Options Update
Generation Supply-Side Options
Draft Results



June 2020

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BC Hydro's resource options inventory

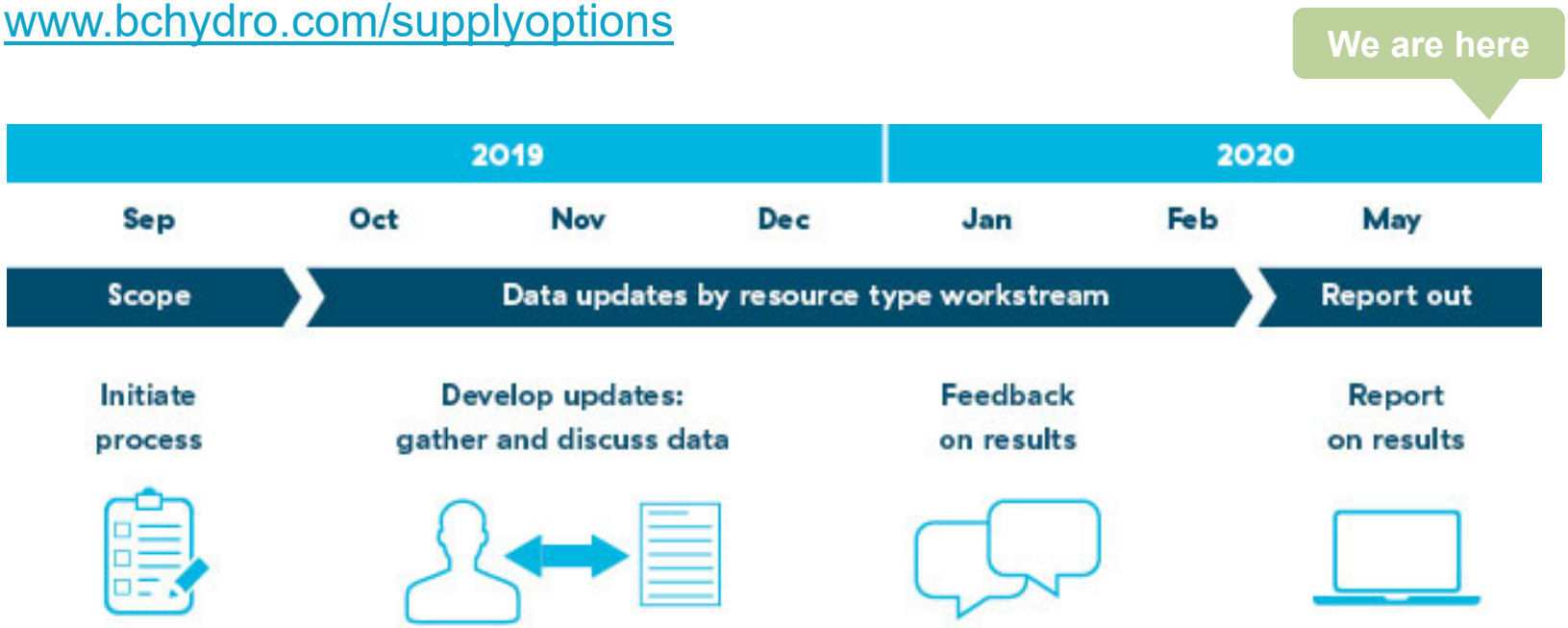
BC Hydro's inventory of potential resources is used as a planning tool and is indicative in nature

- BC Hydro maintains an inventory of potential resources to meet future customer demand
- The update of this inventory will inform BC Hydro's next Integrated Resource Plan (IRP)
- This document presents the draft technical and financial results of the generation supply options update for review and comment

We are reviewing draft results

We've undertaken an engagement process to update our technical and financial attributes for our Resource Options Inventory

Please visit our website for more information:
www.bchydro.com/supplyoptions



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Purpose and outline

This document summarizes the draft findings and invites feedback on the technical and financial characteristics of generation supply-side options in B.C.

This document includes:

- A note about COVID-19 impacts
- Scope and approach of the generation supply-side options update
- Findings from technical engagement workstreams to update **evolving** resources
- Findings from the targeted updates of **existing database** resources
- Summary of draft results
- Approach to monitoring **emerging** resources and technology change
- How to comment on these draft results

COVID-19 impacts on this update

The near-term impact of COVID-19 on global generation development has been severe, and the long-term impacts are uncertain

- In 2020, COVID-19 has brought a freeze in renewable developments due in part to challenges in logistics and sourcing of components; difficulty in mobilizing labour and construction; cancellations of auctions or procurements; and developers taking a ‘wait and see’ approach
- In 2021–2022, a slow recovery in development is anticipated due to continued market uncertainty and weak financial situations for developers
- Post 2022, there is a potential return to renewable generation growth, although government supports may be reduced due to financial constraints
- In the long term, the rate of growth may return to pre-COVID projection levels

COVID-19 impacts on this update

We're assuming global generation resource development industry will be structurally maintained over the long term

- In the near-term period, the uncertainty in project development processes makes it nearly impossible to confidently estimate the costs of resource development.
- In the long term, any lowering of power demand will result in deferrals of planned projects and reduction in the growth of new installations
- At the current time, BC Hydro assumes:
  - Our resource option work is likely to be a reasonable long-term projection
  - Potential effects of COVID-19 on resource costs will be examined through sensitivity analysis and monitoring

Scope and approach to update

Scope of update

Our efforts focus on resources that have seen recent material changes (evolving) and ensure a breadth of coverage of resource options (emerging)

List of generation supply-side options that have been updated

Evolving	Existing database	Emerging
Solar, Wind, Batteries		

Solar
- Utility & community scale
- Customer scale

Wind

Batteries
- Utility scale
- Customer scale

- Geothermal
- Run-of-river hydro
- Biomass
- Municipal solid waste
- Pumped storage
- Natural gas

Next generation:
- New forms of Solar or Storage
- Pre-commercial Renewable Technologies e.g. Marine
- Emerging Customer distributed generation e.g. vehicle to grid

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Approach to update

Our update process includes literature reviews and research, as well as technical workstreams to get feedback from experts

Starting Point

Latest Resource Options Inventory (2015)

Literature & Research

Updates were made based on changes in factors such as:

- Technology
- Fuel availability
- Modelling of resource potential
- Capital costs

The update process may result in changes to estimates of resource potential, location and costs of resource options

Technical Workstreams

Review of assumptions and estimates through technical workstreams for the following resources:

- Solar
- Wind
- Batteries

For details, see our engagement materials

Technical and financial analysis yields unit energy costs based on energy production and costs discounted at 6% (nominal)

Output

Estimates of Annual Energy (GWh) or Capacity (MW)

Measures of financial performance (e.g. $/MWh)

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Financial performance of energy resources

UEC (unit energy cost) is a measure of the levelized cost of energy generated over the life of an asset, with at-gate and POI (point of interconnection) measure available for review

UEC at gate

- What it is – the unit cost of energy produced over the life of the generator measured at the plant gate
- The unit cost of energy at gate is influenced by the cost of building and maintaining the generator, the amount of energy produced, the life of the asset, and financial assumptions

UEC at POI

- What it is – the simple cost of energy produced over the life of the generator measured at the POI that includes the cost of interconnection to the grid
- This number includes costs that are generally incurred by the developer

Adjusted UEC

- What it is – the cost of energy produced over the life of the generator that takes into account the cost of interconnection, and adjusted for locational and other characteristics of the energy to allow for more of an apples-to-apples comparison between different energy resources from the point of view of the ratepayer
- Adjusted UEC not currently available for review

Financial performance of capacity resources

Capacity resources vary in technical capabilities making comparisons difficult, and thus we are showing their capital and OMA (operations, maintenance & admin) costs for review

Capital and OMA Costs

- Describes the upfront and ongoing costs per MW of generation capacity
- Does not account for differences in potential maximum duration of generation or how the resource may be dispatched over a given year

UCC

- Describes the UCC (unit cost of capacity), which is the levelized cost of dependable capacity taking into account the contribution to meeting peak demand
- UCC not currently available for review

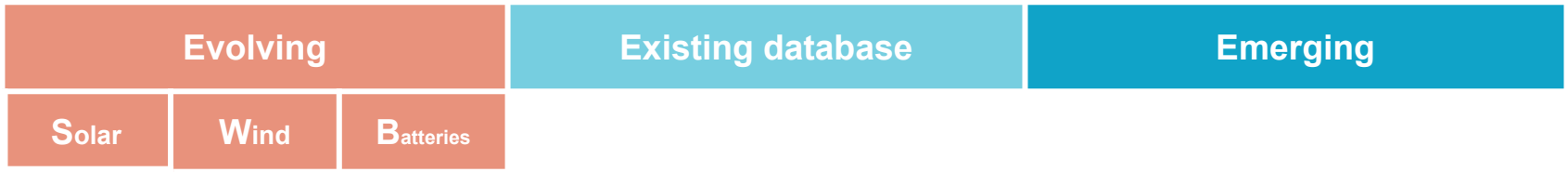
Adjusted UCC

- Describes the levelized cost of dependable capacity taking into further account the additional costs and benefits of optimized utilization in the grid, i.e. accounting for any fuel costs, energy storage round trip efficiency, secondary or tertiary system benefits etc.
- Adjusted UCC not currently available for review

Draft Results

Presenting the results

We will present the results in order of category: evolving, existing and emerging



These resources have seen material changes in cost or performance in recent years

Our update for these resources builds on previous research

These resources are characterized qualitatively

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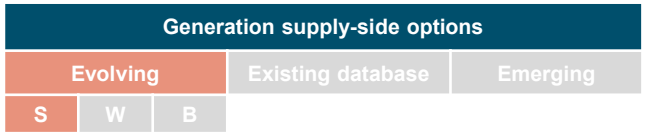
Evolving resources

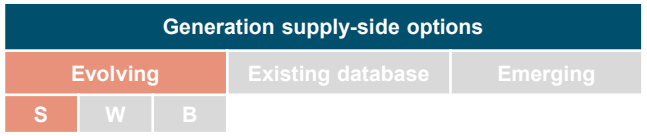
Solar	Wind	Batteries



Solar resources – three categories

Solar resources have been categorized as ‘utility scale’, ‘distributed scale’ and ‘customer scale’

- Solar resources can be differentiated based on scale, mounting system, and where they are located on the grid:
  - **Utility scale** – typically ranging from 15 MW to 500 MW in size, mounted on the ground, and delivering energy directly to the bulk transmission system
  - **Distributed scale** – typically ranging from 1 MW to 15 MW in size, mounted on the ground, and delivering energy into the distribution system
  - **Customer scale** – typically between 5 kW to 250 kW in size, mounted on building rooftops, and delivering energy directly to a customer to offset their load
- Each category has different costs and performances, and has been analyzed individually



Solar – Utility scale

Technical workstream engagement produced working assumptions on the technical and financial parameters for utility scale solar

Methodology

- Technically viable solar resources were defined based on GIS analysis of land use type (e.g. excluding heavily forested areas), terrain (e.g. excluding steep mountain areas), and distance from the existing transmission system
- The National Renewable Energy Laboratory's System Advisory Model (SAM) was used to estimate the hourly solar insolation and model solar generation capabilities for each technically viable resource in B.C.

Key Assumptions

- Solar projects are assumed to be ground mounted with single axis tracking, using monocrystalline passivated emitter and rear cells (PERC)
- In general, capital costs are in line with U.S. average capital costs
- In general, operation and maintenance costs are in line with U.S. average costs, with the exception of B.C. specific property taxes

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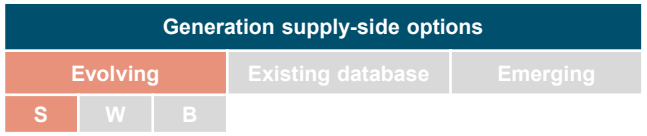

Solar – Utility scale results

We found 194 discrete utility scale solar options based on GIS analysis. There are likely some additional small-scale potential resources in local solar hotspots that could be viable.

TECHNICAL

Number of resource options	194
Average of installed capacity (MW)	75
Average of average annual energy (GWh/yr)	123
Sum of installed capacity (MW)	14,627
Sum of annual firm energy (GWh/yr)	23,775

FINANCIAL

Capital cost min $/kW	$1,910
Capital cost max $/kW	$2,132
OMA cost ($/kW-yr)	$36

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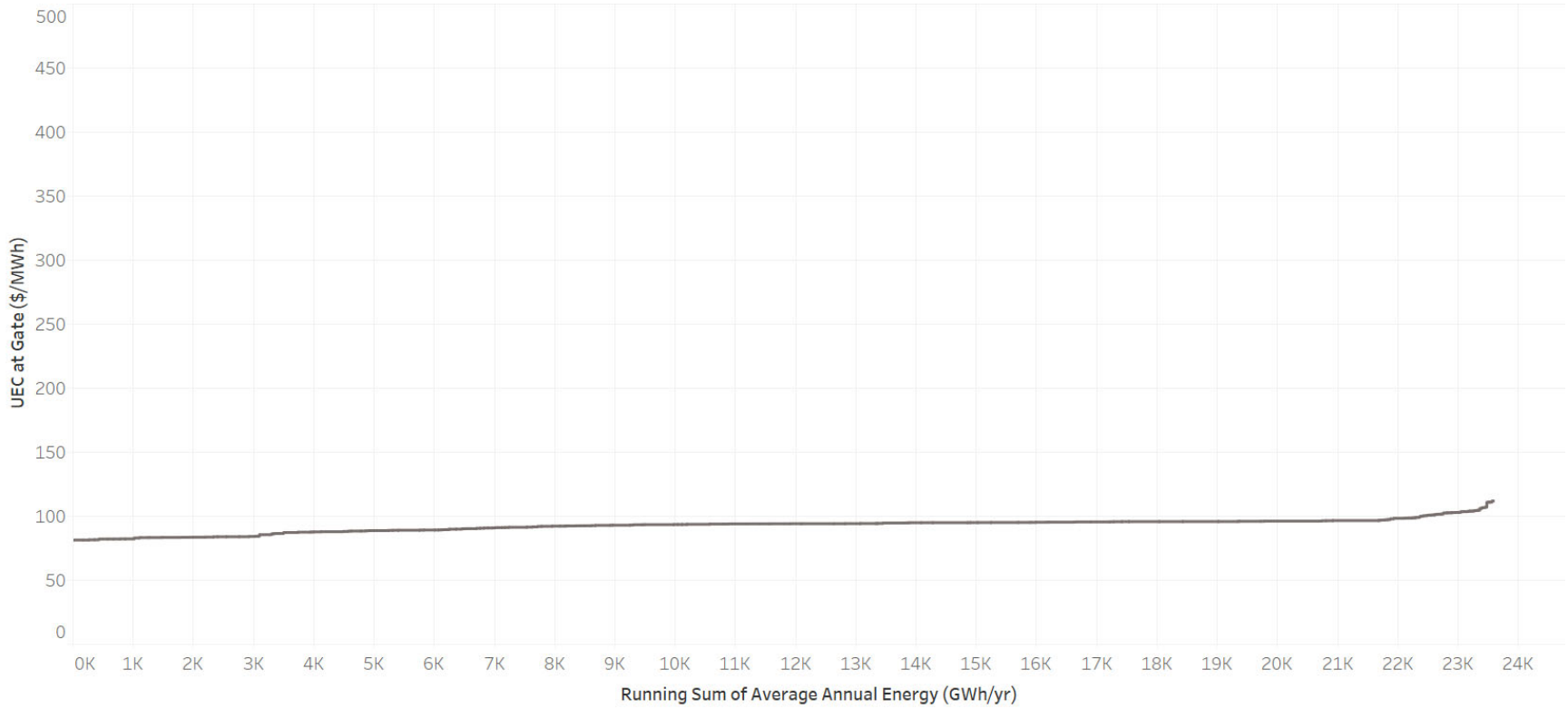
Generation supply-side options			
Evolving		Existing database	Emerging
S	W	B	

Solar – Utility scale solar UEC at gate

At-gate UEC ranges from $81/MWh to $112/MWh



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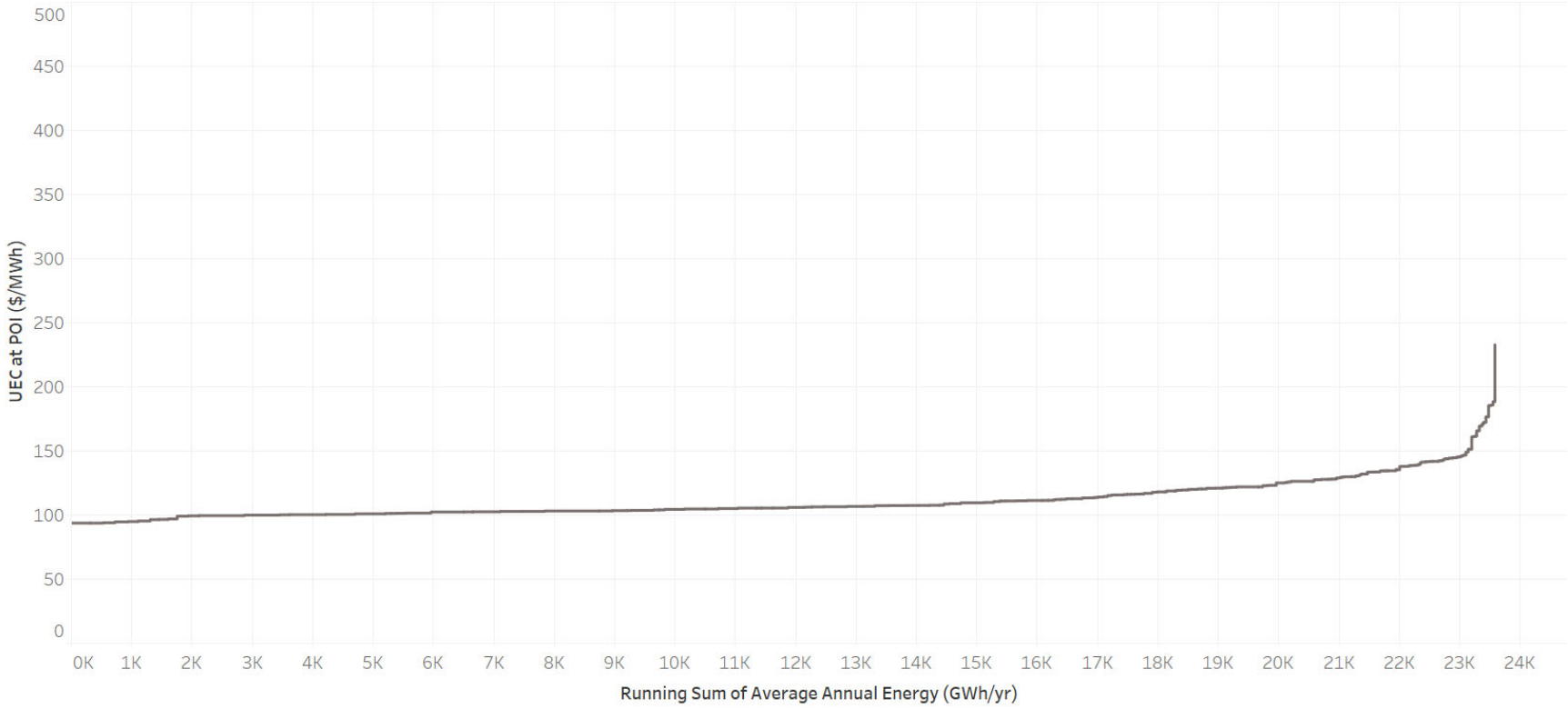
Generation supply-side options			
Evolving		Existing database	Emerging
S	W	B	

Solar – Utility scale solar UEC at POI

UEC at POI ranges from $94 - $233 / MWh



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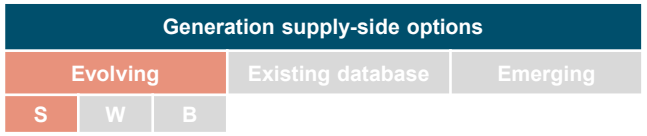


Solar – Distributed scale

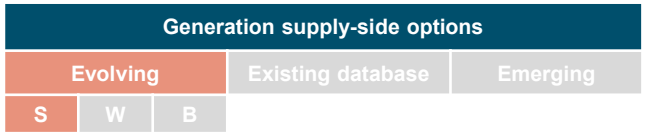
While smaller distribution-connected resources will have higher costs relative to utility scale, inclusion of this resource is important for regional planning

Methodology

- Technically viable solar resources were defined based on GIS analysis of available land in urban areas
- A high-level review of distribution system carrying capabilities was used to filter out resources that are likely not feasible due to costly system upgrades required for interconnection
- National Renewable Energy Laboratory's System Advisory Model (SAM) was used to estimate the hourly solar insolation and model solar generation capabilities for each viable resource

Key Assumptions

- In general, capital costs were in line with U.S. average capital costs for distributed scale resources
- In general, operation and maintenance costs were in line with U.S. average costs, with the exception of B.C. specific property taxes
- There is a wide variability in land acquisition costs between resources, which will not be fully captured in this assessment



Solar – Distributed scale results

We found 59 discrete distributed scale solar options are available across B.C.

TECHNICAL

Number of resource options	59
Average of installed capacity (MW)	8
Average of average annual energy (GWh/yr)	12
Sum of installed capacity (MW)	444
Sum of annual firm energy (GWh/yr)	721

FINANCIAL

Capital cost min $/kW	$2,586
Capital cost max $/kW	$2,586
OMA cost ($/kW-yr)	$36

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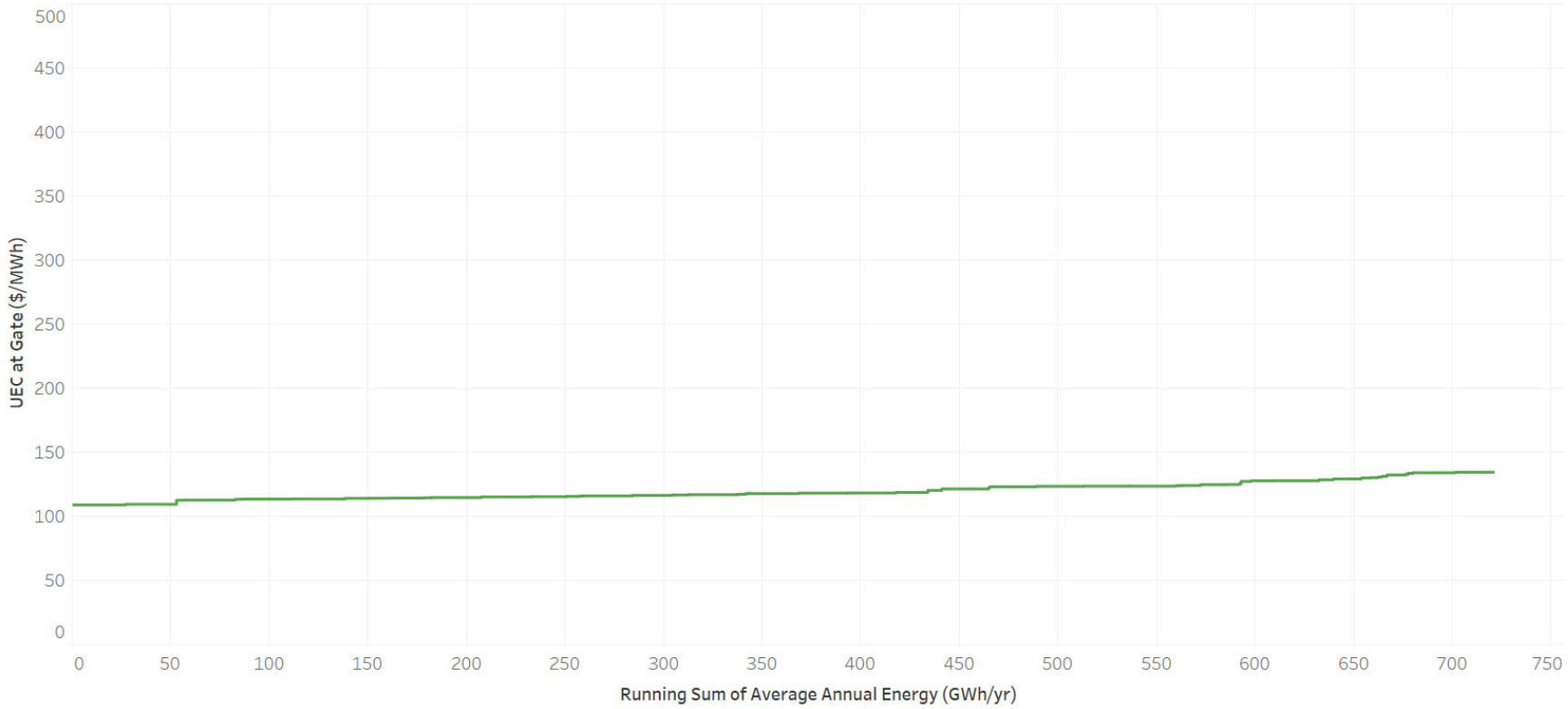
Generation supply-side options		
Evolving	Existing database	Emerging
S W B		

Solar – Distributed scale solar UEC at gate

At-gate UEC ranges from $109 – 135 / MWh



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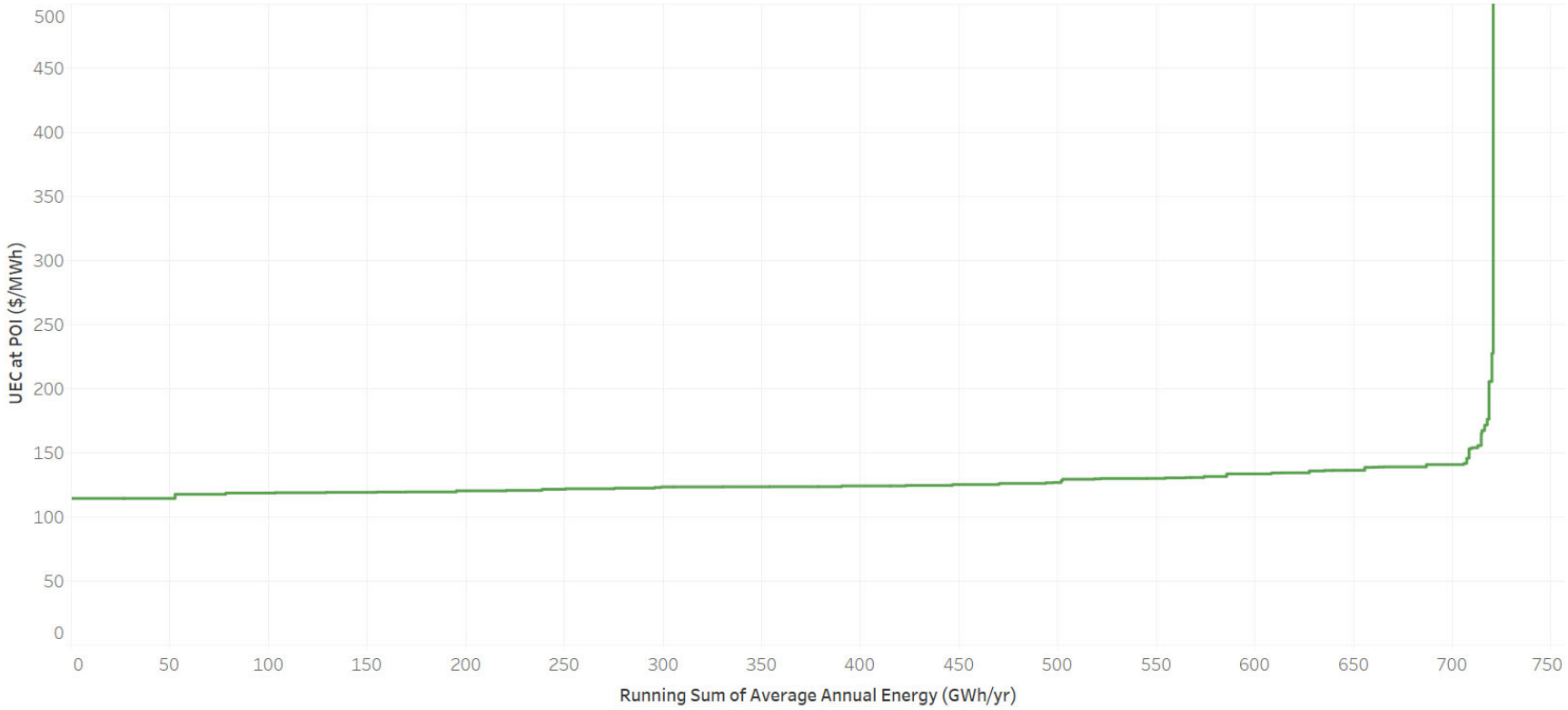
Generation supply-side options			
Evolving		Existing database	Emerging
S	W	B	

Solar – Distributed scale solar UEC at POI

UEC at POI ranges from $115 – 545 / MWh



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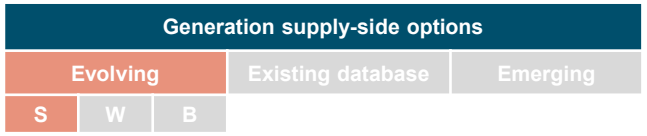


Solar – Customer scale

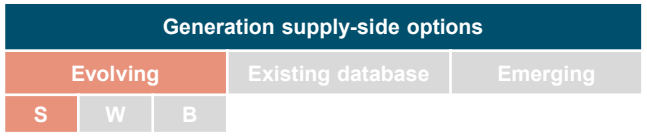
The costs of customer-scale solar resources are estimated based on input from BC-based installers of customer scale solar resources

Methodology

- Generation characteristics of customer-scale resources was modelled using NREL's SAM and a single representative solar resource based on generic residential and commercials rooftops in Victoria

Key Assumptions

- In general, capital costs for smaller systems are lower than the U.S. average capital costs
- In general, customers are assumed to pay lower OMA costs over the life of their systems relative to reported values from U.S. jurisdictions
- For context, the technical potential for customer solar has been estimated at ~6 GW, if every customer with suitable rooftop space adopted solar



Solar – Customer scale results

We found residential or commercial customer solar have estimated capital costs of $2.63 per watt and $2.37 per watt installed respectively

TECHNICAL

	Res	Com
Number of resource options	n/a	n/a
Average of installed capacity (MW)	0.006	0.025
Average of average annual energy (GWh/yr)	0.0067	0.0279
Sum of installed capacity (MW)	n/a	n/a
Sum of annual firm energy (GWh/yr)	n/a	n/a

FINANCIAL

	Res	Com
Capital cost min $/kW	$2,630	$2,370
Capital cost max $/kW	$2,630	$2,370
Cost of Energy ($/MWh)	$215	$195

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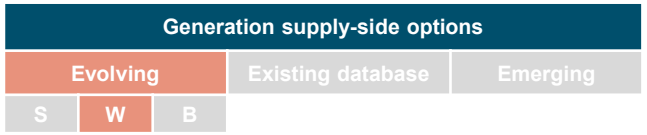
Evolving resources

Solar	Wind	Batteries



Wind – Onshore

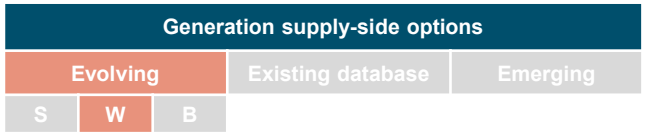
Turbine costs and performance were updated

Methodology

- Analysis based on potential projects identified in the 2009 BC Hydro Wind Data Study and the 2009 BC Hydro Wind Data Study Update
- Installed capacity for each project was left unchanged, but average annual energy for each site was updated by developing generic power curves for leading edge turbines based on information from multiple turbine manufacturers

Key Assumptions

- In general, wind projects will utilize a series of 5 MW turbines with a 110 m hub height
- Capital and OMA cost information updated from 2015 based on
  - 2018 Hatch review of 2015 cost study
  - 2019 Wind Technology Market Report



Wind – Onshore results

The capital costs of onshore wind resources range from $1,962 to $2,827 / kW

TECHNICAL

Number of resource options	122
Average of installed capacity (MW)	129
Average of average annual energy (GWh/yr)	406
Sum of installed capacity (MW)	16,050
Sum of annual firm energy (GWh/yr)	50,317

FINANCIAL

Capital cost min $/kW	$1,962
Capital cost max $/kW	$2,827
OMA cost ($/kW-yr)	$60

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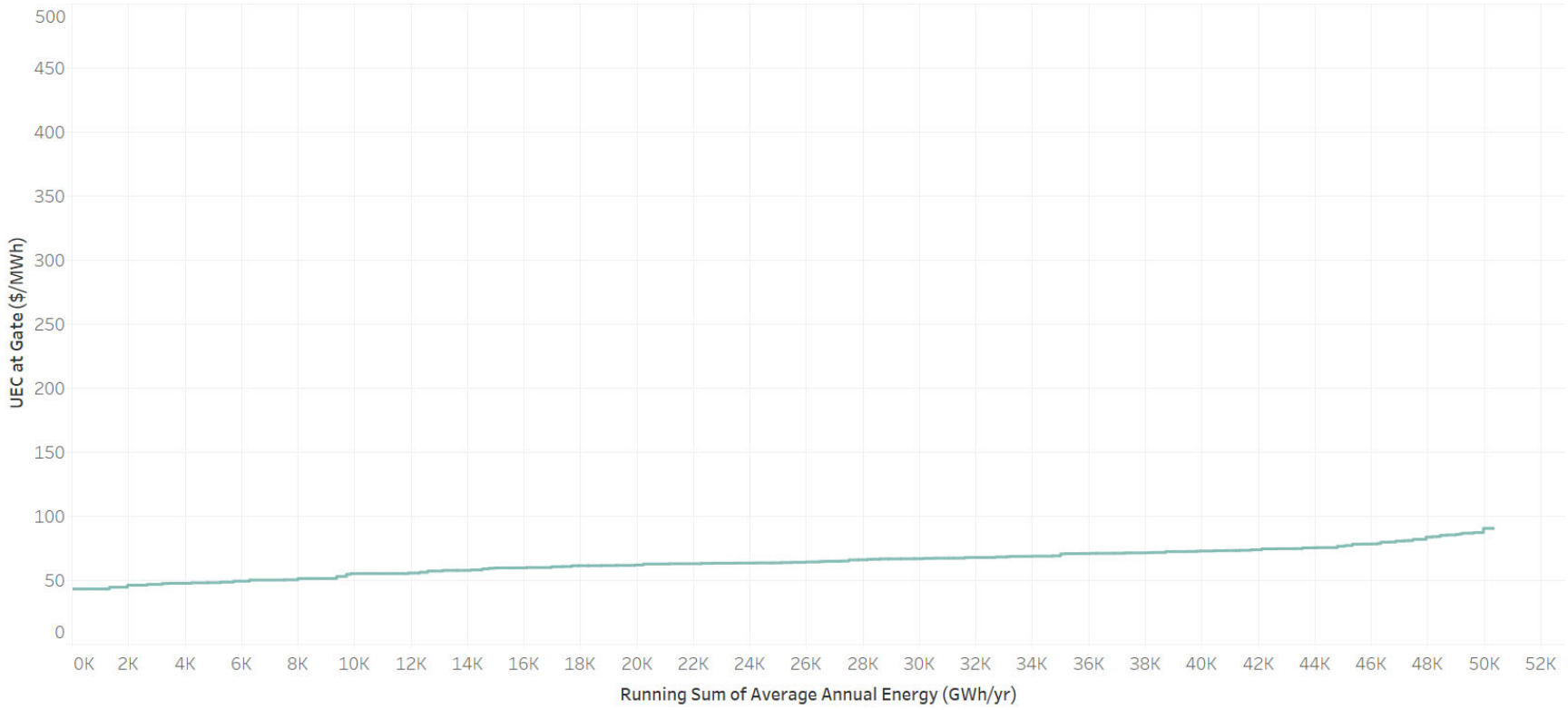
Generation supply-side options			
Evolving		Existing database	Emerging
S	W	B	

Wind – Onshore UEC at Gate

UEC at gate ranges from $45 to $93 / MWh



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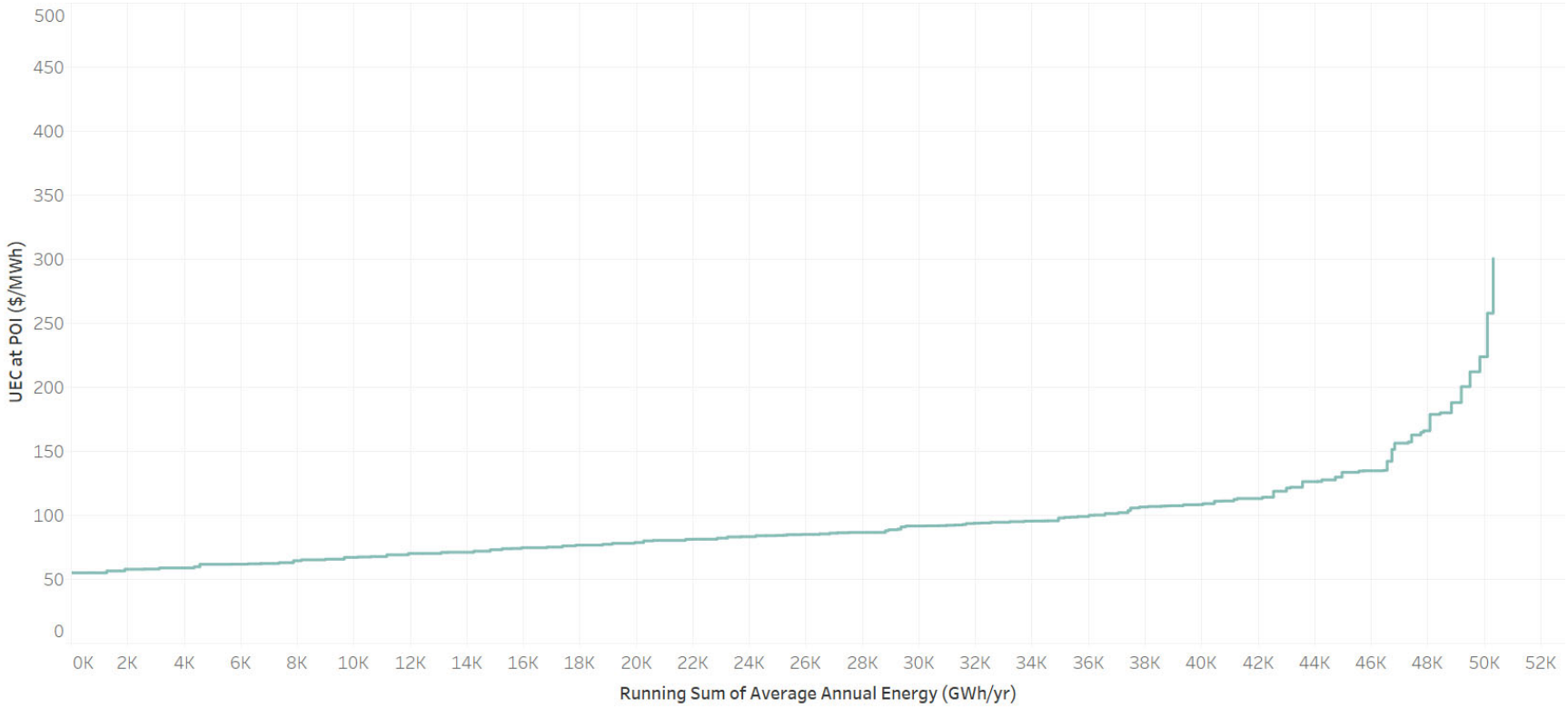
Generation supply-side options			
Evolving		Existing database	Emerging
S	W	B	

Wind – Onshore UEC at POI

UEC at POI ranges from $55 to $300 / MWh



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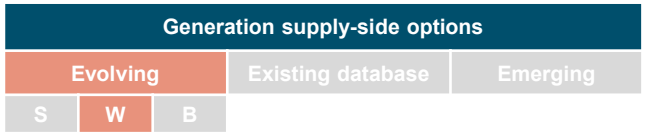


Wind – Offshore

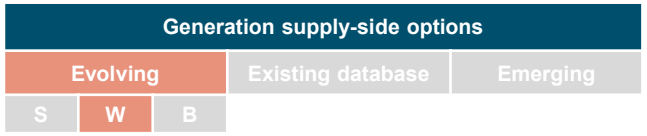
Turbine costs and performance were updated

Methodology

- Analysis is based on potential projects identified in the 2010 and 2013 Resource Options Updates
- Annual energy production was estimated using wind speeds from the Canadian Wind Atlas extrapolated to a hub height of 110 m and updated power curve information received from turbine manufacturers

Key Assumptions

- Off-shore wind plants limited to water depths less than 40 m
- Excludes marine protected areas and shipping routes and assumes that there are no conflicts with offshore petroleum tenures
- Maximum area covered by each wind plant limited to 83 km^2
- Installed capacities were determined based on updated turbine density (0.55 turbine/km2)
- UECs at gate were calculated based on updated capital and OMA costs



Wind – Offshore results

The capital costs of offshore wind resources range from $3,802 to $4,759 / kW

TECHNICAL

Number of resource options	43
Average of installed capacity (MW)	320
Average of average annual energy (GWh/yr)	1,222
Sum of installed capacity (MW)	13,750
Sum of annual firm energy (GWh/yr)	52,549

FINANCIAL

Capital cost min $/kw	$3,802
Capital cost max $/kw	$4,759
OMA costs ($/kW-yr)	$158

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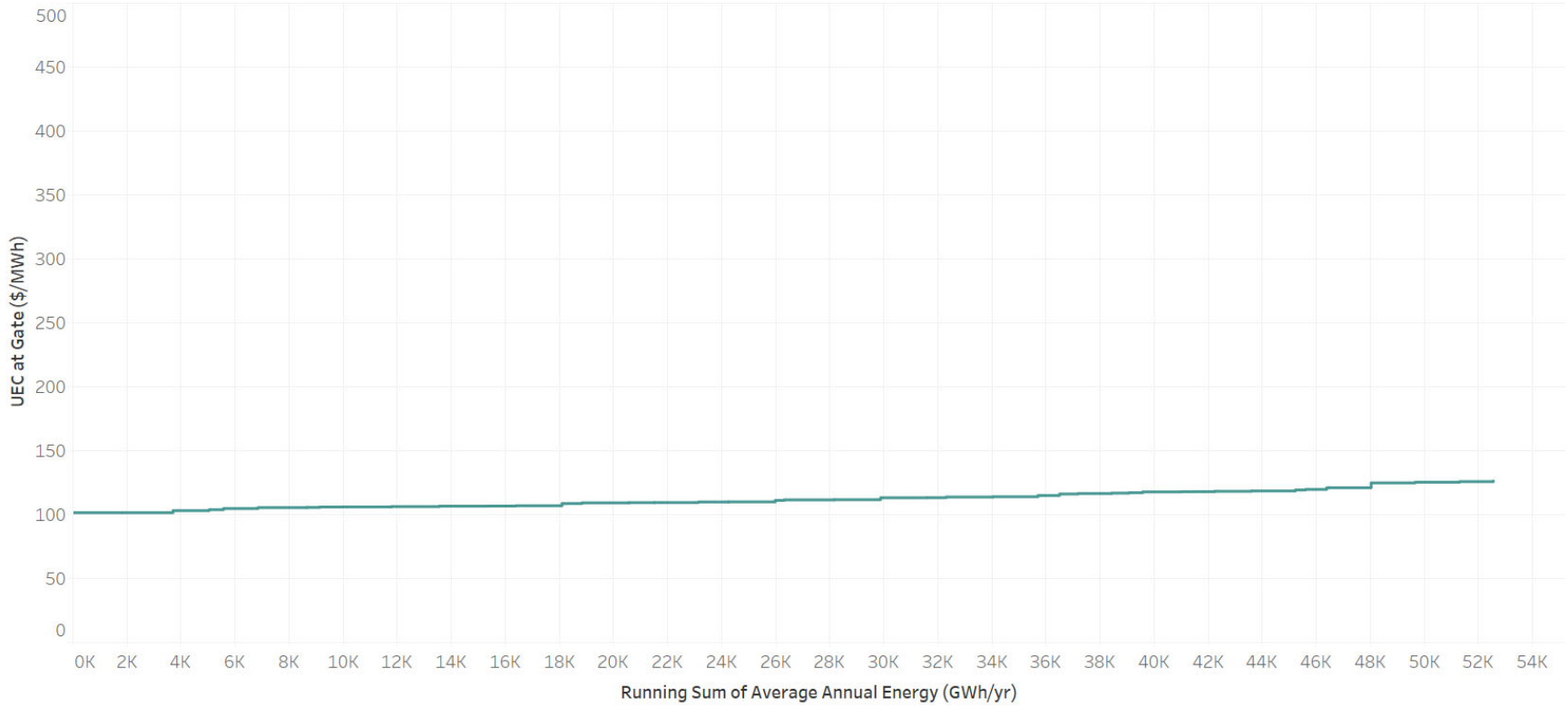
Wind – Offshore UEC at gate

At-Gate UECs range from $102 to $126 / MWh



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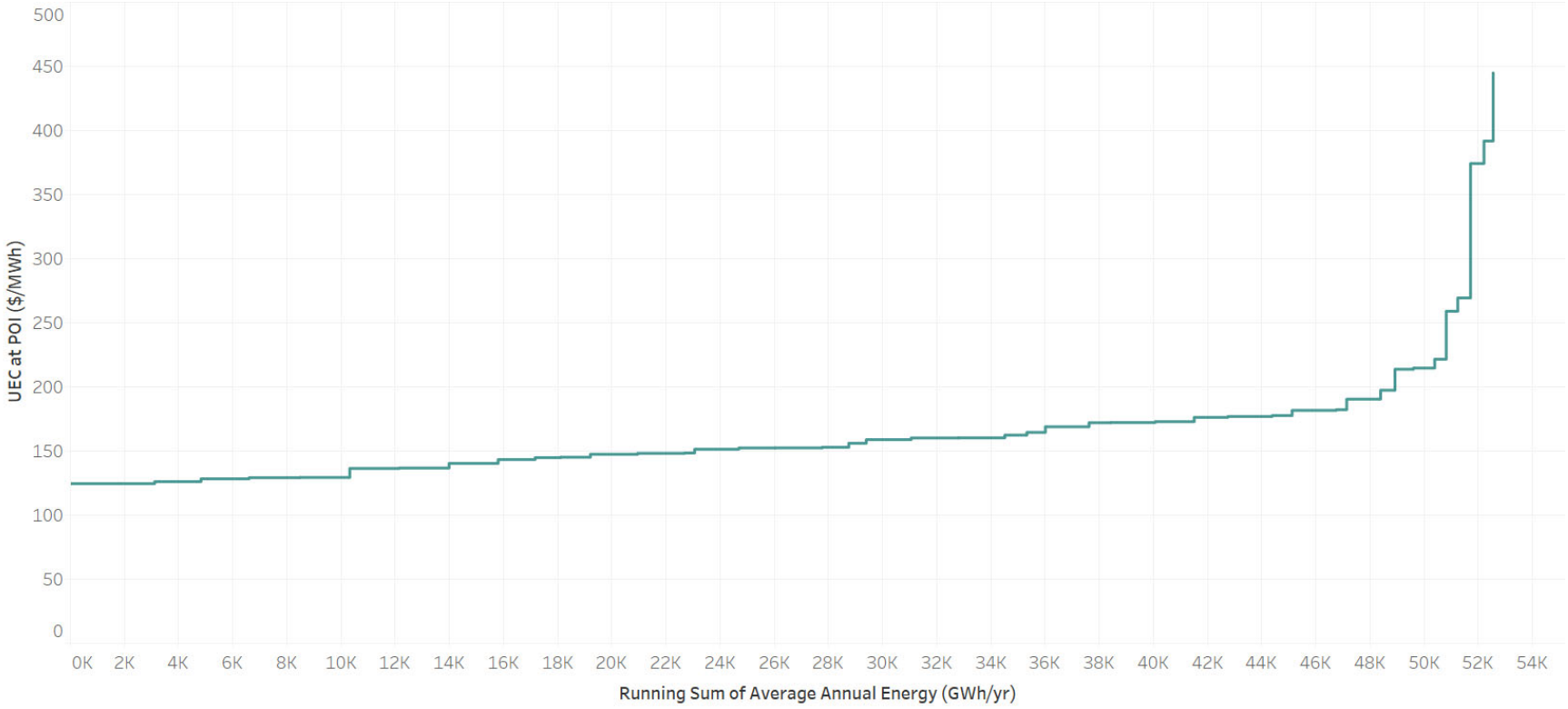
Wind – Offshore UEC at POI

UEC at POI ranges from $125 to $445 / MWh



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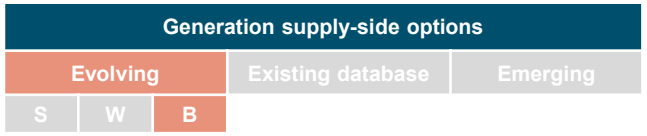
Evolving resources

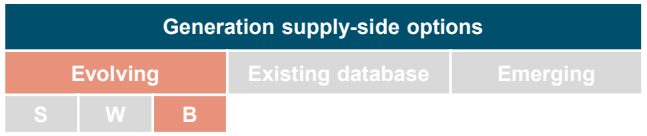
Solar	Wind	Batteries



Batteries

Batteries are generically defined as having a four-hour peak duration, and capable of providing dependable supply capacity during winter peak

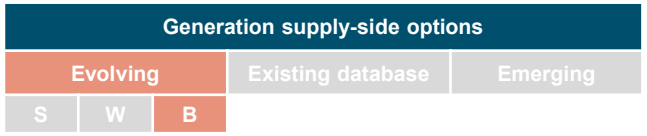
- Relevant battery systems would most likely be located in one of these three grid locations:
  - Transmission connected at existing transmission substation infrastructure
  - Co-located with new transmission-connected renewable generation
  - Distribution connected at existing distribution substation infrastructure
- Both flow battery and lithium ion technology are viable alternatives, although lithium ion is currently more cost competitive
- Compressed air energy storage (CAES) has not yet been appropriately investigated for viability in the B.C. context



Batteries

Three grid configurations of battery systems were evaluated

- **Transmission connected battery** resources are assumed to be located near to existing transmission infrastructure at Burrard, Kelly Lake or Nicola substations
- **Distributed battery** resources are assumed to be located near to or within the perimeter of existing distribution substations, dependent on available space to accommodate the battery systems
- **Co-located battery** resources may be installed alongside new renewable energy resources, e.g. wind or solar, and achieve some cost savings from shared infrastructure such as a shared inverter or shared permitting processes



Batteries results

The capital cost of 4-hour lithium ion battery resources range from $1,581 to $1,900 / kW

TECHNICAL

	Transmission connected	Distributed	Co-located
Number of resource options	54	60	n/a
Average of installed capacity (MW)	50	10	50
Sum of installed capacity (MW)	2700	600	n/a

FINANCIAL

	Transmission connected	Distributed	Co-located
Capital cost ($/kW)	$1,700	$1,900	$1,581
OMA cost ($/kW-yr)	$52	$55	$52

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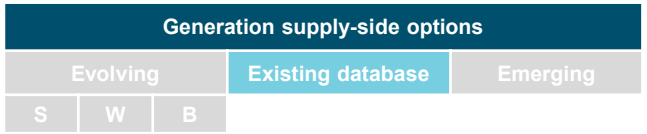
Existing database resources



Existing resources

The table provides a summary of the updates conducted for remaining resources in our existing database

Biogas	Biogas resources removed from inventory. Due to competition from procurers of Renewable Natural Gas (RNG), it is assumed that all available biogas resources will be used to produce RNG rather than electricity.
Biomass	Incorporated latest information on fibre potential; escalate costs from base year to 2020.
Geothermal	Updated exploration and equipment costs for low, medium and high temperature resources; update project lead time for B.C. context.
MSW	Updated tipping fees; escalated costs from base year to 2020.
Natural Gas - CCGT	Updated natural gas forecast costs; escalated costs from base year to 2020; investigated potential to use Renewable Natural Gas (RNG) in order to produce GHG-free electricity but costs are estimated to be >$500 / MWh and thus cost prohibitive.
Natural Gas - SCGT	Updated natural gas forecast costs; escalated costs from base year to 2020.
Pumped Storage	Escalated costs from base year to 2020; added additional smaller pumped storage resource options to inventory.
Run-of-River Hydro	Updated water rental fee schedule; escalate costs from base year to 2020.
Small Storage Hydro	Added small storage hydro facilities with a minimum 20 MW capacity to inventory based on 2018 report.

Generation supply-side options				
Evolving			Existing database	Emerging
S	W	B		

Existing resources

Draft update results in new capital and OMA cost estimates for existing resources

	Number of resource options	Average of installed capacity (MW)	Average of average annual energy (GWh/yr)	Sum of installed capacity (MW)	Sum of annual firm energy (GWh/yr)	Capital cost min ($/kw)	Capital cost max ($/kw)	OMA cost min ($/kw-yr)	OMA cost max ($/kW-yr)
Biogas	Resource removed from viable resource options								
Biomass	20	26	203	510	4,066	$6,426	$6,426	$158*	$158*
Geothermal	11	38	238	418	2,618	$5,700	$14,000	$180	$230
Municipal solid waste	3	18	149	54	447	$18,904	$27,925	$1,061**	$1,179**
Natural gas - CCGT	3+	155	951	465	3,668	$1,655	$2,857	$15*	$63*
Natural gas - SCGT	3+	113	179	340	n/a	$979	$1,784	$5*	$19*
Pumped storage	287	792	n/a	227,200	n/a	$1,460	$8,905	$9*	$74*
Run-of-river hydro	7,088	2	7	16,303	39,401	$1,592	$89,771	$31*	$1,795*
Small storage hydro	16	60	251	n/a	n/a	$3,607	$8,240	$72*	$165*

• - not including fuel costs or other variable OMA costs
** - not including revenues associated with tipping fees

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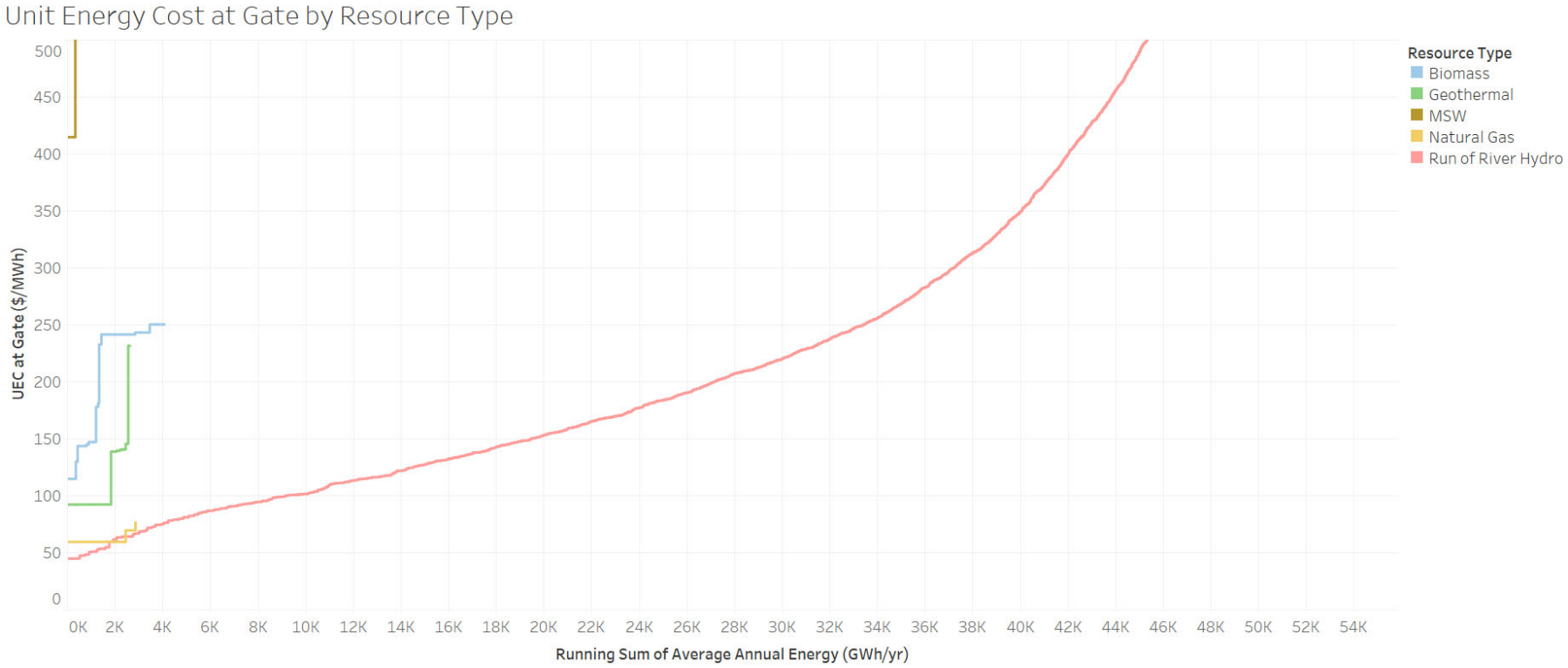
Generation supply-side options				
Evolving			Existing database	Emerging
S	W	B		

Existing resources – UEC at gate

Run-of-river hydro and natural gas combined cycle turbines offers abundant energy at a UEC at gate as low as ~$50 / MWh



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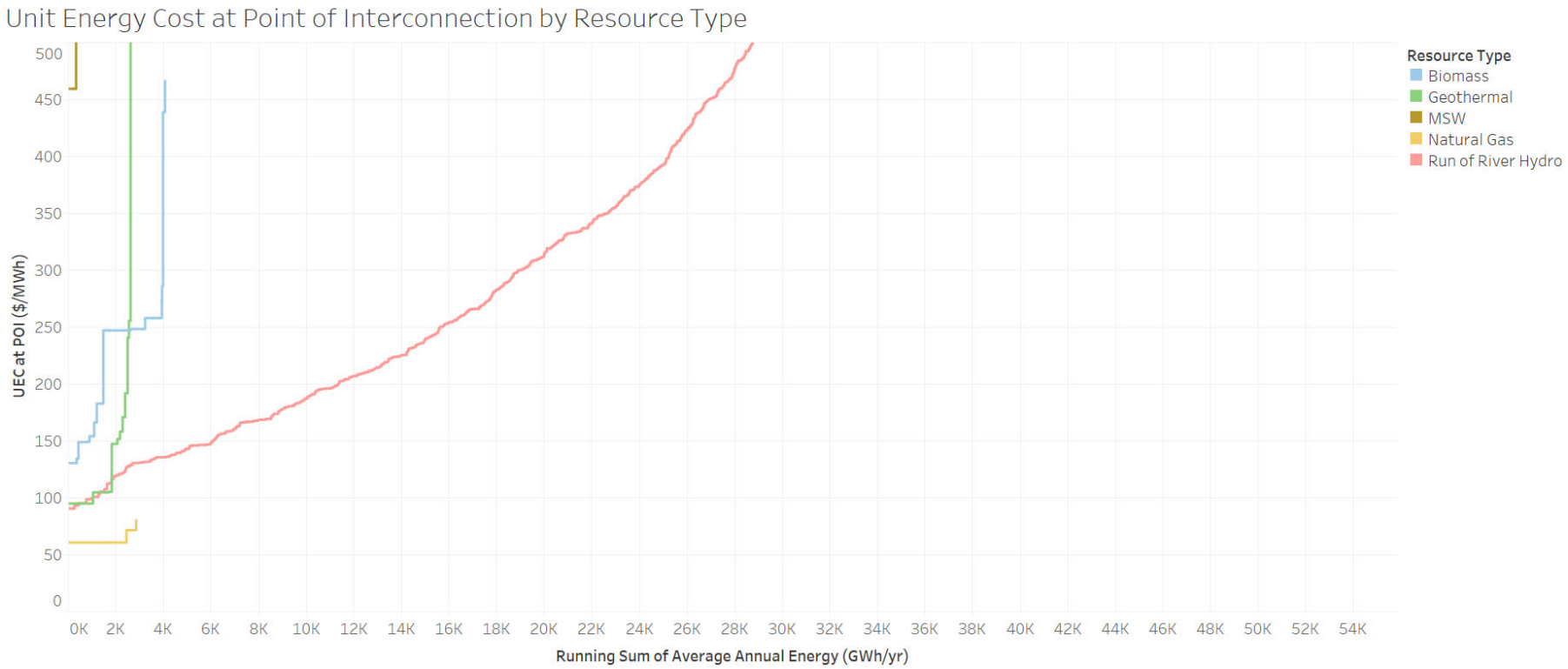
Generation supply-side options				
Evolving			Existing database	Emerging
S	W	B		

Existing resources – UEC at POI

After accounting for interconnection costs, only natural gas combined cycle turbines offer energy at a UEC less than $90/MWh



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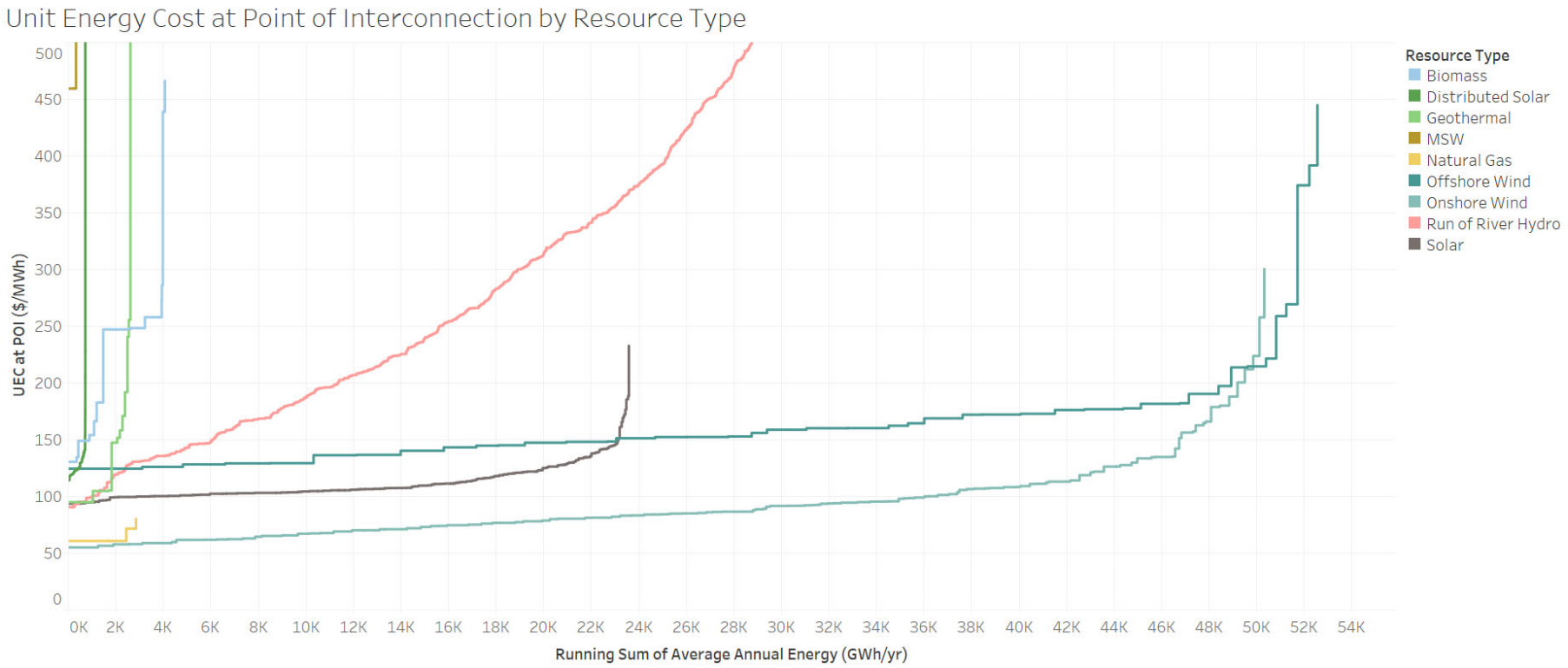
Generation supply-side options			
Evolving			Existing database	Emerging
S	W	B		

Comparison of all energy resources – UEC at POI

Among renewable energy alternatives, onshore wind shows the lowest cost energy based on UEC at POI



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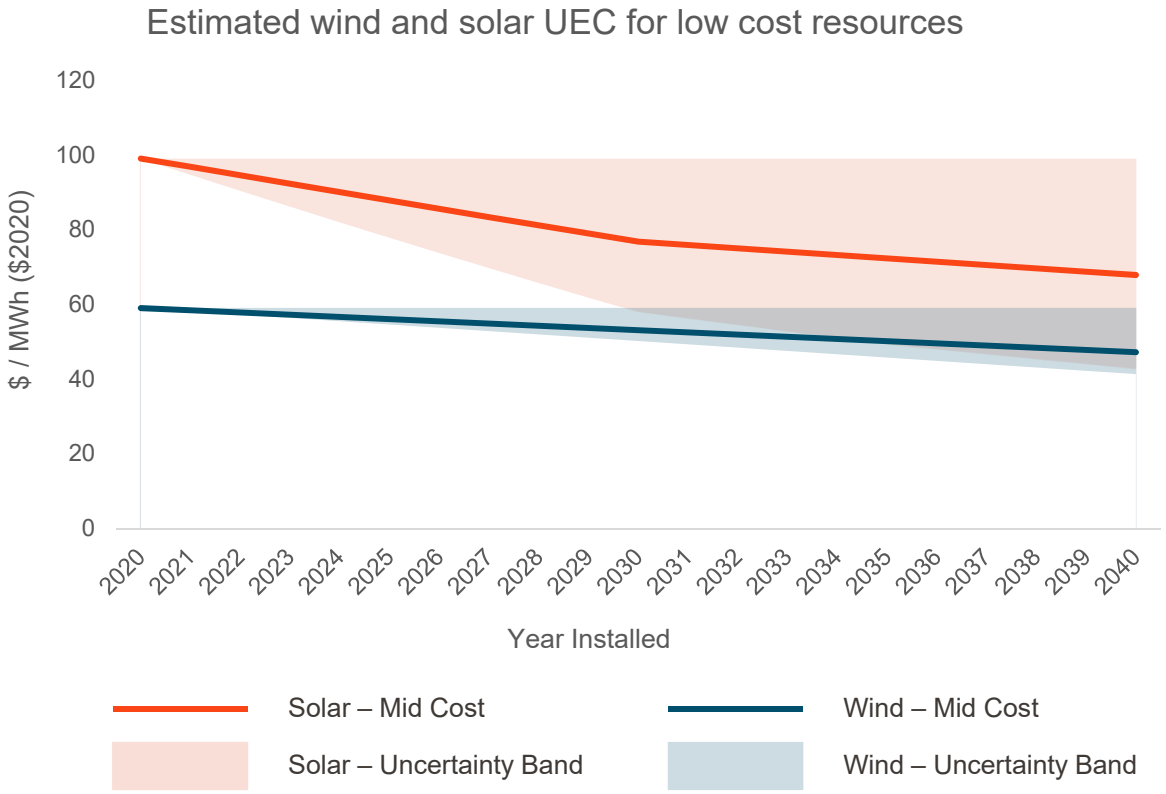
Generation supply-side options					
Evolving			Existing database	Emerging	
S	W	B			

Projecting cost declines

Projecting over the long term, onshore wind resources are likely to remain lower cost than utility scale solar resources based on UEC at POI

- BC Hydro will apply projected technology cost declines described in the National Renewable Energy Laboratory's Annual Technology Baseline report to BC Hydro's 2020 cost estimates for all resources
- Looking at the average cost of the lowest 5000 GWh of wind ($59/MWh in 2020) and solar ($99/MWh in 2020), wind costs are lower in most scenarios out to 2040



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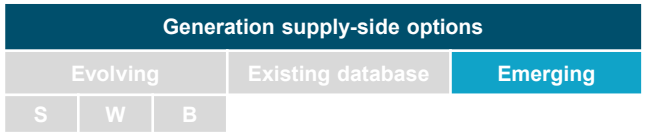
Emerging resources



Emerging – assessing new technologies

We're continuing to monitor an evergreen list of emerging technologies

Emerging solar

- Organic solar cells, floating solar, solar roads

Hydrogen and fuel cells

- Molten carbonate fuel cells, solid-state hydrogen storage, power-to-gas

Emerging storage

- Gravity storage, zinc-air batteries, advanced chemistries

New customer side generation

- Micro-CHP (combined heat and power), vehicle-to-home, vehicle-to-grid

Next generation renewables

- Enhanced geothermal, zero-head hydro / hydrokinetic, floating offshore wind

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We’d like to hear from you

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Your feedback is important to us

- Please email your comments **by June 20, 2020**
  to Alex Tu, Sr. Strategic Technology Specialist, alex.tu@bchydro.com
  - Do you find the costs reasonable? If not, why not?
  - Any further comments?
- We will consider your input as we continue to update our Resource Options Inventory

For more information about resource options,
visit our web page, www.bchydro.com/supplyoptions

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