Using Data to link Solar Energy and Electric Mobility

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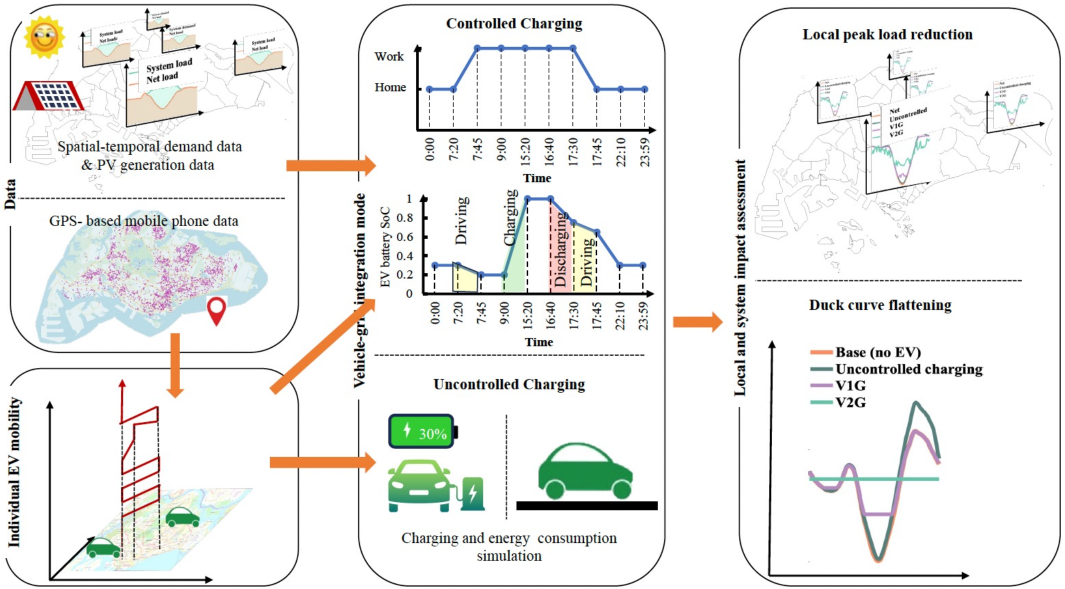
Agenda

- Background
- EV mobility modelling from phone data
- EV charging demand estimation, mitigate grid load
- Mitigate local grid load in tropical climate
- Conclusion and Recommendation



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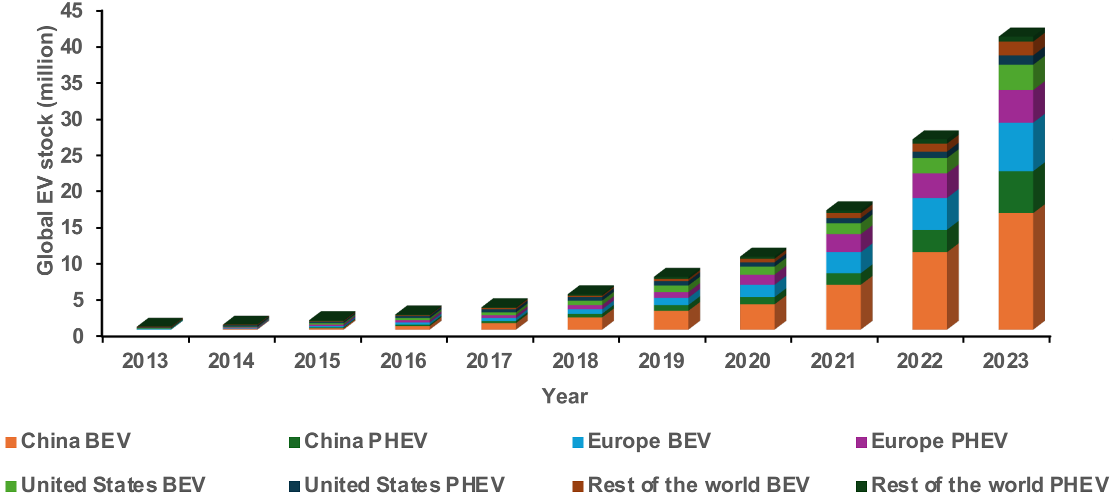
Background

Nearly one in five cars sold in 2023 was electric.



Global EV sales [1]

Vanessa Paige Chelvan
Correspondent

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SINGAPORE – Singapore is forecast to have the largest share of passenger electric vehicles (EVs) in South-east Asia by 2040, according to a report from Bloomberg's energy research service BloombergNEF.

A total of 80 per cent of all passenger vehicles here are expected to be electric by that year, compared with a regional average of 24 per cent, the report said.

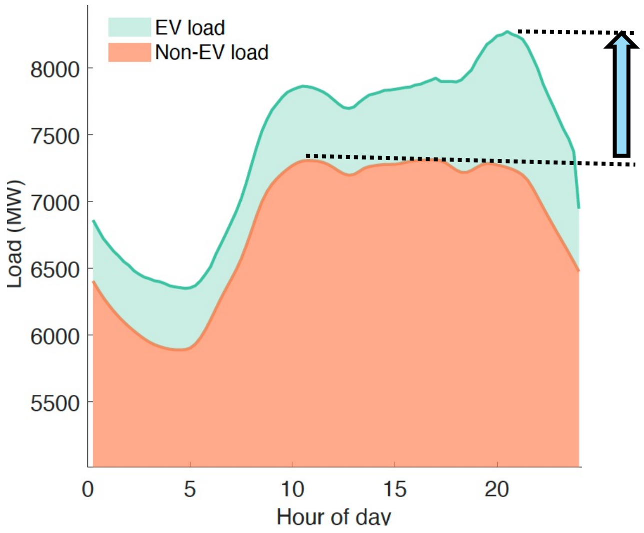
Thailand, in second place, is forecast to have a 41 per cent share, followed by Vietnam (31 per cent), Indonesia (25 per cent), Malaysia (15 per cent) and the Philippines (10 per cent).

Local transportation electrification [2]

[1] International Energy Agency. Global EV Outlook 2024, Trends in electric cars.
[2] Land Transport Authority Singapore, Electric Vehicles. Available at: https://www.lta.gov.sg/content/ltagov/en/industry_innovations/technologies/electric_vehicles.html

Motivation: grand challenges

The transition to EV will increase electricity demand, thus putting tremendous strain on the power grid.



Load profile of EV and non-EV load

Challenges on power grid

- voltage quality
- component overloading
- phase unbalance
- power loss

Accurate modeling of the EV charging demand is crucial.

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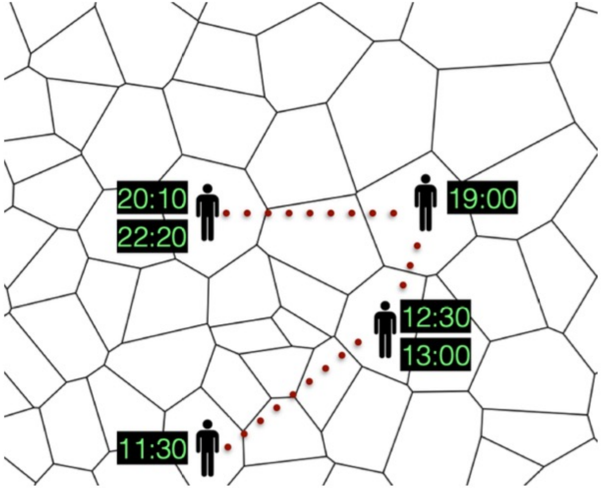
Large-scale mobility data


```
1,2013-01-24 11:30:00,599
1,2013-01-24 12:30:00,608
1,2013-01-24 13:00:00,608
1,2013-01-24 19:00:00,446
1,2013-01-24 20:10:00,323
1,2013-01-24 20:30:00,323
1,2013-01-24 22:00:00,323
1,2013-01-24 22:20:00,323
1,2013-01-25 12:50:00,323
1,2013-01-25 12:50:00,323
```

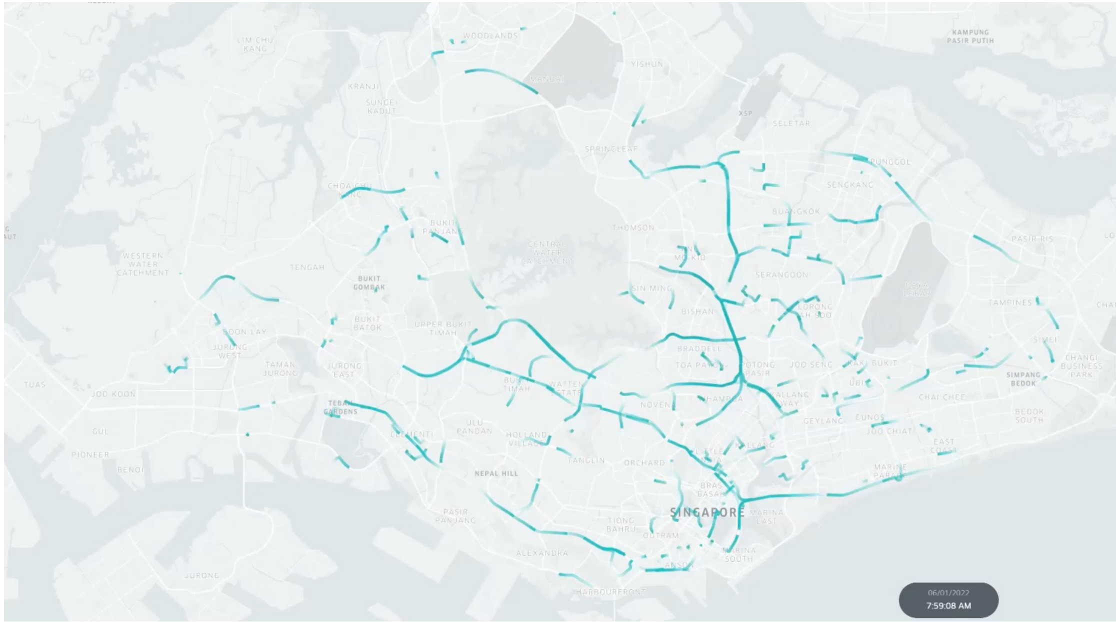
User ID | Timestamp | Tower ID

⇒



EV mobility modeling and charging demand estimation

Mobile phone data (EV mobility)



EV mobility in Singapore

Mobile phone data — Low coverage, Low resolution

↓ Mobility pattern analysis; Data augmentation with TimeGeo [1]

Mobility data — High coverage, High resolution

↓

EV charging demand — Charging Simulation

- [1] Jiang, S., Yang, Y., Gupta, S., Veneziano, D., Athavale, S. and González, M.C., 2016. The TimeGeo modeling framework for urban mobility without travel surveys. *Proceedings of the National Academy of Sciences*, *113*(37), pp.E5370-E5378.

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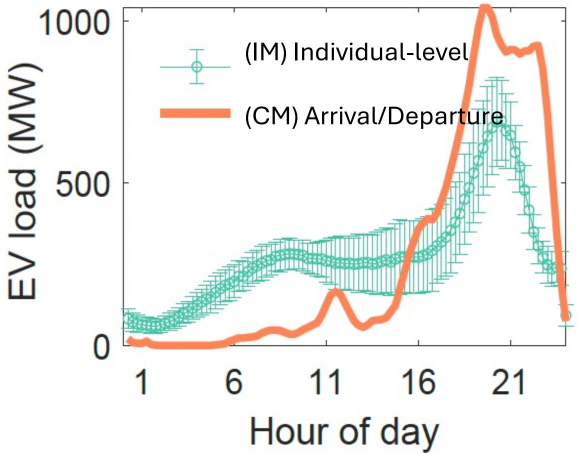
EV charging demand estimation, mitigate grid load

Charging demand estimation

Aggregate EV load for the whole of Singapore



Mobility Input Profiles

(a) Input with **individual-level** trajectory (IM)
- Connected to grid
- Battery SOC < 20% or SOC is not sufficient for the next trip(s)

(b) Input with **collective-level** mobility (CM)
- Departure, arrival distribution & average daily driving distance of EVs
  (spatial information is not available)

- IM and CM shows similar shape; yet IM shows lower peaks and higher saturated load at non-peaks
  - CM assumed home-base charging; hence, higher peak in the evening.
  - IM has high spatial-temporal resolution of trip information; thus, EVs may charge at locations other than home in the setting of IM input at non-peak hours.
    (e.g. EVs are charged at the workplace)
- IM portrays more realistic and accurate modelling of EV charging than using CM.
- This shows the significance of utilizing spatial information (individual-level trajectory).

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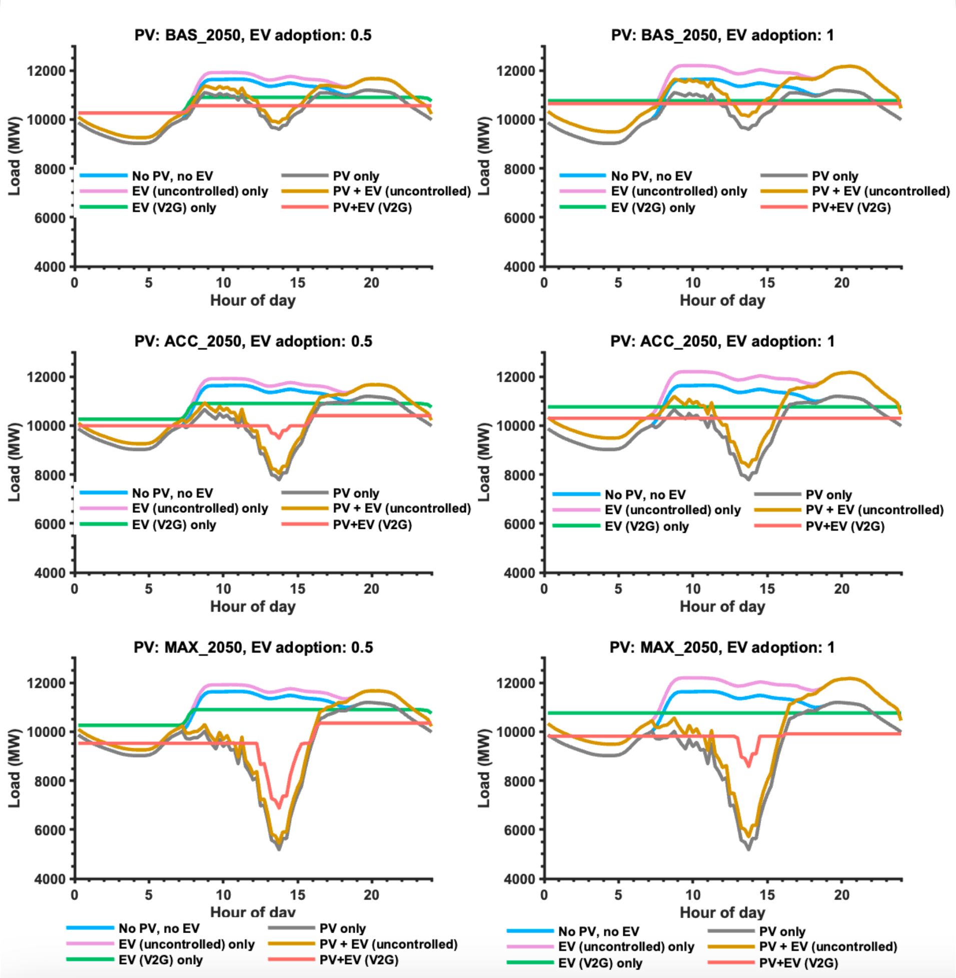
Duck-Curve Flattening

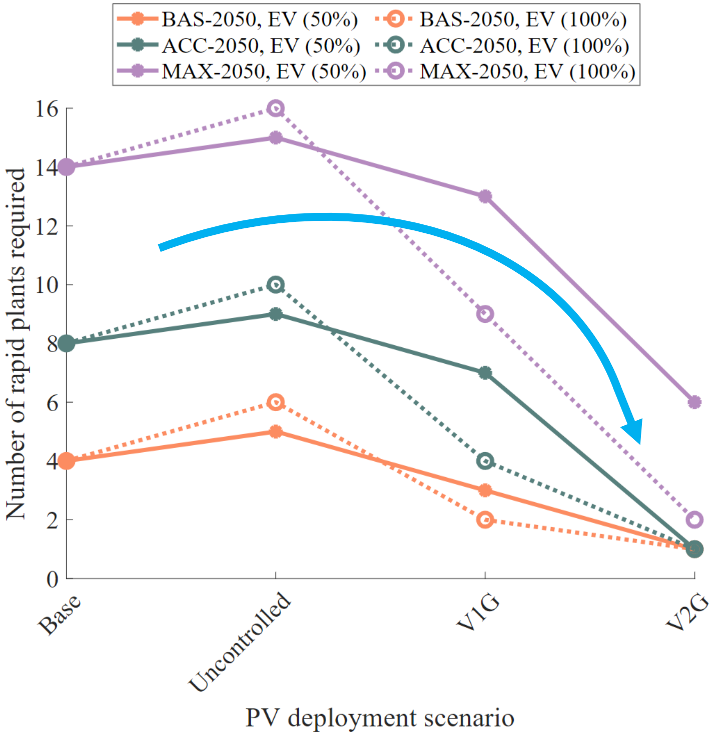


- ❑ V1G adoption primarily addresses valley filling, whereas V2G adoption offers the capability for both peak shaving and valley filling.
- ❑ The potential for V1G and V2G adoption increases with the rise in EV adoption rates, driven by the expanding "moving battery" storage capacity from EVs.
- ❑ If there is insufficient solar energy generation, the overall energy generated by fossil fuel plants increases with the EV adoption rate due to the need for EVs to draw energy from the main grid to support daily travel.

BAS-2050: PV deployment with basic scenario (2.5 GW)
ACC-2050: PV deployment with accelerated scenario (5 GW)
MAX-2050: PV deployment with maximum solar potential (8.6 GW)

Base: no EV scenario
Uncontrolled: EV charging is not controlled/coordinated.
V1G: unidirectional charging only
V2G: Bidirectional charging

Rapidly dispatchable plant reduction



- ❑ Uncontrolled charging increase the number of additional rapid power plants.
- ❑ Controlled charging methods, such as V1G and V2G, significantly reduce the ramping requirement, consequently lowering the cost of additional power plants while enhancing grid stability.
- ❑ The coordinated planning of PV systems and EVs yields the most significant benefits.

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MAX-2050: PV deployment with maximum solar potential (8.6 GW)

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V1G: unidirectional charging only
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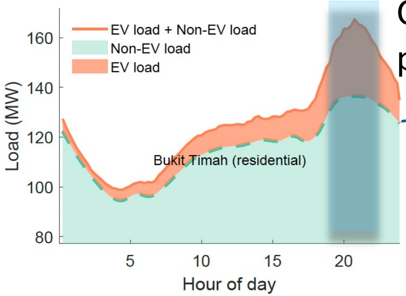
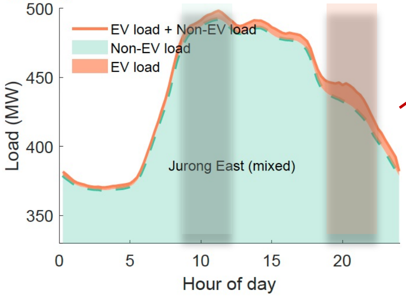
Identifying the areas that require grid upgrade

Local load (district-level impact)



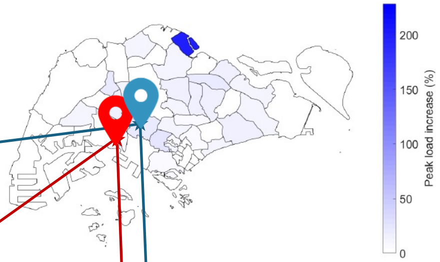
(a) EV load of Bukit Timah planning area (residential)



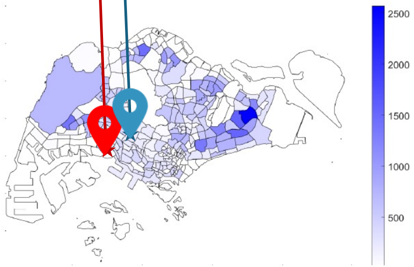
(b) EV load of Jurong East planning area (mixed)

Overlapped peak load hours

Staggered peak hours



(a) Percentage increase in peak load in each planning area



(b) Census population data [21]

Impact of EV charging on local load profile

Peak load increase and the population distribution

[1] CAISO, C., 2012. What the duck curve tells us about managing a green grid. *Calif. ISO, Shape a Renewed Future*, pp.1-4.
[2] LTA Singapore, Electric Vehicles. Available at: https://www.lta.gov.sg/content/ltagov/en/industry_innovations/technologies/electric_vehicles.html

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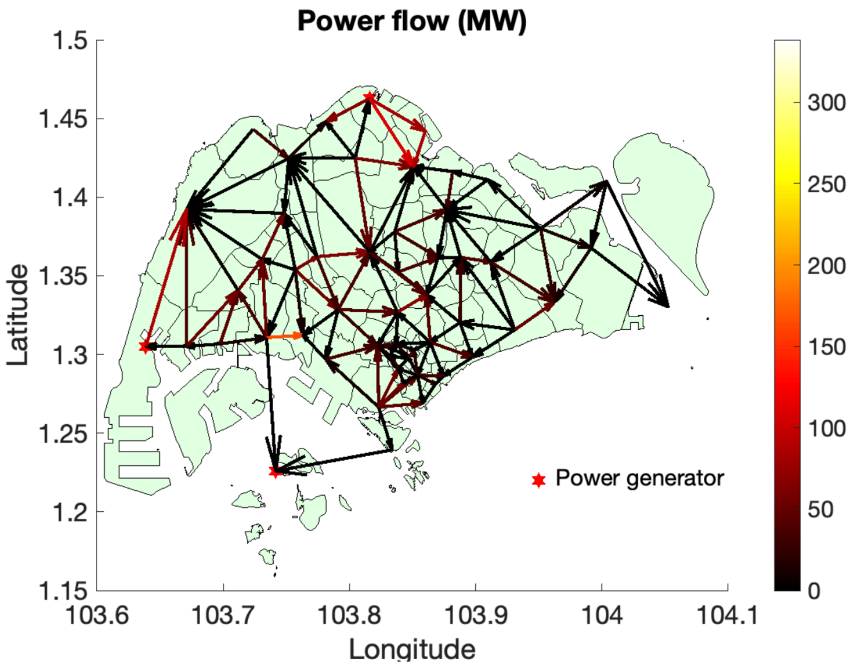
Identifying the areas that require grid upgrade

Power flow analysis (DC power flow model)



The additional peak flow caused by EV charging

Power flow has been increased especially for those planning areas near the power generators (power flow source).

Some planning areas witness high EV charging demand, increasing power flow from neighboring planning areas.

Transmission lines linking residential areas and those connecting to the generation systems might face load congestion, indicating a need for grid expansion.

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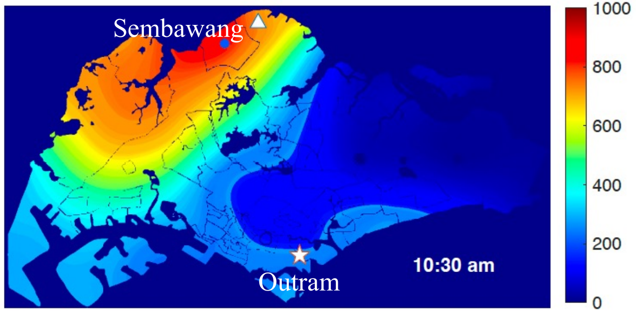
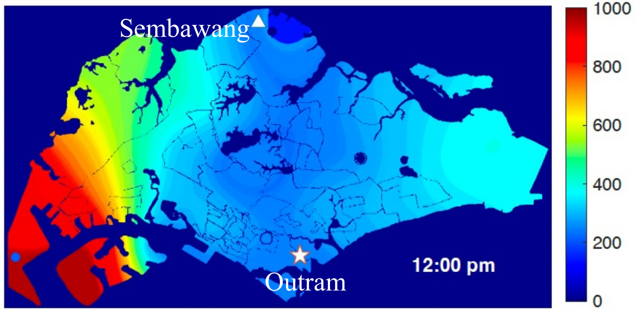
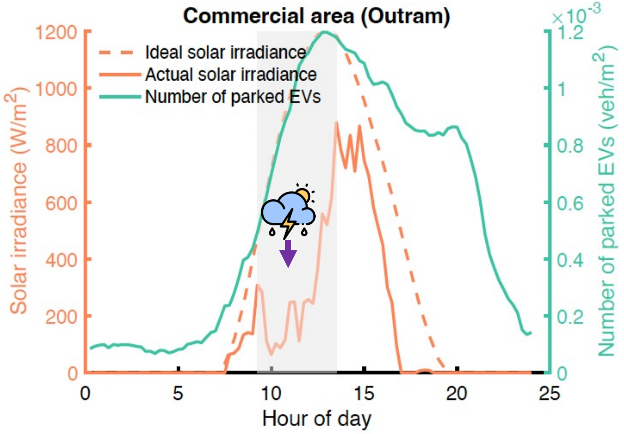
Mitigate local grid load fluctuations in tropical climate

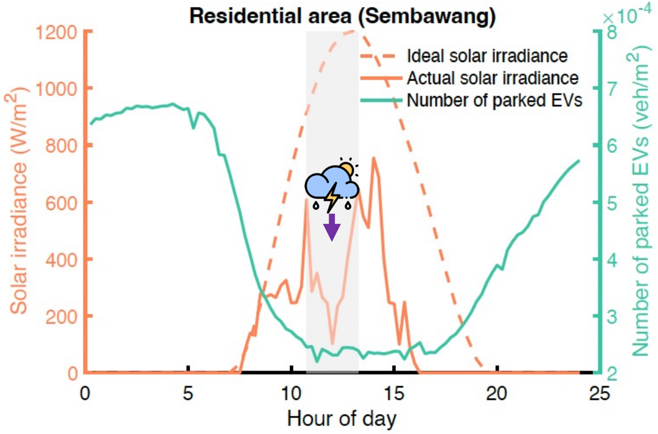
Tropical climate poses challenges to energy stability





- Singapore's tropical climate leads to highly variable solar irradiance and PV output, posing challenges to energy stability.

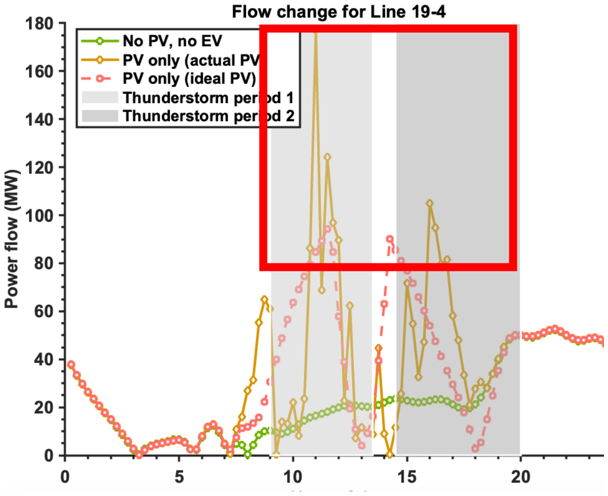




- The interaction between two dynamics, PV generation, and EV mobility, is quite complicated.

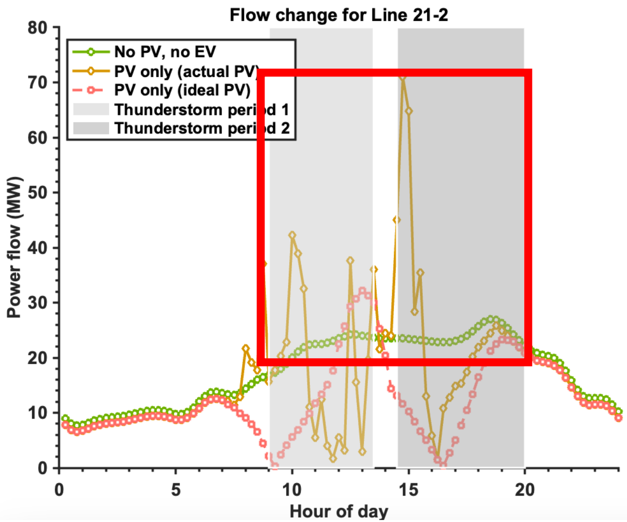
Impact of thunderstorms on power-line

Pioneer to Boon Lay



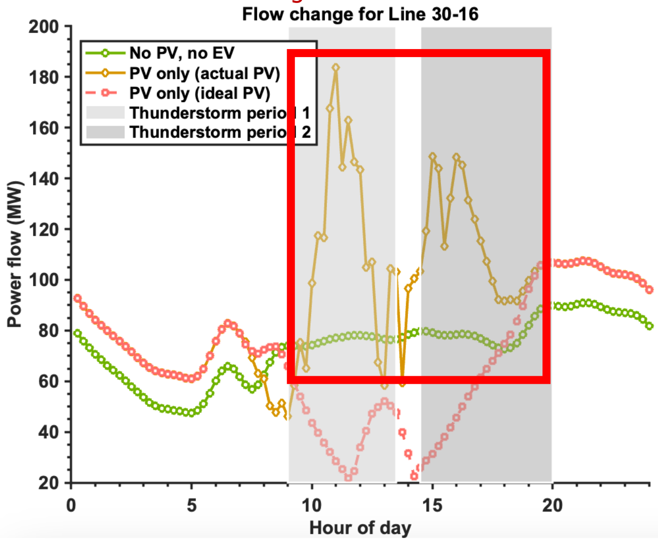
Maximum line load increases by 100% due to thunderstorms

Paya Lebar to Bedok



Maximum line load increases by >100% due to thunderstorms

Mandai to Sugei Kadut



Maximum line load increases by >80% due to thunderstorms

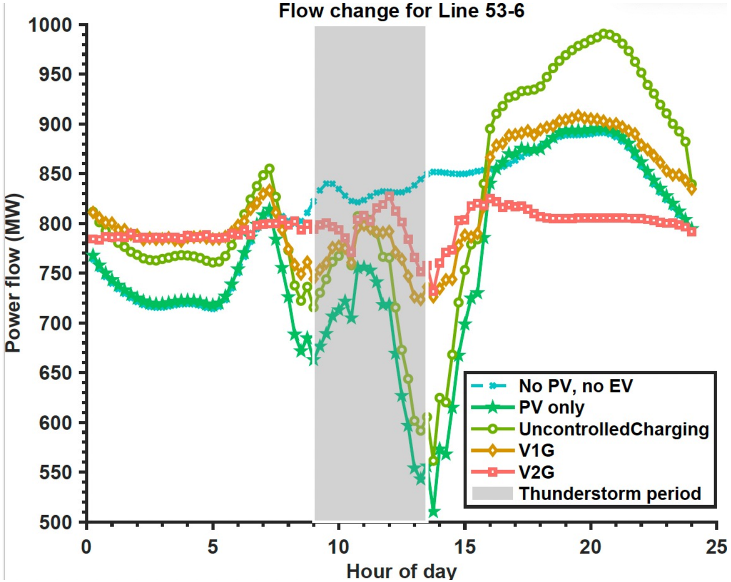
- Thunderstorms lead to increased loads on some lines, which can cause **overloading problems and threaten power stability.**
- On sunny day, power flow increase by 80.5% due to PV production.
- During thunderstorm, flow can increase up to 238.5%
  - Increases in flow put higher pressure on transmission lines.
  - Requires upgrade to power infrastructure.

EV with charging strategy (V2G) flatten the line flows (selected line)

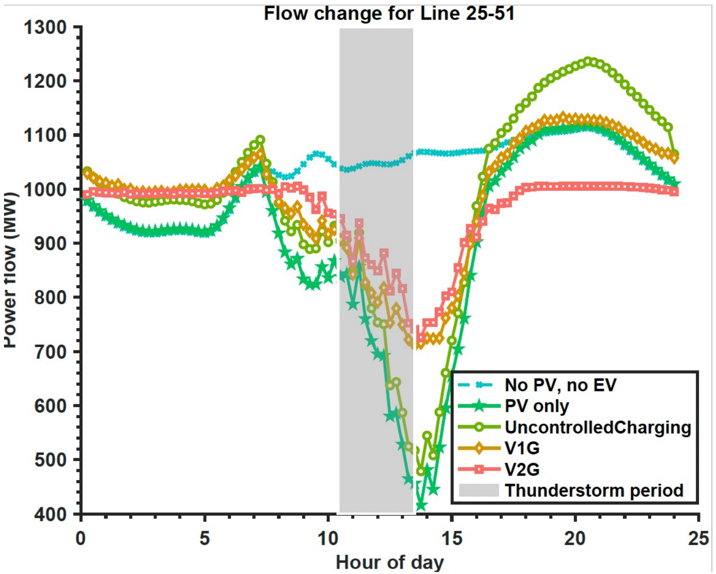
Scenarios：
- **No PV, no EV:** baseline scenario without PV and EV
- **PV only:** baseline + PV
- **Uncontrolled charging:** baseline + PV + controlled EV charging
- **V1G:** baseline + PV + controlled uni-directional charging
- **V2G:** baseline + PV + controlled bi-directional charging

V2G and V1G could reduce peak power flow and reduce fluctuation.

Outram



Sembawang



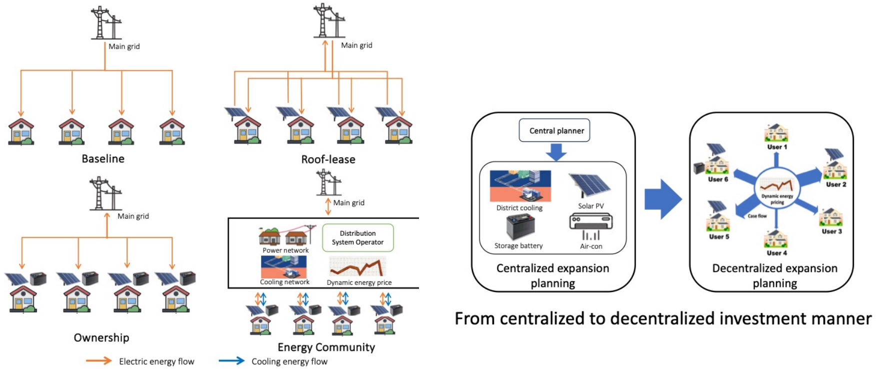
Conclusion

Conclusion

- EV mobility modelling from mobile phone data.
  - Utilize spatial information (individual-level trajectory)
- Peak load reduction (with EV and PV)
  - Show V2G reduced grid load variability by using fine-grained spatial-temporal mobility patterns.
- Local grid load in tropical climates
  - Thunderstorms impacted PV generation and grid stability.
  - V2G could be used to stabilize the load fluctuation.

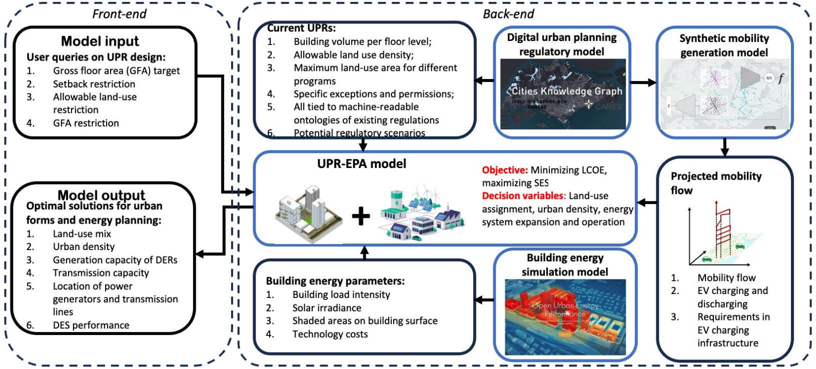
Recommendation

- Stationary Battery Storage & Decentralized business model for solar investment
  - **WP4. Socioeconomic**
- Change in the urban landuse archetype
  - Adaptive landscape mobility generation



Business models for Solar Investment in Singapore

From centralized to decentralized investment manner



Best Application Paper Award

Jiazu Zhou, Seanglidet Yean, Tianyu Dong, Bu Sung Lee, Markus Schlapfer, “Estimating electric vehicle charging demand and its impact on the power grid using mobile phone data”, 27th IEEE International Conference on Intelligent Transportation Systems · September 24 - 27, 2024 · Edmonton, Canada.

Thank you!

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