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Experimental Investigation and Implementation of a Multiple-Inlet BIPV/T System in a Curtain Wall

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OBJECTIVES

- **Assess architectural, structural and energy performance** considerations for a fully integrated envelope system intended for large scale applications

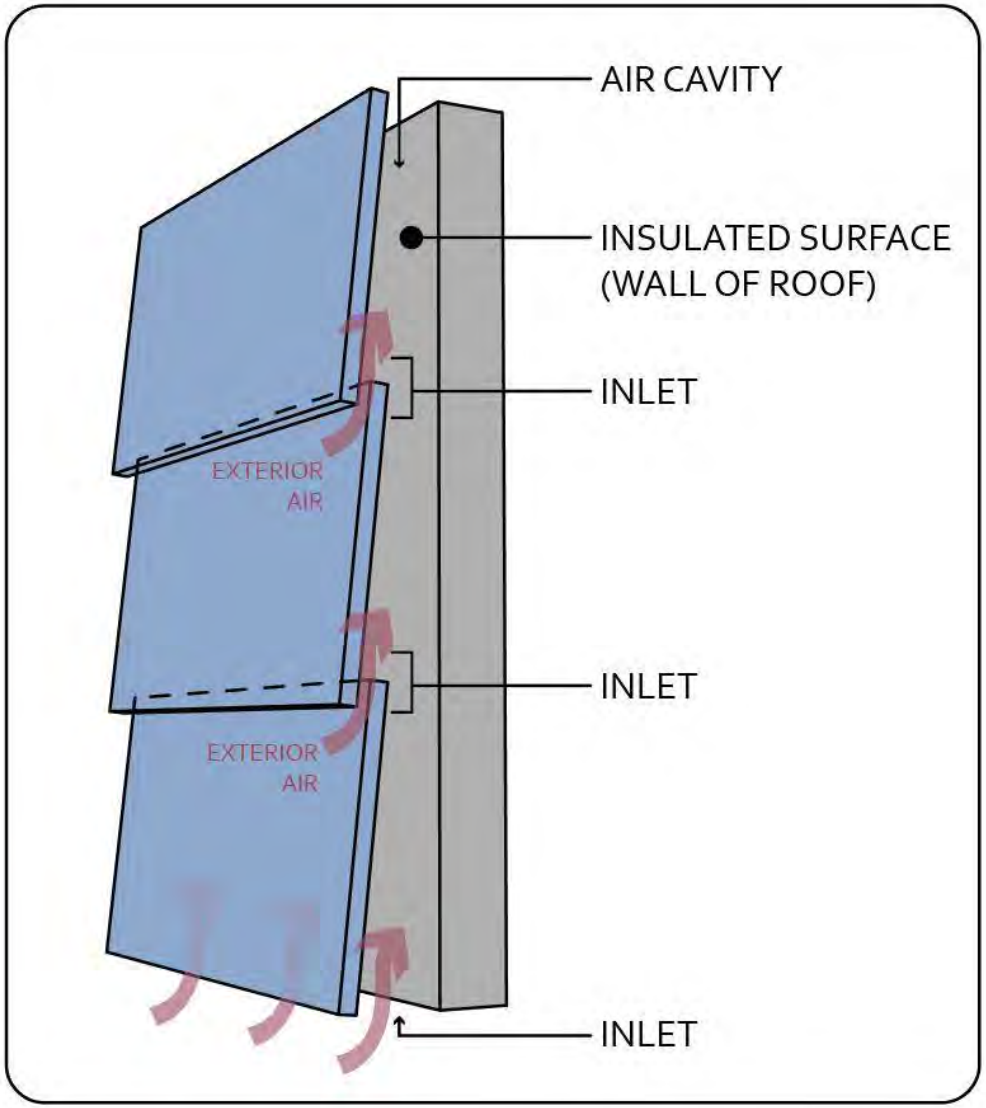
- **Design, build and test a BIPV/T prototype** using a high-performance curtain wall framing system

Concept rendering of a BIPV/T cladding

What is BIPV/T?

- Current practices for photovoltaic (PV) technologies on buildings are mainly **racked systems**
- Concept of **photovoltaic/ thermal systems (PV/T)** originated in the 1970s
- **Building-integrated photovoltaic/thermal (BIPV/T)** systems as alternatives to traditional cladding
- **Heat generated from the PV panels can be collected** and utilized

Multiple-inlet BIPV/T concept

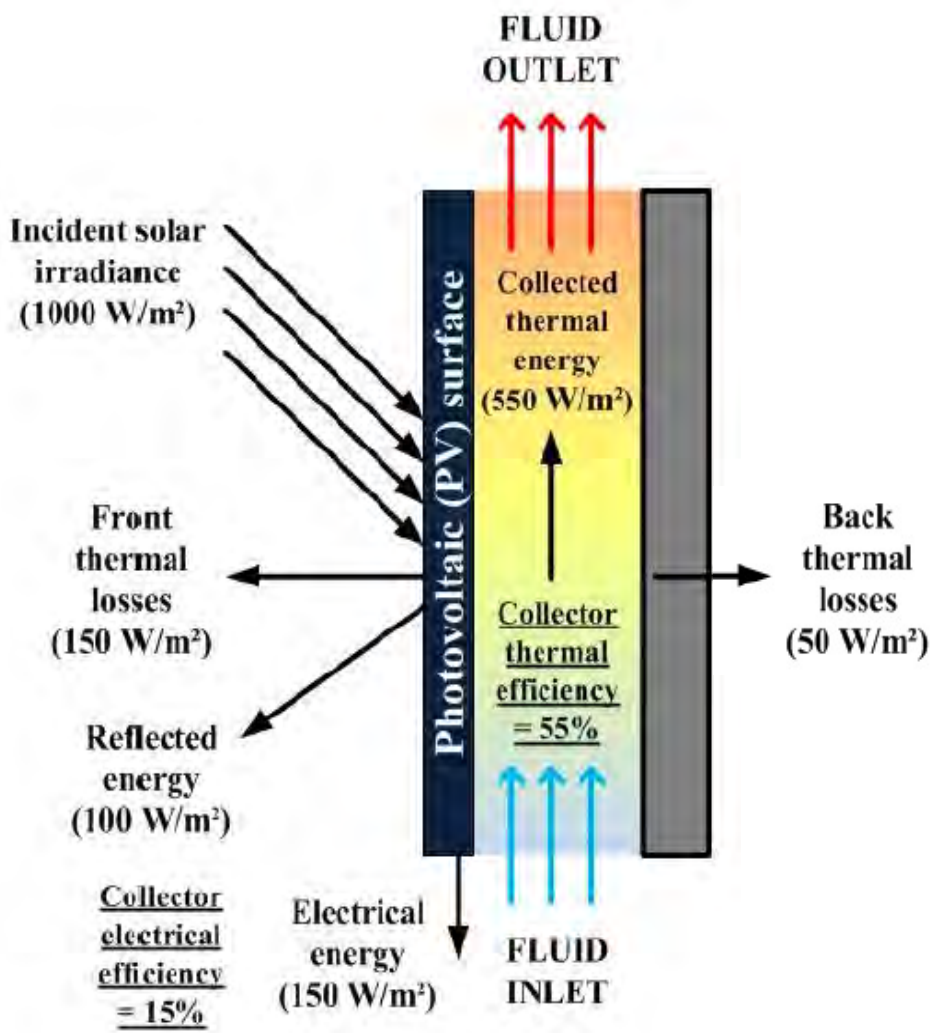


Energy Generation from BIPV/T

- Electricity produced by PV panels is a function of their temperature and solar irradiance

$$E_{PV} = G \cdot [\eta_{stc} \cdot (1 - \beta_{PV} \cdot (T_{PV} - T_{stc})]$$

- **Enhancements of the thermal output of PV/T systems** have been researched and include optimal geometries, flow rates, added glazing, double pass channels and others
- Types of PV/T systems include: water-based, concentrator systems, **air-based systems (passive, active)**



BIPV/T Case Studies

- **Custom designed BIPV/T façade** at mechanical penthouse of John Molson School of Business (Concordia University)

- Net-zero energy design of the Varennes Library includes **fully functional BIPV/T roof**

Design Requirements

- A BIPV/T system design is derived from both **energy production needs** and **the façade design**

Electrical & Thermal Performance:

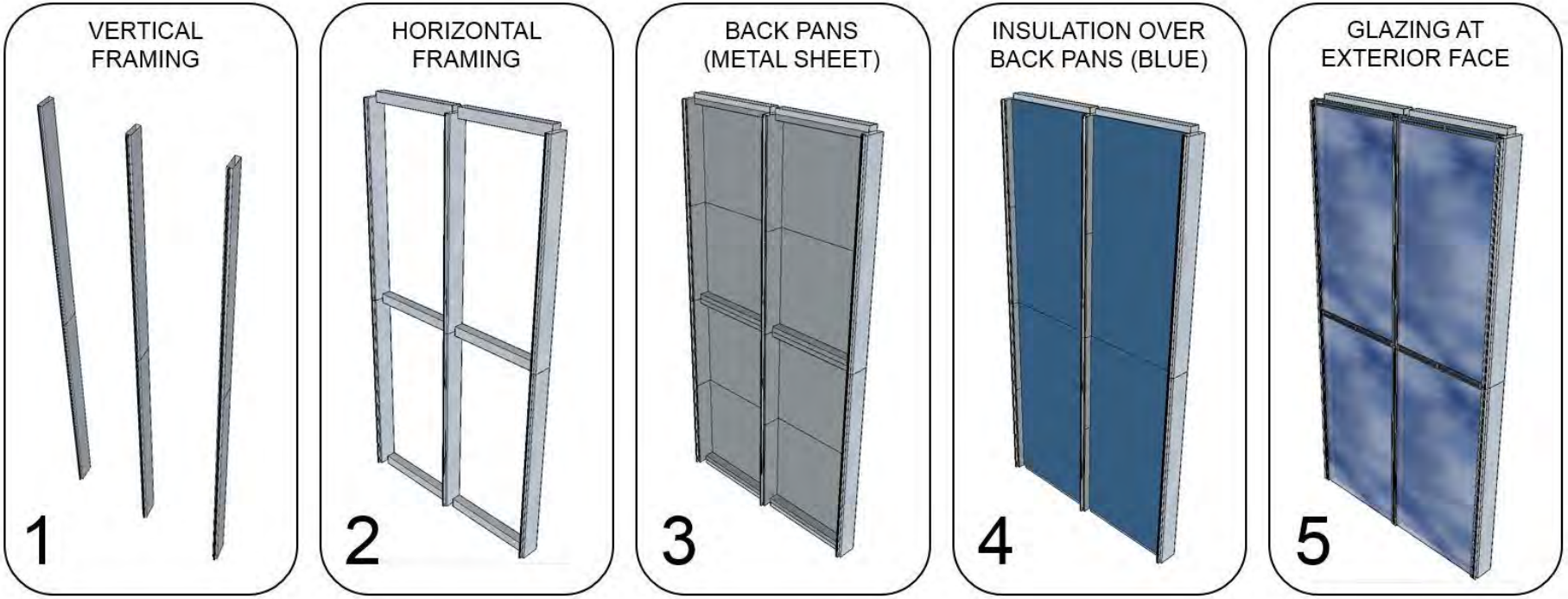
- Building orientation and wall geometries will affect BIPV/T layout & sizing
- PV technologies
  - Mono-crystalline silicon
  - Poly-crystalline silicon
- Mechanical cooling of PV by fan
- Thermal performance enhancements
  - Double glazing
  - Use of fins
  - Other

Envelope Functionality:

- Dead and live loads
- Compatibility with other materials
- Thermal insulation
- Air and water resistance
- Fire safety
- Soundproofing
- Insect and bird protection
- Install sequencing
- Maintenance accessibility
- PV manufacturing availability

Façade Design

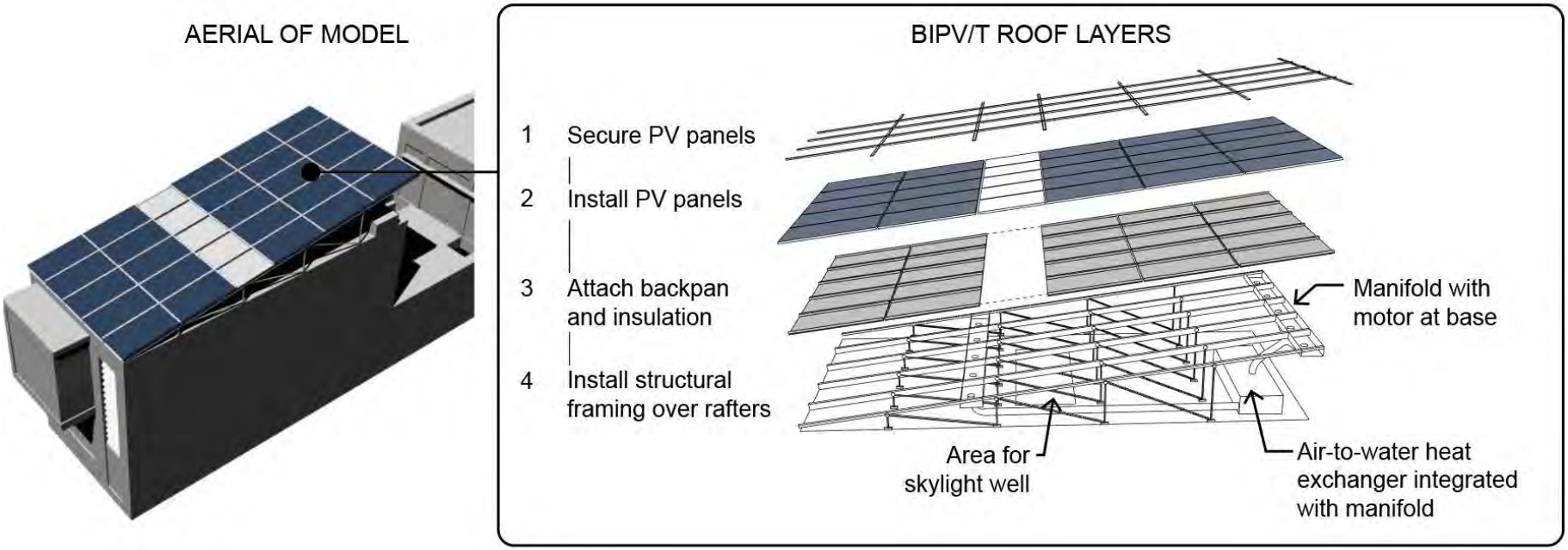
- A **curtain wall (CW) framing assembly** is a good solution for large scale, air-based BIPV/T systems
- **PV panels replace the glazing** at the exterior face of the system
- **Air channel** is created between exterior face and insulation



Retrofits & Roof Applications

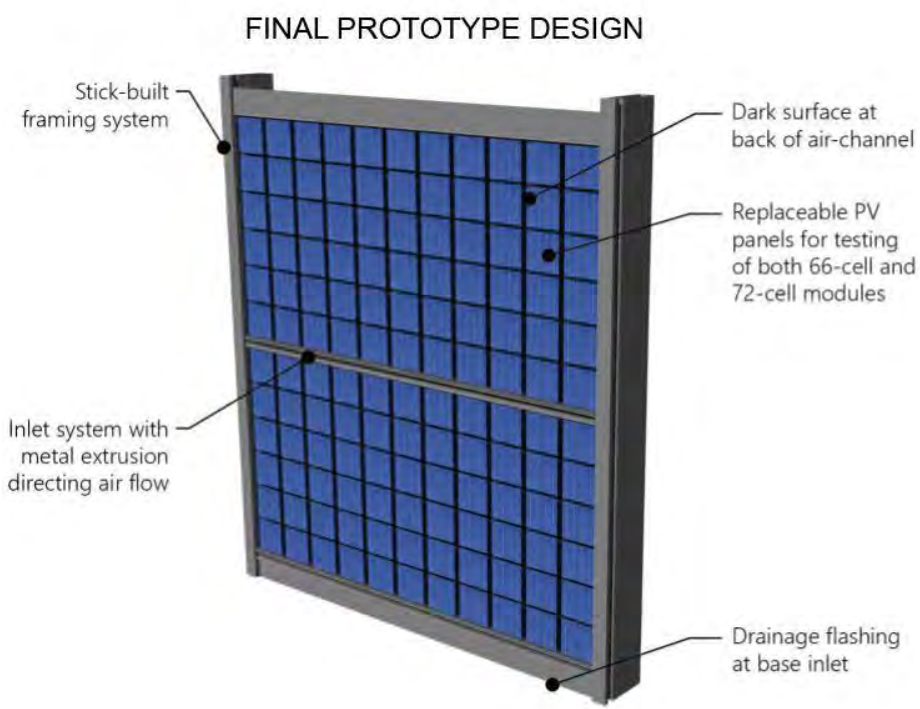
- Overcladding or re-cladding options to **turn unused or semi-conditioned spaces into fully enclosed conditioned spaces**
- Applications on **low-slope roofing systems**
- **Slope close to latitude** preferred for optimal electrical and thermal performance

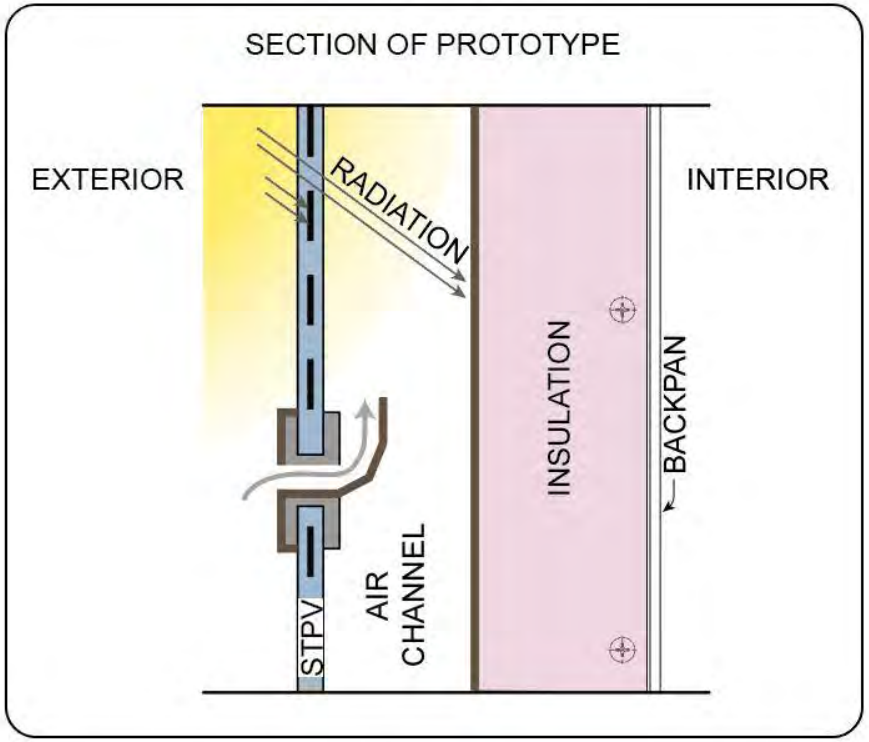
Solar Decathlon roof system design



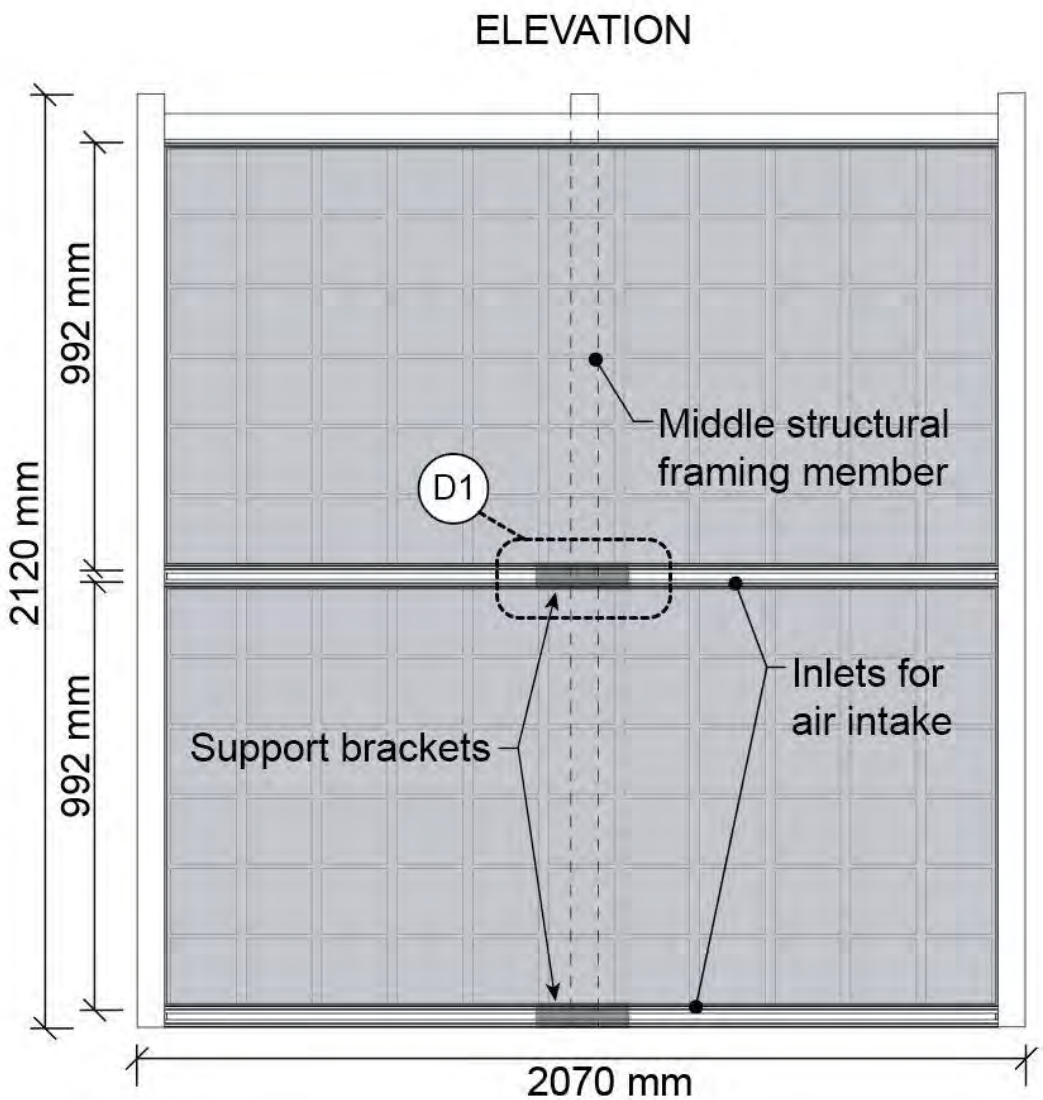
Building a Prototype

- Based on design considerations for **electrical, thermal and envelope performance**
- Emphasis on **facilitation of assembly** and a simple air channel configuration



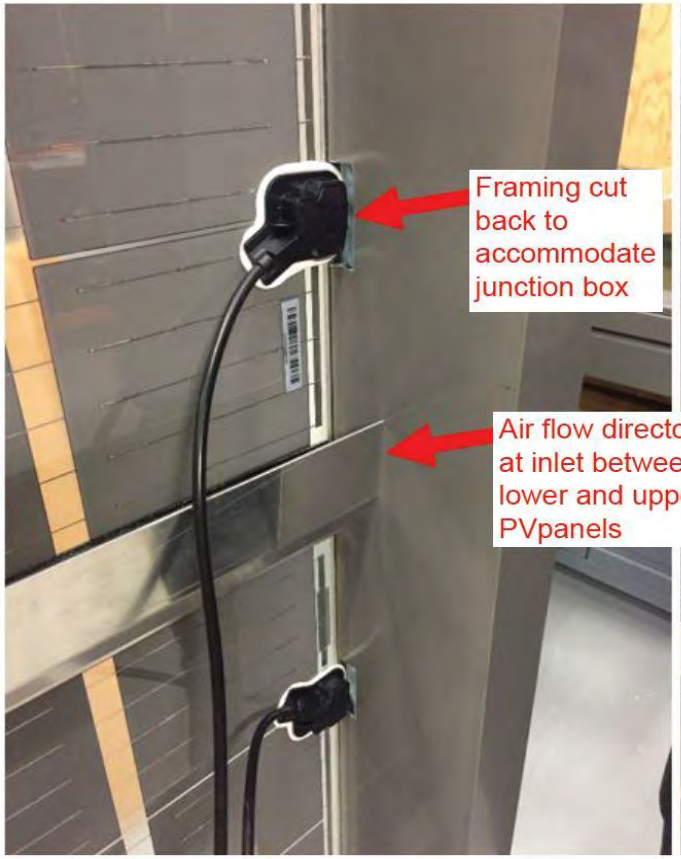


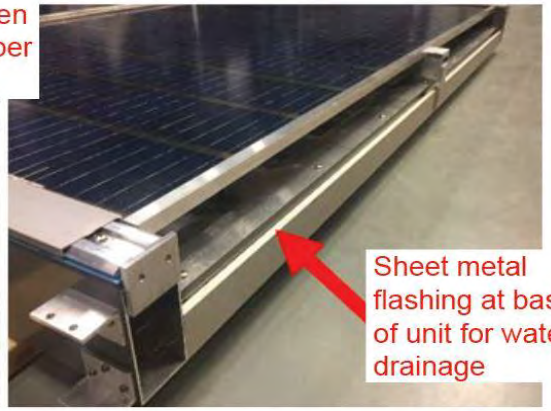
Final Prototype Design and Features



Construction of Prototype

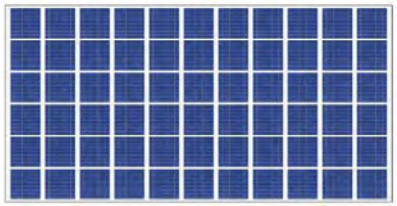
- Framing fabricated and assembled at local curtain wall manufacturer shop facility
- Prototype has **modified structural design** and other adjustments for laboratory testing

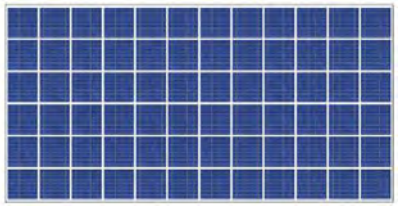


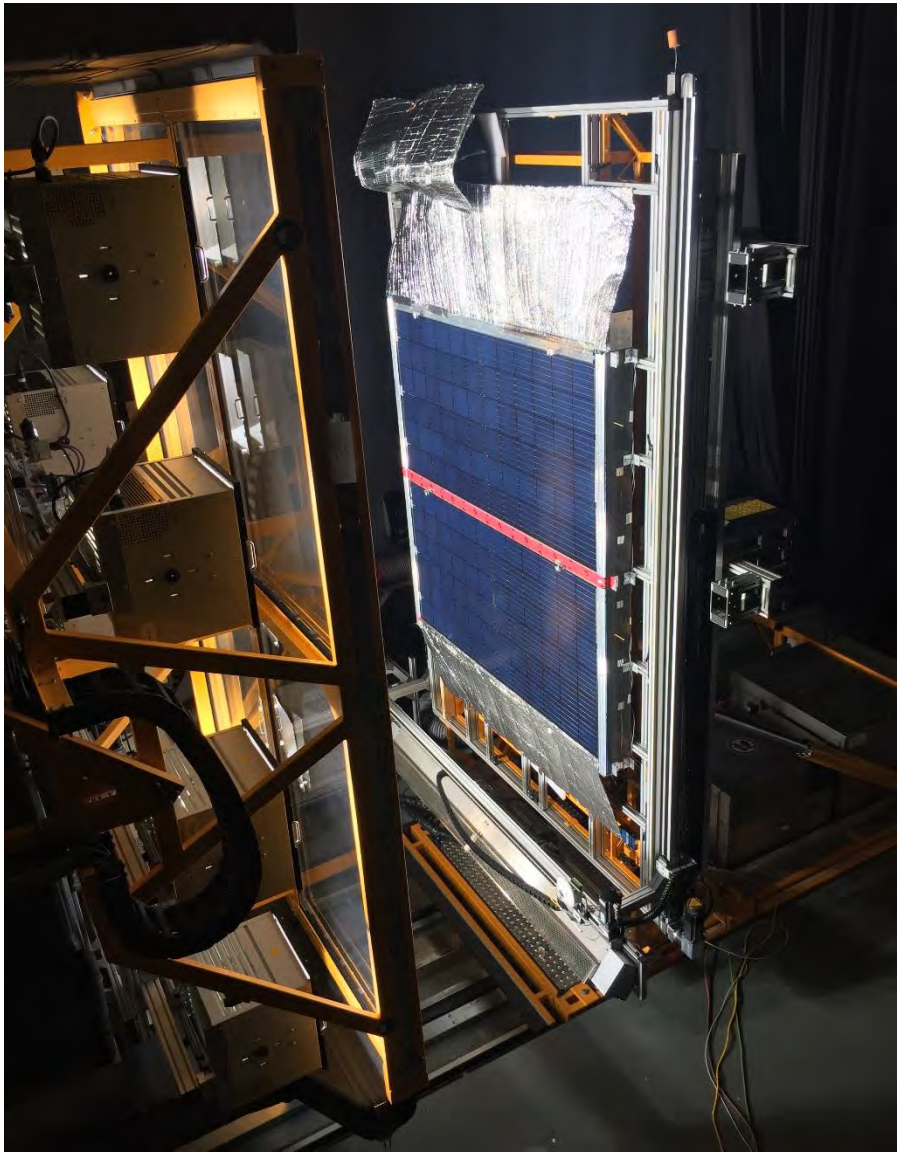


Testing in the Solar Simulator

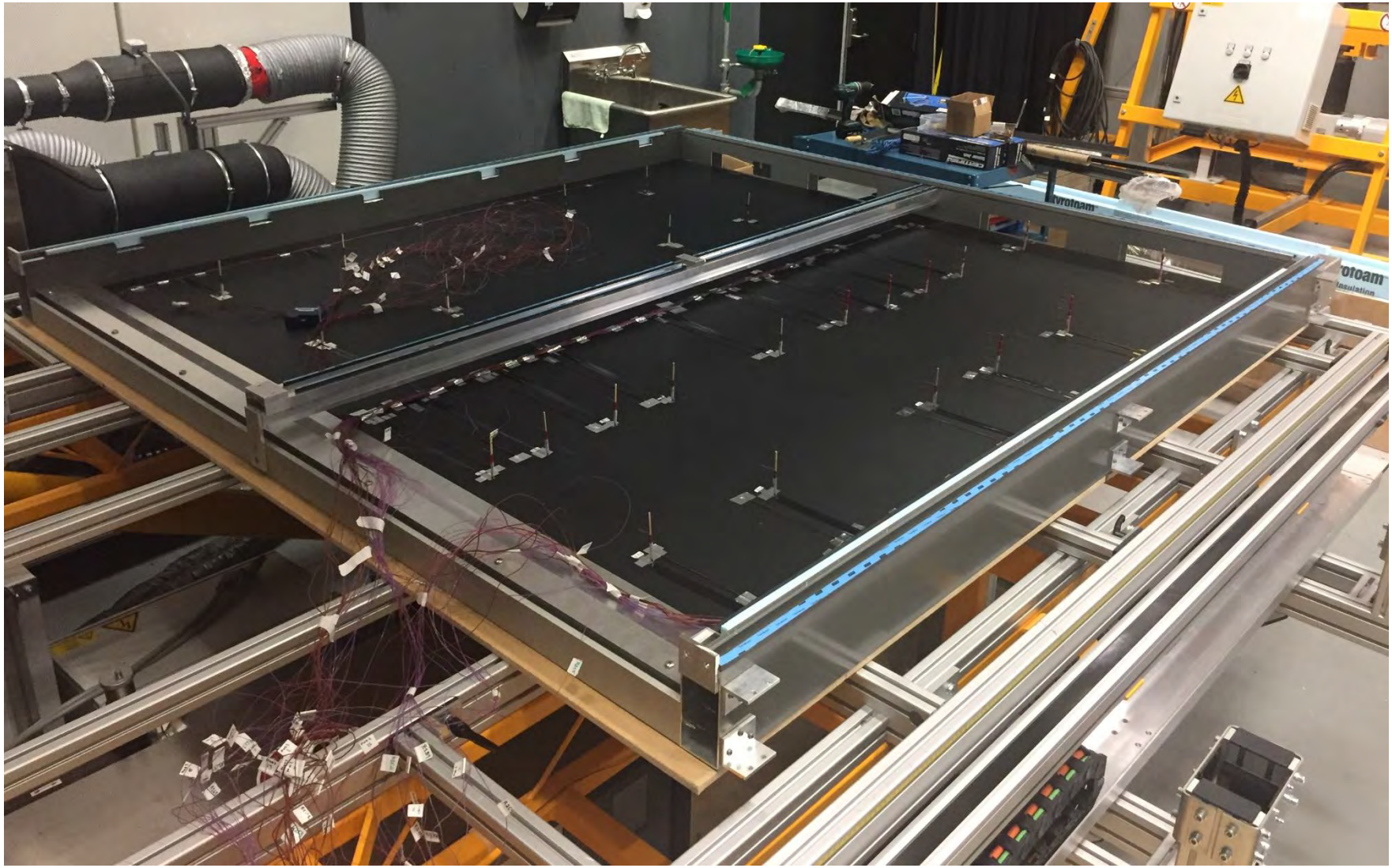
- Testing carried out at Solar Simulator in **vertical position**
- **Fan** at base of platform replicates effect of wind
- Three irradiation levels
- Three flow rates
- **Single inlet and double inlet** configurations
- Modules with **two types of transparencies:**





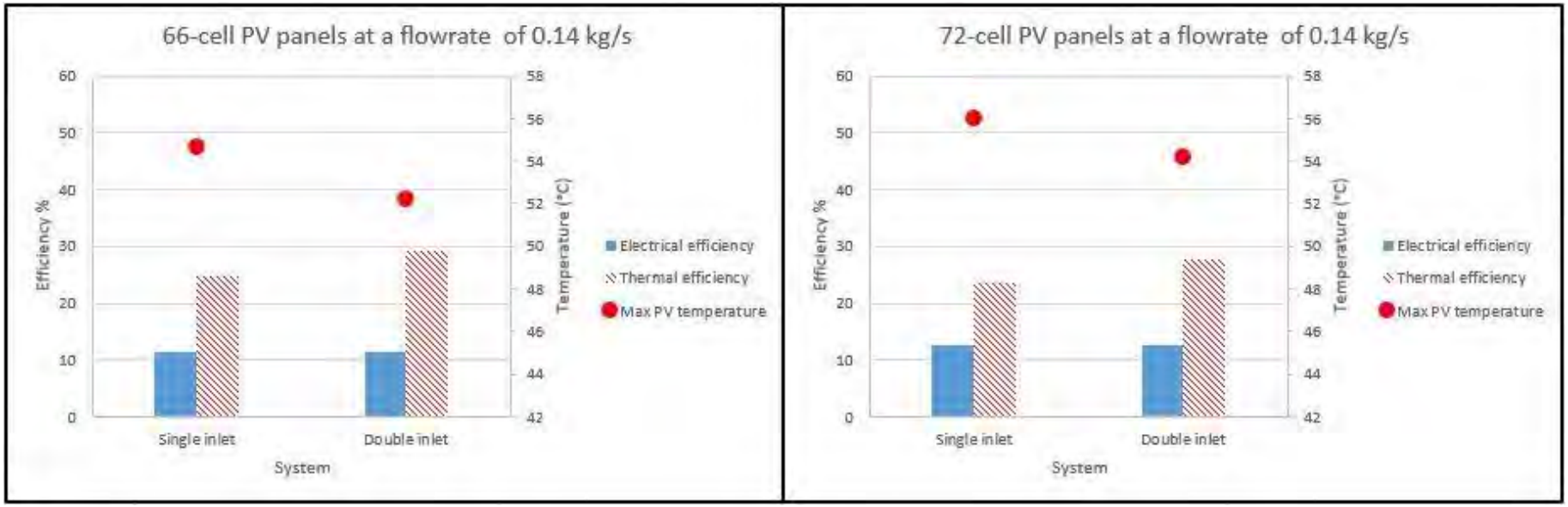


Experimental Setup



Testing Results (NOCT)

- Combined electrical and thermal efficiencies:
  - **38.9% for single inlet** configuration
  - **43.8% for double inlet** configuration
- Double inlet configuration showed best performance:
  - **2% – 5%** higher thermal efficiencies
  - **3°C – 4°C** lower maximum PV temperatures
  - **Marginally higher** electrical efficiencies

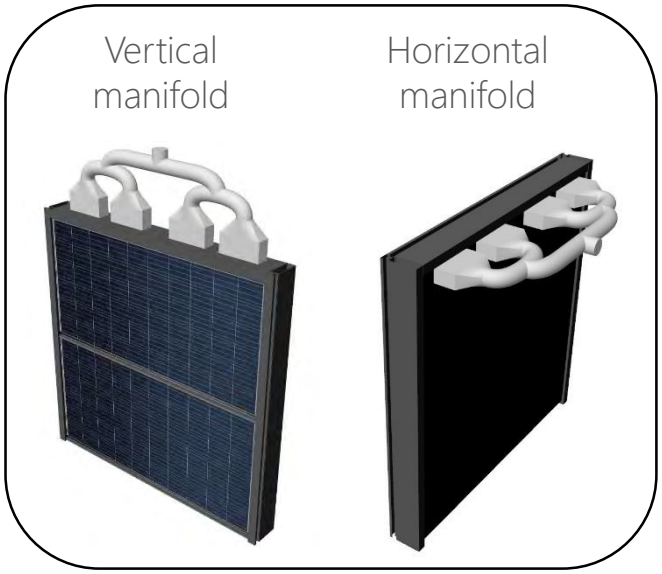


Conclusions

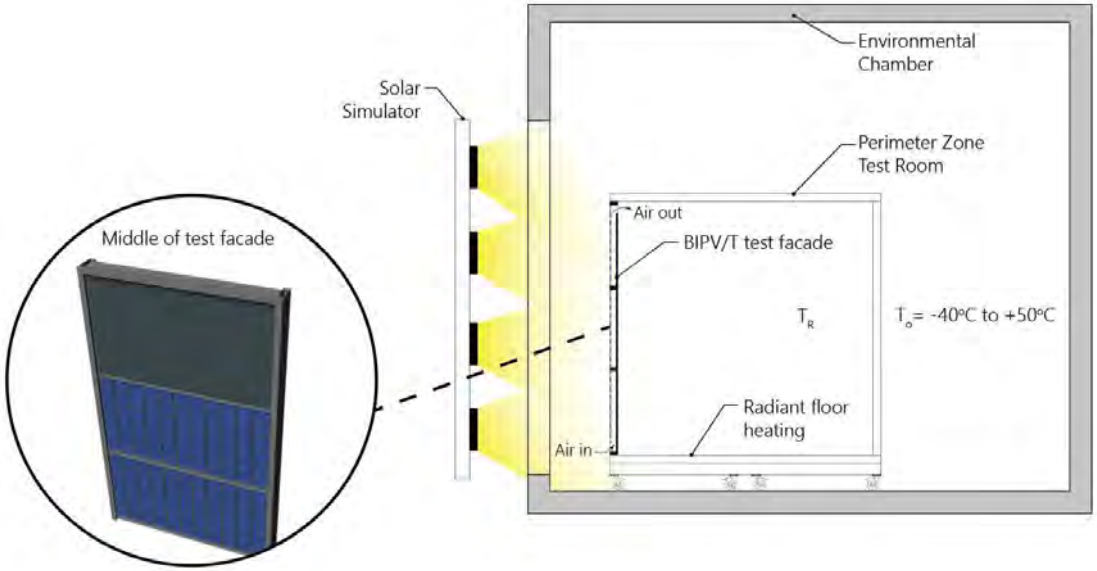
- BIPV/T prototype developed and built based on **typical curtain wall design**
- Focus on **common building practices** and **previous lack of true integration** between façade and PV/T system design
- Prototype **tested under NOCT conditions** at an indoor solar simulator
- **Double inlet configuration of the system showed best results** for combined thermal and electrical efficiencies and maximum PV temperatures
- **Effects of multiple inlet configuration expected to be greater** in larger scale applications

Future Work

- Testing the prototype for electrical and thermal efficiency with adjustments:
  - Use of **meshes** at the inlets
  - **Positioning of manifold** (vertical vs. horizontal)
- **Incorporation of prototype into fully enclosed test hut** for testing in Environmental Chamber



Perimeter Zone Test Room in Environmental Chamber:



Developing a BIPV/T Standard

- One of the biggest challenges to BIPV/T production is the **lack of a unified performance standard**
- Design and optimization of thermal performance should be based on **intended use of preheated air**
- Requirements for building envelope testing standards are needed for **air infiltration, water penetration and thermal performance**

Table of existing standards related to PV and BIPV technologies

PV standards	
EN 61215	Crystalline Silicon Terrestrial PV Modules
EN 61646	Thin-film Terrestrial PV Modules
EN 61730	Photovoltaic Module Safety Qualification
UL 1703	Flat-Plate Photovoltaic Modules and Panels
UL 4703	Outline for Photovoltaic Wire
BIPV standards	
AC 365	BIPV roof covering systems
EN 50583-1	Photovoltaics in Buildings: BIPV modules
EN 50583-2	Photovoltaics in Buildings: BIPV systems
Solar thermal standards	
ISO 9806	Solar thermal collectors – test methods

Thank you! Questions?

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