

# URBAN SOLUTIONS AND SUSTAINABILITY R&D CONGRESS 2023

BUILDING SUSTAINABLE, RESILIENT, AND LIVEABLE CITIES OF TOMORROW

4TH - 5TH OCTOBER 2023



## FCLG - Powering the City (POW)

Urban Energy Demand and Supply with Building Integrated Photovoltaics

By

A/Prof. Bu Sung LEE, Francis  
SCSE, NTU

# Singapore Green plan 2030

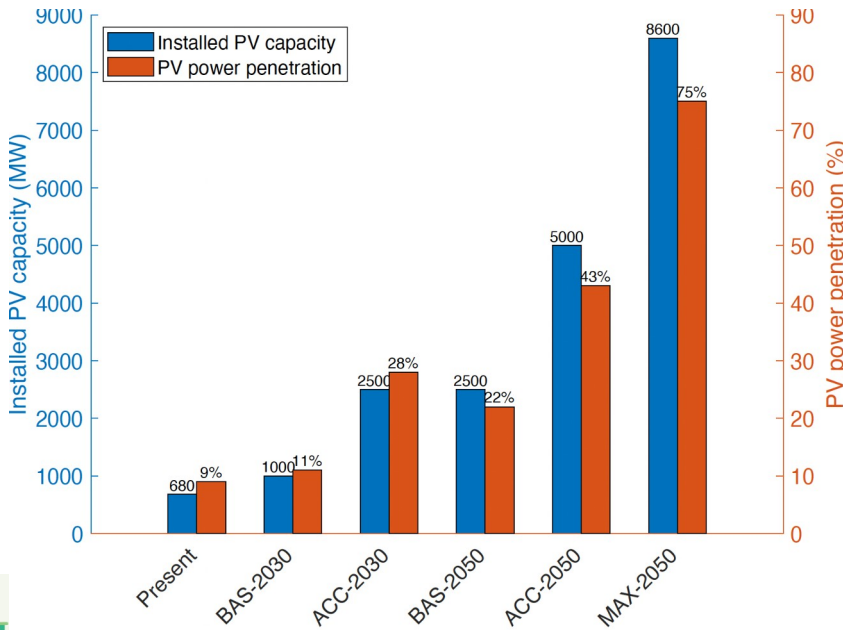
- Plant 1 million more trees

- **Quadruple solar energy deployment by 2025**

- Reduce the waste sent to landfill by 30% by 2030

- At least 20% of schools to be carbon neutral by 2030

- All newly registered cars to be cleaner-energy models from 2030



[1] Green Plan, <https://www.greenplan.gov.sg/>





# Why Building-integrated Photovoltaics (BIPV) ?

Singapore: resource-constrained city-state, has limited renewable energy options [2]

- (1) Low wind speed in Singapore (about 2m/s < 4.5 m/s)
- (2) No tidal power generation due to the narrow tidal range and calm seas.
- (3) No hydroelectric power
- (4) No geothermal energy sources are available.
- (5) Low biomass-based energy generation
- (6) Nuclear power

Solar energy is the only renewable energy source

Limited land resources and dense metropolitan regions in Singapore.



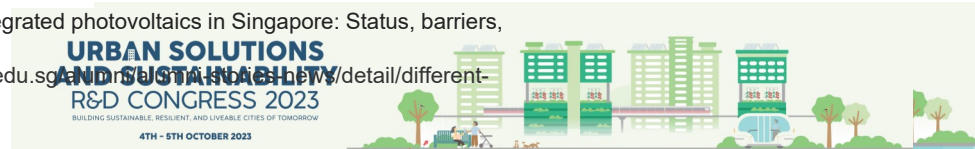
Building-integrated Photovoltaics (BIPV) systems is a viable solution



[1] Green Plan, <https://www.greenplan.gov.sg/>

[2] Chen, T., An, Y. and Heng, C.K., 2022. A review of building-integrated photovoltaics in Singapore: Status, barriers, and prospects. *Sustainability*, 14(16), p.10160.

[3] Different disciplines, same sustainable goals. <https://www.ntu.edu.sg/urban-solutions/news/detail/different-disciplines-same-sustainable-goals>



Asia / Southeast Asia

## Singapore plan to import Indonesia clean energy advancing as region develops renewables 'faster and bigger than people realise'

- Singapore currently generates 95 per cent of its electricity from natural gas, and lack of space limits the building of solar and wind farms
- Asia is rapidly developing a similar energy market to Europe, where countries routinely import electricity from neighbours

8 Sept 2023

## Singapore gives conditional nod for 2GW of electricity imports from Indonesia

CNA 8 Sept 2023

Singapore to get 1GW of renewable energy from Cambodia in largest electricity import to date

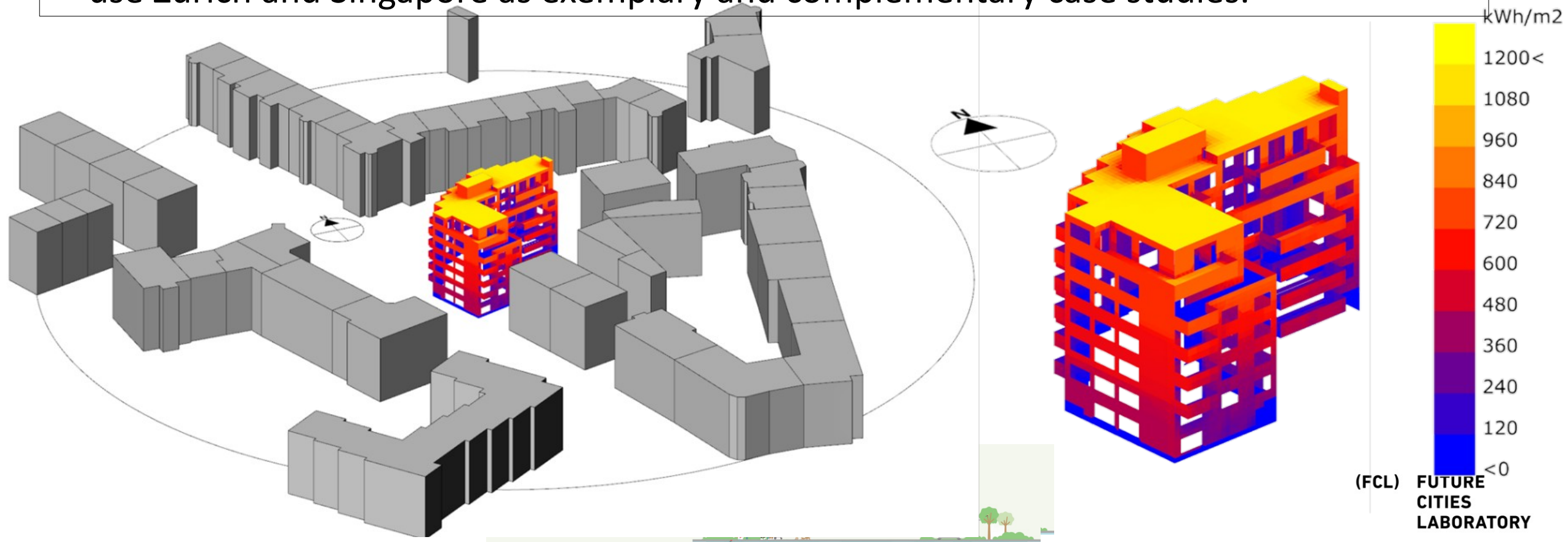
ST, 17 mar 2023



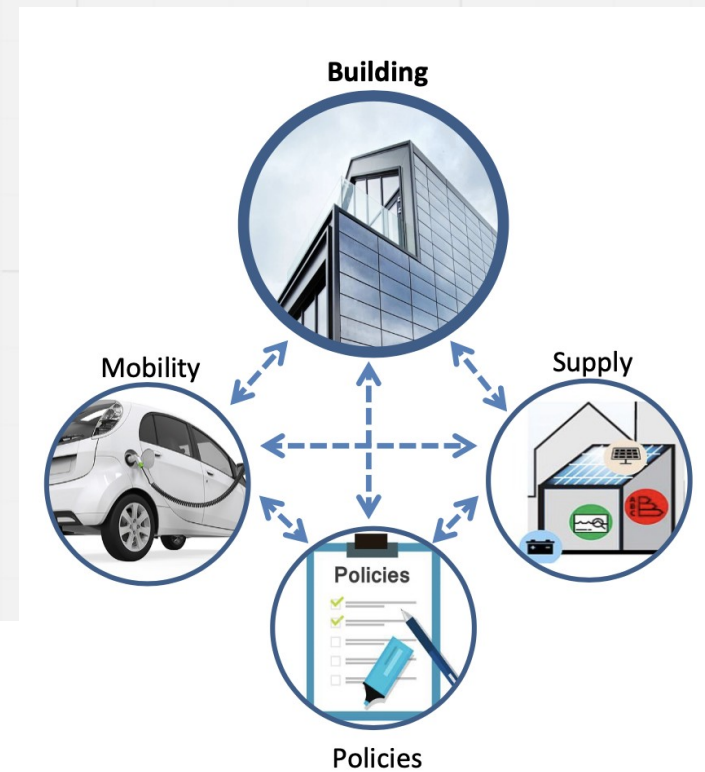
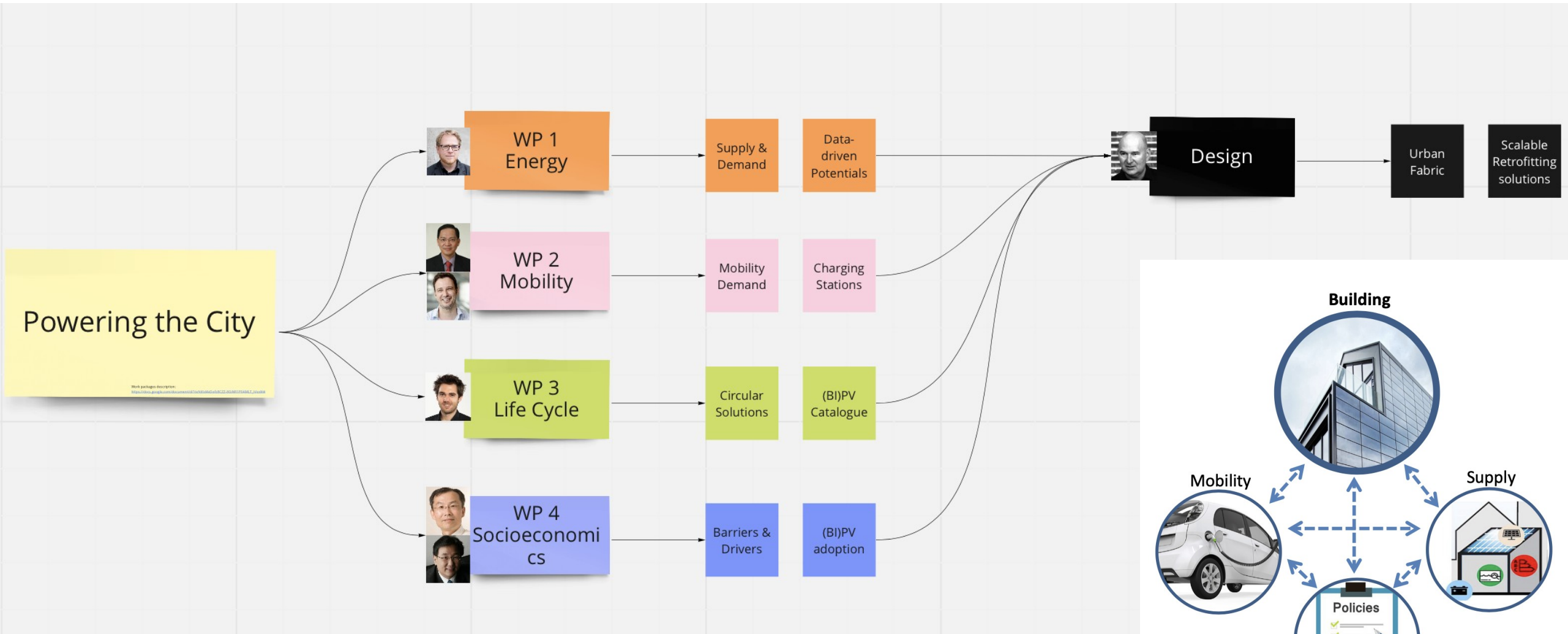


## Objective of POW

- develop a holistic, multi-scale and interdisciplinary approach for assessing large scale deployment of **BIPV** in urban contexts **under different climatic, socio-economic and architectural / urban conditions.**
- use Zurich and Singapore as exemplary and complementary case studies.



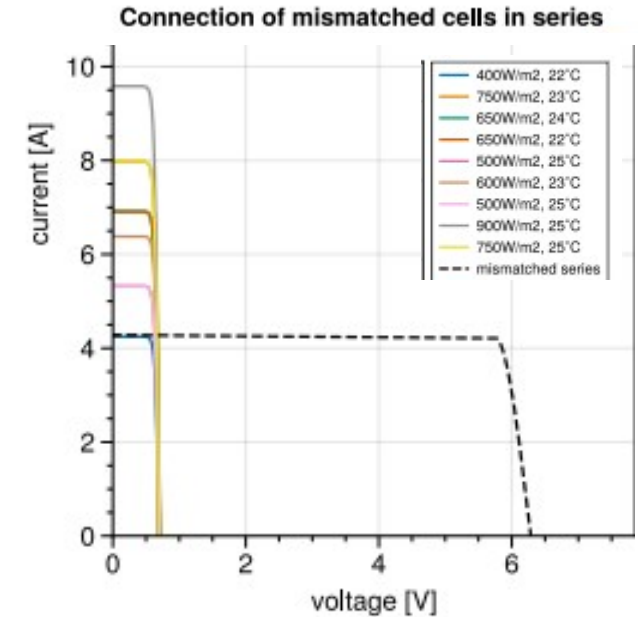
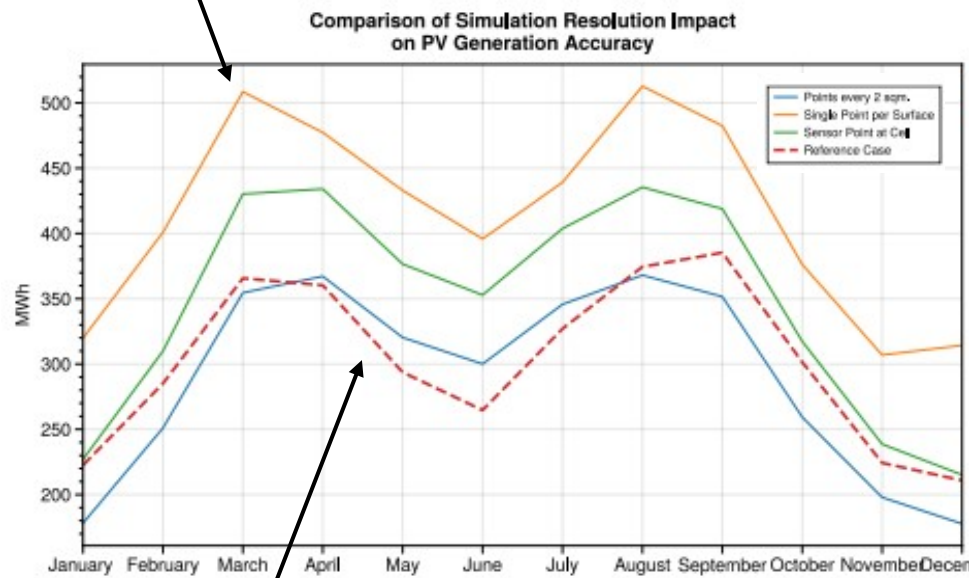
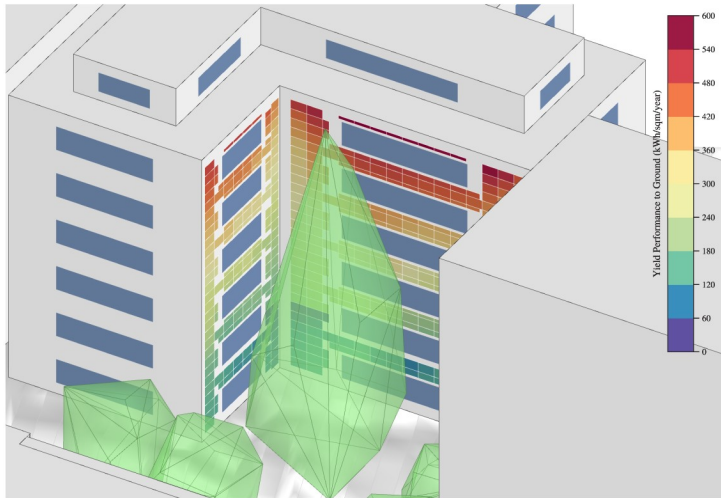
# POW Architectures and work packages



# Energy WP

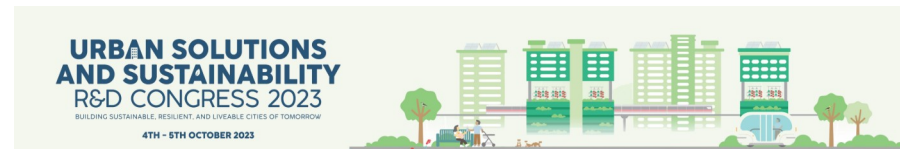
## High-resolution PV simulation

Irradiation \* Efficiency = too optimistic!



Detailed calculation

High-resolution PV modelling. McCarty et al. (ongoing)

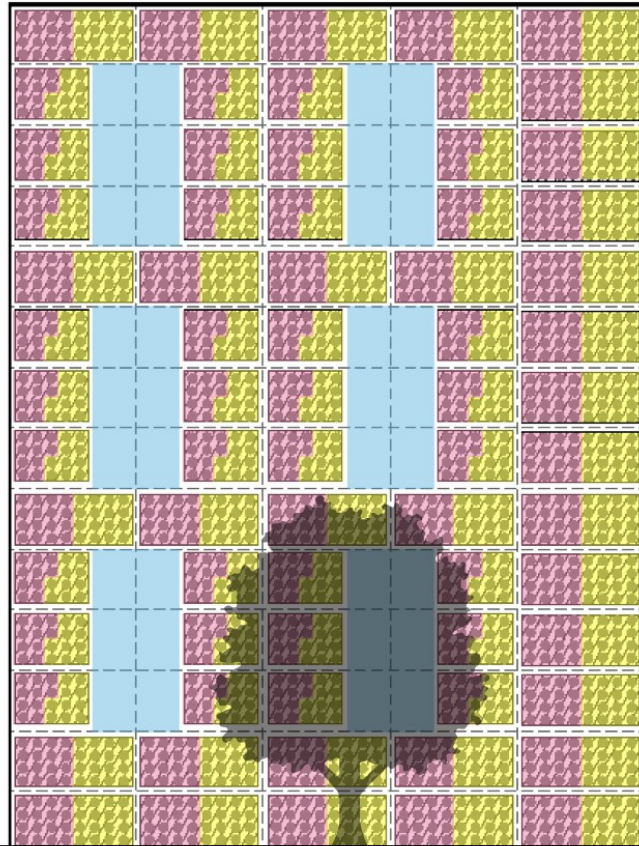


(FCL) FUTURE CITIES LABORATORY

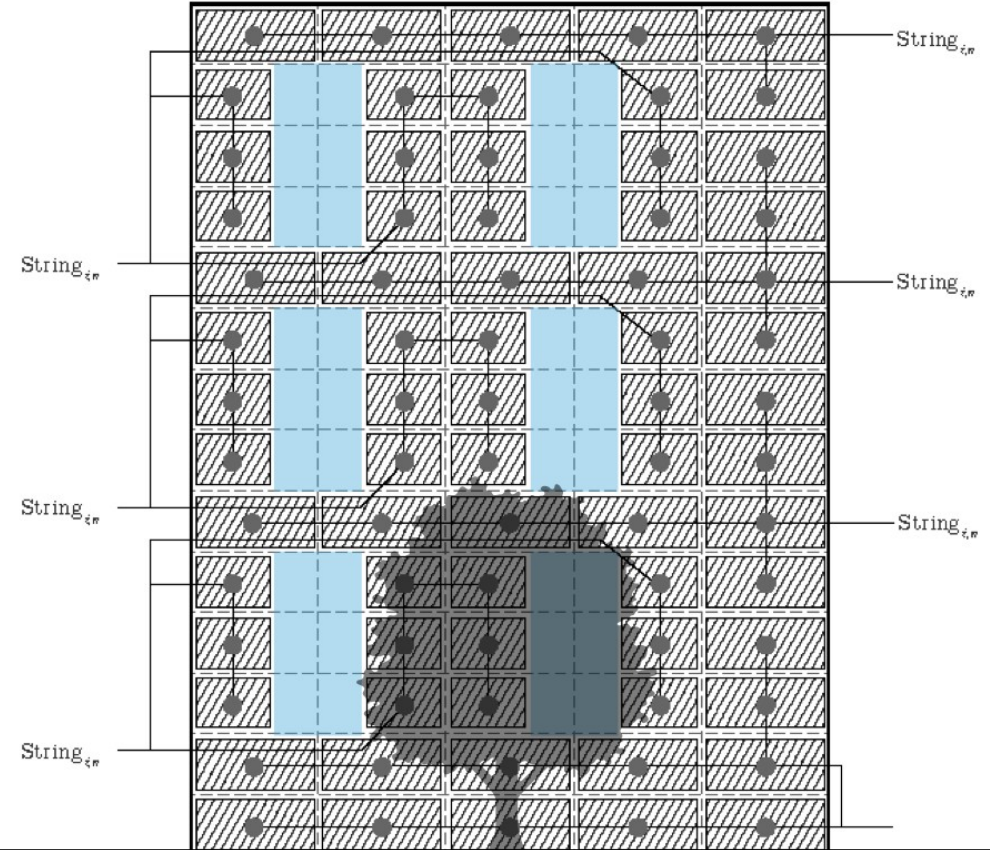


# High resolution PV simulation

High-resolution PV modelling. McCarty et al. (ongoing)

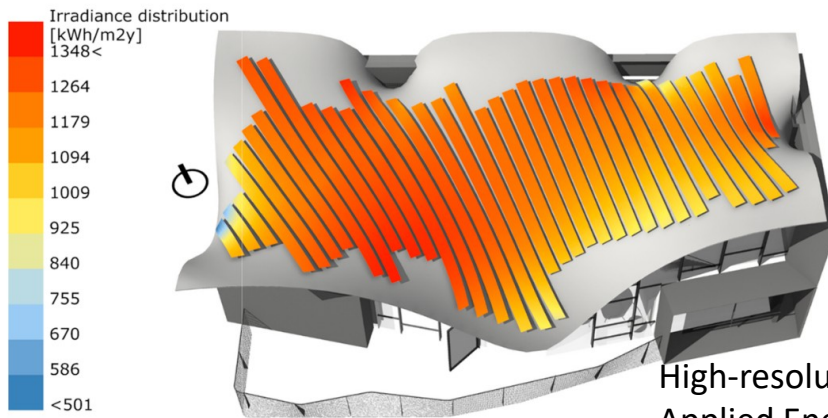
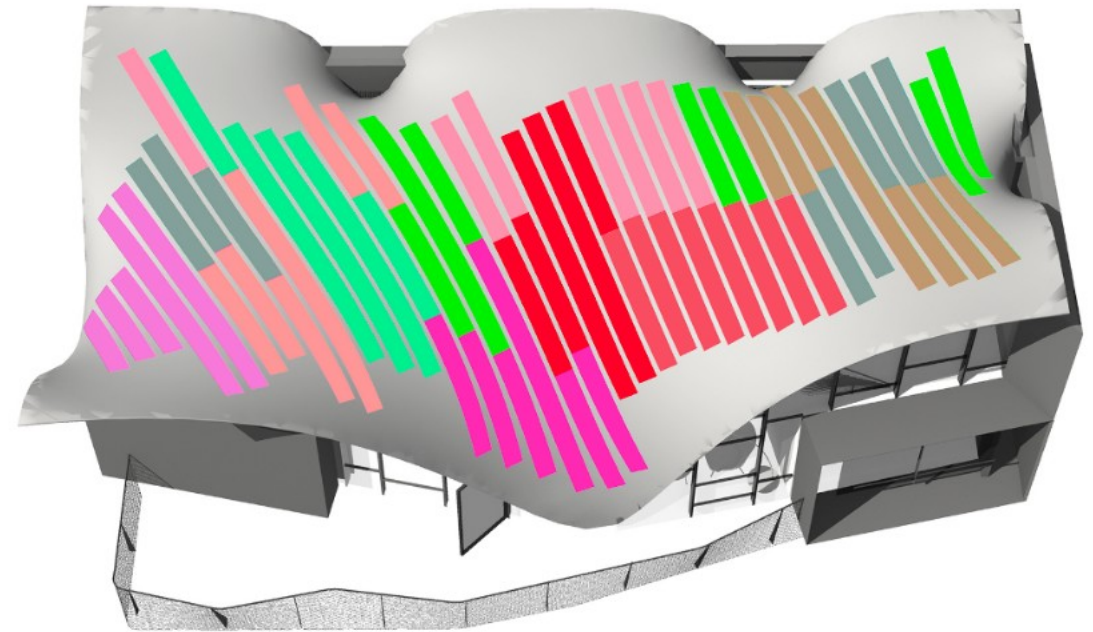


■ Diode Partition A  
■ Diode Partition B



# PV System Architect Optimization

	[a]	[e]	[i]
	[b]	[f]	[j]
	[c]	[g]	[k]
	[d]	[h]	[l]

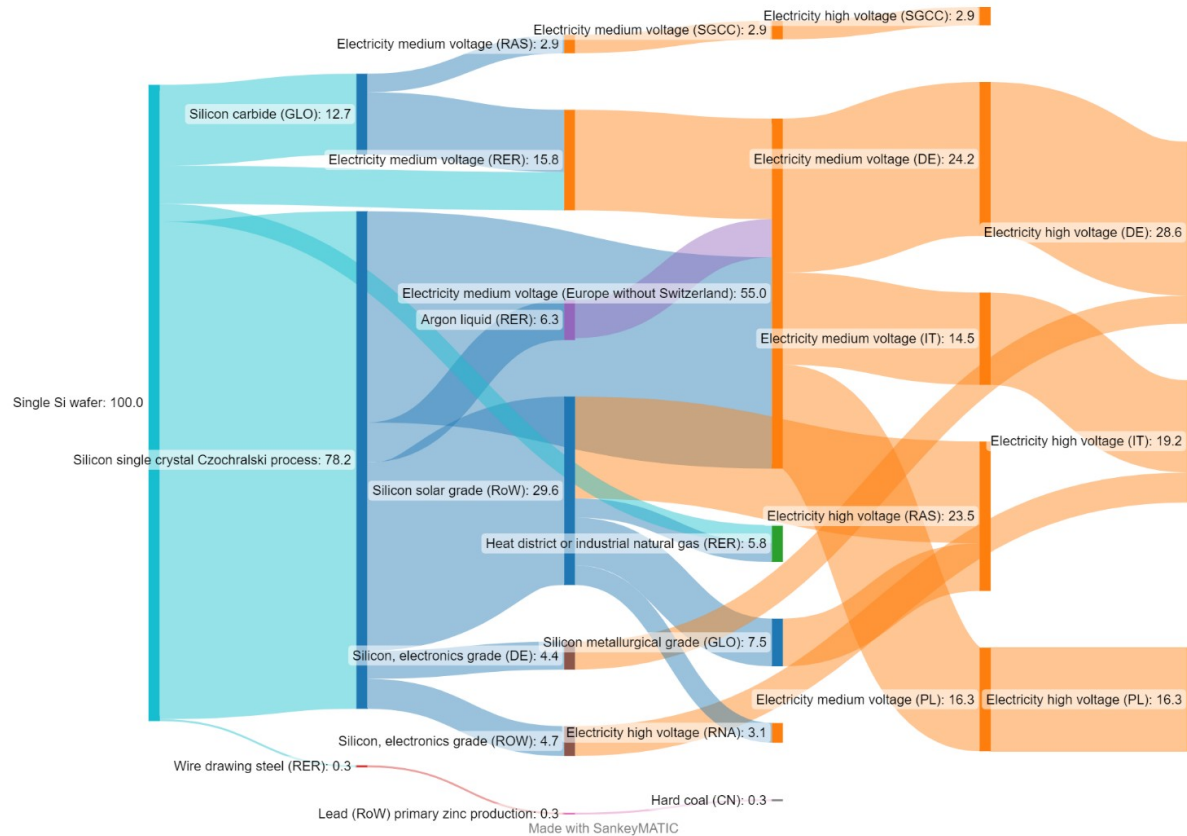


**Fig. 13.** The String Layout proposed by the genetic optimization. Modules with the same color are part of the same string (i.e. electrically connected). The division results in 5 strings of length 8 and 5 of length 7.

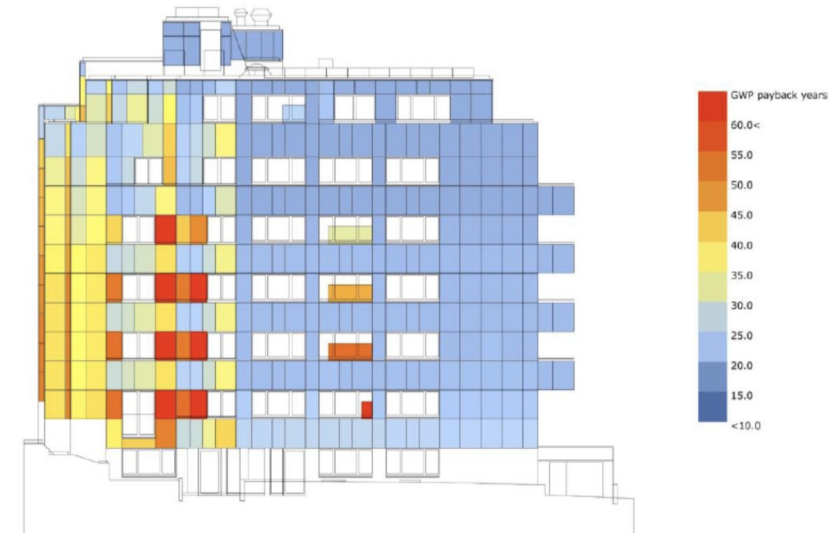
High-resolution, parametric BIPV and electrical systems modeling and design. Walker et al (2019).  
Applied Energy 238: 164-179



## GWP, life cycle assessment



Galimshina et al. (ongoing)



Jianxiang Ma. Dynamic Parametric LCA of BIPV Design, Master Thesis Chair of Sustainable Construction ETH Zürich

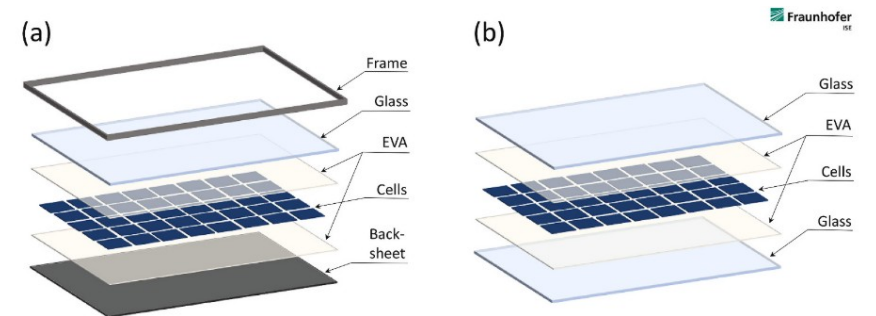
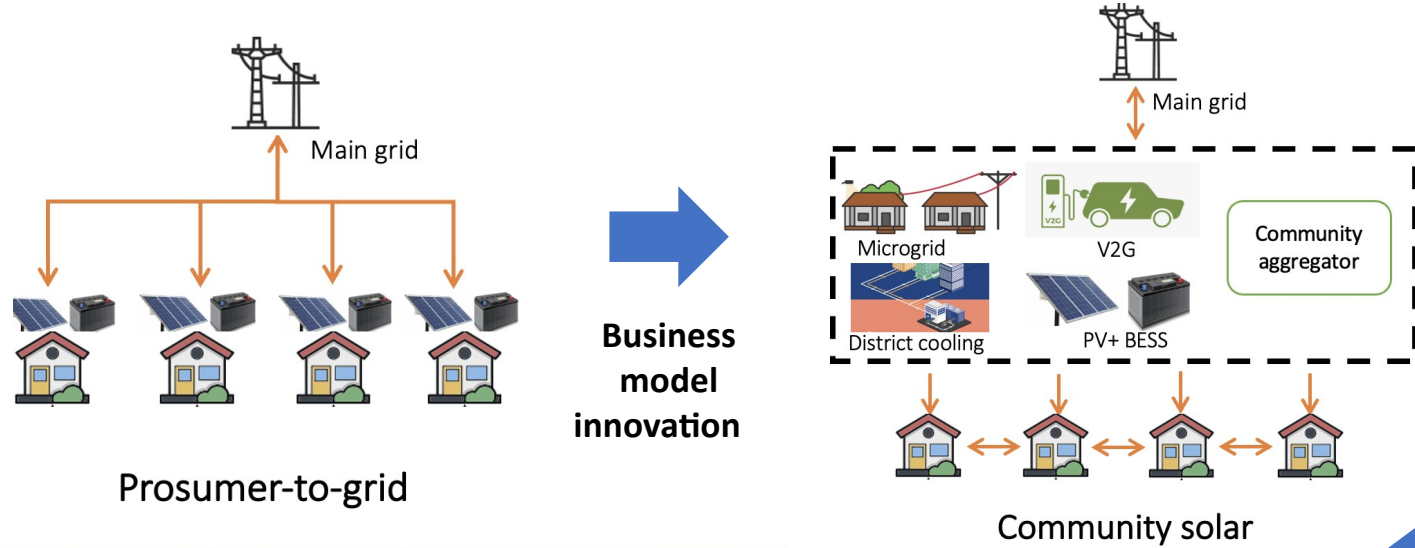


Fig. 1. Structure of glass-backsheet (G-BS) module (a) and glass-glass (G-G) module (b).

Müller, A. et al. A comparative life cycle assessment of silicon PV modules: Impact of module design, manufacturing location and inventory. Sol. Energy Mater. Sol. Cells (2021) **FUTURE CITIES LABORATORY**

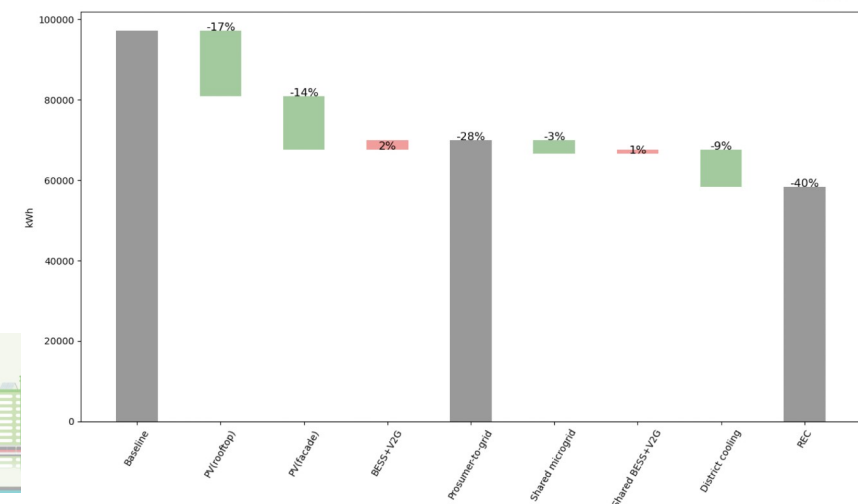
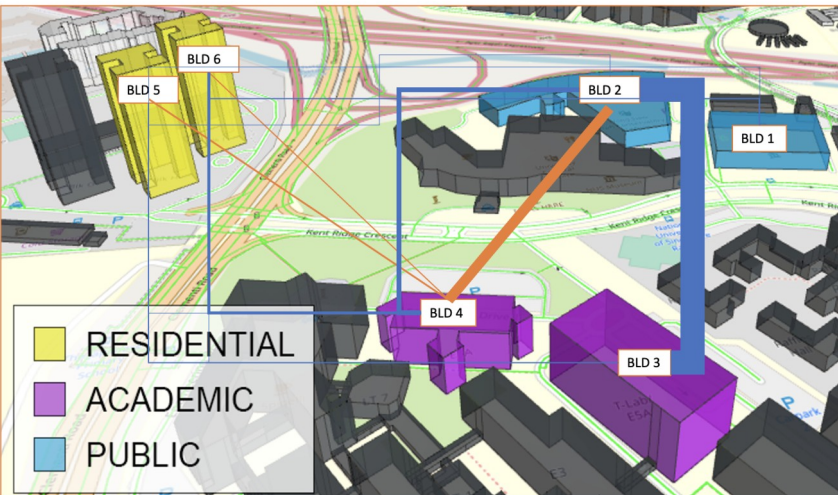
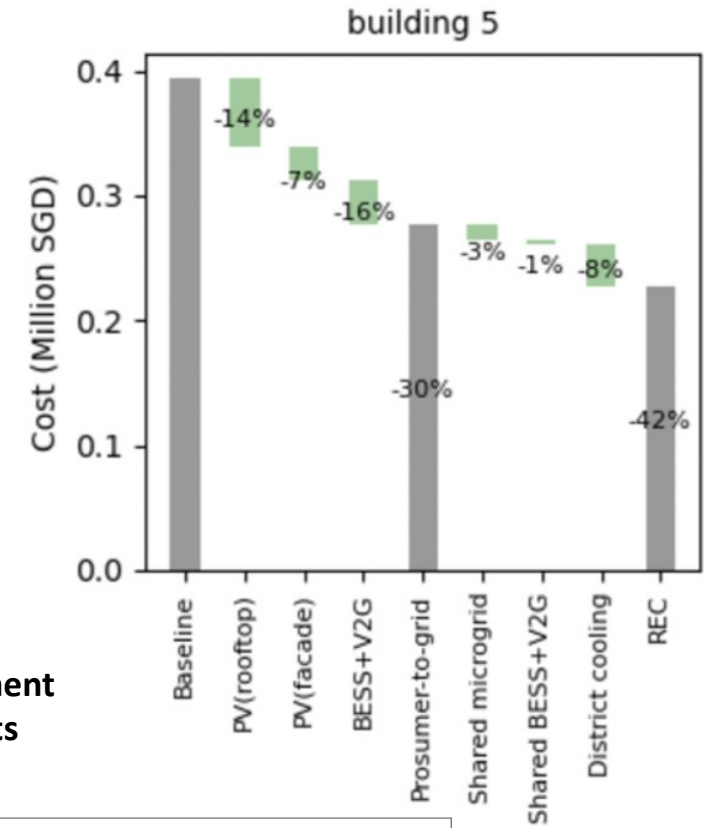


# Solar Socio-economics



**Economic benefits**

**Environment benefits**



## Mobility in Singapore extracted from city-scale mobile phone data

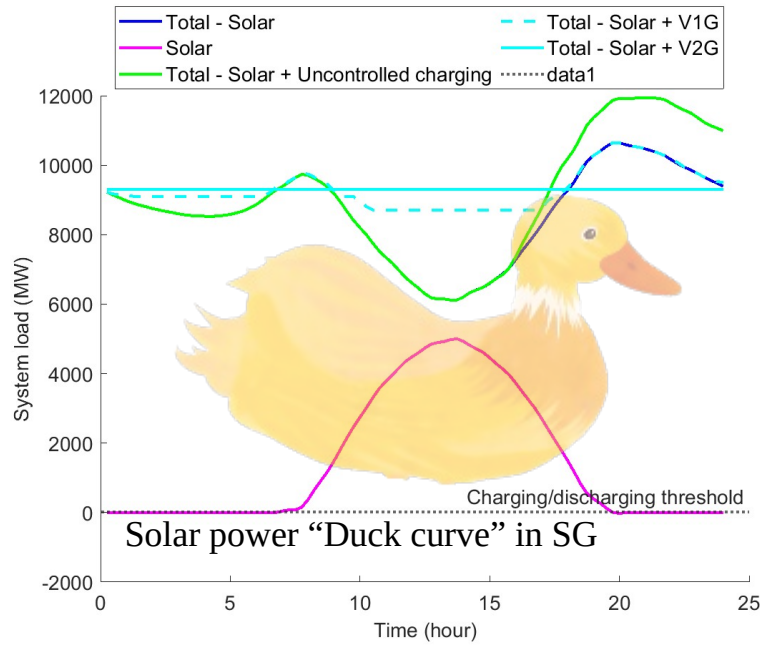


# Mobility WP

Solar photovoltaics (PV)

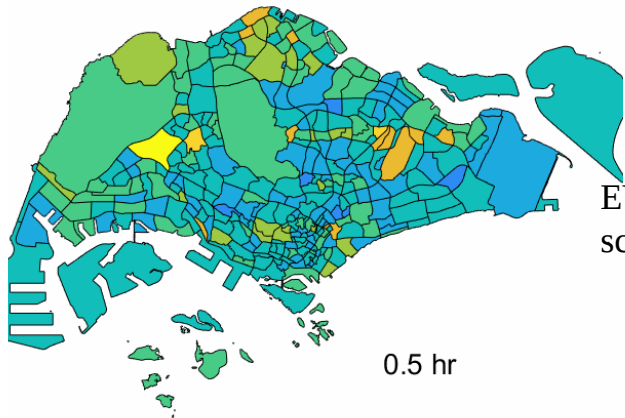


High solar PV penetration



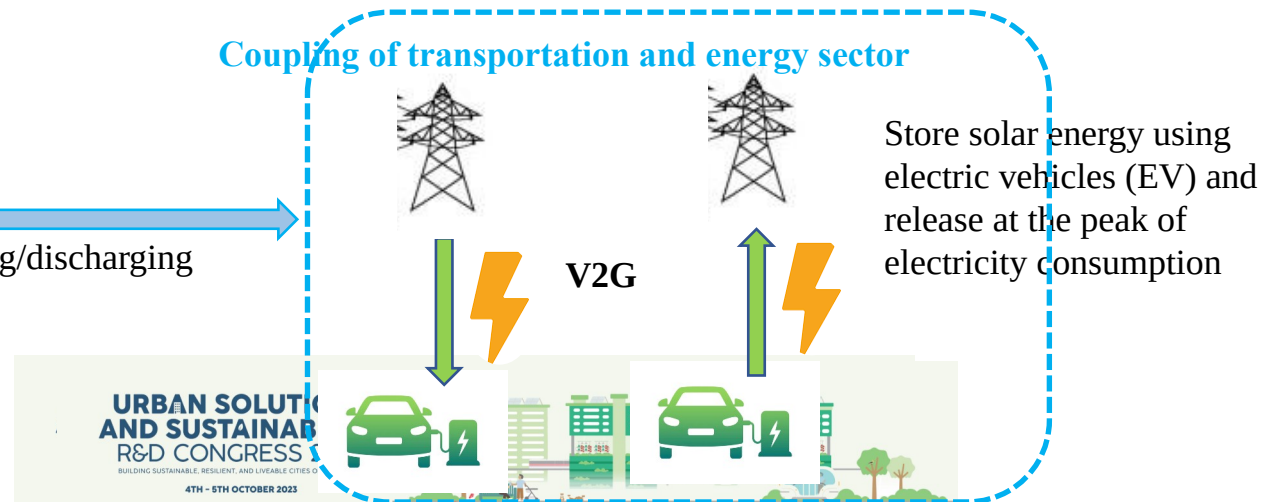
Flatten grid load duck-curve

Charging demand estimation from mobile phone data



EV charging/discharging scheduling

Coupling of transportation and energy sector



Renewable energy



CO<sub>2</sub> reduction

Decarbonization

(FCL) FUTURE CITIES LABORATORY



# Thank you!

**URBAN SOLUTIONS  
AND SUSTAINABILITY**  
R&D CONGRESS 2023  
BUILDING SUSTAINABLE, RESILIENT, AND LIVEABLE CITIES OF TOMORROW

4TH - 6TH OCTOBER 2023



**(FCL) FUTURE  
CITIES  
LABORATORY**