Solar World Congress 2025
04 - 07 November in
Fortaleza, Brazil

Solar Energy Integration For Sustainable Cities

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International Energy Agency
Photovoltaic Power Systems Programme

AUSTRALIAN PV INSTITUTE

TRENDS IN PV APPLICATIONS - 2025

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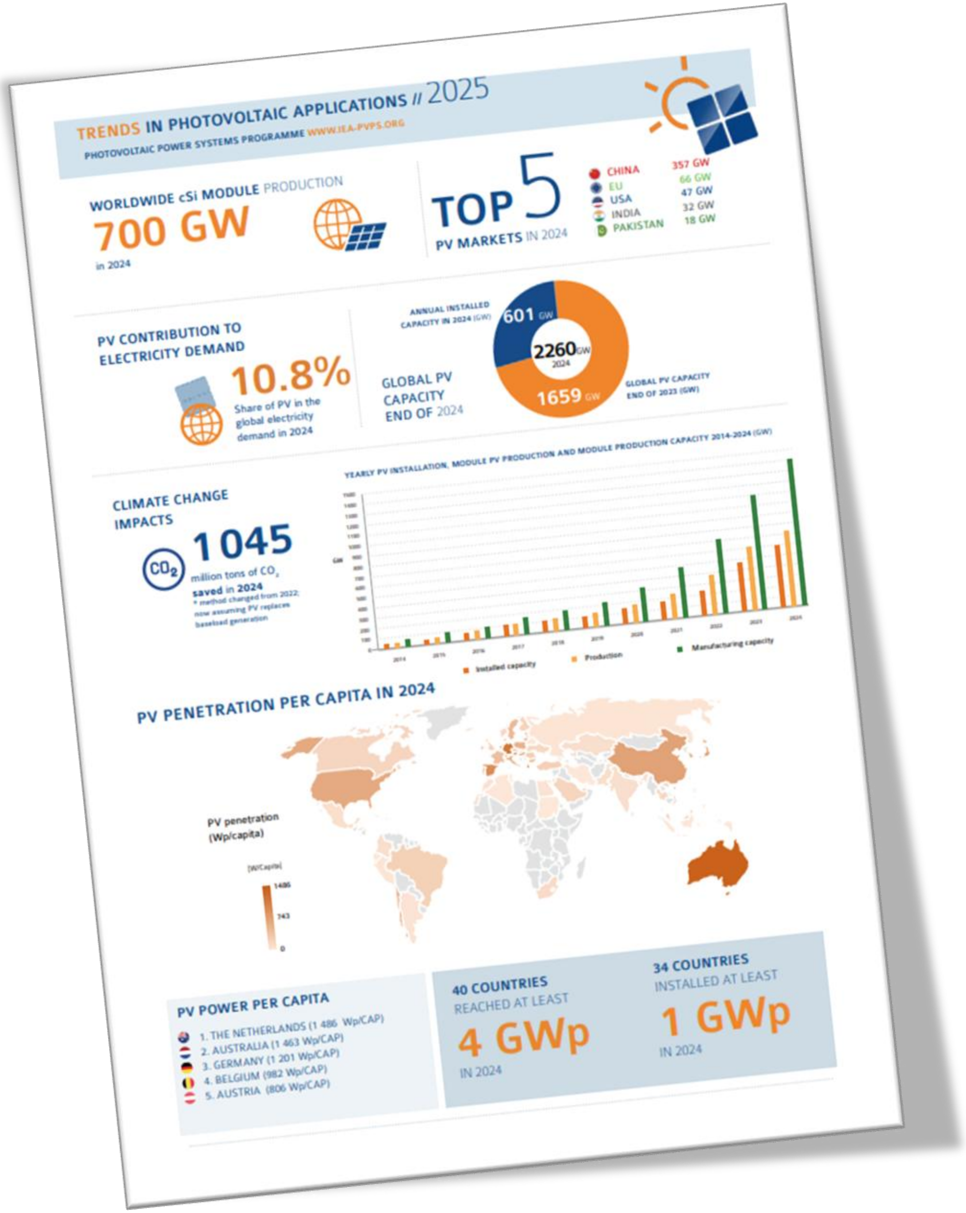

Worldwide Highlights

- Over 2.26 TW of PV plants have been installed globally
- Over 47% has been installed in the past three years.

PV in Global Electricity Mix

- **PV supplied 10.8% of global electricity in 2024**
- **Global PV capacity:**
  - End of 2024 → 2,260 GW
  - End of 2023 → 1,659 GW
  - Newly installed (2024): 601 GW
- **40 countries reached ≥ 4 GWp installed in 2024**
- **34 countries reached ≥ 1 GWp**

International Energy Agency
Photovoltaic Power Systems Programme

Reference: Trends in PV Applications 2025

PV'S EXPANDING FOOTPRINT

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- **Environmental & Economic Impact**
- **Industrial & Technological Development**
- **Systemic & Social Value**

Climate change mitigation
avoid up to 1 045 million tonnes of CO2 eq annually

Value for the economy
turnover PV sector minimum of 430 billion USD

Employment
~9.1 million jobs (installation & O&M dominant)

Manufacturing shifts
overcapacity in 2023 → price stabilization late 2024

Module innovation
70% n-type wafers; bifacial modules = 75% of production

Challenges
Grid curtailment rising → need for storage & flexibility

System value
PV+ projects and industrial decarbonization emerging

Social inclusion
First Nations partnership models in Australia, Canada, USA

Reference: Trends in PV Applications 2025

International Energy Agency
Photovoltaic Power Systems Programme

HIGHLIGHTS IN TECHNOLOGICAL AND MARKET TRENDS OF PV

Module efficiencies

continue to improve, with n-type technologies now representing 70% of global production.

Bifacial modules

dominate the market, making up over 75% of production.

Utility-scale systems

represent 62% of new installations, while distributed and prosumer markets continue to grow through self-consumption and innovative business models.

Dual-use applications

such as agrivoltaics, floating PV, and infrastructure/building-integrated PV are becoming increasingly relevant, helping balance land use, food production, and renewable energy generation.

Reference: Trends in PV Applications 2025

International Energy Agency
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AUSTRALIA – A SOLAR NATION

AUSTRALIAN PV INSTITUTE

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Global rank

#2 in PV per capita –

1,463 W/capita

Market type

~66% 26.4GW distributed,

~ 33%13.4GW centralised – Among top 10 countries

Trends

- Battery + solar hybrid uptake rising
- Dual-use PV pilots expanding
- Community energy & virtual networks developing

Cumulative capacity

≈ 39.8 GW (> 10× 2015 levels)

2024 additions

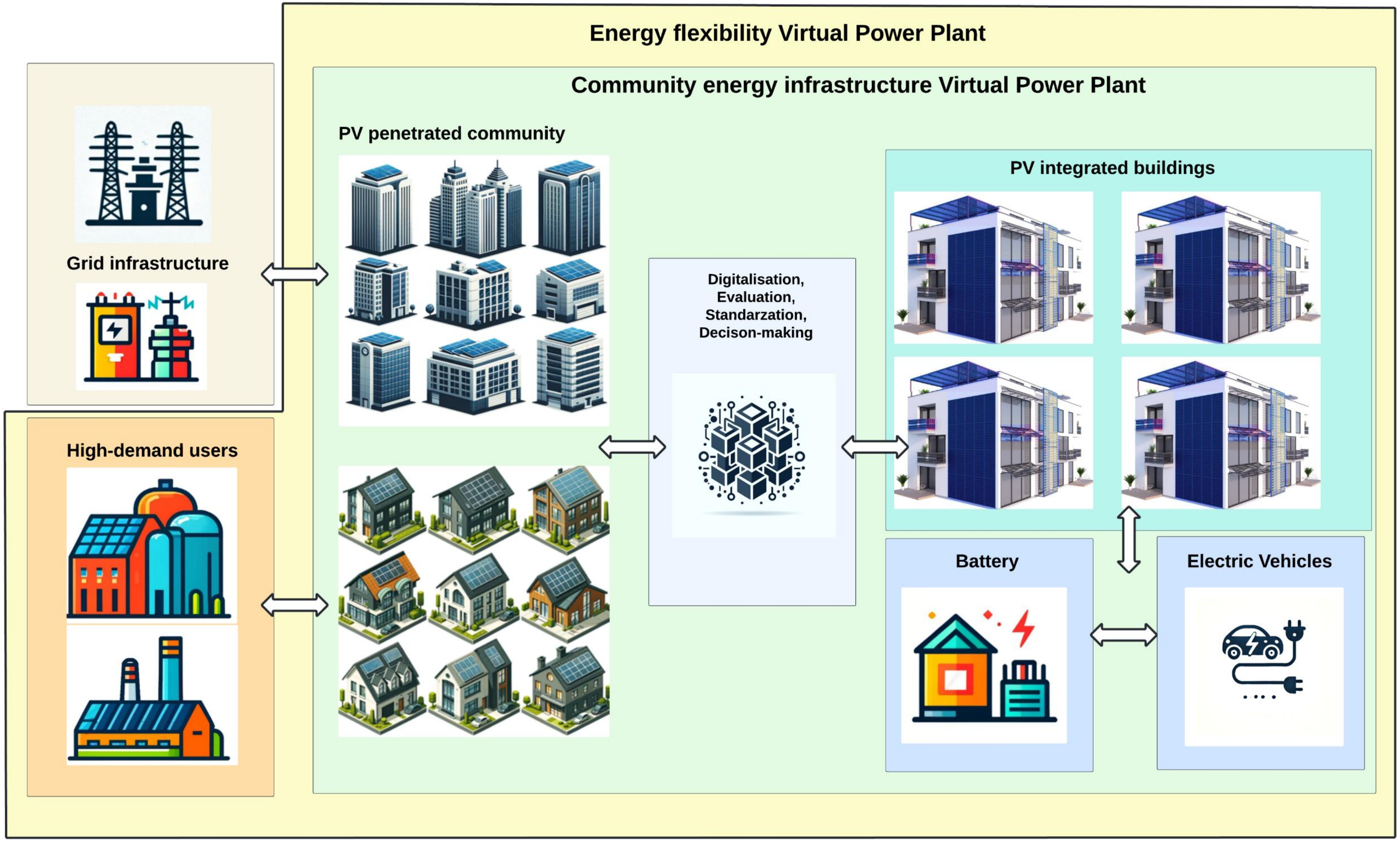
~4 GW new PV (+ steady growth)

Socio-economic

Growing regional and First Nations partnership models

Reference: Trends in PV Applications 2025

International Energy Agency
Photovoltaic Power Systems Programme



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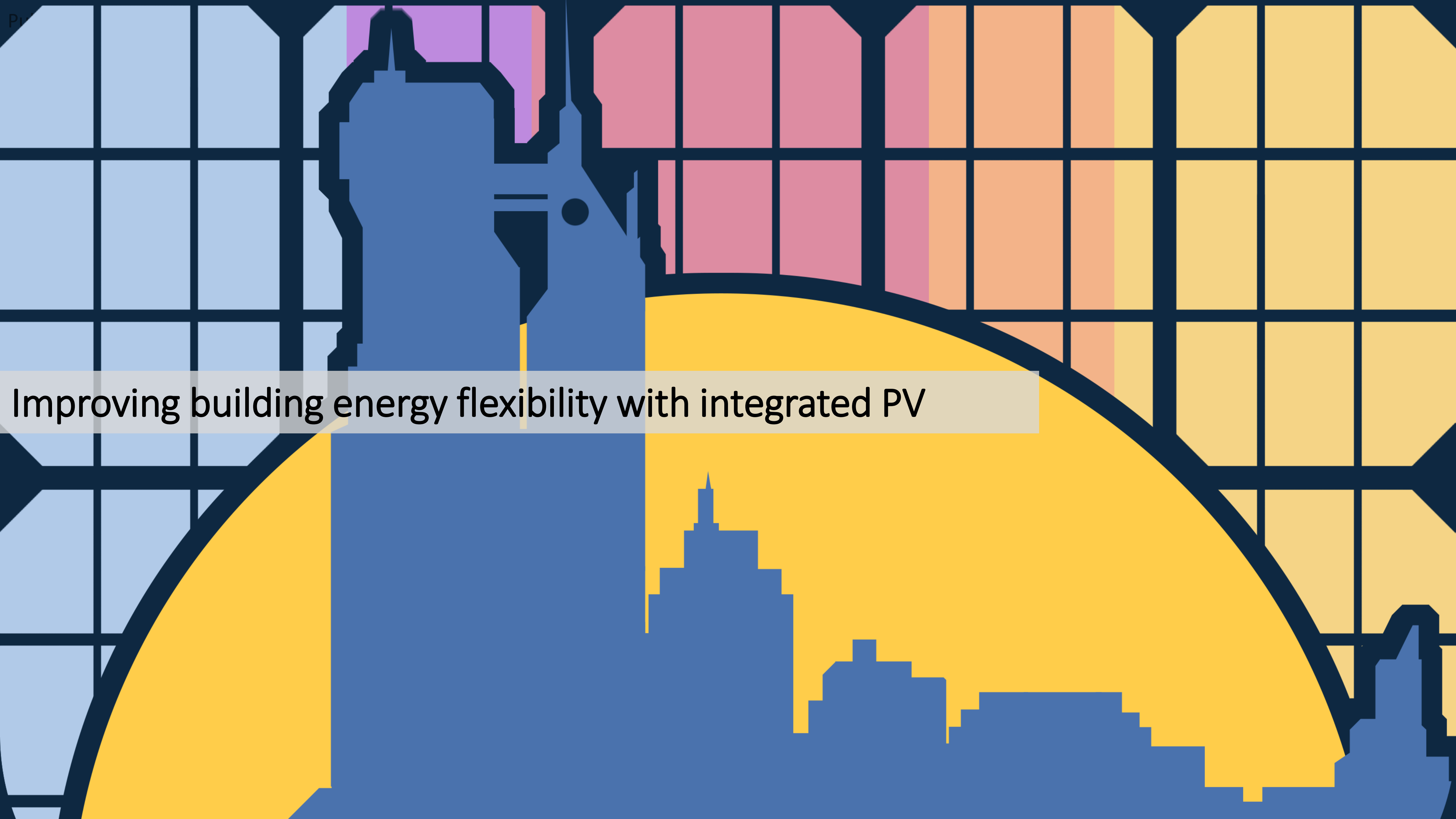
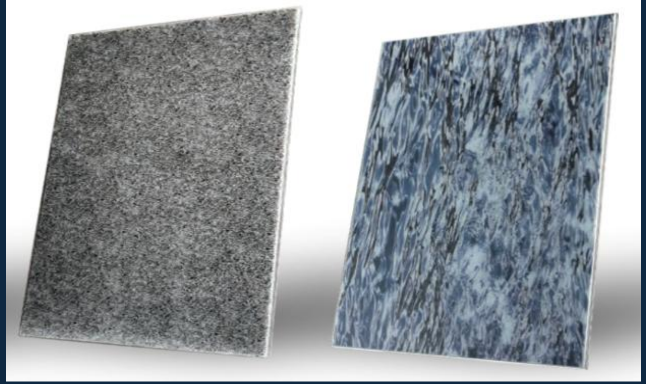
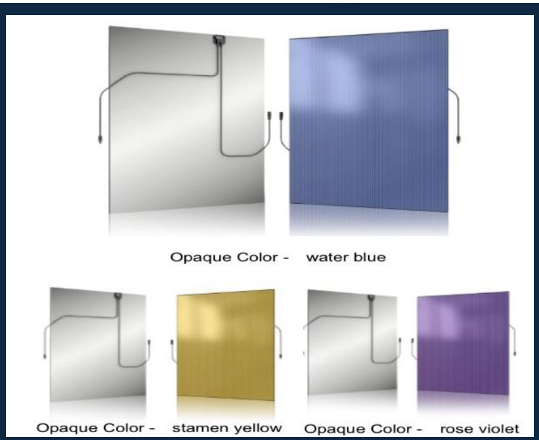
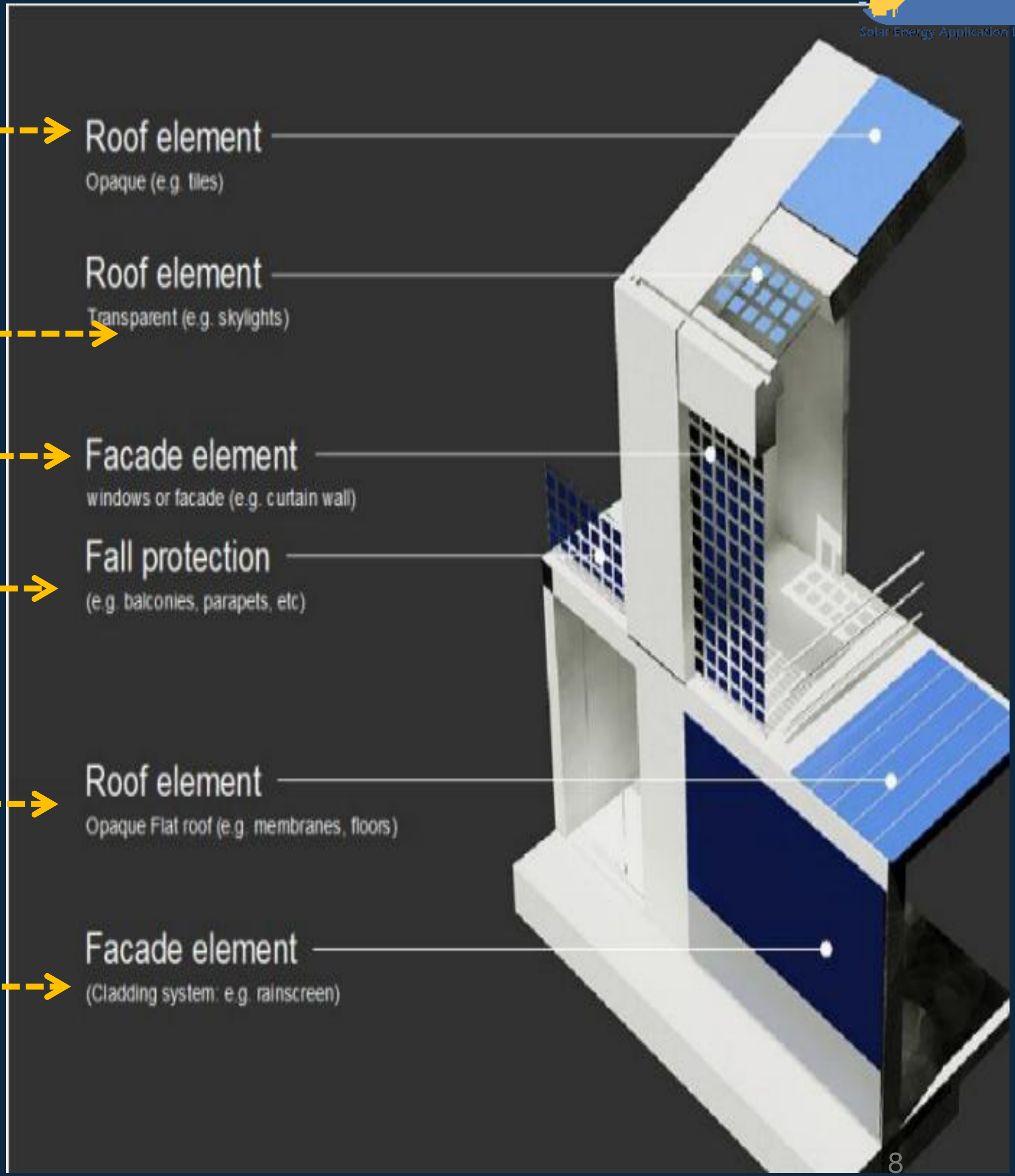
Solar Energy Application Laboratory

Improving building energy flexibility with integrated PV









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

Enabling Framework for the Development of BIPV

Objective:

- Create an enabling framework to accelerate the penetration of BIPV products in the global market of renewables.
- Resulting in an equal playing field for BIPV products, BAPV products and regular building envelope components.
- Respecting multifunctional aspects, mandatory issues, regulatory issues, aesthetic issues, reliability and financial issues.

Task 15 jouney so far

Task 15: 2016-2019

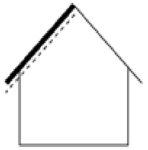
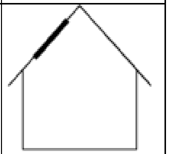
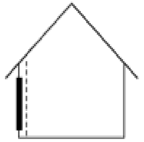
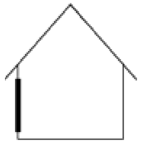
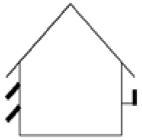
- BIPV project database
- Transition towards Sound BIPV Business Models
- International framework of BIPV specifications
- Environmental Benefits of BIPV

Task 15: 2020-2023

- TIS Analysis of BIPV
- Cross-sectional analysis
- BIPV Guidelines
- Digitalization for BIPV
- Pre-normative international research on BIPV

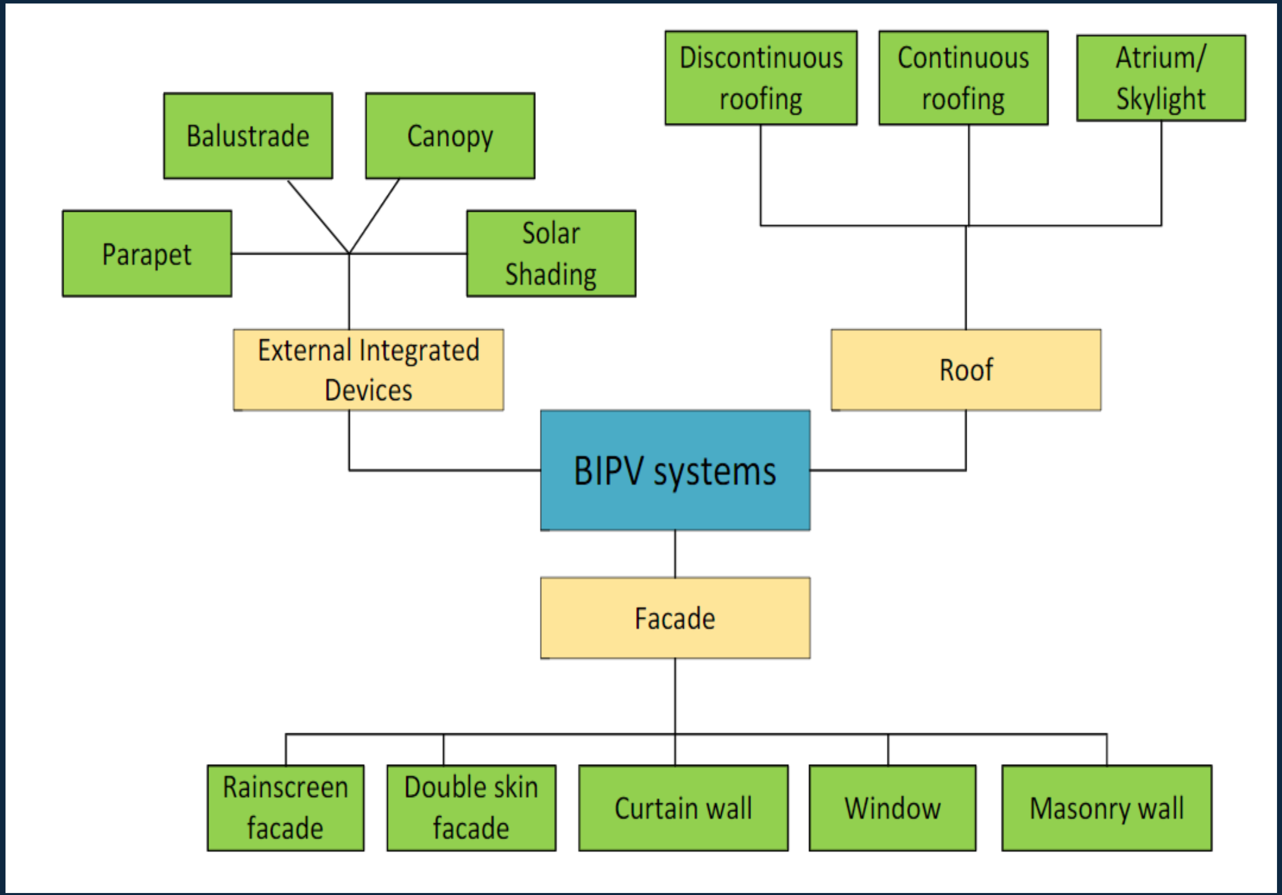
Task 15: 2024-2027

- BIPV market and in circular economy
- Pre-Standardization
- Digital environment
- Product, demo and long-term behavior

Category A:	**Sloping, roof-integrated, not accessible from within the building** The BIPV modules are installed at a tilt angle between 0° and 75° from the horizontal plane [0°, 75°), with another building product installed underneath.	
Category B:	**Sloping, roof-integrated, accessible from within the building** The BIPV modules are installed at a tilt angle between 0°and 75° from the horizontal plane [0°, 75°).	
Category C:	**Non-sloping (vertically) envelope-integrated, not accessible from within the building** The BIPV modules are installed at a tilt angle between 75° and 90° from the horizontal plane [75°,90°], with another building product installed behind.	
Category D:	**Non-sloping (vertically), envelope-integrated, accessible from within the building** The BIPV modules are installed at a tilt angle between 75° and 90° from the horizontal plane [75°, 90°].	
Category E:	**Externally integrated, accessible or not accessible from within the building** The BIPV modules are installed to form an additional functional layer that provides a building requirement E.g. balcony balustrades, shutters, awnings, louvers, brise soleil etc.	

IEC 63092:2020

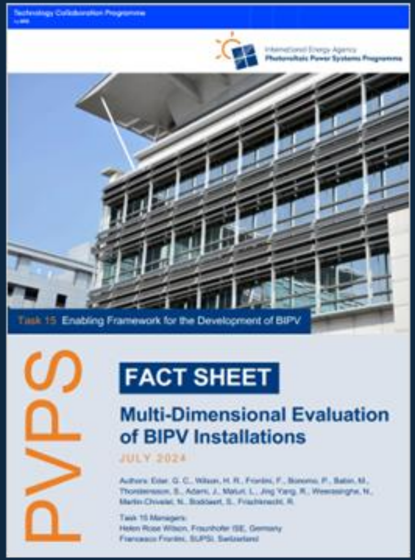
Photovoltaics in buildings



Bonomo, P., ..Yang, R. et. al. Categorization of BIPV applications. Task 15 Enabling Framework for BIPV acceleration. Report IEA-PVPS T15-12:2021

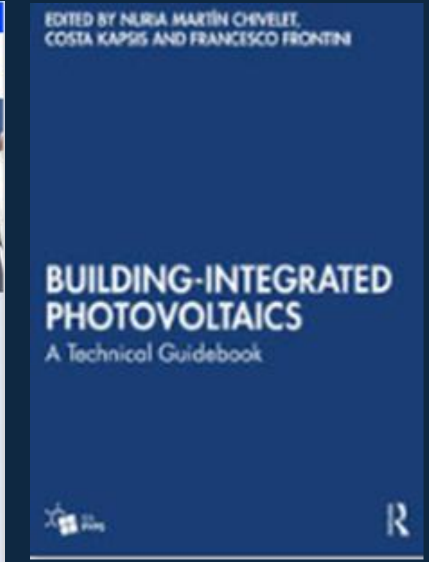
Public

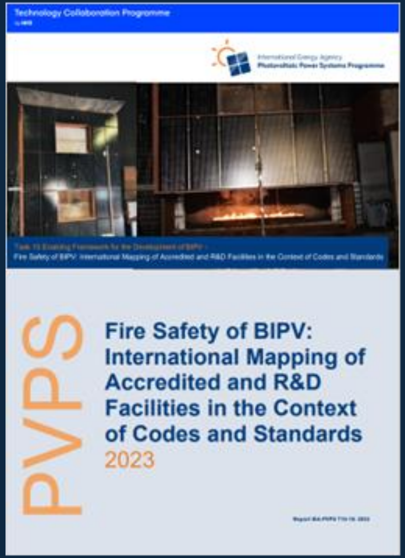

Technology Collaboration Programme
PVPS
JOURNAL ARTICLE
Energy and Buildings
Digitalising BIPV energy simulation: A cross tool investigation
August 2024


Technology Collaboration Programme
Task 15 Enabling Framework for the Development of BIPV
PVPS
FACT SHEET
Multi-Dimensional Evaluation of BIPV Installations
JULY 2024


Technology Collaboration Programme
PVPS
Analysis of the Technological Innovation System for BIPV in Australia
2024


Technology Collaboration Programme
PVPS
Digital BIM-based process for BIPV Digital product data models
2024


EDITED BY NURIA MARTÍN CHIVELET, COSTA KAPSIS AND FRANCESCO FRONTINI
BUILDING-INTEGRATED PHOTOVOLTAICS
A Technical Guidebook

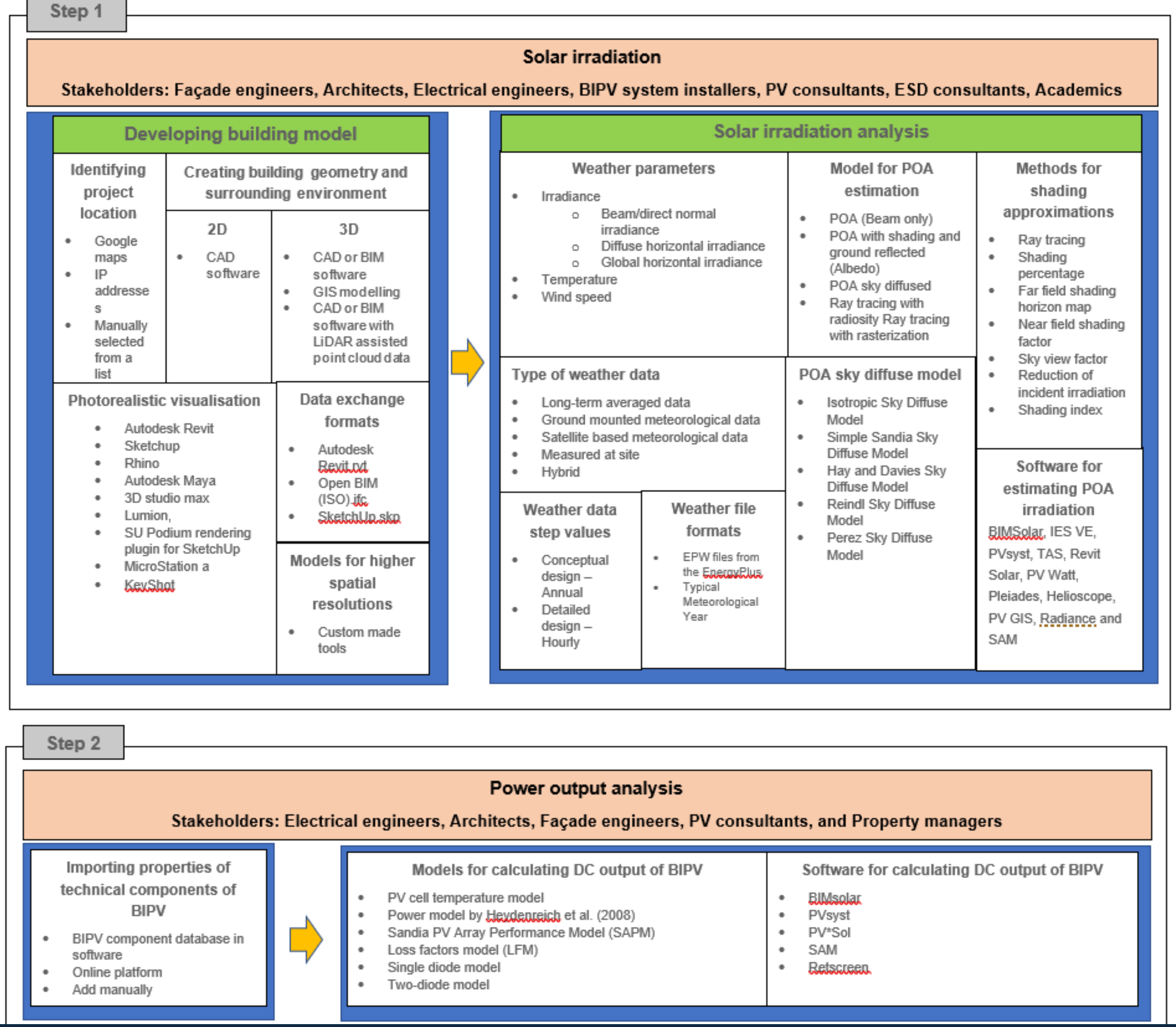

Technology Collaboration Programme
PVPS
Fire Safety of BIPV: International Mapping of Accredited and R&D Facilities in the Context of Codes and Standards
2023

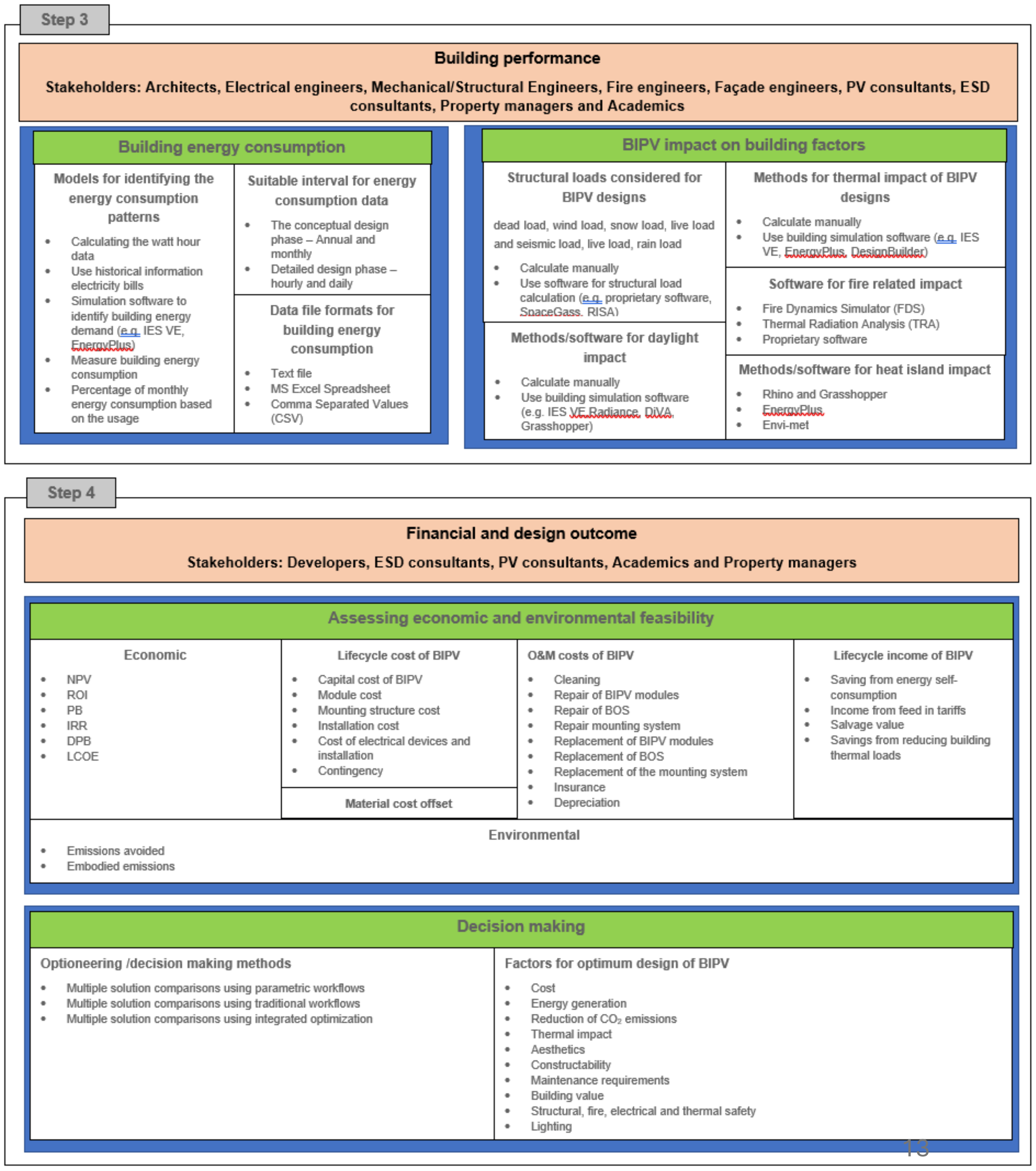

Technology Collaboration Programme
PVPS
BIPV Digitalization: Design Workflows and Methods – A Global Survey
2022


Technology Collaboration Programme
PVPS
Categorization of BIPV applications
2021


BIPV Design and Performance Modelling: Tools and Methods
PVPS
PHOTOVOLTAIC POWER SYSTEMS PROGRAMME
Report IEA-PVPS T15-09:2019

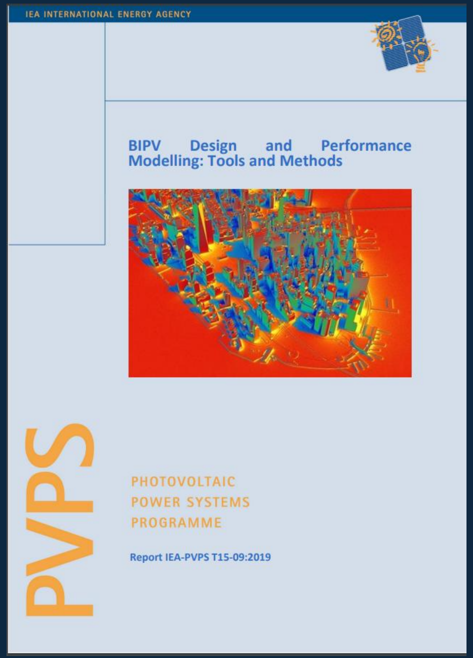

Technology Collaboration Programme
Task 15 Enabling Framework for the Development of BIPV
JOURNAL ARTICLES
Energy and Buildings
Solar Heat Gain Coefficient of BIPV Modules for Electricity-Generating Facades





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/

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



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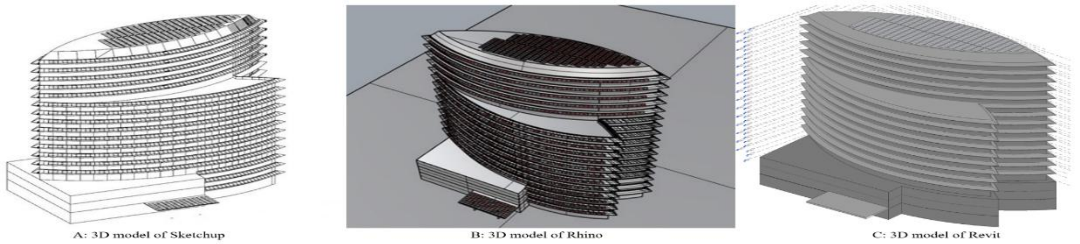
Design tool comparison



Steps	Skelion	SAM	PVsyst	BIMsolar	Ladybug Tools	PV*SOL	Solarius PV	INSIGHT
Building geometry modelling	Create 3D Model	Create simplified 3D Model	Import 3D Model in COLLADA format	Import 3D Model in Skp format	Create 3D Model	Import 3D Model in COLLADA format	Import 3D Model in IFC format	Create 3D Model
Weather data inputs	Input from Meteonorm 8.1	Built-in Meteonorm 8.1	Built-in Meteonorm 8.1	Input from Meteonorm 8.1	Input from Meteonorm 8.1	Built-in Meteonorm 8.1	Built-in Meteonorm 7.1	Built-in Autodesk Climate Server
PV module and inverter data inputs	Manual input PV module power rating	Manual input detailed specifications	Input detailed specifications via PAN/OND files	Manual input detailed specifications	No input	Input detailed specifications via PAN files and inverter template	Manual input detailed specifications	No input
System layout and array configuration	Reposition but not define array configuration	Reposition and reconfigure façade system array	Reposition and reconfigure façade system array	Reposition and configure case system array	No array configuration defined	Reposition and reconfigure façade system array	Reposition and configure case system array	No array configuration defined
POA irradiance	Perez model	Perez model	Perez model	Ray tracing	Ray tracing	Hay & Davies model	Perez model	Ray tracing
Shading evaluation	Shading factor analysis based on building geometry	Shading calculator based on simplified geometry	Shading factor analysis based on building geometry	Ray tracing	Ray tracing	Near shade calculation based on building geometry	Manual input shading factor	Ray tracing
PV energy conversion simulation	Built-in empirical model	Built-in equivalent circuit model	Built-in equivalent circuit model	Built-in equivalent circuit model	Calculation based on formula	Built-in equivalent circuit model	Built-in empirical model	Calculation based on formula
PV system losses	Manual input based	Simulation	Simulation	Simulation	Manual input based	Simulation	Manual input based	Manual input based

Yang, R. et al., Digitalising BIPV energy simulation: A cross tool investigation, Energy and Buildings, Volume 318, 2024,114484

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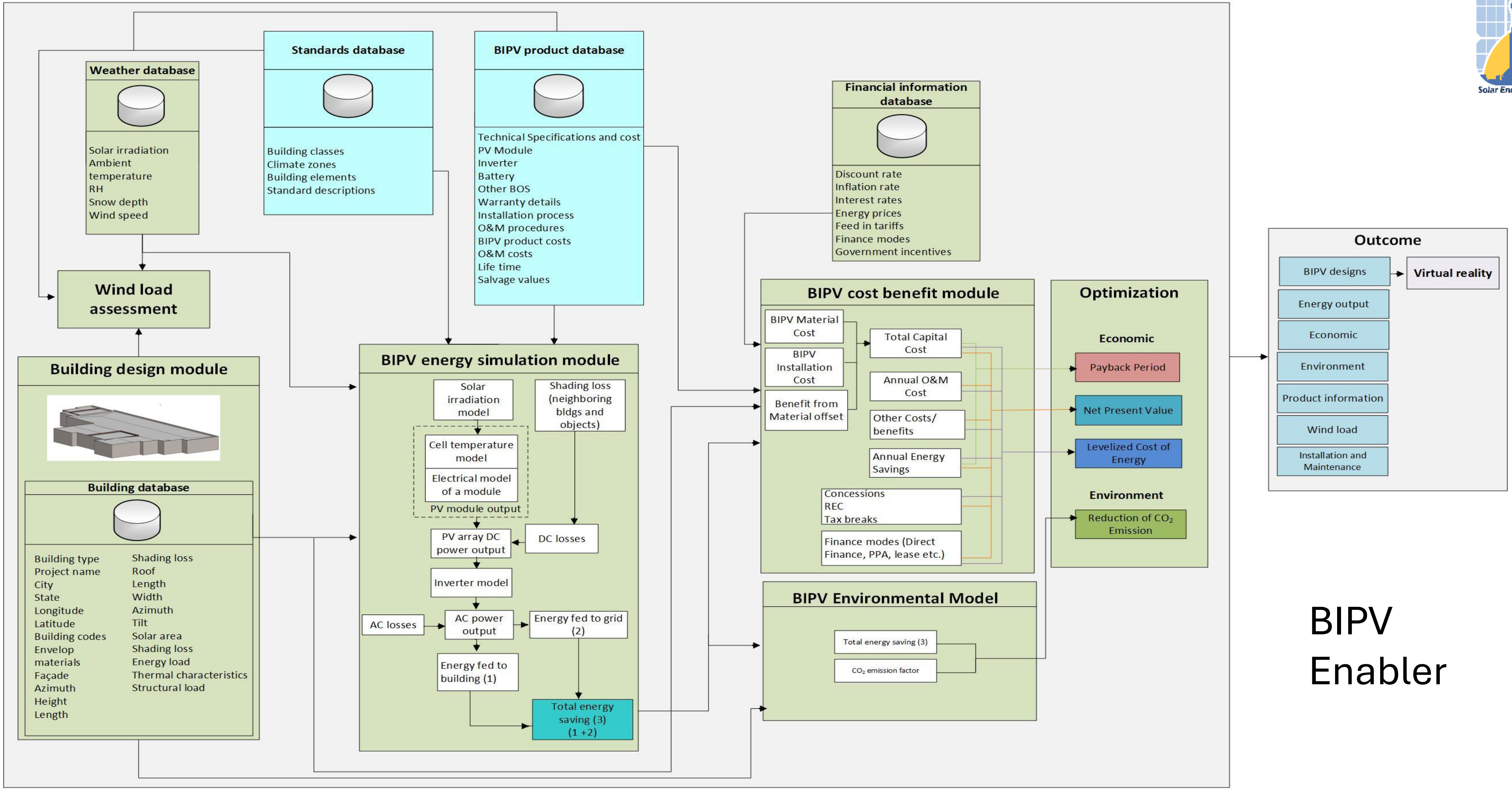
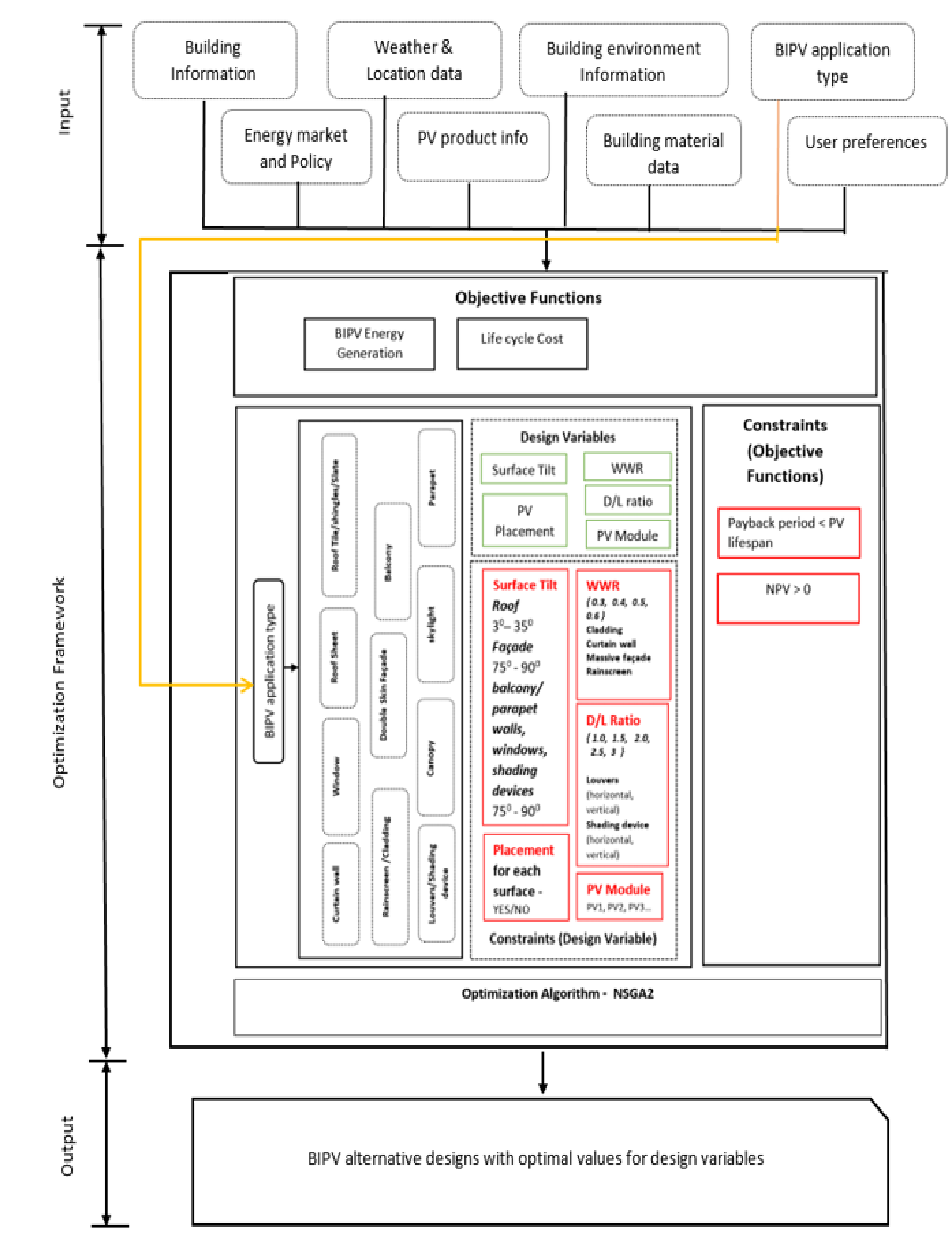
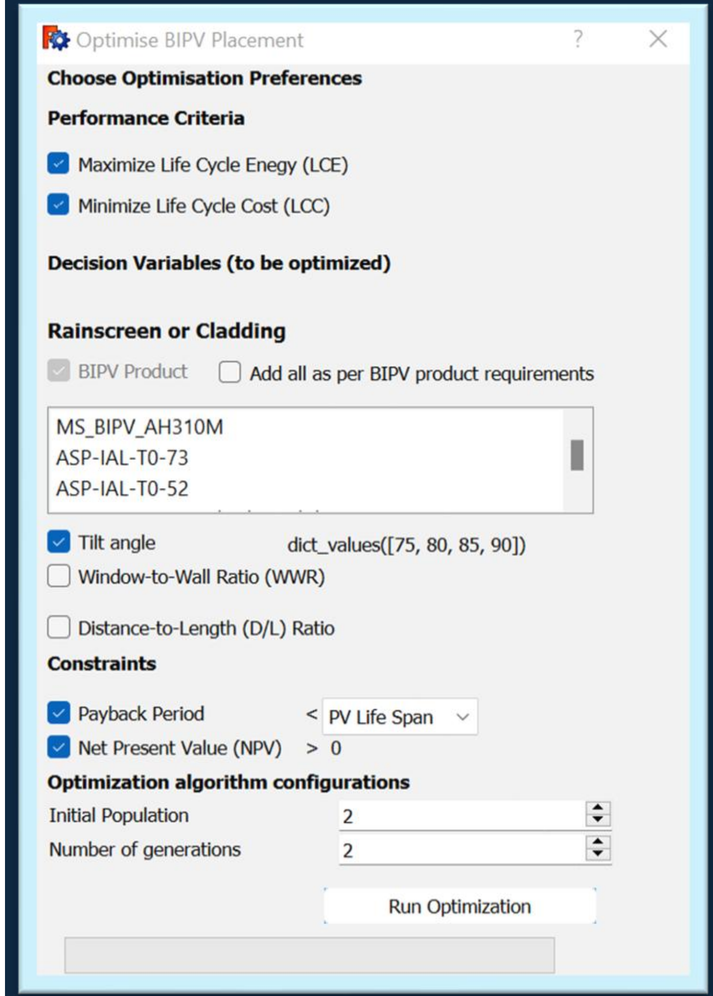
BIPV Enabler



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.

BIPV Design Optimisation

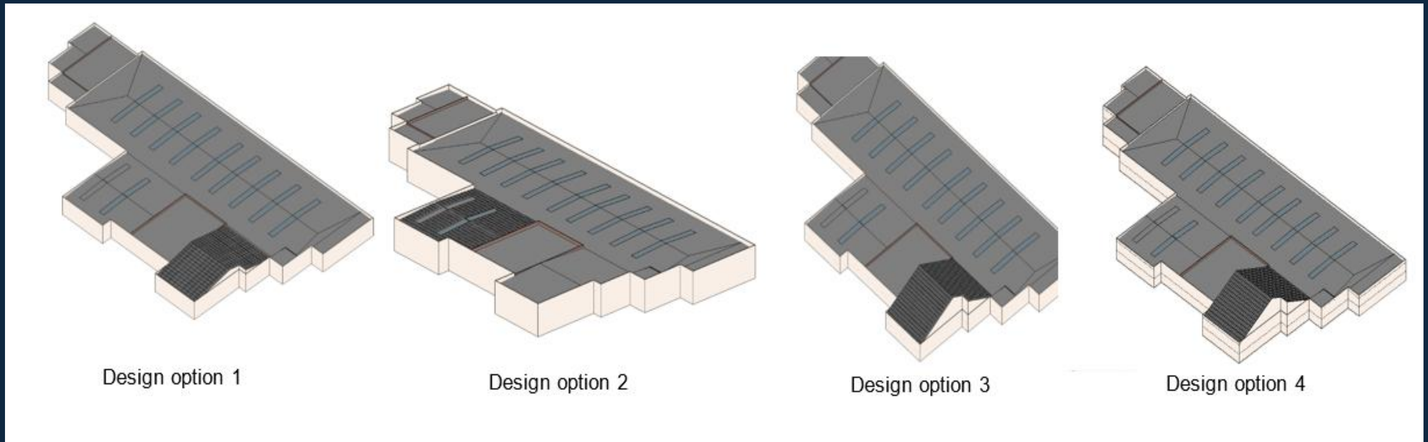




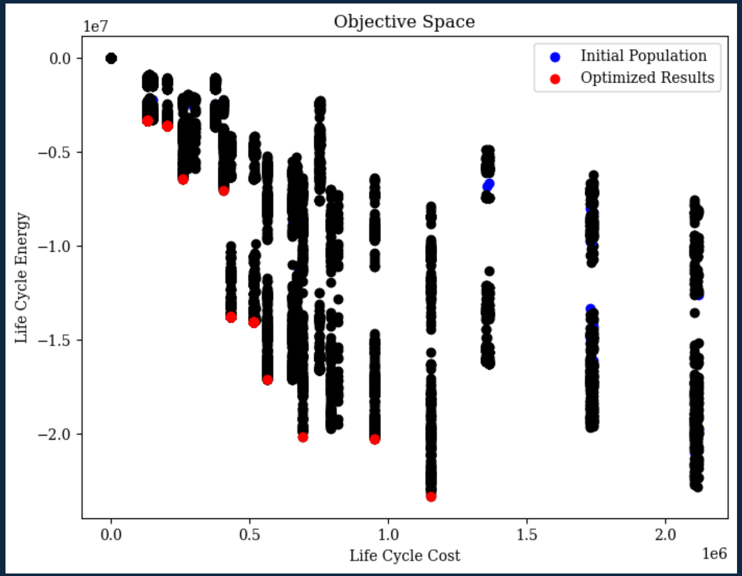
Samarasinghalage, T. I., Yang, R. J., et al. (2022). A multi-objective optimization framework for building-integrated PV envelope design balancing energy and cost. *Journal of Cleaner Production*, *342*, 130930.

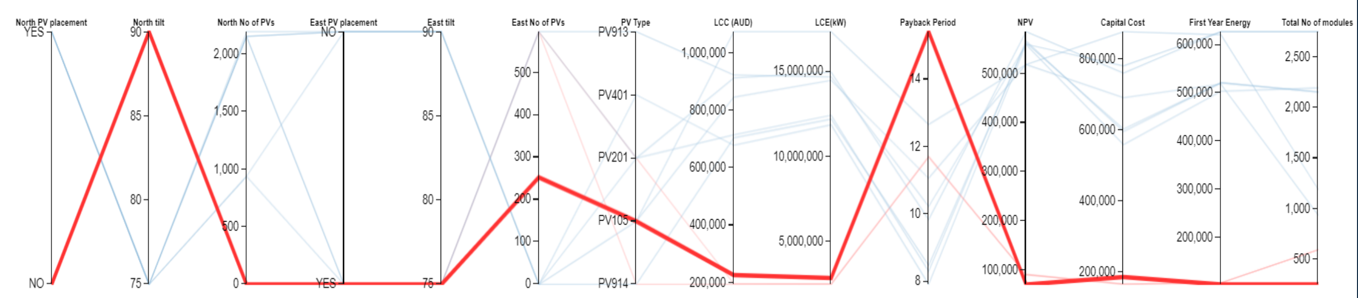
Yang, R. J. et al. (2023). Digitalizing building integrated photovoltaic (BIPV) conceptual design: A framework and an example platform. Building and Environment, 243, 110675.

BIPV Design Optimisation



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

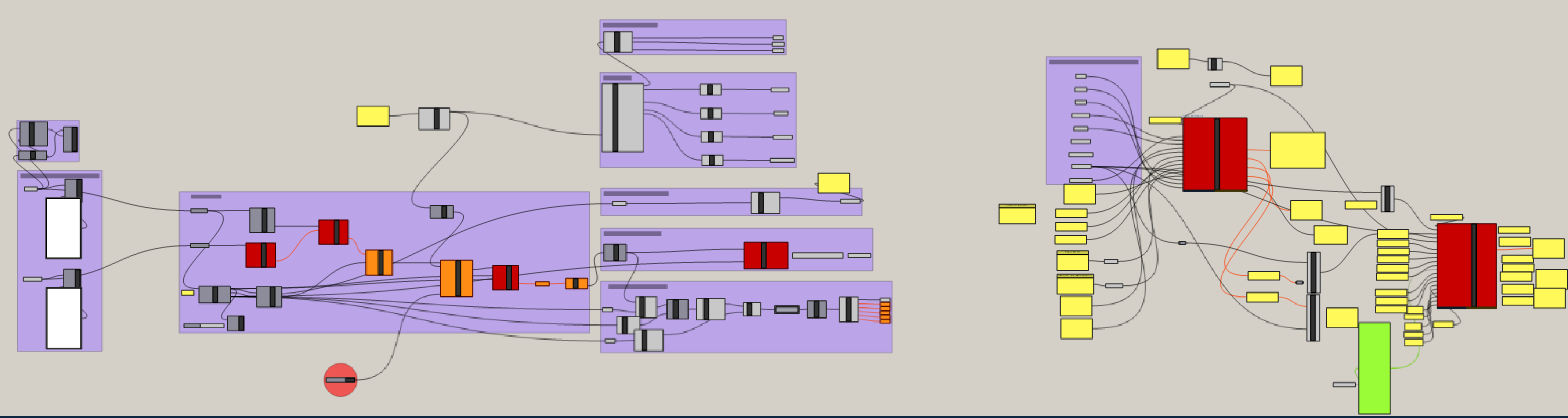




North PV placement	North tilt	North No of PVs	East PV place...	East tilt	East No of PVs	PV Type	LCC (AUD)	LCE(kW)	Payback Period	NPV	Capital Cost	First Year Ener...	Total No of mo...	Rating
NO	90	0	YES	75	595	PV914	194613.9018	2478471	11.7006	90203.72	166557.74	105901.8613	595	0
YES	75	936	NO	90	0	PV105	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

BIPV parametric modelling and simulations

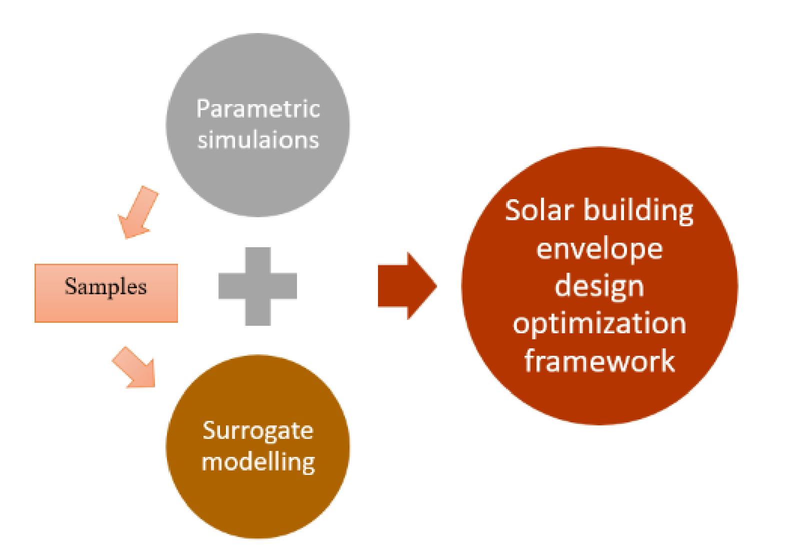
- ❑ BIPV system modelling in Rhino parametric environment
- ❑ BIPV energy performance based on sandia array performance model
- ❑ LCE, LCE, NPV, Payback calculation using scripts

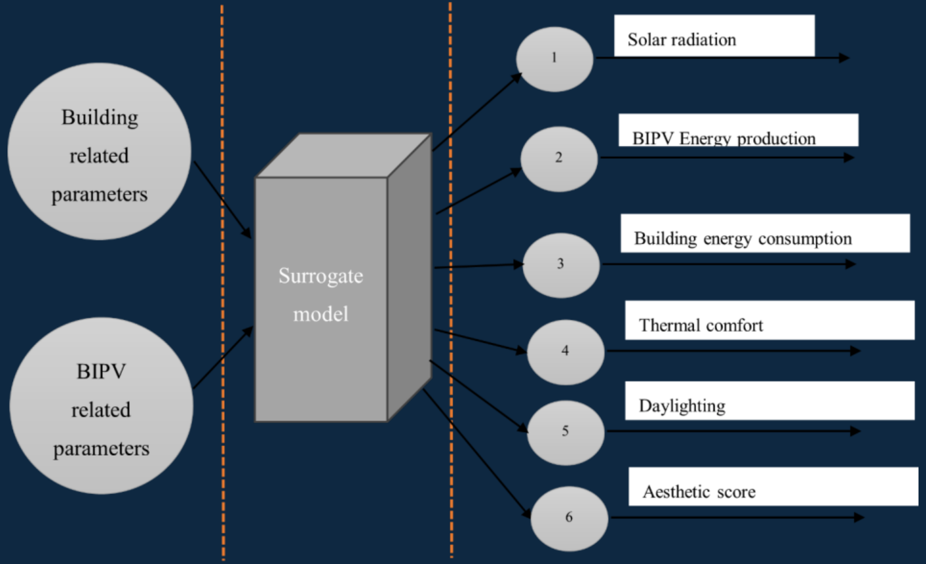


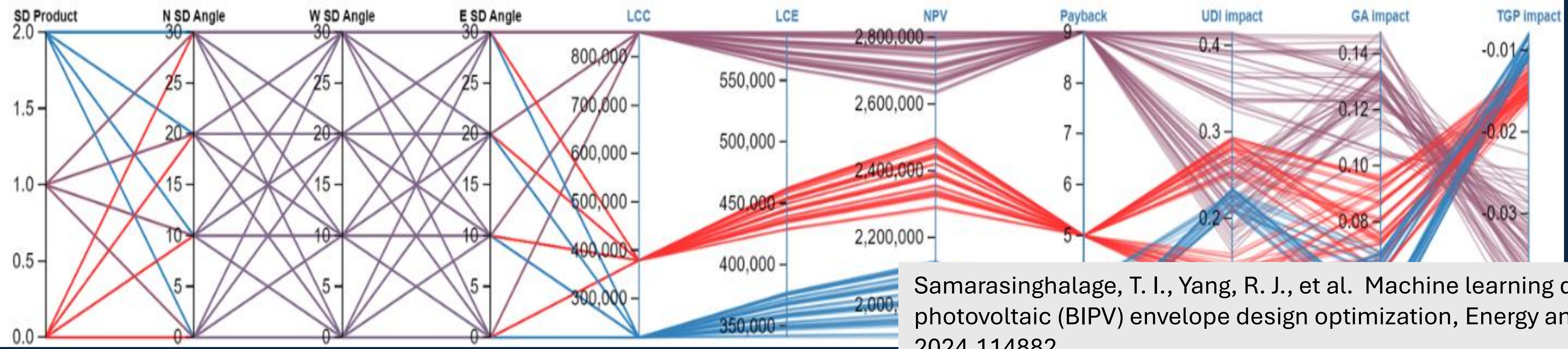
in:SD Product	in:N SD Angle	in:W SD Angle	in:E SD Angle	out:PV Surface area	out:Energy_Consumption	out:PV_Yeild	out:Self_Consumption	out:Capital_Cost	out:LCC	out:LCE	out:NPV	out:Payback	out:LCOE	out:UDI impact	out:GA impact	out:TGP impact
1	0	0	0	587.519959	1.31E+06	26018.44063	26018.44063	528483.016	851544.6448	586870.6825	2800363	9	1.450991965	0.186322	0.11973	-0.022776
2	0	0	0	168.126132	1.32E+06	16459.35886	16459.35886	136991.6943	219602.8765	371256.4987	2091161	3	0.591512545	0.210333	0.038921	-0.007802
0	10	0	0	296.639647	1.32E+06	20338.13391	20338.13391	236811.8798	379188.9533	458745.9603	2475806	5	0.826577204	0.253553	0.079993	-0.01255
1	10	0	0	587.519778	1.31E+06	26011.71237	26011.71237	528482.8531	851544.3824	586718.9203	2799431	9	1.451366835	0.325917	0.103507	-0.024702
2	10	0	0	168.12615	1.32E+06	16500.43491	16500.43491	136991.7088	219602.8997	372183.008	2096945	3	0.590040101	0.209819	0.059875	-0.008042
0	20	0	0	296.639585	1.32E+06	20337.50928	20337.50928	236811.8303	379188.874	458731.8711	2475734	5	0.826602418	0.114875	0.080434	-0.013155

Machine learning based BIPV envelope design optimization

- Many objective optimization **with** **machine learning based surrogate modelling**
- More efficient and reliable optimization framework







Samarasinghalage, T. I., Yang, R. J., et al. Machine learning driven building integrated photovoltaic (BIPV) envelope design optimization, Energy and Buildings, Volume 324, 2024,114882,

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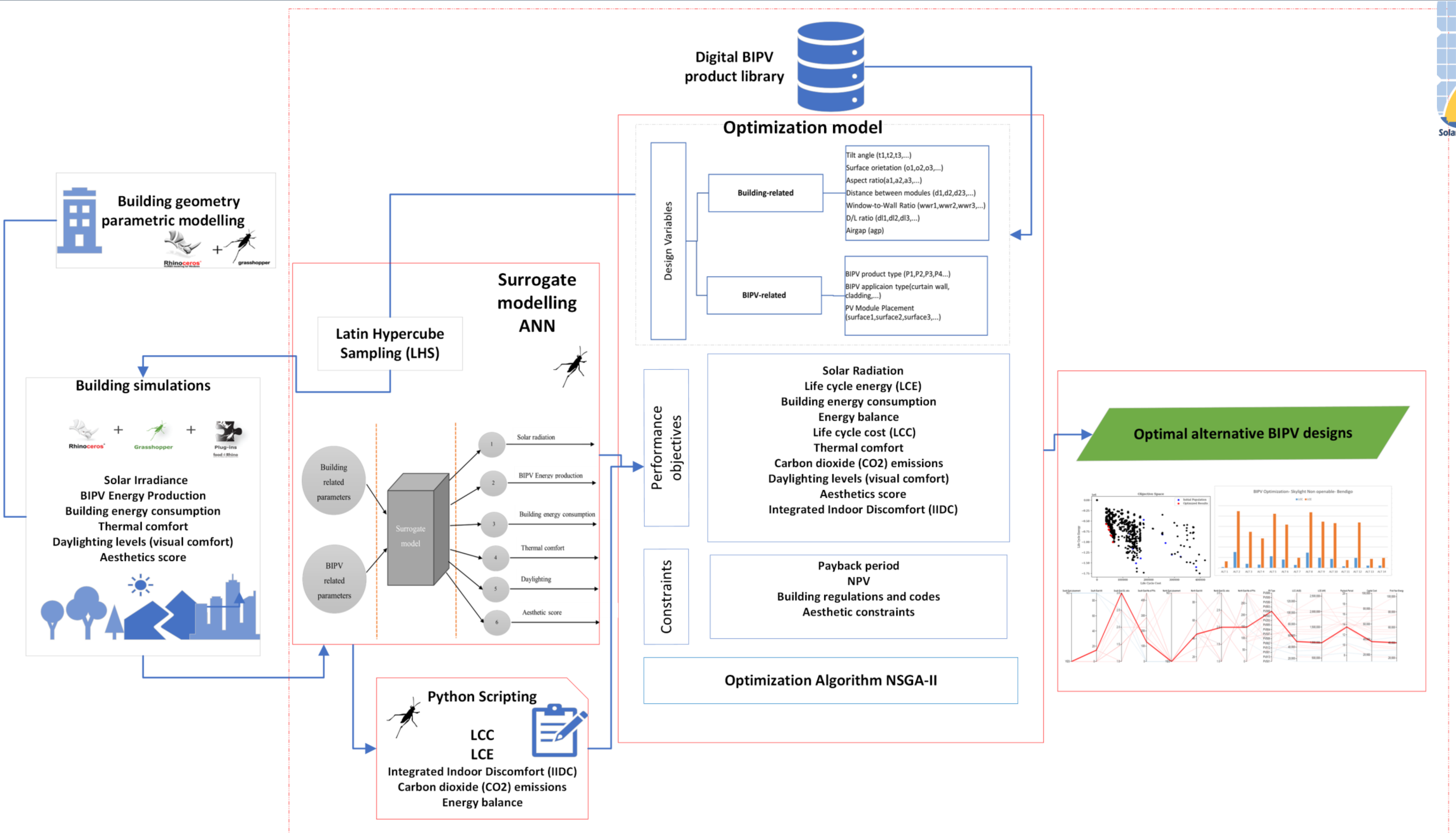

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What is the Energy and Economic Viability?

Cities Overview

Acknowledgement: Clarissa Zomer
CEO Arquitetando Energia Solar

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Energy Assessment: BRAZIL

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City	LAT	LON	North	East	South	West
Curitiba	25°25′47″S	49°16′16″W	24.22	3.58	-	-
Rio de Janeiro	22°54′40″S	43°12′20″W	21.86	21.25	-	-
Cuiaba	15°35′45″S	56°05′49″W	19.43	24.81	-	-
Teresina	5°05′42″S	2°48′15″W	9.13	21.44	-	-

Optimization results for tilt angle that achieves highest irradiance under different azimuth in Brazil

City	Roof design option		Façade design option	
	Best	Second best	Best	Second best
Curitiba	Optimal-N	Lat-N	75-N	75-E
Rio de Janeiro	Optimal-N	Lat-N	75-E	75-N
Cuiaba	Optimal-E	Lat-E	75-E	90-E
Teresina	Optimal-E	Lat-E	75-E	90-E

Best and second-best orientation and tilt configurations for rooftop-(BI)PV and façade-BIPV for Brazil

Economic Analysis: Method

- Input: Capital cost, conventional material replacement cost, operation and maintenance cost, inverter replacement cost, degradation rate, salvage value, electricity price, electricity price growth rate, system lifespan, module efficiency (5%-25%)
- BIPV Price tiers: Low (133-600USD/m2), Medium (500-1160USD/m2), High (500-1720USD/m2)
- BIPV Price includes
  - Hardware costs – Expenditure for physical components (modules, inverters, electrical equipment and cabling)
  - Soft costs – additional installation and development cost due to BIPV
- Effective NPV

$$\text{Effective NPV} = \frac{\text{EBS} + \text{GS} - [\text{CC} - \text{MRV} + \text{LMC} + \text{IRC} - \text{RE} - \text{SV}]}{\text{SC}}$$

- Effective LCOE

$$Effective\ LCOE = \frac{CC - MRV + LMC + IRC - RE - SV}{Lifecycle\ Energy}$$

R.P.N.P. Weerasinghe, R.J. Yang, R. Wakefield, E. Too, T. Le, R. Corkish, S. Chen, C. Wang, 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, Volume 137, 2021, 110622,

Improving energy flexibility in communities

AEMO - Australia's national grid operator

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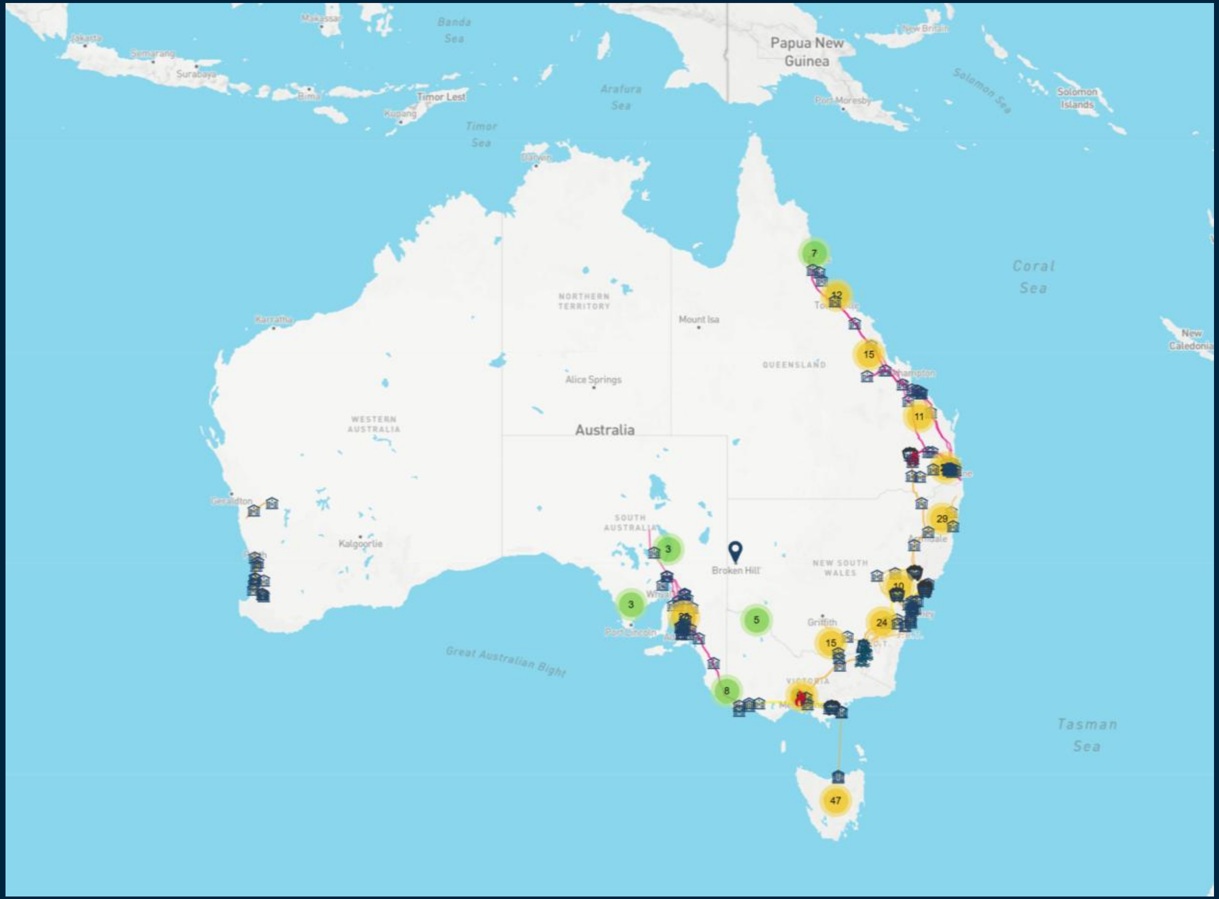
- **Australian Energy Market Operator (AEMO)**

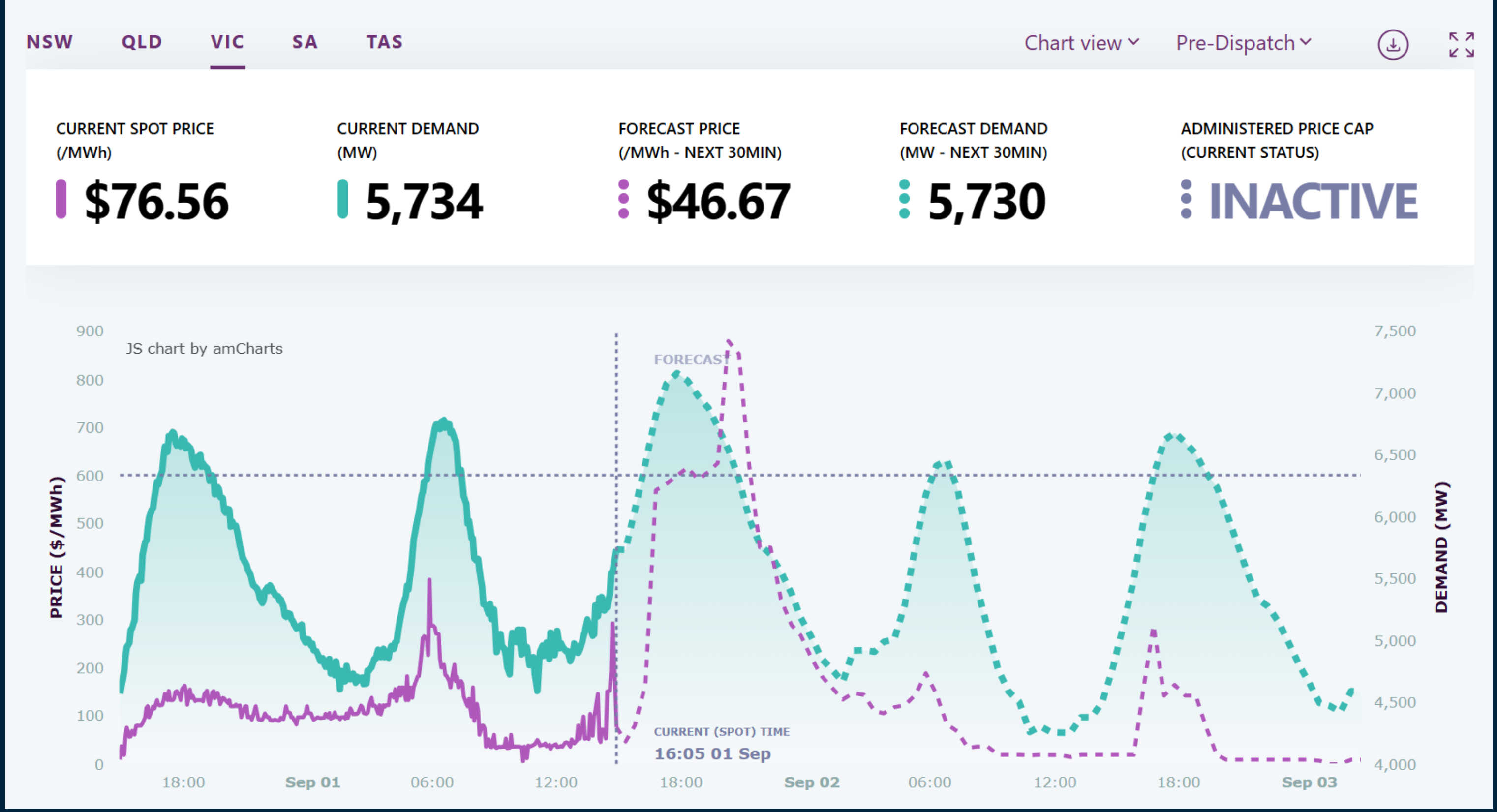
➢ National Electricity Market (NEM), which operates in eastern and south-eastern Australia,

➢ Wholesale Electricity Market (WEM), which operates in Western Australia.



How the NEM works (wholesale electricity supply)

- Generators bid into the spot market
- AEMO dispatches lowest-cost generation to meet demand, subject to constraints
- Market price set every 5 minutes → averaged into 30-min settlement price (Spot price)
- Transmission network delivers power to consumers via DNSPs/retailers
- Key objective: secure, reliable, least-cost supply
- Risks: Arbitrage can cause significant price spike, hence the introduction of Administered Price Cap (APC) after June 2022 when the spot price routinely hit over $15k per MWh
- The current permanent APC is $600/MWh valid until 2028.



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How the NEM works (market mechanism)

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1. Spot Price
- Core price signal, determined by supply–demand balance
- Capped/floored by Market Price Cap (MPC) & Market Floor Price (MFP)

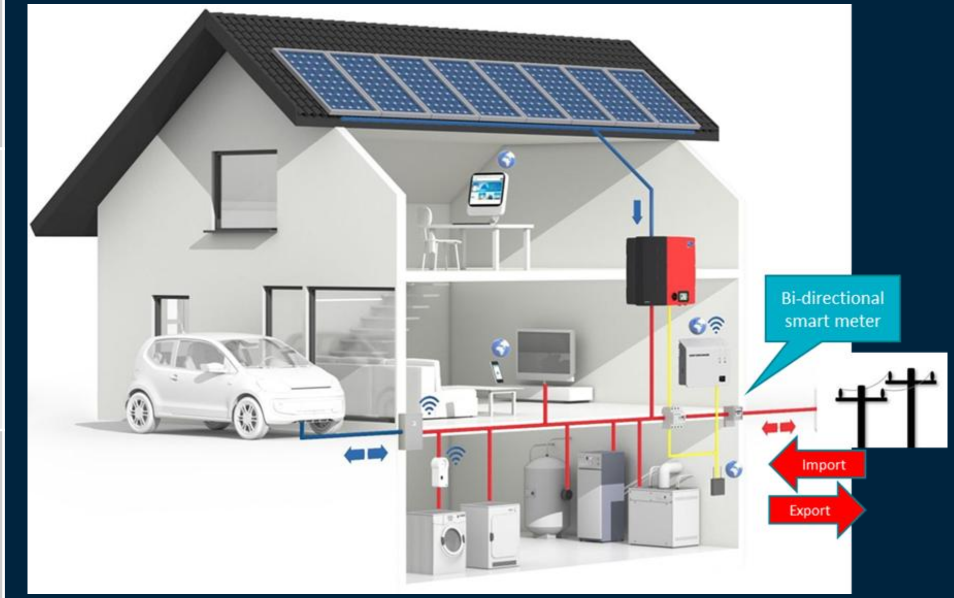
2. Frequency Control Ancillary Services (FCAS)
- Maintain system frequency at 50 Hz
- Types:
    - **Regulation FCAS**: continuous fine-tuning
    - **Contingency FCAS**:
        - rapid response to sudden events (e.g. generator trip)
        - Similar bidding system as of wholesale energy
        - 8 channels of raise/lower frequency depending on response time

3. Other Mechanisms
- Reliability & Emergency Reserve Trader (RERT)
- Wholesale Demand Response

Price	QLD	NSW	SA	VIC	TAS
Energy	$222.22	$79.22	$91.15	$94.41	$65.34
Raise Reg	$16.88	$16.88	$16.88	$16.88	$7.77
Lower Reg	$8.00	$8.00	$8.00	$8.00	$5.12
Raise 1 sec	$0.30	$0.30	$0.30	$0.30	$0.30
Raise 6 sec	$0.38	$0.38	$0.38	$0.38	$0.38
Raise 60 sec	$0.36	$0.36	$0.36	$0.36	$0.36
Raise 5 min	$0.10	$0.10	$0.10	$0.10	$0.10
Lower 1 sec	$0.00	$0.00	$0.00	$0.00	$0.00
Lower 6 sec	$0.39	$0.39	$0.39	$0.39	$0.39
Lower 60 sec	$0.39	$0.39	$0.39	$0.39	$0.39
Lower 5 min	$0.39	$0.39	$0.39	$0.39	$0.39

How Homes Use Solar PV and Battery – and Impacts on Bills

Setup	Electricity Flow	Impact on Bills
Solar PV Only	- Solar powers home first - Imports from grid when solar is insufficient - Exports excess to grid	- Reduces bills by offsetting grid usage
Solar + Battery (Direct Use)	- Excess solar stored in battery - Battery discharges when solar is unavailable - Imports from grid if solar + battery are insufficient	- Further bill reduction by using stored solar - Limited to fixed tariffs in most cases
Solar + Battery (VPP Managed)	- Battery controlled by third-party (e.g. VPP) - Charges during low-price periods (even from grid) - Discharges during peak prices / FCAS events	- Optimised costs via market price timing - Additional FCAS revenue (if ≥1 MW aggregated capacity)



Background

- **VPP Pilot Program – Solar Victoria**:
Aimed to explore the benefits of battery orchestration and grid services.

- Conducted under the **Solar Homes Battery Rebate Program** by Solar Victoria (a division within DEECA).
- From 2019–2023, over **15,000 Victorian households** installed solar batteries with support from the program.
- The **VPP Pilot** was a targeted initiative to evaluate technical, economic, and operational aspects of VPP participation.

Virtual Power Plant (VPP) pilot program

The VPP pilot program has helped Victorian households create and share power, save money on energy bills and reduce reliance on the grid.

Technical assessment

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- Three VPP provider models were evaluated:
  - **Reposit VPP**: Full control for arbitrage and FCAS.
  - **Tesla VPP**: Partial control focused on FCAS with limited battery cycling.
  - **Mondo VPP**: Partial control with real-time energy arbitrage integration.
- Assessment included:
  - Analysis of battery utilisation, customer load profiles, and market participation strategies.
  - Evaluation of economic outcomes for both customers and VPP operators.
  - Investigation of grid support contributions, especially through FCAS and spot price signal responsiveness.
  - Review of customer-level impacts from FCAS participation.

Yang, R.J.; Wang, K; Seymour, J.; Lu, C (2025) VPP Technical Assessment report, Prepared for the Department of Energy, Environment and Climate Action (DEECA) – The provision of Virtual Power Plant Research Services (T2024-0193)

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VPP value creation

VPP operation can create and capture value

VPPs generated $810–$1,160/year per customer, depending on market participation (arbitrage, FCAS, or both) and contract structure.

VPP participation can lower costs for customers

VPP participation lowers overall consumer costs. This value can be passed to customers in multiple ways, including an upfront capital discount, reduced electricity bills, or an annual fixed rebate.

Battery costs are pivotal to VPP viability

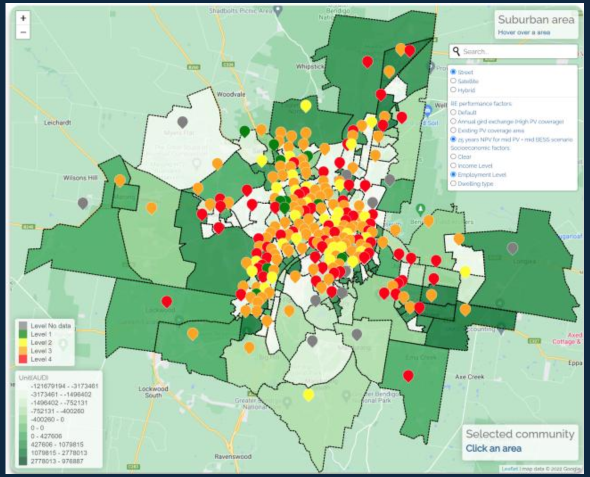
Falling battery prices are driving greater home storage uptake, making it easier for VPP providers to meet FCAS aggregation thresholds and spread overhead costs.

Yang, R.J.; Wang, K; Seymour, J.; Lu, C (2025) VPP Technical Assessment report, Prepared for the Department of Energy, Environment and Climate Action (DEECA) – The provision of Virtual Power Plant Research Services (T2024-0193)

Community energy infrastructure VPP

Solar Energy Application Laboratory

The ‘Transitioning Bendigo’s Energy Economy’ Project implemented the city level VPPs to integrate community-owned PV and battery resources in the City of Greater Bendigo.



Benefits:

- Great adaptability and robustness among diverse community profiles;
- Value creations for distributed PV and BESS through providing demand response and load management services at a large scale ;
- Supporting future growth of renewable capacity on city level;
- Reinforcement learning algorithm to support tailored energy management solutions for individual communities

Challenges:

- Reliance on battery capacity
- Capital investment and infrastructure upgrade may be challenging for certain communities

Case study city

- Demographic and Geographic conditions
  - 235 communities – Statistical Area level 1 (SA1)
  - Total population of 110,477 at 2020
  - Total number of building footprints: 73,607
- Supply and demand conditions
  - Total annual electricity demand: around 550 GWh
  - Existing PV installation: ~50MW total capacity covering 0.3 square kilometres (km2) rooftop
- Renewable energy and sustainability target
  - 100% energy demand by renewables by 2036 and carbon neutral by 2050

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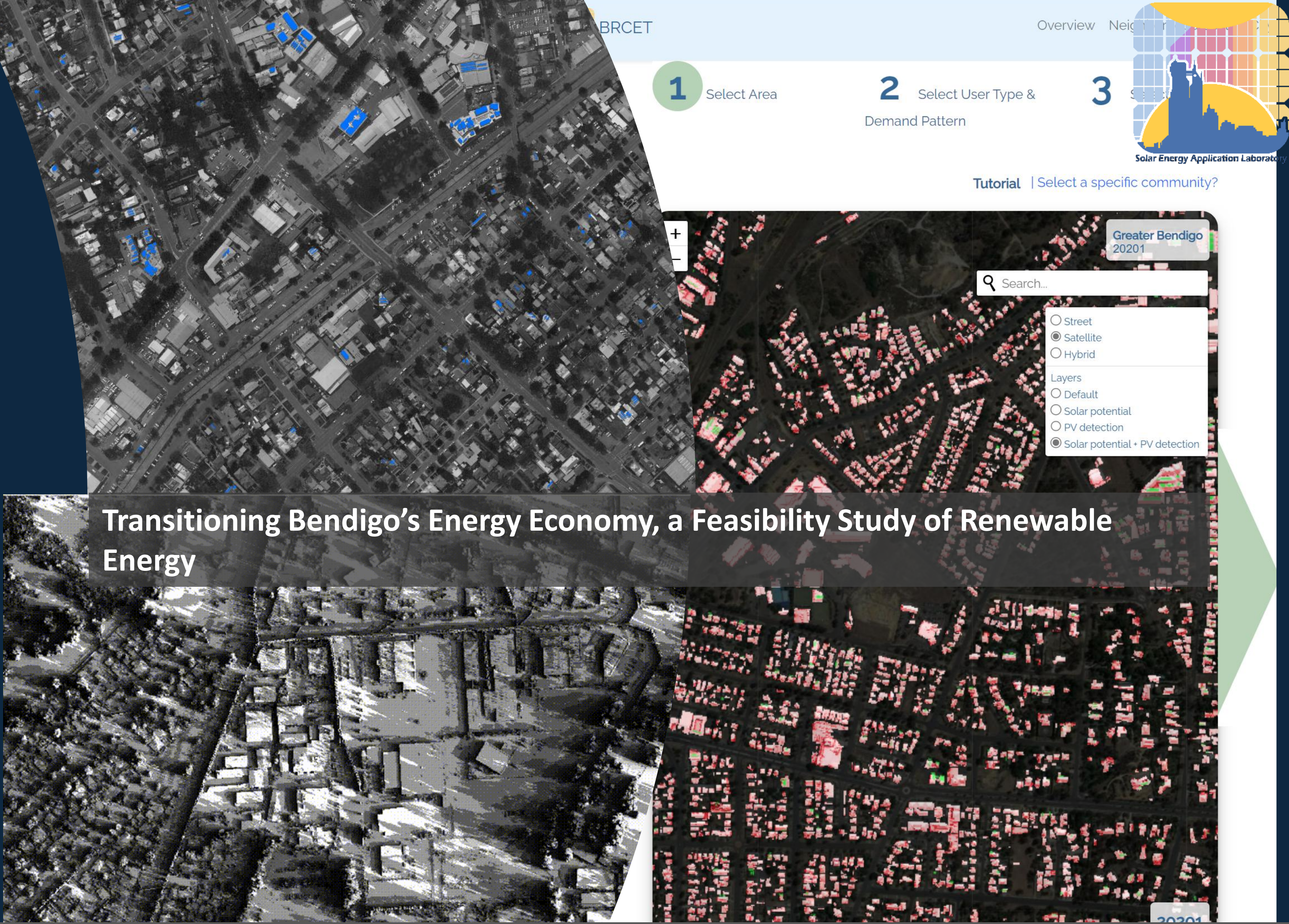
Community focused renewable transition

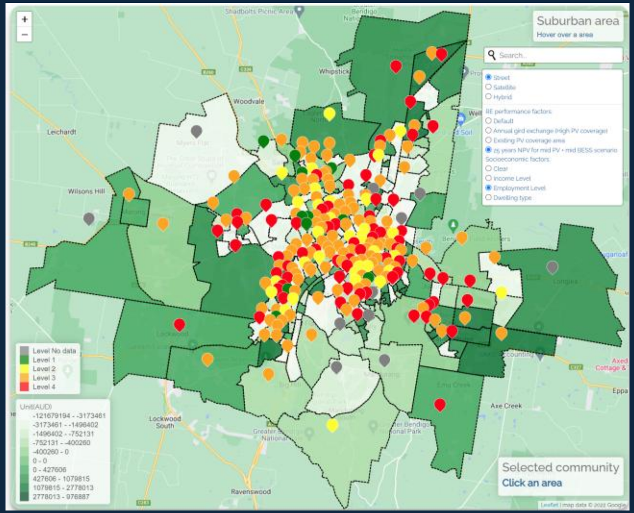
- Support the renewable energy transition with local renewable resources
- Advocate for investment in Greater Bendigo region
- Explore the synergy of solar and community battery

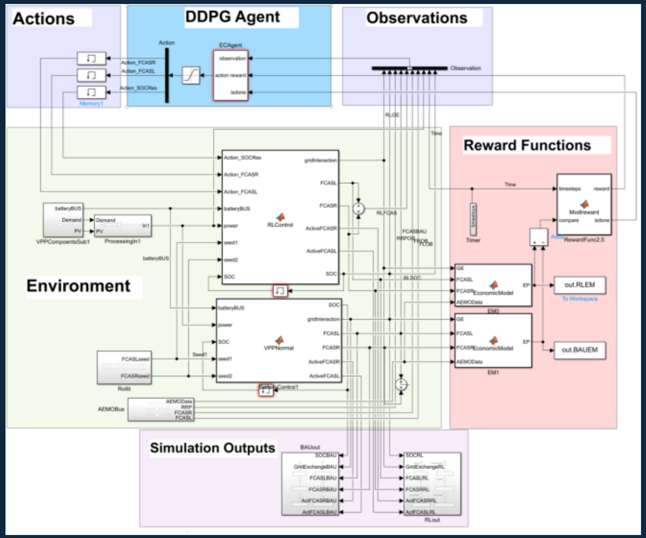


Liu C, Yang R, Wang K, Zhang J. Community-Focused Renewable Energy Transition with Virtual Power Plant in an Australian City—A Case Study. *Buildings*. 2023; 13(4):844. https://doi.org/10.3390/buildings13040844

Liu, C., Yang, R. J., Yu, X., Sun, C., Rosengarten, G., Liebman, A., Wakefield, R., Wong, P. S. P., & Wang, K. (2023). Supporting virtual power plants decision-making in complex urban environments using reinforcement learning. Sustainable Cities and Society, 99, 104915. https://doi.org/https://doi.org/10.1016/j.scs.2023.104915

Community focused renewable transition – Community Virtual Power Plant





Social-economic-technical feasibility analysis for community based Virtual Power Plants

Region (SA2 Name)	SA1 Code	Type	IRSAD Score	PV capacity (MW)	Battery capacity (MWH)	25 years NPV(Millions AUD)
East Bendigo - Kennington	2102036	I	986	7.34	10.27	20.66
Kangaroo Flat - Golden Square	2102240	I	904	7.24	10.14	19.13
Kangaroo Flat - Golden Square	2102217	C	838	5.77	8.08	17.29
East Bendigo - Kennington	2102006	I	1001	9.82	13.75	14.09
Bendigo	2101803	I	938	5.94	8.32	12.43
White Hills - Ascot	2102503	C	995	5.77	8.07	11.90
Kangaroo Flat - Golden Square	2102234	I	912	7.78	10.89	11.21
Bendigo	2101835	C	959	10.95	15.33	10.97
Kangaroo Flat - Golden Square	2102245	R	1032	5.33	7.47	9.56
White Hills - Ascot	2102513	R	998	5.38	7.53	9.56

Region (SA1 Name)	SA1 Code	Type	IRSAD Score	PV capacity (MW)	Battery capacity (MWH)	25 years NPV (Millions AUD)
Maiden Gully	2102309	A	1030	2.48	3.48	-8.09
Kangaroo Flat - Golden Square	2102202	C	888	4.64	6.50	-1.11
Bendigo	2101834	R	1026	1.87	2.62	-0.78
Bendigo	2101807	C	888	2.83	3.96	-0.75
Flora Hill - Spring Gully	2102103	C	920	1.82	2.55	-0.55
White Hills - Ascot	2102520	C	913	6.57	9.20	-0.37
East Bendigo - Kennington	2102017	A	967	1.55	2.17	-0.06
Bendigo	2101838	C	826	5.44	7.62	0.09
California Gully - Eaglehawk	2101915	I	906	2.46	3.44	0.12
Bendigo	2101828	C	809	1.74	2.44	0.29

Liu C, Yang R, Wang K, Zhang J. Community-Focused Renewable Energy Transition with Virtual Power Plant in an Australian City—A Case Study. *Buildings*. 2023; 13(4):844. https://doi.org/10.3390/buildings13040844
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Energy Flexibility for water corporations

Flexible load:
- Pumps with variable speed drives (VSDs)
- Aeration systems in wastewater treatment

Energy storage:
- Battery Energy Storage Systems (BESS):
- Biogas storage
- Pumped hydropower storage

Energy trading:
- Peer-to-peer (P2P) trading
- Virtual Power Plant (VPP) aggregation

Flexible renewable generation:
- PV generation (smart inverter)
- Biogas CHP (combined heat and power)
- Hydropower

Flexible load

Energy storage

Energy trading

Flexible renewable generation

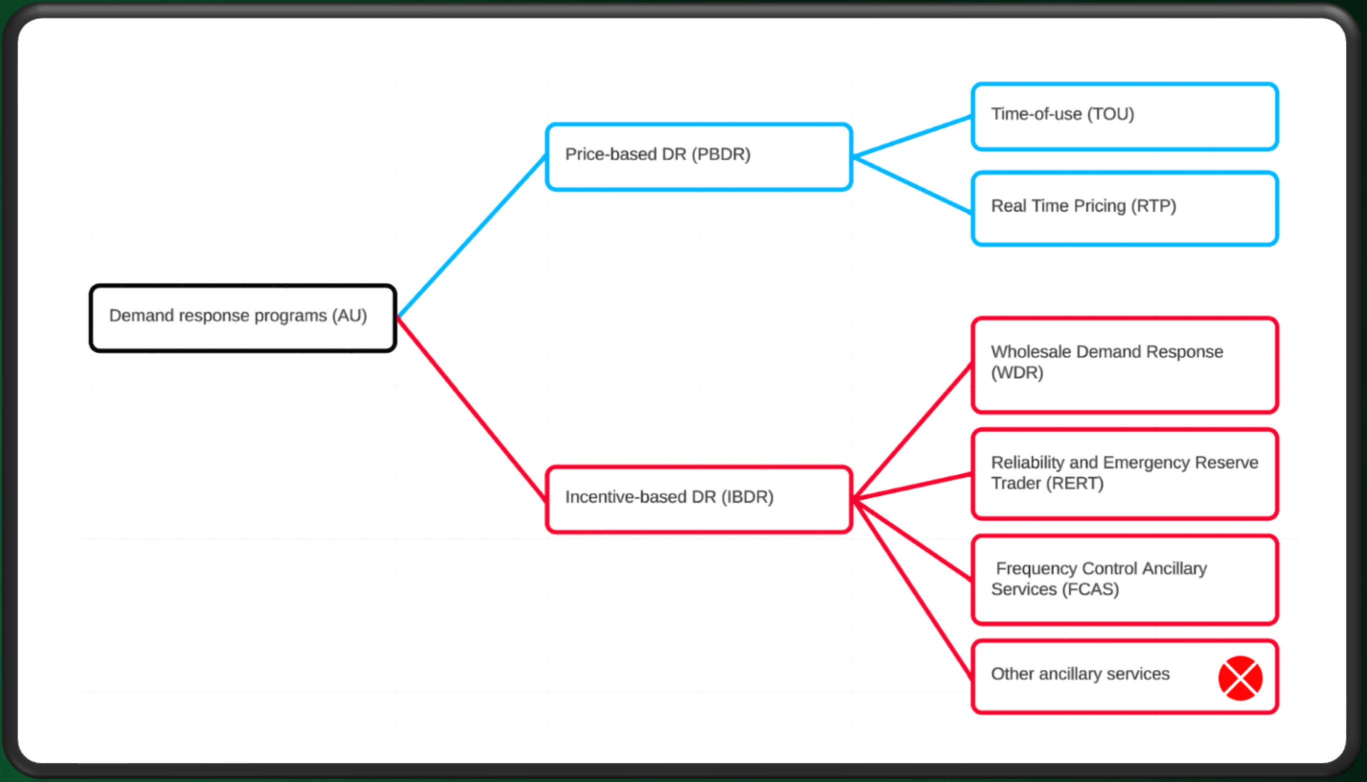
Demand response

Price based demand response

- Energy users voluntarily adjust their electricity usage in response to time-varying electricity prices, without receiving direct incentives.

Incentive-based demand response

- Participants reduce or shift load during certain events for direct payments or incentives from third parties (e.g., AEMO or aggregators).



Assessment matrix

Demand resposne options \ Flexibility and RE options		R0: Flexible load	R1: On-site generation with ESS	R2: Flexible load On-site generation with ESS	R3: Flexible load On-site generation P2P trading with neighbouring DERs
Price-based DR	Retailer contract (TOU)	TOU-R0	TOU-R1	TOU-R2	TOU-R3
	Spot market (RTP)	RTP-R0	RTP-R1	RTP-R2	RTP-R3
Incentive-based DR	NEM-FCAS demand response (FCAS)	FCAS-R0	FCAS-R1	FCAS-R2	FCAS-R3
	NEM-Wholesale demand response (NEM-W)	NEM-W-R0	NEM-W-R1	NEM-W-R2	NEM-W-R3
	Emergency demand response (RERT)	RERT-R0	RERT-R1	RERT-R2	RERT-R3

Public

Case study - Epsom Wastewater Reclamation Plant

Consumption:

- ~1.2 MWh per hour

Flexible load:

- 700 KVA (switching off the aerators)

Proposed Renewable Energy assets:

- PV: 2 MW
- BESS: 1.5 MWh

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Assessment - Cost Reduction Matrix

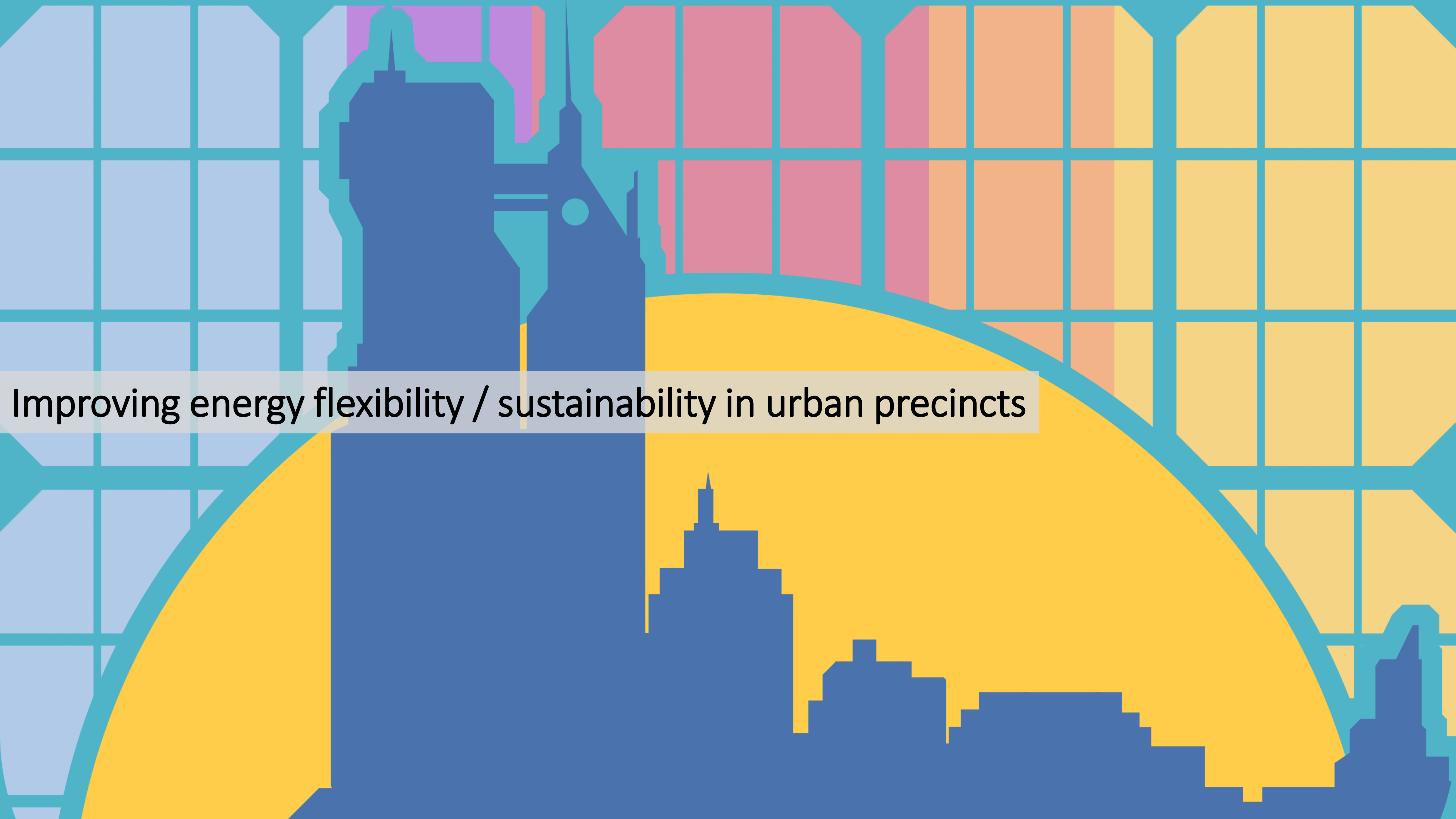
Epsom WWTP	Flex load shifting	PV + BESS	Flex + PV + BESS	Flex + PV + BESS + Energy trading
Cost Change under Retailer tariff	-4.0%	-30.0%	-35.0%	-39.0%
Cost Change under Spot market	13.0%	-31.0%	-36.0%	-41.0%
Cost Change under Spot + FCAS	8.2%	-43.3%	-48.3%	-53.3%
Cost Change under Spot + WDR	7.8%	-43.7%	-53.1%	-59.7%
Cost Change under Spot + RERT	9.6%	-34.4%	-39.4%	-44.4%

* With 2MW PV and 1.5MWh BESS installation

Lifecycle cost in scenario of PV+BESS under Spot + WDR

PV	2 MW	2.5 MW	3 MW
BESS	1.5 MWh	1.875 MWh	2.25 MWh
Cost Reduction (%)	53%	77%	99%
Payback Year	15	12	11

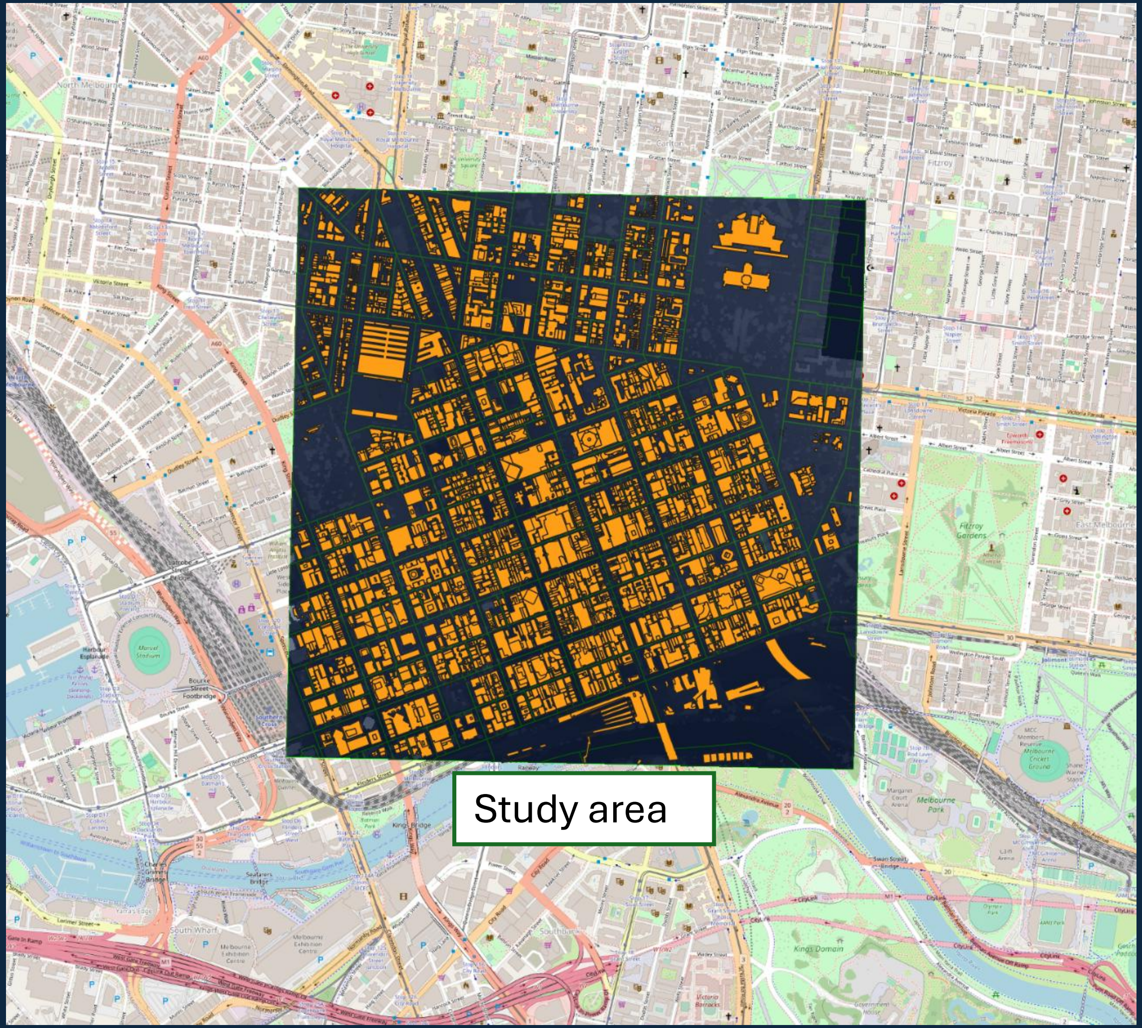
Improving energy flexibility / sustainability in urban precincts



Public

Research Design and Methodologies – Case study in a typical Australian city – City of Melbourne

- The **City of Melbourne** is selected, which is located in Victoria, Australia, which is the capital city of Victoria and the second largest city in Australia.
- The City of Melbourne has made great effort to reduce the greenhouse gas emission, making it a world leading city to act on the climate change (Melbourne, 2021). The City of Melbourne plans to realise the Net Zero Emissions by 2040 for the entire municipality (Melbourne, 2021).
- The study area covers the majority of Melbourne CBD, with a total area of 2000m*2000m.

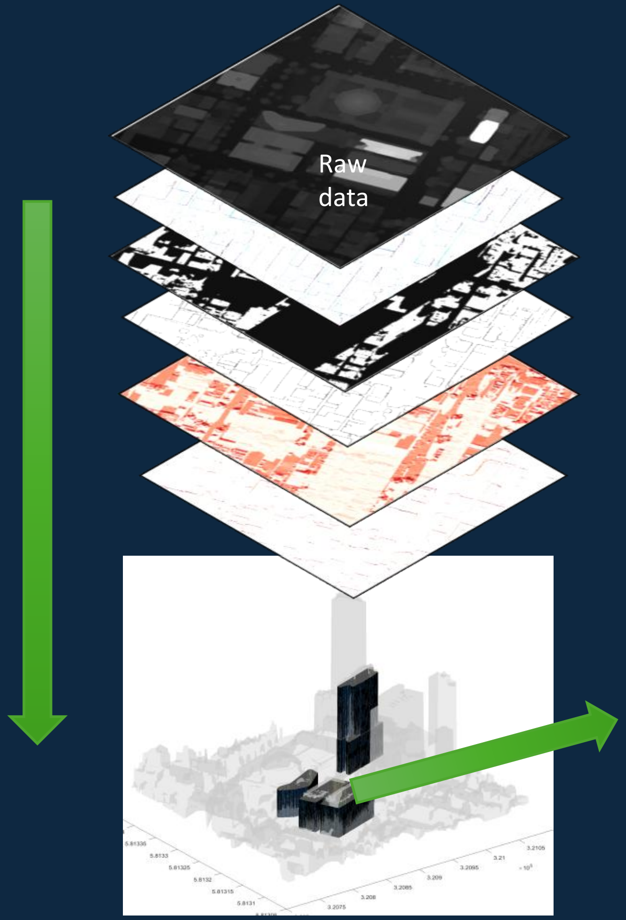


Zhao, H., Yang, R. J., Liu, C. and Sun, C., 2023. Solar building envelope potential in urban environments: A state-of-the-art review of assessment methods and framework. Building and Environment, 244, 110831. Available at: https://doi.org/10.1016/j.buildenv.2023.110831

Public

Machine learning-based digitalisation and evaluation of urban solar energy

Simulation process



Simulation results

ML-based process

Inputs

1. Meshblock level urban morphology factors from ABS
2. Raster layer parameters
   - Wall height
   - Wall azimuth

ML Prediction Models

Outputs

1. Annual average shading height on building façade
2. Annual solar potential on building façade
3. Annual electricity output from solar PV

What are the benefits of the ML-based process?

- A simplified workflow for evaluating solar energy and shading impacts in the urban environment
- Accelerate simulation process and reduce computation resources
  - Simulation process for Melbourne CBD: 4 - 8 hours (1m resolution)
  - ML-based process for Melbourne CBD: 15 seconds (1m resolution)
- Easier data collection/management process
  - Simulation process: Geospatial layers (Raster and vector)
  - ML-based process: ABS urban morphology data and user-defined inputs (Numeric)
- Does not rely on highly accurate LiDAR data or existing models. Suitable for new-development and early-stage planning.
- Support the decision-making of renewable transition and development by increasing visibility of urban renewable energy potential and challenges.

Zhao, H., Yang, R. J., Liu, C. and Sun, C., 2023. Solar building envelope potential in urban environments: A state-of-the-art review of assessment methods and framework. Building and Environment, 244, 110831. Available at: https://doi.org/10.1016/j.buildenv.2023.110831

Sunshine Precinct Development

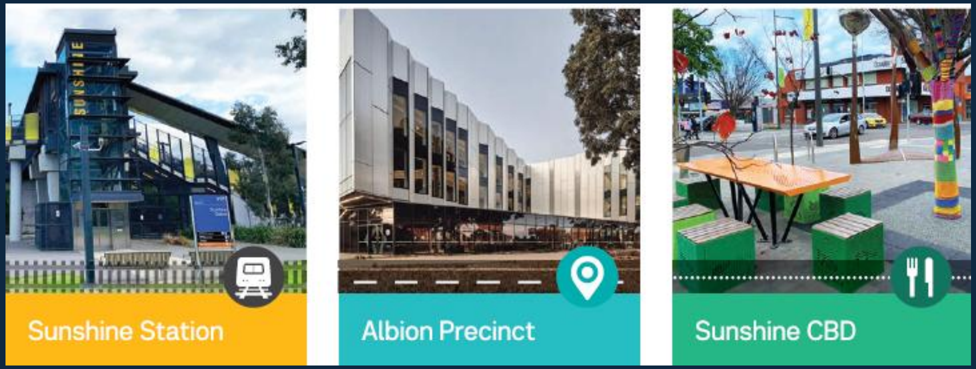
The government's vision for Sunshine Precinct is to emerge as the center of Melbourne's booming west providing key opportunities to boost employment, investment and livability through planning.

The Victorian government is delivering a record investment of AUD 20 Billion to grow and develop Sunshine precinct as the center of Melbourne's west.

Sustainability is the core approach of this urban development.

The purpose of our research project is to help implement the Sunshine Precinct Opportunity Statement by providing a comprehensive analysis of sustainable urban design strategies including urban heat, water supply, embodied energy and renewable energy transition opportunities.

In this project, data collected will be integrated into a model to analyze the impacts of hypothetical scenarios for the Sunshine Precinct.



1. State Government of Victoria (2024). *Sunshine Precinct*. Available at: https://engage.vic.gov.au/sunshine [Accessed on 27 August 2024].
2. Race for 2030 (2024). *Digital twin enabled sustainable sunshine precinct development*. Available at: https://racefor2030.com.au/project/digital-twin-enabled-sustainable-sunshine-precinct-development/ [Accessed on 27 August 2024].

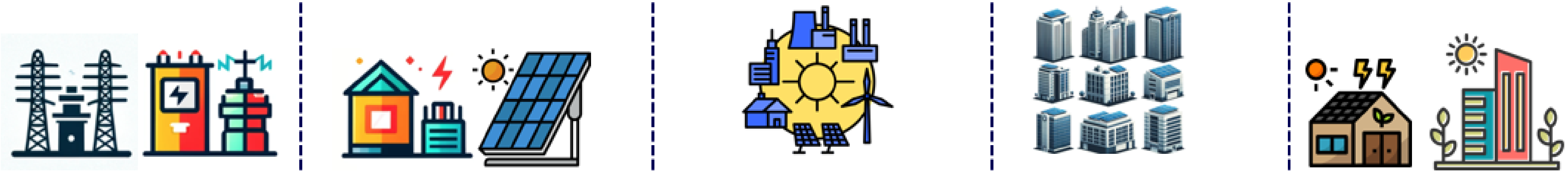
Digital Twin Enabled Sustainable Sunshine Precinct Development

Support the creation of a resilient and sustainable urban precinct, capable of adapting to future environmental and infrastructural challenges

- Urban heat
- Water balance and efficiency
- Sustainable energy infrastructure
- Embodied carbon

Stakeholders and options for sustainable precinct energy infrastructure

Sustainable High-Density Urban Precinct Energy Options



Infrastructure upgrade	Distributed generators, BESS, and EV	Energy flexibility and smart grid	Demand side management	Energy efficiency urban and building design
Key Stakeholders				
• NEM • DNSP	• Community • DEECA/Solar Victoria • City Council • Sustainability Victoria • DTP • Retailer	• Community • DEECA/Solar Victoria • DTP • Sustainability Victoria • City Council • NEM • DNSP • Retailer	• Community • City Council • Retailer • DEECA/Solar Victoria	• Community • City Council • DEECA/Solar Victoria • Sustainability Victoria • DTP

ISES SWC 2025

Solar World Congress 2025
04 - 07 November in
Fortaleza, Brazil

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Thank you!

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