BIPV in A Digital Environment

Associate Professor Rebecca Yang

- Solar Energy Application Lab (SEAL), RMIT University
- Vice Chair & Board Member, Australian PV Institute

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Solar Energy Application Lab (SEAL)

SEAL is a research organization under RMIT University that focuses on applied research to enable the integration of solar energy in buildings and suburban. We concentrate on practical solutions and collaboration with stakeholders to become a key player in the field of solar energy research and development.

SEAL is a member of Australian PV Institute, a member of the Australian National Mirror Committee for International Electrotechnical Commission (IEC) TC 82 Solar photovoltaic energy systems, and represents Australia in International Energy Agency (IEA) collaborative programs: the Photovoltaic Power Systems Programme (PVPS) Task 15 Enabling Framework for the Development of BIPV, and the Solar Heating and Cooling Programme (SHC) Task 66 Solar Energy Buildings. The lab also has developed the first BIPV design tool in Australia.

MEMBERS

> 20 researchers from various backgrounds including architecture, civil engineering, electrical engineering, fire engineering, mechanical engineering, computer science, construction and project management.


RESEARCH DOMAINS

- Building integrated solar energy
- Solar enabled community/industry decarbonization
- Solar energy in urban scale

Contact us: sealsolarlab@rmit.edu.au

Building integrated solar energy

SEAL conducts research on a range of topics related to the integration of solar energy in buildings:

- BIPV product database
- Building and construction standards & regulations
- BIPV design modelling, simulation and optimization
- Technical feasibility and economic viability
- Decision making and data mining
- IFC enabled BIPV product digital process
- Mounting system design and optimization
- BIPV product performance
  - e.g., Fire safety, Solar Heat Gain Coefficient (SHGC)
- Policy support

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Solar enabled community/industry decarbonization

SEAL projects contribute to the decarbonization of communities and industries by empowering them to generate their own energy and reduce their dependence on centralized power plants and distribution networks. This can lead to a more sustainable, resilient, and decentralized energy system that benefits both the environment and the local economy.

VIRTUAL POWER PLANT
Conducting urban/community level virtual power plant (VPP) simulation and analysis to provide renewable energy and load management strategies and decision-making supports for high demand users.

DEMAND RESPONSE AND ENERGY FLEXIBILITY
Investigating the load management and energy trading strategies that support the renewable transition and energy efficiency of high energy users while also benefiting the electricity grid.

GAME THEORY
Applying game theory in P2P trading to gain better understanding of the behavior of buyers and sellers in P2P energy markets.

GEOSPATIAL MAPPING AND DEEP LEARNING
Analyzing patterns of energy consumption in buildings and inform decision-making related to a wide range of urban planning and design.
<table>
<thead>
<tr>
<th>Geo-physical</th>
<th>Terrain</th>
<th>City</th>
<th>Open terrain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar irradiation</td>
<td>Temperature</td>
<td>Humidity</td>
<td>Wind</td>
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<td>Rain fall patterns</td>
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<table>
<thead>
<tr>
<th>Technical</th>
<th>Grid</th>
<th>System components</th>
<th>Losses</th>
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<tbody>
<tr>
<td>Grid type</td>
<td>Grid voltage</td>
<td>PV modules</td>
<td>DC/AC losses</td>
</tr>
<tr>
<td>Number of phases</td>
<td>Displacement power factor</td>
<td>Inverters</td>
<td>Shading losses</td>
</tr>
<tr>
<td>Feed-in power clipping</td>
<td>Mounting/form systems</td>
<td>Energy storage</td>
<td>Soiling losses</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Building physics</th>
<th>Construction &amp; commissioning</th>
<th>Operation and maintenance</th>
<th>Decommissioning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building type</td>
<td>Interactive design</td>
<td>Installation process</td>
<td>Monitoring &amp; control</td>
</tr>
<tr>
<td>Structural load</td>
<td>Energy load/user profile</td>
<td>Commissioning process</td>
<td>O &amp; M procedures</td>
</tr>
<tr>
<td>Neighbouring buildings/objects</td>
<td>Building standards &amp; codes</td>
<td>Quality assurance</td>
<td>Warranties and replacement</td>
</tr>
<tr>
<td>Building thermal load</td>
<td>Building thermal load</td>
<td>Health and safety</td>
<td>Insurance</td>
</tr>
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<table>
<thead>
<tr>
<th>Emissions</th>
<th>Environmental</th>
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<tbody>
<tr>
<td>Embedded CO₂ emissions</td>
<td>Emissions</td>
</tr>
<tr>
<td>CO₂ emissions avoided</td>
<td>Heat island effect</td>
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</tbody>
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<table>
<thead>
<tr>
<th>Economical</th>
<th>Benefits</th>
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<tbody>
<tr>
<td>Government incentives</td>
<td>Renewable energy certificates</td>
</tr>
<tr>
<td>Feed in tariffs</td>
<td>Feed in tariffs</td>
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<tr>
<td>Finance and loan programmes</td>
<td>Finance and loan programmes</td>
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<tr>
<td>Tax breaks</td>
<td>Tax breaks</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Finance modes/ Contract arrangements</th>
<th>Direct finance</th>
<th>Finance and loan programmes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fully owned or leased by a third party</td>
<td>Fully owned or leased by a third party</td>
<td></td>
</tr>
<tr>
<td>Finance by a third party and lease arrangement made with building owner</td>
<td>Finance by a third party and lease arrangement made with building owner</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Financial performance evaluation</th>
<th>Payback period</th>
<th>BOQ prices</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPV/IRR/ROI</td>
<td>LCOE</td>
<td>Installation cost</td>
</tr>
</tbody>
</table>

Improvements

- Detailed local meteorological data and local geographic/terrain data
- Localised PV system product database (e.g. panel, storage, BOS)
- Localised cost data on PV system products and installation
- Localised energy price data
- Accurate energy consumption data
- Information on local building regulations and codes
- Information on local government incentives and policies
- Information on financial modes and contract arrangements
- Database on previous project examples
- Information on product performance in previous projects
- Information on installers’ track record and experiences
- Information on commissioning and O&M procedure
- Information on decommissioning procedures

- Efficient 3D model creation of the physical environment
- Generation and comparison of alternative PV module designs
- Visualization of shading impact and losses
- Automatic PV system configuration and optimization
- Accurate energy consumption data simulation
- Installation process simulation and impact analysis (e.g. impact of harsh weather conditions, occupational health and safety risks etc. on the project completion and cost)
- Matching and optimizing energy outputs with fluctuating demands and electricity prices
- Balancing revenue against cost to optimise PV module and storage sizes
- Analysis on environmental impact (carbon footprint, heat island)
- Lifecycle cost-benefit analysis

The Building Integrated Photovoltaics (BIPV) Enabler tool is a user friendly platform that integrates product, regulation, technical, economic and construction data to create a leading BIPV solution in conceptual building design stage.

Supported by ARENA, APVI, and several industry partners
Building Type and Location

Building Modelling and Simulation
# BIPV Enabler Report

<table>
<thead>
<tr>
<th>PV Module Name</th>
<th>Attribute</th>
<th>Value</th>
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<tbody>
<tr>
<td>Module_4</td>
<td>Manufacturer</td>
<td>Company M</td>
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<tr>
<td></td>
<td>BPV Cell Technology</td>
<td>polycrystalline</td>
</tr>
<tr>
<td></td>
<td>Module Length (m)</td>
<td>1.33</td>
</tr>
<tr>
<td></td>
<td>Module Width (m)</td>
<td>1.33</td>
</tr>
<tr>
<td></td>
<td>Module Colour</td>
<td>black</td>
</tr>
<tr>
<td></td>
<td>Module Transparency</td>
<td>semi-transparent</td>
</tr>
<tr>
<td></td>
<td>System Size (KW)</td>
<td>8.16</td>
</tr>
<tr>
<td></td>
<td>First year energy (kW)</td>
<td>18829.824367508622</td>
</tr>
<tr>
<td></td>
<td>Life cycle Cost (LCC) (AUD)</td>
<td>21274.96</td>
</tr>
<tr>
<td></td>
<td>Life Cycle Energy (LCE) (kW)</td>
<td>443584.0</td>
</tr>
<tr>
<td></td>
<td>Payback period (Years)</td>
<td>5.919</td>
</tr>
<tr>
<td></td>
<td>Net Present Value (NPV)</td>
<td>2699.8898</td>
</tr>
<tr>
<td></td>
<td>Capital Cost (AUD)</td>
<td>17426.82</td>
</tr>
<tr>
<td></td>
<td>Levelized cost of electricity (LCOE)</td>
<td>0.0565</td>
</tr>
<tr>
<td></td>
<td>No of PVs</td>
<td>68</td>
</tr>
<tr>
<td></td>
<td>Total PV Area (sqm)</td>
<td>120.2852</td>
</tr>
<tr>
<td></td>
<td>Carbon Emission Factor</td>
<td>0.98</td>
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<tr>
<td></td>
<td>Carbon Emissions</td>
<td>434482.92</td>
</tr>
</tbody>
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**Building Power data**

- **Enable Peak Off-Peak Calculation**: Check
- **Electricity Price (AUD/kWh)**:
  - Flat Rate: 0.122
  - Time of Use:
    - Peak Price: 0.24 (7:00 AM - 11:00 PM)
    - Off-peak Price: 0.19
- **Tariff (AUD/kWh)**:
  - Flat Rate: 0.102
  - Time of Use:
    - Peak Price: 0.102 (7:00 AM - 11:00 PM)
    - Off-peak Price: 0.091
- **Building Energy Consumption (kW)**:
  - Annual Energy Consumption: 0.00
  - Hourly Energy Consumption: 0.01
Placement and Visualization

Optimization
Building model design

Input BIPV/Building parameters for the calculations

Report generation

Irradiance simulation

Optimization results

Optimization

Wind load calculation

Automatic BIPV placement

BIPV Design Optimisation

Geospatial analysis and simulation of urban dynamics

Shading casting on roof and wall

Shadow volume calculation using sun path algorithm – Determine the volume of space in shadow cast by surrounding objects determined by the sun movement at a certain time

Machine-learning based image recognition for building elements
Urban level building envelop solar potential mapping and analysis
Task 15 BIPV - Subtask D: Digitalization for BIPV

Upcoming reports
D.3. Digital products - Lead by SUPSI

To facilitate the application of BIPV over the whole value chain by defining the requirements for digital product data models in a BIM-based process

1. **Understanding** the various approaches in using digital product data models for multifunctional BIPV systems
2. **Enabling** manufacturers, planners and owners of BIPV systems to define digital product data models
3. Defining **requirements** in compliance with **BIM standards**
4. Making **BIPV products more easily accessible** thanks to digitization of the AEC process
Objectives:

1. Current BIM-based tools for BIPV
   Definition of the BIPV process stages and workflows and review of current available BIM-based tools.

2. Collection of BIM-BIPV case-studies
   Collection of 5-6 BIPV case-studies where BIM has been adopted. Interviews to identify needs to overcome current bottlenecks and support process optimization towards a greater interoperability.

3. Information Management (IM) strategies for improving the main BIPV process stages
   Definition of digitalization goals, workflows and IM structure to support an integrated and interoperable process for BIPV
D.1 Comparison of BIPV real data with simulated performance
- Lead by RMIT, Astrid Schneider, Lucisun

Goal: overview of state of the art software for BIPV-planning and BIM / 3D simulation
- PVsyst
- Revit
- Rhino – Plugins: Honeybee with energy Plus / radiance
- SAM
- Sketchup
- PV*Sol
- Solarius PV
- Lucisun
- BIMSolar
D.1 Chinese Building representation in different 3D-formats

Rhino with Grasshopper, ladybug
SKETCHUP
Revit
Rhino
D.5: Data mining for decision-making – Method - Lead by RMIT

Sample size
1 sqm

Orientations
- Roof
  - Pitch Roof - North, South, West, East
  - Flat roof
  - Façade (90 /75 degree)- North, South, West, East

BIPV applications/alternative materials
- Continuous roof
- Discontinuous roof
- Skylight
- Balustrade
- Curtain wall
- Rainscreen
- Double skin façade
- Shading device

PVPS

BIPV product ref. efficiency
Electricity price
BIPV Product cost

Economic aspects
- BIPV Building Element cost
- Effective/standard NPV
- Effective/standard LCOE
- Effective/standard IRR
- Effective/standard payback period
- Cost substituted building material

Environmental aspects
- Carbon emission reduction

Energy aspects
- Specific DC final system yield [kWh/kWp]
- Area-specific DC final system yield (kWh/m2)
IEA PVPS Task 15 Phase 3 plan

STC – BIPV in the Digital Environment (2024-2027)

- BIPV Product properties
- IFC-BIPV Digital Representation
- BIM-based BIPV digital products and project simulation

Express of Interests!
Australian BIPV Alliance aims to enable *collaborations* within the entire stakeholder ecosystem cross different industry sectors in addressing design, technical, practical, policy and standard related issues in BIPV adoption, showcasing good practices, filling in industry knowledge gaps and providing training opportunities.
SEAL@RMIT
Thank you!

Contact:
Rebecca Yang
rebecca.yang@rmit.edu.au