Partnerships and Agrivovoltaic Research

Joshua M. Pearce

Thompson Chair in Information Technology & Innovation

Director: Free Appropriate Sustainable Technology (FAST) Lab

Department of Electrical & Computer Engineering

Thompson Centre for Engineering Leadership & Innovation

Ivey Business School

Western University

Western Engineering

Ivey Business School
WESTERN UNIVERSITY · CANADA

Why Open Source?

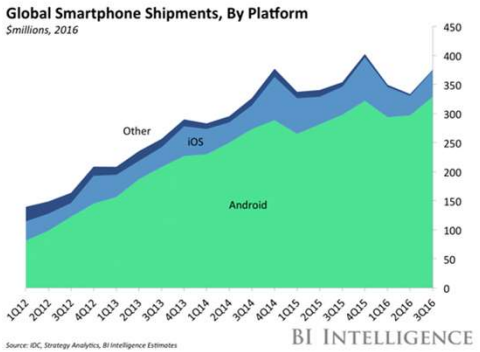
Free and open source software - software that is freely licensed to grant users the right to use, copy, study, change, and improve its design through the availability of its source code or be “open source”. Usually viral “share alike”

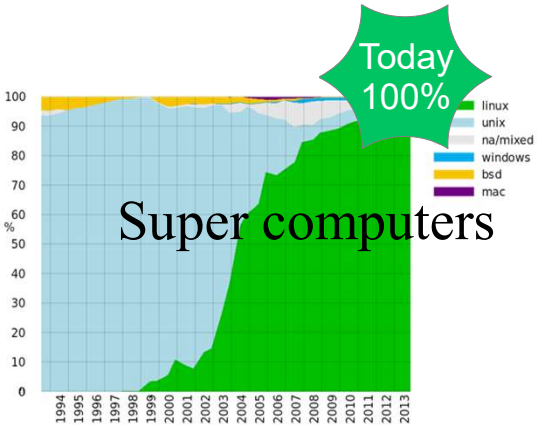
- More rapid innovation
- Superior technology
- Value harvesting for everyone

TECH

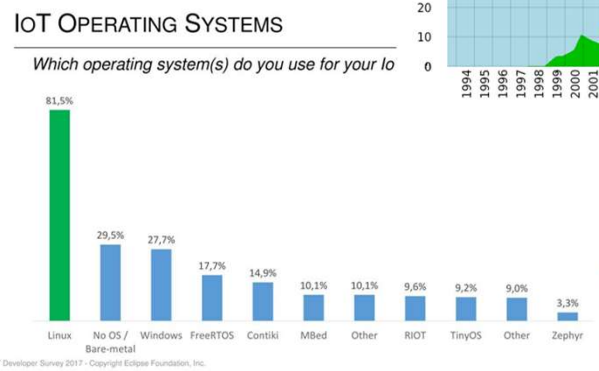
IBM closes its $34 billion acquisition of Red Hat

PUBLISHED TUE, JUL 9 2019·8:33 AM EDT | UPDATED TUE, JUL 9 2019·11:41 AM EDT





Super computers



Western Engineering

FAST

Ivey Business School
WESTERN UNIVERSITY · CANADA

Free Makes FAST, fast!

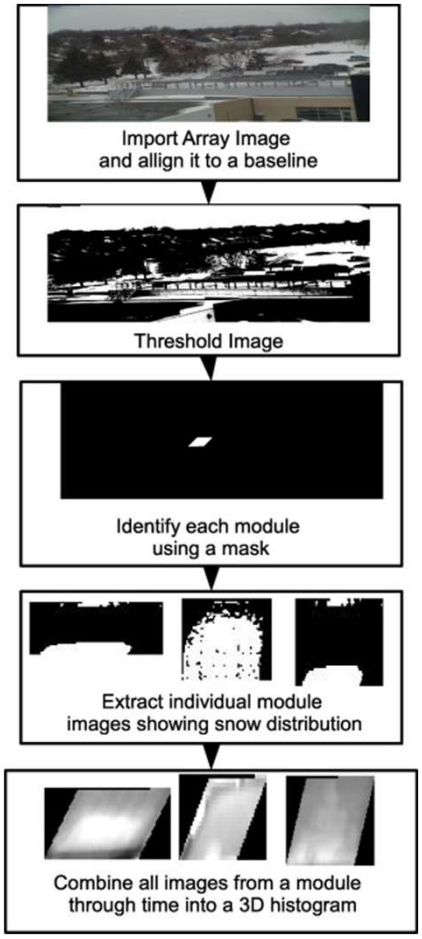
Advantages

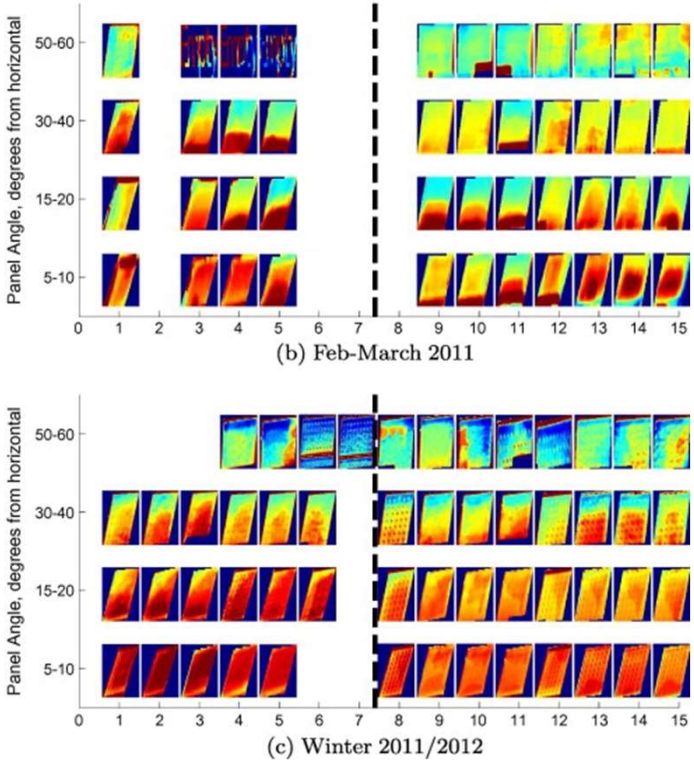
1. Free and open source leads to faster innovation!
2. No lawyers, NDAs, immediate collaboration
3. You know you can always use all of our tech for any purpose
4. Open access articles, Books, Literature reviews, Methods, Hardware designs, Software source code – all free at **appropedia.org/FAST**
5. UWO top 1% university, FAST students top 10%

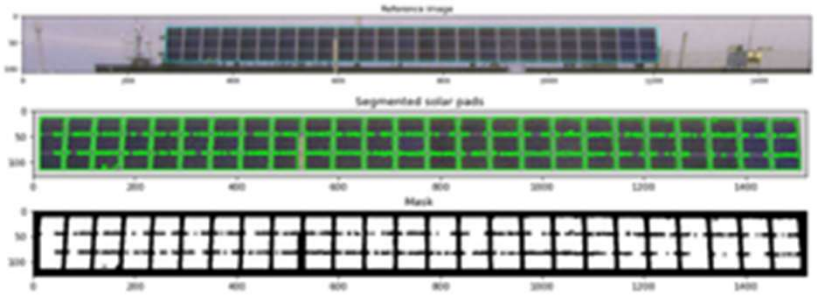
   = top 0.1 Academia, 40-50 studies/year

Must agree to allowing students to publish (good publicity for you)

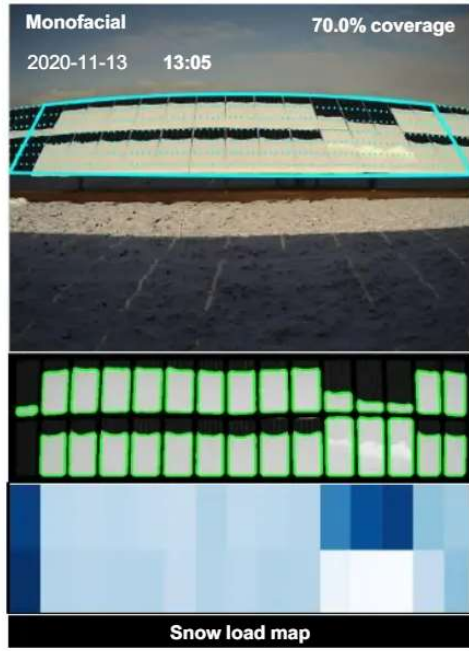
OS Snow Analysis





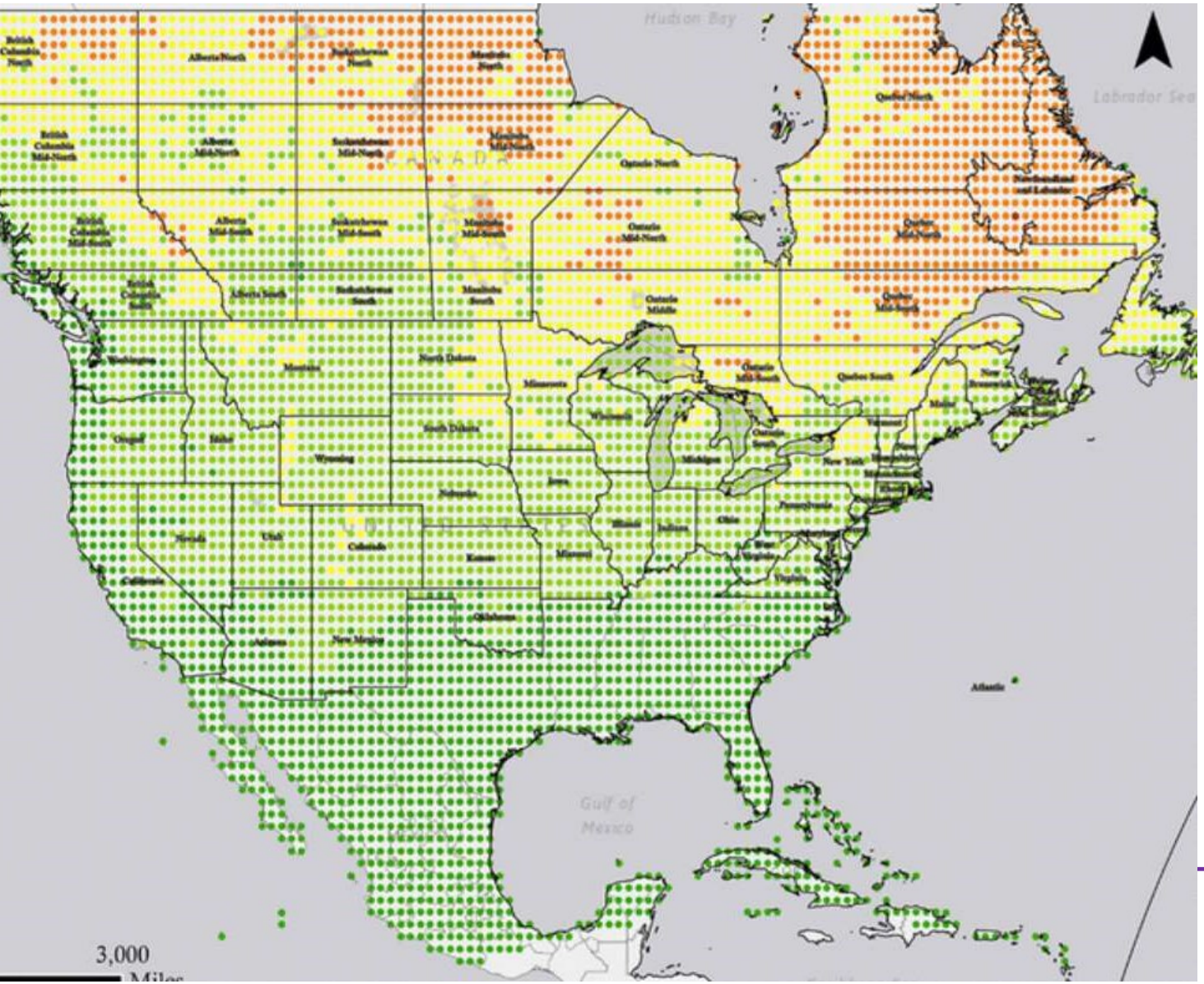


* Baldus-Jeursen, et al. Validating Marion and Townsend Snow Shedding Models for Solar Photovoltaic Systems. *IEEE J. of Photovoltaics*, 13(4) pp. 610-620, 2023.
* Hayibo, et al., Monofacial vs bifacial solar photovoltaic systems in snowy environments, *Renewable Energy*, 193, 2022, 657-668



Rob W. Andrews, Andrew Pollard, Joshua M. Pearce, "The Effects of Snowfall on Solar Photovoltaic Performance ", *Solar Energy* **92**, 8497 (2013).

FAST

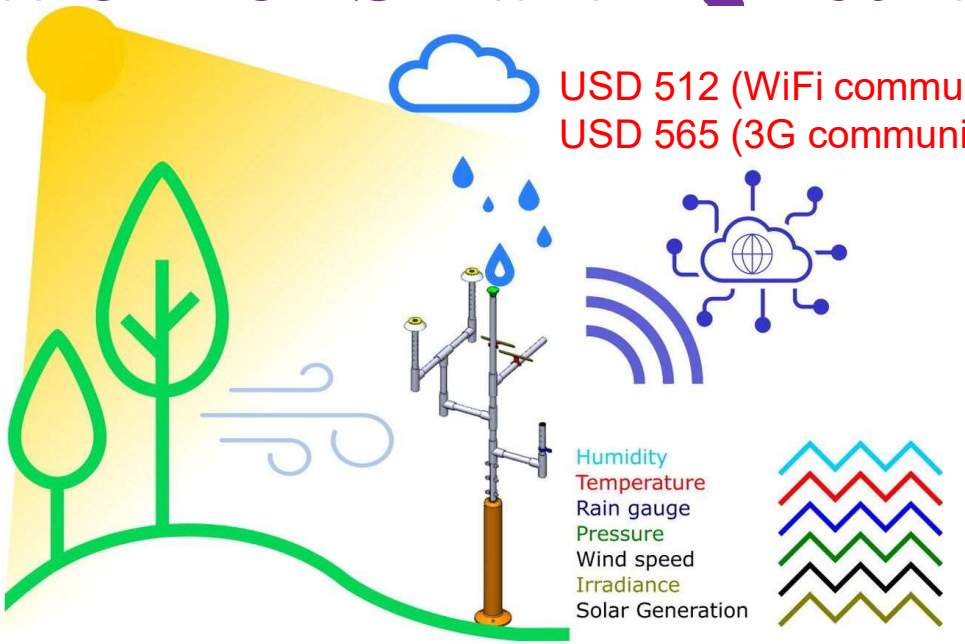


- Results show in 20 years even in the most optimistic SSP126 scenario many areas in the northern U.S. and southern Canada will be reduced below 5% snow losses.
- In the more pessimistic SSP585 scenario, heavy snow regions become nearly snowless.
- **Overall, climate change is substantially reducing snow losses for PV systems over most of North America.**
- R. Williams, D. Lizzadro-McPherson, J. Pearce, The Impact of Snow Losses on Solar Photovoltaic Systems in North America in the Future, *Energy Advances* 2, 1634-1649 (2023). https://doi.org/10.1039/D2YA00310D

IVEY Business School
WESTERN UNIVERSITY · CANADA

Low Cost Climate Station for Smart Agriculture

- Station measures:
  - relative humidity,
  - temperature,
  - atmospheric pressure,
  - precipitation,
  - wind speed, and
  - light radiation.
  - charge state of the main battery
  - energy generated by the photovoltaic module to act as a reference cell for solar energy generation capability and agrivoltaic potential in the installation area.
- The station can be remotely controlled and reconfigured.



Can use to quantify impacts of local environment e.g. haze

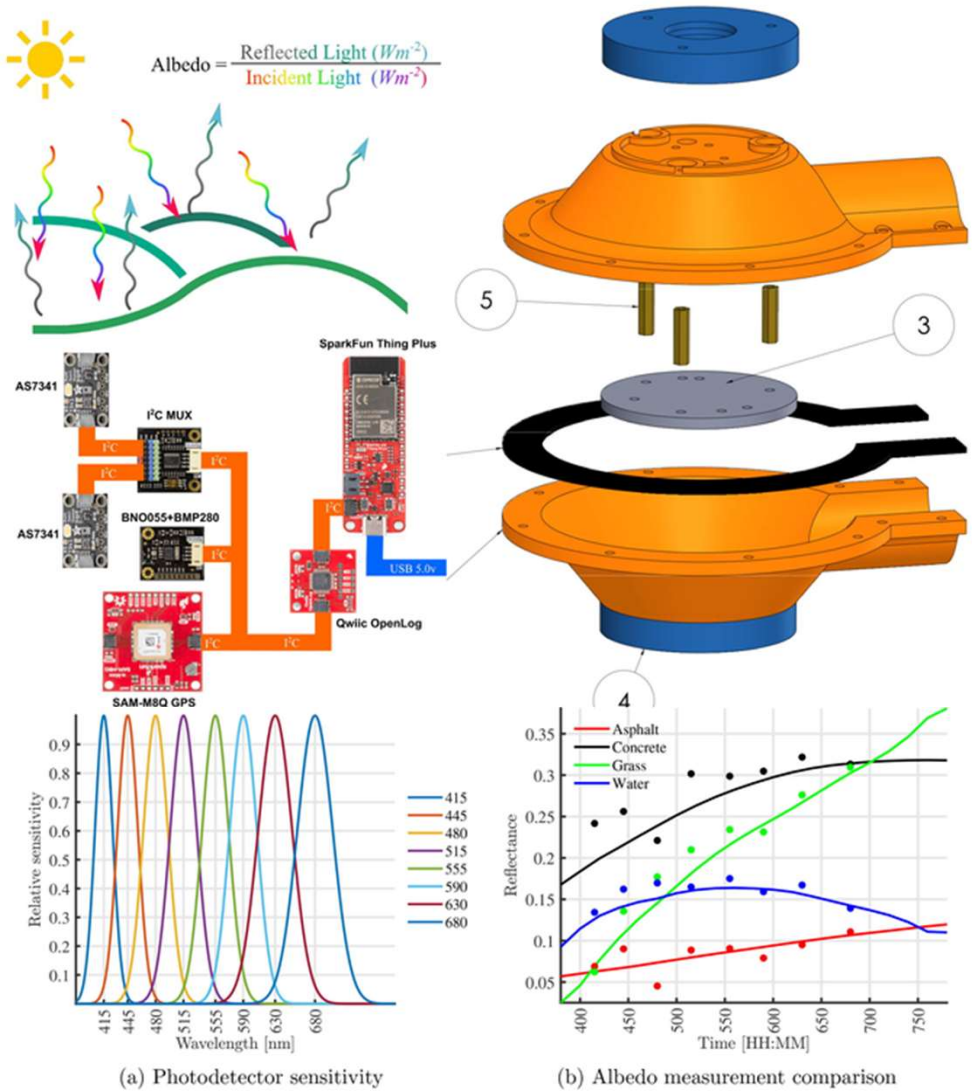
- J.S. Botero-Valencia, M. Mejia-Herrera, Joshua M. Pearce, Low cost climate station for smart agriculture applications with photovoltaic energy and wireless communication, *HardwareX*, 11, 2022, e00296,https://doi.org/10.1016/j.ohx.2022.e00296

Seyyed Ali Sadat, Bram Hoex, Joshua M. Pearce, A Review of the Effects of Haze on Solar Photovoltaic Performance, *Renewable and Sustainable Energy Reviews*, 167, 2022,112796. https://doi.org/10.1016/j.rser.2022.112796

Multispectral Albedometer

USD 180

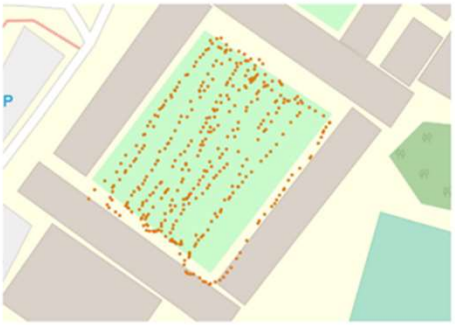
- J.S. Botero-Valencia, M. Mejia-Herrera, Joshua M. Pearce, Design of a low-cost mobile multispectral albedometer with geopositioning and absolute orientation, *HardwareX*, 12, 2022, e00324 doi: https://doi.org/10.1016/j.ohx.2022.e00324



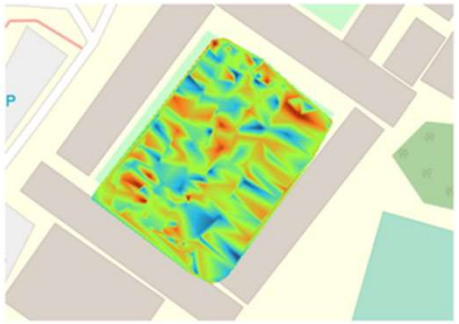
(a) Photodetector sensitivity

(b) Albedo measurement comparison

Aerial view



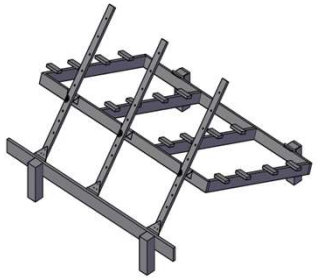
Acquisition points

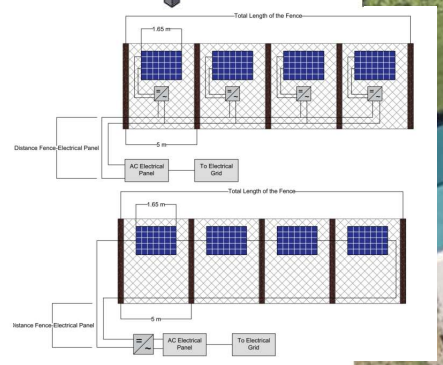


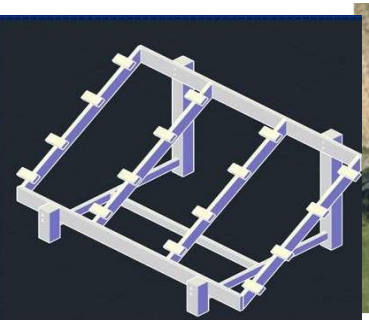
Intensity map

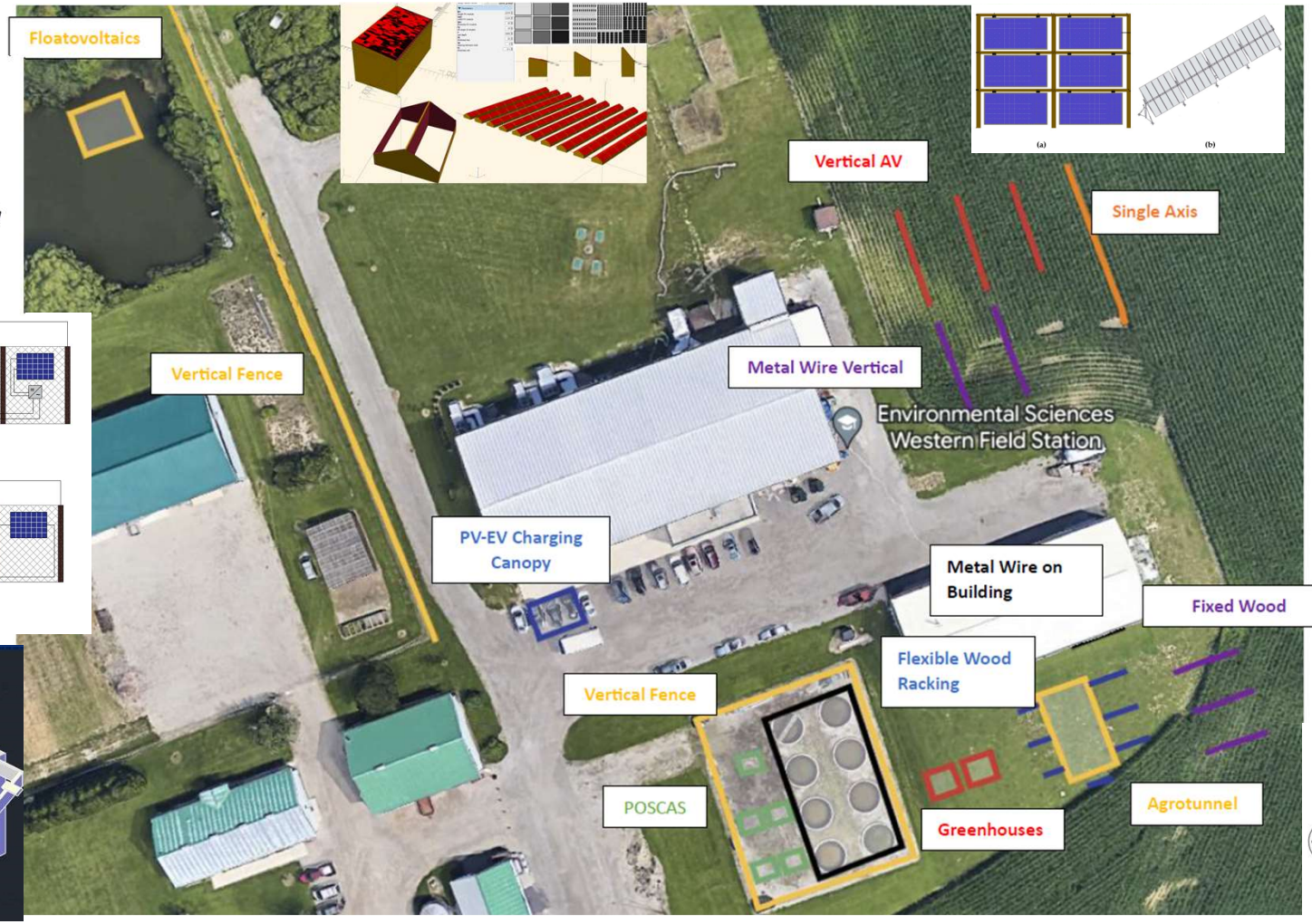
Western Engineering

Western Innovation for Renewable Energy (WIRED)



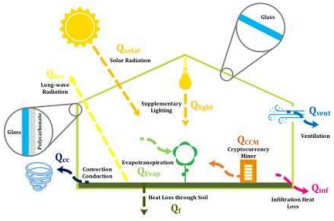






Uzair Jamil

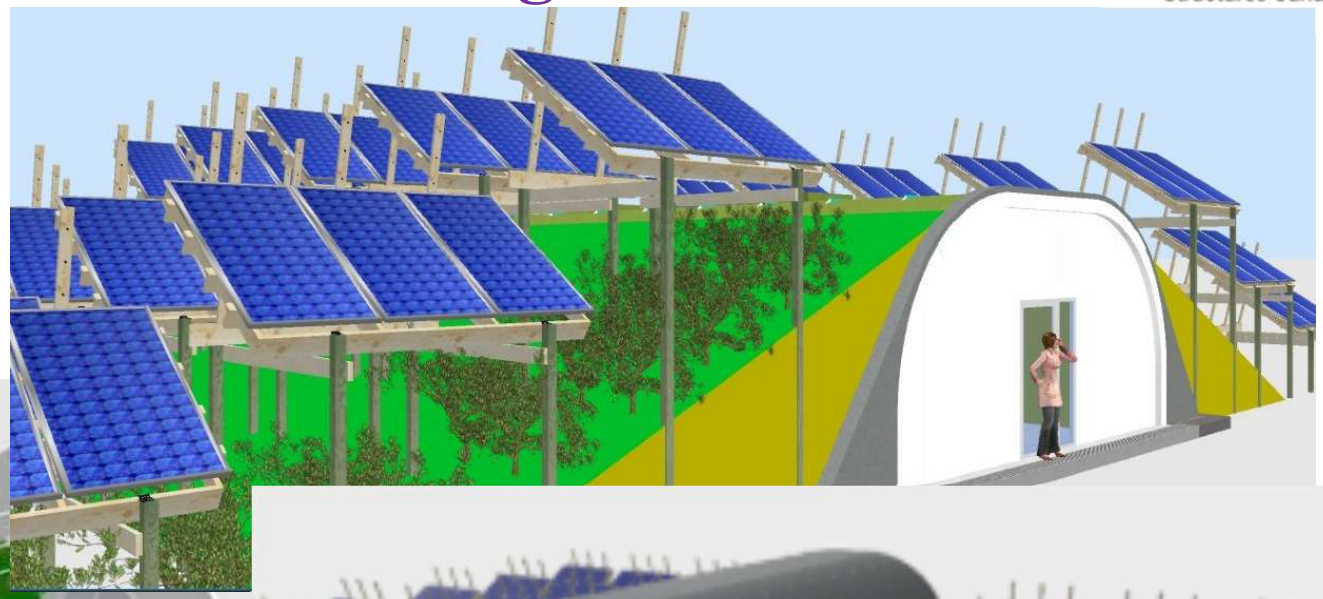
Kashish Mittal



Agrivoltaic Agrotunnel with Vertical Grow Walls for berries and greens

FSSC
Food Security
Structures Canada

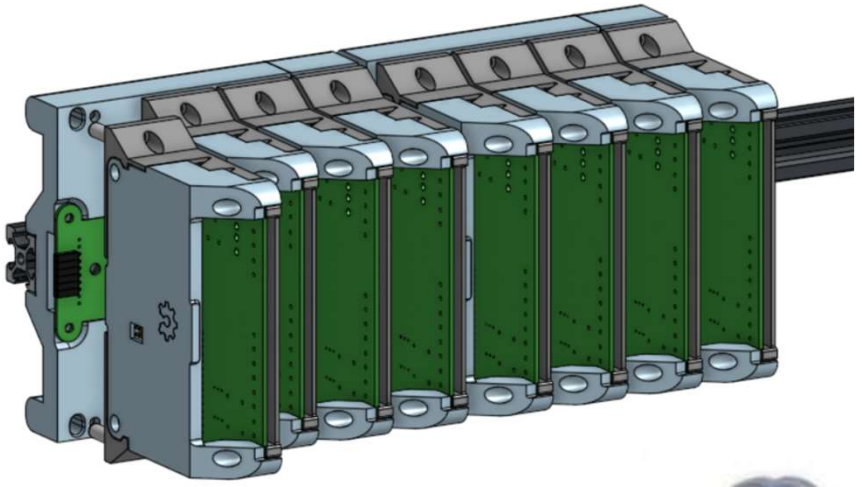
Will work anywhere
Zero food miles



A+

Broadly Expandable and Reconfigurable Data Acquisition and Automation Device (BREAD)

- BREAD is a novel, modular, open-source framework that reduces the cost of supervisory control systems without sacrificing performance.
- Each card (slice) has a unique function from heating control to DC motor actuation. There are currently 15 slices fully designed with more on the way.
- Anyone can access the free electrical schematics and design their own slices.
- BREAD has been used to develop a PV powered modular pyrolysis reactor and bioreactor controller.

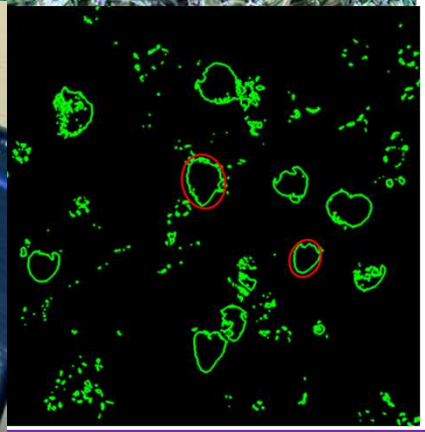


- **Supervisory control and data acquisition (SCADA)**

Computer Vision/ Synthetic Images/ Machine Learning/AI for Crop Monitoring

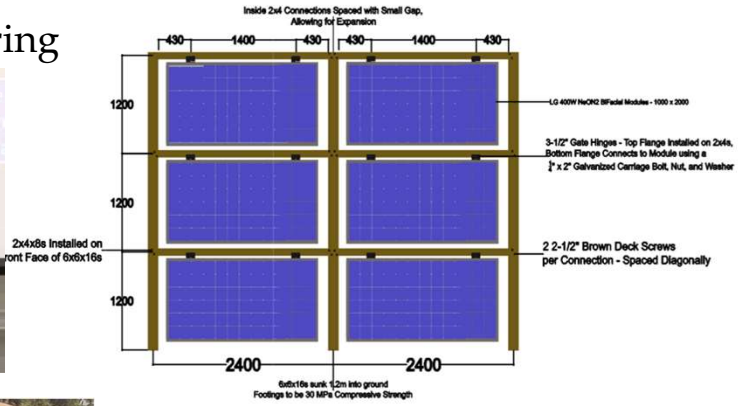
Kimia Ketabforoosh

Aliaksei Petsiuk



Vertical Agrivoltaics Field/Fence any Scale Active Windbreaks

Nicholas Vandewetering



- 15 kW vertical bifacial ground-mounted PV modules shall be installed to run trials on agriculture/crops.
- E-W facing while the racking system shall use the already available low-cost lumber
  - Hayibo, K.S., Pearce, J.M., 2022. Optimal inverter and wire selection for solar photovoltaic fencing applications. *Renewable Energy Focus*. 42, (2022), 115-128. https://doi.org/10.1016/j.ref.2022.06.006
  - Sudhachandra Masna, Stephen M. Morse, Koami Soulemane Hayibo and Joshua M. Pearce. The Potential for Fencing to be Used as Low-Cost Solar Photovoltaic Racking (to be published).

Koami Hayibo

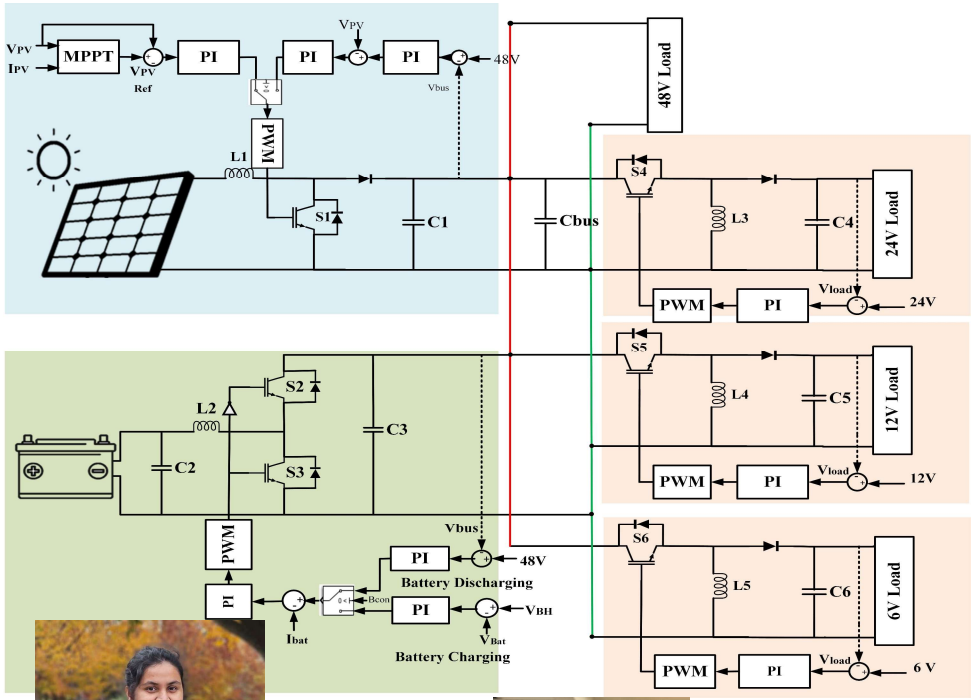
Sudhachandra Masna

Western Engineering

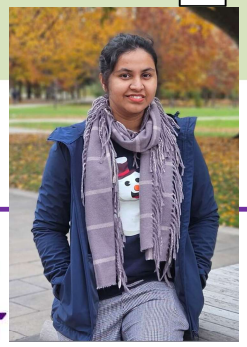
FAST

Open Source Solar Photovoltaic Powered DC Nano Grid, H2 Production and Life Cycle Analysis – to Select Best Option

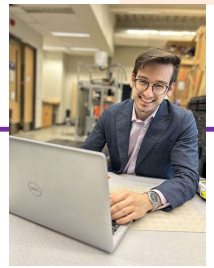
- The DC Nano grid is a plug-and-play modular PV system, comprising batteries to facilitate off-grid power supply.
- DC power to loads of different voltage levels (48V, 24V, 12V and 6V) simultaneously.
- H2 production for fuel or water treatment
- LCA of PV systems to assist design/deployment



Motakabbir Rahman



Sara Khan



Giorgio Antonini

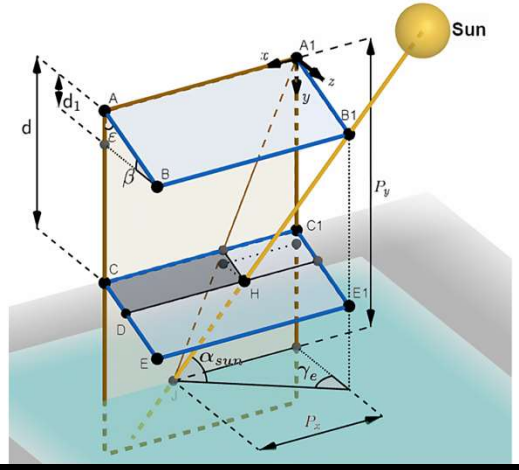
Riya Roy

FAST

IVEY Business School
WESTERN UNIVERSITY · CANADA

Vertical Swinging PV Racking for Agrivoltaics

- Free-swinging design has the potential to be the cheapest on-ground PV racking.
- We proposed a new simulation tool to evaluate the energy generation performance of the system including the shading losses while the system is swinging = **12% gains!**

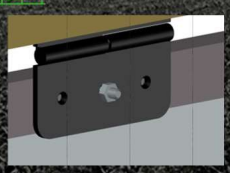


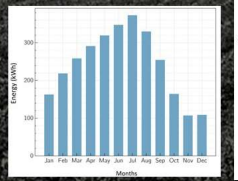
- K.S.Hayibo, J. M. Pearce, Vertical free-swinging photovoltaic racking energy modelling: A novel approach to agrivoltaics, *Renewable Energy*, 2023, 119343, https://doi.org/10.1016/j.renene.2023.119343
- Vandewetering, N., Hayibo, K. S., & Pearce, J. M. (2023). Open-Source Vertical Swinging Wood-Based Solar Photovoltaic Racking Systems. *Designs*, 7(2), Article 2. https://doi.org/10.3390/designs7020034

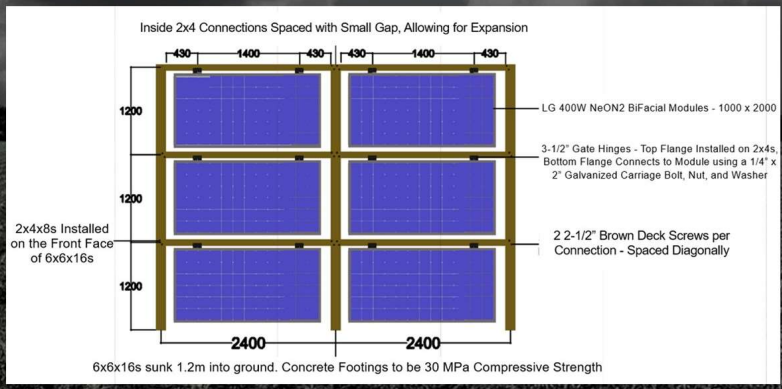
Open Source Vertical Swinging Wooden PV Racking

Objectives

- Locally Accessible & Sustainable Materials
- Easily Fabricated
- 25-year Lifetime (Equal to PV Warranties)
- Adheres to Canadian Building Code







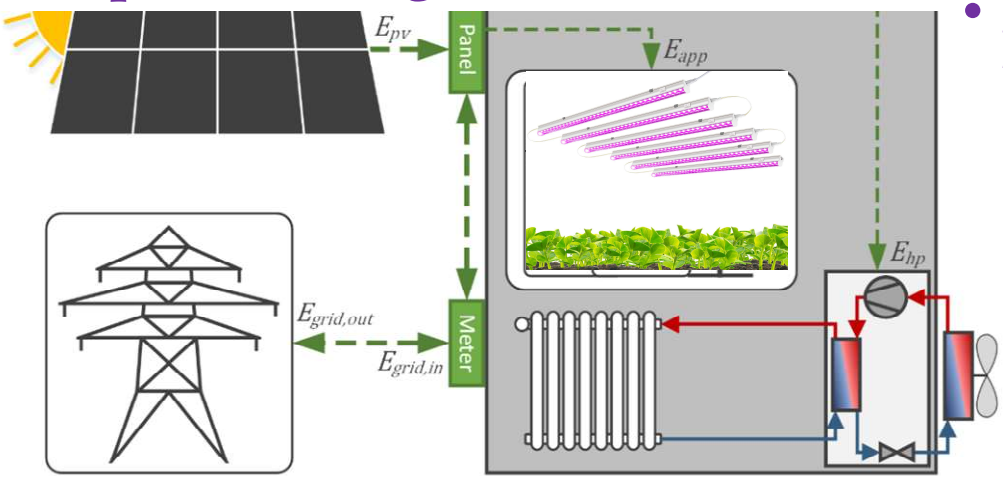
- CAD$0.21 per unit section.
- 77% LCOE of the cost of equivalent commercial racking system.
- 22%, 34%, and 38% less expensive than commercial metal vertical racking, wood fixed tilt racking, and wood seasonal tilt racking costs, respectively.
- Provides a potential increase in energy yield thanks to its unique swinging mechanism.

Western Engineering

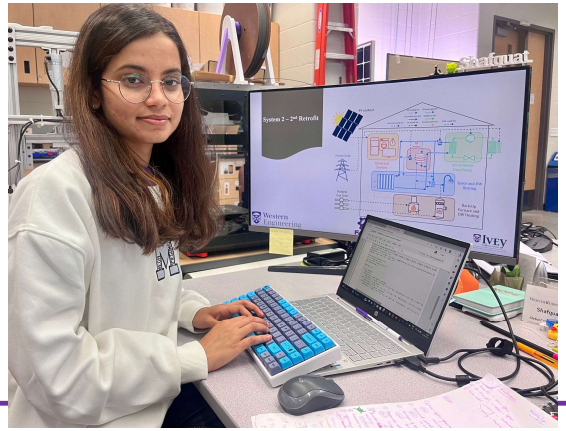
Building Integrated Greenhouse PV

- Partially transparent
- PV with spectral shifting encapsulant for greenhouses

Nima Asgari



- PV-powered Heat Pumps and Thermal Batteries for residential



Shafquat Rana

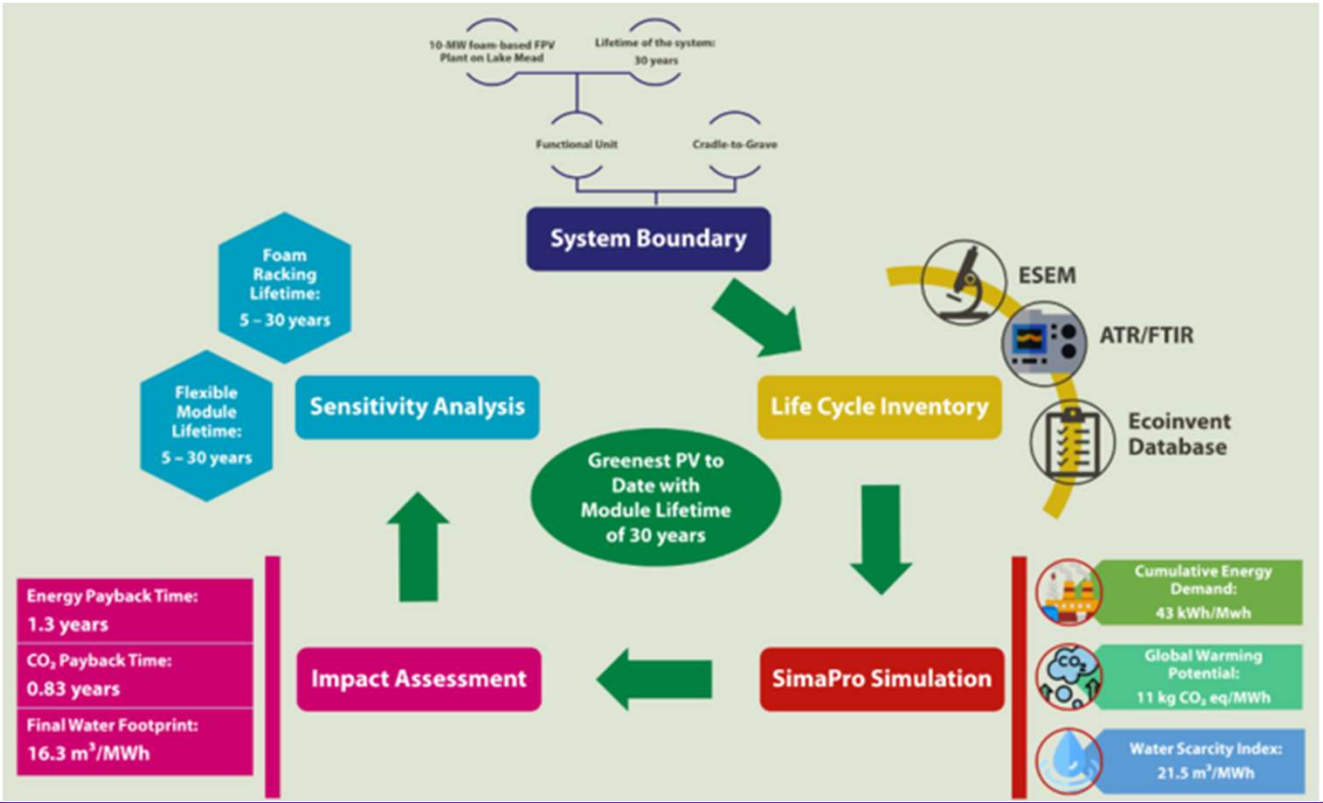
Abolfazl Fini

Western Engineering

FAST

IVEY Business School
WESTERN UNIVERSITY · CANADA

Floating Flexible Solar PV in Canada

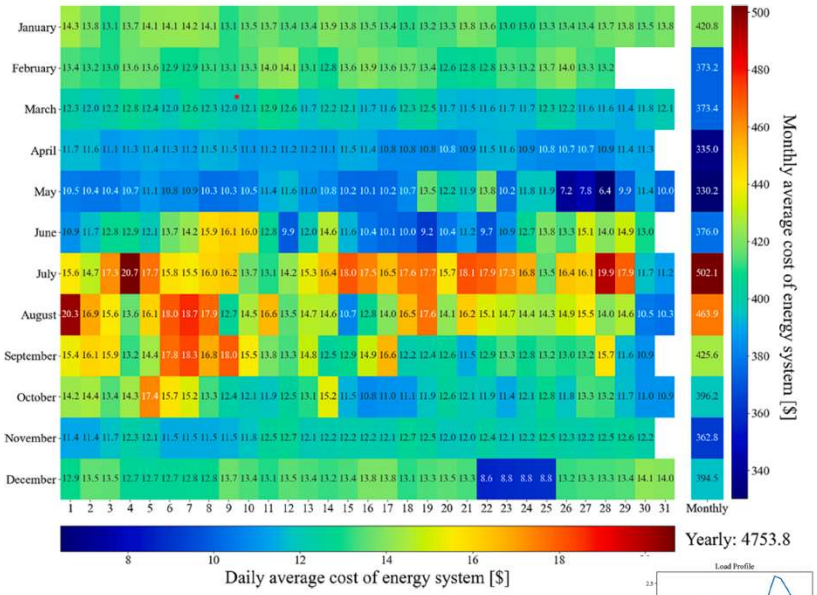


- [The Greenest Solar Power? Life Cycle Assessment of Foam-Based Flexible Floatovoltaics]
- [Water Conservation Potential of Self-Funded Foam-Based Flexible Surface-Mounted Floatovoltaics]
- [Foam-based floatovoltaics: A potential solution to disappearing terminal natural lakes]

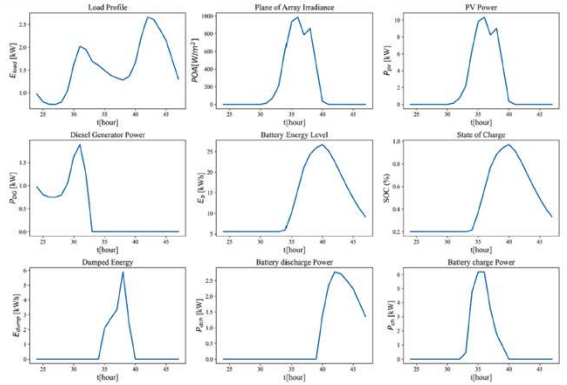
SAMA (Solar Alone Multi-objective Advisor)

HOMER is great but…not open source anymore and:

- ✓ i) high costs that limit accessibility to low- resource labs and individuals,
- ✓ ii) incapable of conducting multi-objective optimization,
- ✓ iii) constrained on any new innovations in hybrid energy system design and operation,
- ✓ iv) difficulties for users to specifically define prices and costs in inputs,
- ✓ v) inability to model different electric utility billing structures,
- ✓ vi) complex pricing methodology, and
- ✓ vii) the absence of machine learning-based predictive modeling.



SAMA is HOMER but Better

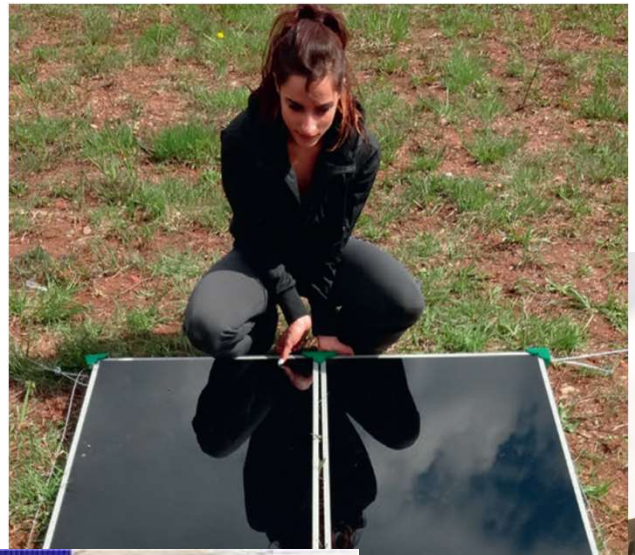


Ali Sadat

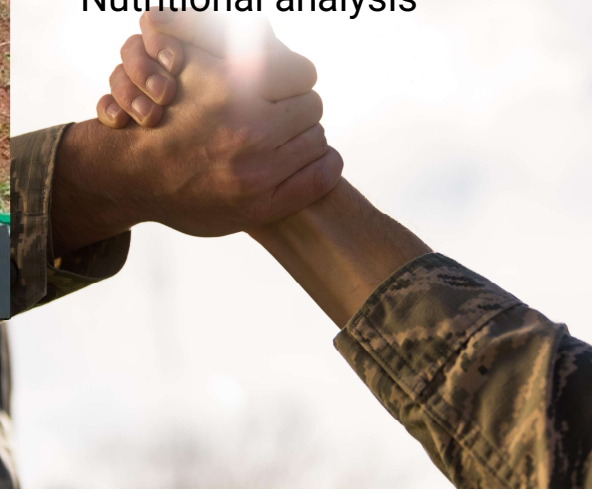
FAST

Collaborators: Crazy Genius Ideas? We Want to Help Make Them Reality!

- Fully instrumented site
- Pilot test your products/ideas
- World-class interns (top 10%)
  - NSERC Alliance 2:1 match
  - MITACS (starts $7,500)
- Future employees
  - Western Engineering
  - Ivey Business
- Publishing partner
- PR partner



Biotron: Synthetic environments
Nutritional analysis



Western Engineering

Free Solar Panels- for Real!!

The deal – you get the PV and the free electricity, you pay for install, we get data.

Lender (Western) agrees to provide:

- **Free** designs for agrivoltaics system to match specific crops
- **Free** XX kW of solar photovoltaic (PV) modules
- Open source data acquisition (DAQ) system
- Electronic access to analysis via papers
- Credit in papers and on website
- Opportunities for media attention if they become available

Borrower agrees to:

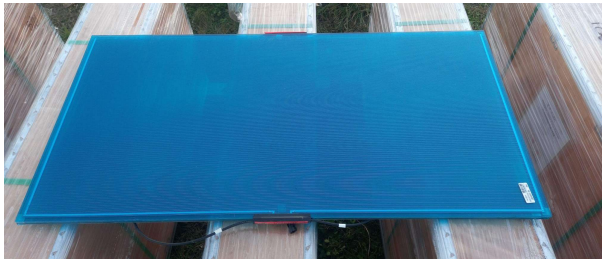
- Pay to pay or pay UWO $XXX to have the PV system installed following UWO specifications
- Allow for UWO students to access farm to install DAQ and collect data.
- **Farm normally**, help UWO collect yield data and other data for agrivoltaics system and control for XX years.

Lender in charge of DAQ and Borrower in charge of PV.
This would be based off of in-hand quotes as you suggest from 3rd parties.

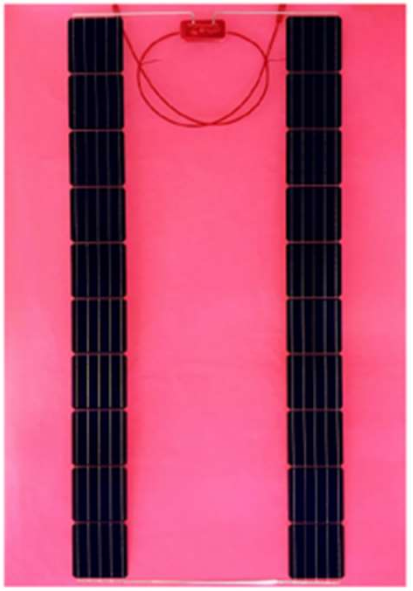
SOLAR PV MODULES AT WESTERN UNIVERSITY

Types of Solar Module	No. of Modules	Pictures
Solar Glass (69% Transparent, 150W)	39	
Solar Glass (45% Transparent, 275W)	9	
Solar Glass (8% Transparent, 450W)	20	

SOLAR PV MODULES AT WESTERN UNIVERSITY

Types of Solar Module	No. of Modules	Pictures
Solar Glass (10% Transparent, 69W)	24 (transparent, blue, green and red – 6 each)	
Solar Glass (12% Transparent, 61W)	24 (transparent, blue, green and red – 6 each)	
Solar Glass (30% Transparent, 52W)	24 (transparent, blue, green and red – 6 each)	
Solar Glass (40% Transparent, 46W)	24 (transparent, blue, green and red – 6 each)	
Solar Glass (45% Transparent, 42W)	24 (transparent, blue, green and red – 6 each)	
Solar Glass (50% Transparent, 38W)	24 (transparent, blue, green and red – 6 each)	
Solar Glass (55% Transparent, 34W)	24 (transparent, blue, green and red – 6 each)	
Solar Glass (60% Transparent, 30W)	24 (transparent, blue, green and red – 6 each)	
Solar Glass (70% Transparent, 23W)	24 (transparent, blue, green and red – 6 each)	
Solar Glass (80% Transparent, 15W)	24 (transparent, blue, green and red – 6 each)	

SOLAR PV MODULES AT WESTERN UNIVERSITY

Types of Solar Module		Picture
Red PV Module – Bifacial (108 W)	 	

Pre-Approved Agreements!

EQUIPMENT LOAN AGREEMENT

The University of Western Ontario having a place of business located at 1151 Richmond Street, London, Ontario, N6A 3K7 herein called "**Lender**", hereby lends to [**Company Name**], having a place of business located at **[insert address]** herein called "**Borrower**", and Borrower borrows from Lender for valuable consideration, the following personal property of Lender, which property together with all replacement parts, additions, repairs and accessories heretofore or hereafter incorporated therein or affixed thereto are herein called "Equipment" to be used by the Borrower and for a term and under the conditions as hereinafter set forth.

EQUIPMENT

PV modules and an open source DAQ, as further detailed in Appendix A.

Term

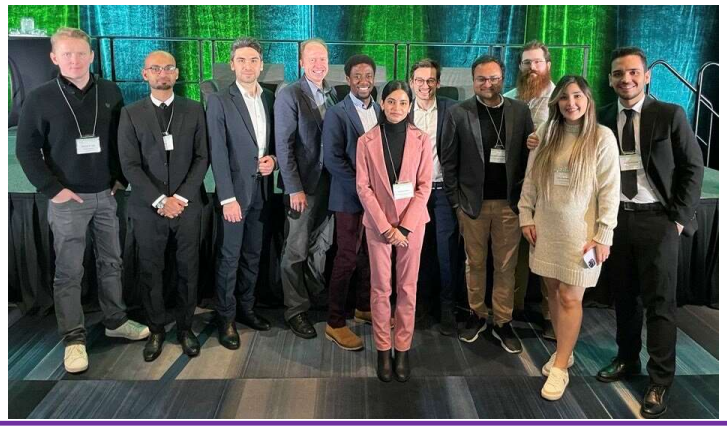
Start to End Date:

Renewable for XX years based on project performance.

Methods to Collaborate with FAST:

Companies/Farmers

1. MITACS - internships
2. NSERC Alliance 1:1, 1:2
3. Experiments on your property – free PV



Academics

1. Design solar-powered version of X
2. Apply OS computer vision/AI to X
3. Interested in Policy Development to Expand Agrivoltaics Penetration Rates
4. Rapid Prototyping/ Distributed Manufacturing Using Distributed Power
5. Broadly Expandable and Reconfigurable Data Acquisition and Automation Device (BREAD)
6. Use our OS hardware designs (racks)

All FAST Research Output is FREE to Maximize Innovation and Tech Diffusion

appropedia.org/FAST

- Open access articles
- Literature reviews
- Methods
- Hardware designs
- Software source code

joshua.pearce@uwo.ca

Western Engineering

FAST

Collaborate?

Ivey Business School
WESTERN UNIVERSITY · CANADA