Photovoltaic Systems

CHBA Net Zero Energy Housing Council
Local Energy Efficiency Partnership (LEEP)
Webinar Series - January 26, 2016.

Addressing specific questions identified by the BC Lower Mainland Climate Zone 4 LEEP Builder Group

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Riverside ENERGY SYSTEMS

Recap of this Builder Group's Requests

Part A: Introduce our company and services.

Part B: Respond to the following questions and requests

1. Describe PV shading implications and shade mitigation strategies.
2. Describe monitoring/metering systems and the feedback they provide to homeowners on energy production and building consumption.

Part C: Describe and cost PV design options for an example home provided. Discuss key challenges.

- String inverter vs micro-inverter approach
- Shading considerations

Part D: Discussion

Part A: Introduction

Riverside Energy Systems

For **Photo-voltaics (PV),** wind & micro-hydro, we provide:

- Consulting and assessment
- Engineering design
- Equipment sales
- Installation and Maintenance
- Single service through to full design/build “turn-key”

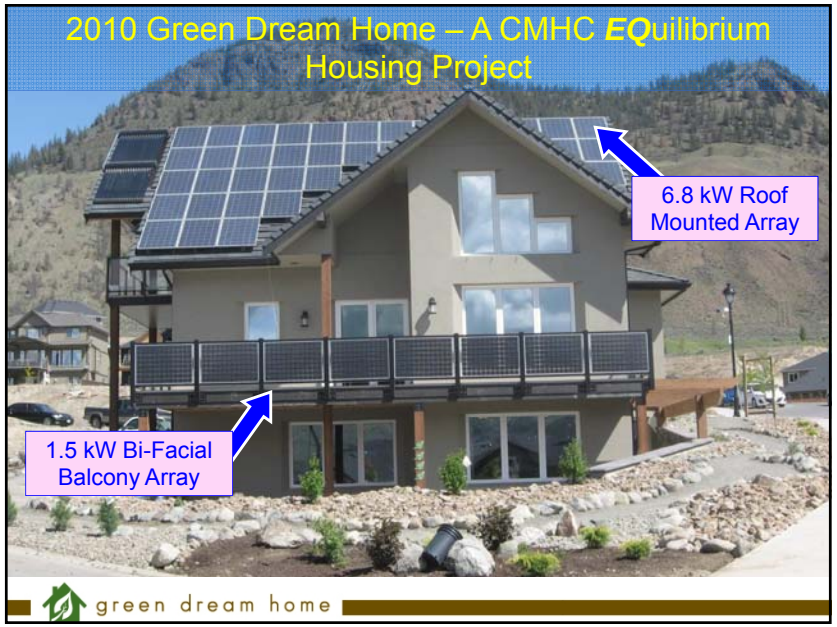
We work on **Sustainable Building Design and Renovation, Net-Zero, Net-Zero Ready Projects**

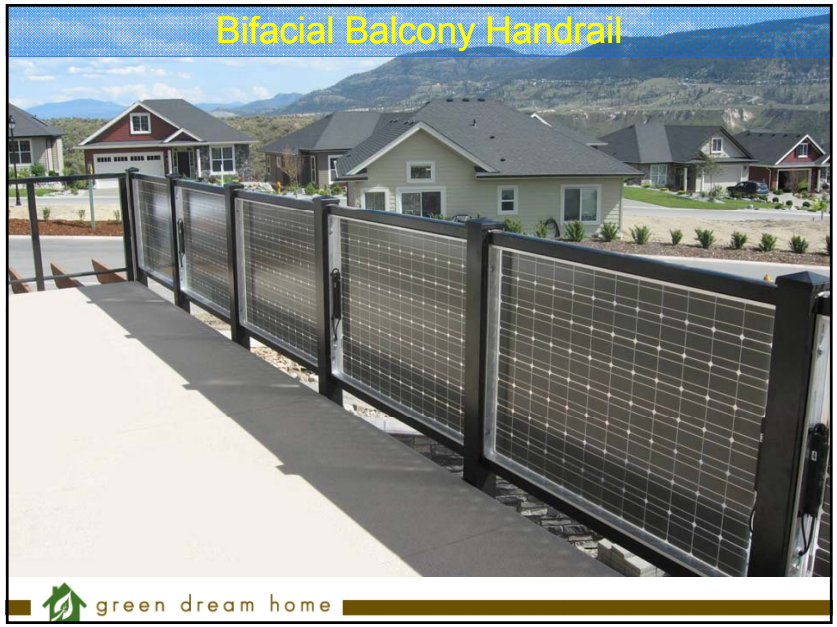
Kamloops based staff include professional engineer, and Red Seal certified electrical tradesmen with FSR credentials.

Available for work throughout BC.

Some Residential Project Examples

1. 2010 YMCA Green Dream Home (8.3 kW)
2. Spina Laneway Home (1.9 kW)
3. Rare Birds Housing Cooperative (6.75/11.25 kW)
4. Silvercrest Suites (3 kW)




Bifacial Balcony Handrail
green dream home


Spina Laneway Home 1.9 kW
240 W Solar Modules with 250 W Micro-inverters

Rare Birds Housing Cooperative

Phase 1 - 6.75 kW (String Inverters with Dual MPPT)
Phase 2 - Expansion to 11.25 kW

Silvercrest Suites

Phase 1 – 3 kW (String Inverter with Dual MPPT)
Solar Ready Design for up to 30 kW

Part B: Responses to Specific Questions from LEEP-Builder Group

#1: System Performance

Describe the shading implications for different types of systems you design and supply.

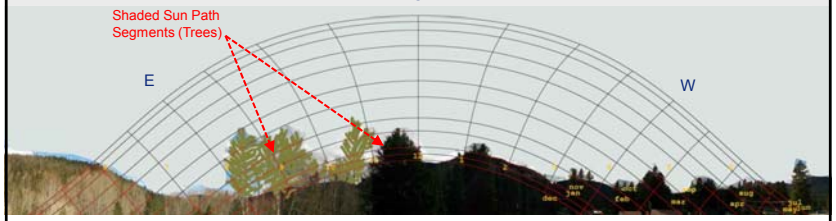
Shading can have a significant impact on PV system performance. It can be caused externally (mountains, trees, other buildings) or self caused (gables, plumbing stacks, chimneys).

Design steps illustrated on following slides:

1. Assess shading where PV is to be applied
2. Decide best inverter strategy.

External Shading – Assess with Solar Photographic Analysis

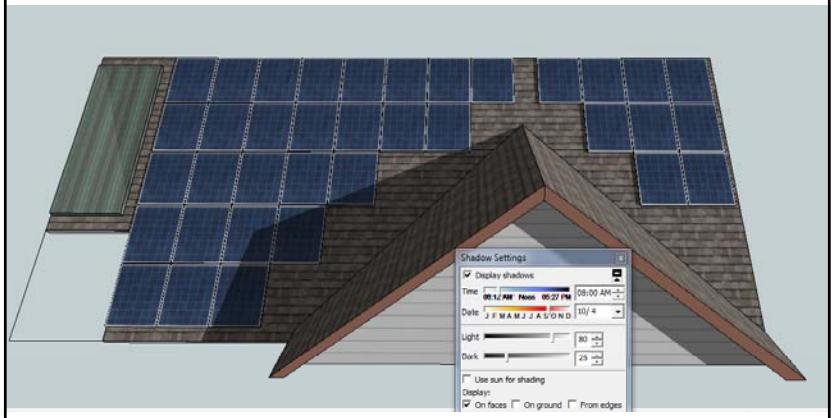
Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Ave.
Light Shaded %	75.9	29.3	10.3	2.6	2.6	3.0	2.8	2.4	4.7	21.8	59.2	86.9	25.2
Sunlight/Day (Hours)	1.07	1.95	3.46	4.94	5.79	6.34	6.25	5.63	4.21	2.36	1.1	0.82	3.67
Available Sunlight (Hours)	0.26	1.38	3.1	4.81	5.64	6.15	6.07	5.49	4.01	1.85	0.45	0.11	3.29
Shading Factor	0.9												



- Monthly sun paths superimposed on composite NE through NW panorama shots.
- Shaded sun path segments are identified in red.
- Software model calculates monthly shading loss and annual shading factor.
- SF = 0.9 meaning about 10% of annual harvest would be lost to shade.

This is a “very good” solar site where PV performance would improve using micro-inverters to lessen shading impacts.

Self Shading – Assess with 3D Modeling



Green Dream Home sub-arrays are subject to morning and afternoon shading by the prominent south roof gable during much of the year.

green dream home

Shade Tolerance of Available Inverter Strategies

Inverters convert DC electricity from PV panels, to AC for building use and export to the grid.

- Conversion efficiency as high as possible. (96% – 98%)
- Extract as much PV energy as possible using **Maximum Power Point Tracking** (MPPT).

Vehicle transmissions adjust mechanical gear ratios so engines can deliver maximum horsepower as load conditions vary. **Mechanical MPPT.**

Similarly inverters adjust electrical voltage switching ratios so PV can deliver maximum electrical power as light conditions vary. **Electronic MPPT**.

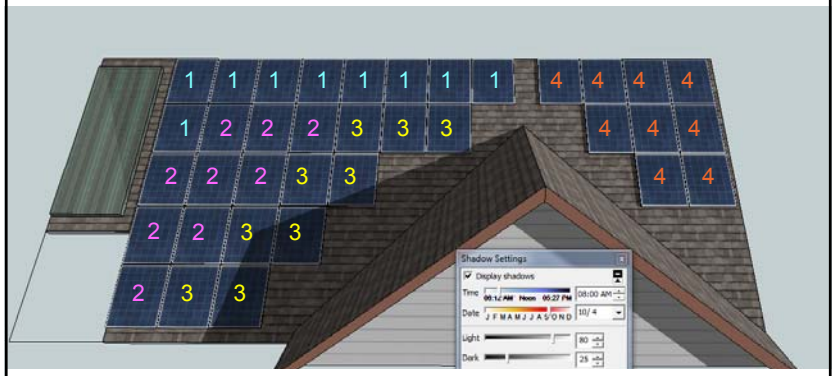
Appropriate inverter selection requires:

1. First identifying shading constraints specific to the site.
2. Then matching inverter MPPT features to shading constraints for maximum energy harvest.

Shade Tolerance of Available Inverter Strategies

Inverter Type	Simple String Inverter	Advanced String Inverter	Micro-Inverter	Optimized String Inverter
MPPT Channels	Single	Two or more	One per solar panel by microinverter	One per solar panel by optimizer
String Length	Strings must all be the same length.	Individual channels can have differing string length. Strings on the same channel must all be the same length.	Each inverter serves one panel. String length is one.	Multiple strings of varied lengths are possible (8 - 24)
Partial Shading of One String	Lowers available power to the entire inverter	Lowers available power to only one inverter MPPT channel. Other MPPT channels continue to produce at full power.	Lowers available power from only shaded panel microinverters	Lowers available power from only shaded panels optimizers
Typical Conversion Efficiency	96.5%	96.5% each channel	96.5%	97.5%
Best Applications	All PV panels on the same roof surface with no shading concerns	Separate strings are not likely to be simultaneously shaded. Strings will be mounted on differently oriented roof sections.	Shading affects multiple strings simultaneously. Differently oriented roof sections to be used. Small systems (8 panels or less). Where module level monitoring is desired.	Shading affects multiple strings simultaneously. Differently oriented roof sections to be used. Where module level monitoring is desired.
Relative Cost	100%	102%	108%	106%

Self Shading – Green Dream Home Strategy

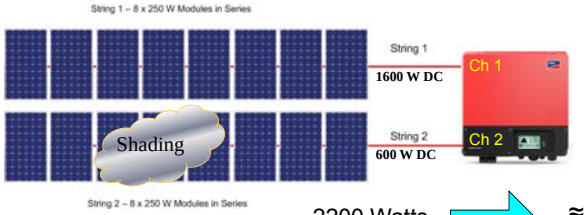


- Grouped 36 x 190 Watt panels into 4 strings of 9 per colours
- Strings 1 & 2 → are never shaded by the gable
- Strings 3 & 4 → suffer AM/PM gable shading but never simultaneously

Used two simple string inverters (Inverter A: Strings 1+2, Inverter B: Strings 3+4) as advanced string inverters or micro-inverters were not an option.

green dream home

Advanced String Inverters (Dual MPPT Channels)



Strings connected to separate MPPT channels

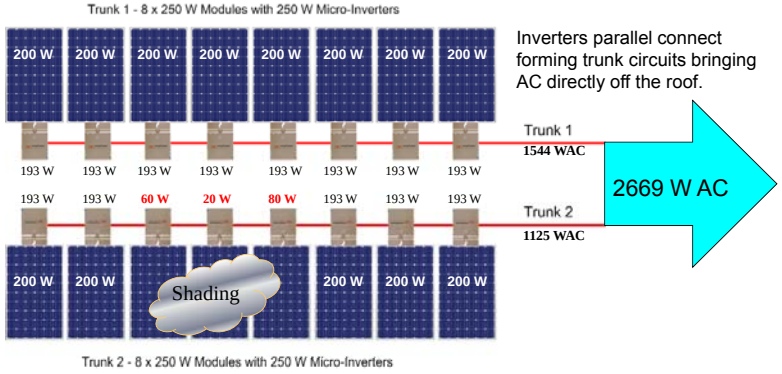
2200 Watts DC In → 96.5% → ≈ 2120 Watts AC Out

- Reduced output on shaded string does not cause **Mismatch Losses** since each string drives a separate MPPT channel.
- Inverter delivers maximum AC power after **Conversion Losses**.

Advanced string inverters are best used where:

- Predictable, clearly defined shading results in no more than one string being shaded simultaneously.
- Eg. Strings are located on diverse roof surfaces.

Micro-Inverters (1 MPPT Inverter/Module)

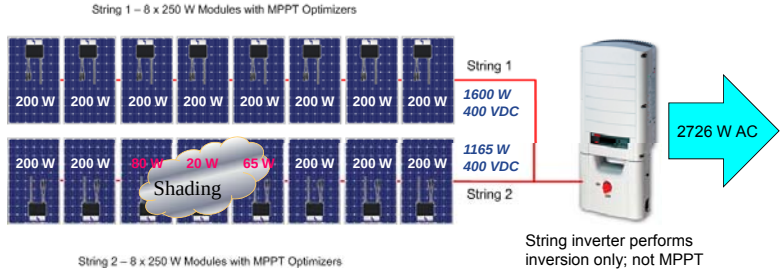


Inverters parallel connect forming trunk circuits bringing AC directly off the roof.

- Each micro-inverter has conversion losses.
- Only inverters with shaded modules give reduced output.
- Remaining inverters in the shaded trunk continue at full output.

Micro-inverters give better results over time under diverse shading conditions than simple or advanced string inverters.

Optimized String Inverter (1 MPPT Optimizer /Module)



String inverter performs inversion only; not MPPT

- Optimizers perform MPPT function at modules.
- Un-shaded optimizers continue at full power, and boost output voltage to hold constant string voltage under shaded conditions.
- String mismatch losses are eliminated.
- Shade tolerance comparable to micro-inverters.
- Optimized string inverters give better results over time under diverse shading conditions than simple or advanced string inverters.

Micro-Inverter – Morning and Afternoon Shading

#2: PV System Monitoring/Metering:
Describe available PV monitoring/metering systems and the feedback they provide to the homeowners on an ongoing basis.

- Dedicated production metering
- String inverter versus micro-inverter and optimized string inverter web monitoring.
- Web and Smart Phone based monitoring logging.
  - Proprietary = inverter specific
  - Third party = inverter non-specific

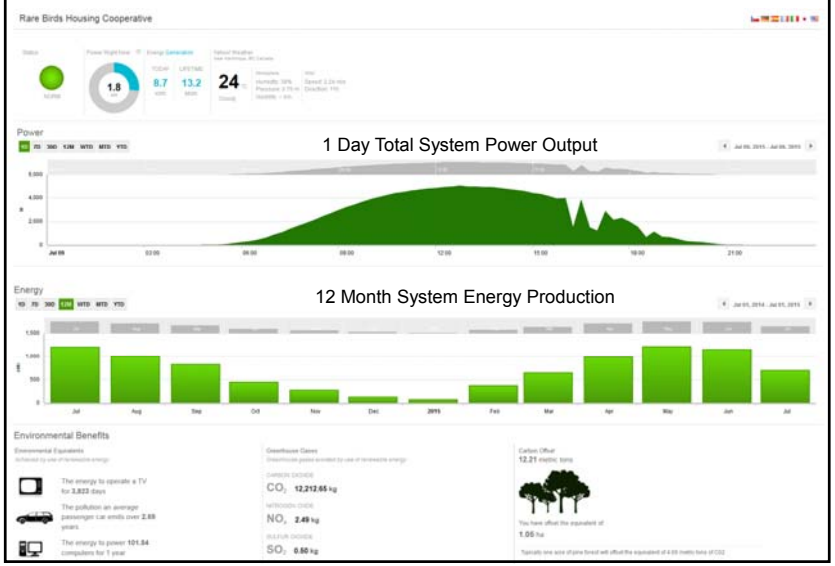
Dedicated Solar kWh Production Metering

- Simple and accurate but limited to energy production of the PV system only.
- Power measurements, data logging, individual inverter data, etc, are not available.

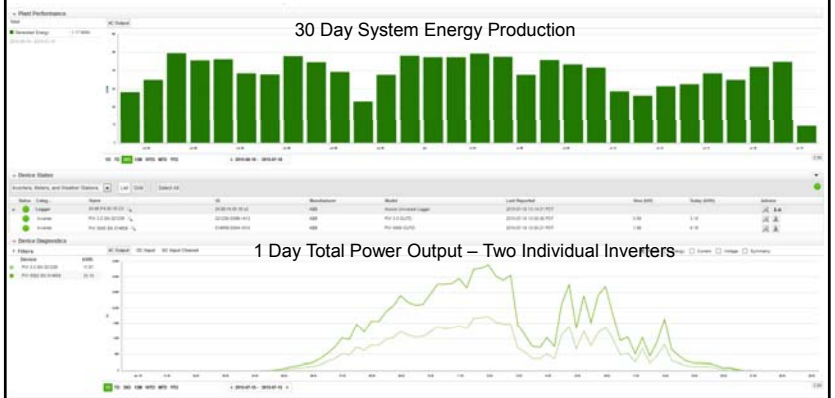
Proprietary String Inverter Monitoring

- Inverters are networked to a vendor specific data logger that uploads data to a web site at regular intervals.
- Real-time power, and historical energy production can be viewed in daily, weekly, monthly, and year format.
- Information viewable as total system, inverter by inverter, and individual MPPT channels.
- Customized reports can be generated.

Example – ABB Inverter Monitoring Rare Birds Housing Cooperative



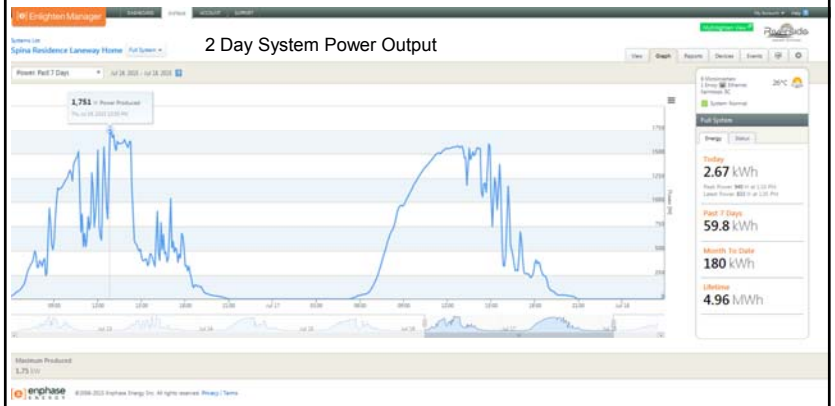
Example – ABB Inverter Monitoring Rare Birds Housing Cooperative



Proprietary Micro-Inverter & Optimized String Inverter Monitoring

- micro-inverters or optimizers are networked to a data logger that uploads measurements to a web site at regular intervals.
- Real-time power, and historical energy production can be viewed in daily, weekly, monthly, and yearly format.
- Information viewable as total system or individual solar modules allowing module level diagnostics.
- Customized reports can be generated for the system as a whole or by individual solar modules.

Example – Enphase Monitoring: Spina Laneway Home



Example – Enphase Monitoring: Spina Laneway Home

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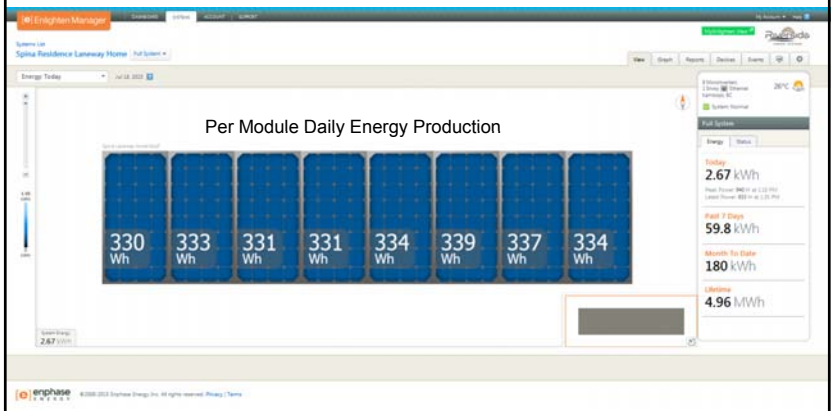
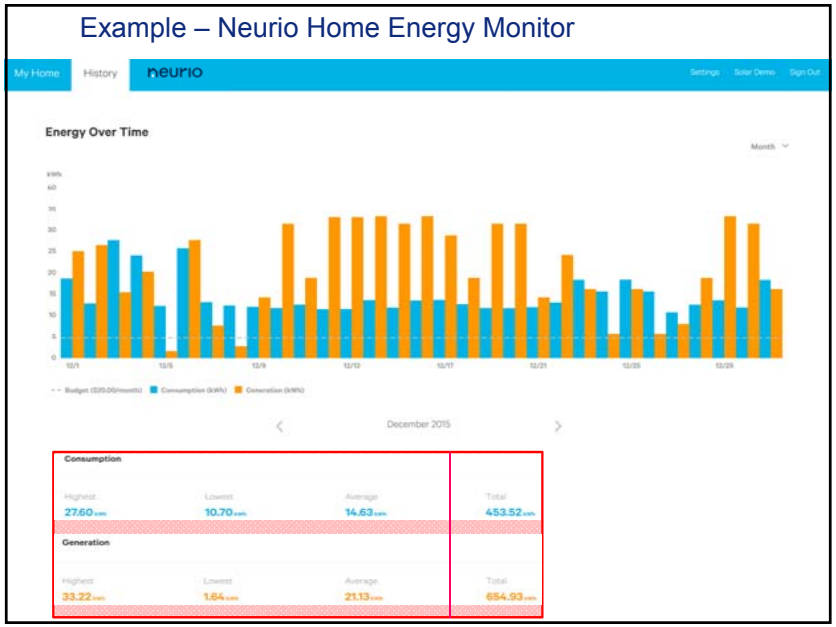


Spina Laneway Home - Morning and Afternoon Shading

Third Party Home Energy Monitors

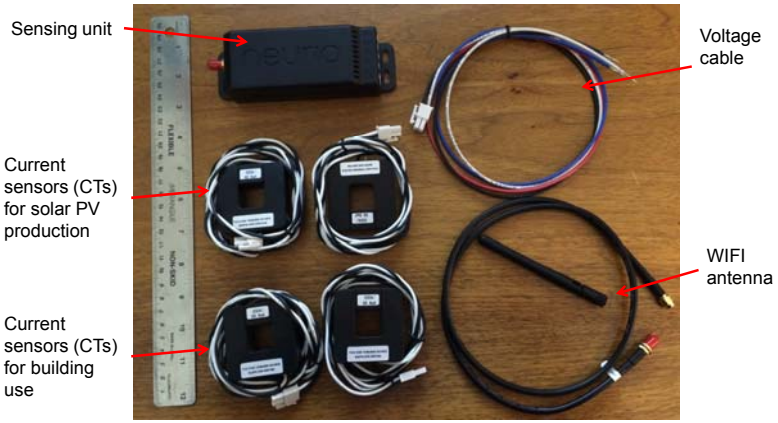
- Work with any PV system to measure, log, and upload solar PV generation.
- More sophisticated units also measure building use showing direct impact of the solar PV system on building electrical demand and energy use over time.
- Real-time power, and energy for both generation and demand in daily, weekly, monthly, and yearly formats using a PC or Smart phone.
- An example is the Neurio Home Energy Monitor

Example – Neurio Home Energy Monitor

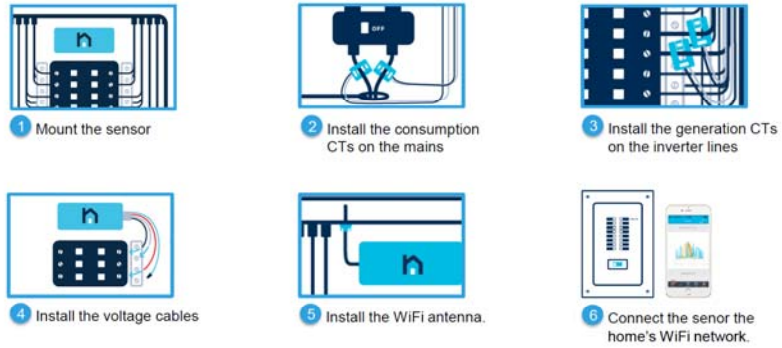


Example – Neurio Home Energy Monitor

Neurio Monitor Parts



Neurio Monitor Installation

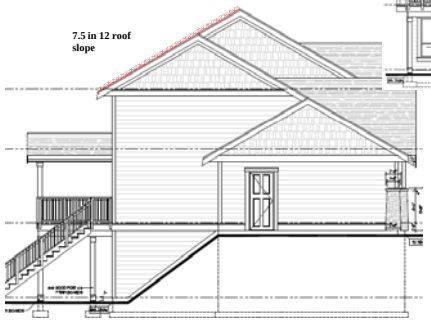


Part C: Costed Application

Costing PV Installation Options in Sample Home

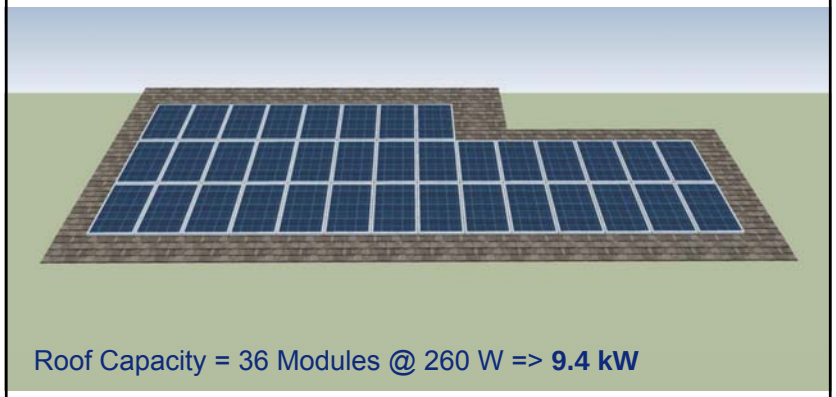
Front Elevation

Rear Elevation (Apply on this upper face only)



Assume within 5 degrees of perfect orientation

South Facing Roof Configuration (60 Cell Modules)



Roof Capacity = 36 Modules @ 260 W => **9.4 kW**

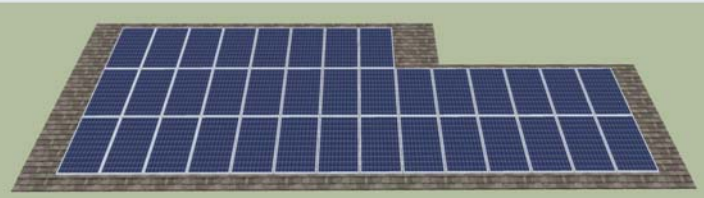
South Facing Roof Configuration (60 Cell Modules)

36 Modules @ 260 W => **9.4 kW**

Suggested Advanced String Inverter choices using 2 strings of 9 modules (4.7 kW) per inverter. Example appropriate dual MPPT string inverters:

- 2X - SMA Sunny Boy 5000TL US
- 2X - Dual ABB PVI5000 OUTD-US

South Facing Roof Configuration (72 Cell Modules)



Roof Capacity = 36 Modules @ 305 W => **11.0 kW**

South Facing Roof Configuration (72 Cell Modules)

36 Modules @ 305 W => **11.0 kW**

Advanced String Inverter choices using 2 strings of 9 modules (5.5 kW) per inverter. Example appropriate dual MPPT string inverters:

- 2X - Dual SMA Sunny Boy 6000TL US inverters
- 2X - Dual ABB PVI6000 OUTD-US inverters
- 2X - Dual Fronius Primo 6.0-1 inverters

Ooops! What About That Tree?

If it were really there, it would be a problem.

The tree would cause serious afternoon shading likely Sept through Mar. Microinverters or optimized string inverter choices include:

1. Enphase M250 micro inverters for 60 cell modules.
2. ABB Micro-0.3 OUTD-US for 72 cell modules.
3. Solaredge SE10000 or SE11400 inverter with P300 or P320 optimizers

Specifications and Costing (String Inverter)

Design	9.4 kW Adv String		11.0 kW Adv String
Function	**Descriptor**		**Descriptor**
PV System Size (kW)	9.4		11.4
PV Panels	36 x 260 Watt - 60 cell/Poly		36 x 305 Watt - 72 cell/Poly
Inverter Type	2 x 5 kW String (Dual MPPT)		2 x 6 kW String (Dual MPPT)
Efficiency	96.5%		96.5%
Element	**Cost to Builder**		**Cost to Builder**
PV Panels	$10,935		$12,442
Inverters	$6,897		$8,019
Racking	$3,275		$3,275
Balance of System	$1,232		$1,364
Web Monitoring Hardware	$1,168		$1,168
Design and Installation	$10,544		$12,073
Total Installed Cost	**$34,051**		**$38,340**
$ per Watt	$3.62		$3.36

Specifications and Costing (Micro-Inverter)

Design	9.4 kW Micros		11 kW Micros
Function	**Descriptor**		**Descriptor**
PV System Size (kW)	9.4		11.4
PV Panels	36 x 260 Watt - 60 cell/Poly		36 x 305 Watt - 72 cell/Poly
Inverter Type	250 W Micro-Inverters		300 W Micro-Inverters
Efficiency	96.5%		96.5%
Element	**Cost to Builder**		**Cost to Builder**
PV Panels	$10,935		$12,442
Inverters	$8,213		$9,207
Racking	$3,460		$3,460
Balance of System	$2,930		$2,899
Web Monitoring Hardware	$678		$495
Design and Installation	$11,429		$12,317
Total Installed Cost	**$37,645**		**$40,819**
$ per Watt	$4.00		$3.58

Energy Harvests and Benefits

Performance	9.4 kW PV System	11.0 KW PV System
South Facing Performance		
Horizontal Tilt Angle	32 Degrees	32 Degrees
Climate Model	Abbotsford Airport	Abbotsford Airport
Annual Energy Generated (kWh)	9505	11123
Value per kWh with BC Hydro Net Metering (Based on Offsetting Step 2 Use) [1]	11.95 cents/kWh	11.95 cents/kWh
Annual Benefit to Homeowner [2]	$1,252	$1,465
Fractional Performance (% of South)		
Facing Southeast	95%	95%
Facing East	83%	83%
Facing North	61%	61%
Facing West	83%	83%
Facing Southwest	95%	95%

Notes

1. Beyond Net-Zero energy value = 9.99 cents/kWh
2. Includes GST and Rate Rider but not invested returns

Part D: Discussion

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