THE UNIVERSITY OF MELBOURNE

Energy Networks Australia

The Australian Power Institute

C4NET Centre for New Energy Technologies

Part 1
Managing EVs in Australian Urban and Rural Grids: Initial Findings

Part 2
EV Charging Consumer Survey: Insights Report

Managing EVs in Australian Urban and Rural Grids: Initial Findings

Electric Vehicle Integration Project

Prof Luis(Nando) Ochoa

Dr William Nacmanson

Webinar

15th February, 2022

Outline

1. The “EV[1] Integration” Project
2. Context: EVs and the Grid
3. EV Charging Point Management (Initial Findings)
4. Key Remarks and Next Steps

[1] EV = Electric Vehicle

1 The “EV Integration” Project

- UoM Project Website
- C4NET Project Website

EV Integration Project
Scope

The project (Sep 2020 to Sep 2022) explores four key research areas:

1. Customer acceptance and expectations around EVs (Apr 2021)
2. Distribution network impacts from unmanaged EVs (Sep 2021)
3. **Distribution network integration of EVs using active management strategies** (Mar 2022)
4. Techno-economic network and system integration of EVs (Sep 2022)

EV Integration Project
Team

- Prof Pierluigi Mancarella (Techno-Economics)
- Prof Luis(Nando) Ochoa (Distribution Networks)
- Dr Patricia Lavieri (Customers)
- Prof Majid Sarvi (Transport)
- Dr William Nacmanson, Dr Shariq Riaz
- Carmen Bas Domenech, Jing Zhu, Gabriel Oliveira
- Data and know-how from DNSPs

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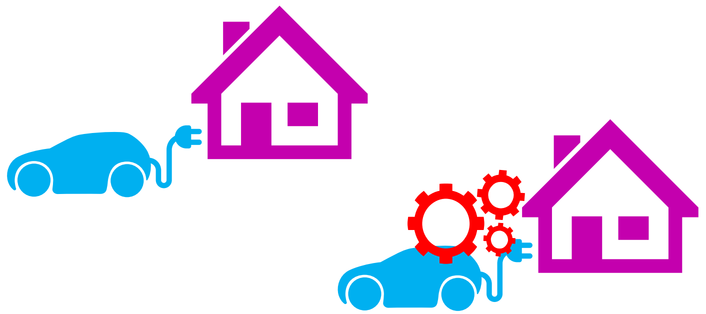
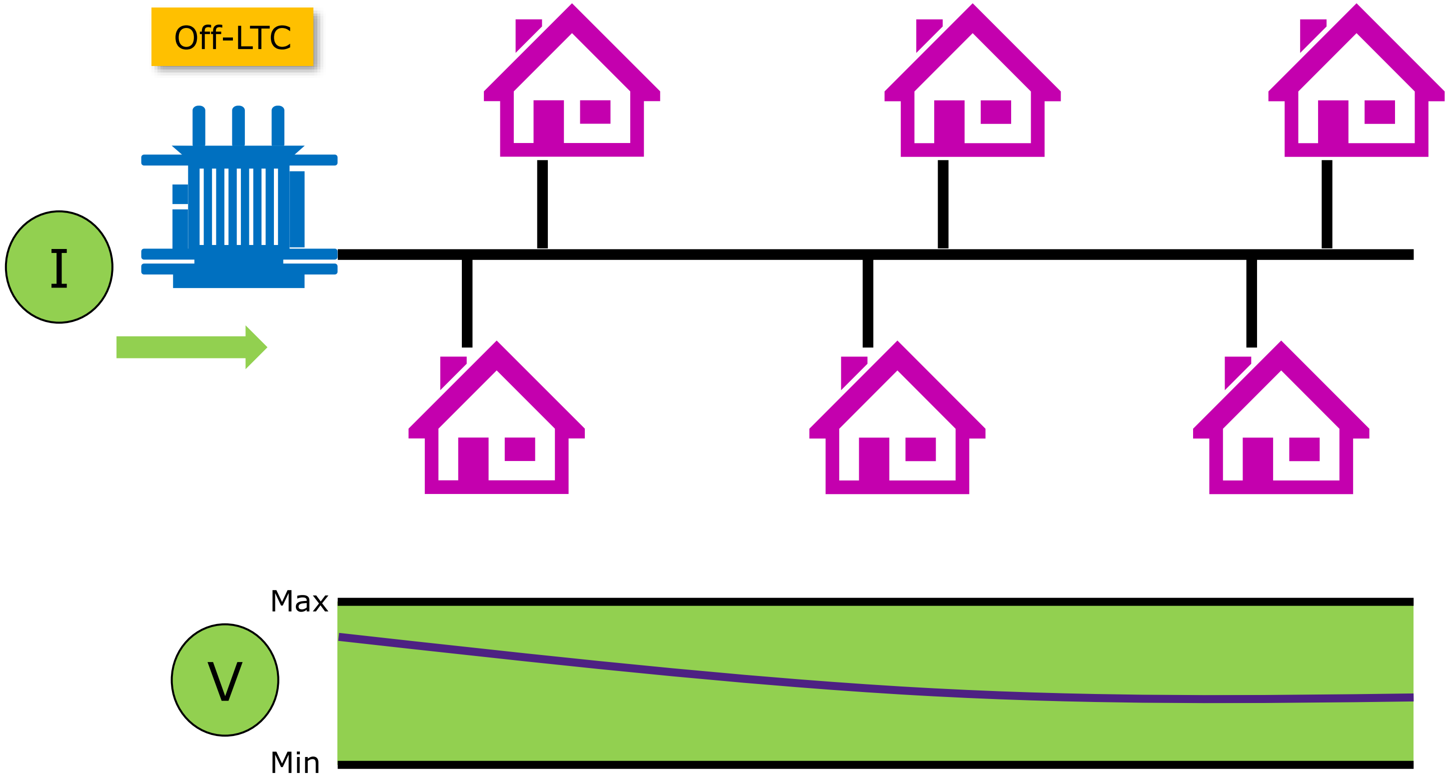


2 Context: EVs and the Grid

Low Voltage (LV) Networks – Design Principles



LV Feeder (3ϕ): 400V L-L
Homes (1ϕ): 230V L-N

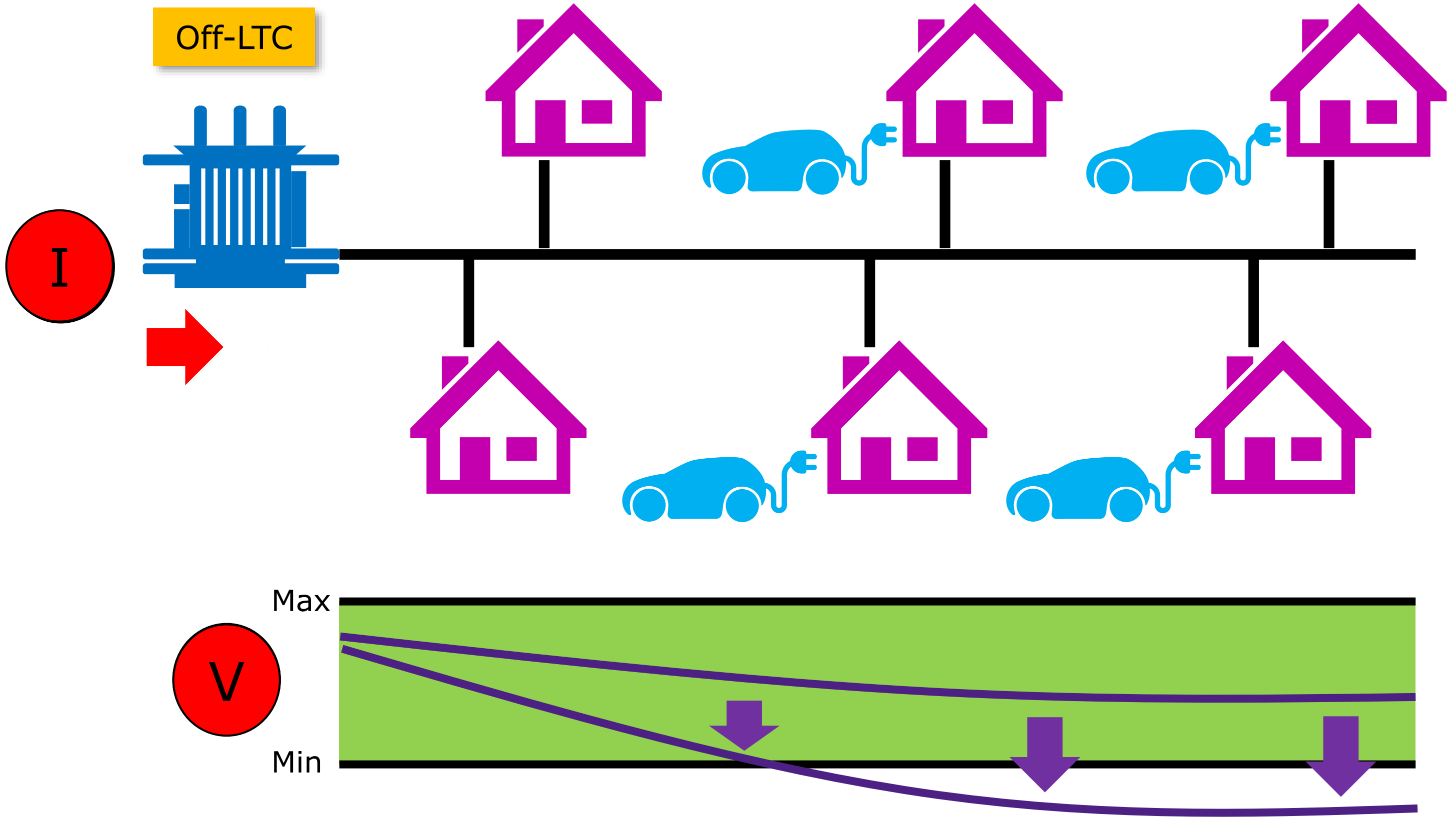
- ✓ Diversity
- ✓ Demographics
- ✓ Demand growth

Typical 1ϕ ADMD[2]	
NSW	6.5 kVA
VIC	3 to 5 kVA
TAS	4 to 6 kVA

Australian LV Networks are **designed** for an ADMD[1] of 3 to 7kW per house.
In practice, we use a bit less → There is room for EVs ☺. *But how much room?*

[2] ADMD = After Diversity Maximum Demand. Estimated average coincident peak demand.

Residential EV Charging and LV Networks

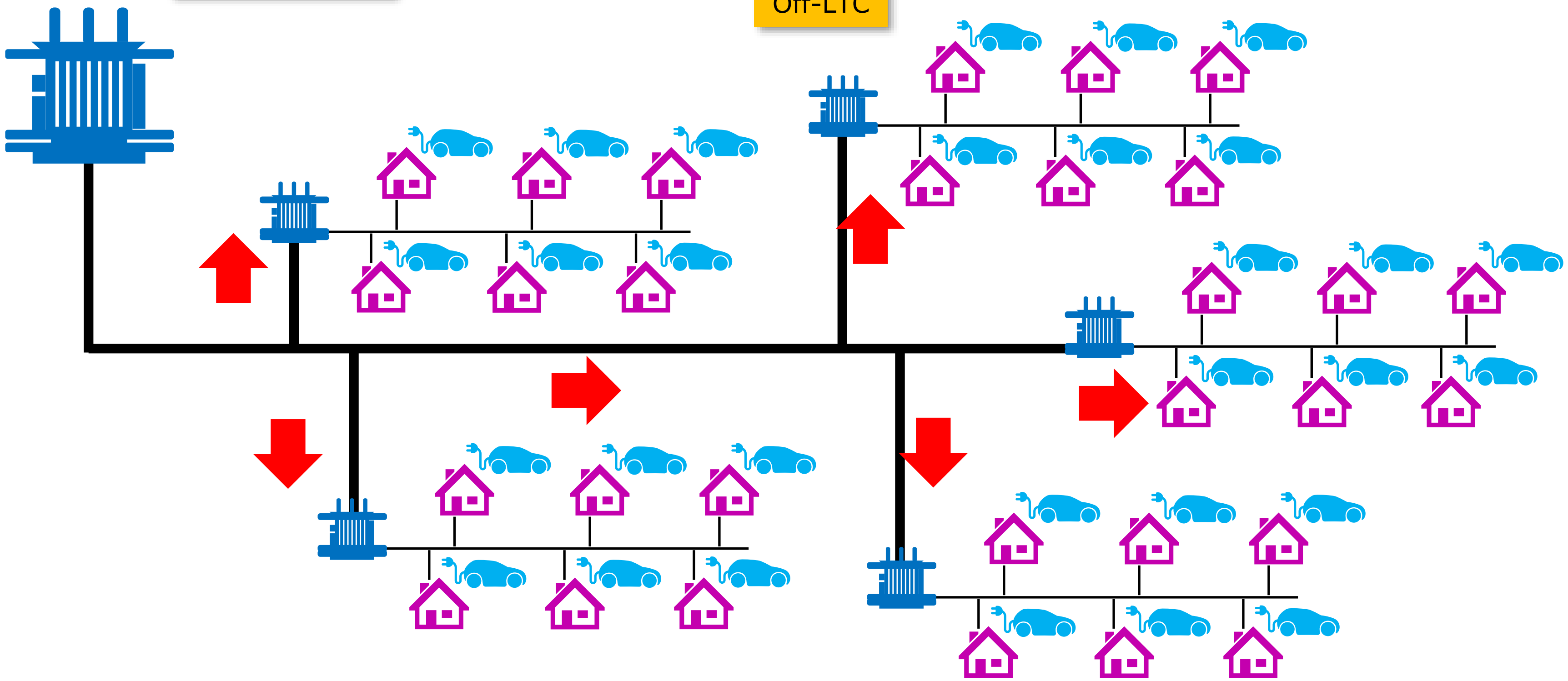


IEC 61851-1 1ϕ Modes	
Level 1	3.7 kW (16A, 230V)
Level 2	7.4 kW (32A, 230V)

EVs are charged when people return home → Larger peak demand

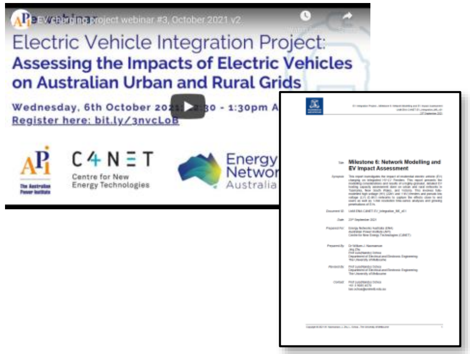
The trend is for *Level 2* charging → **New avg peak per house could be much larger**

EVs & High Voltage (HV) Networks



HV Feeder (3ϕ): 22kV L-L

Network Type	
Urban	⇩ Area ⇩ Z ⇧ Density ⇧ Tx kVA
Rural	⇧ Area ⇧ Z ⇩ Density ⇩ Tx kVA



I
V

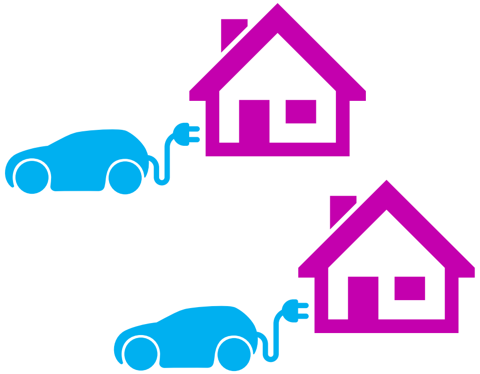
Widespread EV adoption → Widespread problems

1st How can we *determine* the EV hosting capacity of our networks?

2nd How can we *increase* that EV hosting capacity?

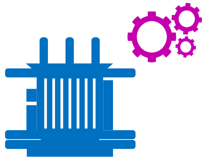
… Some Definitions

- EV <u>Hosting Capacity</u>
  - The maximum amount of EVs that a given distribution network (or part of it) can host *without negatively affecting its normal operation at any point in time*.
- Normal Operation
  - Voltages (statutory limits), asset utilisation (no congestion), protection, etc.
- Amount of EVs
  - Number (or %) of customers with EVs, kW of total charging infrastructure capacity, etc.



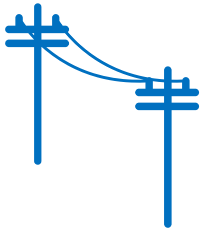
How can we increase EV Hosting Capacity?
(Some) Potential Solutions

- With existing assets
  - Better tap settings for **LV Off-LTCs** and better voltage target for **HV OLTCs**



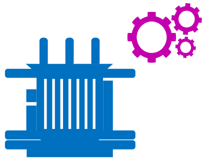
V✓ I✗ $$$

- With new assets
  - **Reinforcements** (transformer, conductors)



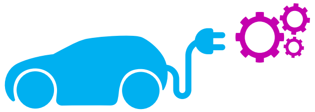
V? I✓ $$$

  - Voltage regulation with **HV/LV OLTCs**



V✓ I✗ $$$

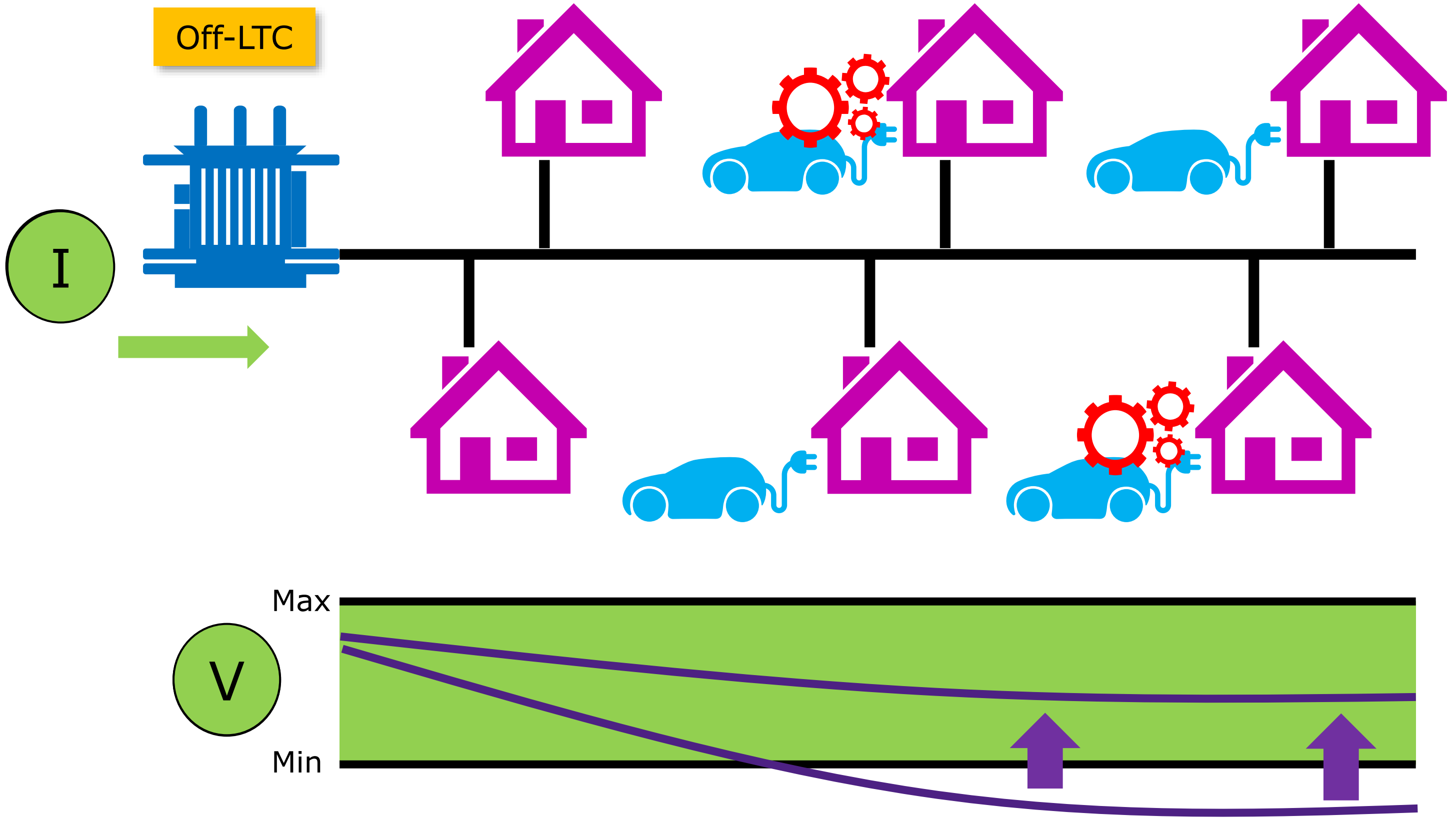
  - <u>Direct</u> or <u>indirect</u> management of **EVs**



V✓ I✓ $$$

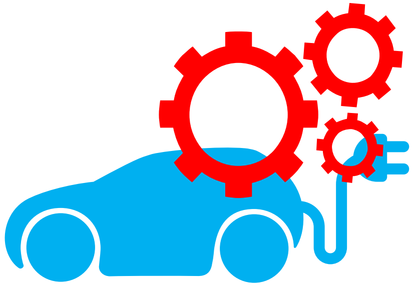
So, the management of EVs might be a good option ☺
But to what extent? And what about EV users?

Direct or Indirect Management of EVs



Direct (DNSP or third party)	
Disconnection of charging points	
Throttling or scheduling of charging	
Indirect	
Time-of-Use (ToU) tariffs	

EV impacts ***could*** be avoided by managing EVs.
But each management strategy has challenges.



Disconnection of charging points

3 EV Charging Point Management

Initial Findings

J. Quiros-Tortos, L. F. Ochoa, S. W. Alnaser, T. Butler, *Control of EV charging points for thermal and voltage management of LV networks*, IEEE Trans. On Power Systems, July 2016 (DOI and ResearchGate)

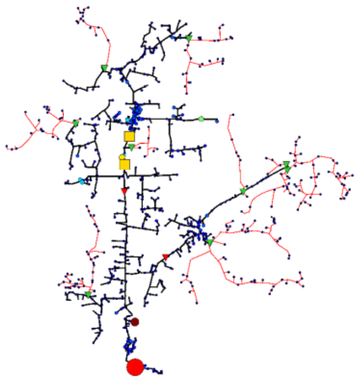
J. Quiros-Tortos, L. F. Ochoa, *Multi-year planning of LV networks with EVs accounting for customers, emissions and techno-economics aspects: A practical and scalable approach*, IET Generation Transmission & Distribution, Feb 2021 (DOI and ResearchGate)

Recap 1/2

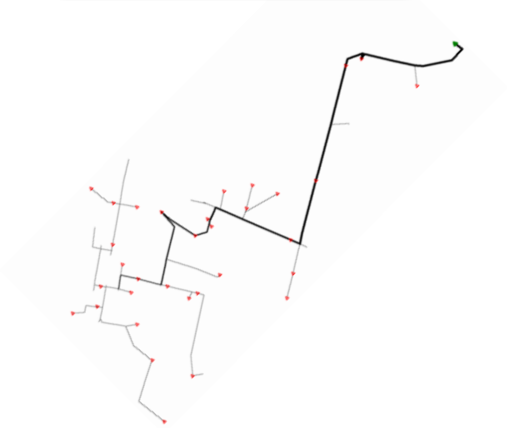
Six HV feeders (VIC, TAS and NSW) → HV-LV Feeders

Urban TAS
West Hobart (11kV)

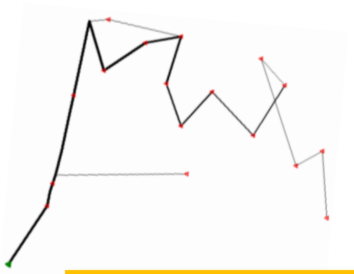
Feeder	Voltage Level (Total HV length)	No. Customers	No. LV Dist. Tx	Avg Residential Peak Size (kW)	Residential Data Used	ADMD (kW)	PV Penetration for Base Case (%)	Avg PV Size (kW)
Rural NSW (Hazelbrook)	11kV (20km)	1,401	39	2.0	VIC Smart Meter	6.5	24	3.8
Urban NSW (Preston)	11kV (6km)	616	17	2.0	VIC Smart Meter	6.5	30	5.8
Rural TAS (Norwood)	22kV (11km)	1,506	33	3.0	Avg Profile	5.0	0	-
Urban TAS (West Hobart)	11kV (6km)	620	12	3.5	Avg Profile	5.0	0	-
Rural VIC (SMR8)	22kV (486km)	3,669	765	2.0	VIC Smart Meter	4.0	0	-
Urban VIC (CRE21)	22kV (30km)	3,383	80	2.0	VIC Smart Meter	4.0	0	-



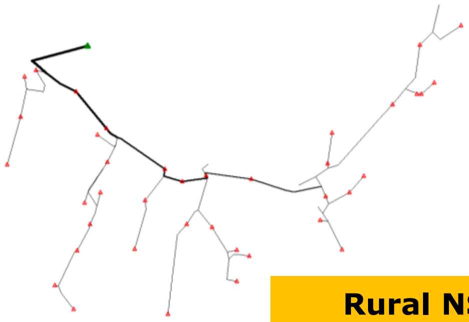
Rural VIC
SMR8 (22kV)



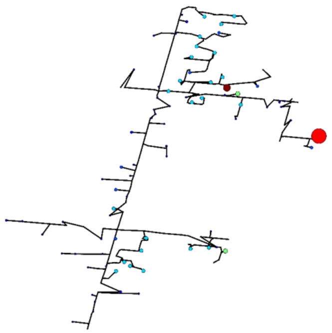
Rural TAS
Norwood (22kV)



Urban NSW
Preston (11kV)



Rural NSW
Hazelbrook (11kV)



Urban VIC
CRE21 (22kV)

Recap 2/2

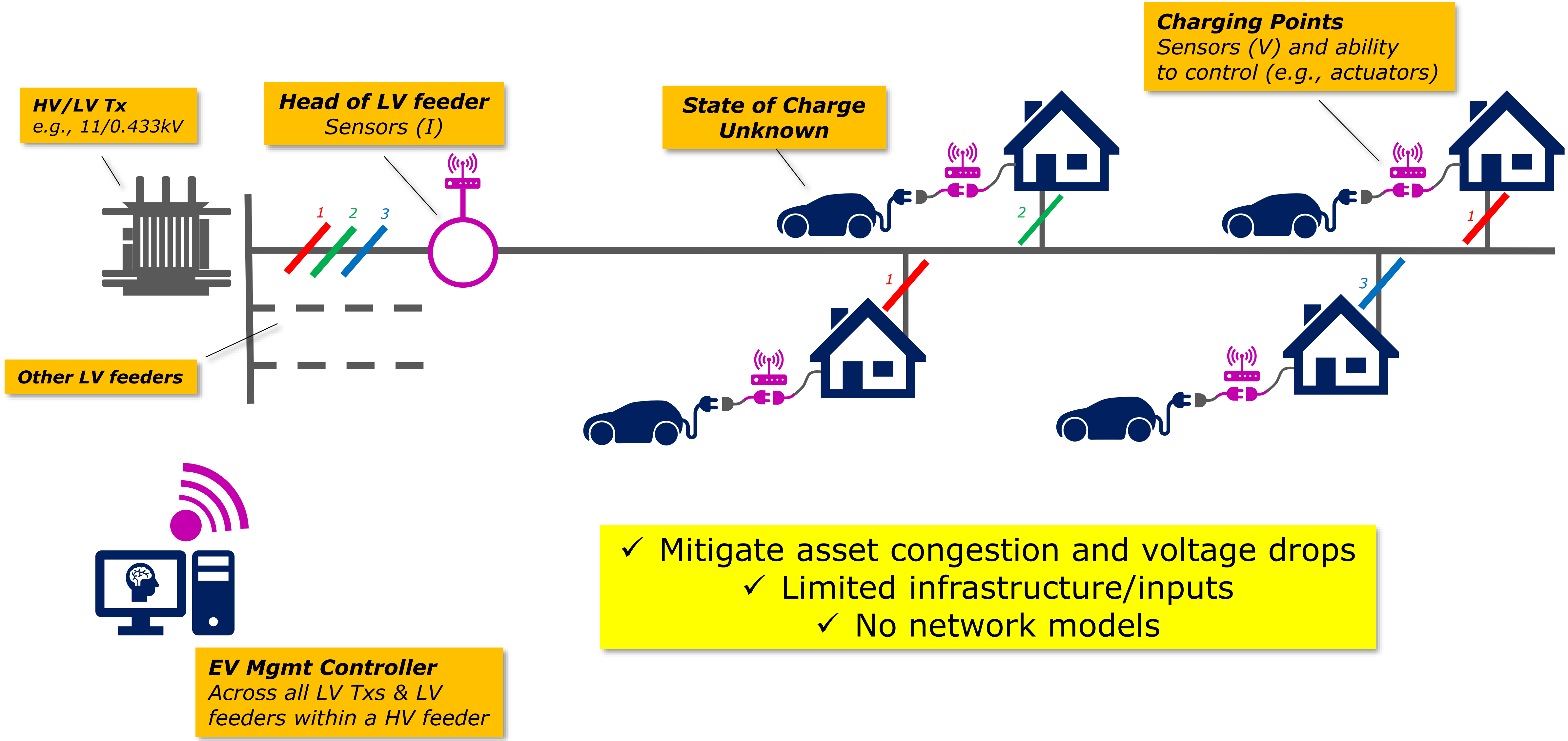
EV Hosting Capacity Summary (BAU)

All within limit
Marginally exceeding limit
Significantly exceeding limit

Network	EV Hosting Capacity							
	20%	40%	60%	80%	100%	120%	140%	160%
Rural NSW	V Cust LV TX LV Cond HV Cond	V Cust LV TX LV Cond HV Cond	V Cust LV TX LV Cond HV Cond	V Cust LV TX LV Cond HV Cond	V Cust LV TX LV Cond HV Cond	V Cust LV TX LV Cond HV Cond	V Cust LV TX LV Cond HV Cond	V Cust LV TX LV Cond HV Cond
Urban NSW	V Cust LV TX LV Cond HV Cond	V Cust LV TX LV Cond HV Cond	V Cust LV TX LV Cond HV Cond	V Cust LV TX LV Cond HV Cond	V Cust LV TX LV Cond HV Cond	V Cust LV TX LV Cond HV Cond	V Cust LV TX LV Cond HV Cond	V Cust LV TX LV Cond HV Cond
Rural TAS	V Cust LV TX LV Cond HV Cond	V Cust LV TX LV Cond HV Cond	V Cust LV TX LV Cond HV Cond	V Cust LV TX LV Cond HV Cond	V Cust LV TX LV Cond HV Cond	V Cust LV TX LV Cond HV Cond	V Cust LV TX LV Cond HV Cond	V Cust LV TX LV Cond HV Cond
Urban TAS	V Cust LV TX LV Cond HV Cond	V Cust LV TX LV Cond HV Cond	V Cust LV TX LV Cond HV Cond	V Cust LV TX LV Cond HV Cond	V Cust LV TX LV Cond HV Cond	V Cust LV TX LV Cond HV Cond	V Cust LV TX LV Cond HV Cond	V Cust LV TX LV Cond HV Cond
Rural VIC	V Cust LV TX LV Cond HV Cond	V Cust LV TX LV Cond HV Cond	V Cust LV TX LV Cond HV Cond	V Cust LV TX LV Cond HV Cond	V Cust LV TX LV Cond HV Cond	V Cust LV TX LV Cond HV Cond	V Cust LV TX LV Cond HV Cond	V Cust LV TX LV Cond HV Cond
Urban VIC	V Cust LV TX LV Cond HV Cond	V Cust LV TX LV Cond HV Cond	V Cust LV TX LV Cond HV Cond	V Cust LV TX LV Cond HV Cond	V Cust LV TX LV Cond HV Cond	V Cust LV TX LV Cond HV Cond	V Cust LV TX LV Cond HV Cond	V Cust LV TX LV Cond HV Cond

We need to mitigate asset congestion and voltage drops
… per transformer, per LV feeder, per phase, per customer

EV Charging Point Management Philosophy 1/2



- ✓ Mitigate asset congestion and voltage drops
- ✓ Limited infrastructure/inputs
- ✓ No network models

EV Charging Point Management Philosophy 2/2

1. **Check**
   - ✓ Per phase: voltages, LV conductor, LV transformer
   - ✓ Per LV feeder: voltages, LV conductor

2. **Disconnect** charging points when problems are detected
   - Following a hierarchical (corrective) approach

3. **Reconnect** charging points when no problems are detected
   - Following a hierarchical (preventive) approach

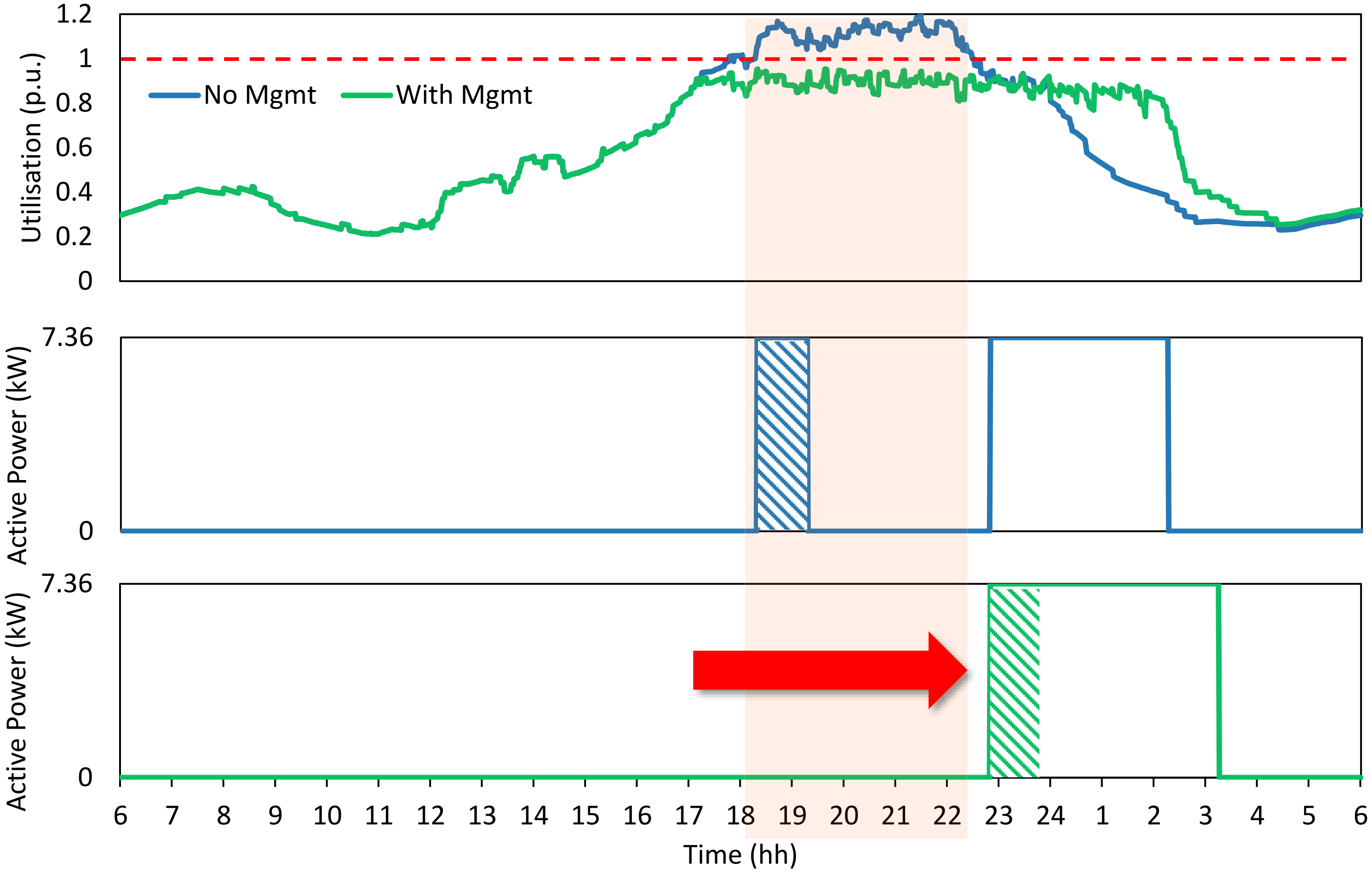
4. Selection of charging points based on length of connection (or disconnection)

EV Management: Effects on EV Users

LV Transformer Utilisation

No EV Management

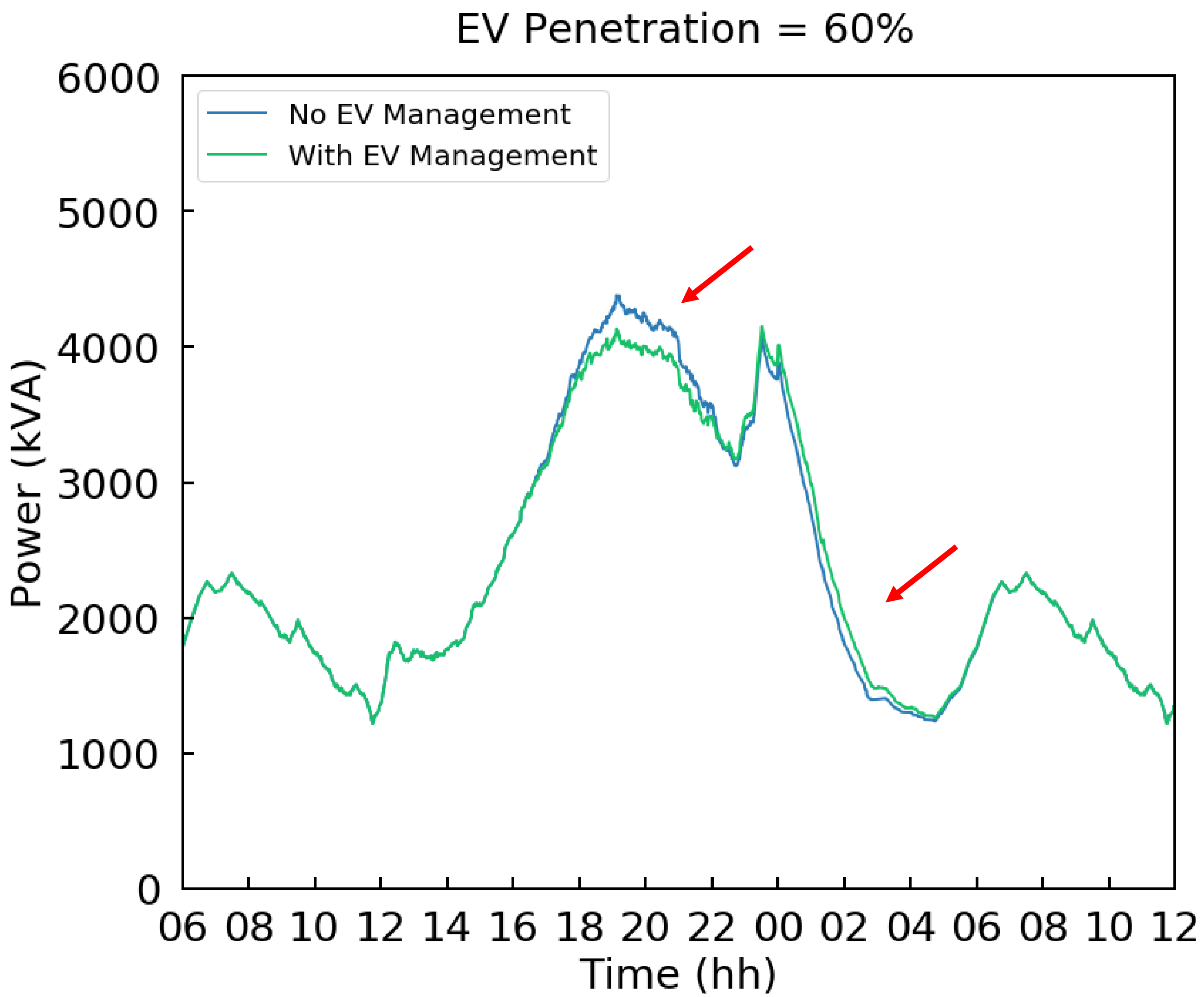
With EV Management



EV Management → Larger charging times
These effects need to be capture

Rural NSW: Results
Aggregated Demand (60% EV Penetration)

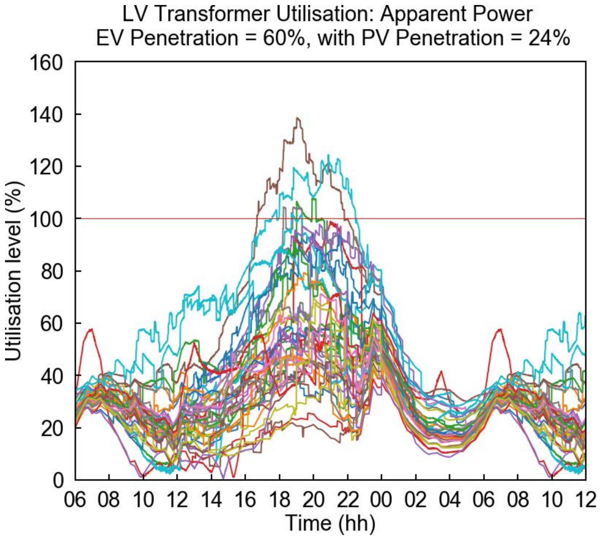
- **No EV Management**
  - ➢ Transformer congestion
  - ➢ Voltage drop issues
- **With EV Management**
  - ✓ No Tx congestion
  - ✓ No voltage issues
  - ✓ Reduced peak demand (6pm-9pm)
- EV charging for some customers is delayed to periods with spare capacity

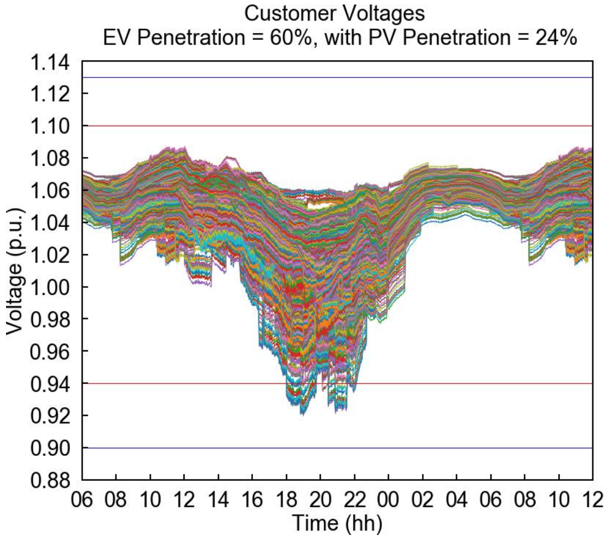


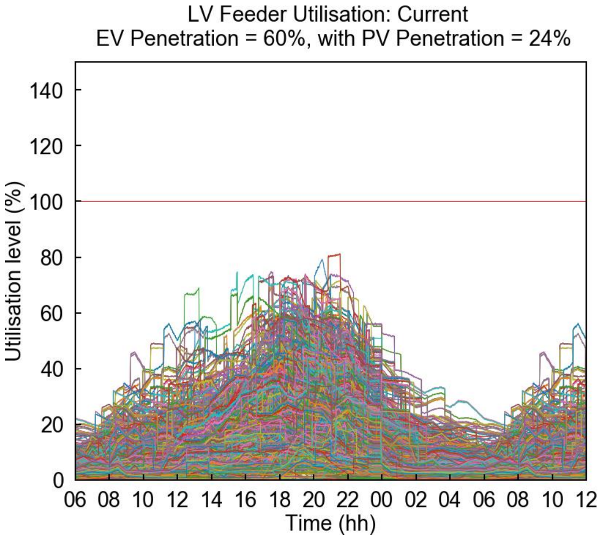
EV Management → Reduced Peak

Rural NSW: Results
Asset Congestion and Voltages (60% EV Penetration)

No EV Management

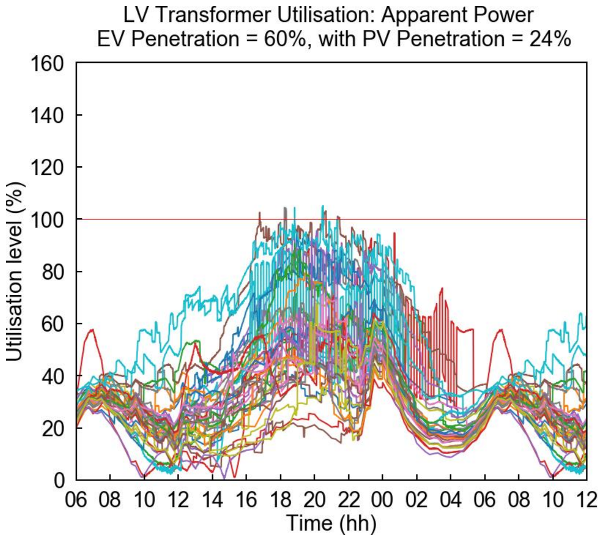


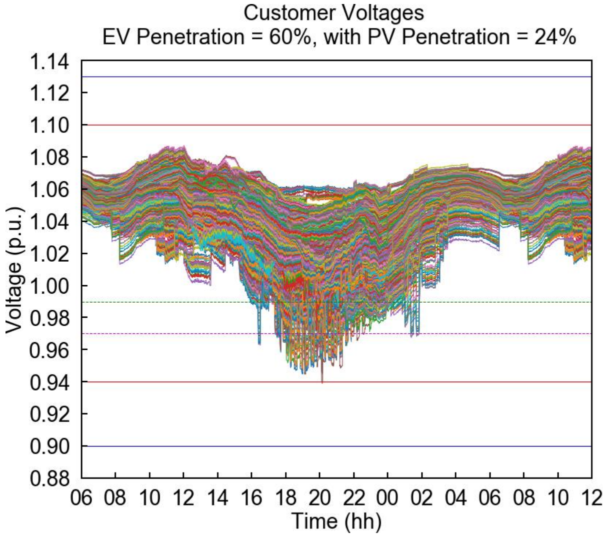


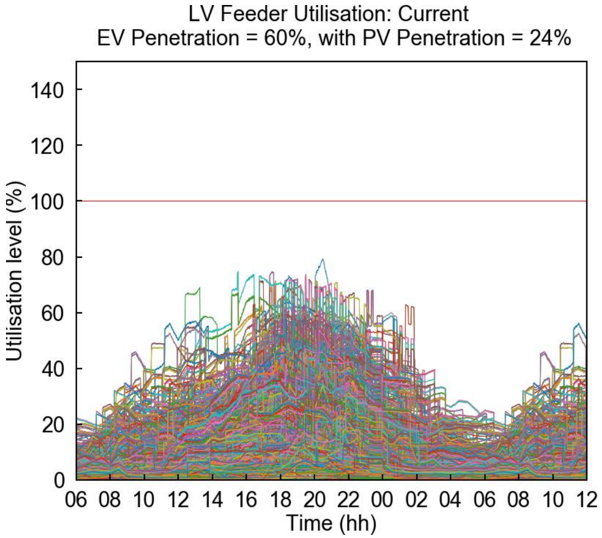


With EV Management

No network issues ☺

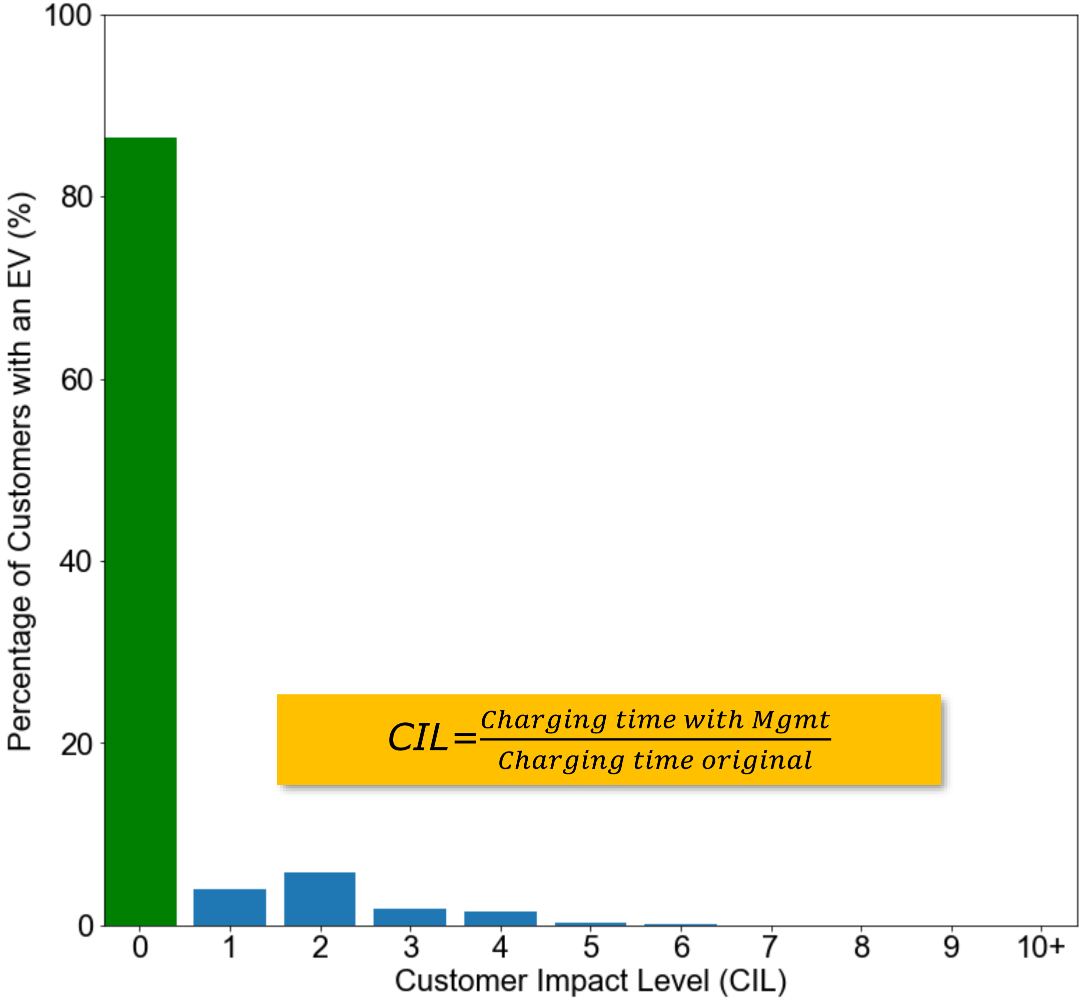


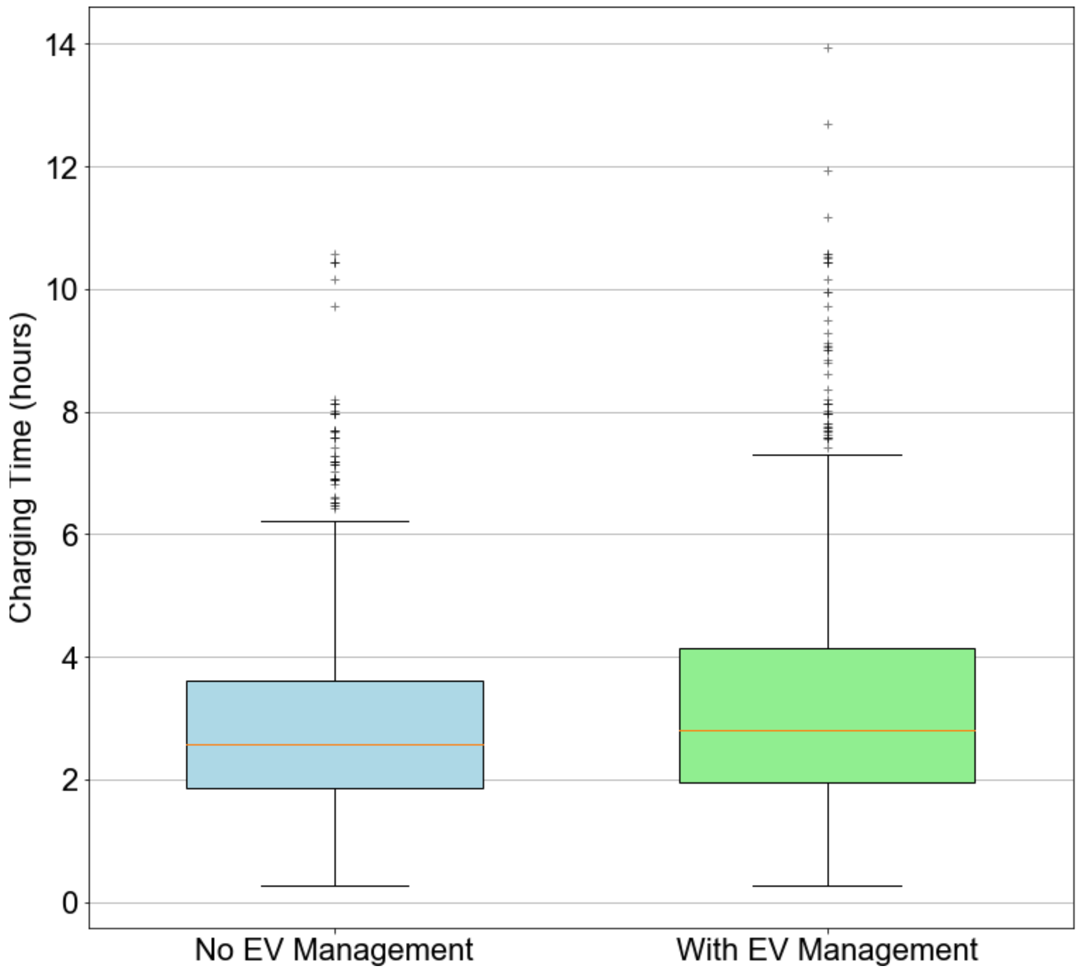




Rural NSW: Results

Customer Impact Level, CIL (60% EV Penetration)



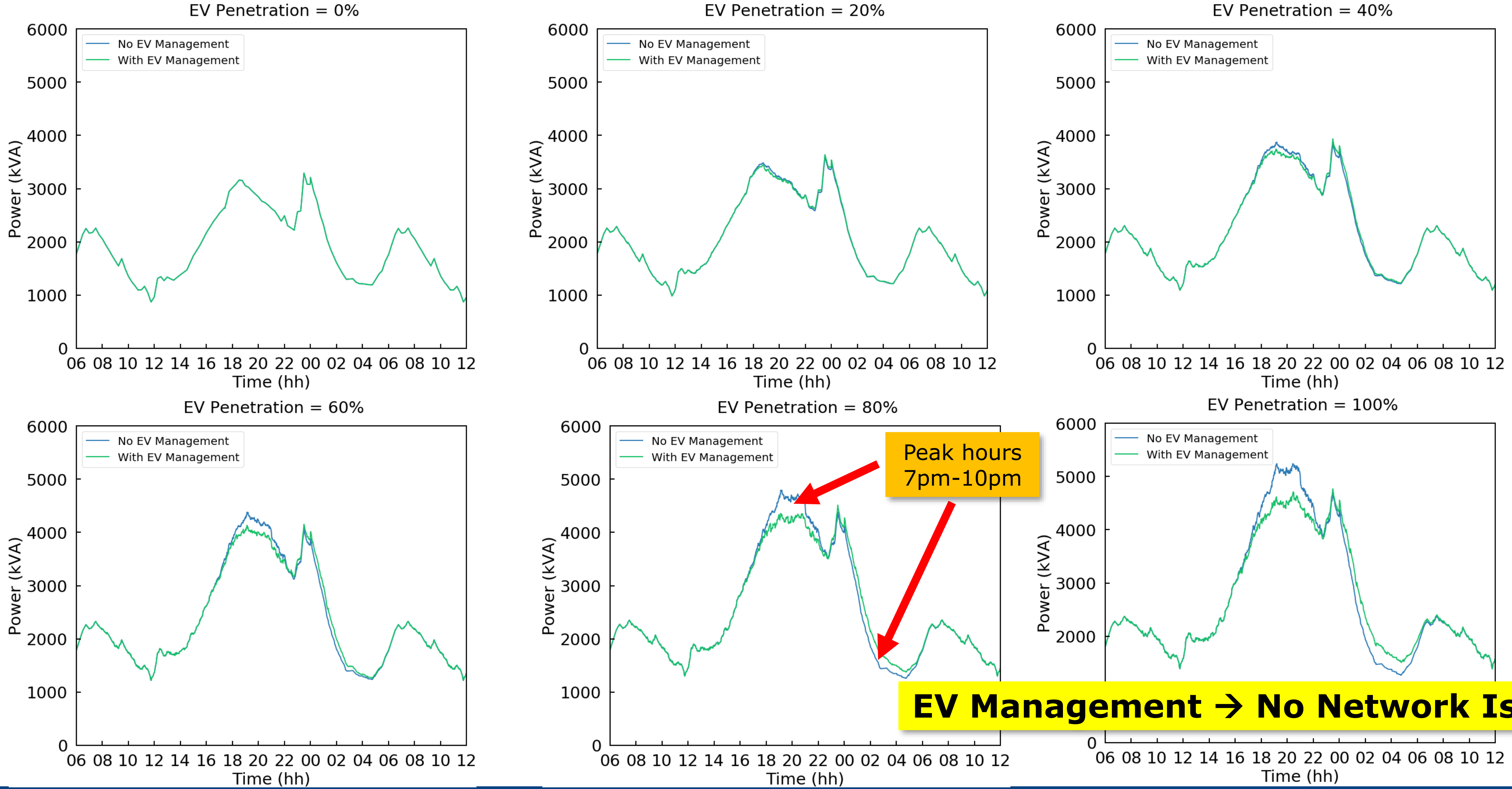


Most EV users are not affected ☺

… and longer charging happens mostly at night ☺

Rural NSW: Results

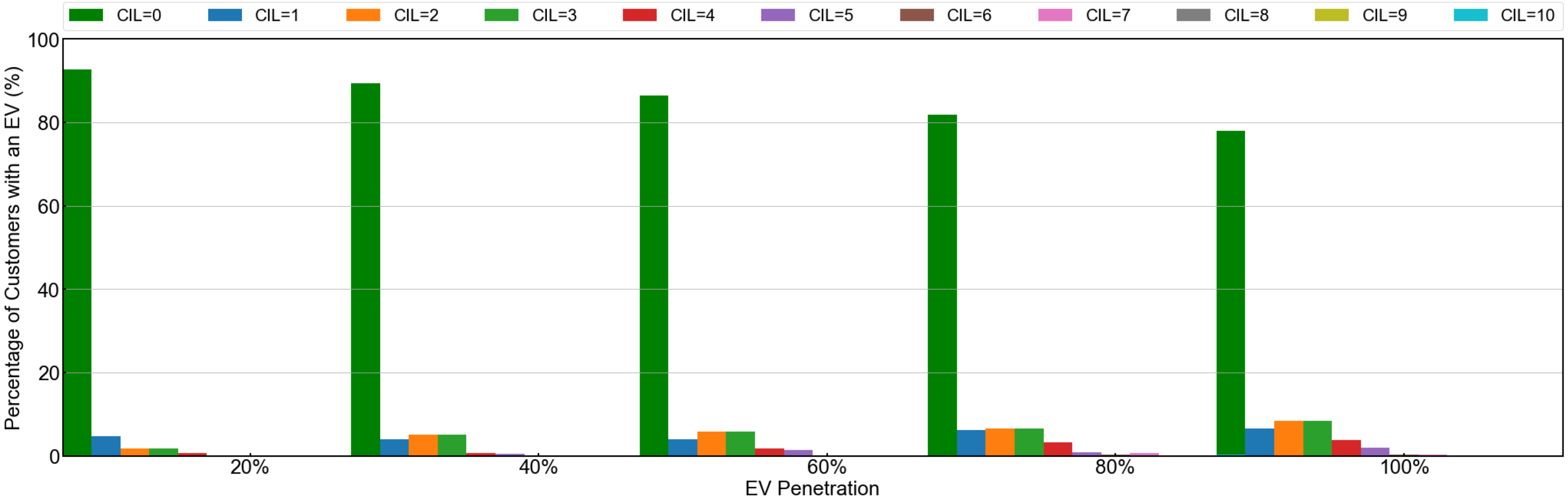
Aggregated Demand (0-100% EV Penetration)

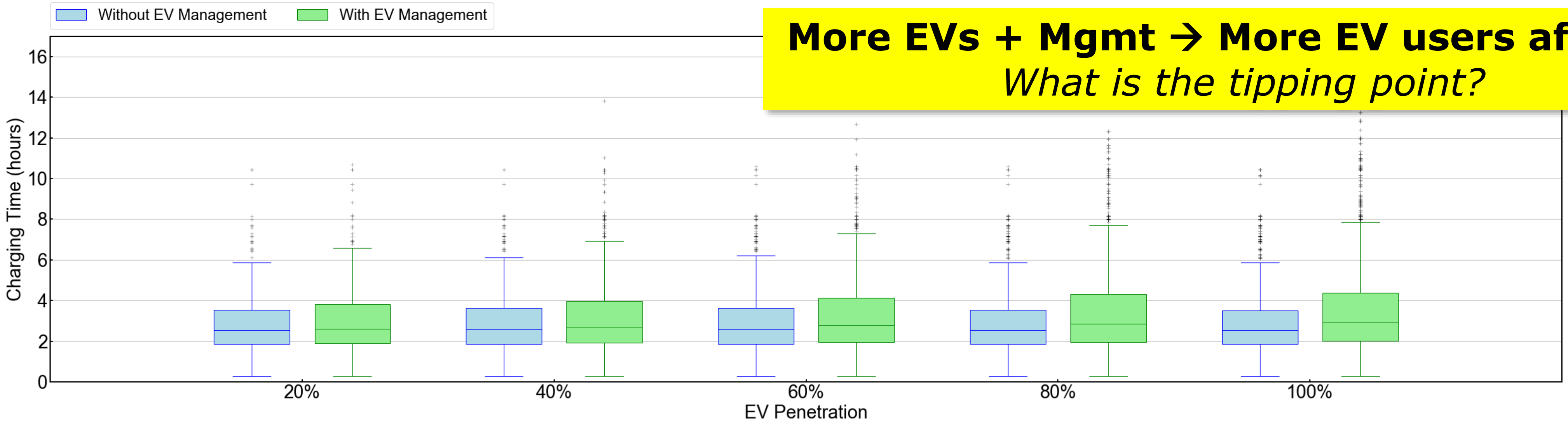


EV Management → No Network Issues

Rural NSW: Results

Customer Impact Level, CIL (0-100% EV Penetration)





More EVs + Mgmt → More EV users affected

What is the tipping point?

5 Key Remarks and Next Steps

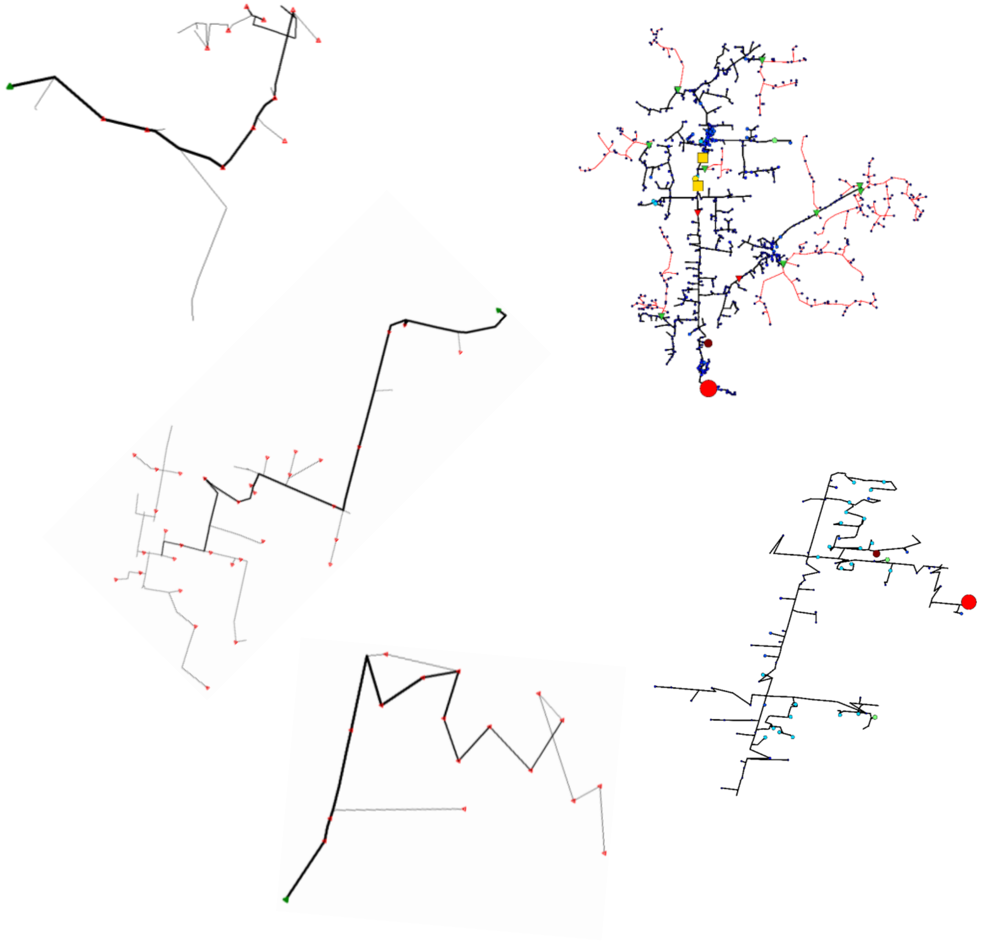
Key Remarks (Initial Findings)

- EV Charging Point Management brings opportunities and challenges
  - ✓ Simple rule-based control, limited info, scalable
  - ✓ Mitigates networks issues (voltages, asset congestion)
  - ✗ New infrastructure, cost
  - ✗ EV users will face longer charging periods

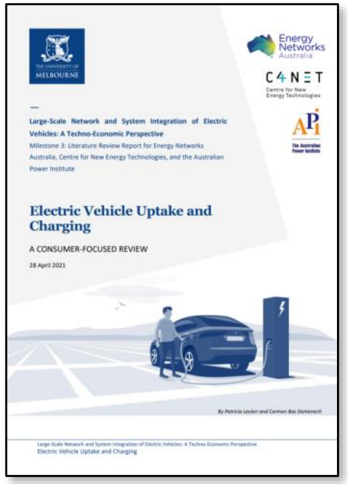
- What is the tipping point for EV management?
  - EV user acceptance vs. no/limited network augmentation
  - At high EV penetrations >75% of users are unaffected

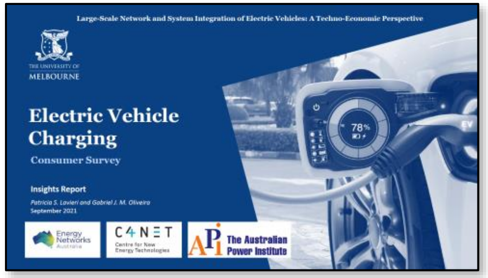
Next Steps

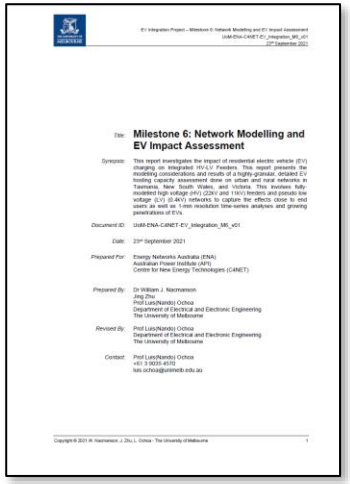
- EV Charging Point Management
  - Extended to the other HV-LV Networks
- Time-of-Use (ToU) Tariffs
  - Sensitivity analysis using the HV-LV Networks
- Report and Webinar in March/April ☺



Project Reports and Webinars



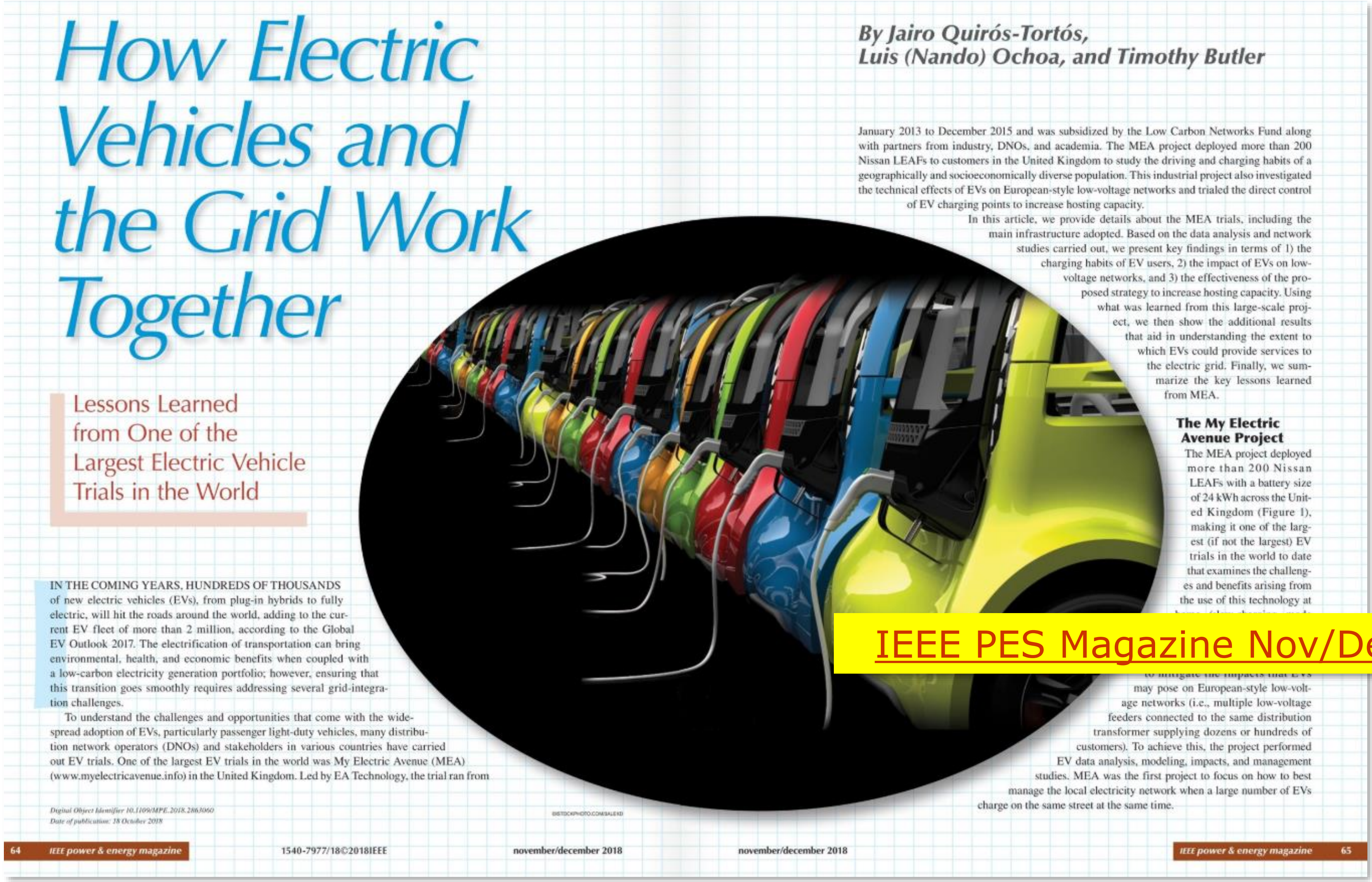




- **UoM Project Website**
- **C4NET Project Website**
- ✓ EV Demand Profiles (GitHub Repository)
- ✓ Milestone 6: Network Modelling and EV Impact Assessment
- ✓ Milestone 3: Electric Vehicle Charging: Consumer Survey
- ✓ Milestone 3: Electric Vehicle Uptake and Charging: A Consumer-Focused Review

GitHub

Further Reading 1/2



How Electric Vehicles and the Grid Work Together

Lessons Learned from One of the Largest Electric Vehicle Trials in the World

By Jairo Quirós-Tortós, Luis (Nando) Ochoa, and Timothy Butler

IN THE COMING YEARS, HUNDREDS OF THOUSANDS of new electric vehicles (EVs), from plug-in hybrids to fully electric, will hit the roads around the world, adding to the current EV fleet of more than 2 million, according to the Global EV Outlook 2017. The electrification of transportation can bring environmental, health, and economic benefits when coupled with a low-carbon electricity generation portfolio; however, ensuring that this transition goes smoothly requires addressing several grid-integration challenges.

To understand the challenges and opportunities that come with the widespread adoption of EVs, particularly passenger light-duty vehicles, many distribution network operators (DNOs) and stakeholders in various countries have carried out EV trials. One of the largest EV trials in the world was My Electric Avenue (MEA) (www.myelectricavenue.info) in the United Kingdom. Led by EA Technology, the trial ran from January 2013 to December 2015 and was subsidized by the Low Carbon Networks Fund along with partners from industry, DNOs, and academia. The MEA project deployed more than 200 Nissan LEAFs to customers in the United Kingdom to study the driving and charging habits of a geographically and socioeconomically diverse population. This industrial project also investigated the technical effects of EVs on European-style low-voltage networks and trialed the direct control of EV charging points to increase hosting capacity.

In this article, we provide details about the MEA trials, including the main infrastructure adopted. Based on the data analysis and network studies carried out, we present key findings in terms of 1) the charging habits of EV users, 2) the impact of EVs on low-voltage networks, and 3) the effectiveness of the proposed strategy to increase hosting capacity. Using what was learned from this large-scale project, we then show the additional results that aid in understanding the extent to which EVs could provide services to the electric grid. Finally, we summarize the key lessons learned from MEA.

The My Electric Avenue Project

The MEA project deployed more than 200 Nissan LEAFs with a battery size of 24 kWh across the United Kingdom (Figure 1), making it one of the largest (if not the largest) EV trials in the world to date that examines the challenges and benefits arising from the use of this technology at

[...] may pose on European-style low-voltage networks (i.e., multiple low-voltage feeders connected to the same distribution transformer supplying dozens or hundreds of customers). To achieve this, the project performed EV data analysis, modeling, impacts, and management studies. MEA was the first project to focus on how to best manage the local electricity network when a large number of EVs charge on the same street at the same time.

Digital Object Identifier 10.1109/MPE.2018.2863060
Date of publication: 18 October 2018

IEEE PES Magazine Nov/Dec 2018

Further Reading 2/2

- My Electric Avenue Project
  - Research Gate Website
  - EA Technology Summary Report and Data
- Electric Nation Project
  - Project Website and Data
- Relevant Publications

Multi-Year Planning of LV Networks with EVs Accounting for Customers, Emissions and Techno-Economics Aspects: A Practical and Scalable Approach, IET GTD, 2021 (DOI, ResearchGate)

Regional-Scale Allocation of Fast Charging Stations: Travel Times and Distribution System Reinforcements, IET GTD, 2020 (DOI, ResearchGate)

Advanced Control of OLTC-Enabled LV Networks with PV Systems and Electric Vehicles, IET GTD, 2019 (DOI, ResearchGate)

Control of EV Charging Points for Thermal and Voltage Management of LV Networks, IEEE Trans. on Power Systems, 2016 (DOI, ResearchGate)

Thanks!

Questions?

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Acknowledgement

- AusNet Services
- Energy Queensland
- Endeavour Energy
- Jemena
- Powercor/CitiPower/United Energy
- Powerlink
- TasNetworks

- Jing Zhu