RMIT UNIVERSITY

BIPV in A Digital Environment

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- *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

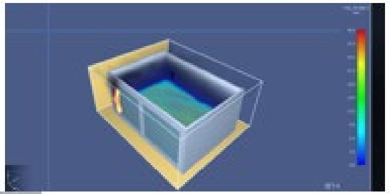
>20 researchers from various backgrounds including architecture, civil engineering, electrical engineering, fire engineering, mechanical engineering, computer science, construction and project management.

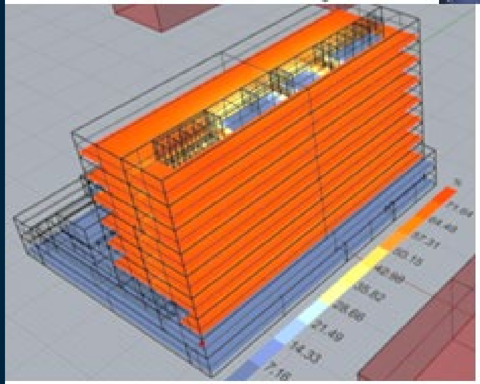
Skills: Auto CAD, CAD 3D, Rhino, Revit, SPACE GASS, Ansys, PyroSim, ArcGIS, QGIS, PowerFactory, EnergyPlus, SIMULINK, MATLAB, Python, Machine learning, Optimization, Block-chain, Socio-economic assessment

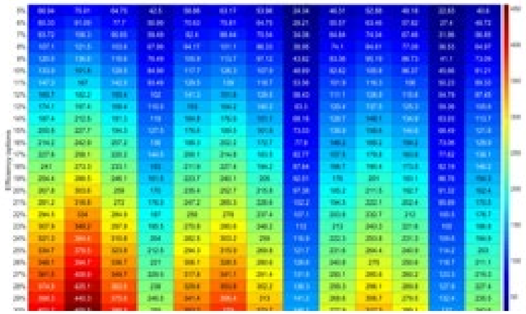
RESEARCH DOMAINS

- 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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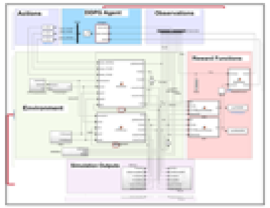
Solar enabled community/industry decarbonization

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.

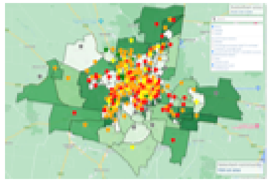
VIRTUAL POWER PLANT

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



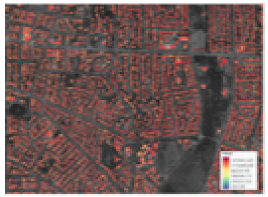
DEMAN RESPONSE AND ENERGY FLEXIBILTITY

Investigating the load management and energy trading strategies that support the renewable transition and energy efficiency of high energy users while also benefitting the electricity grid.



GAME THEORY

Applying game theory in P2P trading to gain better understanding of the behaviour 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.

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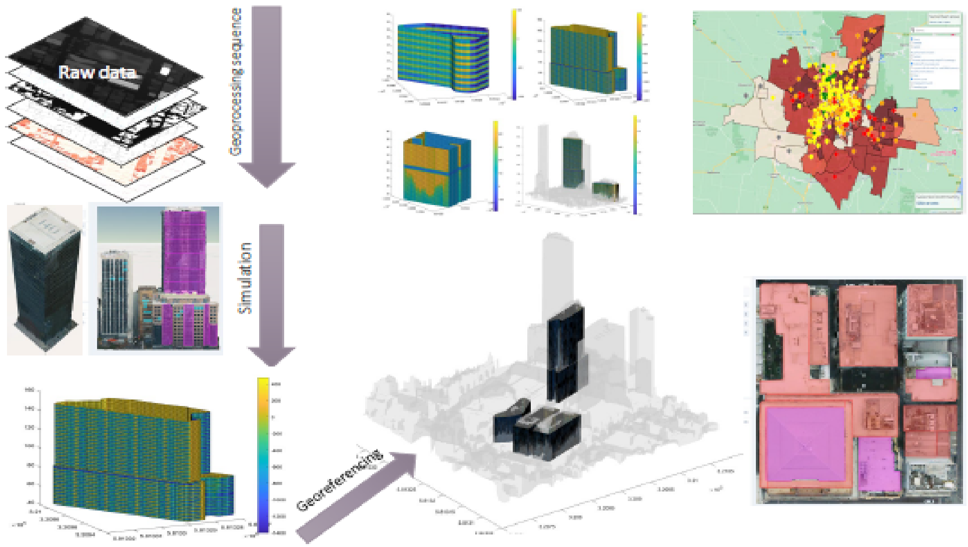
Solar energy in urban scale

SEAL's research in solar energy in urban scale includes the development of advanced modeling, simulation, and optimization tools to analyze the technical feasibility and economic viability of solar energy systems in urban areas. This includes the use of machine learning-based algorithms to analyze building images and identify suitable locations for the installation of solar panels on buildings, as well as the development of sophisticated tools to analyze the performance and efficiency of solar energy systems in urban environments.

SEAL is helping to improve the use of renewable energy and promote more sustainable infrastructure development. We are interested in the application and deployment of infrastructure-integrated PV systems, such as noise barriers that incorporate PV panels. In the urban environment, infrastructure-integrated PV systems have great potential to provide a significant source of renewable energy.



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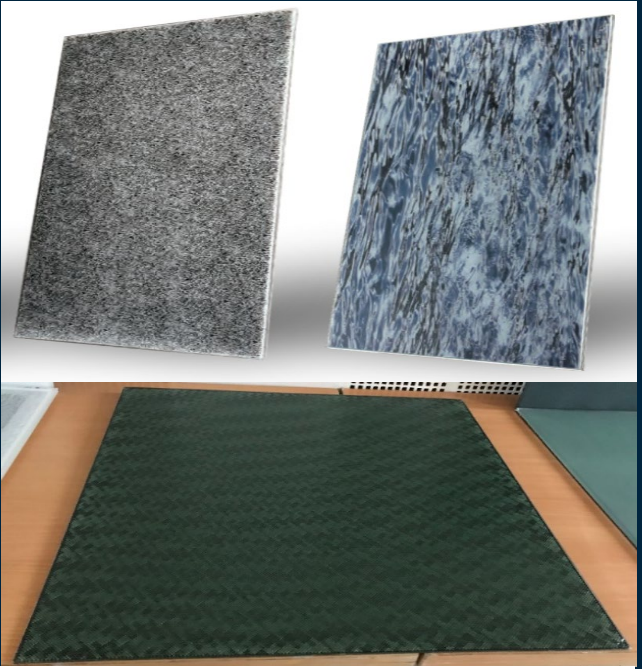
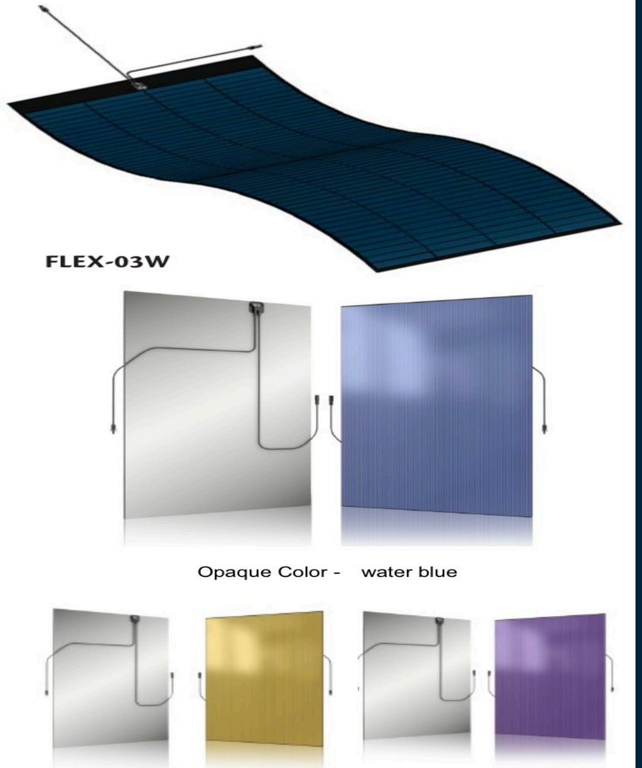
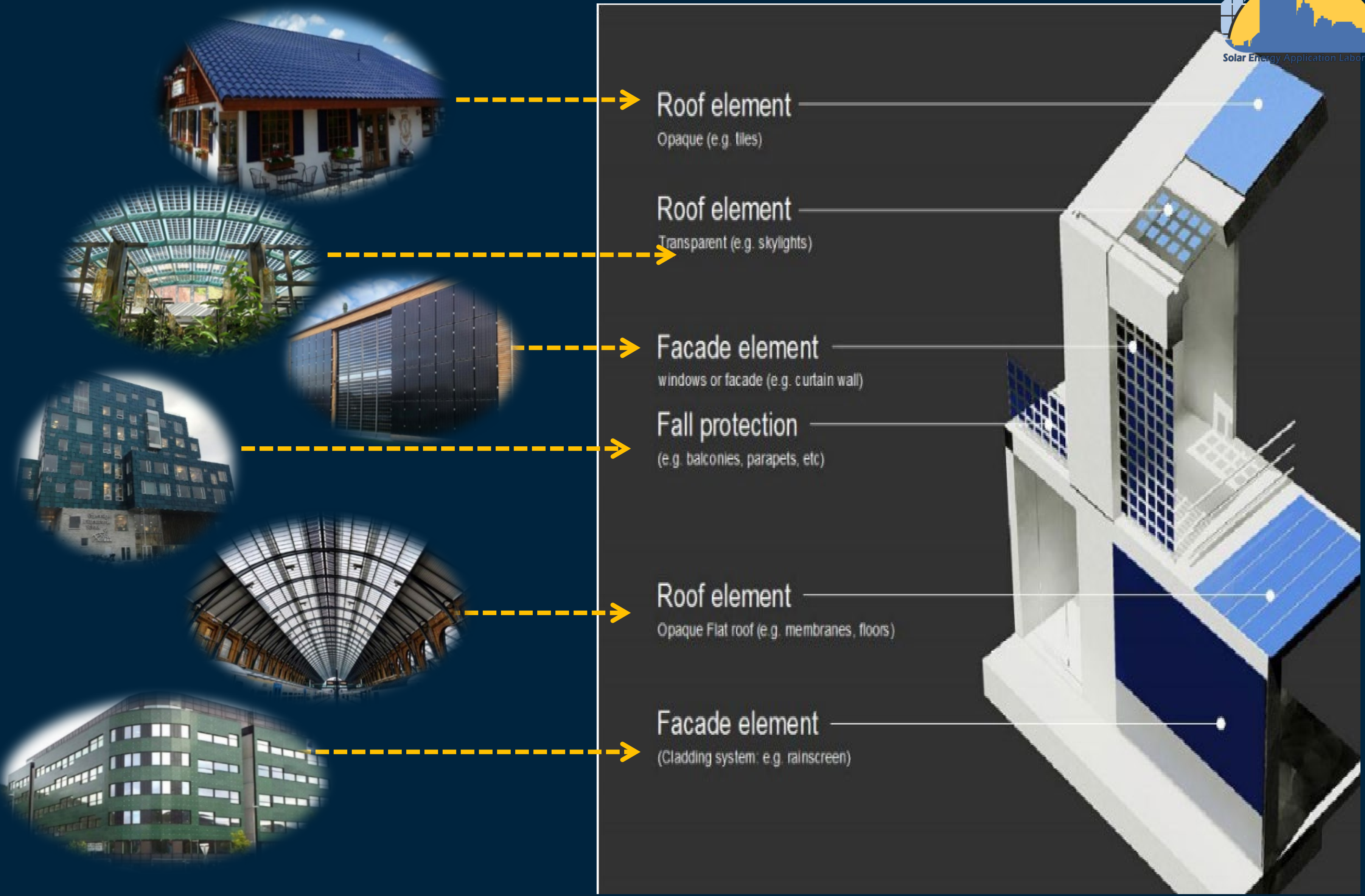
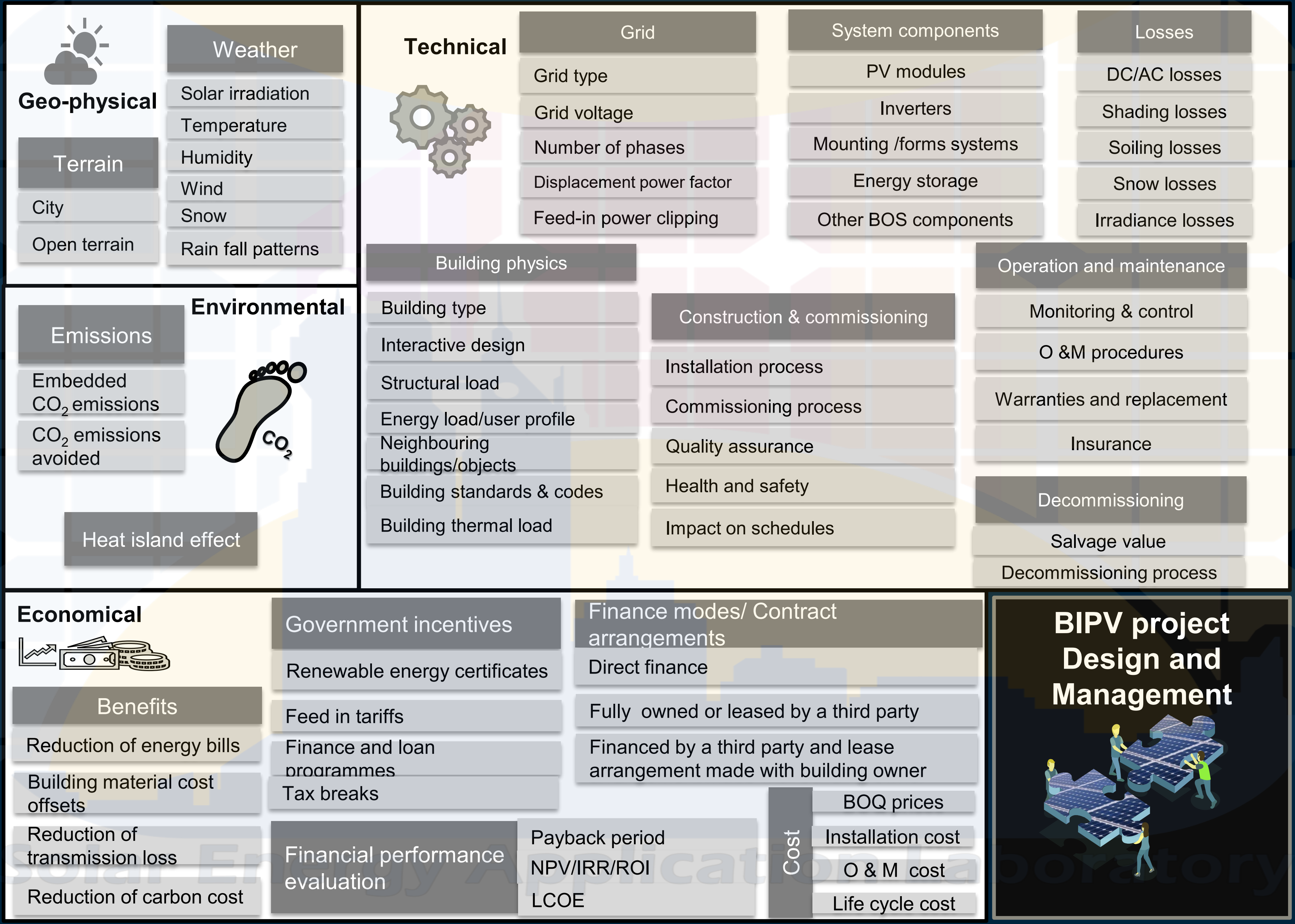


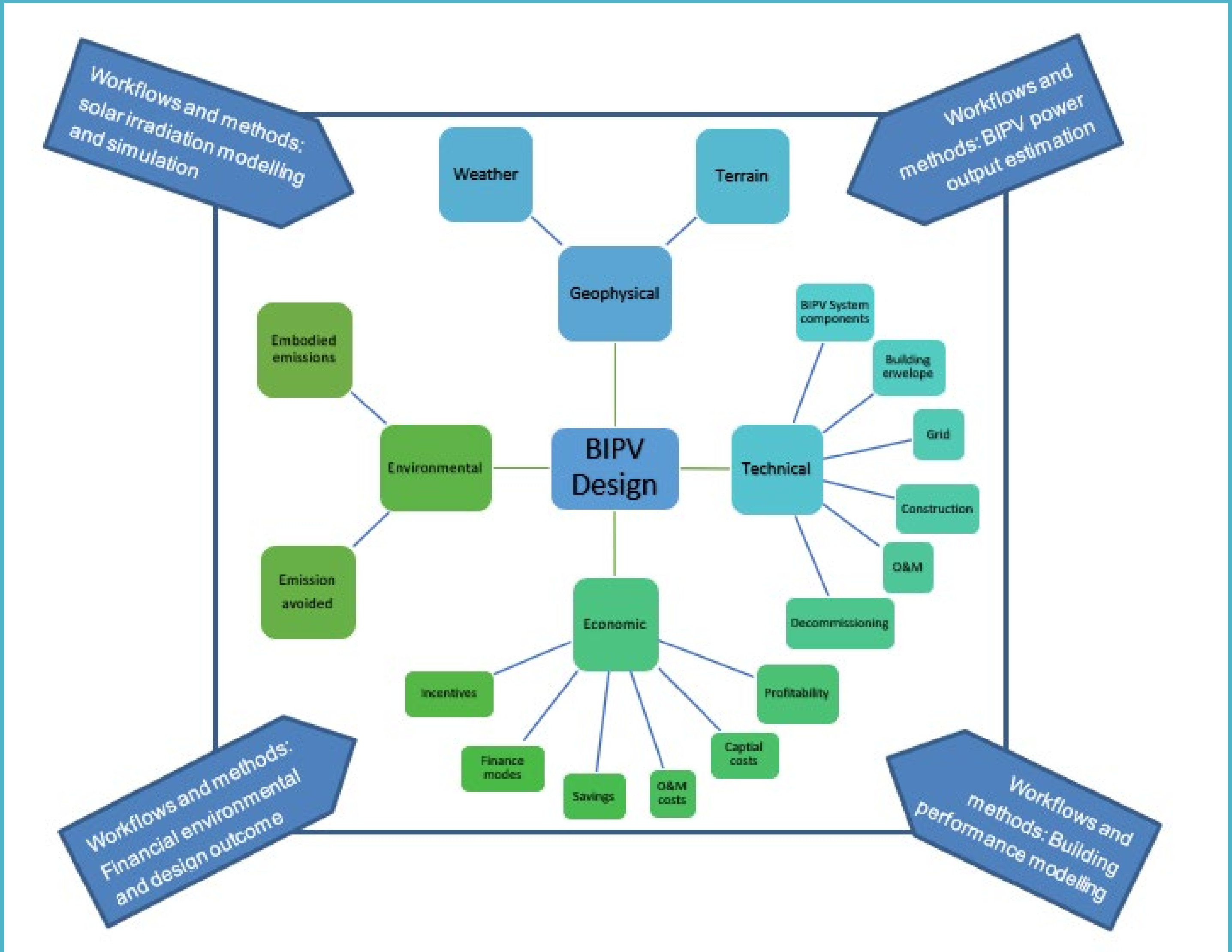


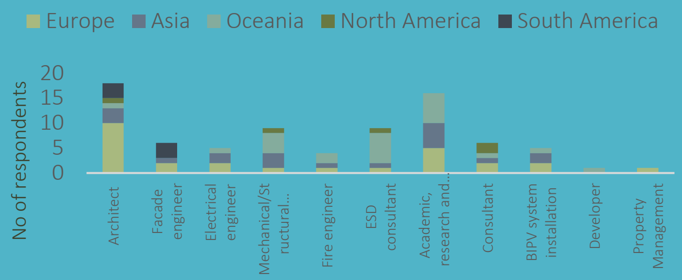


(Source: Gieseking, 2012; SUPSI, 2015; Hislop, 2016; Pvresources, 2018; Selfa photovoltaic, 2018)



Wijeratne, W.P.U., Yang, R.J., Too, E. and Wakefield, R., 2019. Design and development of distributed solar PV systems: Do the current tools work?. *Sustainable cities and society*, *45*, pp.553-578.


Workflows and methods: solar irradiation modelling and simulation
Workflows and methods: BIPV power output estimation
Workflows and methods: Financial environmental and design outcome
Workflows and methods: Building performance modelling
Weather
Terrain
Geophysical
Embodied emissions
Environmental
Emission avoided
BIPV Design
Technical
BIPV System components
Building envelope
Grid
Construction
O&M
Decommissioning
Economic
Incentives
Finance modes
Savings
O&M costs
Captial costs
Profitability


Europe
Asia
Oceania
North America
South America
No of respondents
20
15
10
5
0
Architect
Facade engineer
Electrical engineer
Mechanical/St ructural...
Fire engineer
ESD consultant
Academic, research and...
Consultant
BIPV system installation
Developer
Property Management


Technology Collaboration Programme
by iea
International Energy Agency
Photovoltaic Power Systems Programme
Task 15 Enabling Framework for the Development of BIPV
PVPS
BIPV Digitalization: Design Workflows and Methods – A Global Survey
2022
Report IEA-PVPS T15-14:2022

Step 1

Solar irradiation

Stakeholders: Façade engineers, Architects, Electrical engineers, BIPV system installers, PV consultants, ESD consultants, Academics

Developing building model

Identifying project location
- Google maps
- IP addresses
- Manually selected from a list

Creating building geometry and surrounding environment

2D
- CAD software

3D
- CAD or BIM software
- GIS modelling
- CAD or BIM software with LiDAR assisted point cloud data

Photorealistic visualisation
- Autodesk Revit
- Sketchup
- Rhino
- Autodesk Maya
- 3D studio max
- Lumion,
- SU Podium rendering plugin for SketchUp
- MicroStation a
- KeyShot

Data exchange formats
- Autodesk Revit.rvt
- Open BIM (ISO) ifc
- SketchUp.skp

Models for higher spatial resolutions
- Custom made tools

Solar irradiation analysis

Weather parameters
- Irradiance
  - Beam/direct normal irradiance
  - Diffuse horizontal irradiance
  - Global horizontal irradiance
- Temperature
- Wind speed

Model for POA estimation
- POA (Beam only)
- POA with shading and ground reflected (Albedo)
- POA sky diffused
- Ray tracing with radiosity Ray tracing with rasterization

Methods for shading approximations
- Ray tracing
- Shading percentage
- Far field shading horizon map
- Near field shading factor
- Sky view factor
- Reduction of incident irradiation
- Shading index

Type of weather data
- Long-term averaged data
- Ground mounted meteorological data
- Satellite based meteorological data
- Measured at site
- Hybrid

POA sky diffuse model
- Isotropic Sky Diffuse Model
- Simple Sandia Sky Diffuse Model
- Hay and Davies Sky Diffuse Model
- Reindl Sky Diffuse Model
- Perez Sky Diffuse Model

Weather data step values
- Conceptual design – Annual
- Detailed design – Hourly

Weather file formats
- EPW files from the EnergyPlus
- Typical Meteorological Year

Software for estimating POA irradiation

BIMSolar, IES VE, PVsyst, TAS, Revit Solar, PV Watt, Pleiades, Helioscope, PV GIS, Radiance and SAM

Step 2

Power output analysis

Stakeholders: Electrical engineers, Architects, Façade engineers, PV consultants, and Property managers

Importing properties of technical components of BIPV
- BIPV component database in software
- Online platform
- Add manually

Models for calculating DC output of BIPV
- PV cell temperature model
- Power model by Heydenreich et al. (2008)
- Sandia PV Array Performance Model (SAPM)
- Loss factors model (LFM)
- Single diode model
- Two-diode model

Software for calculating DC output of BIPV
- BIMsolar
- PVsyst
- PV*Sol
- SAM
- Retscreen

Step 3

Building performance

Stakeholders: Architects, Electrical engineers, Mechanical/Structural Engineers, Fire engineers, Façade engineers, PV consultants, ESD consultants, Property managers and Academics

Building energy consumption

Models for identifying the energy consumption patterns
- Calculating the watt hour data
- Use historical information electricity bills
- Simulation software to identify building energy demand (e.g. IES VE, EnergyPlus)
- Measure building energy consumption
- Percentage of monthly energy consumption based on the usage

Suitable interval for energy consumption data
- The conceptual design phase – Annual and monthly
- Detailed design phase – hourly and daily

Data file formats for building energy consumption
- Text file
- MS Excel Spreadsheet
- Comma Separated Values (CSV)

BIPV impact on building factors

Structural loads considered for BIPV designs

dead load, wind load, snow load, live load and seismic load, live load, rain load
- Calculate manually
- Use software for structural load calculation (e.g. proprietary software, SpaceGass, RISA)

Methods/software for daylight impact
- Calculate manually
- Use building simulation software (e.g. IES VE Radiance, DIVA, Grasshopper)

Methods for thermal impact of BIPV designs
- Calculate manually
- Use building simulation software (e.g. IES VE, EnergyPlus, DesignBuilder)

Software for fire related impact
- Fire Dynamics Simulator (FDS)
- Thermal Radiation Analysis (TRA)
- Proprietary software

Methods/software for heat island impact
- Rhino and Grasshopper
- EnergyPlus
- Envi-met

Step 4

Financial and design outcome

Stakeholders: Developers, ESD consultants, PV consultants, Academics and Property managers

Assessing economic and environmental feasibility

Economic
- NPV
- ROI
- PB
- IRR
- DPB
- LCOE

Lifecycle cost of BIPV
- Capital cost of BIPV
- Module cost
- Mounting structure cost
- Installation cost
- Cost of electrical devices and installation
- Contingency

Material cost offset

O&M costs of BIPV
- Cleaning
- Repair of BIPV modules
- Repair of BOS
- Repair mounting system
- Replacement of BIPV modules
- Replacement of BOS
- Replacement of the mounting system
- Insurance
- Depreciation

Lifecycle income of BIPV
- Saving from energy self-consumption
- Income from feed in tariffs
- Salvage value
- Savings from reducing building thermal loads

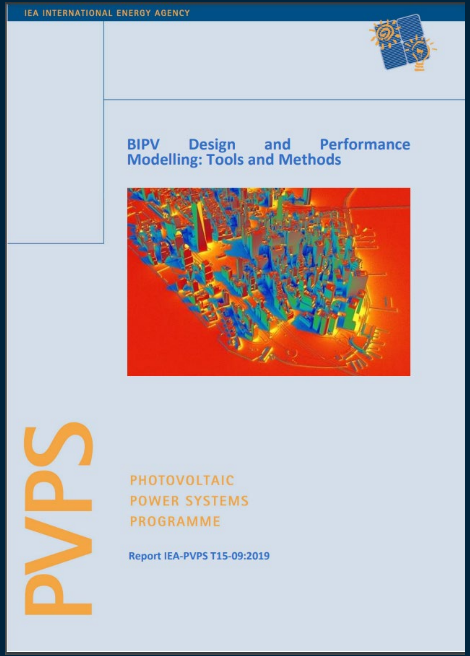
Environmental
- Emissions avoided
- Embodied emissions

Decision making

Optioneering /decision making methods
- Multiple solution comparisons using parametric workflows
- Multiple solution comparisons using traditional workflows
- Multiple solution comparisons using integrated optimization

Factors for optimum design of BIPV
- Cost
- Energy generation
- Reduction of CO_2 emissions
- Thermal impact
- Aesthetics
- Constructability
- Maintenance requirements
- Building value
- Structural, fire, electrical and thermal safety
- Lighting

Yang et al., 2022, BIPV Digitalization: Design Workflows and Methods – A global survey, IEA PVPS, https://iea-pvps.org/research-tasks/enabling-framework-for-the-development-of-bipv/



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Improvements

Information

- 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

Simulation and analysis

- 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

Terrain
Weather
Grid
Building Physics
System Component
Loss
Constructio
Maintenanc
Decommiss
ffect

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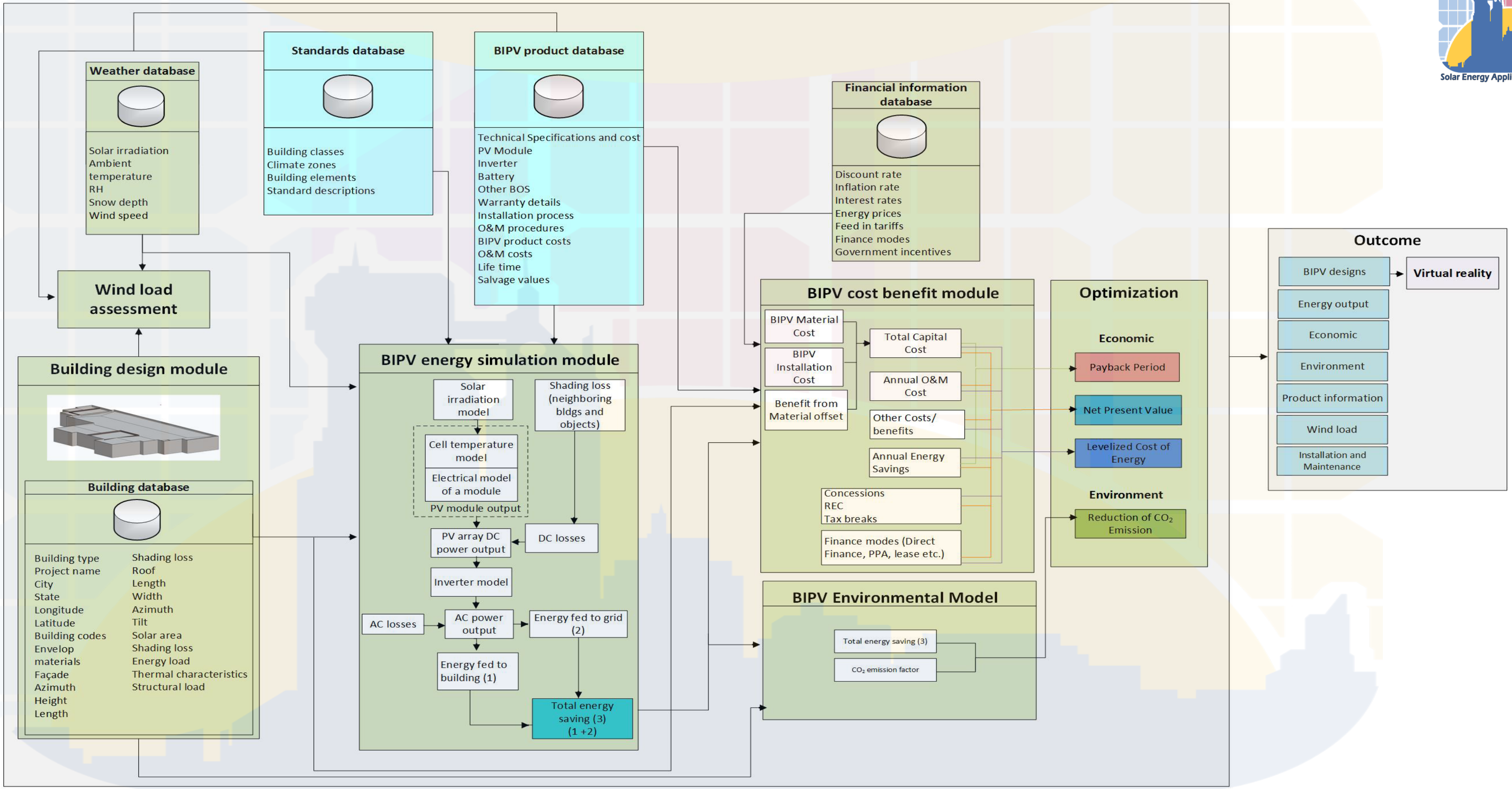
The Building Integrated Photovoltaics (BIPV) Enabler tool is a user friendly platform that integrates product, regulation, technical, economic and construction data to create a leading BIPV solution in conceptual building design stage.

Supported by ARENA, APVI, and several industry partners



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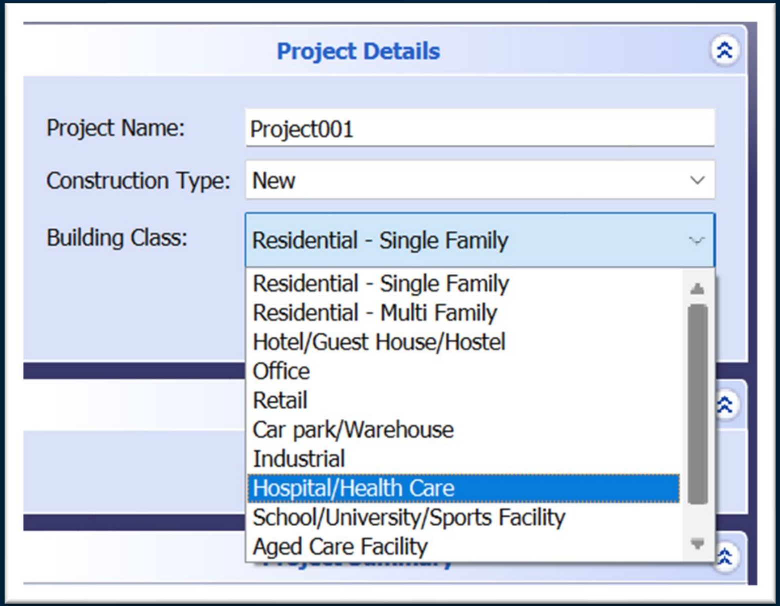
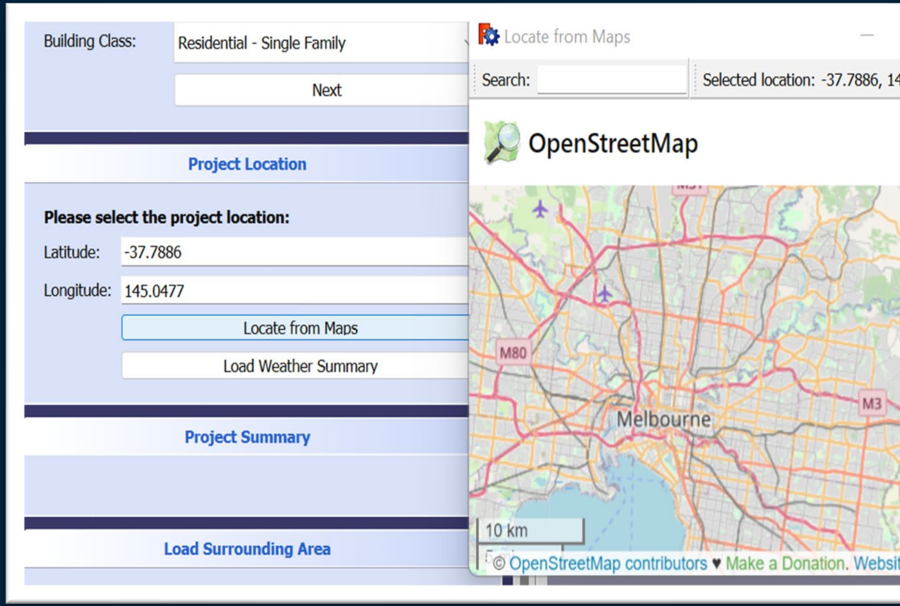
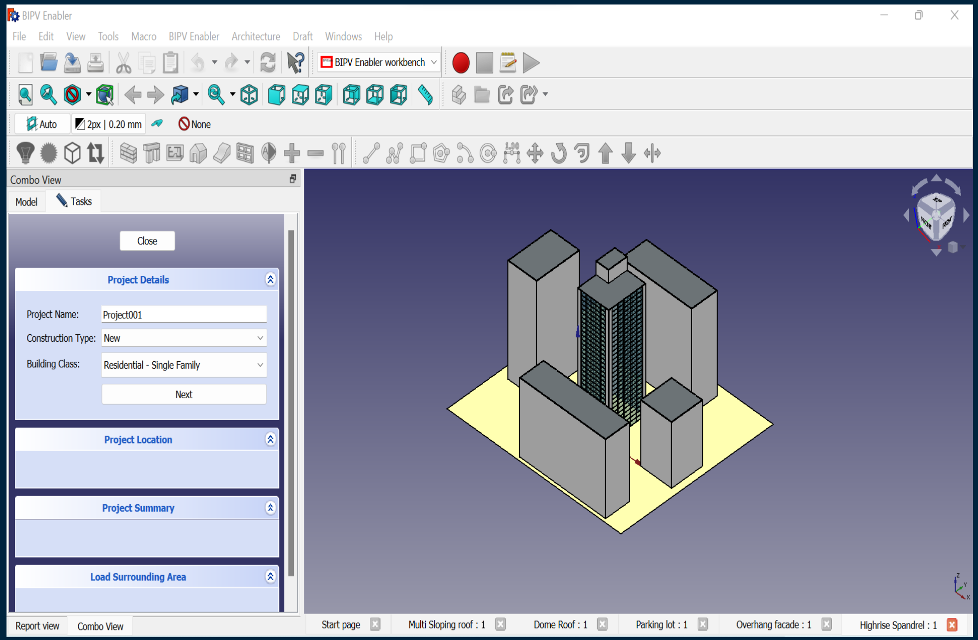
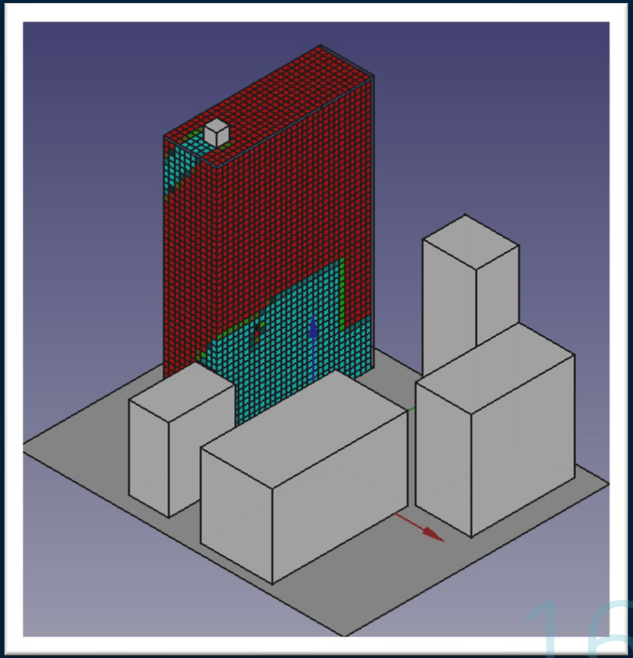
Building Type and Location

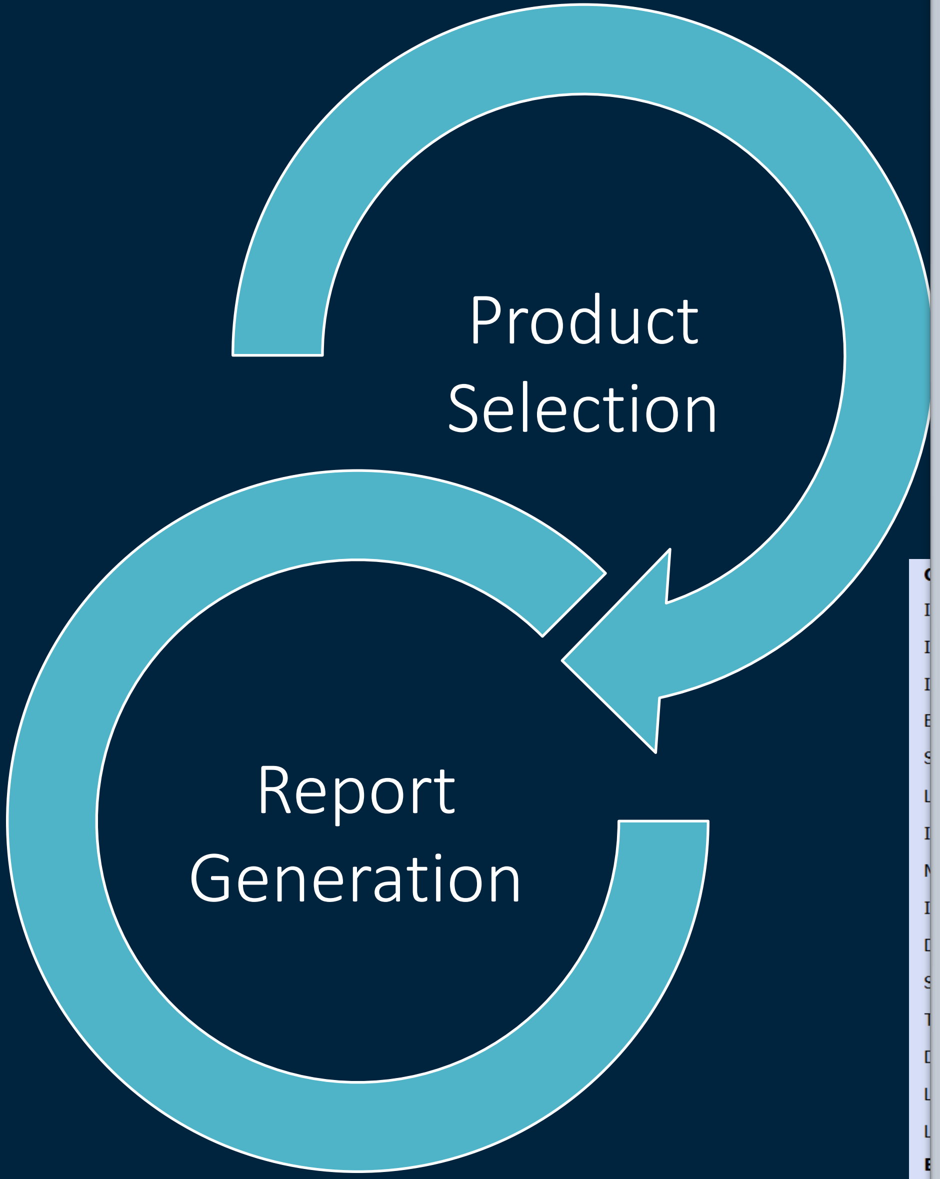
Building Modelling and Simulation





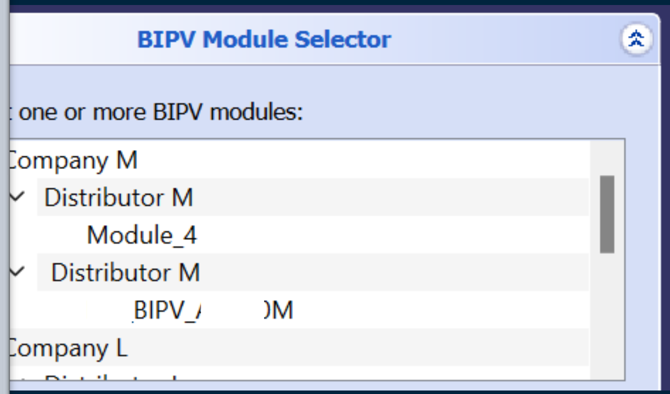


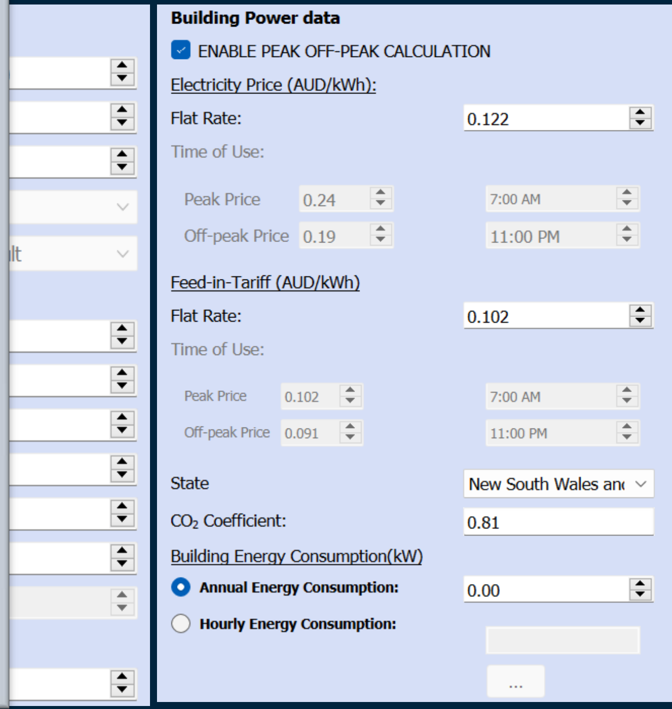


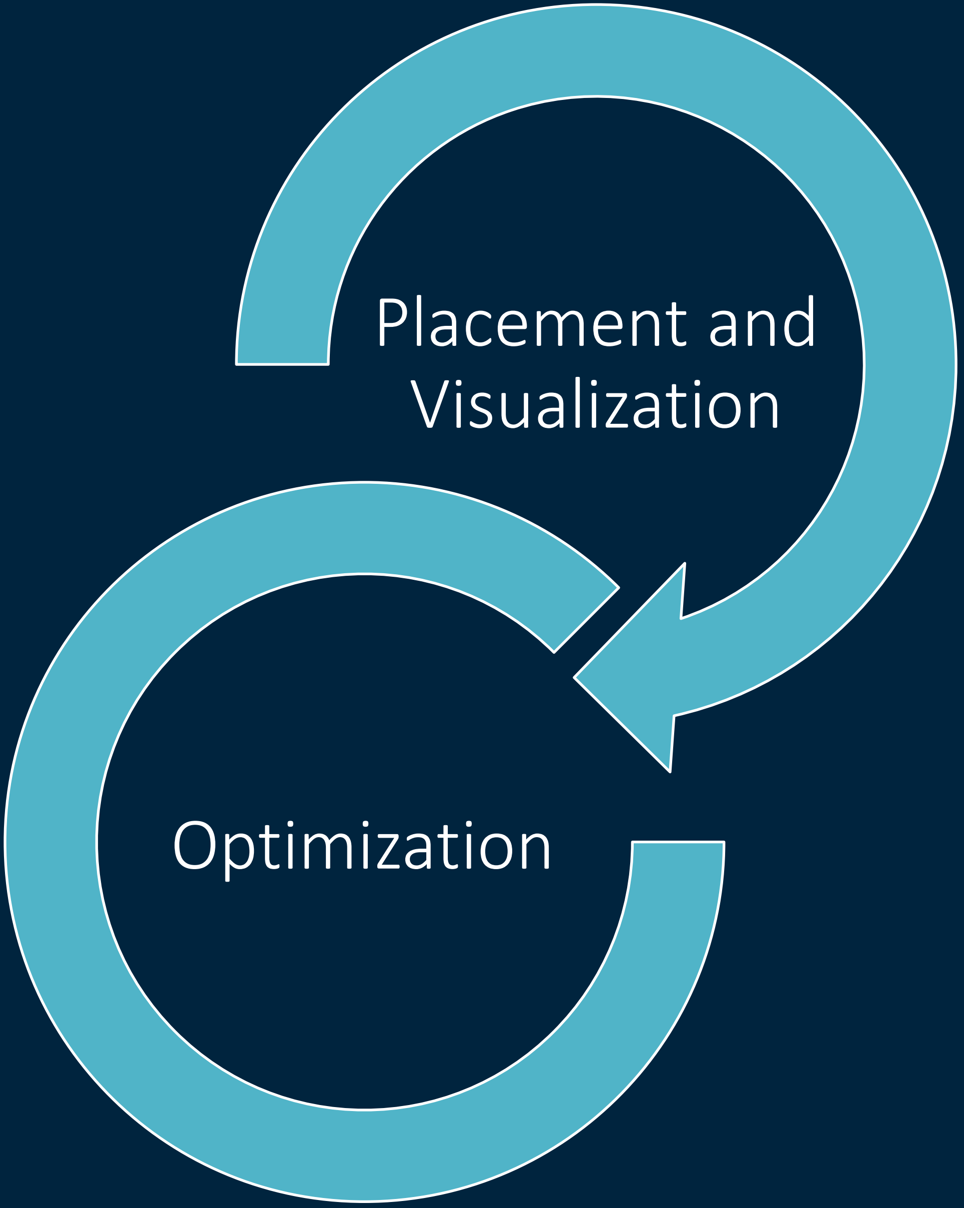


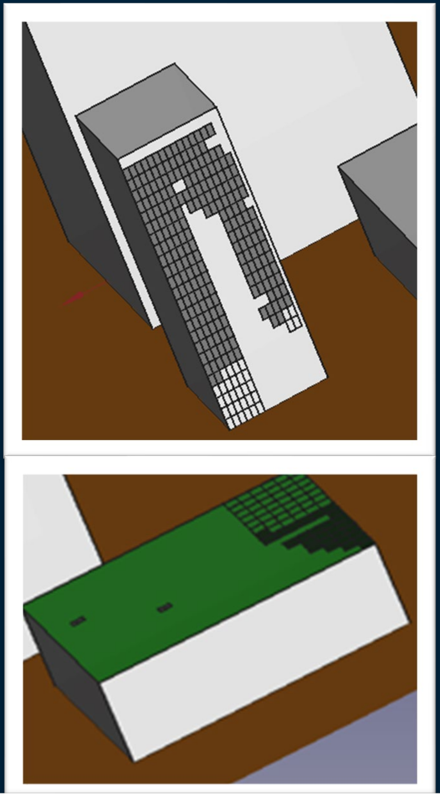
BIPV Enabler Report

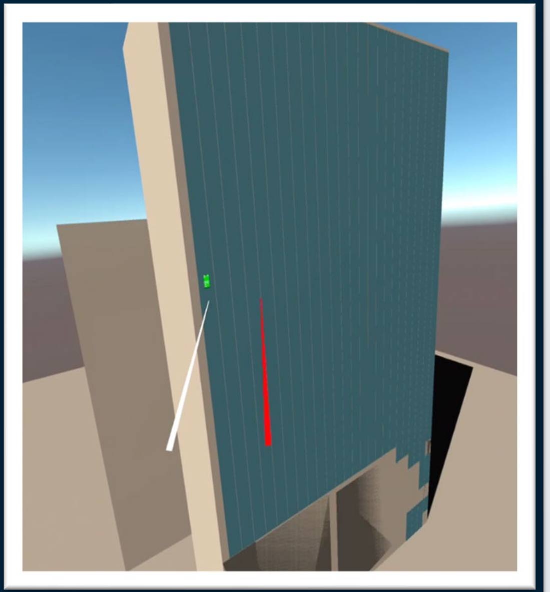
PV Module Name	Attribute	Value
Module_4	Manufacturer	Company M
	BIPV Cell Technology	po-c-Si
	Module Length (m)	1.33
	Module Width (m)	1.33
	Module Colour	black
	Module Transparency	semi_transparent
	System Size (kW)	8.16
	First year energy (kW)	18829.824367580622
	Life cycle Cost (LCC) (AUD)	21274.96
	Life Cycle Energy (LCE) (kW)	443554.0
	Payback period (Years)	5.919
	Net Present Value (NPV)	26699.8898
	Capital Cost (AUD)	17426.82
	Levelized cost of electricity (LCOE)	0.0565
	No of PVs	68
	Total PV Area (sqm)	120.2852
	Carbon Emission Factor	0.98
	Carbon Emissions	434682.92
BIPV_	Manufacturer	Company M
	BIPV Cell Technology	mo-c-Si
	Module Length (m)	1.658
	Module Width (m)	0.992
	Module Colour	black
	Module Transparency	opaque
	System Size (kW)	21.39
	First year energy (kW)	17765.57889716739
	Life cycle Cost (LCC) (AUD)	40479.34
	Life Cycle Energy (LCE) (kW)	496071.0

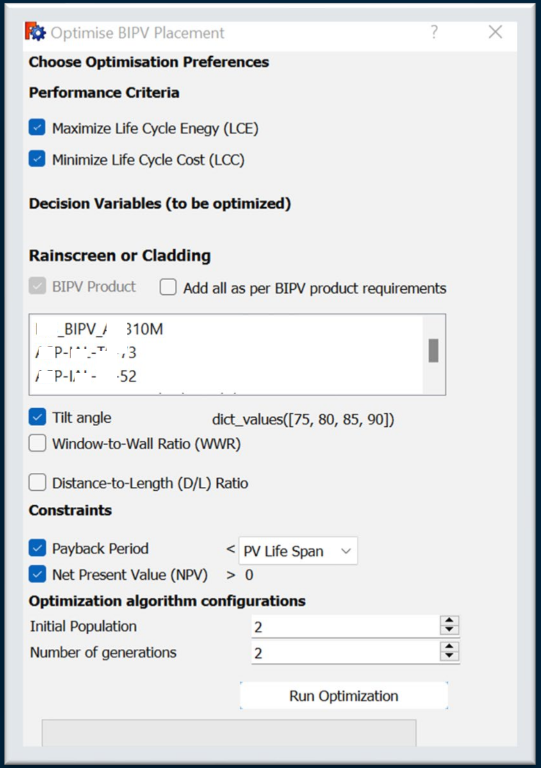




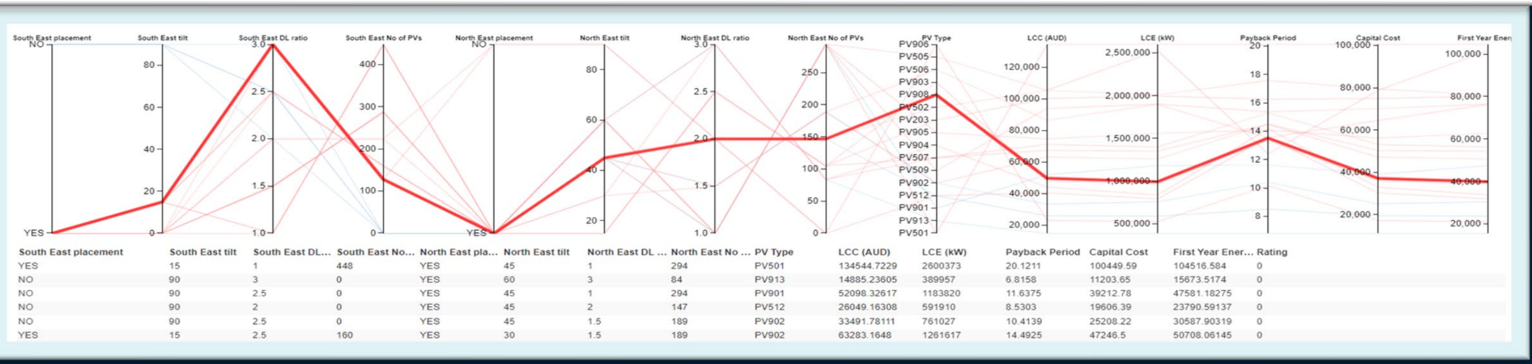


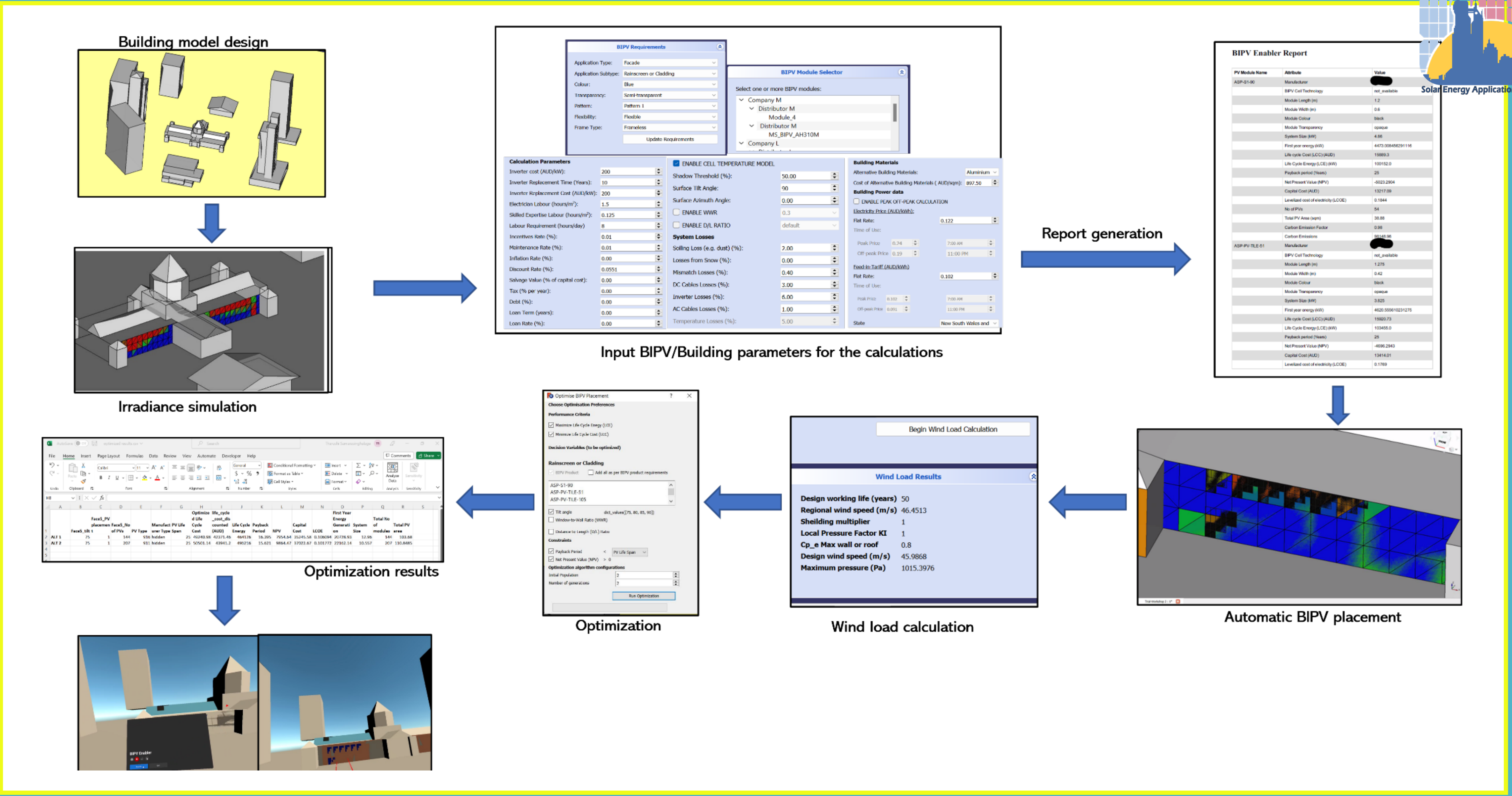




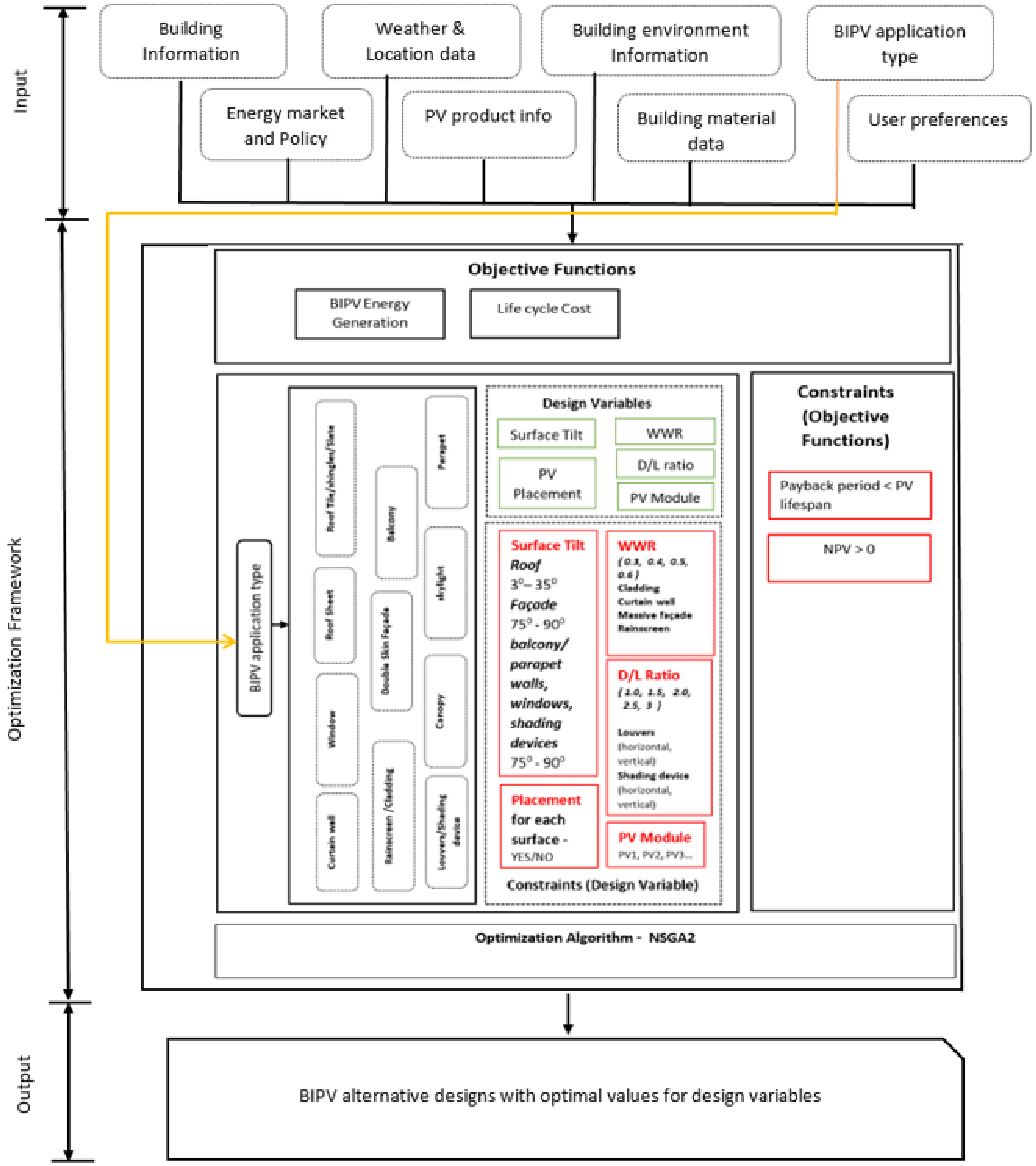


1		Cuboid002 Face6_tilt	Cuboid002 Face6_PV placement	Cuboid002 Face6_No of PVs	PV Type	PV name	Manufacturer Type	PV Life Span	Optimized Life Cycle Cost	life_cycle_cost_discounted (AUD)	Life Cycle Energy	Payback Period	NPV	Capital Cost	LCOE	First Year Energy Generation	System Size	Total No of modules
2	0	22.5	1	56	109	[illegible]	[illegible]	25	20627.37	17520.54	391545	5.403	25029.84	14351.49	0.052682	16621.93	6.72	56
3	1	20	1	63	105	[illegible]	[illegible]	30	45657.95	36959.39	898532	10.72	51731.22	29112.27	0.050814	32178.74	19.53	63
4																		





Building model design
Irradiance simulation
Input BIPV/Building parameters for the calculations
Report generation
BIPV Enabler Report
Automatic BIPV placement
Wind load calculation
Begin Wind Load Calculation
Wind Load Results
Design working life (years) 50
Regional wind speed (m/s) 46.4513
Sheilding multiplier 1
Local Pressure Factor KI 1
Cp_e Max wall or roof 0.8
Design wind speed (m/s) 45.9868
Maximum pressure (Pa) 1015.3976
Optimization
Optimization results
Solar Energy Application Laboratory

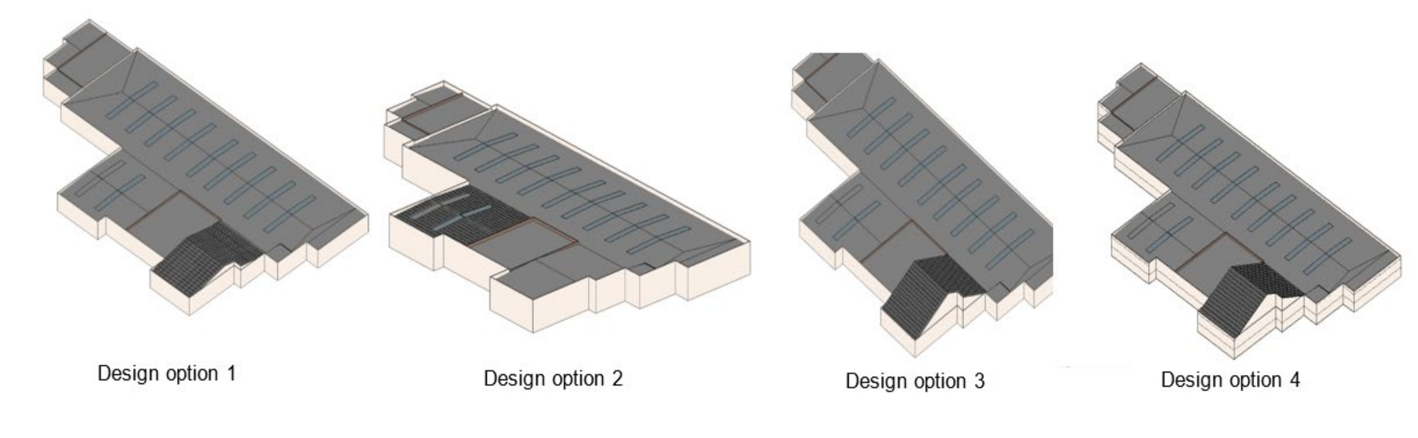


BIPV Design Optimisation

Wijeratne, W.P.U., Samarasinghalage, T.I., Yang, R.J. and Wakefield, R., 2022. Multi-objective optimisation for building integrated photovoltaics (BIPV) roof projects in early design phase. *Applied Energy*, *309*, p.118476.

Mudiyanselage, P.W., Samarasinghalage, T., Yang, J. and Wakefield, R., 2022. Multi-objective optimisation for Building Integrated Photovoltaics (BIPV) roof projects in early design phase. *Applied Energy*, *309*(March 2022), pp.1-21.

BIPV Design Optimisation



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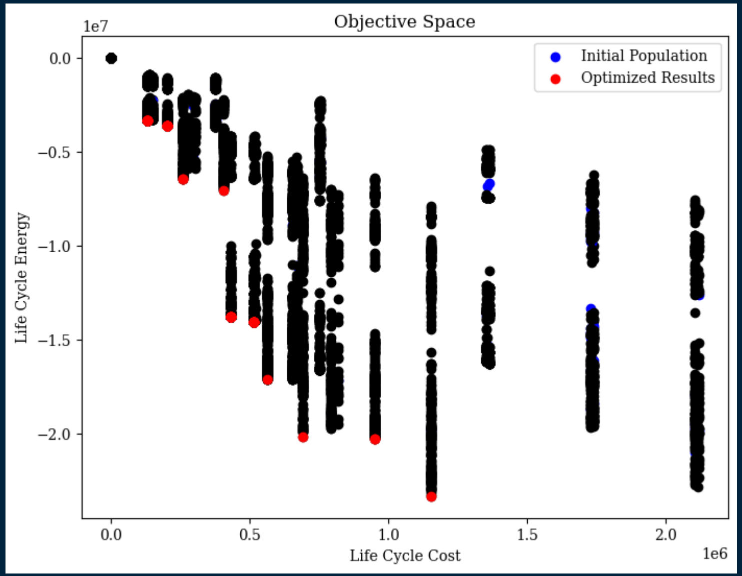
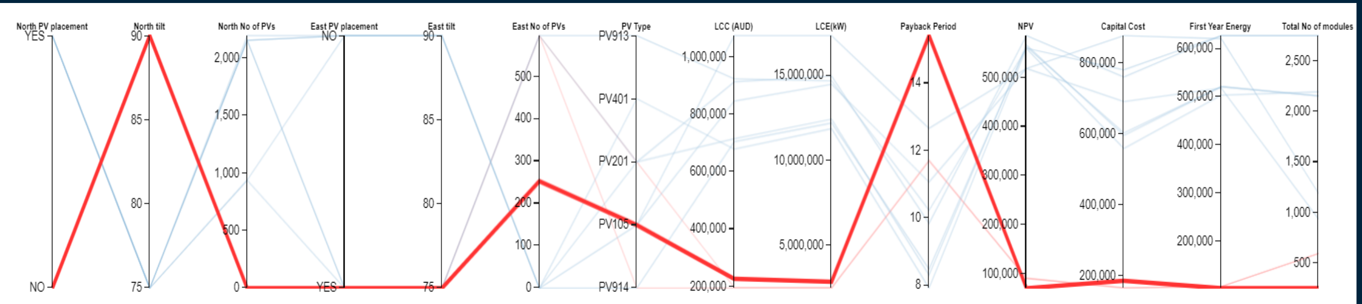
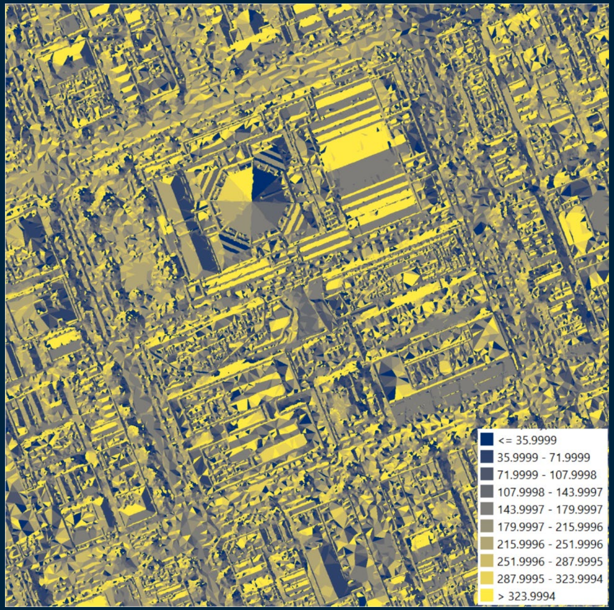




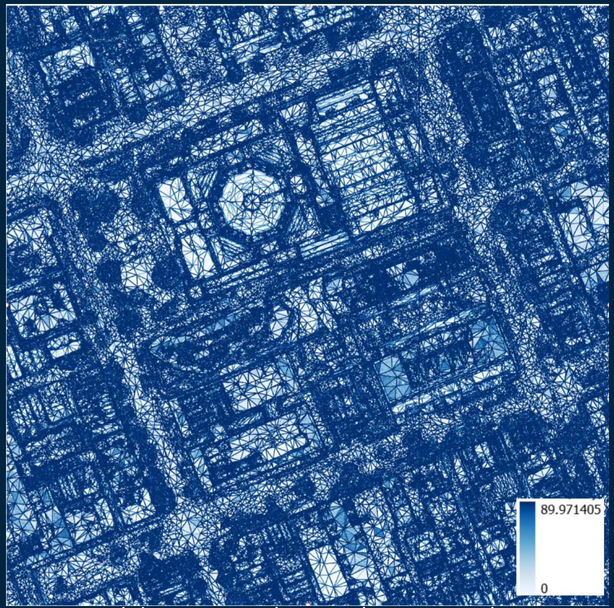
North PV placement	North tilt	North No of PVs	East PV place...	East tilt	East No of PVs	PV Type	LCC (AUD)	LCE(kW)	Payback Period	NPV	Capital Cost	First Year Ener...	Total No of mo...	Rating
NO	90	0	YES	75	595	PV914	194613.9018	2478471	11.7006	90203.72	166557.74	105901.8613	595	0
YES	75	936	NO	90	0	PV105	844467.4981	14445297	11.0602	517430.61	690438.55	517323.1143	936	0
YES	75	2150	NO	90	0	PV201	713668.1727	12399216	8.3056	565126.07	595062.15	520188.5548	2150	0
NO	90	0	YES	75	252	PV105	227356.6306	2860984	15.3933	70671.54	185887.3	102459.1787	252	0
YES	75	2190	NO	90	0	PV401	677518.1307	11841832	7.919	557696.5	558071.11	502710.8242	2190	0
YES	75	2150	NO	90	0	PV914	703226.696	12174216	8.481	561177.83	601847.3	520188.5548	2150	0
YES	75	2150	YES	75	595	PV201	911171.6915	14923494	9.8341	584001.16	759742.14	626090.4161	2745	0
YES	75	936	YES	75	252	PV105	1071824.129	17306281	12.648	517209.9	876325.84	619782.2929	1188	0
NO	90	0	YES	75	595	PV201	197503.5187	2524277	11.6844	91333.58	164679.99	105901.8613	595	0
YES	75	2150	YES	75	595	PV913	921601.456	14652687	10.2214	558296.6	779934.04	626090.4161	2745	0

Geospatial analysis and simulation of urban dynamics



Building envelope aspect angle

Shading simulation and visualisation



Building envelope slope angle

Liu, C.; Yang, R., W, K., Zhang, J. (2023) Community-Focused Renewable Energy Transition with Virtual Power Plant in an Australian City—A Case Study, Buildings, March 2023

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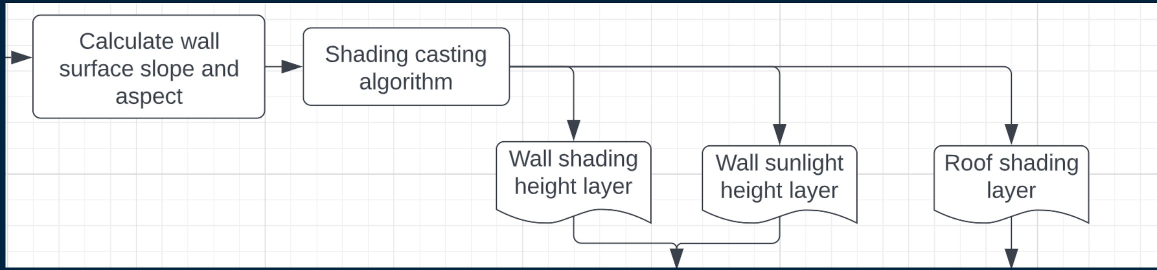
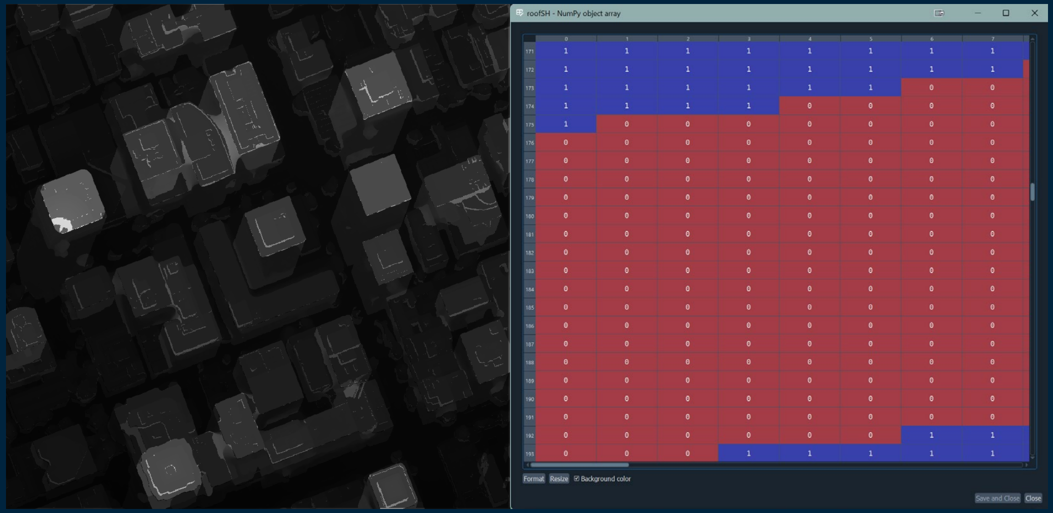
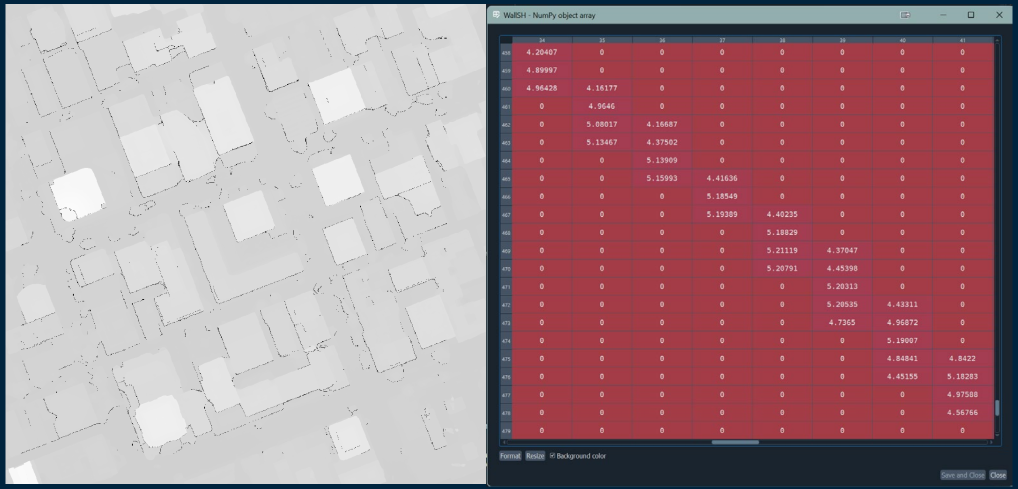
Shading casting on roof and wall



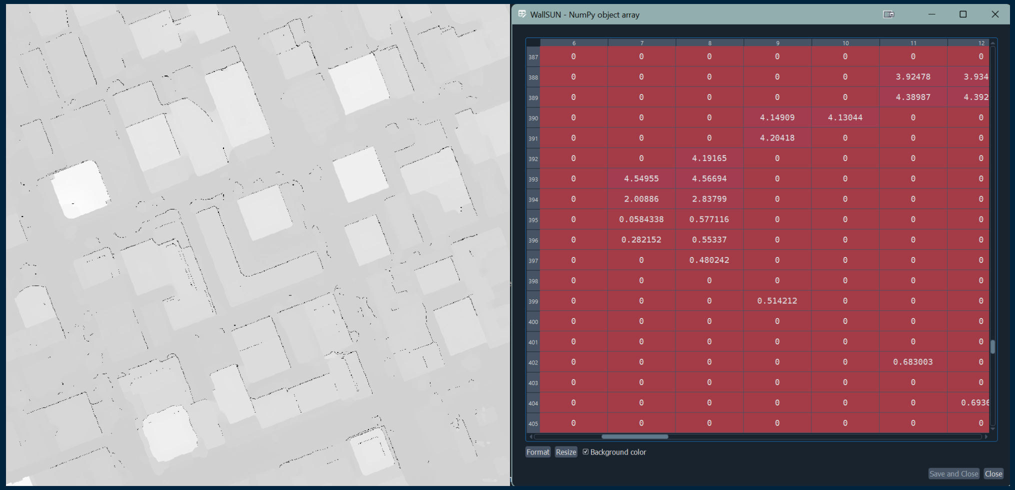
Shadow volume calculation using sun path algorithm – Determine the volume of space in shadow cast by surrounding objects determined by the sun movement at a certain time



Roof shadow logical raster (1-no shading; 0-shading) and numeric result (4000 x 4000 data array)



Wall shadow height raster and numeric result (4000 x 4000 data array)



Wall sunlight height raster and numeric result (4000 x 4000 data array)

Liu, C.; Yang, R., W, K., Zhang, J. (2023) Community-Focused Renewable Energy Transition with Virtual Power Plant in an Australian City—A Case Study, Buildings, March 2023

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Machine-learning based image recognition for building elements

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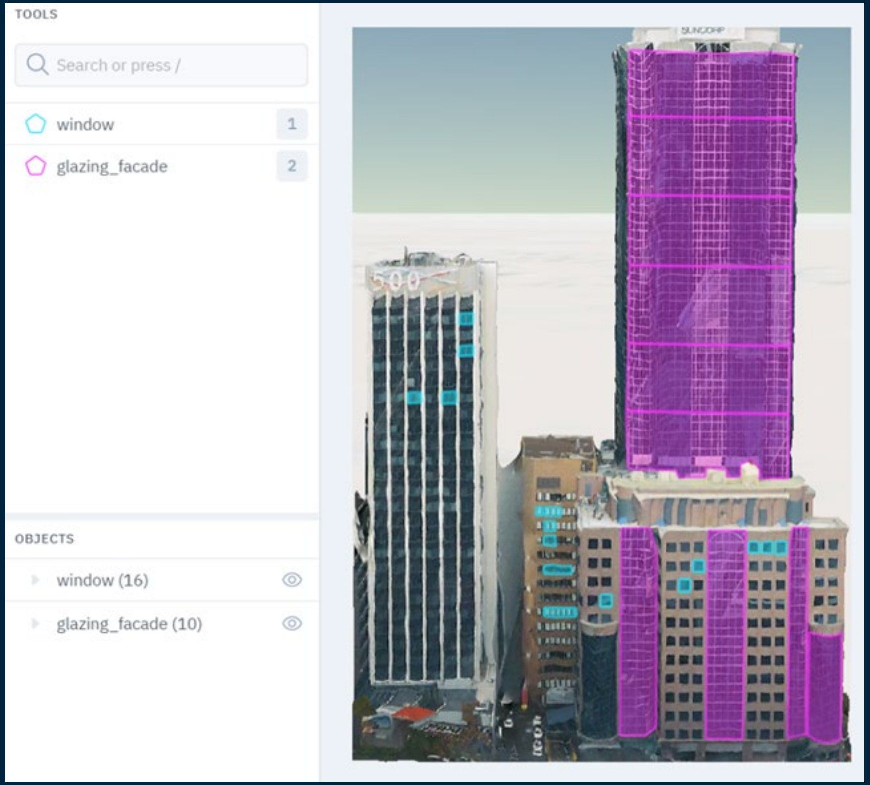

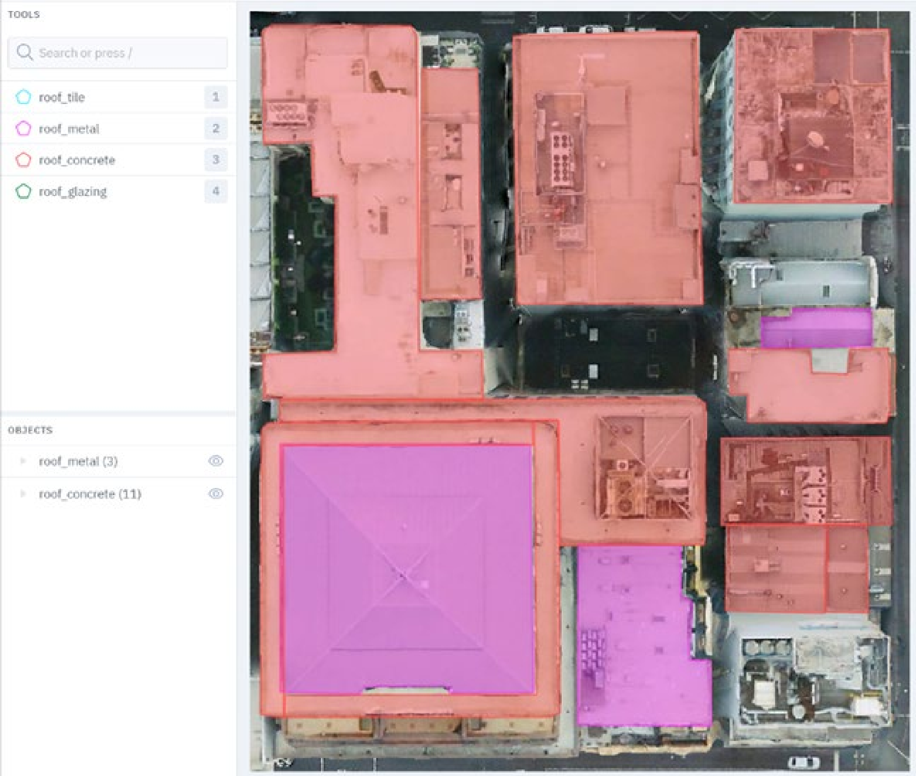

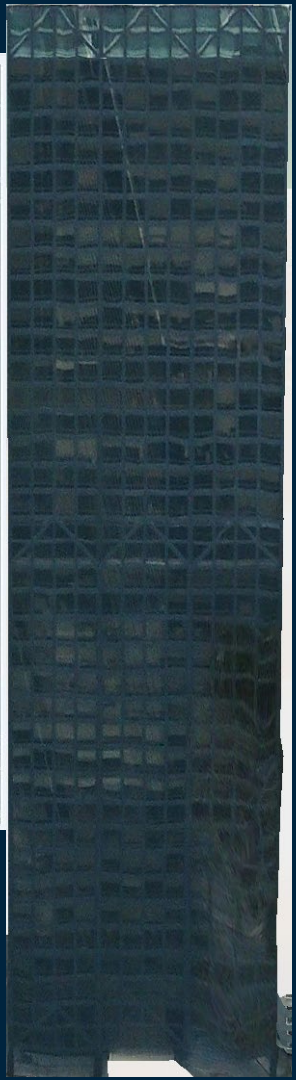

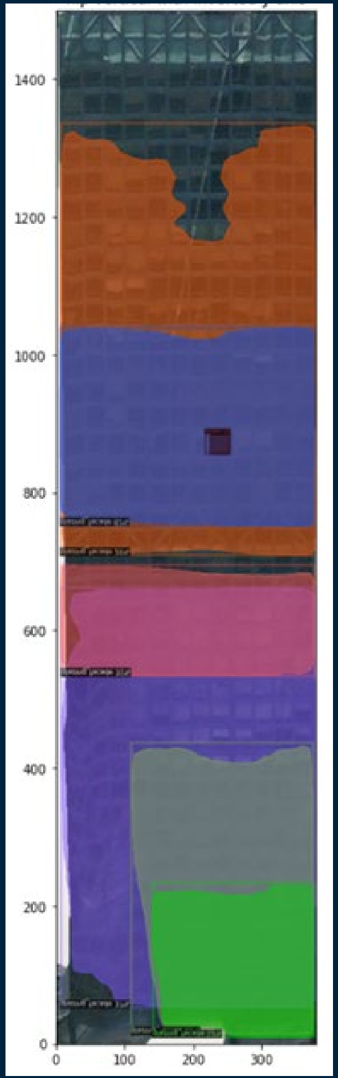

Urban level building envelop solar potential mapping and analysis

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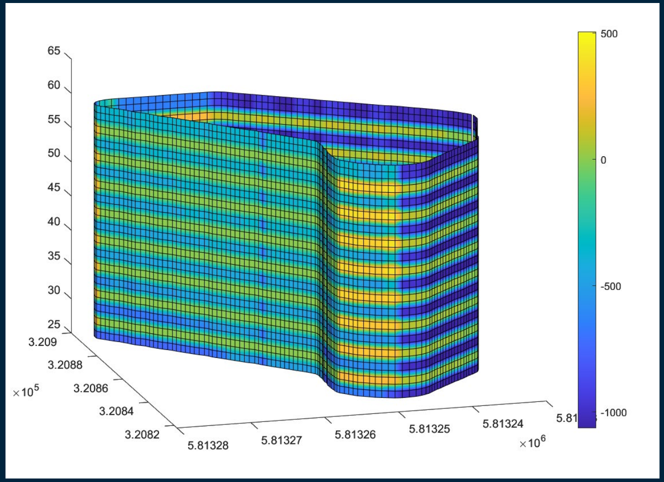
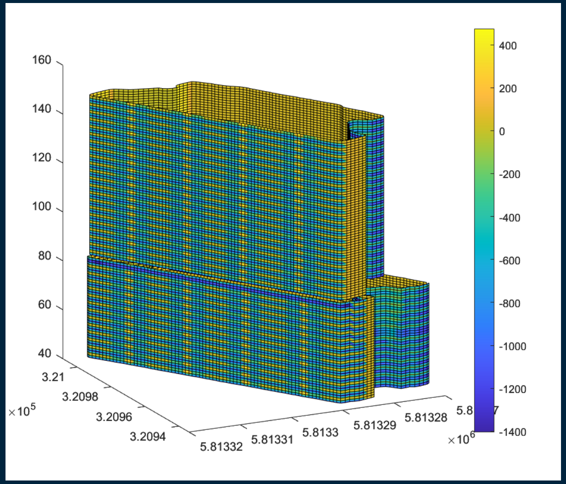
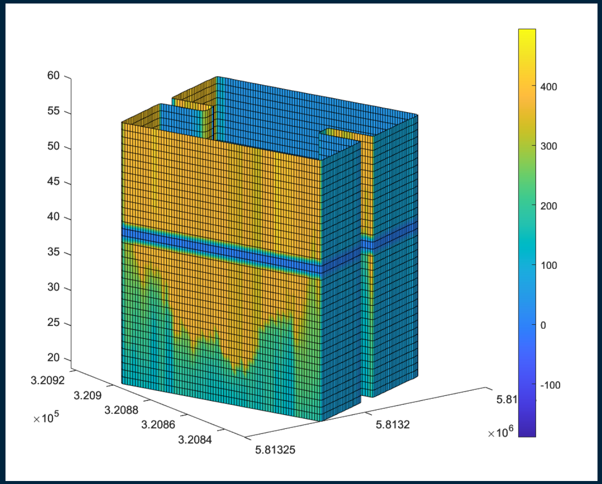
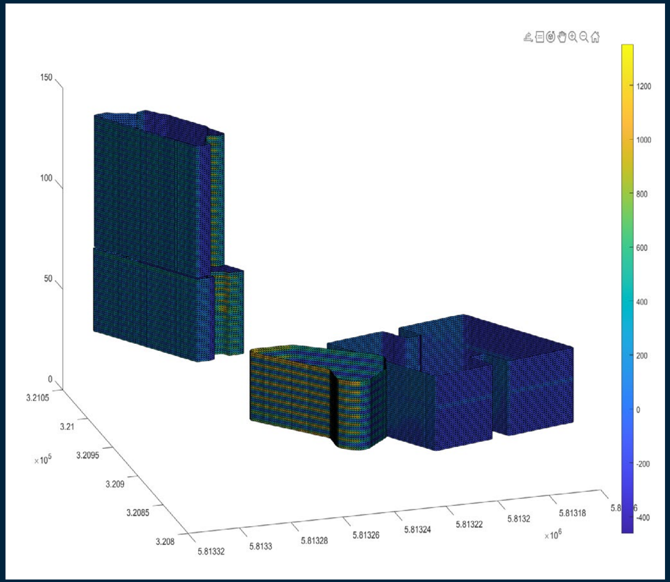
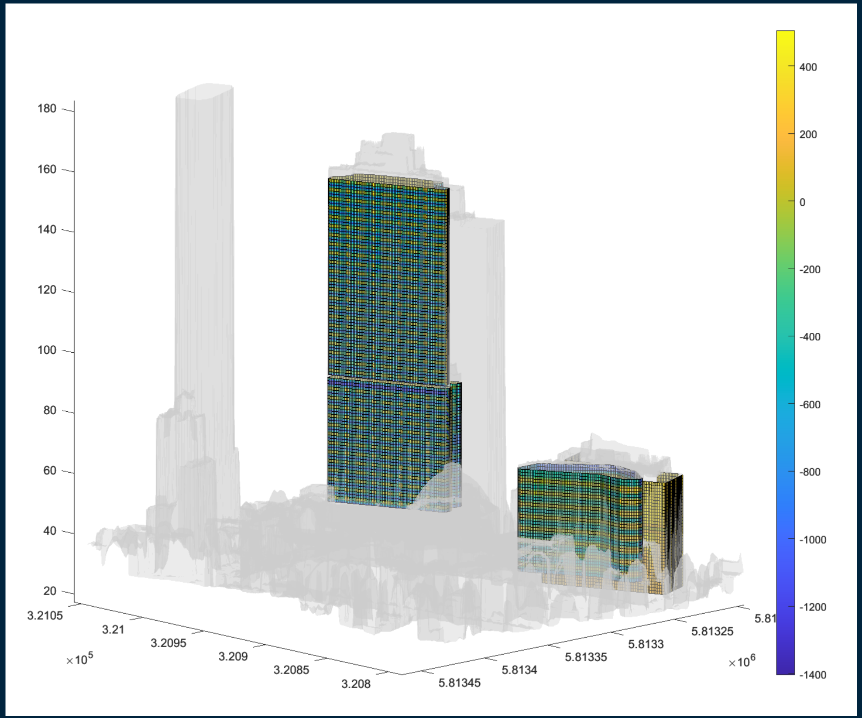










IEA PVPS

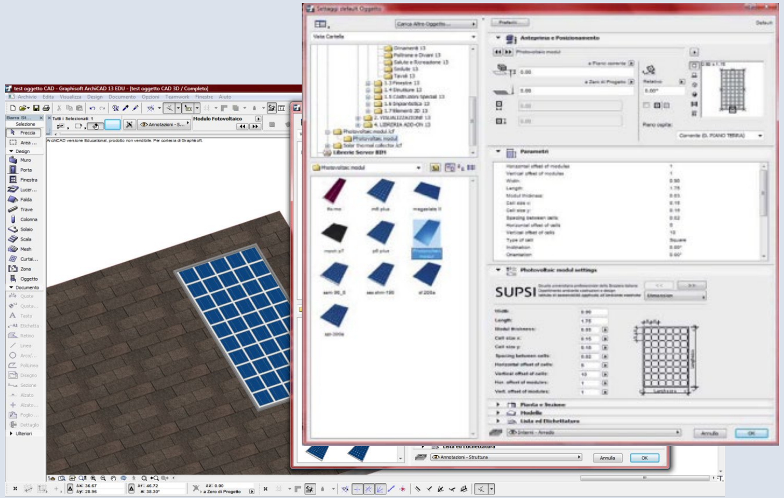
Task 15 BIPV - Subtask D: Digitalization for BIPV

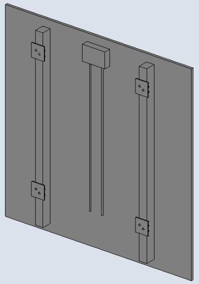
Upcoming reports

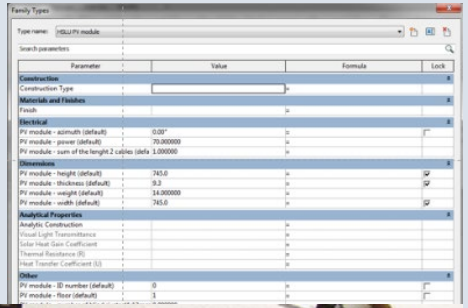
D.3. Digital products - Lead by SUPSI

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







D.4. Digital BIM-based process for BIPV - Lead by SUPSI

Objectives:

1. Current BIM-based tools for BIPV

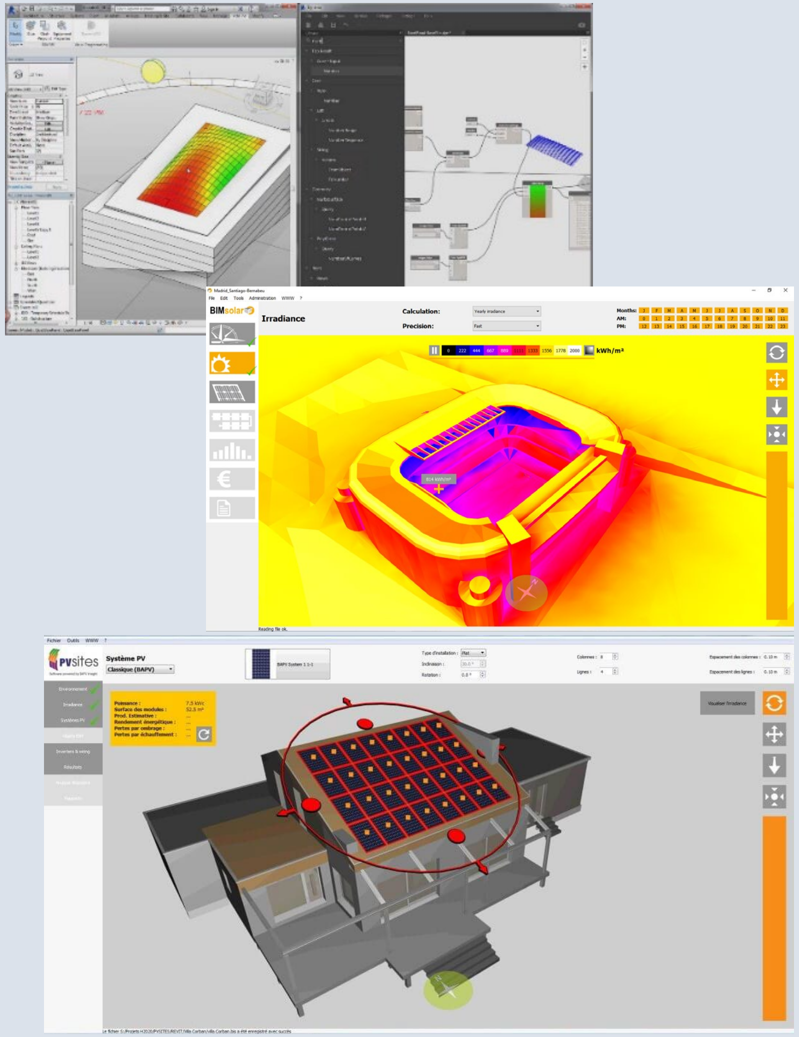
Definition of the BIPV process stages and workflows and review of current available BIM-based tools.

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

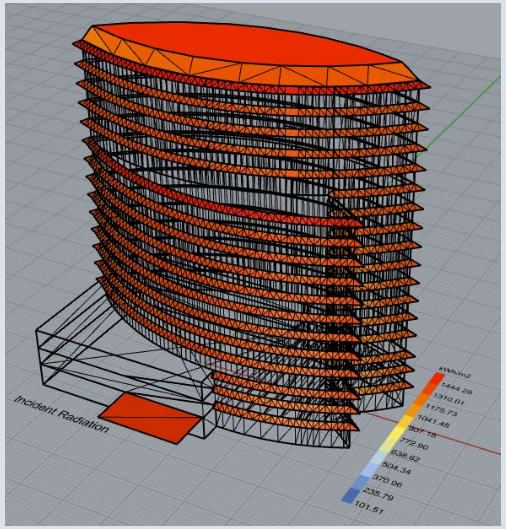
- Lead by RMIT, Astrid Schneider, Lucisun

Goal: overview of state of the art software for BIPV-planning and BIM / 3D simulation

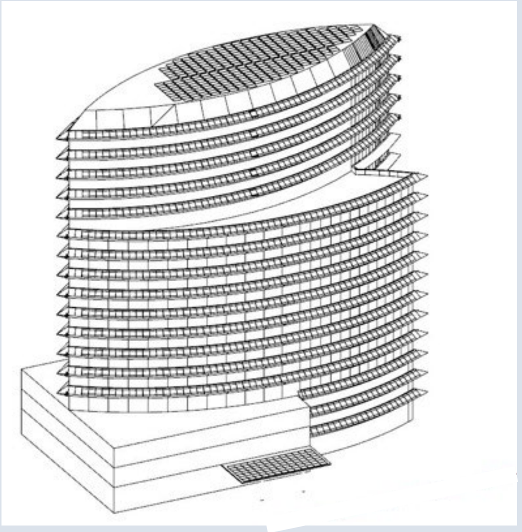
- PVsyst
- Revit
- Rhino – Plugins: Honeybee with energy Plus / radiance
- SAM
- Sketchup
- PV*Sol
- Solarius PV
- Lucisun
- BIMSolar

PVPS

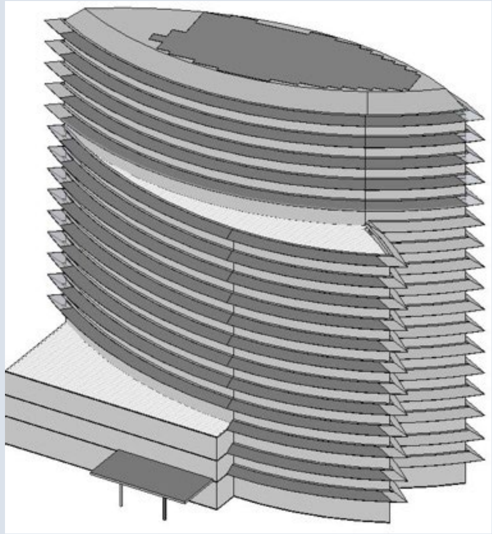
D.1 Chinese Building representation in different 3D-formats



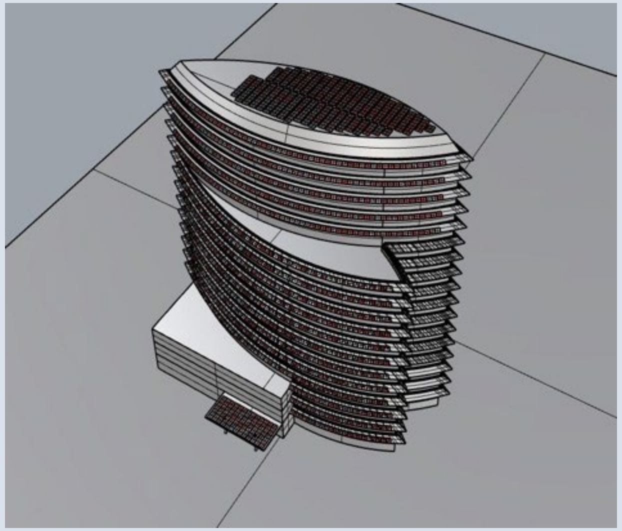
Rhino with Grasshopper, ladybug



SKETCHUP

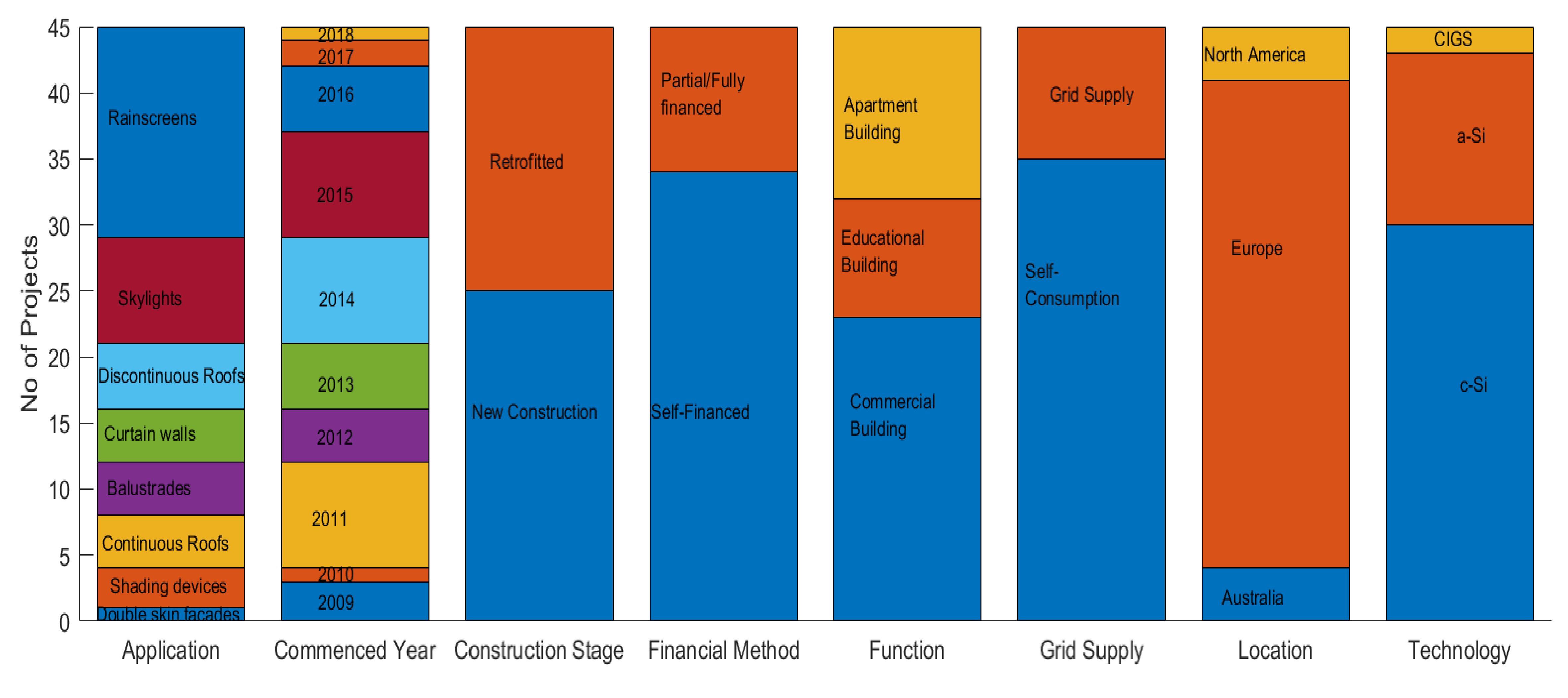


Revit



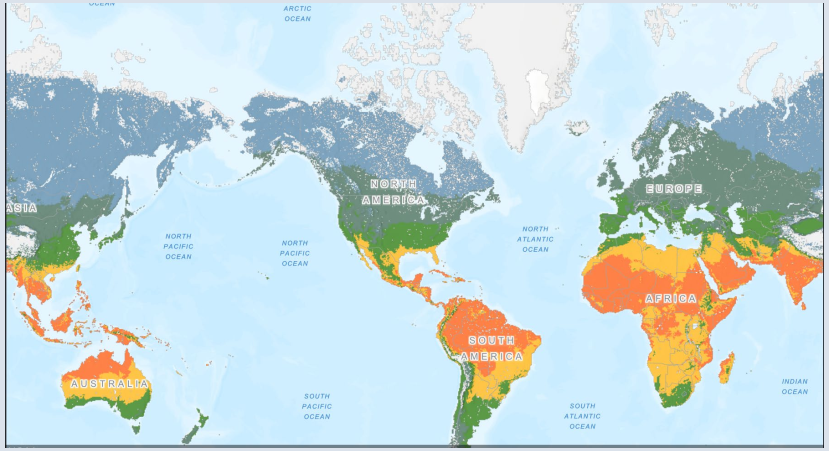
Rhino

PVPS



Weerasinghe, R.P.N.P., Yang, R.J., Wakefield, R., et. al., 2021. Economic viability of building integrated photovoltaics: A review of forty-five (45) non-domestic buildings in twelve (12) western countries. *Renewable and Sustainable Energy Reviews*, *137*, p.110622.

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

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)

PVPS

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!

RMIT UNIVERSITY

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.

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SEAL@RMIT

Thank you!

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