NRC·CNRC

Canadian Conference on Building Science and Technology 2017

Performance Assessment of Energy Positive Roofs

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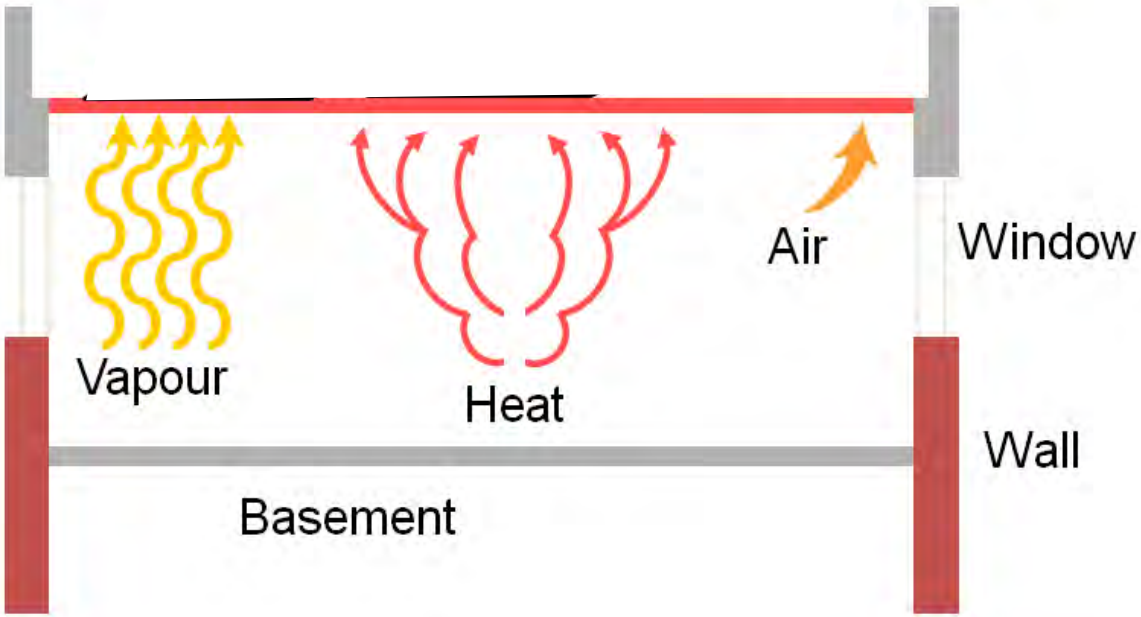
Presentation Outline

- Background
- Experimental Approach
- Results
- Conclusions and Future Work

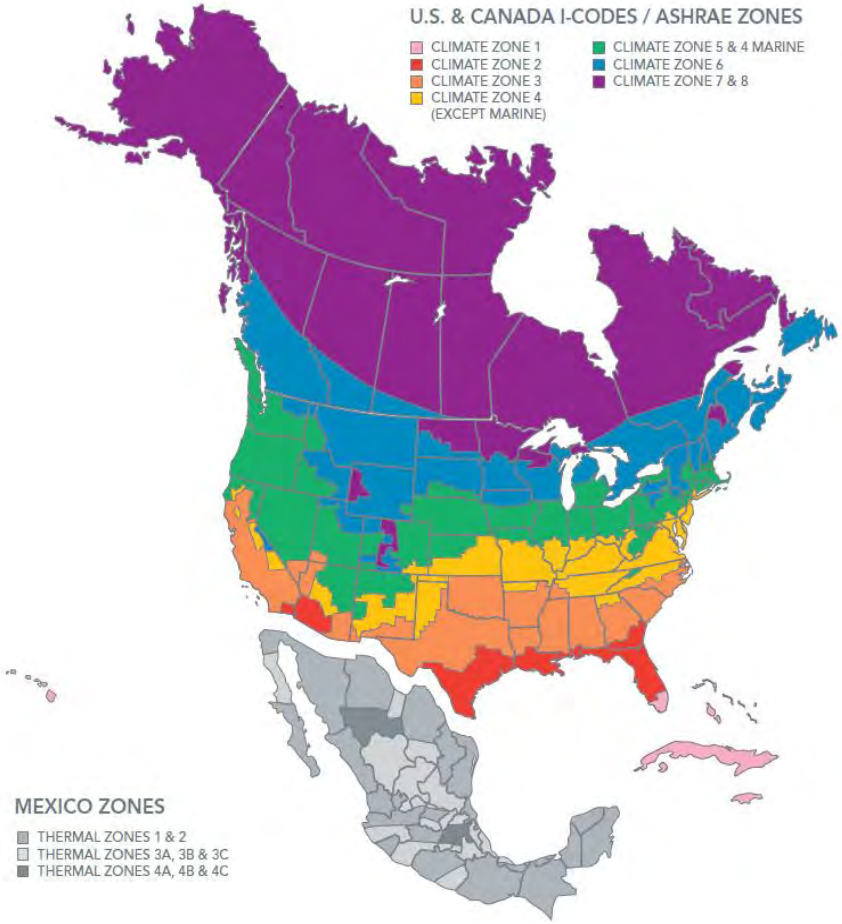
Background
Energy Positive Roof



- Roofs represent substantia portion of the building thermal Envelope
- Significant opportunity for reducing energy in heating and Cooling
- Platform for energy harvesting

Simultaneously minimize energy loss through the use of advanced insulation AND harvest energy through the use of PVs

Energy Saving

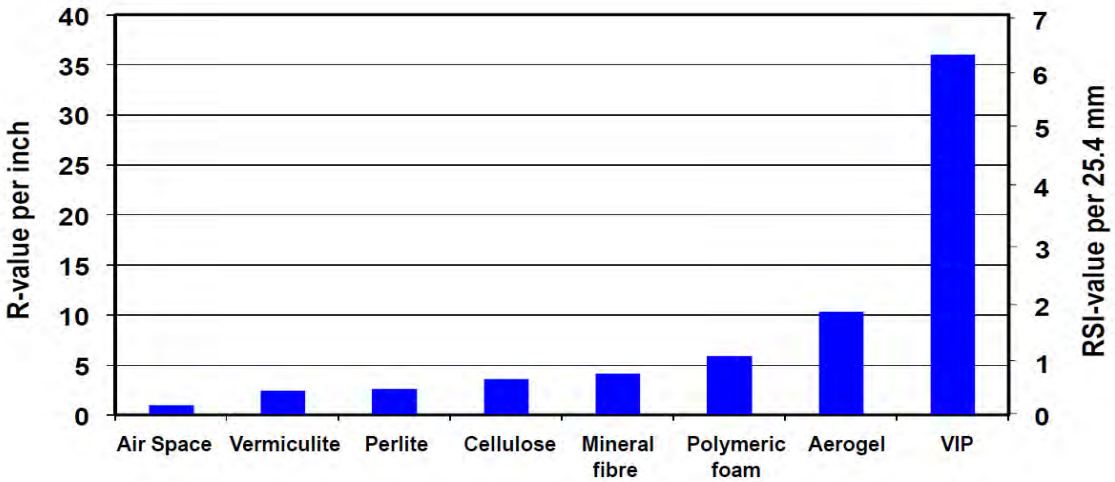


- The energy code provide prescriptive requirements for the effective use and conservation of energy over the useful life of each building.

Zone	4	5	6	7A	7B	8
Maximum Overall Thermal Transmittance ($W/(m^2K)$)	0.227	0.183	0.183	0.162	0.162	0.142
Effective Thermal Resistance ($(m^2K)/W$)	4.41	5.46	5.46	6.17	6.17	7.04
Effective Thermal Resistance ($ft^2hr°F/BTU$)	25	31	31	35	35	40

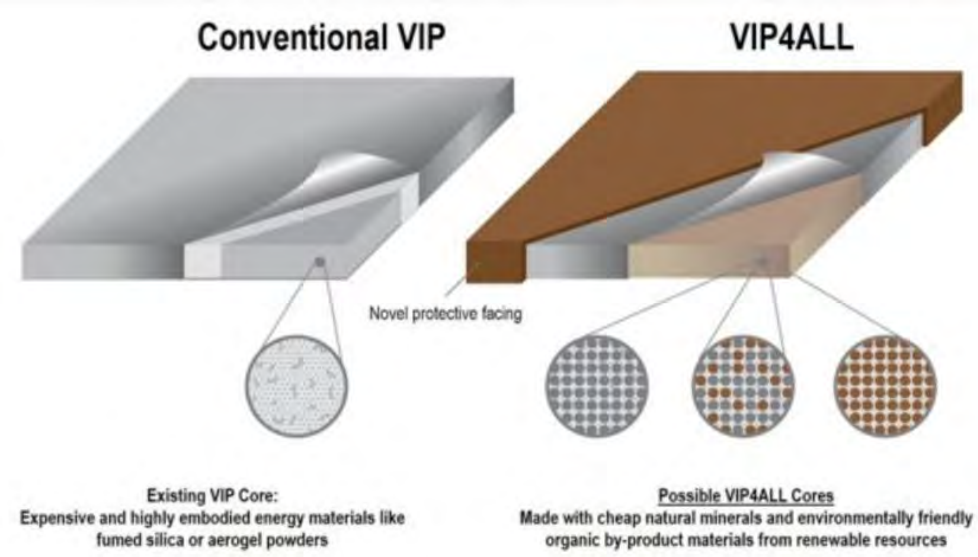
Integrating Advanced Insulation

- A material with superior thermal performance can be added to compliment the current system, such as Vacuum Insulation Panels (VIPs)
- Maintain desired thickness and achieve specified R-values



VIP4ALL

VIP4ALL is the acronym of a research project entitled "Highly Sustainable and Effective Production of Innovative Low Cost Vacuum Insulation Panels for Zero Carbon Building Construction". It was launched in 2013 and it's funded by the [Seventh Framework Program] ([FP7])



VIP4ALL will completely or substantially replace these core materials by natural, cheaper and more sustainable ones, creating hybrid multi-level networking structured cores, using wood-based materials and/or special minerals.

Complementary, **VIP4ALL** intends to create a new thin protecting facing for its VIPs, making it much more user-friendly to handle, stock and transport before and during installation.

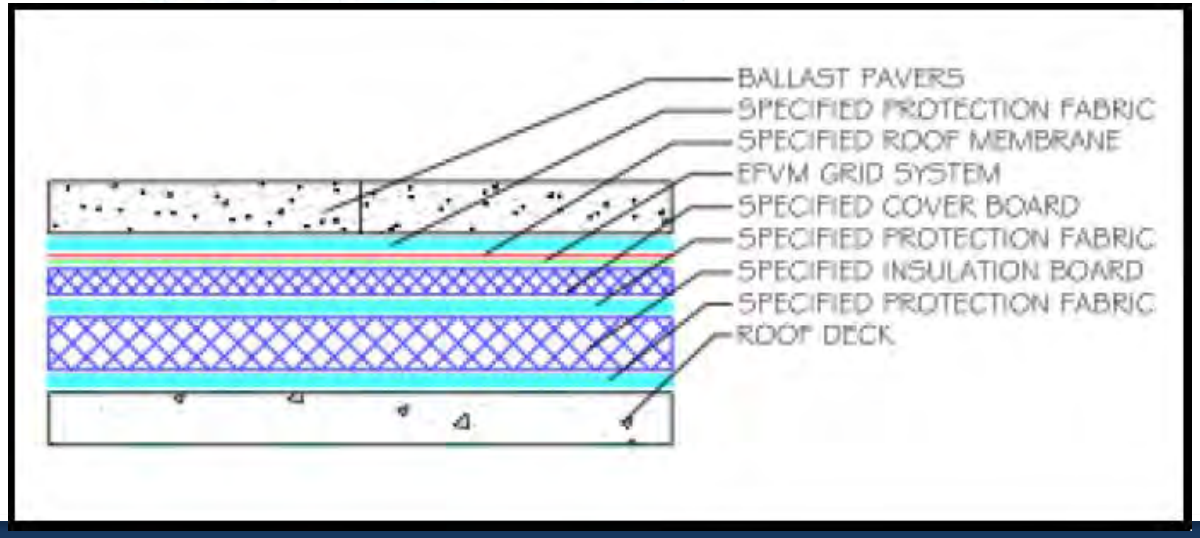
http://www.vip4all.com/project-proposal/

VIP in Roofing Applications

Courtsey: Kingspan

Courtsey: Chalmers University of Technology

VIP in Roofing Applications



Camden U.S Post Office
And Court House – New Jersey

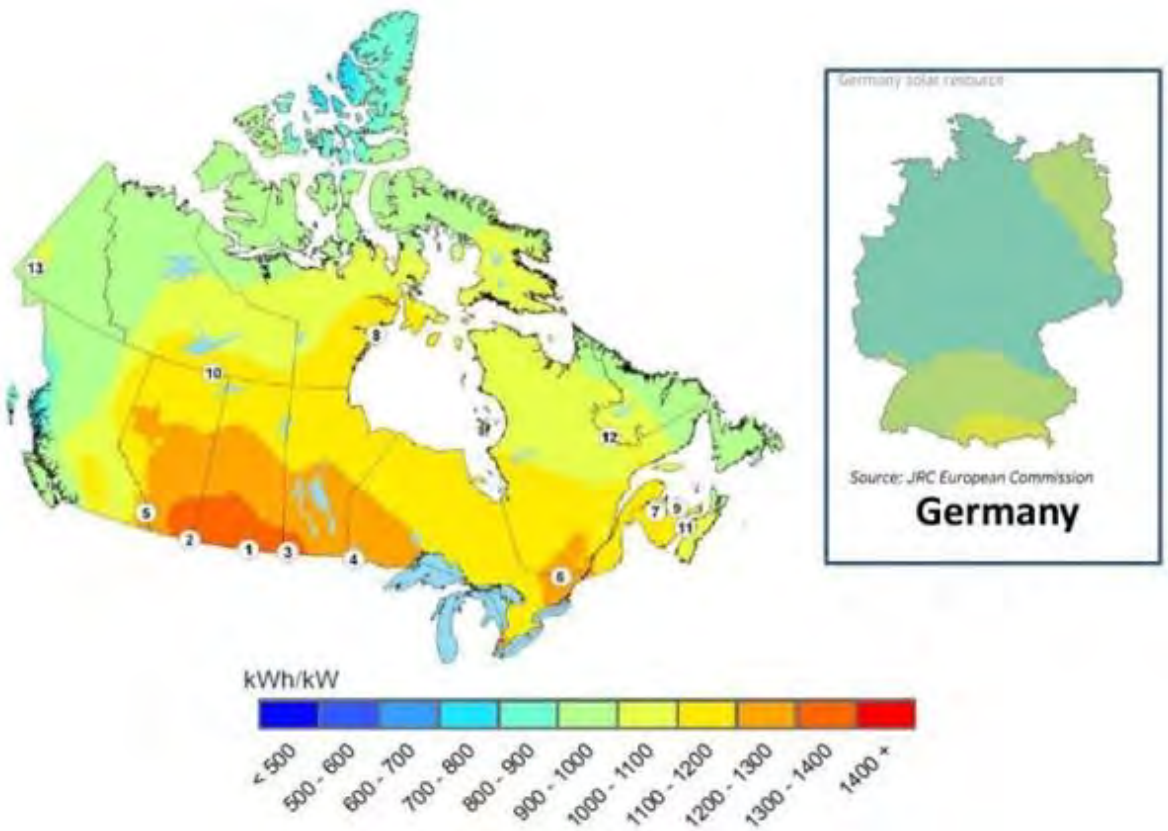
Courtsey: ORNL

VIP in Roofing Applications

Energy Harvesting

- Incorporation of renewable energy sources such as solar energy by photovoltaic (PV) systems
- Reduce of even eliminate a building's energy demand
- Achieve status of energy positive building

Canada PV Potential



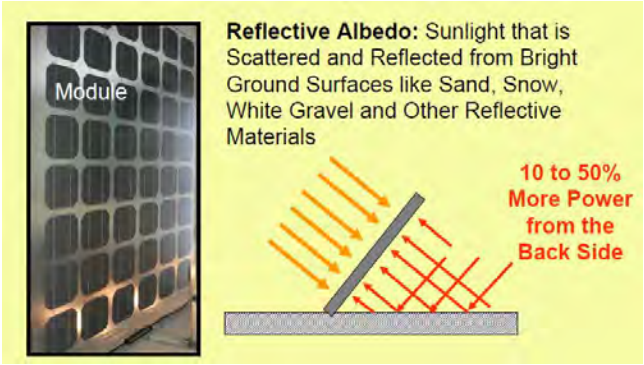
Major Canadian cities and capitals	Yearly PV potential (kWh/kW)	Major cities worldwide	Yearly PV potential (kWh/kW)
Regina (Saskatchewan)	1361	Cairo, Egypt	1635
Calgary (Alberta)	**1292**	Capetown, South Africa	1538
Winnipeg (Manitoba)	1277	New Delhi, India	1523
Edmonton (Alberta)	**1245**	Los Angeles, U.S.A.	1485
Ottawa (Ontario)	1198	Mexico City, Mexico	1425
Montréal (Quebec)	1185	Regina, Canada	1361
Toronto (Ontario)	1161	Sydney, Australia	1343
Fredericton (New Brunswick)	1145	Rome, Italy	1283
Québec (Quebec)	1134	Rio de Janeiro, Brazil	1253
Charlottetown (Prince Edward Island)	1095	Beijing, China	1148
Yellowknife (Northwest Territories)	1094	Washington, D.C., U.S.A.	1133
Victoria (British Columbia)	1091	Paris, France	838
Halifax (Nova Scotia)	1074	St. John's, Canada	933
Iqaluit (Nunavut)	1059	Tokyo, Japan	885
Vancouver (British Columbia)	1009	Berlin, Germany	848
Whitehorse (Yukon)	960	Moscow, Russia	803
St. John's (Newfoundland and Labrador)	933	London, England	728

Advanced PV - Bi-facial PV

Bifacial PV

Roofing Albedo Effect

Snow Cover



Advanced PV- Pilot Study

BiFacial (320 W - 5kW)

Mono Facial (320 W- 5kW)

Experimental Approach:
Roof Mock-up with Composite VIP

Construction of supporting structure

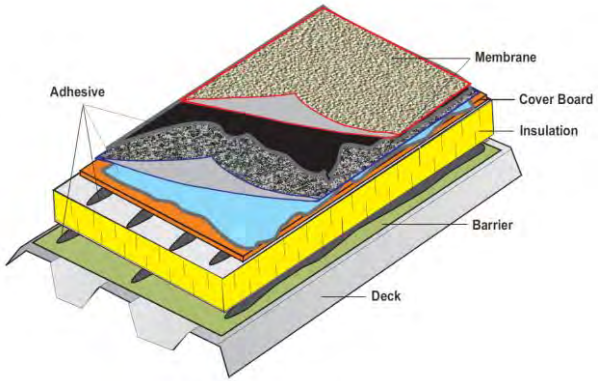
Installation of steel deck

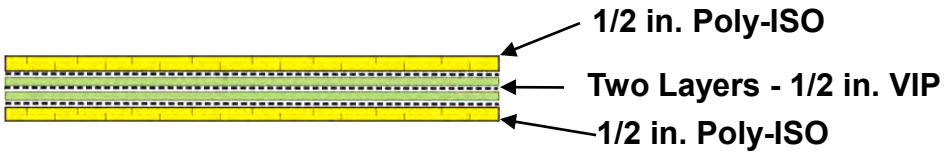
Installation of vapor barrier

Installation of insulation

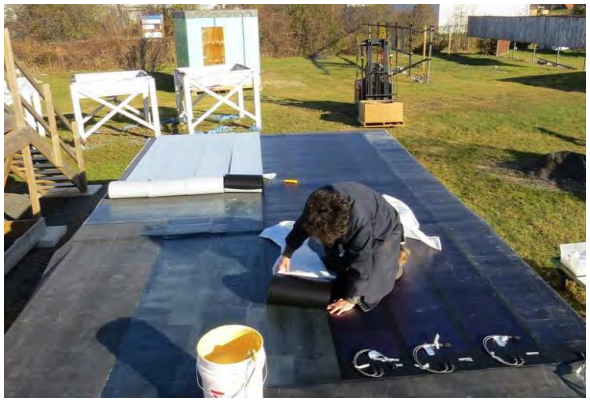
Installation of adhesive applied EPDM membrane

Completion of mock-up

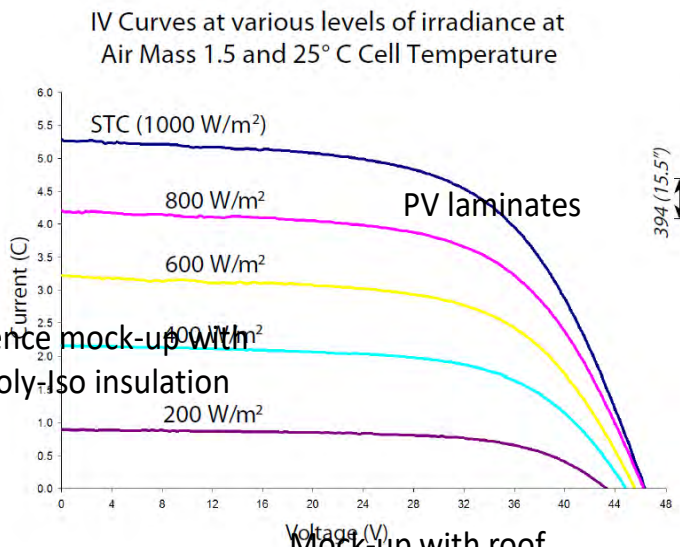




Experimental Approach – PV Installation

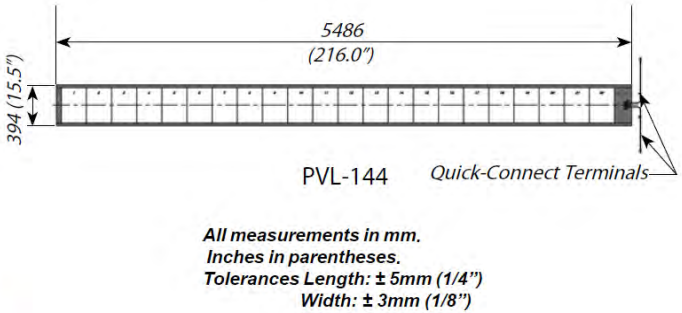


PV laminates using amorphous silicon technology



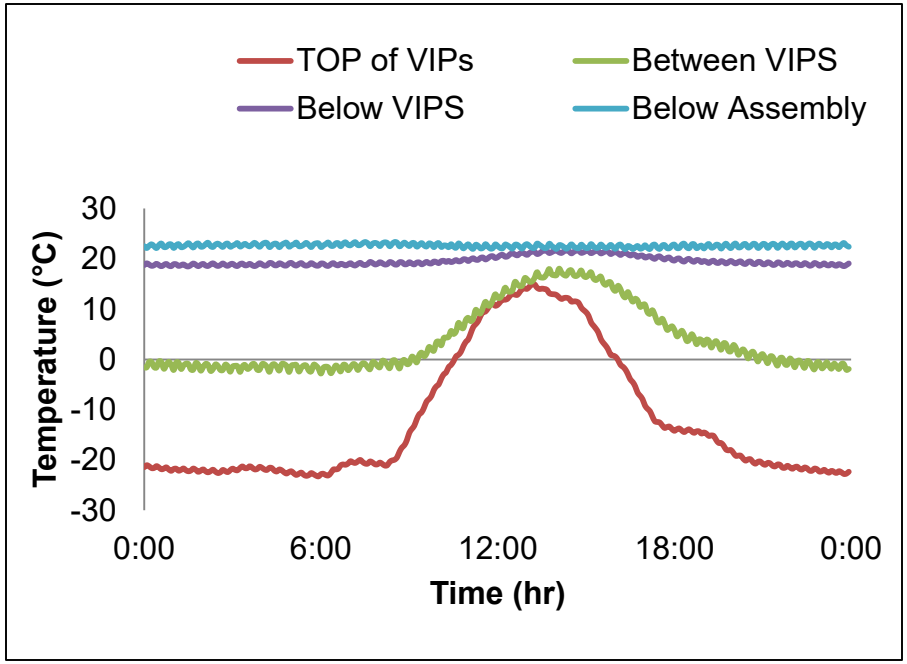
Reference mock-up with roof Poly-Iso insulation

Mock-up with roof VIP insulation

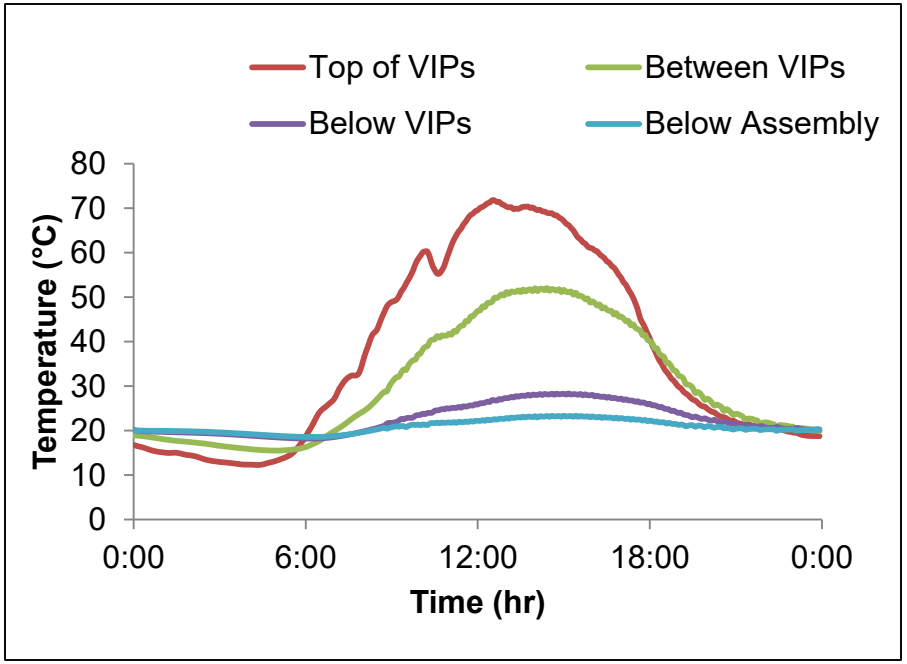


Results – Temperature Profiles

Typical Winter Day

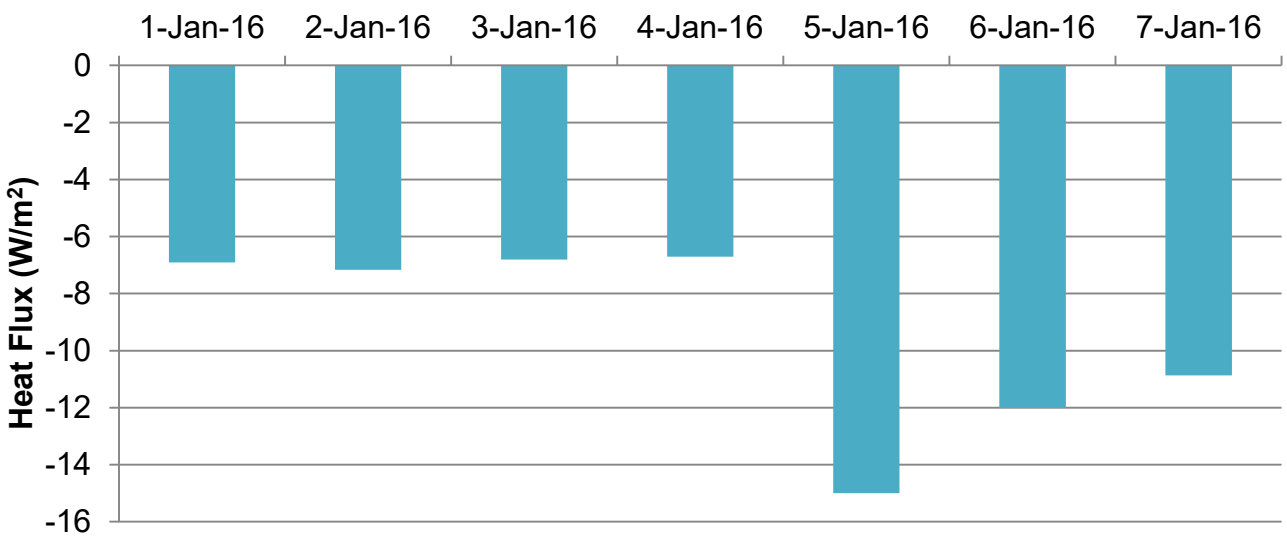


Typical Summer Day



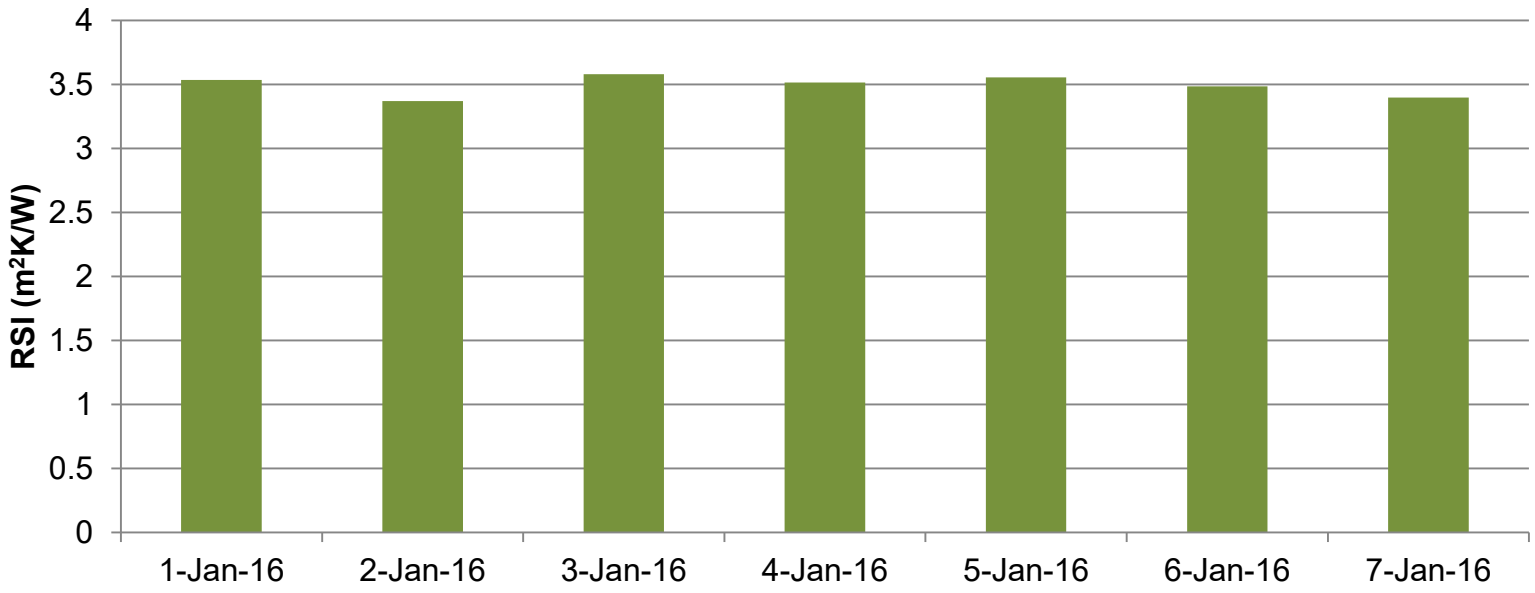
Results – Heat Flux

- Average daily heat fluxes for a typical winter week in 2016
- Average heat flux = 9.73 W/m^2
- When compared to an identical system with 2“ of conventional polyiso, the heat flux was reduced by 52.4% for the system with the VIP composite



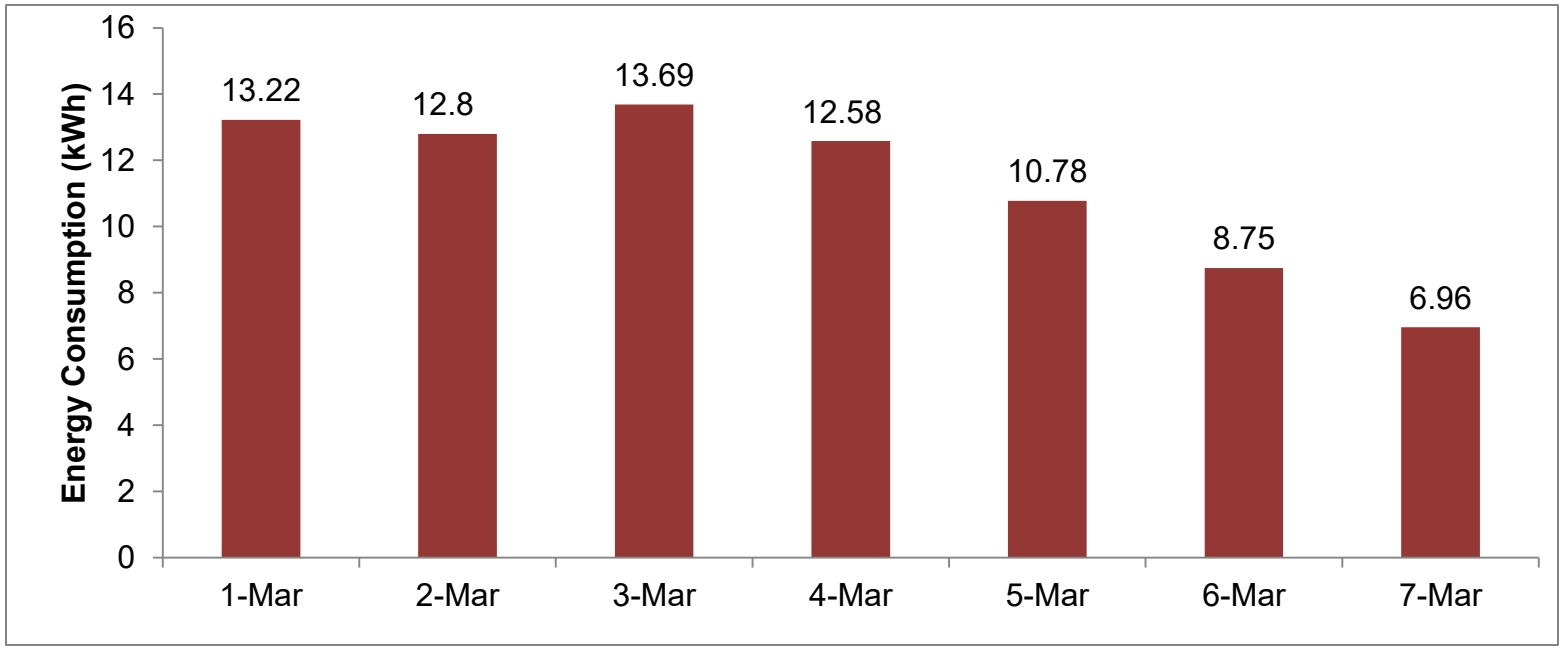
Results – Thermal Resistance

- Average daily R-values for a typical winter week in 2016
- Average monthly R-value for January 2016 = 3.57 m^2K/W



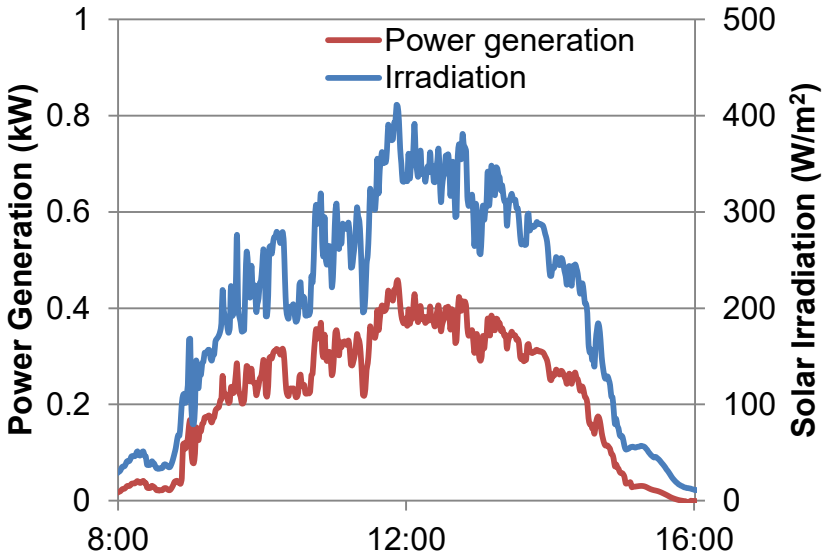
Results – Energy Consumption

- Total daily energy consumption for a typical winter week in March 2016
- The walls of the mock-up were constructed of regular polyiso insulation
- Highly insulated walls are being considered for next phase of the project

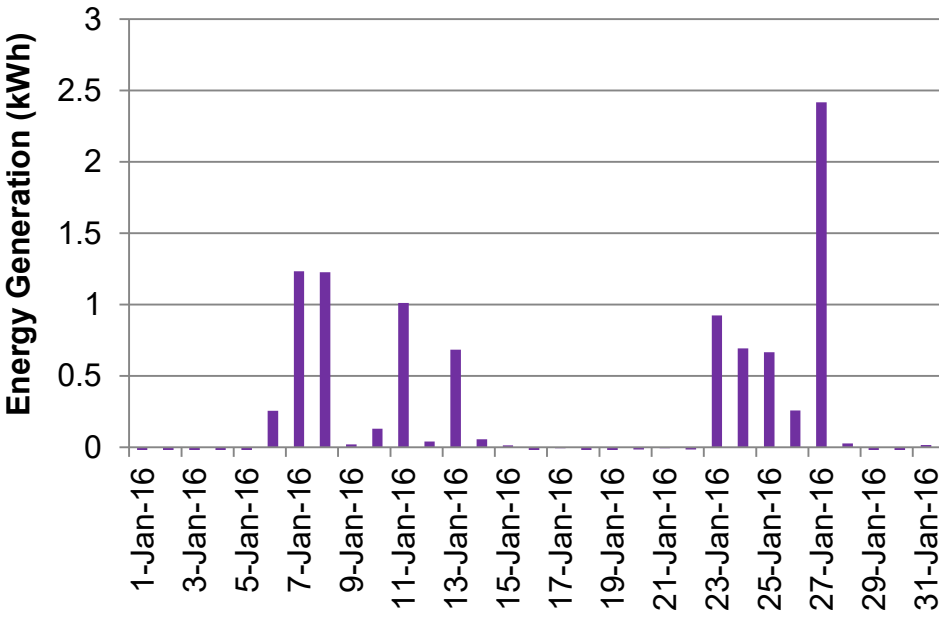


Results – Energy Generation

- Energy generation is low in winter months due to snow coverage and low solar radiation in Ottawa in January (maximum of 8 hours)



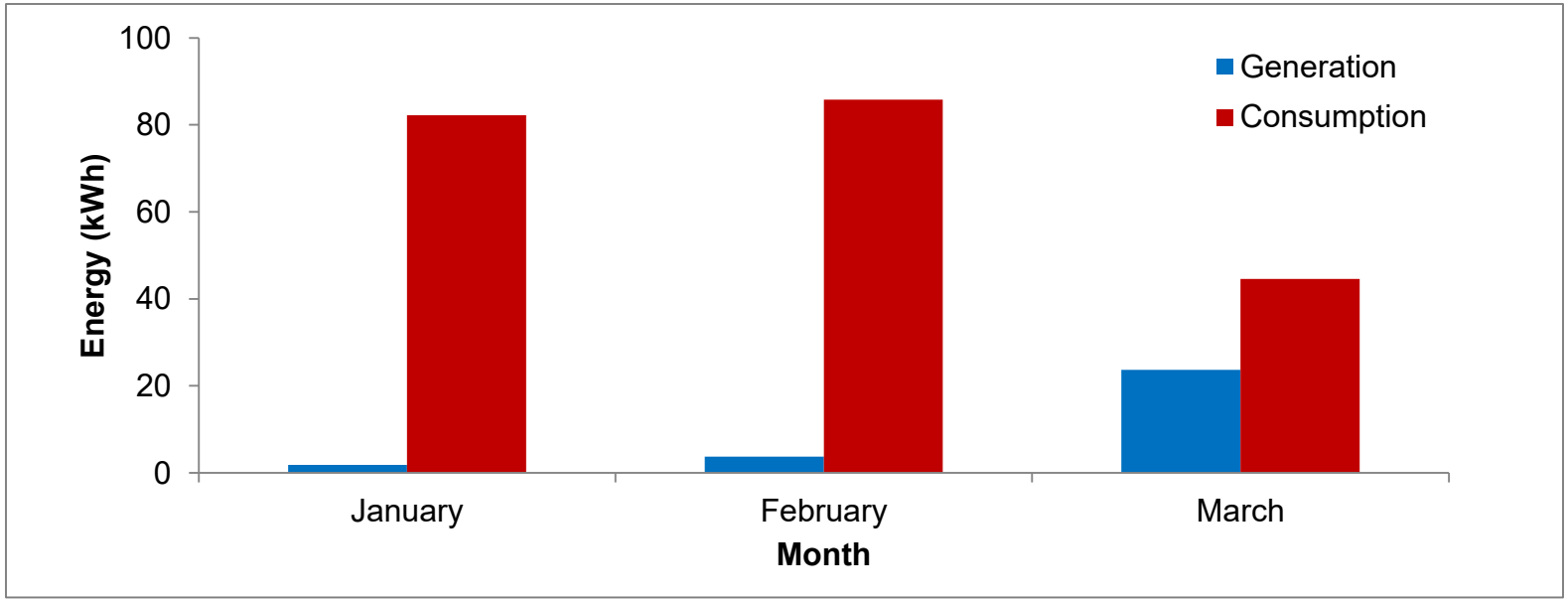
PV power generation vs. solar irradiation for January 2016



Daily energy generation for January 2016

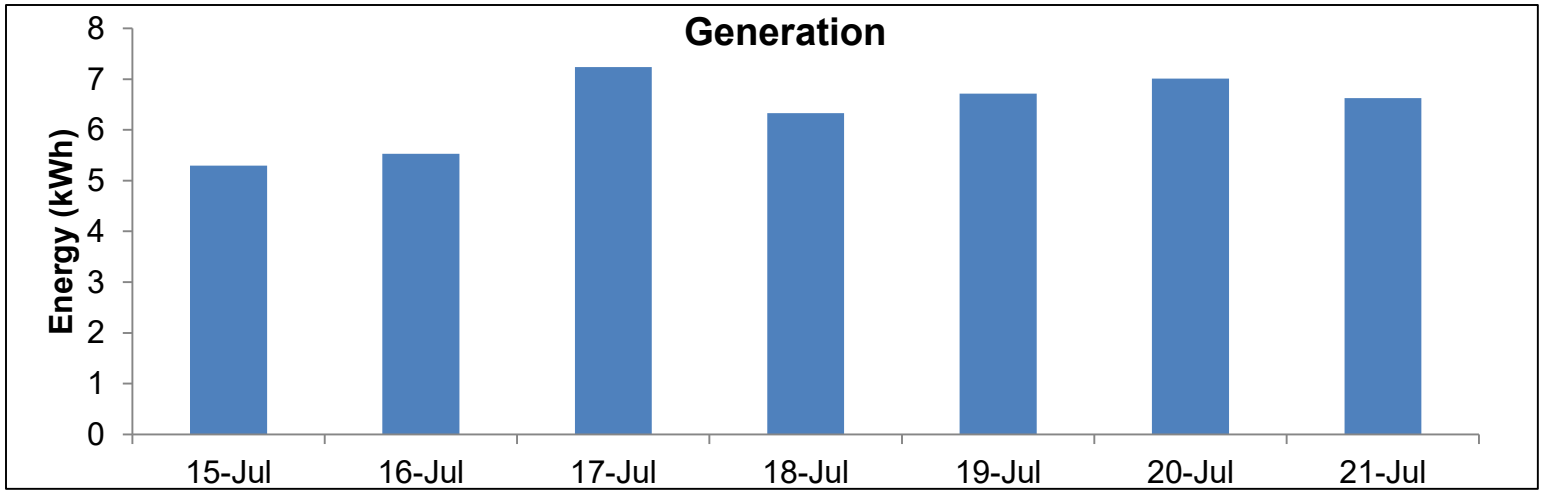
Results – Energy Generation vs. Energy Consumption Winter

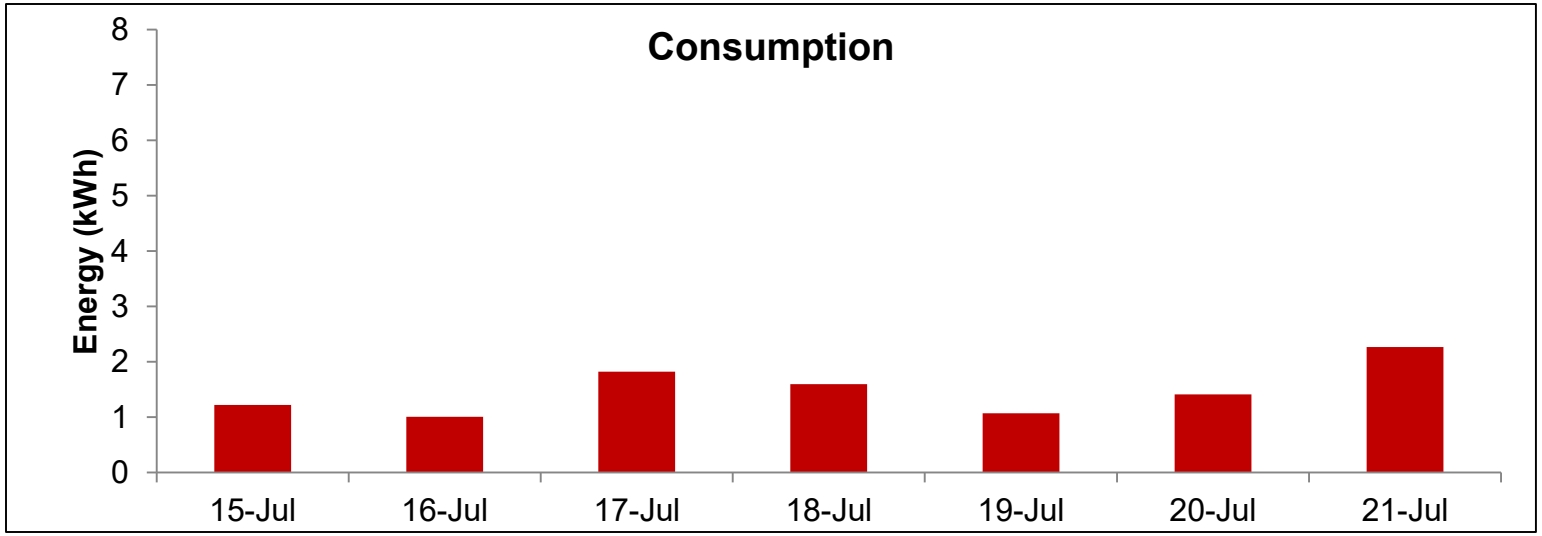
- Winter 2016
- Expected due to climate



Generation < Consumption

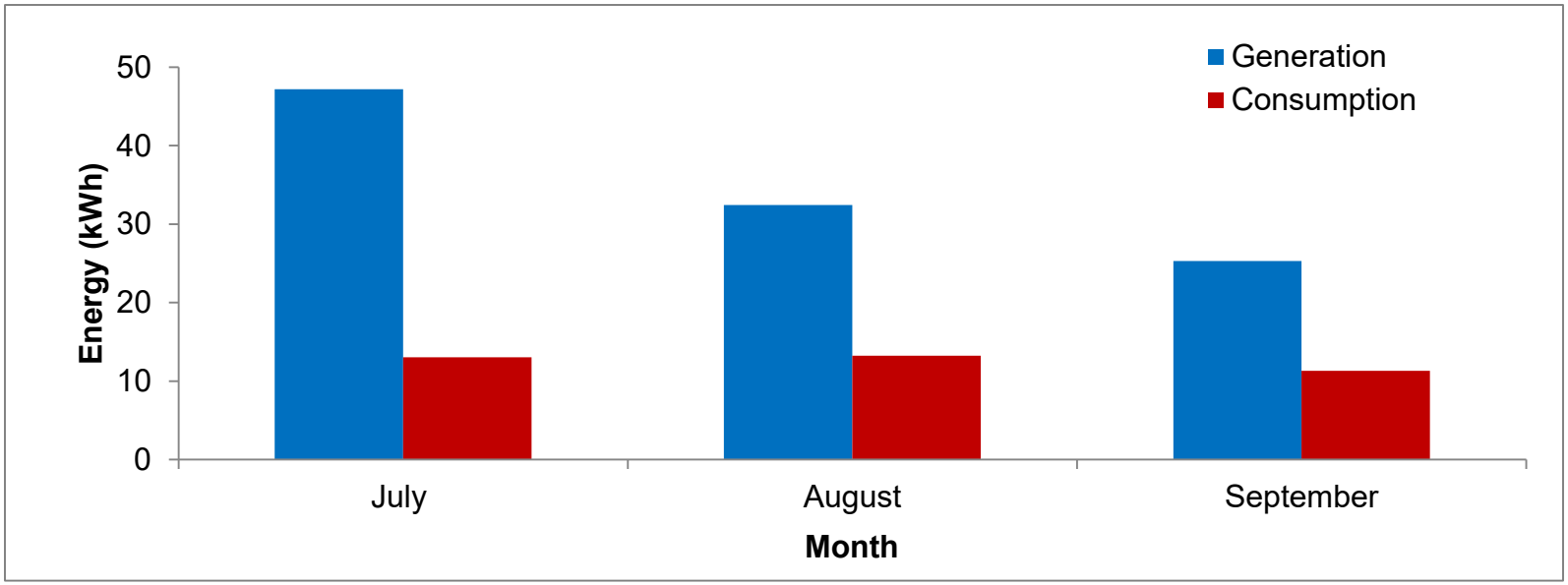
Results – Energy Generation vs. Energy Consumption Summer – Daily Data





Results – Energy Generation vs. Energy Consumption Summer – Monthly Data

- Summer 2016
- Successfully demonstrates the preliminary concept of net energy positive roofs



Generation > Consumption

Conclusion and Future Work

- ✓ Demonstrated the preliminary concept of energy positive roofs
- ✓ High performance insulation incorporated with energy generating photovoltaics
- ✓ VIPs as a complimentary insulation for integration into current roofing insulation

- ✓ Develop strategies for VIP implementation
- ✓ Further studies on energy positive roofs

Acknowledgements

Canada NRC-CNRC

Natural Resources Canada / Ressources naturelles Canada

Canada

HPB Program

PERD

Panasonic Canada

Carlisle SynTec

Thank You