BC HYDRO & FORTIS BC

RESOURCE OPTIONS UPDATE TECHNICAL ENGAGEMENT – SOLAR

EDMUND LAI

BC hydro
FOR GENERATIONS

March 25, 2015

AGENDA

- Background & Meeting Objectives
- Scope of Study
- Presentation by Compass
- Wrap up/Q&A
- Next Steps/How to Connect

BACKGROUND

Purpose of Resource Options Inventory and Update

- To maintain an accurate, up-to-date understanding of resource potentials, prices and technical capabilities of different technologies in B.C.
- To engage industry associations, equipment manufacturers, suppliers, consultants and others that can provide information important for this process
- To serve as input into BC Hydro and Fortis BC’s long term analysis which further considers the value of these resources as they may be integrated into the system over time

OBJECTIVES AND EXPECTATIONS OF THE MEETING

- Introduce consultant and work to date
- Gather input from industry
  - Technology advancements
  - Project development costs
  - Status of industry in B.C.

SCOPE OF STUDY

- Technology Trends for Solar
- Solar Potential in BC
- Potential sites across BC
- Current and Future Cost of Solar System Components

PRESENTATION BY COMPASS

QUESTIONS/COMMENTS?

NEXT STEPS / HOW TO CONNECT

Next Steps

Comment period – send to Edmund by April 10

Consideration and incorporation of comments – end of April

Contact information

- Edmund Lai Edmund.Lai@bchydro.com
- IRP inbox integrated.resource.planning@bchydro.com

General information and engagement materials

- www.bchydro.com/generationoptions

THANK YOU FOR YOUR INPUT

BC Solar Market Update 2015

Compass Renewable Energy Consulting Inc.

March 25 2015

FIT Expertise – Policy Support – Due Diligence

Overview

1. **Introduction**
2. **Technology Trends for Solar Electrical Energy**
    a. Adoption of Solar Technology
    b. Current Solar Technology Options
        i. Solar: 100 kW to 1 MW
        ii. Solar: 1 MW to 5 MW
        iii. Solar: Over 5 MW
3. **Solar Potential in British Columbia**
    a. Methodology
    b. Technical and Financial Implications
    c. Environmental Characteristics and Development Timelines
    d. Seasonal Variability of Solar Production
4. **Potential Sites Across the IRP Regions**
5. **Current and Future Cost of Solar System Components**
    a. Fixed PV and Tracking PV
        i. Solar Costs: 100 kW to 1 MW
        ii. Solar Costs: 1 MW to 5 MW and Solar Costs: Over 5 MW
    b. Solar Thermal
6. **Conclusions**
    a. Pricing Forecast for BC

1. Introduction

- Compass Renewable Energy Consulting Inc. has prepared this solar market update to BC Hydro and Fortis BC
    - Compass has been involved in supporting Ontario developers and owners of solar assets since 2011
    - Its principals have been involved in the solar industry for over 25 years.
    - Compass has also undertaken US and global market support to clients assessing conditions in other jurisdictions to guide investment decisions
- Goal is to provide a current overview of solar technology and price and performance expectations in British Columbia
- Most market pricing information comes from US and Ontario experience, however the prevalence of solar developers operating globally means that the experience and commodity costs of solar components is transferable to most Canadian jurisdictions

a. Adoption of Solar Technology

- Since 2009, market prices for solar photovoltaic (PV) panels or modules have dropped five-fold
  - System prices dropping three-fold
- Total installed capacity has risen from 23 GW in 2009 to 135 GW at the end of 2013
  - 5.3% of German electrical consumption,
  - 7% of Italian consumption,
  - Over 3% in five other European countries in 2013

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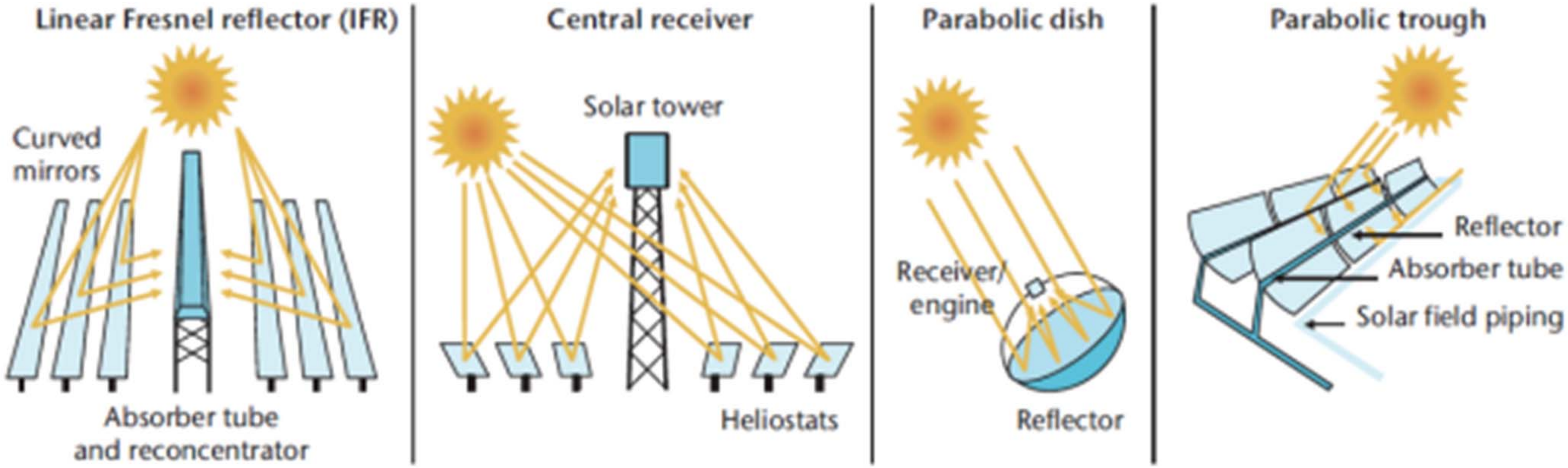
a. Adoption of Solar Technology

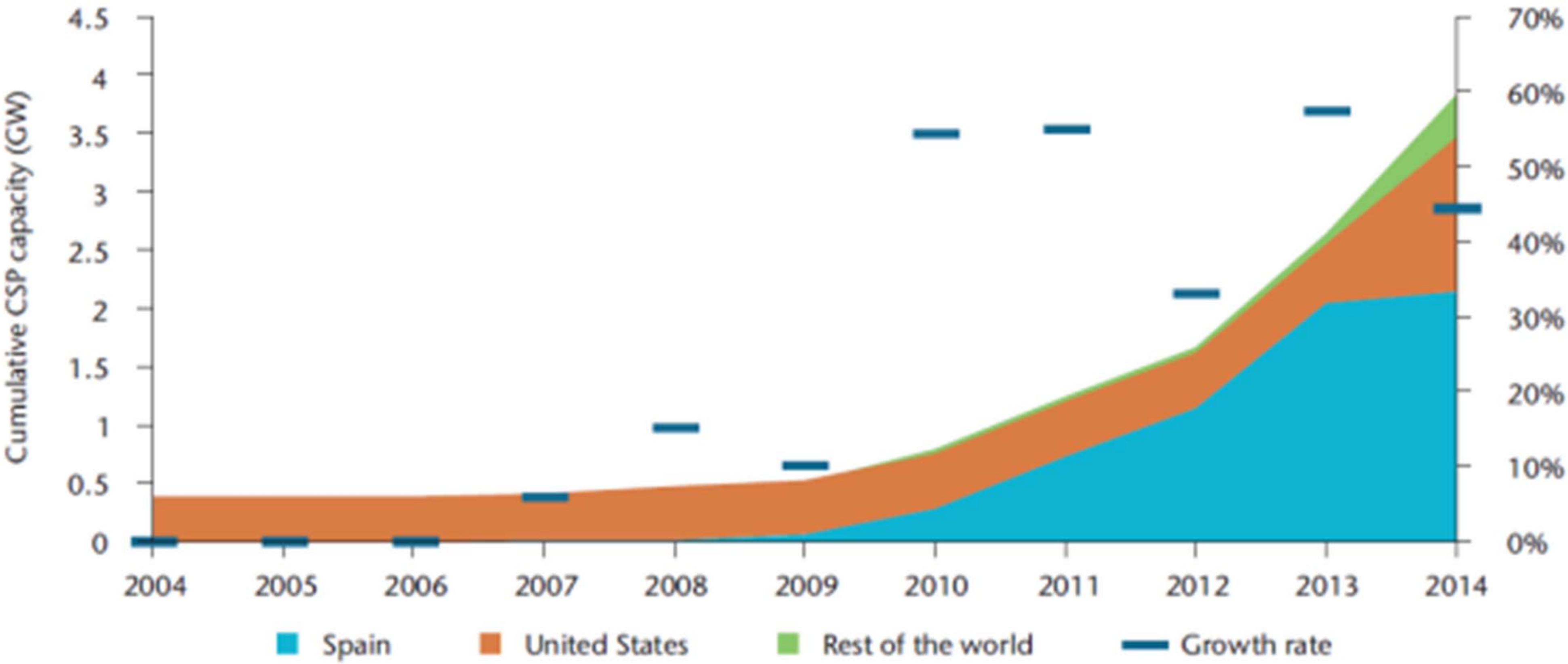
- Where photovoltaic solar technologies convert sunlight to electric current, Concentrating Solar (thermal) Power (CSP) uses the sun to heat a working fluid
  - Has an ability to store thermal energy – reducing intermittence
  - CSP deployment has been much slower than expected since 2009
  - Solar PV has grown much faster

b. Current Solar Technologies

- The main CSP technologies are Linear Fresnel Reflector (LFR), towers (central receivers), Parabolic Dish (PD) and Parabolic Trough (PT)



Global Cumulative Installed Capacity and Growth Rate of CSP (IEA)



b. Current Solar Technologies

- CSP plants with thermal storage may take a greater market share when it is less sunny in geographies
- CSP generally requires good irradiation and often clear skies, compared to solar PV
- Direct Normal Irradiance (DNI) is especially important to CSP facilities because thermal losses and parasitic consumption are nearly constant, whatever the amount of sunshine received by the facility
- Areas with high levels of Direct Normal Irradiance are usually within latitudes from 15° to 40° north or south and thus are less likely to represent a significant opportunity for large scale deployment in British Columbia.

b. Current Solar Technologies

- Solar PV systems use semiconductors to generate direct current electricity
- Solar cells – typically silicon – are sliced from larger wafers or ingots, arranged into modules surrounded by glass on the front and a frame surrounding it
- The larger balance of system components consist of inverters, transformers, wiring, racking and other structural components used for mounting, and potentially also tracking components and monitoring devices

b. Current Solar Technologies

- Thin-film modules are often less efficient than crystalline silicon modules –
  - 15% efficiency for CdTe thin film
  - 19-21% for the best c-Si modules, both in 2013
- The market share of thin-film and standard c-Si cell technologies has been and is expected to continue to drop, as more advanced and efficient c-Si technologies are adopted
- The growth rate of global cumulative solar PV installed capacity has grown by 49% on average since 2003

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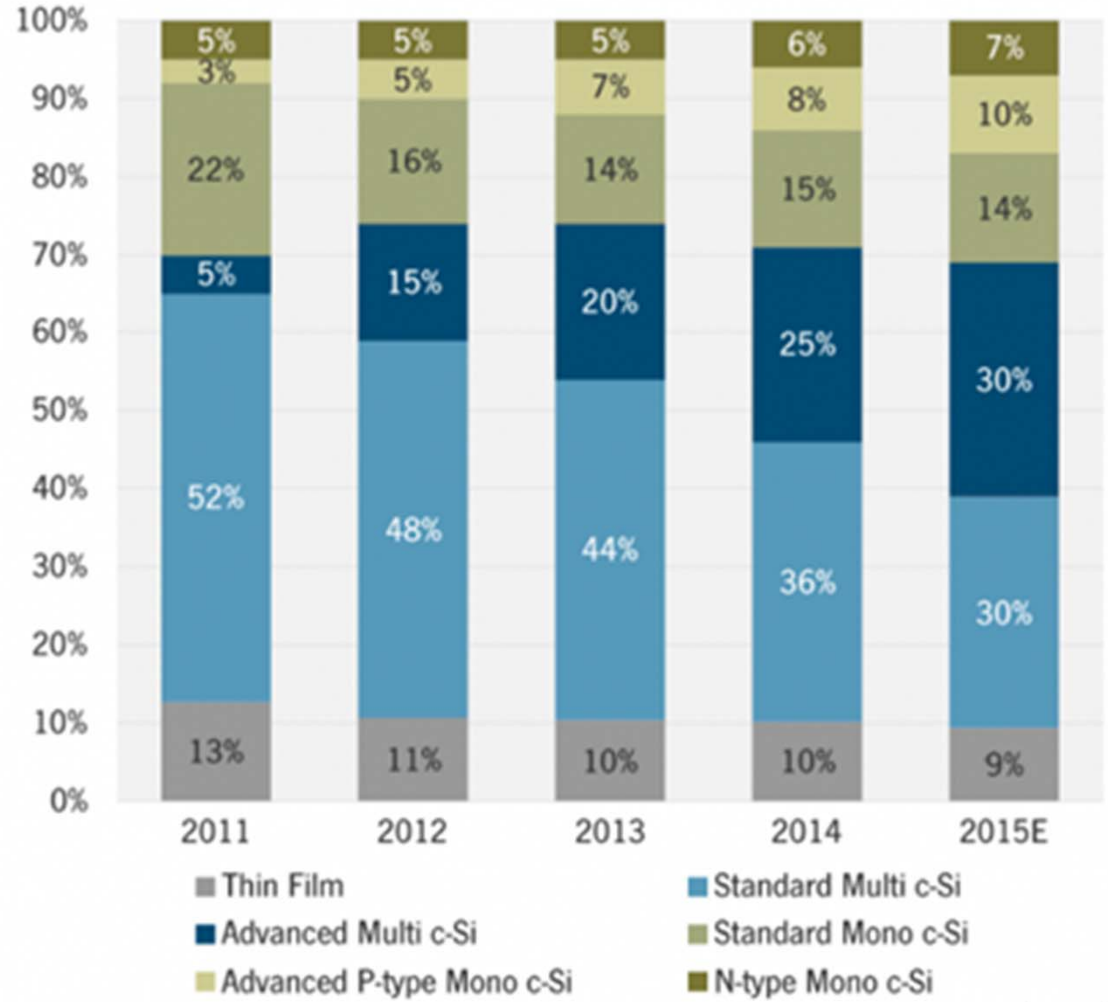
Global PV Market Share by Cell Technology 2011 - 2015 (GTM Research)



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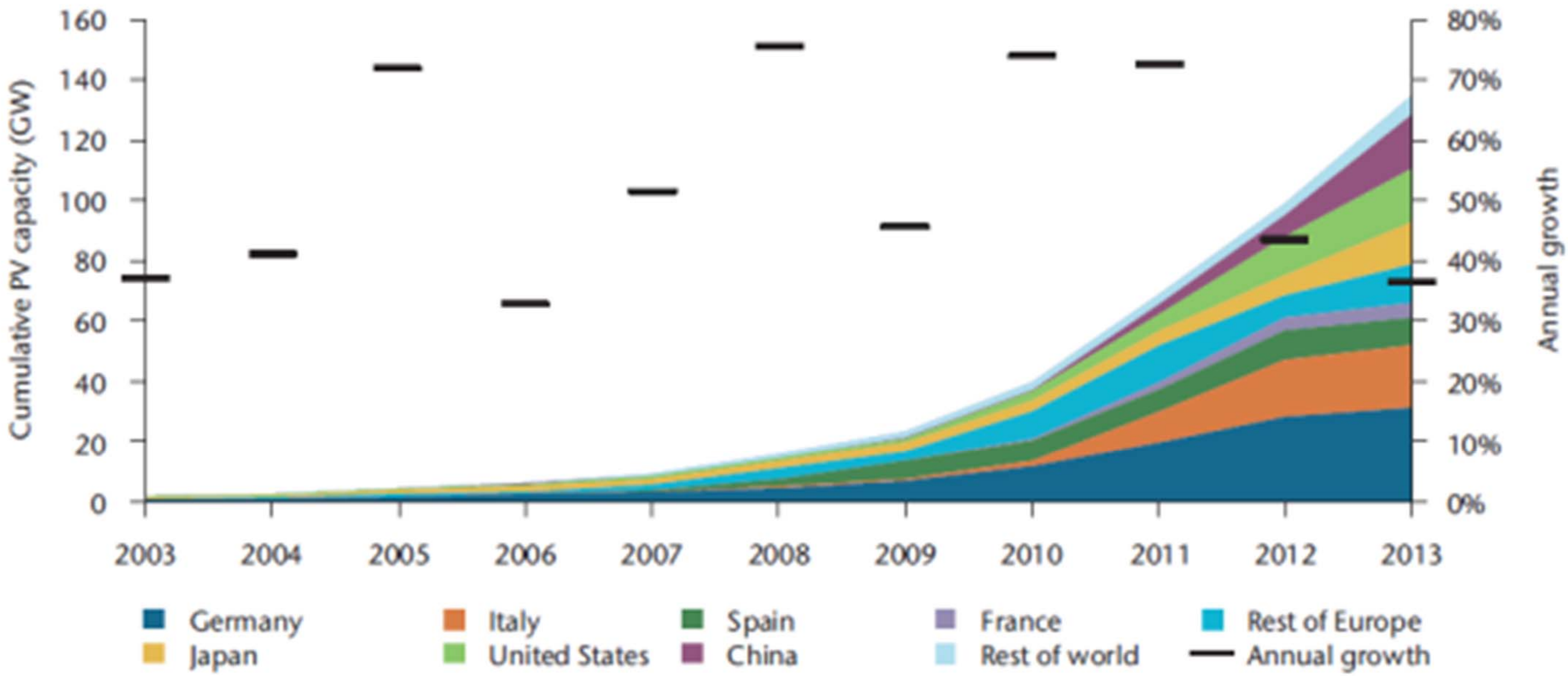
Global Cumulative Installed Capacity and Growth Rate of Solar PV (IEA)



b. Current Solar Technologies
i. Solar: 100 kW to 1 MW

- Solar PV installations in this size category are often distribution connected and often cited near or at the end-user
- Solar PV projects of this scale can be procured under BC's Standing Offer Program (e.g. the Kimberley SunMine project) or alternatively under the BC Hydro Net Metering program
- In many markets, projects of this size are installed on the basis of saving the electricity customer money, through reduced metered consumption at site

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b. Current Solar Technologies
i. Solar: 1 MW to 5 MW

- Solar PV projects of this size are not often designed to offset customer demand, and are at the small end of utility scale projects
- They are more common in jurisdictions that have less available land area for solar farm installations
- Due to interconnection costs, projects in this size category are often distribution connected onto a feeder or directly into a distribution sub-station

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b. Current Solar Technologies
i. Solar: Over 5 MW

- Solar PV installations in this size category are utility scale and can be sized as large as hundreds of MW given suitable available land area and grid connection capability.

- Projects that are 10 MW or greater in this category are often directly connected onto a transmission circuit, depending on the requirements for generator connections in the jurisdiction

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b. Current Solar Technologies
i. Solar: Over 5 MW

- Depending on the project size, a solar PV project of this size may be located on a single property or spanning multiple properties, and would require approximately 5.5 acres of land per MW
- Projects of this size and cost typically require a long term PPA with a utility for financial support
- CSP projects average 60 MW in appropriate climates

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a. Methodology

- Two sources of solar irradiation data were used in assessing and comparing the solar resource in different parts of British Columbia, NRCan (Cartes PV Maps) and PVWatts
- NRCan's maps describe a solar system in kWh/kW/a featuring a fixed axis, tilt equal to the system's latitude, and azimuth of due South (180 degrees)
- PVWatts does the same but can also analyze fixed, single and dual axis trackers

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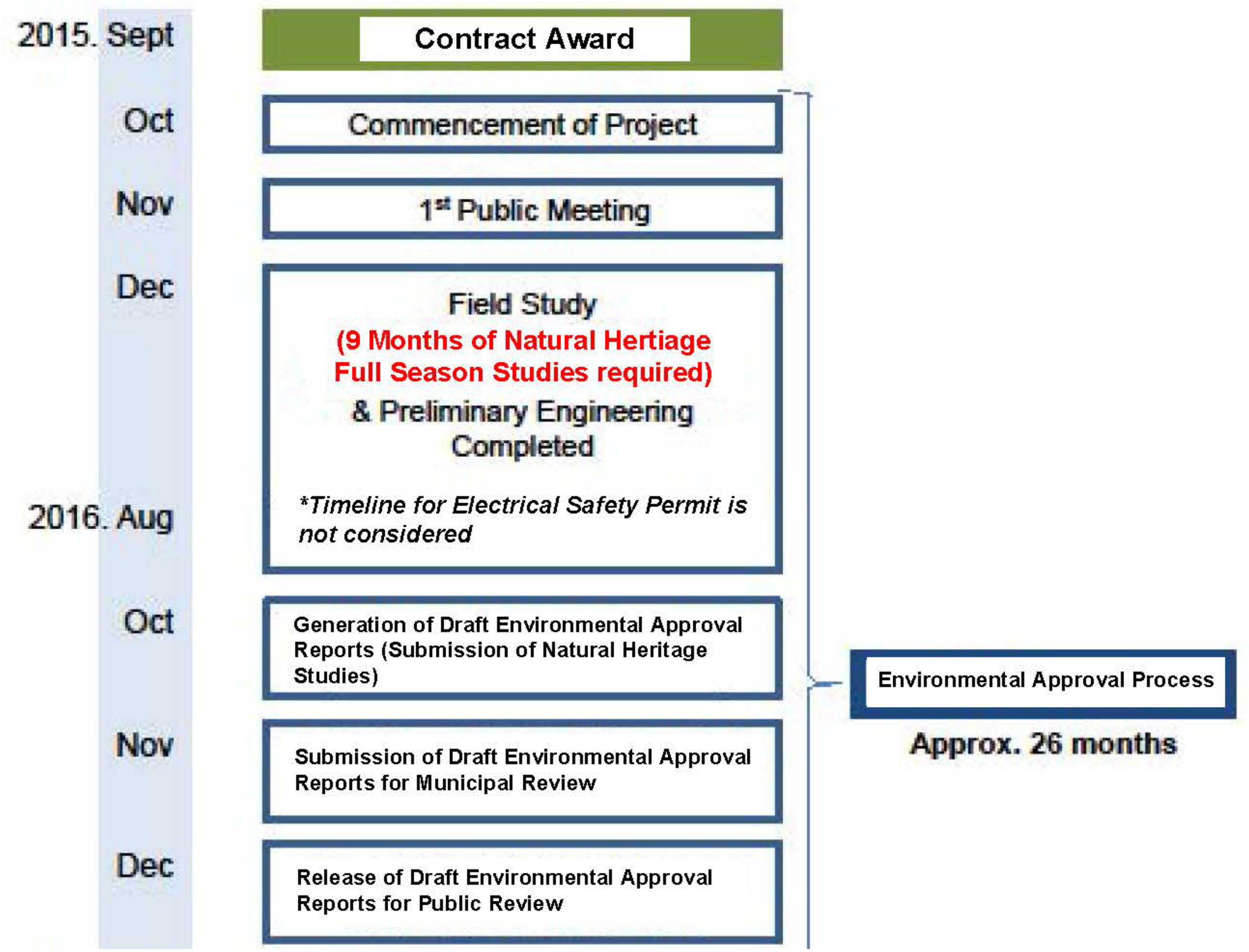
b. Technical and Financial Implications

- Various fixed, dual-axis and single-axis tracking systems are available
- Dual-axis trackers are most efficient from a kWh/kW perspective, but also are the most costly
- Fixed systems also generally are less effective at more Northern latitudes.
- Choosing the correct technology for a given project involves a trade-off between system efficiency (kWh/kW) and overall economics and cost (LCOE, or $/kWh)

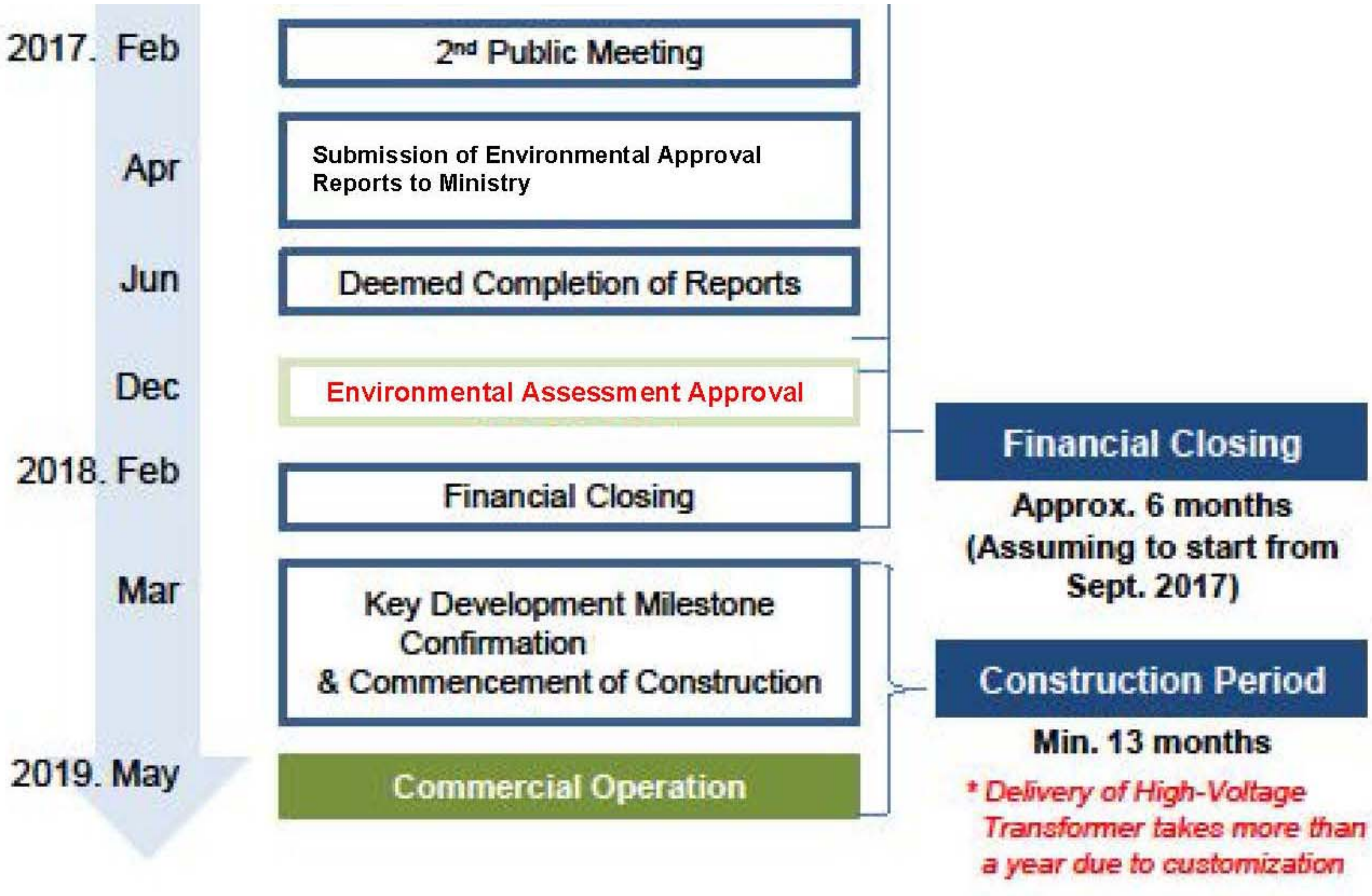
c. Environmental Characteristics and Development Timelines

- CanSIA created a project development timeline for consideration to the Ontario government that included a 26 month timeline for environmental approvals, within an overall three to three and a half year project development timetable

Development Timeline for Large-Scale Solar Project in Ontario (CanSIA)



Development Timeline for Large-Scale Solar Project in Ontario (CanSIA)



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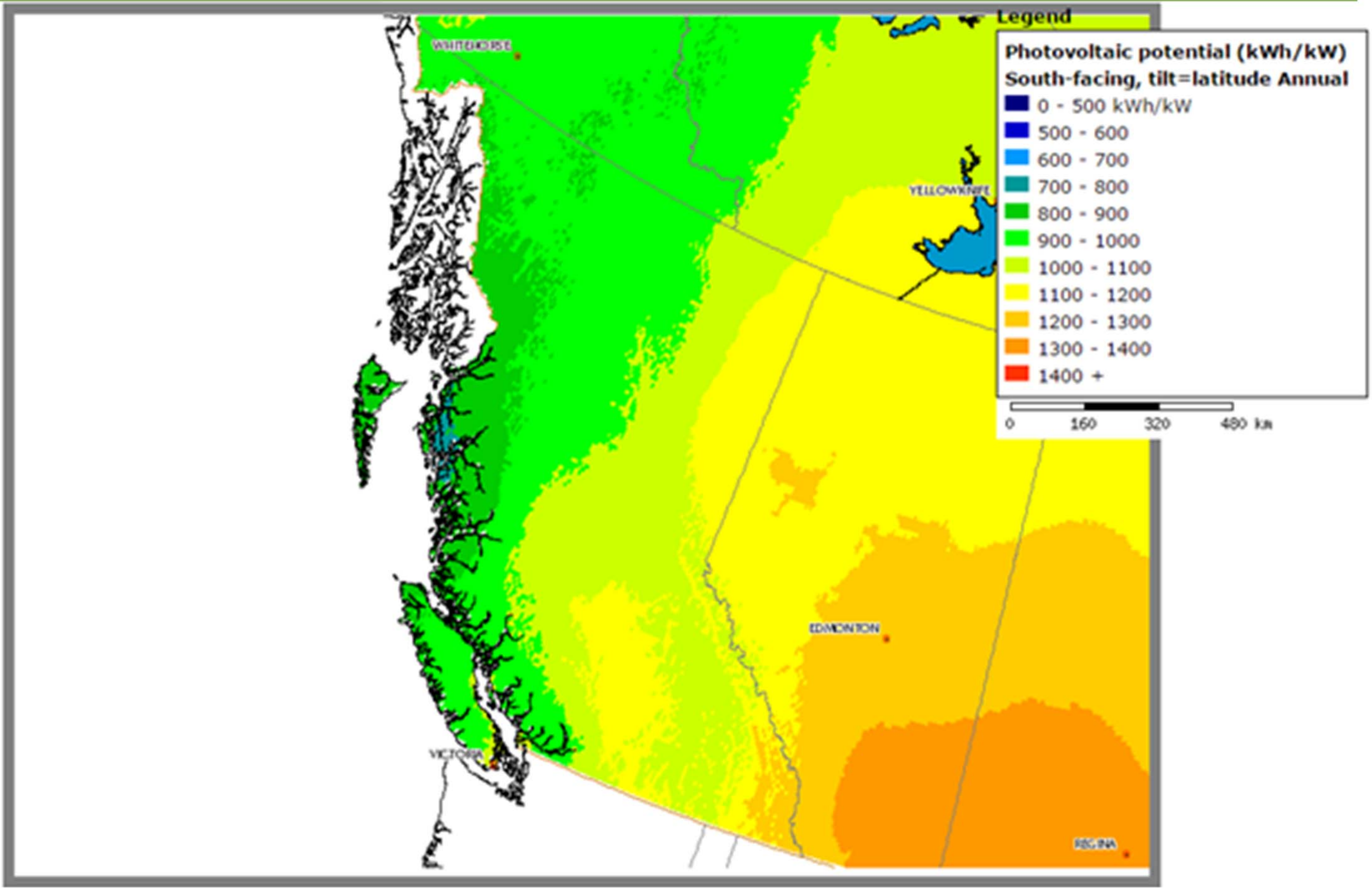
BC Solar Potential (NRCan Cartes PV Maps)



Sites for Solar Potential Analysis and BC Transmission Region

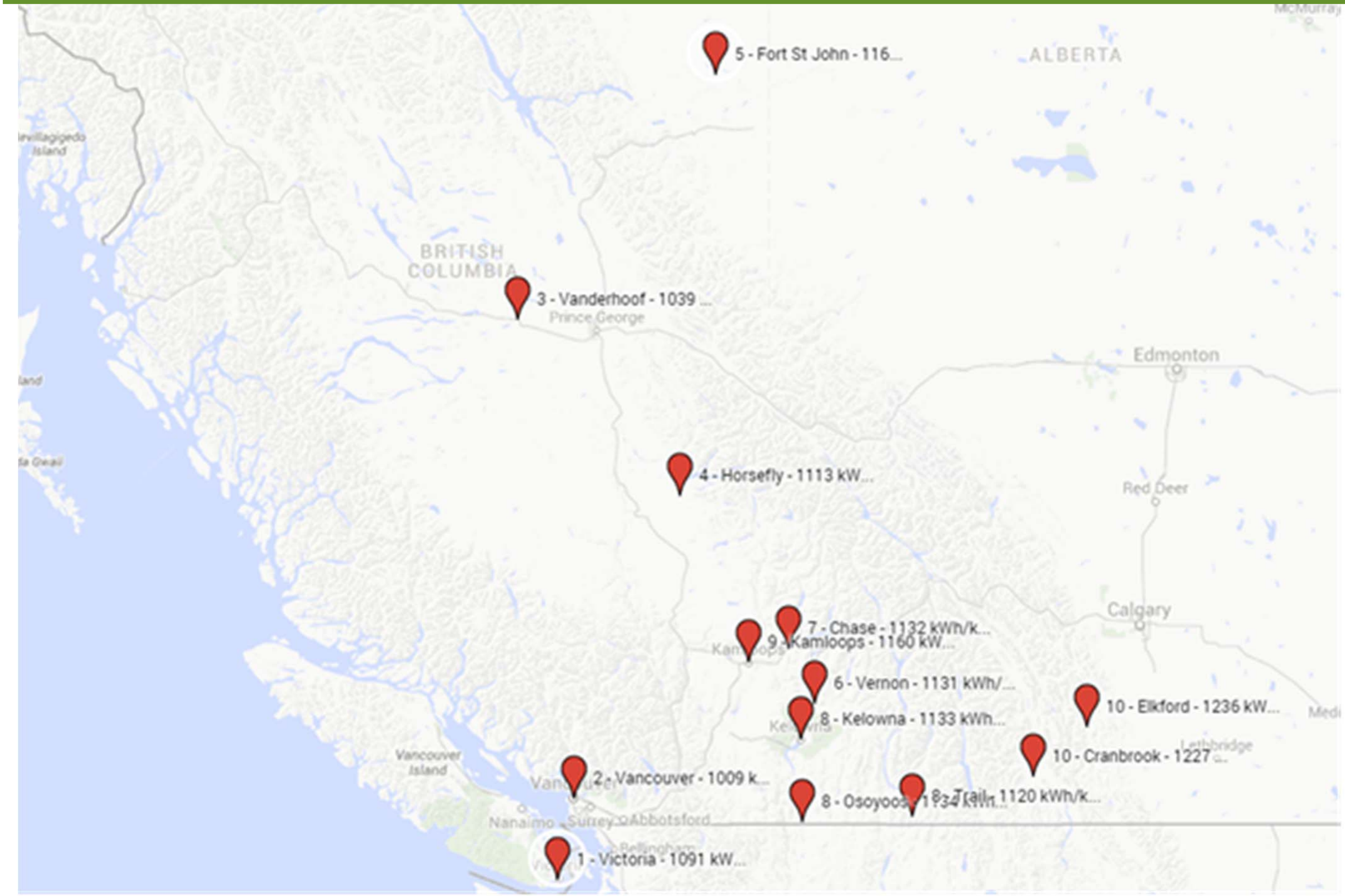
Transmission Region Number	Transmission Region Name	Analysis Site	Solar Potential (kWh/kW/a)
1	Vancouver Island	Victoria	1091
2	Lower Mainland	Vancouver	1009
3	North Coast	Vanderhoof	1039
4	Central Interior	Horsefly	1113
5	Peace Region	Fort St. John	1162
6	Revelstoke	Vernon	1131
7	Mica	Chase	1132
8	Selkirk	Osoyoos	1134
8	Selkirk	Kelowna	1133
8	Selkirk	Trail	1120
9	Kelly/Nicola	Kamloops	1160
10	East Kootenay	Elkford	1236
10	East Kootenay	Cranbrook	1227

Solar Potential of Select Sites with Fixed, Single and Dual-Axis Trackers in PVWatts

Analysis Site	Solar Potential with Fixed System (kWh/kW/a)	Solar Potential with Single-Axis Tracker (kWh/kW/a)	Percent Increase from Fixed System with Single-Axis Tracker	Solar Potential with Dual-Axis Tracker (kWh/kW/a)	Percent Increase from Fixed System with Double-Axis Tracker
Vancouver	1010	1224	21.2%	1386	37.2%
Victoria	1092	1364	24.9%	1570	43.8%
Kamloops	1157	1429	23.5%	1640	41.7%
Fort St. John	1157	1421	22.8%	1658	43.3%

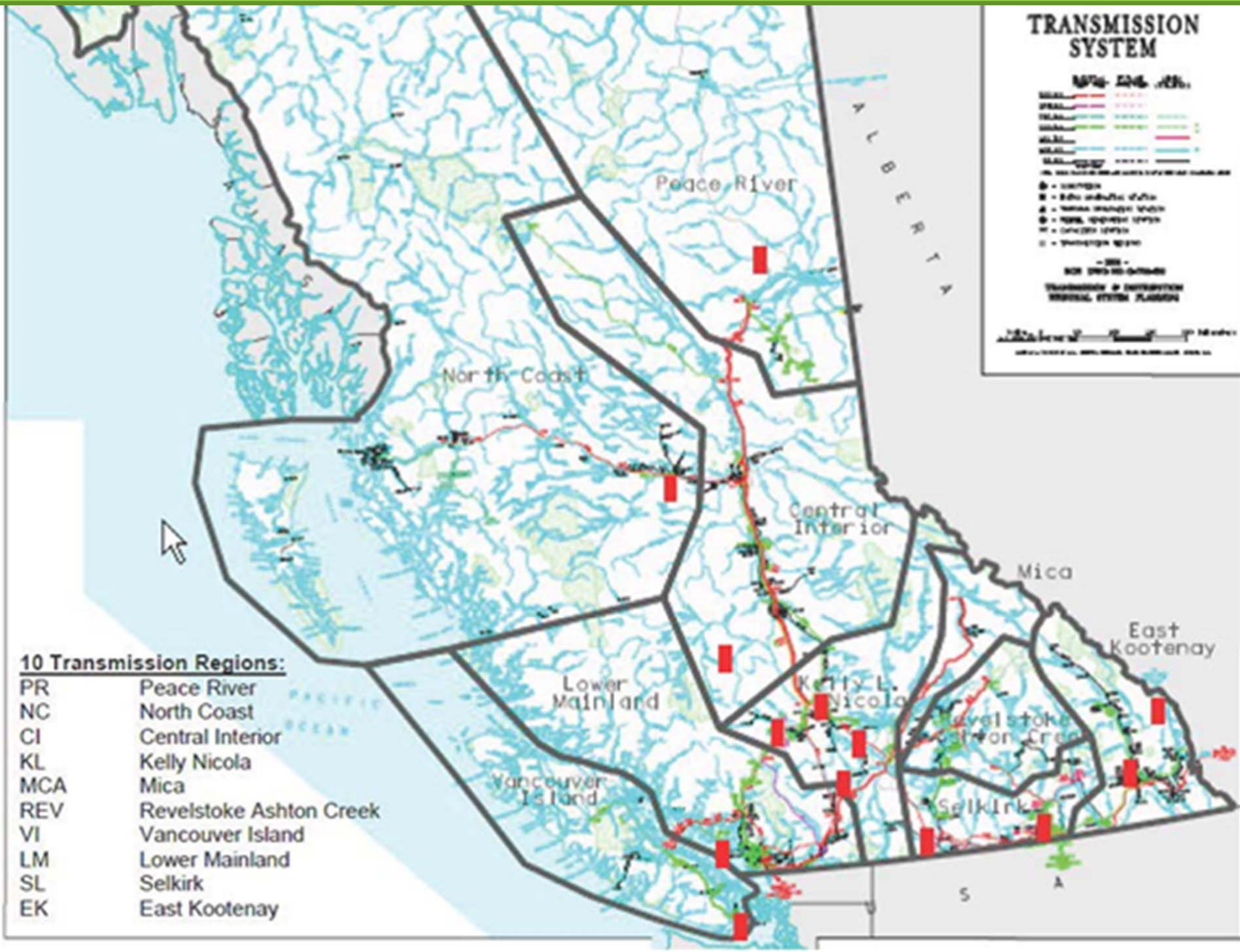
4. Potential Sites Across the IRP Regions

Sites for Analysis of Solar Potential



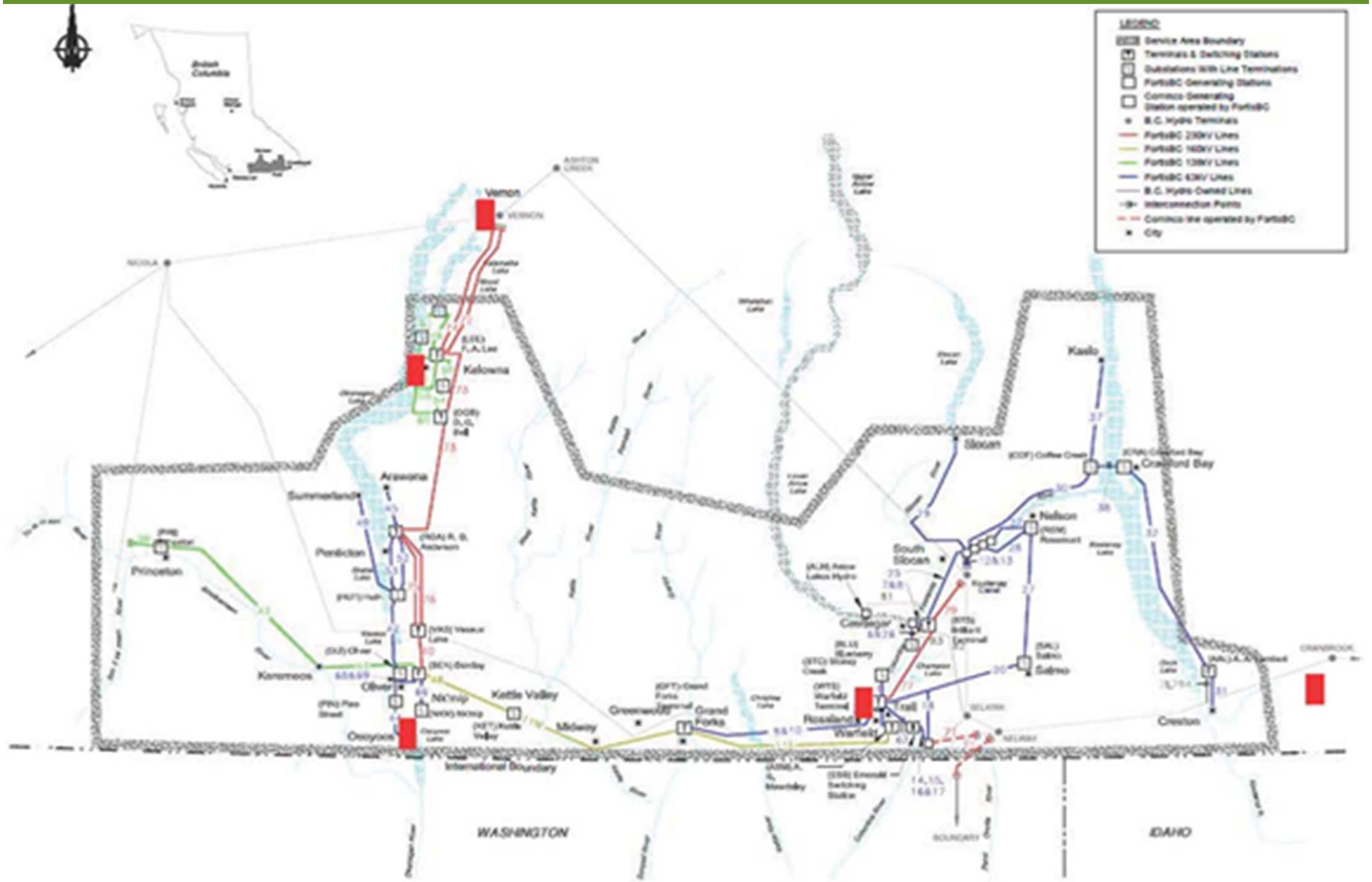
4. Potential Sites Across the IRP Regions

BC Transmission Planning Regions



4. Potential Sites Across the IRP Regions

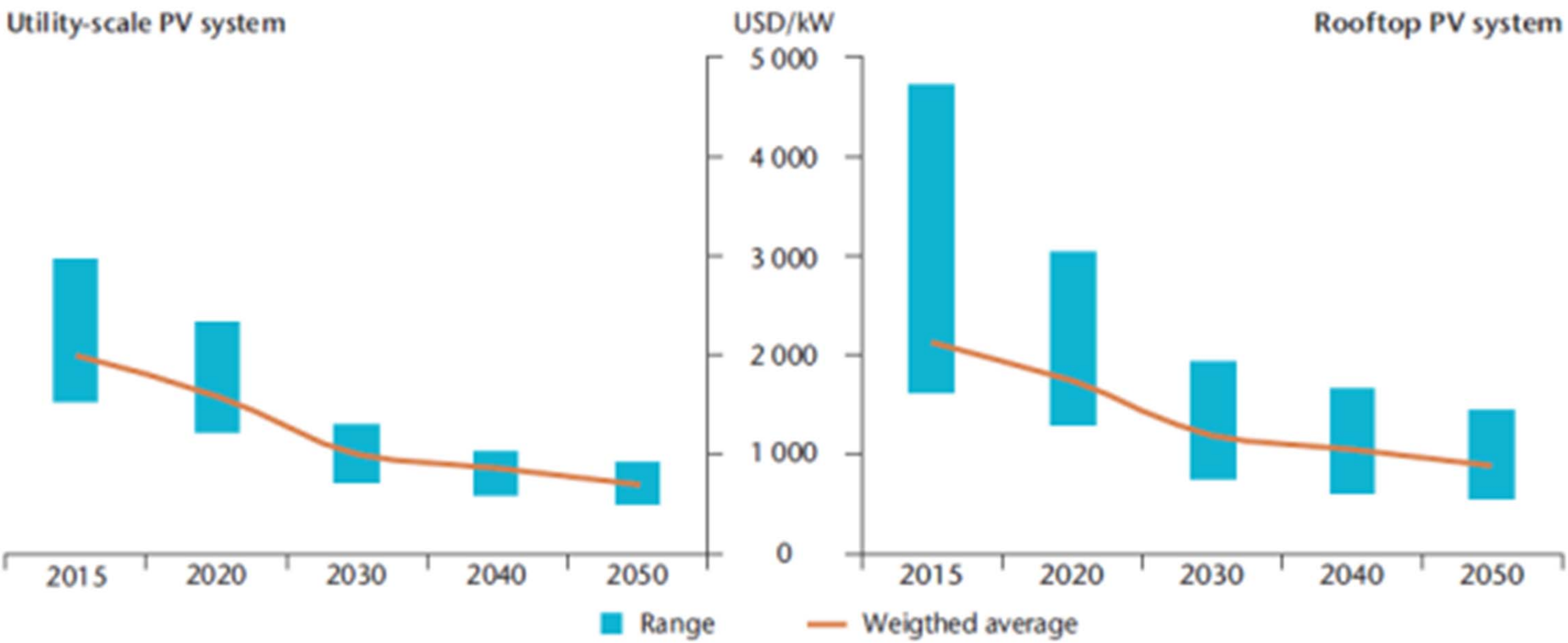
Fortis BC Service Area



a. Fixed and Tracking PV

- Various technologies and processes under development will further lower the cost of solar PV in the near term
- The current path for conventional solar technologies is improving and continuously reducing in cost
- Other new disruptive solar technologies are unlikely to play a major role in the near term, due to the time lag from innovation to commercialization
- In the long term, the IEA predicts PV system costs will decline from 2013 by 50% by 2040

Utility Scale and Rooftop PV System Cost Projections (IEA)



a. Fixed and Tracking PV

- Cost declines have continued in spite of more stabilized module prices
  - System cost dropped 10-15% in California in the first half of 2013 with stable module prices
- Cells and modules are global commodities and vary much less than installed system costs
  - This difference can be attributed to soft costs like customer acquisition, permitting, inspection and interconnection, installation labour and utilization efficiency, and financing
- U.S. system costs are expected to continue to drop into the near future

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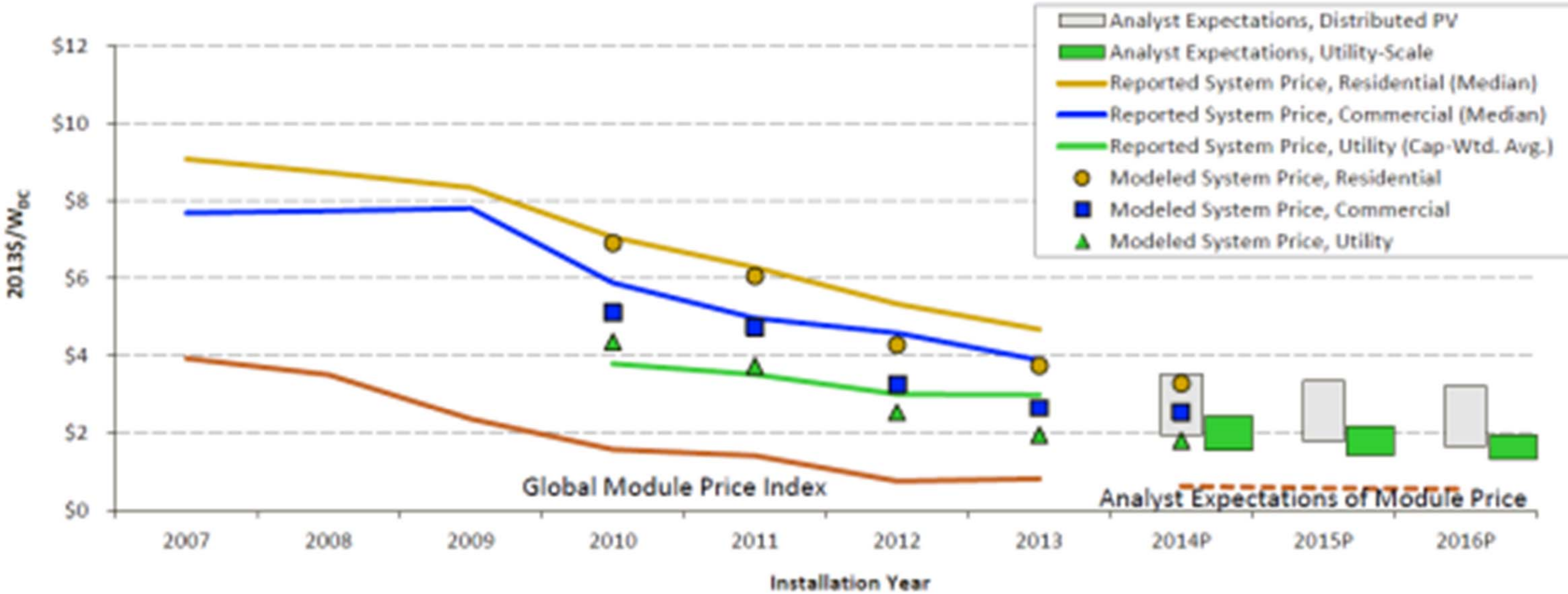
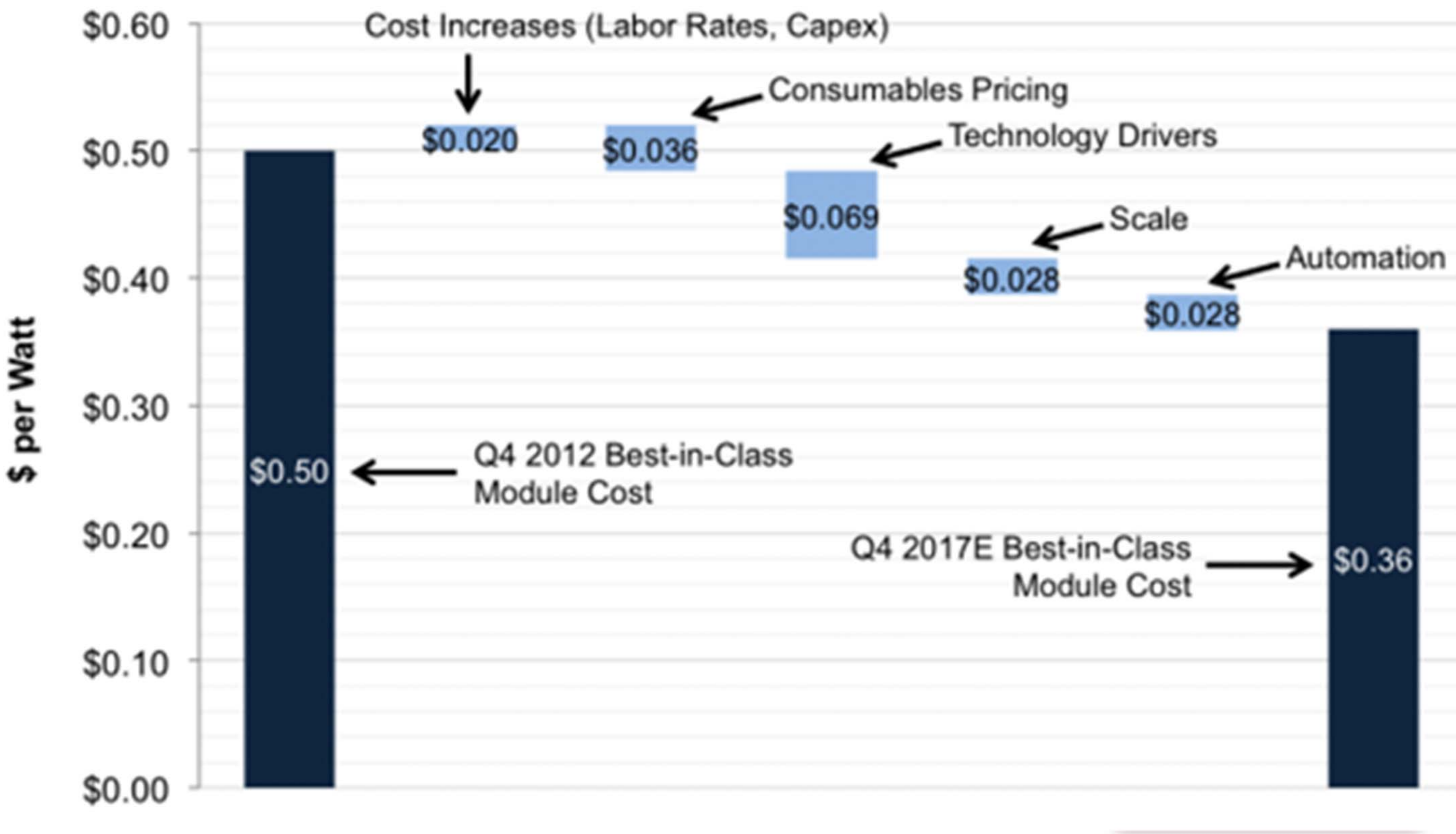
5. Current and Future Cost of Solar System Components

U.S. PV System Prices over Time (Sunshot)



5. Current and Future Cost of Solar System Components

Expected Chinese c-Si Module Cost and Key Drivers (GTM Research)



a. Fixed and Tracking PV
i. Solar Costs: 100 kW to 1 MW

- NREL and LBNL estimates that systems quoted in Q4 2013
  - $3.29/W for residential (~5 kW)
  - $2.54/W for commercial (~200 kW)
- The Sunshot study also found that price reductions for residential and small commercial systems are increasing, averaging 6-7% per year from 1998-2013, but 12-15% from 2012-2013
- Analysts' projections for the global average near term price of distributed scale systems describe a price of $1.50 - $3.00 by 2016

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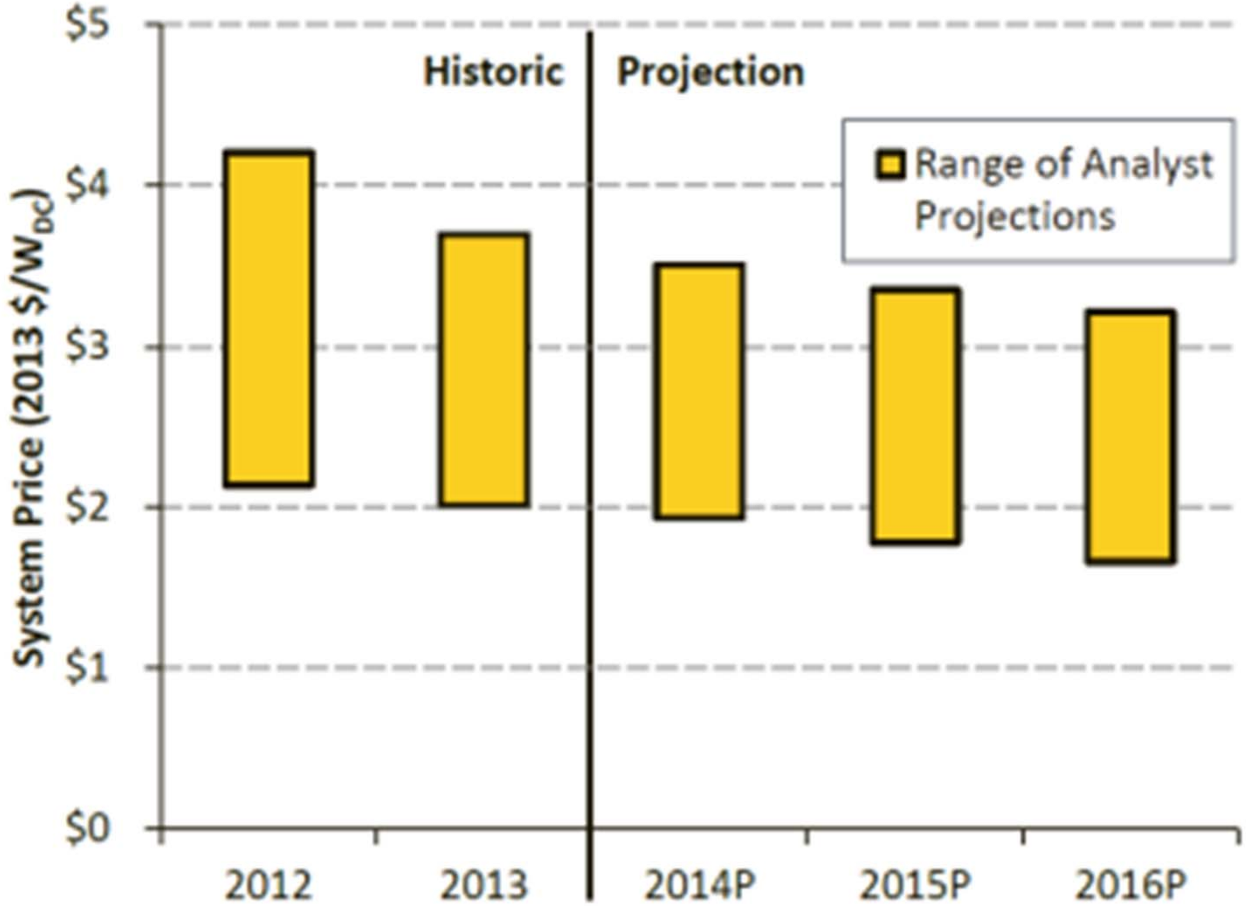
5. Current and Future Cost of Solar System Components

Recent Analyst Estimates (2012-2013) and Projections (2014-2016) of Global Average Distributed System Price (Sunshot based on Various Sources)



a. Fixed and Tracking PV
ii. Solar Costs: 1 MW to 5 MW and Solar Costs: Over 5 MW

- In 2013, over 3 GW of utility-scale solar was installed in Canada and in the U.S
- 43% of all new capacity additions in Ontario (337 MW)
- 30% of that in the US (2847 MW).
- Ontario ranked second in North American behind California for new utility-scale solar
- A confluence of low capital costs and cost of capital makes utility-scale solar close to competitive with day-time retail electricity prices in many markets today

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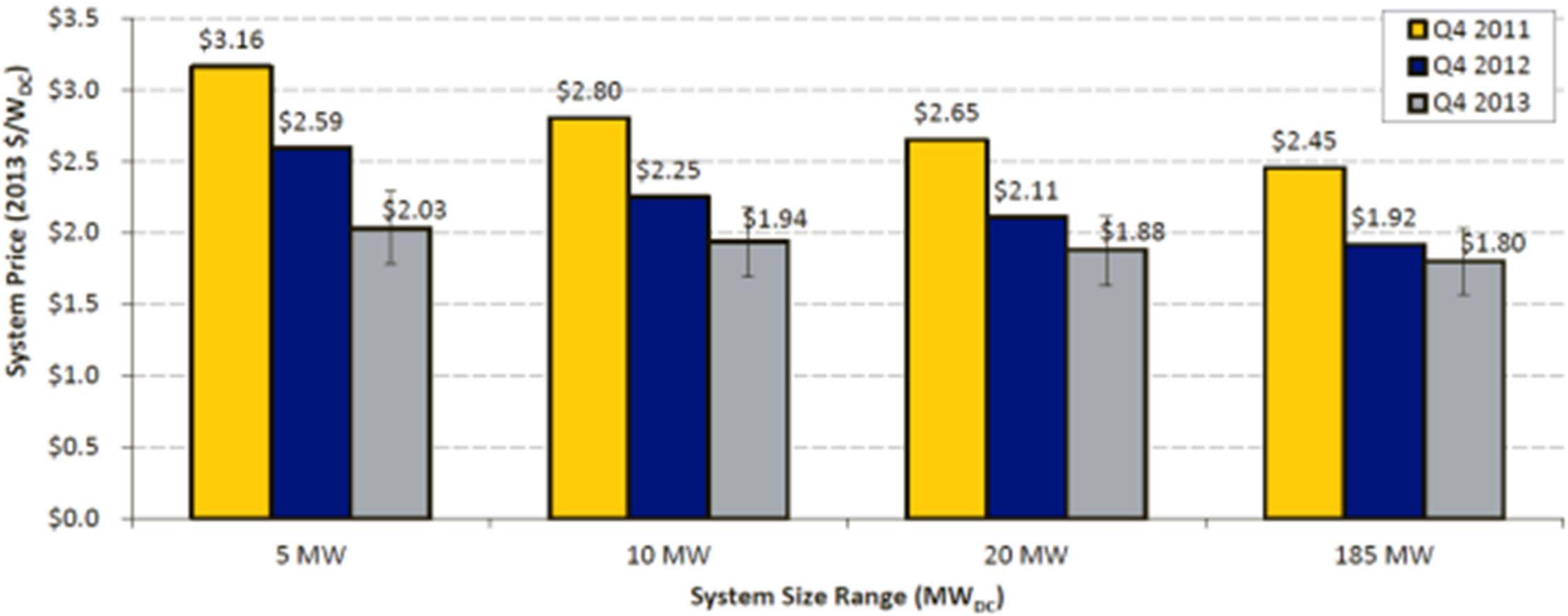
a. Fixed and Tracking PV
ii. Solar Costs: 1 MW to 5 MW and Solar Costs: Over 5 MW

- The U.S. Sunshot Initiative, using reported pricing in part, estimated that utility scale (=> 5 MW) cost $3.00/W on a capacity weighted average in 2013
- Sunshot also projected an installed cost in 2014 (quoted Q4 2013) for utility scale systems (=> 185 MW) of $1.80/W – 5% lower than the previous year
- This discrepancy can likely be explained by a difference in the scale of systems examined, perhaps due to many smaller systems in the Sunshot data and PPA timing

a. Fixed and Tracking PV
ii. Solar Costs: 1 MW to 5 MW and Solar Costs: Over 5 MW

- The next slide shows that most of the recent gains in reduced cost from economies of scale in utility scale systems (~70%) were found between 5 and 20 MW
- As project size grew beyond 20 MW, there was a diminishing return to scale in reductions
- Analysts' projections for the global average near term price of utility scale systems describe a price of $1.30 - $1.95 by 2016
- In a jurisdiction like BC, there is no need for projects greater than 10 – 20 MW

Bottom-up Modeled Overnight Capital Cost of U.S. Utility-scale PV Systems by Size, 2011-2013 (Sunshot)



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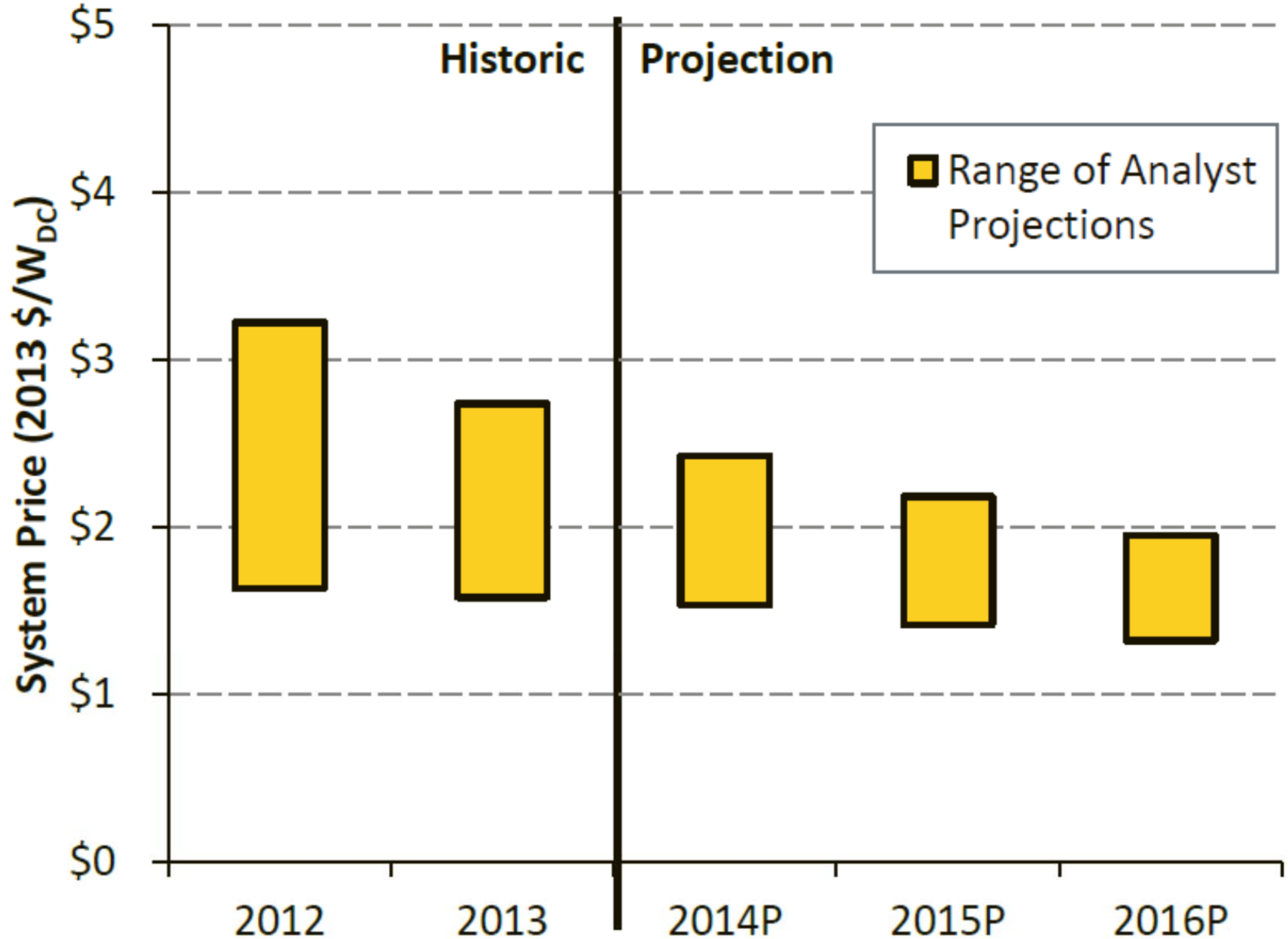
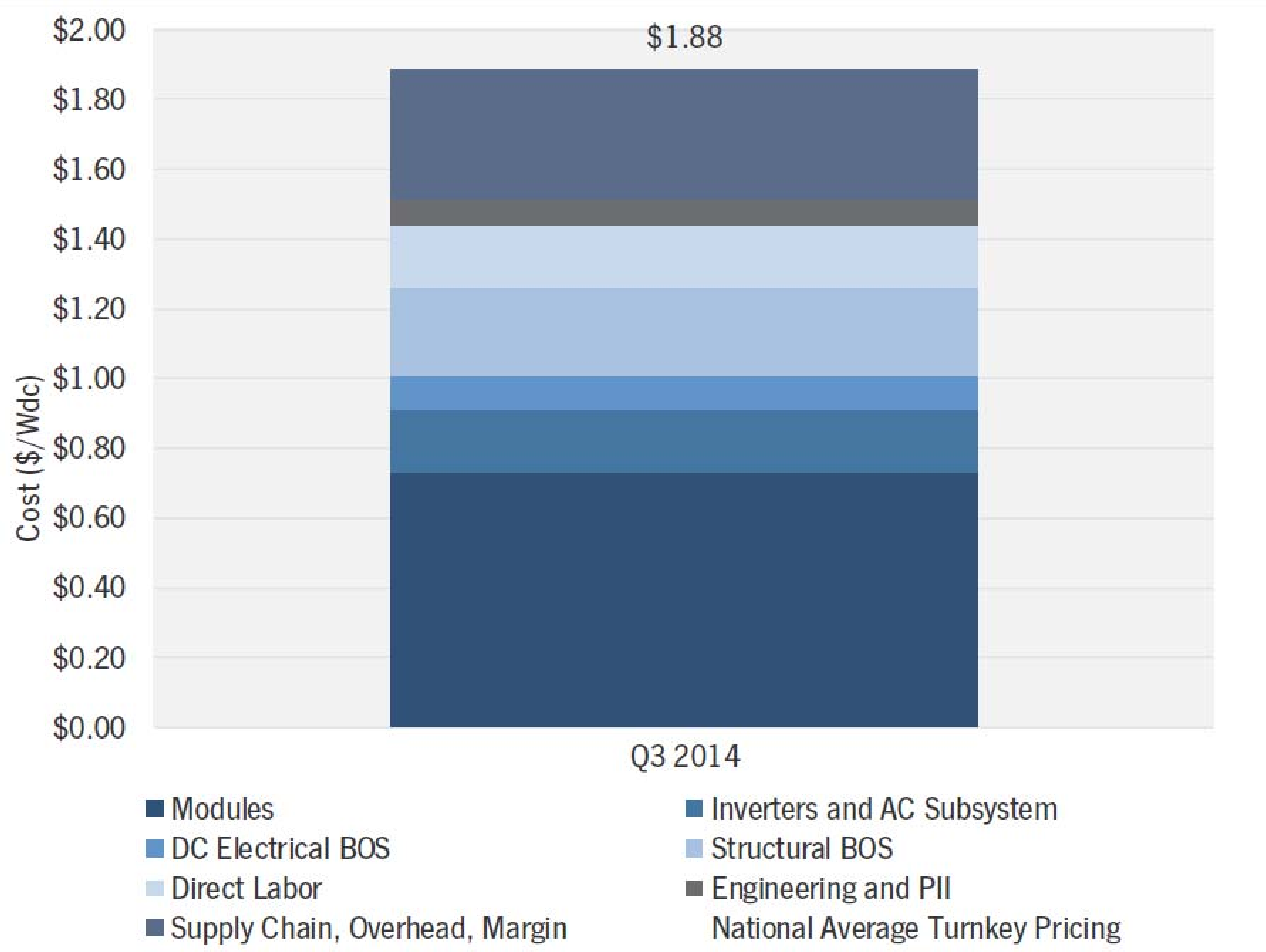
5. Current and Future Cost of Solar System Components

Recent Analyst Estimates (2012-2013) and Projections (2014-2016) of Global Average Utility Scale System Price (Sunshot based on Various Sources)



5. Current and Future Cost of Solar System Components

Modeled Utility Turnkey Single-Axis Tracking PV System Pricing With Cost Breakdown (GTM Research)



a. Pricing Forecast for BC

- Compass has analyzed a number of studies and amalgamated them into its own projection of system and component costs through the year 2025
- This incorporates analyst's projections as collected by NREL, GTM Research, Black and Veatch and the IEA
- System prices have fallen between 16% – 19% per year since 2009, with half to two thirds of this drop related to module price reductions

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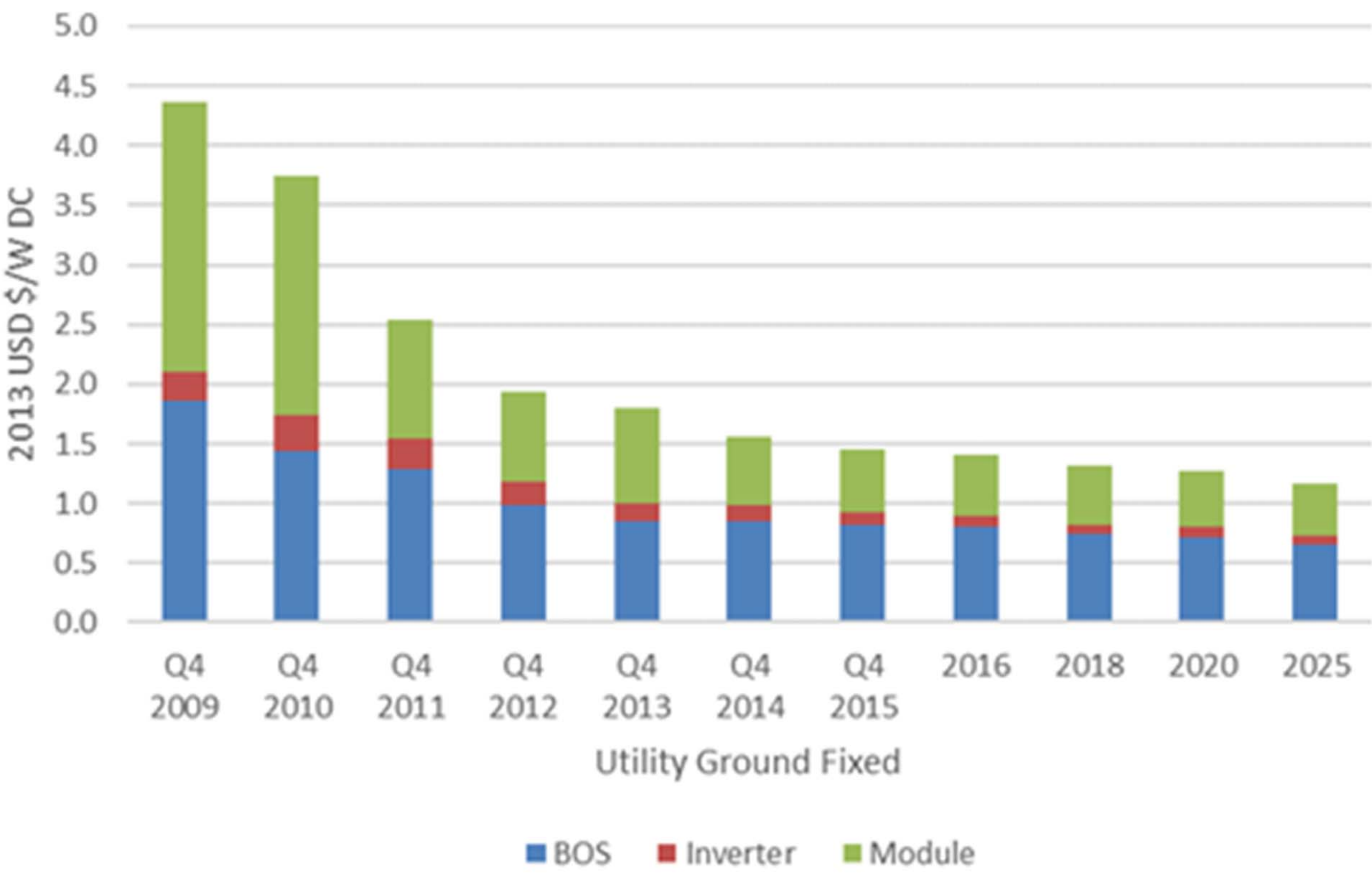
a. Pricing Forecast for BC

- The pricing and costing analysis also takes into consideration the current market conditions in Ontario
- PV modules are available from a number of bankable Tier 1 Ontario manufacturers
- These modules are offered at prices ranging from $0.65 - $0.75 CDN per watt DC.
- The recent decision of the Canadian Borders Services Agency to establish interim duties on imported Chinese modules in the range of 10%-200% is not expected to have any immediate impact on these prices
  - Duties on finished modules only
  - Canadian capacity is available at competitive prices
  - Alternative sources outside of China

a. Pricing Forecast for BC

- With increasing inverter sizes, unit costs for Canadian products has decreased to a level of approximately $0.16 CDN today
- Some manufacturers offering such equipment for 2015/16 delivery at $0.11/W CDN
- Balance of system costs is the area where a number of factors will influence the ultimate cost to construct a solar PV project
- The following slides show the historical and projected component and system costs in 2013 USD, followed by a similar slide with projected component and system costs using a $1 USD = $1.20 CDN conversion

Historical and Projected Component and System Costs (Compass)



a. Pricing Forecast for BC

- System cost components include the following:
  - Modules
  - Balance of System (inverters, racking and mounting, electrical hardware, grid connection etc.)
  - Labour, engineering and construction
  - Shipping
- Module efficiency represents a leading driver of future cost reductions because:
  - Balance of System material costs are unlikely to fall
  - Declines in inverter cost have a smaller percentage difference
  - Increased module efficiency reduces the need for all other inputs on a per kW basis

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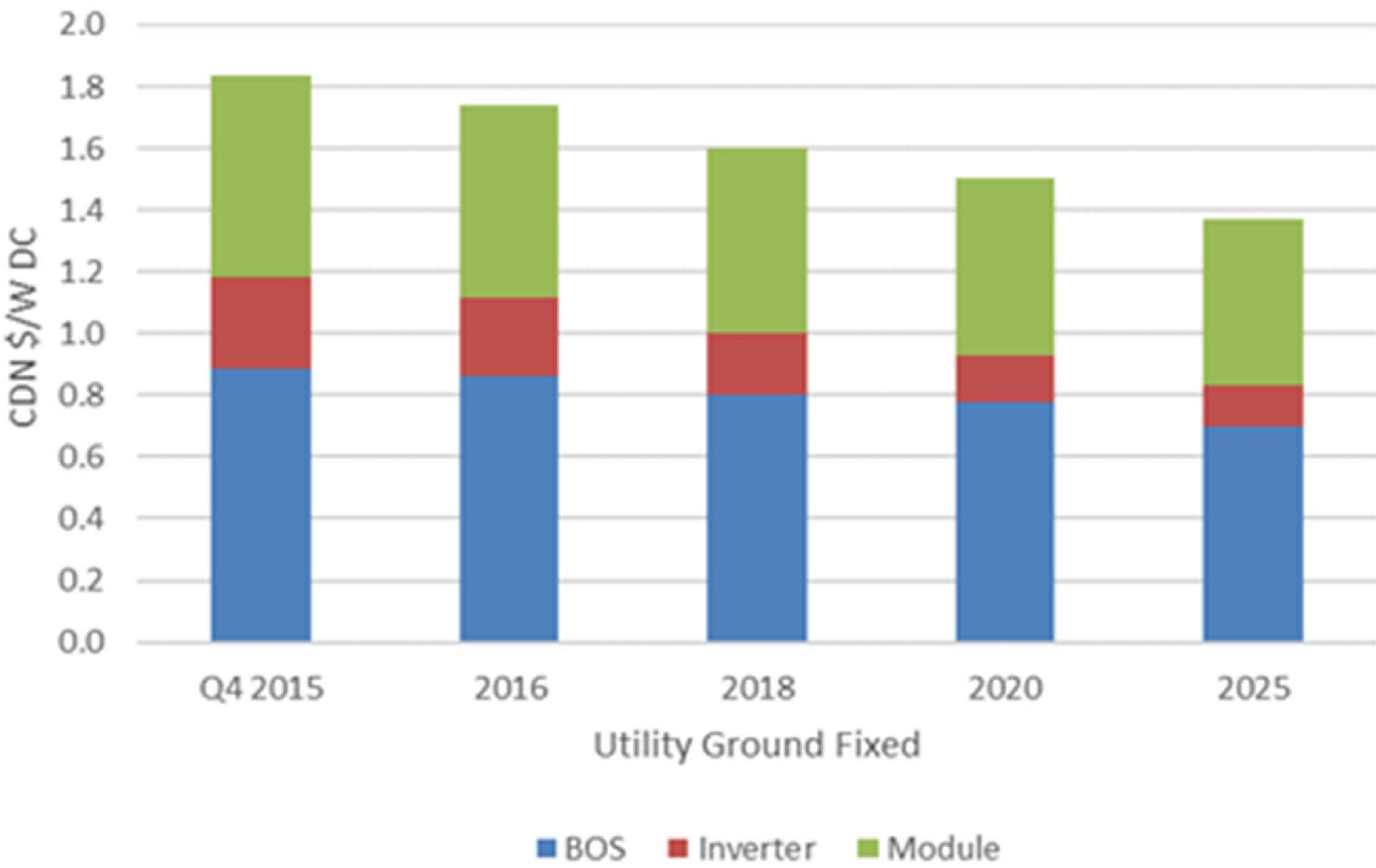
a. Pricing Forecast for BC

- Compass projects an average 2.5% annual system cost reduction of from Q4 2014 – 2025
  - NREL projects 0.4 - 4.7% annual system cost decline 2014-2025
  - Black and Veatch projected 0.8% annual system cost decline 2014-2025
    - February 2012 report using 2010 market data
  - IEA projects 4.2% annual system cost decline 2015-2020
  - GTM Research projects 5.6% annual module cost decline 2012-2017

Projected System and Component Costs in $CDN (Compass)



Contact Information

Jim MacDougall
President

p. 416-294-0803
e. jim@compassenergyconsulting.ca
w. http://compassenergyconsulting.ca

Andrew Clare
Senior Consultant

p. 416-880-3796
e. andrew@compassenergyconsulting.ca
w. http://compassenergyconsulting.ca

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