Short Course on "Operating Envelopes and Their Implementation"

Day 2 Block 1

Actual Implementation of OEs in Australia

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14th March, 2024

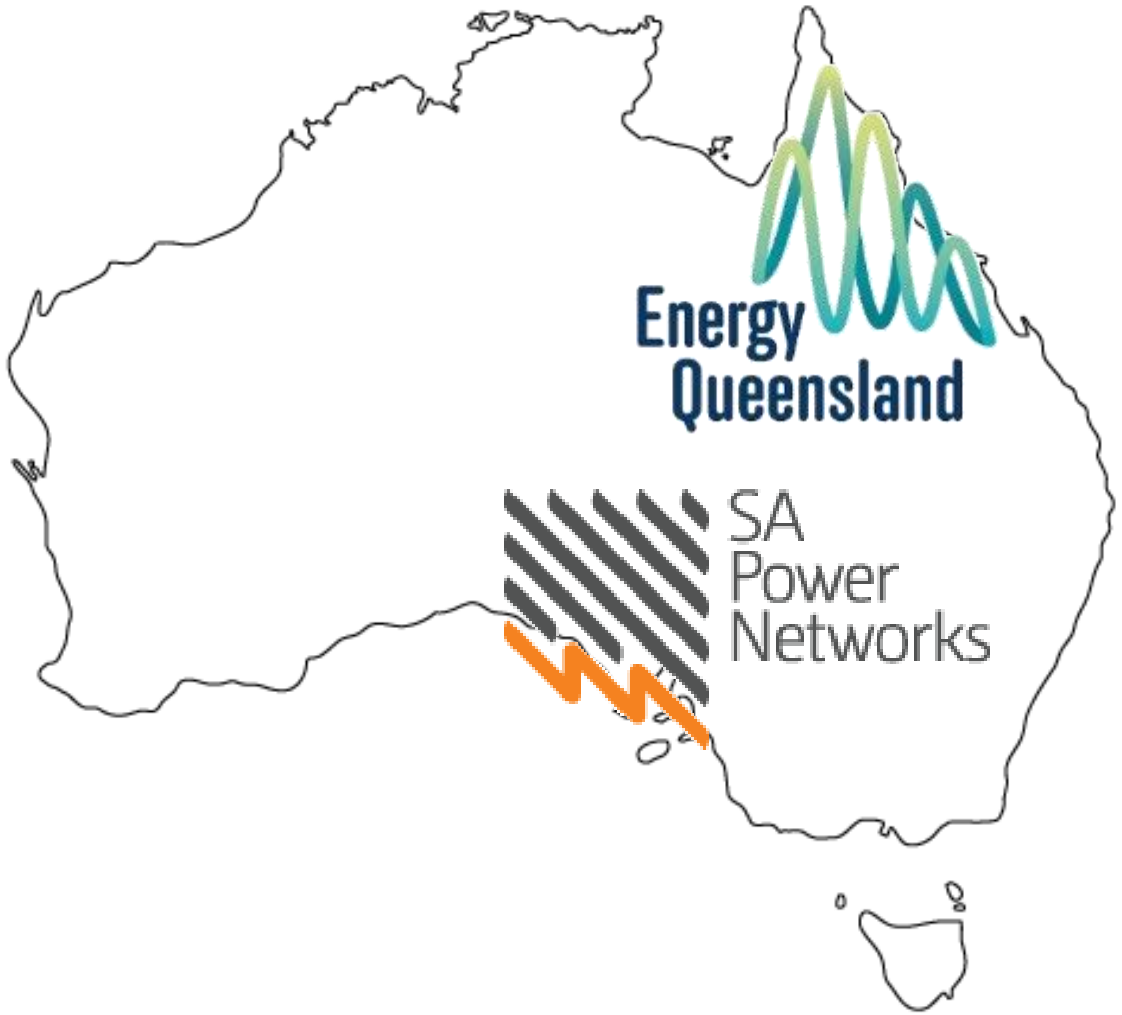
Acknowledgement of Country

We acknowledge the Traditional Owners of all the lands we are on today as well as where all The University of Melbourne campuses are situated.

We pay our respects to their Elders, past, present and emerging.

Actual Implementation of OEs in Australia
Structure

- 9:00am to 9:30am Alex Guinman
  - Preso followed by Q&A
- 9:30am to 9:55am Liam Mallamo
  - Preso followed by Q&A

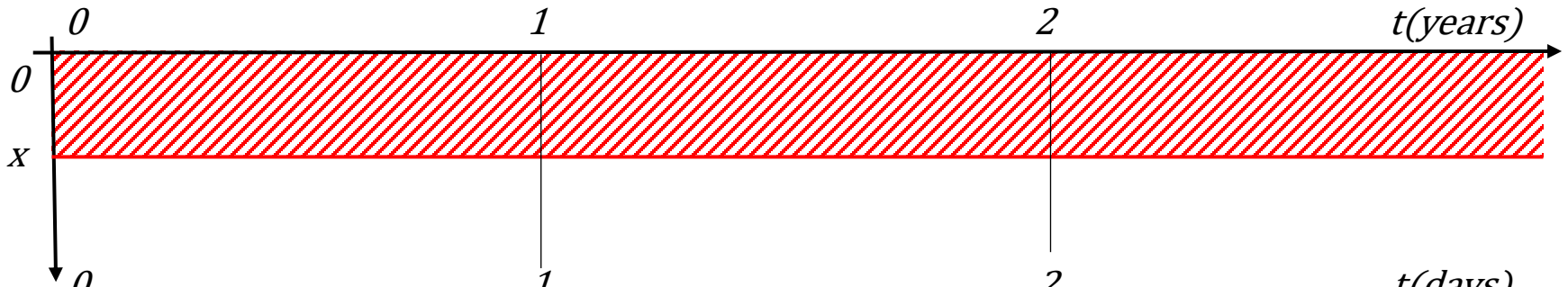


Dynamic Operating Envelopes

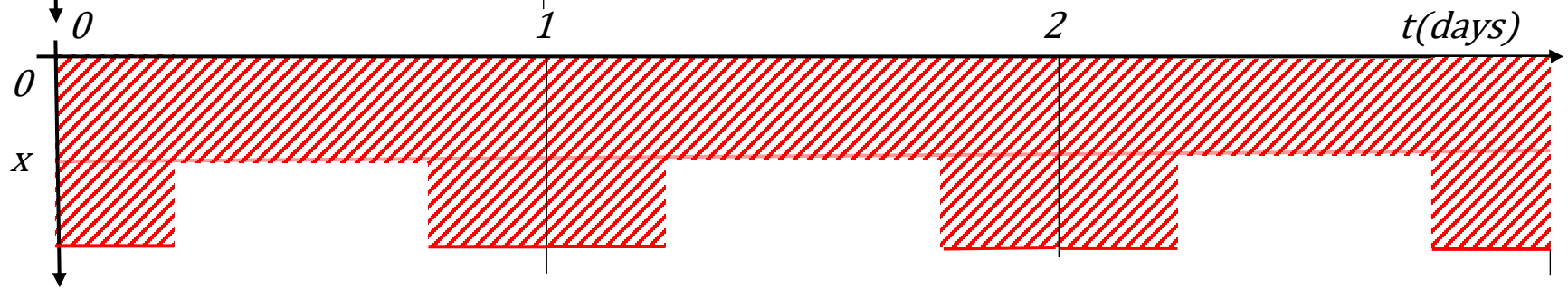
Part of Energy Queensland

Export Limits

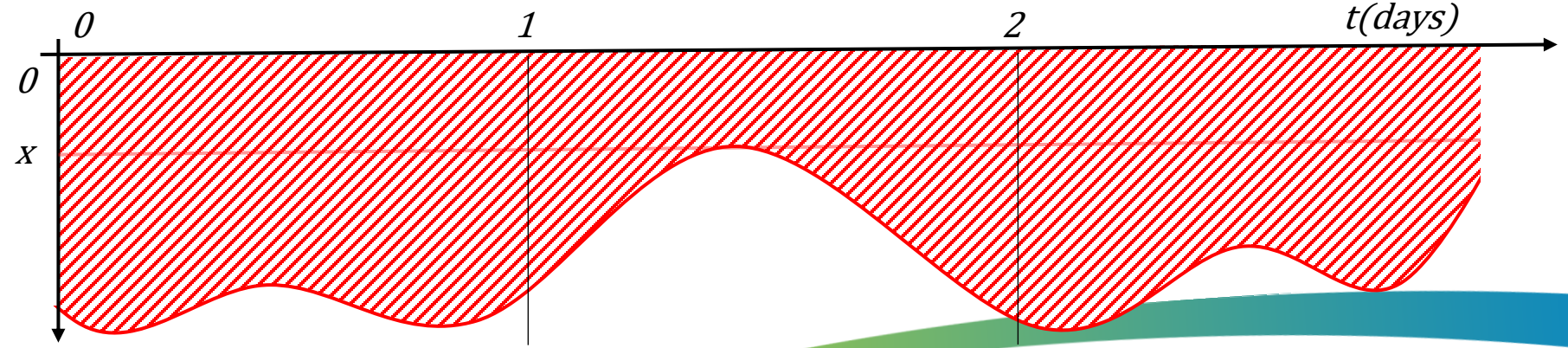
Static (-kW)



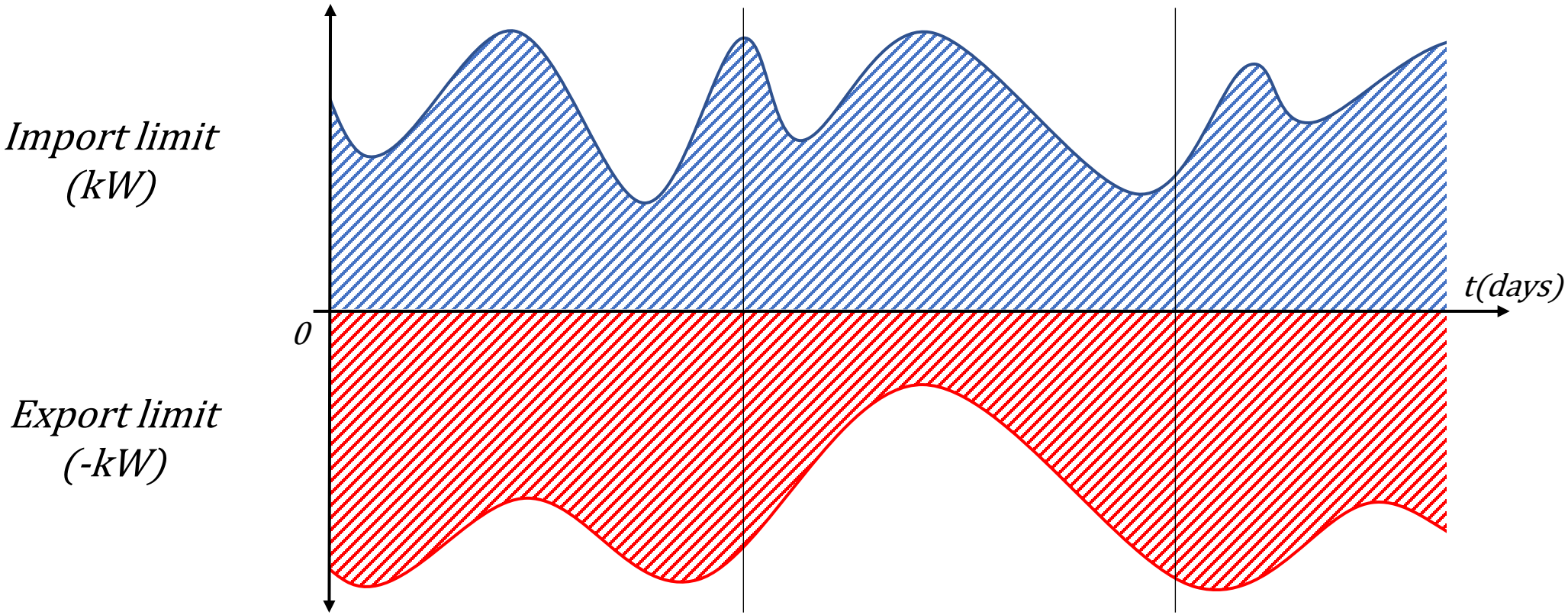
Scheduled (-kW)



Dynamic (-kW)



Dynamic Operating Envelopes (DOE)

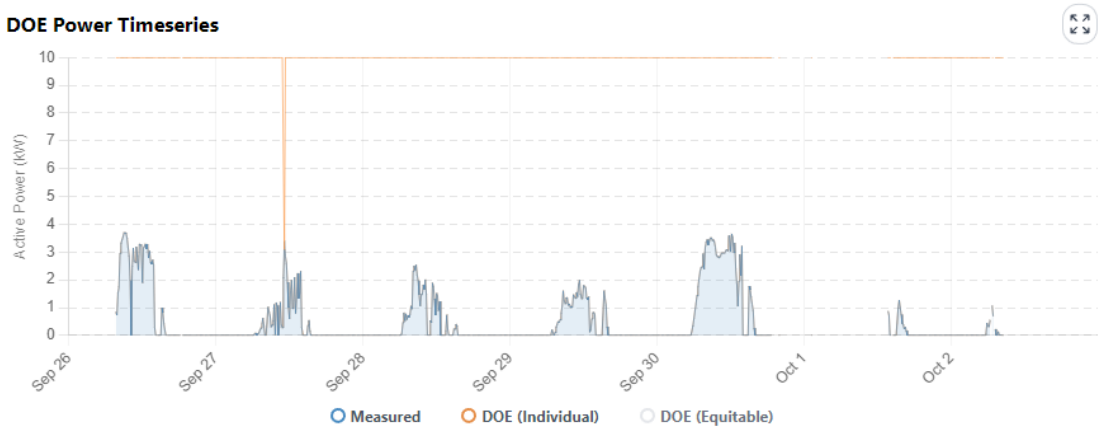


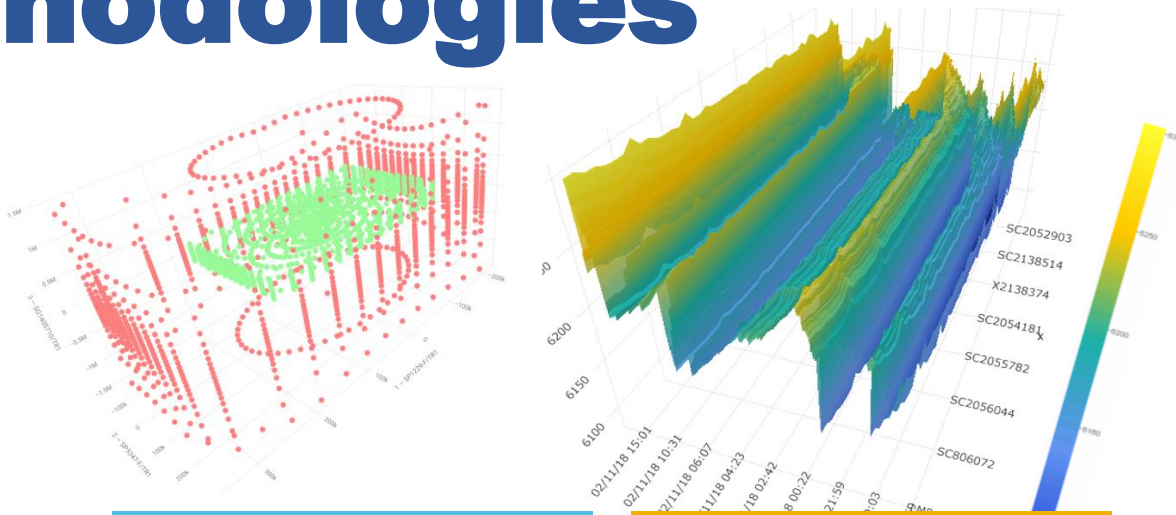
Why dynamic?

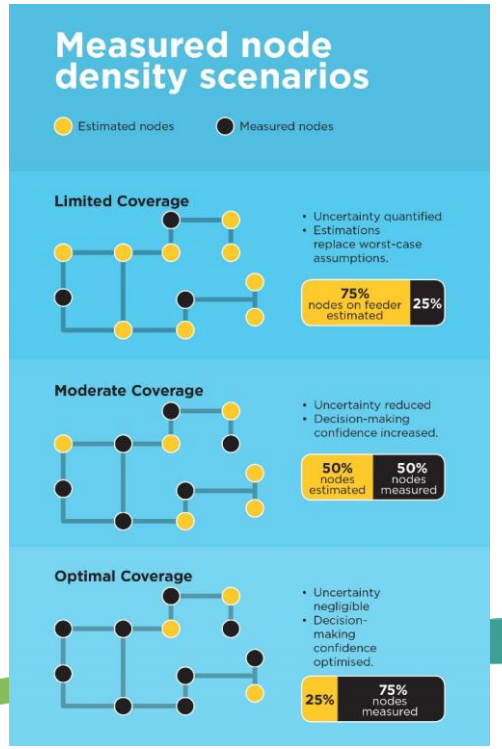
- Dynamic Embedded Generator Connections (negotiated)
  - Customers wanting more than 5 kW per phase export limit
  - Customers offered nil-export due to transformer constraint
    - 1.5 – 10 kW is an improvement from a nil-export
    - unlikely to get full 10 kW in middle of the day unless a PQ monitor installed
  - Single phase customers can get 10 kW PV + 10 kW BESS (20kW total)
- Dynamic EVSE
  - Single phase EVSE >20 A (as alternative to AFLC)

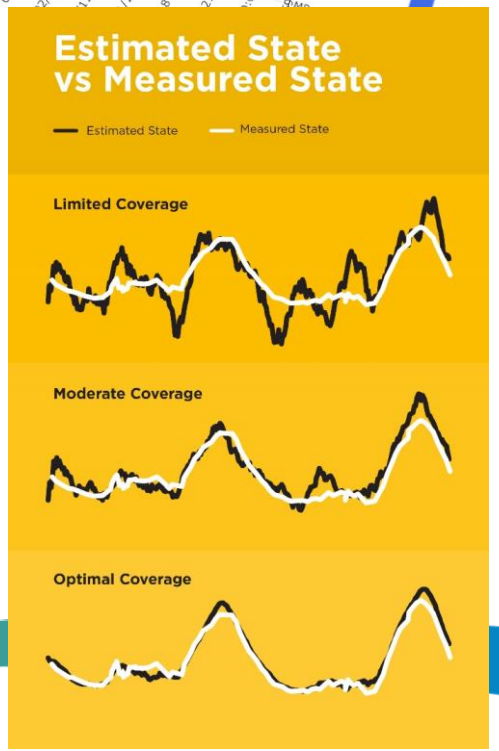
DOE Calculation Methodologies

- Basic/Scheduled DOE
  - Where no telemetry
  - DERMS fallback method
- Basic/Telemetered DOE
  - With Dtx. PQ monitor (or synthetic power flow)
- External/Advanced DOE
  - DSSE Capacity Constrained Optimisation
  - Model Free Optimisation







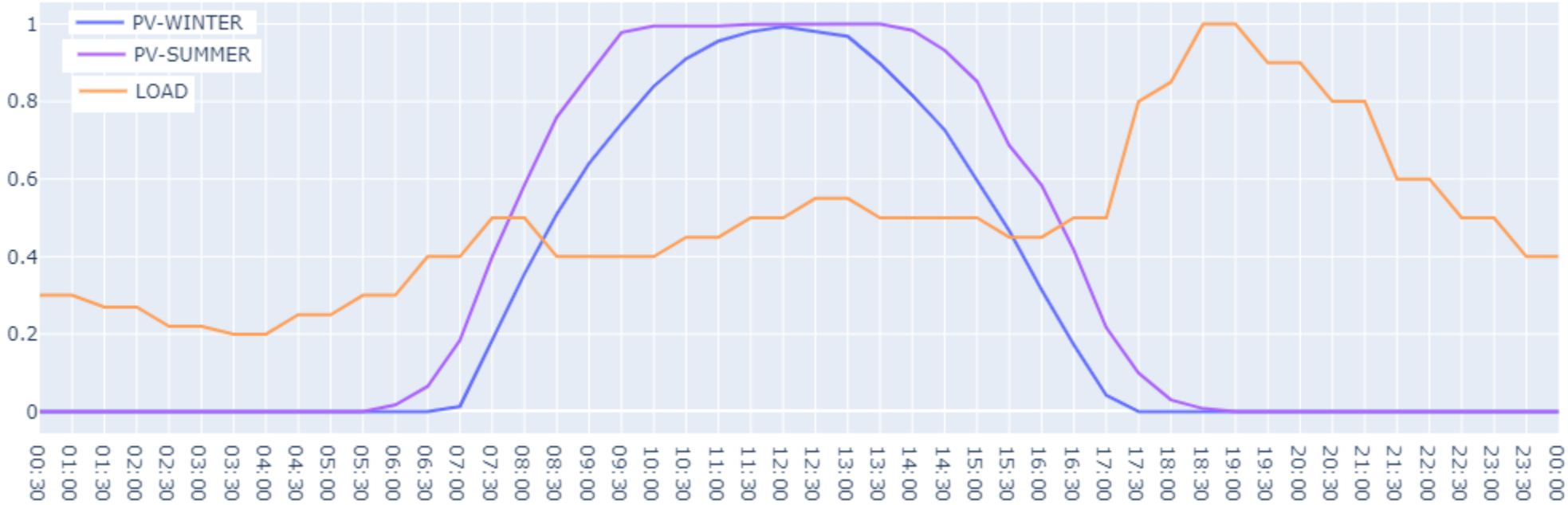


What determines the constraint?

- Thermal constraints
  - Transformer nameplate rating
  - Conductor ratings
- Voltage constraints
  - On the MV and at transformer
  - End of LV Line
- Protection constraints
  - Transformer fuse
  - Service fuse
  - Recloser overcurrent settings
- Upstream constraints
  - Feeder, Zone Sub or Transmission
  - System (AEMO)
- Contractual Constraints
  - Min and max limits in connection agreement

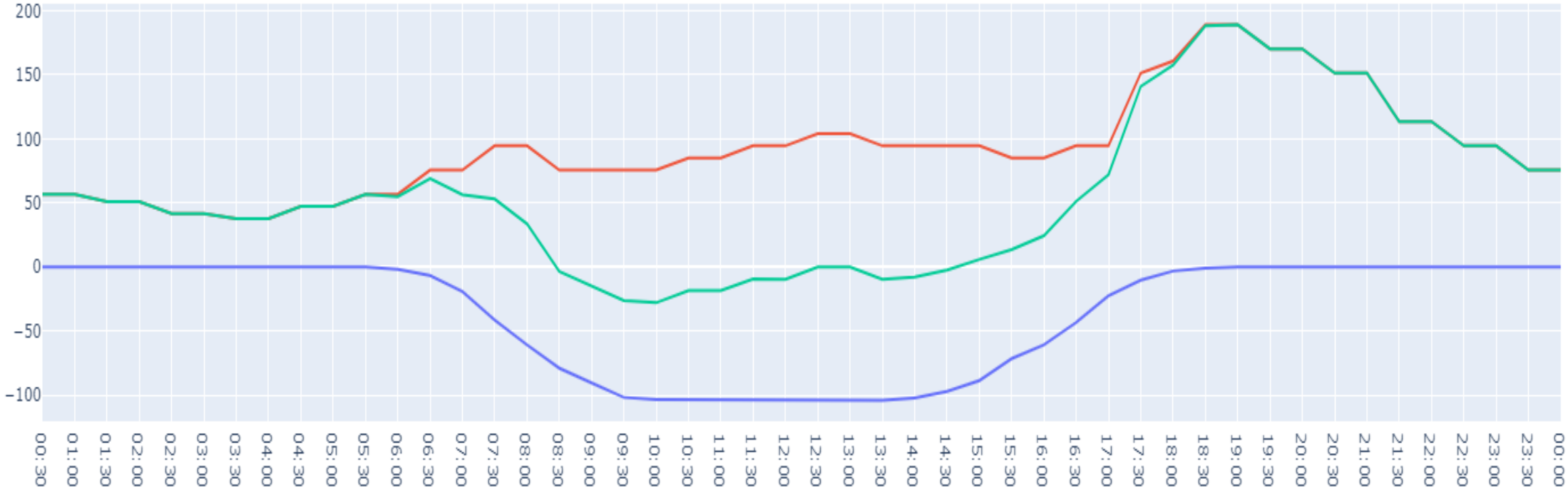
Normalised Load Curves

- Could change by season / day of week etc.
- Could have different curves for different regions or customer types



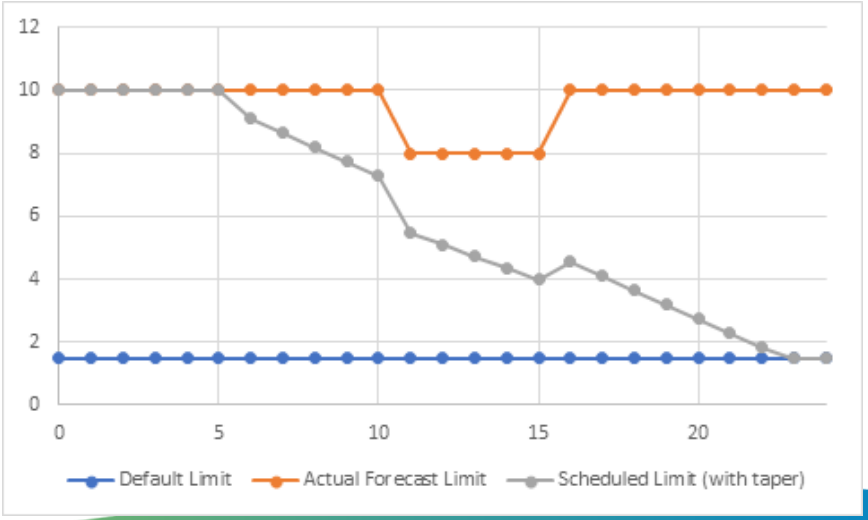
Transformer Load Profiles

- Export worst case = PV Curve x Installed Capacity
- Import worst case = Load Curve x Historical Max Demand

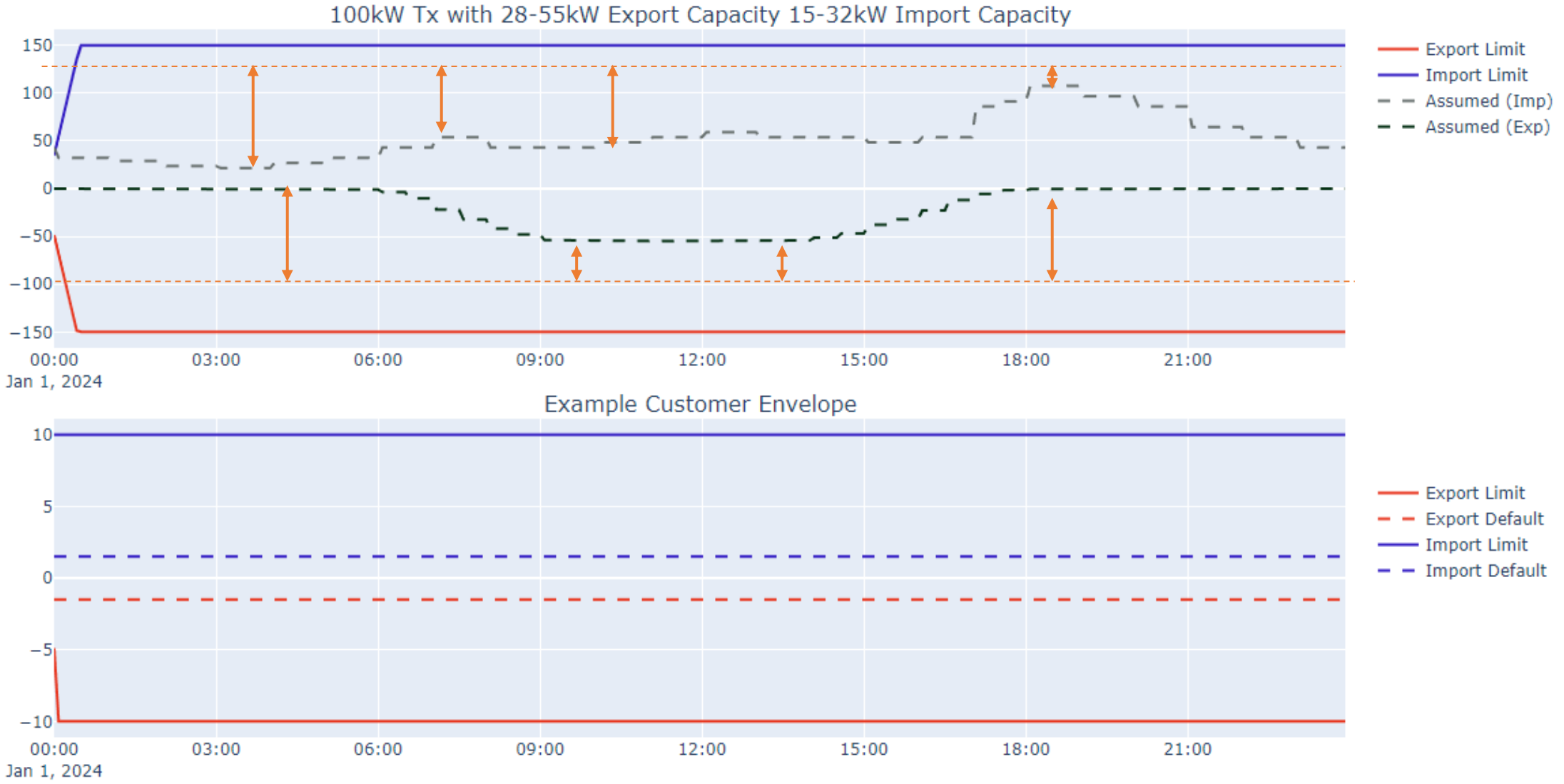


Forecasting

- Import / Export Limits can be scheduled into the future in case of loss of comms
- CSIP-AUS requires device support for at least:
  - 5 min intervals for first hour (12 events)
  - 30 min intervals for next 23 hours (46 events)
- Once the forecasted schedule is exhausted (prolonged internet outage or customer changed WiFi password), the site will fall back the default limits (e.g. 1.5 kW export and 1.5 kW import)
- Customers are not required to maintain connection (but will miss out on the increased network access)



Example – no telemetry or constraint



Overallocation

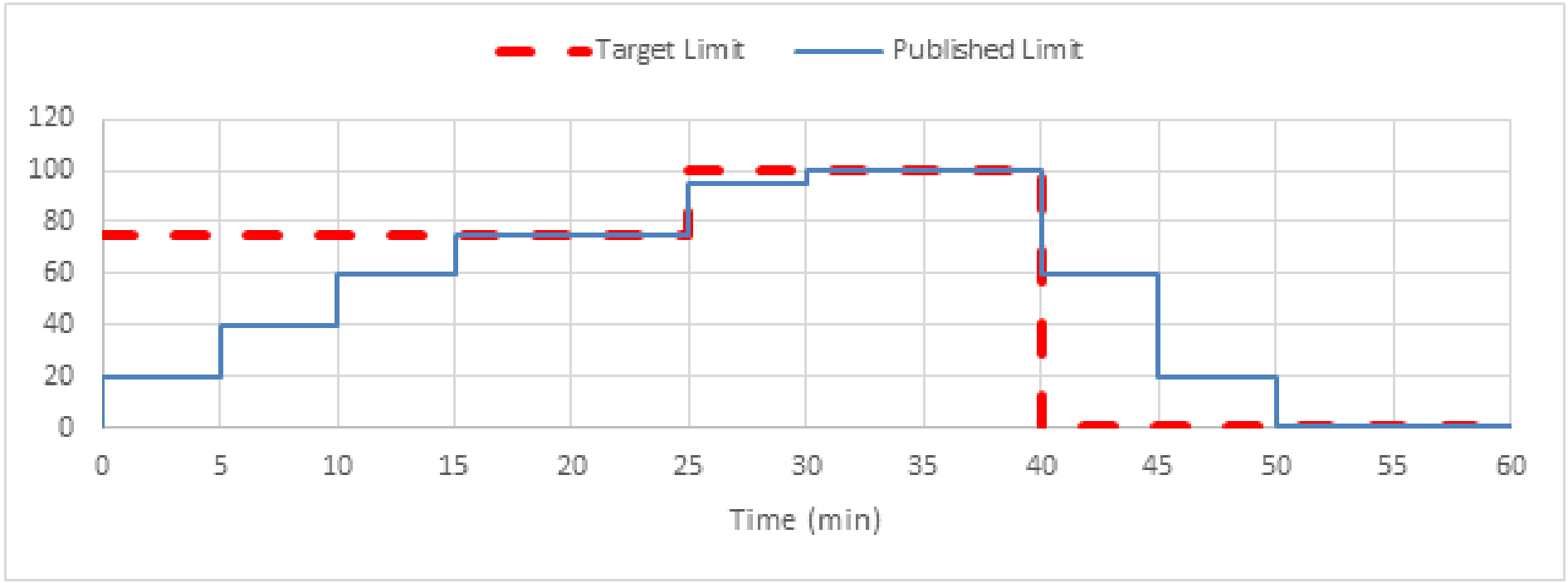
- Overallocation if unused headroom (on next iteration)
  - E.g. Up to 150% of transformer nameplate rating

ANSI Standard C57 series (IEEE, n.d.)

DT capacity	Time limit
125%	4 hr
150%	1 hr
200%	30 min

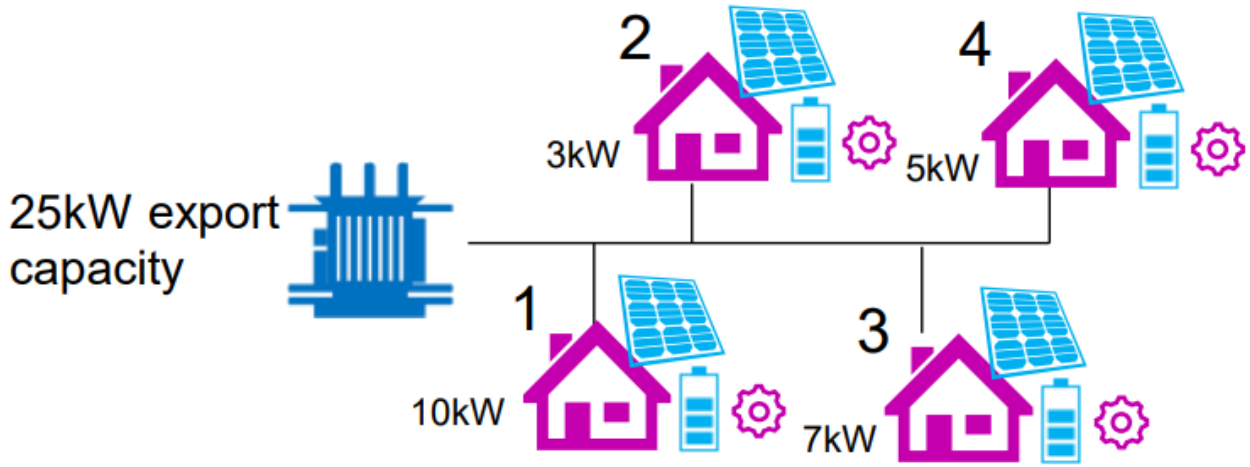
Rate Limiting

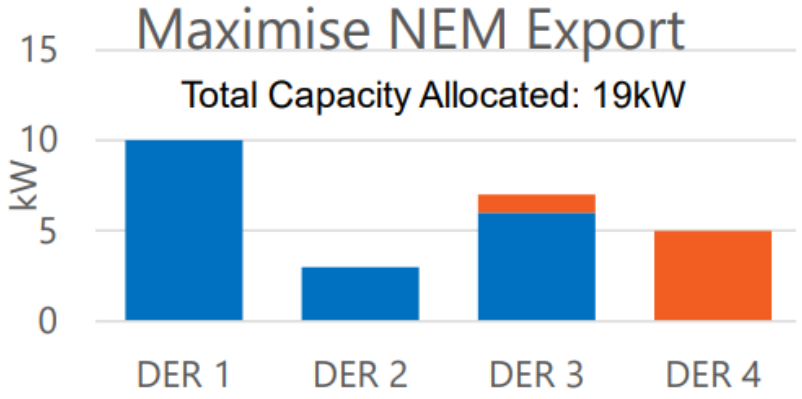
- E.g. at most 20% increase / 40% decrease on transformer rating



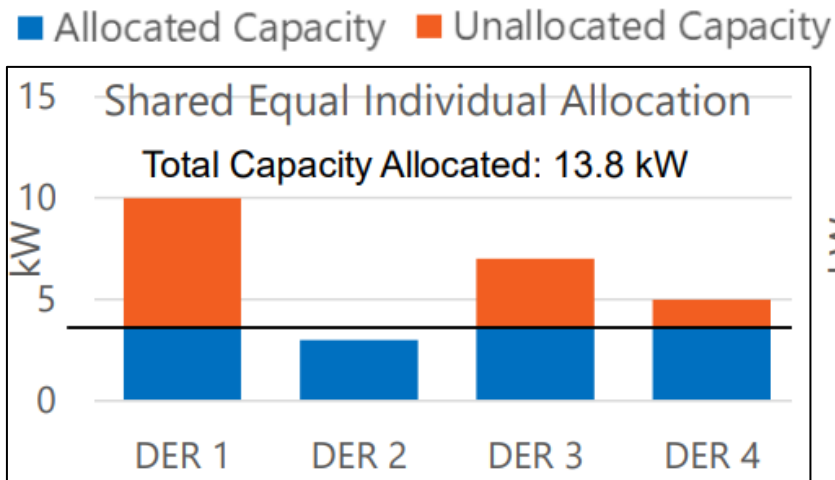
LV Allocation Methods

- Equal
- Proportional
- Maximise Export

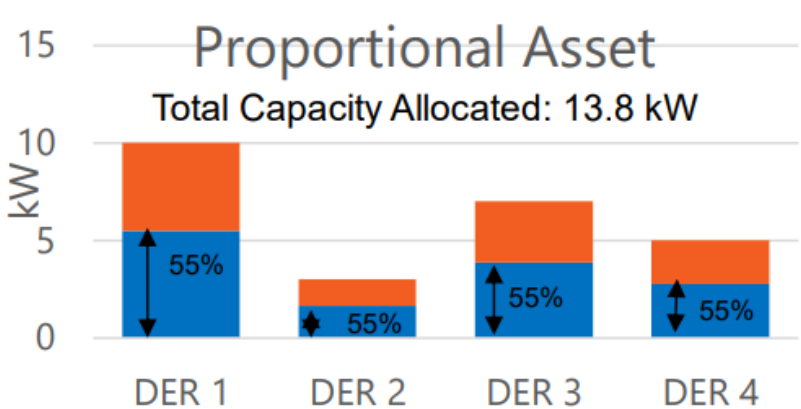




- Customers at end of line may never be able to export
- Max renewable generation



- Less renewable generation
- Simple to implement
- Favours smaller systems



- Favours largest systems

https://aemo.com.au/-/media/files/initiatives/der/2023/the-fairness-in-dynamic-operating-envelope-objectives-report.pdf

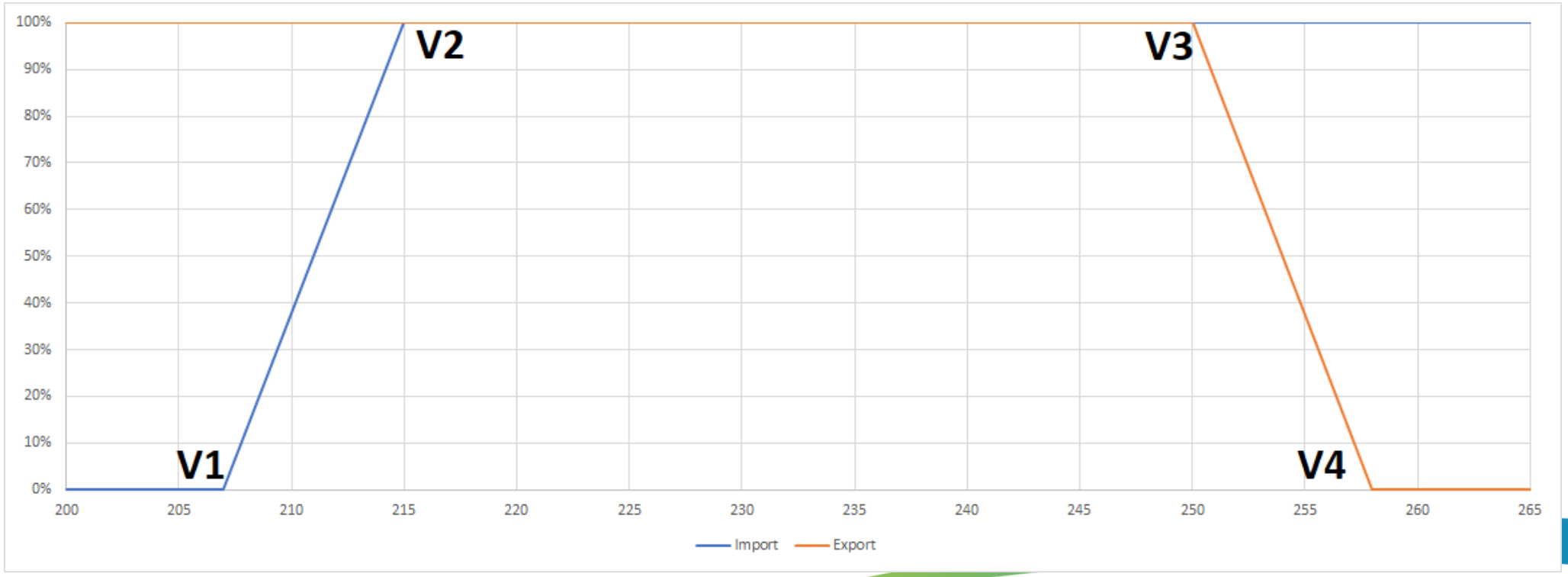
LV Allocation Example

Connection	Approved Export	Equal Allocation			Proportional Allocation (alternative)		
		50 kW Avail.	100 kW Avail.	200 kW Avail.	50 kW Avail.	100 kW Avail.	200 kW Avail.
CP-A (Fixed)	5.0 -> 5.0 kW	5.0 kW	5.0 kW	5.0 kW	5.0 kW	5.0 kW	5.0 kW
CP-B (Fixed)	1.5 -> 1.5 kW	1.5 kW	1.5 kW	1.5 kW	1.5 kW	1.5 kW	1.5 kW
CP-C (1PH)	1.5 -> 10.0 kW	7.3 kW	10.0 kW	10.0 kW	3.9 kW	7.4 kW	10.0 kW
CP-D (1PH)	1.5 -> 10.0 kW	7.3 kW	10.0 kW	10.0 kW	3.9 kW	7.4 kW	10.0 kW
CP-E (1PH)	1.5 -> 10.0 kW	7.3 kW	10.0 kW	10.0 kW	3.9 kW	7.4 kW	10.0 kW
CP-F (2PH)	1.5 -> 20.0 kW	7.3 kW	20.0 kW	20.0 kW	6.8 kW	14.4 kW	20.0 kW
CP-G (3PH)	1.5 -> 30.0 kW	7.3 kW	21.8 kW	30.0 kW	9.6 kW	21.4 kW	30.0 kW
CP-H (>30)	1.5 -> 50.0 kW	7.3 kW	21.8 kW	50.0 kW	15.3 kW	35.4 kW	50.0 kW
Total	**15.5 -> 136.5 kW**	**50.0 kW**	**100.0 kW**	**136.5 kW**	**50.0 kW**	**100.0 kW**	**136.5 kW**

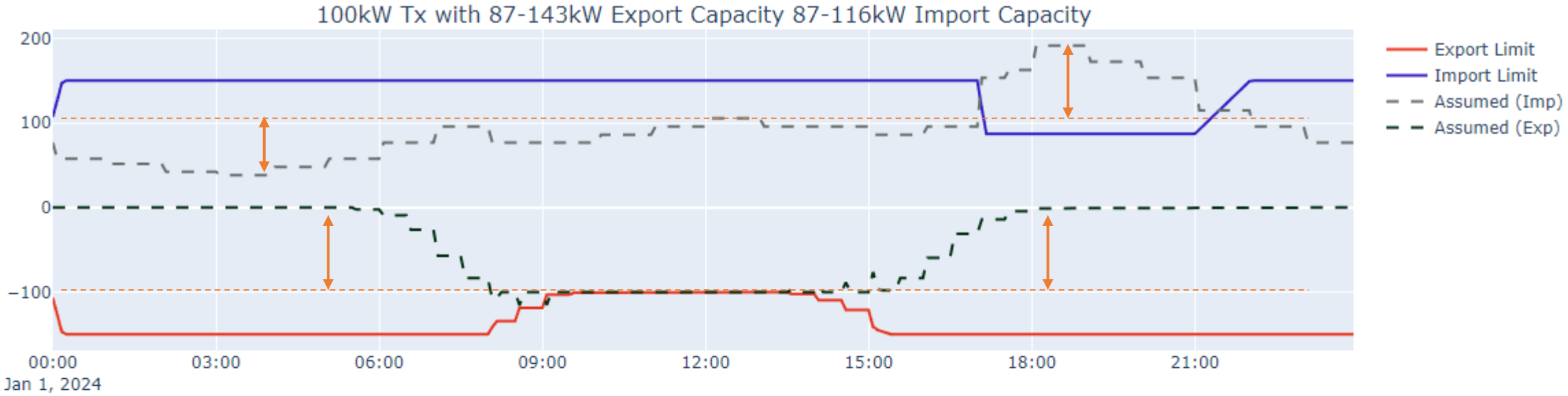
What about voltage?

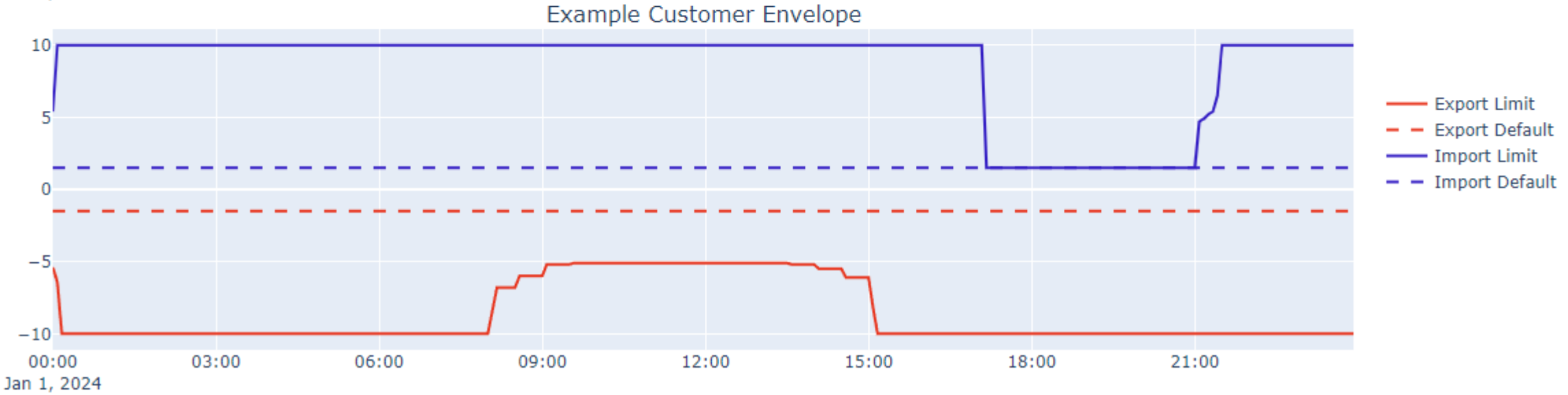
DOE	V1	V2	V3	V4
Transformer	216	221	248	253
End-of-line	207	215	250	258

AS4777	V1	V2	V3	V4
volt-var	207	220	240	258
volt-watt	207	215	253	260

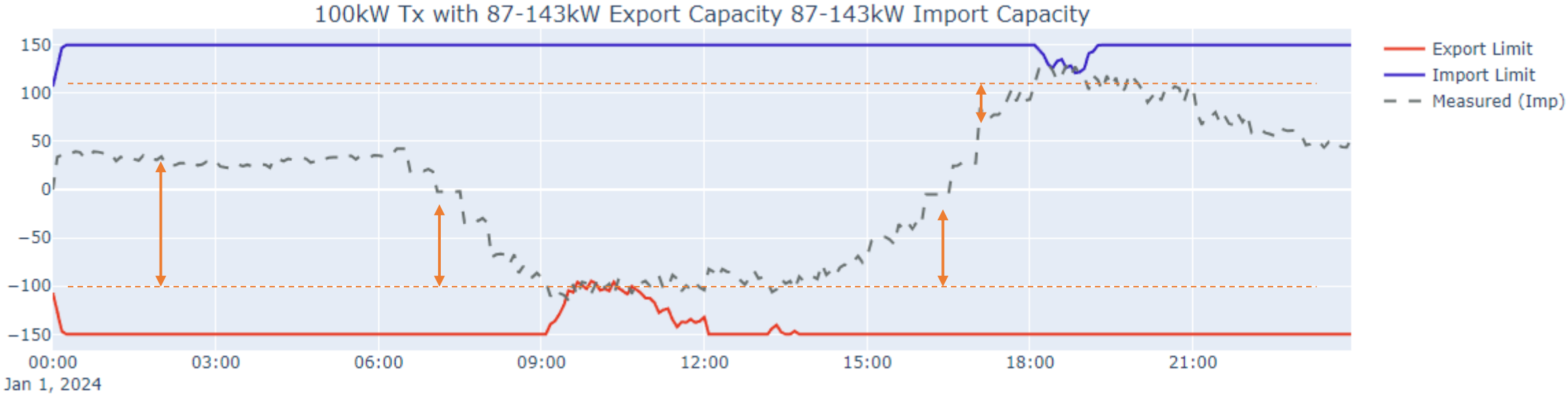


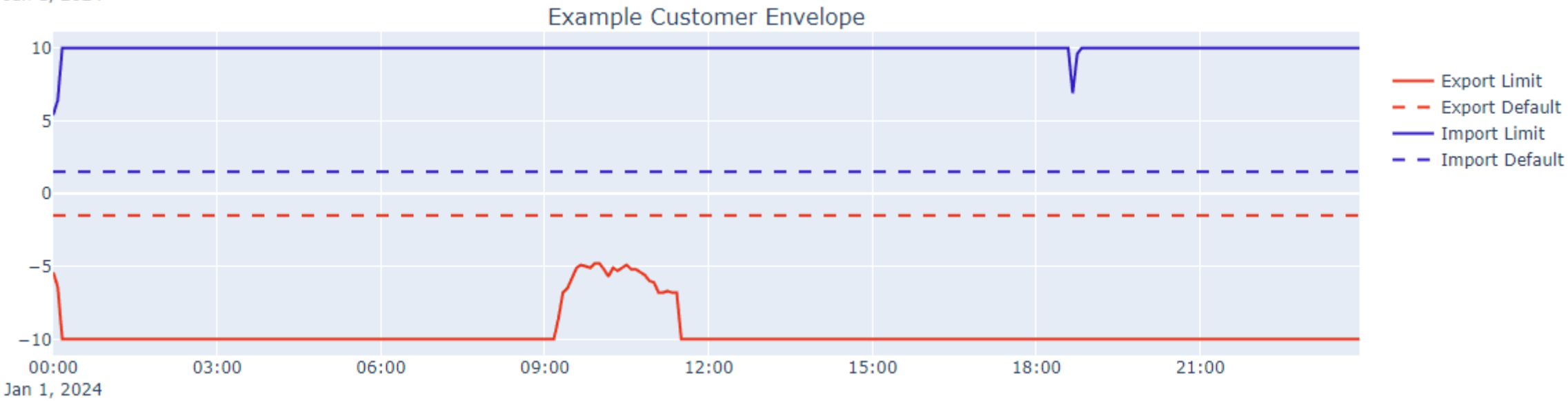
Example – no telemetry / constrained





Example – constrained with PQ Mon





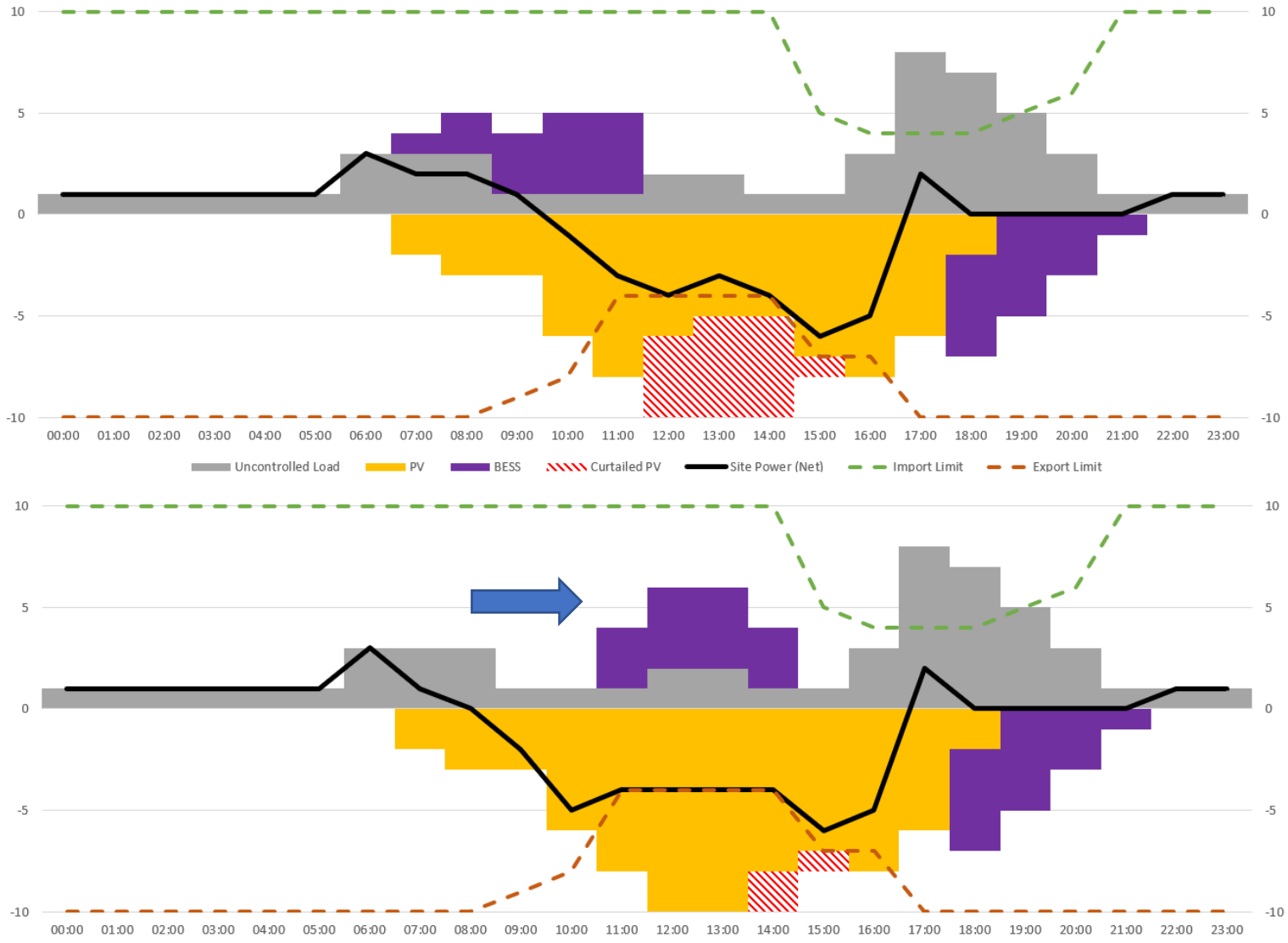
When is basic useful?

- Network is not constrained (lower compute)
- No network model available
- No telemetry or state estimation available
- For basic forecasting or fallback

% of Transformers	No PV	0-75%	75-100%	100%+
1 customer	26.6%	10.0%	0.4%	0.3%
2-25 customers	22.7%	20.1%	1.2%	1.0%
25+ customers	0.7%	15.4%	1.2%	0.4%
Total	50.1%	45.5%	2.8%	1.7%

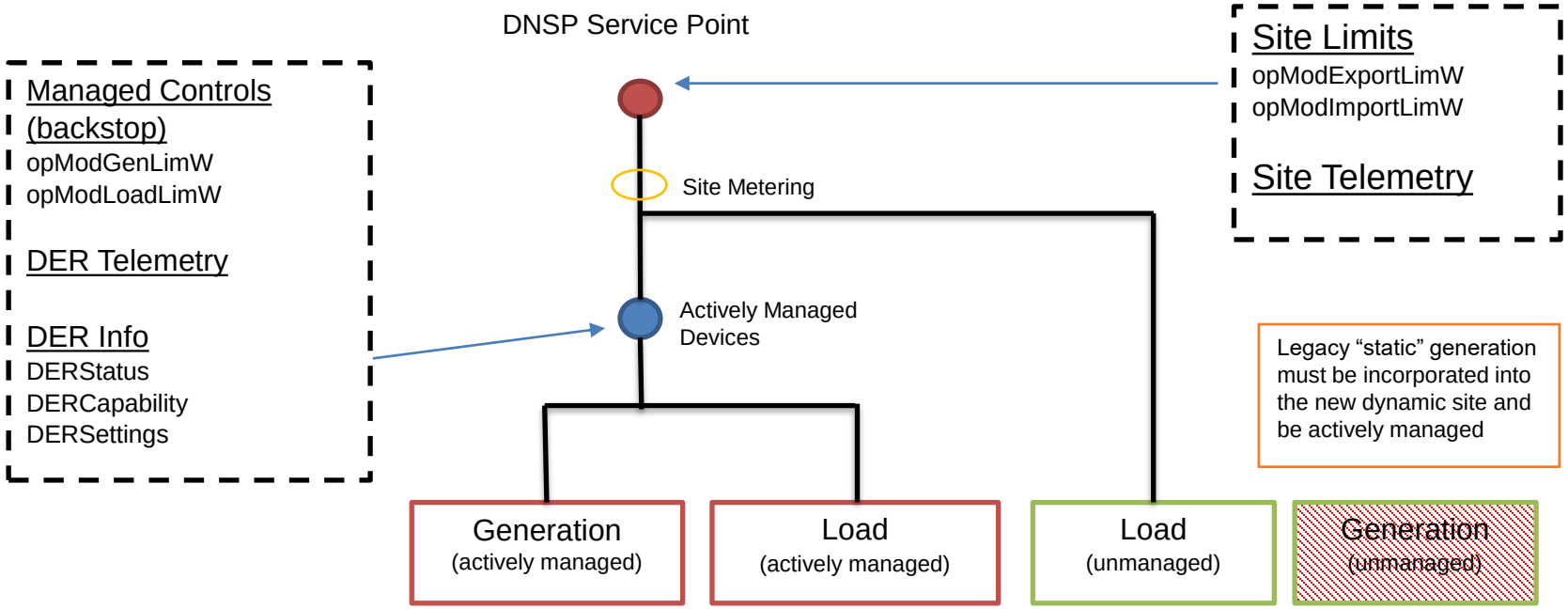
- If still constrained….
  - Install a PQ monitor
  - Upgrade to an external/advanced DOE
  - Upgrade the network

Importance of local site control



- Example based on a real customer scenario with a BESS and daytime export constraint
- BESS is generally fully charged by 11:00
- Changing time of BESS charging could significantly reduce the amount of curtailed PV generation

Dynamic Site



Telemetry

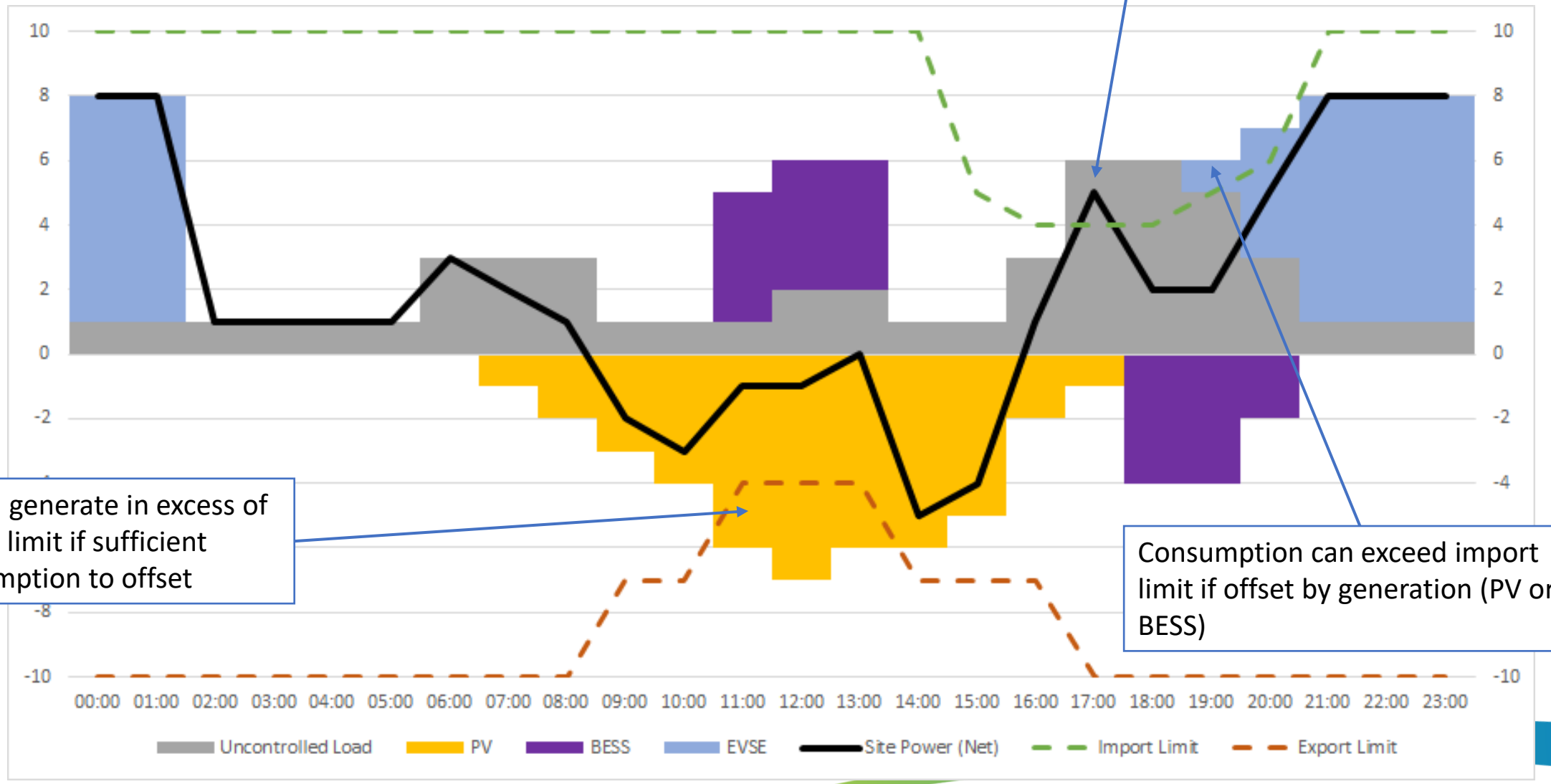
- Real Power
- Reactive Power
- Voltage

every 5 minutes

per phase

Site Example

Unmanaged load (such as cooking, aircon) can exceed import limits as long as managed load (EVSE) is not consuming



PV can generate in excess of export limit if sufficient consumption to offset

Consumption can exceed import limit if offset by generation (PV or BESS)

Dynamic Operating Envelopes
The South Australian Experience

Operating Envelopes & Their Implementation **Short Course**

Melbourne Energy Institute

14/03/2024

Liam Mallamo

Future Networks Engineer

SA Power Networks

Empowering South Australia

The history of DOEs in SA

ARENA

Advanced VPP Grid Integration
2019

- Dynamic export limits dispatched to 1,000 Tesla Powerwall 2 batteries operating in a VPP
- Communication via a bespoke SAPN <> Tesla API
- Export limits from 5kW – 10kW

SA Power Networks

TESLA

CSIRO

ARENA

Flexible Exports for Solar PV
2021

- Dynamic export limits for PV inverters
- Communication via IEEE2030.5, using CSIP-AUS profile
- Trialled on 400+ residential customers.
- No equipment subsidies or incentives offered – just a higher export limit (1.5kW – 10kW)

SA Power Networks

AusNet

Fronius

switchDin

SMA

solaredge

Dynamic Exports Guideline
2023

- Update to SA Electricity Regulations, to require *all* new PV inverters to be *capable* of receiving a DOE via CSIP-AUS
- Enables DOEs at scale
- Gives SAPN the power to set cybersecurity requirements

Government of South Australia

Department for Energy and Mining

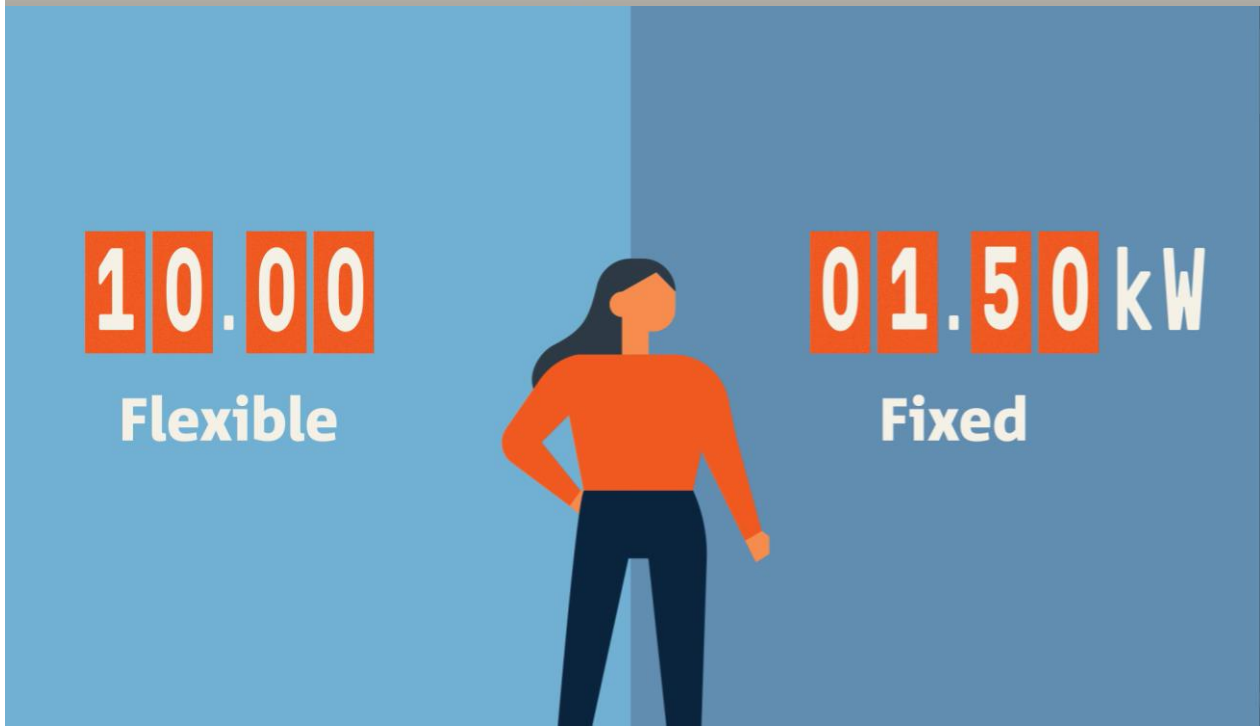
Flexible Exports today

- Flexible Exports is now the **standard connection offer** for new PV installations in many parts of South Australia

- Flexible Exports is available to **188,000 customers today**, and will be available to all **900,000+ customers** in SA by the **end of the year**

- **1700+ customers** currently active and receiving a DOE, **1200** more waiting on installation

- A **‘staged rollout’** strategy was used, targeting highly constrained substation areas first. This helps us manage:
  - customer experience;
  - engagement with solar retailers & installers;
  - compliance issues *(more on that later!)*



The offer has been successful

2909

Flexible Approvals

86% opt-in rate

99%+

Export limits at 10kW

Or max inverter capacity

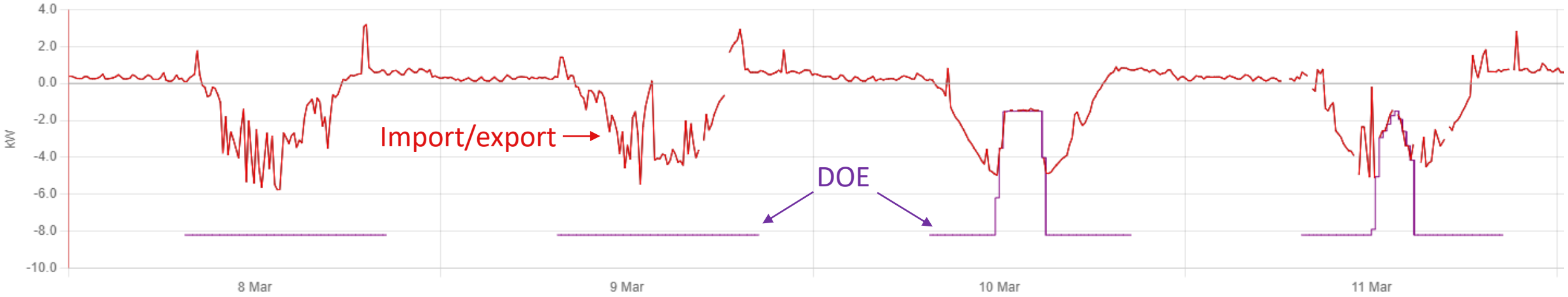
2.25x

Energy exported

compared to static limit of 1.5kW

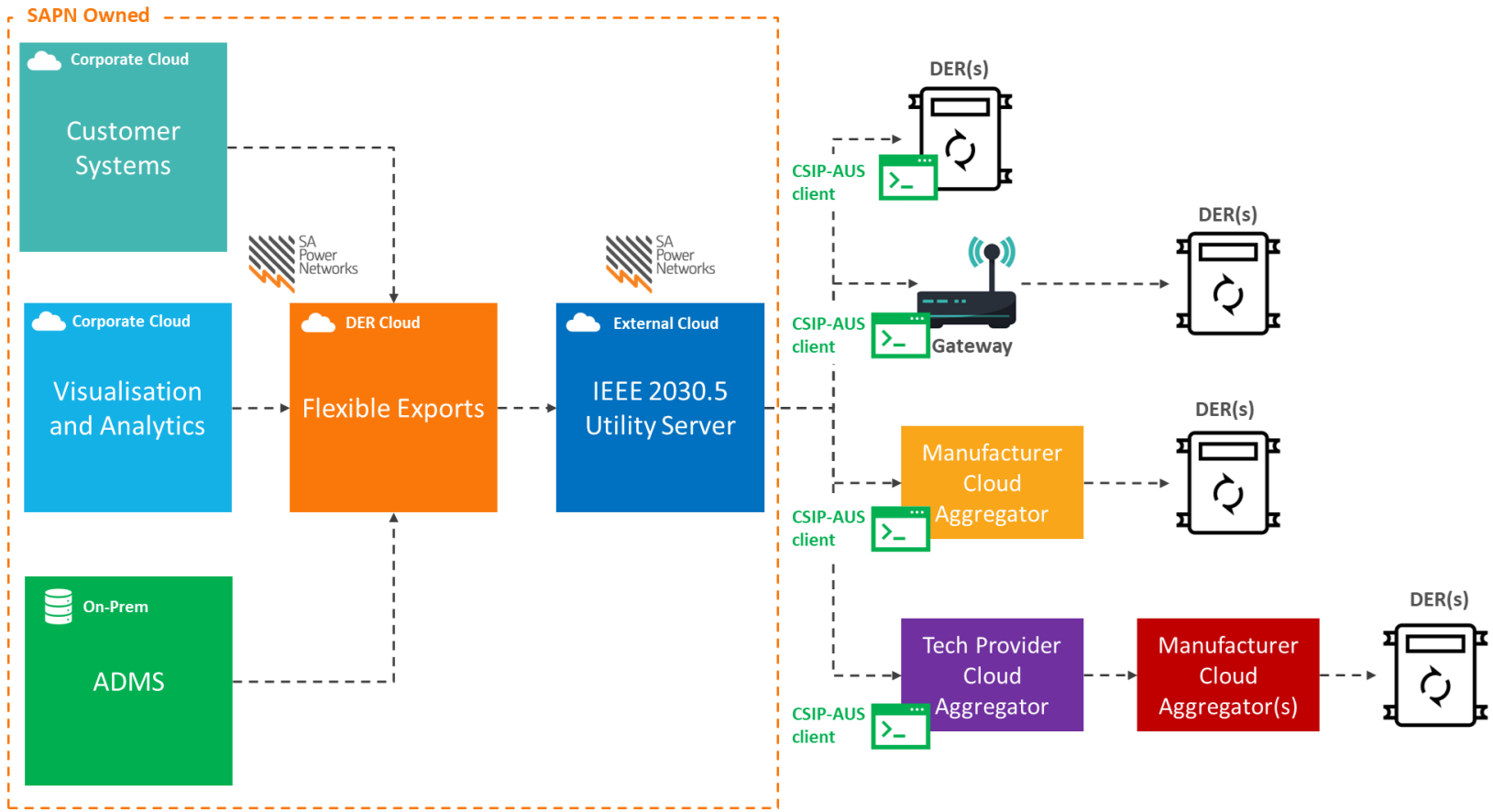
85%

Customer satisfaction rating



Flexible Exports today

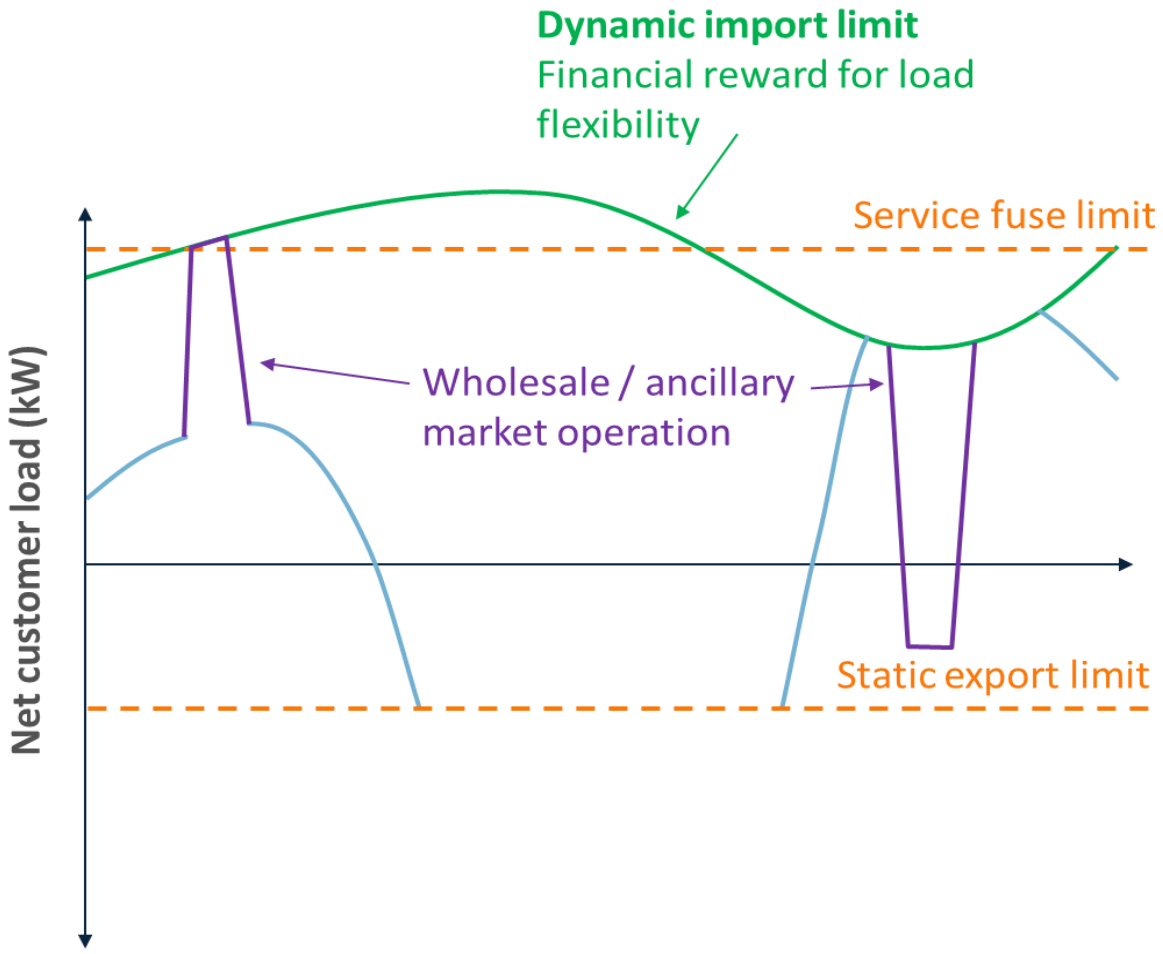
- We calculate 15-minute network capacity based on site-level load & PV forecasts
- The primary constraints on our network are **voltage** based
- Available network capacity is calculated at the **LV TF** level
  - Capacity is allocated between sites using a **waterline allocation** methodology (equal allocation with unused capacity returned to a 'pool' and reallocated)
- Site level limits are communicated to a **site CSIP-AUS client**
  - Available export capacity can then be 'mediated' by that CSIP-AUS client across multiple flexible devices on-site



Flexible Exports (& imports!) tomorrow

- Flexible Exports currently only covers residential & commercial PV systems up to 200kW, connected to the LV network
  - Export constraints exist across the HV network, and have impact on all downstream customers
  - We are developing the capability to mediate HV constraints with rooftop PV using a **tiered capacity allocation**

- Our 2025-2030 Regulatory Proposal includes a *Demand Flexibility* program, through which we will rolling out the capability to calculate & dispatch **flexible import limits**
  - We've already started building the systems and will be demonstrating it soon….
  - Flexible import limits will be **opt-in** per device and **reward based** – pricing is the key!



Challenge 1 – standardising communications

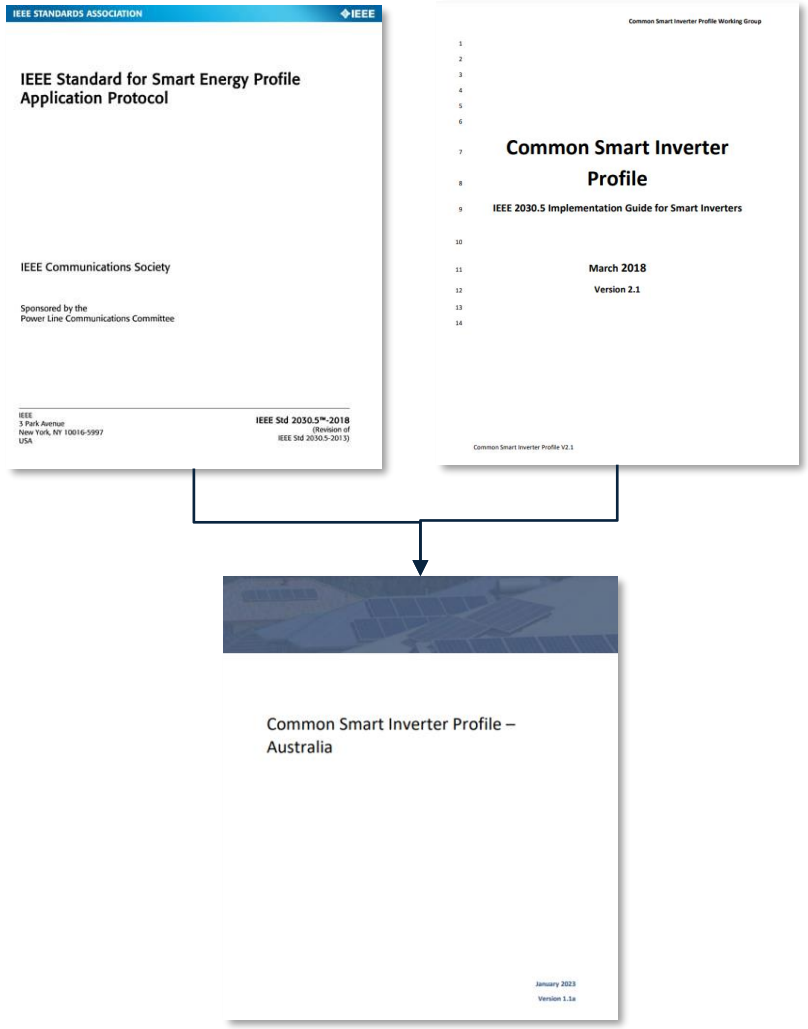
- Initial DOE trials were used non-standard communications protocol
  - *Advanced VPP Grid Integration* used a bespoke SAPN <> Tesla API

- If we want DOEs to become widespread, and the 'default' way to manage CER, we need a single, standardised communications protocol between a DNSP & site CER

- **IEEE2030.5** was already mandated for **DNSP <> CER interoperability** in California (Rule 21)
  - Adapted for Australian context into **CSIP-AUS** by SA Power Networks and an industry working group
  - CSIP-AUS added **site level controls** to the existing CSIP profile of IEEE2030.5
  - CSIP-AUS has since become a Standards Australia handbook (SA HB 218: 2023)

- CSIP-AUS **capability** is now a legal requirement for all new PV inverters installed in South Australia & Victoria, and is the enabler of Queensland's Dynamic Connections

CALIFORNIA
Public Utilities Commission

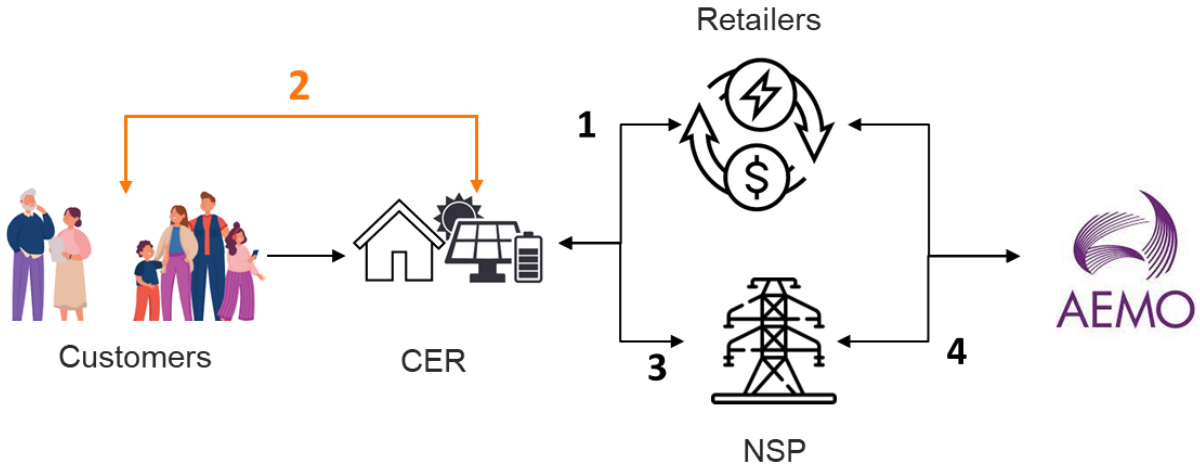


Challenge 1 – standardising communications

- Behind-the-meter interoperability is the next frontier

- DOEs are calculated at the **site level**, but typically only **one device** can respond per site currently
  - A site level export limit could be met by reducing PV generation **or increasing load**
  - There is little to no **mediation of site response** to a CSIP-AUS site DOE due to non-standard communications protocols used for CER <> CER communications

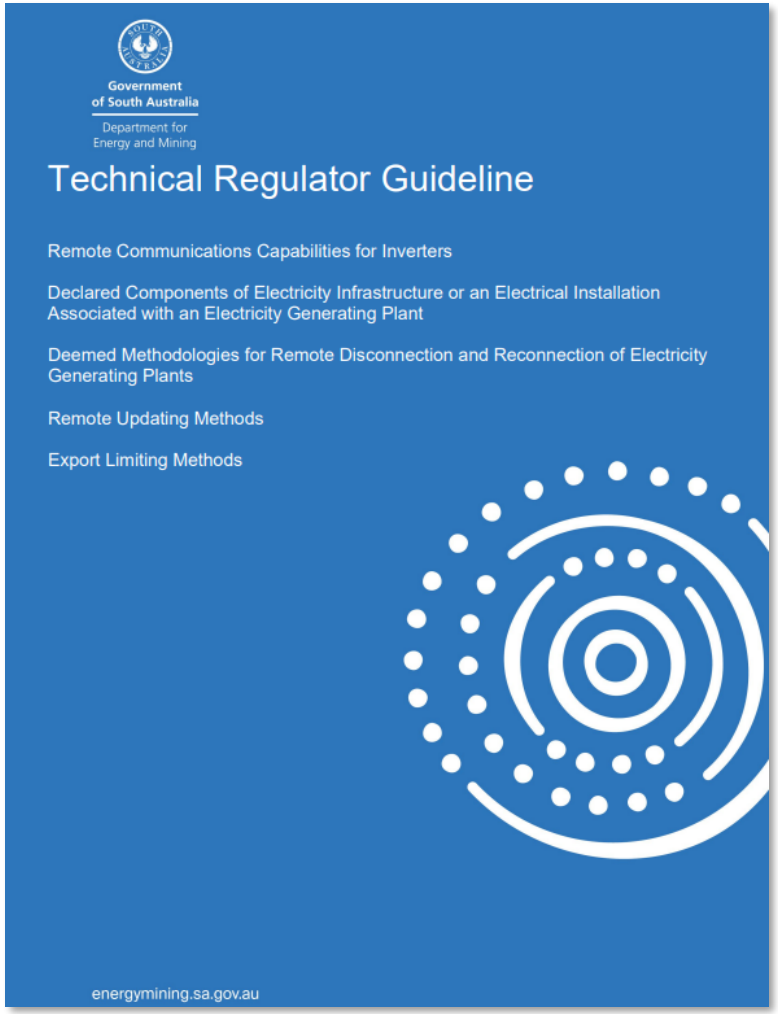
- Standardising communications behind-the-meter will lead to maximum value from DOEs



1. CER-market interoperability
2. Behind-the-meter interoperability
3. CER-network interoperability
4. Network-AEMO interoperability

Challenge 2 – DOEs and the law

- To implement DOEs at scale, **as many devices as possible** must be **capable** of receiving a CSIP-AUS DOE
  - But how could we make sure that all PV inverters supported CSIP-AUS?
- South Australian Government implemented the **Dynamic Exports Guideline**
  - Requires that all new PV inverters support CSIP-AUS dynamic **export** limits by **1 July 2023**
- Delayed due to lack of industry readiness
  - Solar retailers needed to be educated on how DOEs work and how to **explain them to customers**
  - Solar installers needed to be trained on **how to commission a DOE system**
  - PV inverter manufacturers needed **time to develop their CSIP-AUS clients**, test and be certified by SAPN
- **Victoria** has implemented similar regulations, in place from **March 2024**
- There is no national requirement for DOE capability **yet**



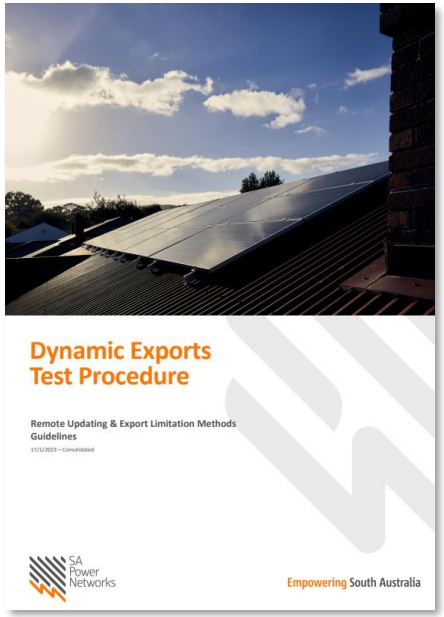
Challenge 3 – testing & certifying equipment

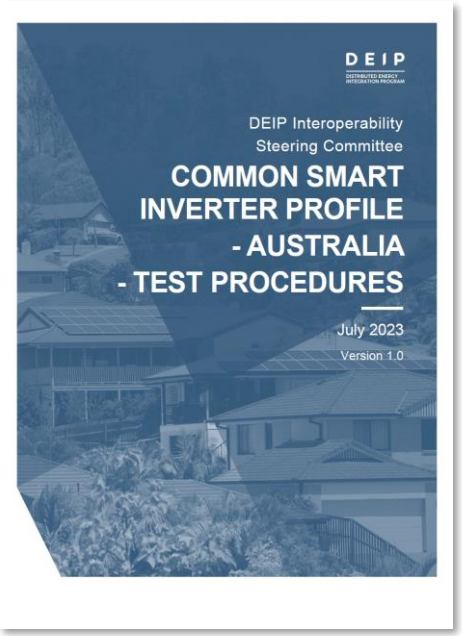
- Equipment ***should*** be capable of receiving a DOE via CSIP-AUS, but how can we be **sure** it will operate as intended?

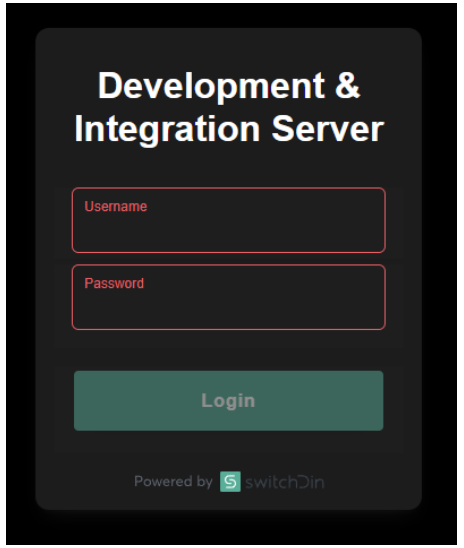
- SA Power Networks provides a ***Development & Integration*** CSIP-AUS server for equipment manufacturers to test their CSIP-AUS clients against

- SA Power Networks **tests & certifies** equipment to **confirm CSIP-AUS capability**
  - Our team performs 'witnessing tests' of the CSIP-AUS DOE capabilities for new equipment
  - The Clean Energy Council maintains a database of all equipment certified by SA Power Networks
  - This database is used to meet South Australian requirements & will shortly be used to determine what equipment can be installed in Victoria

- Working towards a national approach to testing & certifying as more states roll out Flexible Exports





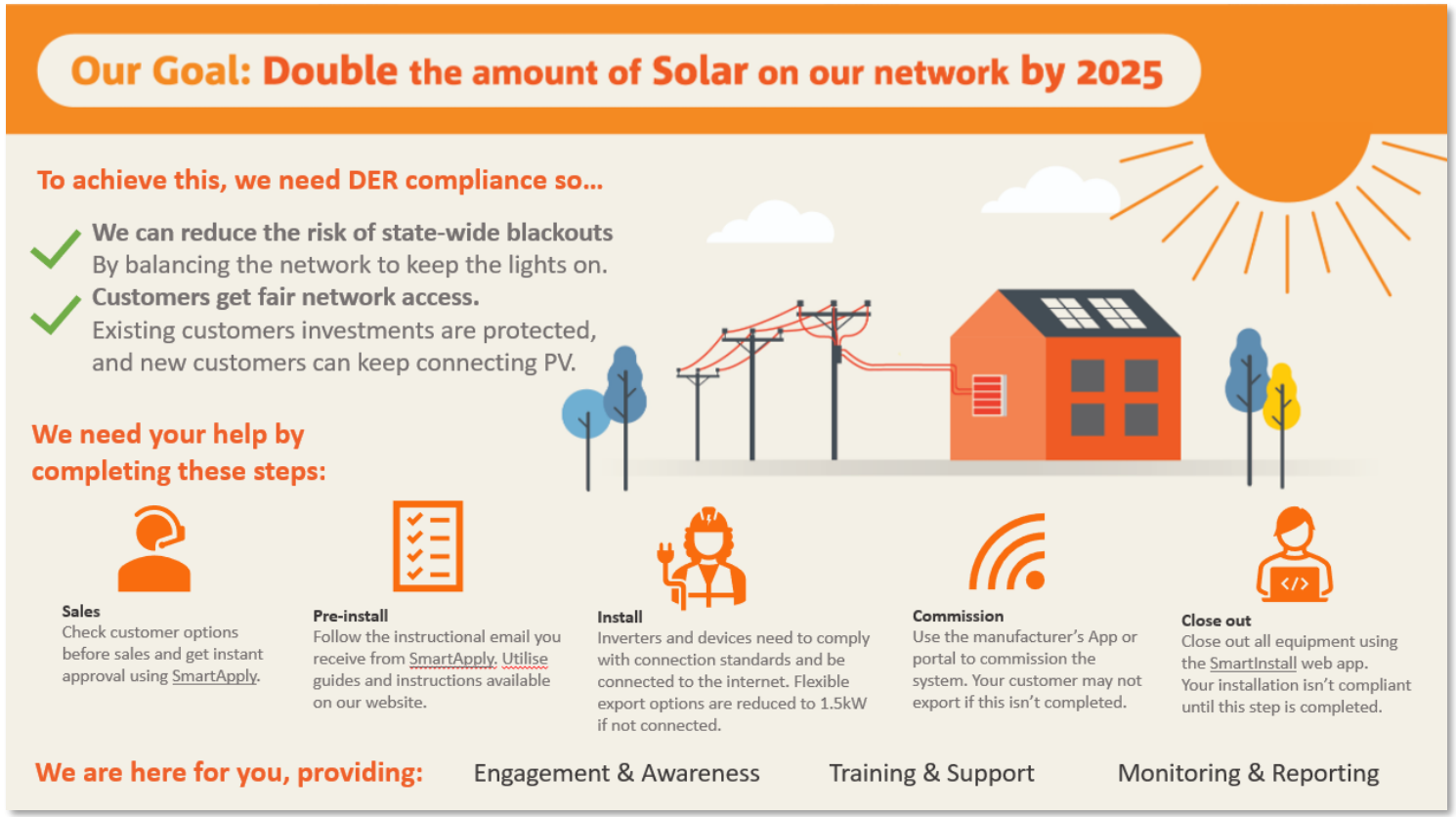


CSIP-AUS certified inverter equipment (>97% by SA market share)

And many more, all tested & certified by SA Power Networks!

Challenge 4 – compliance

- Our testing & certification process means that every PV system **receives & interprets** CSIP-AUS controls correctly
  - **If installed and commissioned correctly**
  - Incorrect installations, firmware updates and system tampering mean that many installations do not properly apply the DOE
- Developed an automated ***Capability Test***
  - Tests the installation with sample CSIP-AUS controls
  - One-button test for installers
- SAPN runs installer training sessions, working with solar industry bodies (SEC, CEC)
- Dedicated SAPN support team for DOE installations & manufacturers – customer service & engineers



Challenge 5 – the cost

- Our Flexible Exports program was funded by **$32M** CAPEX in our last Regulatory Proposal
- We've proposed an **$80M+** CER Integration program for in our upcoming Regulatory Proposal
- Huge amounts of **IT development**, cloud architecture, data storage & processing are needed
- Stakeholder engagement, working with inverter manufacturers, solar retailers, solar installers and **customers!**
- Years of collaboration with **state & federal government**, research institutions and other DNSP
- The benefits far outweigh the costs when compared to network augmentation – but the costs still need to be considered.
- The 2021 SAPN led **Access & Pricing** rule change makes it easier for DNSPs to get funding for DOE programs in future

Empowering South Australia

Questions?

Ask them now, or email liam.mallamo@sapowernetworks.com.au