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THE UNIVERSITY OF MELBOURNE

Melbourne Energy Institute

Seminar #6:

Enabling the DER revolution: from dynamic pricing to virtual power plants, energy communities, and microgrids

Speaker:

Professor Pierluigi Mancarella

Chair Professor of Electrical Power Systems

University of Melbourne

MEI*network*24 Seminar Series

Seminar topic	Month
1. System overview: from generation to customer	2 May 2024
2. Transmission and distribution networks	4 Jun 2024
3. Wholesale markets	17 Jul 2024
4. Financial markets	7 Aug 2024
5. Retail markets	3 Sep 2024
6. Distributed energy resources	**8 Oct 2024**
7. Energy communities and microgrids	7 Nov 2024

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Enabling the DER revolution:
From dynamic pricing to virtual power plants, energy communities, and microgrids

Prof Pierluigi Mancarella, FIEEE

Chair of Electrical Power Systems, The University of Melbourne

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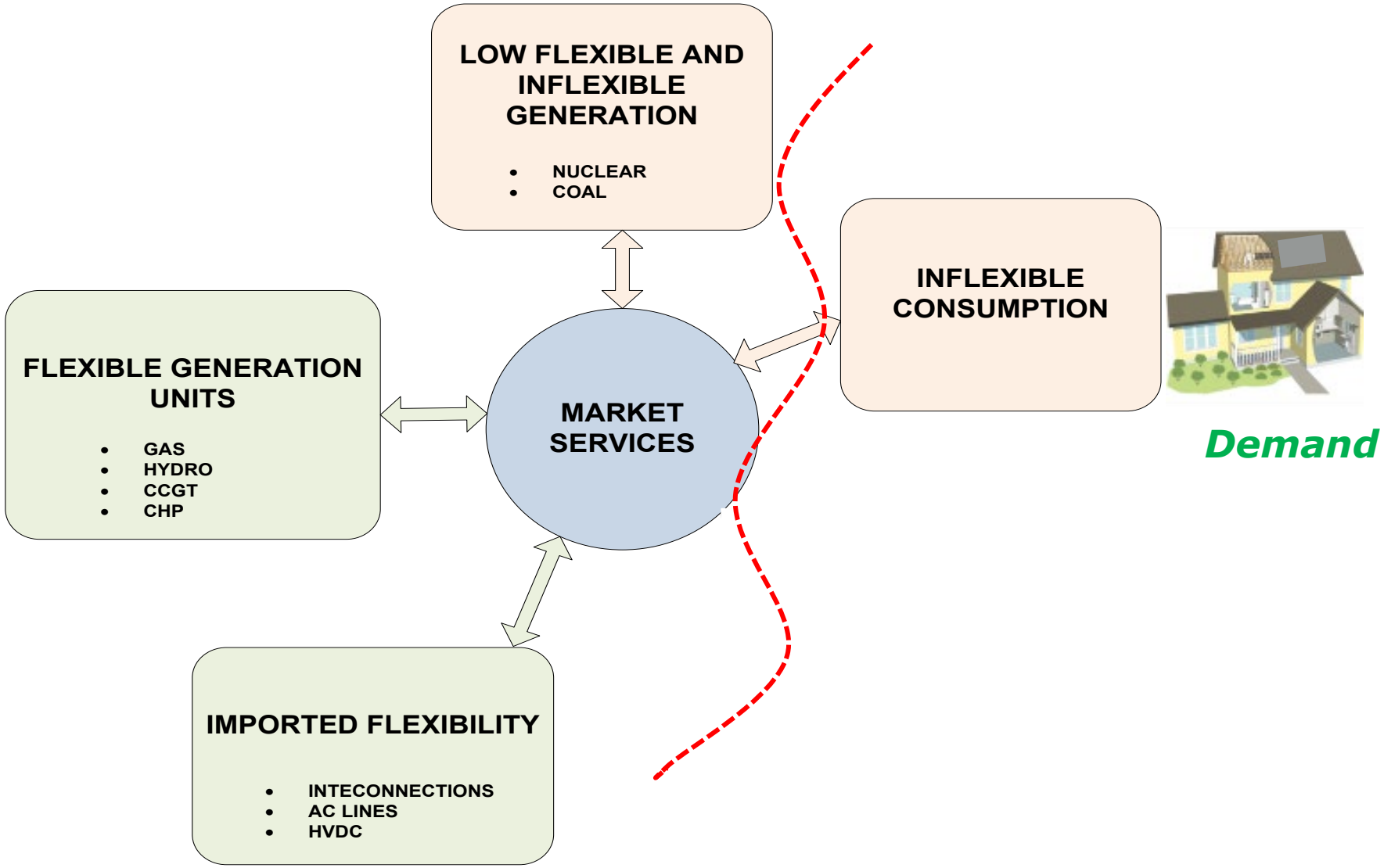
Melbourne Energy Institute Seminar Series 2024

Melbourne, 7th October 2024

Historical system balancing

Supply side

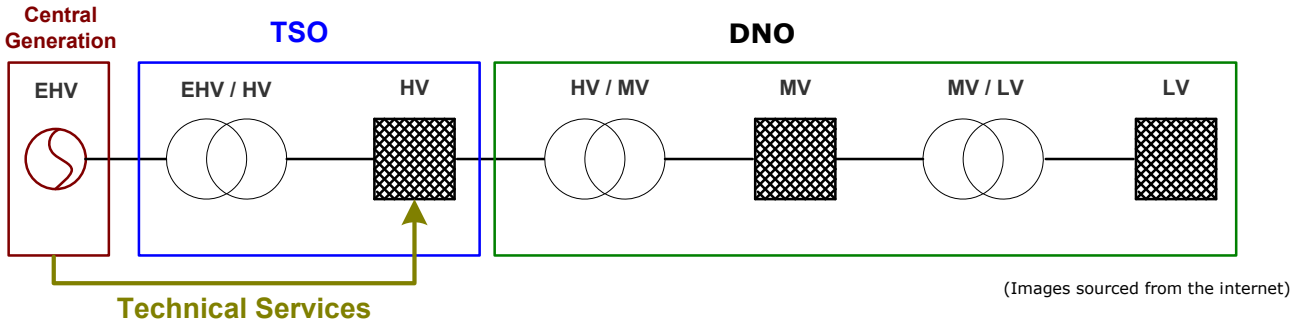
Large scale, centralised generation



Demand side

(Images sourced from the internet)

Historical direction of flexibility

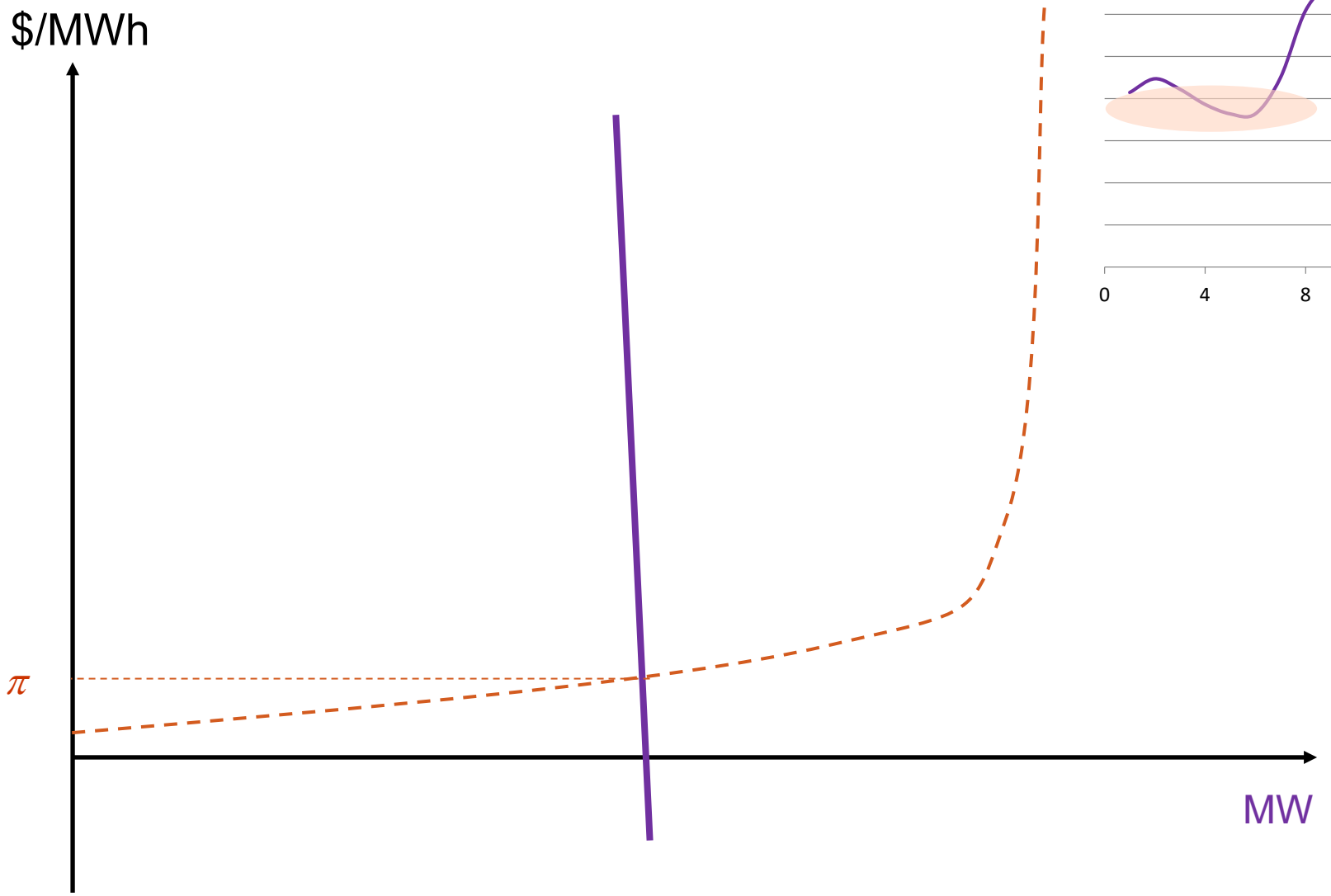


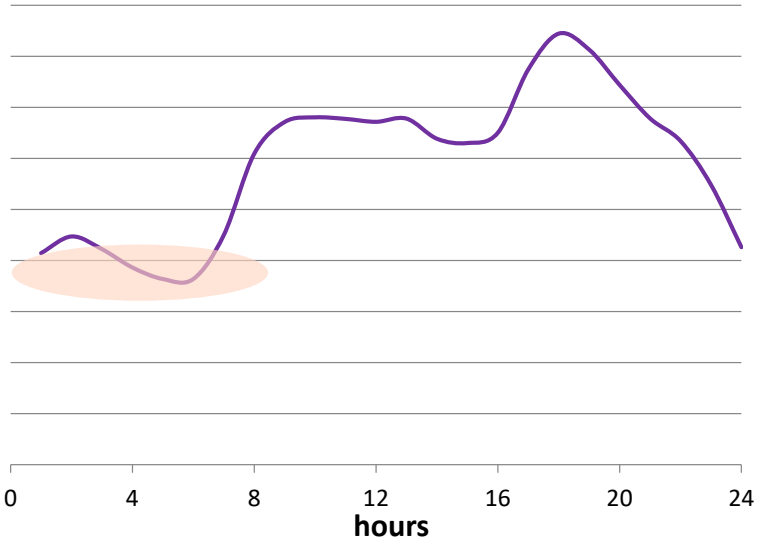
(Images sourced from the internet)

Flexibility → **Inflexibility**

Source: More Microgrids project, 2010

Historical market sketch





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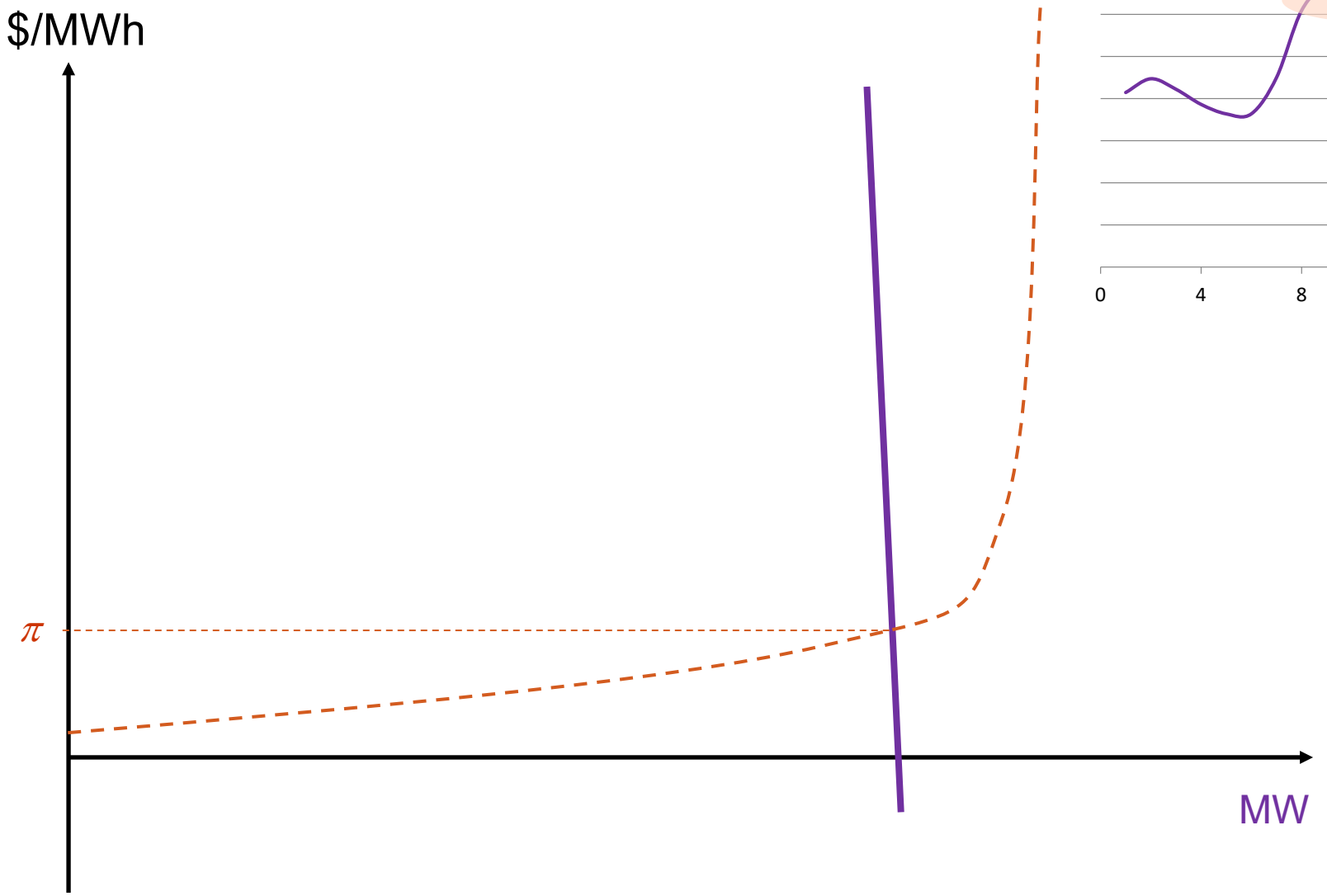

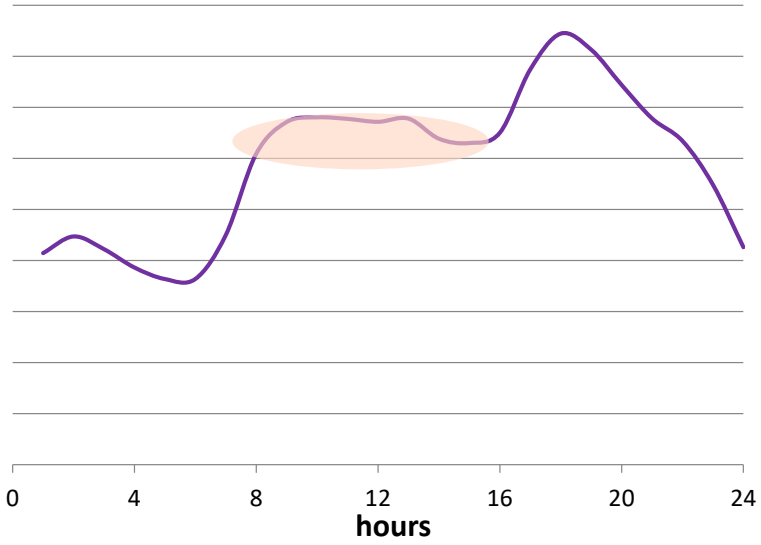

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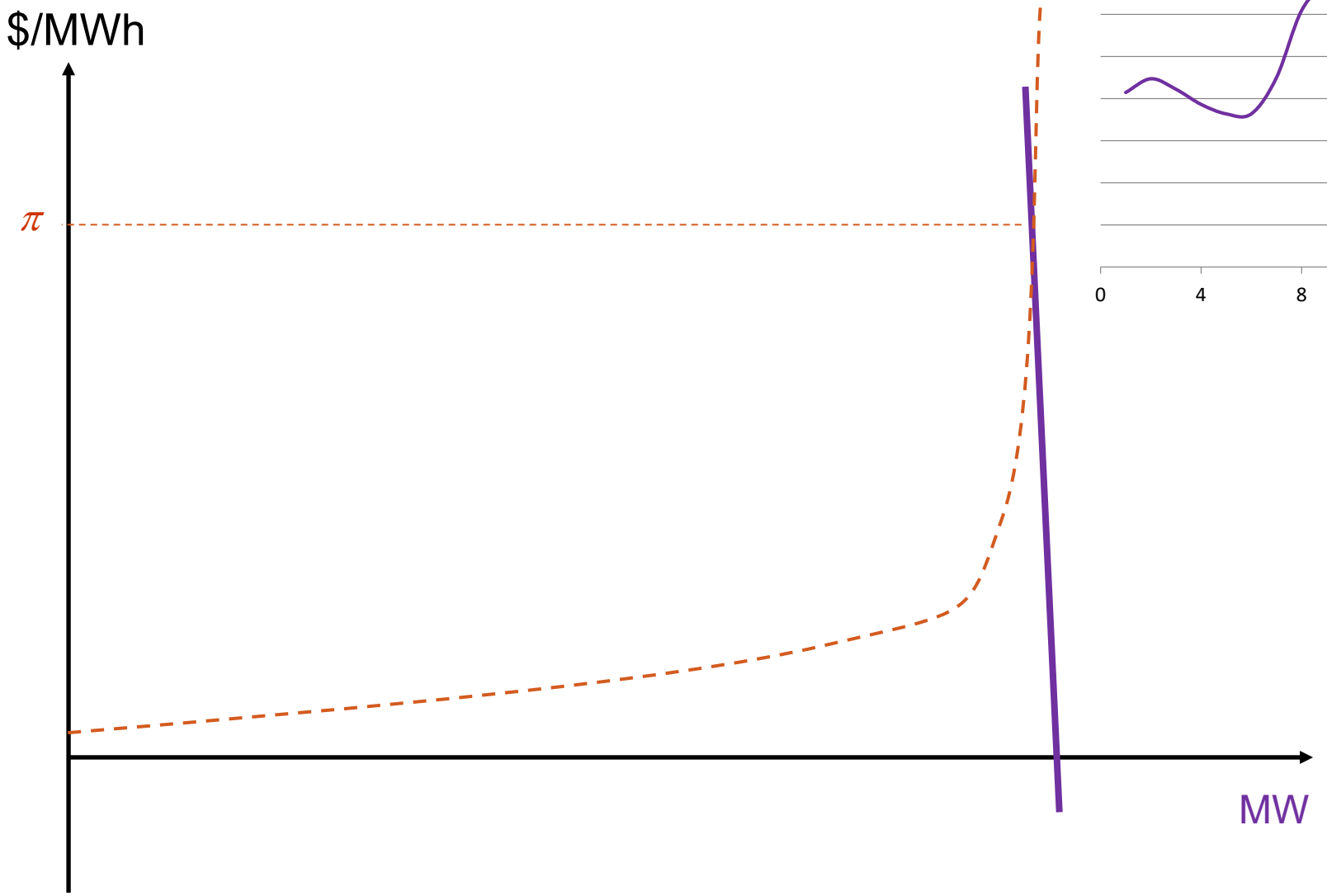
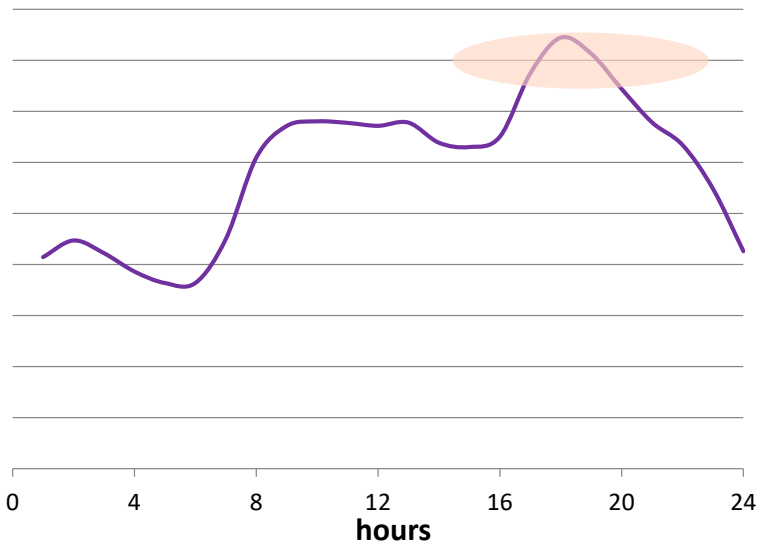


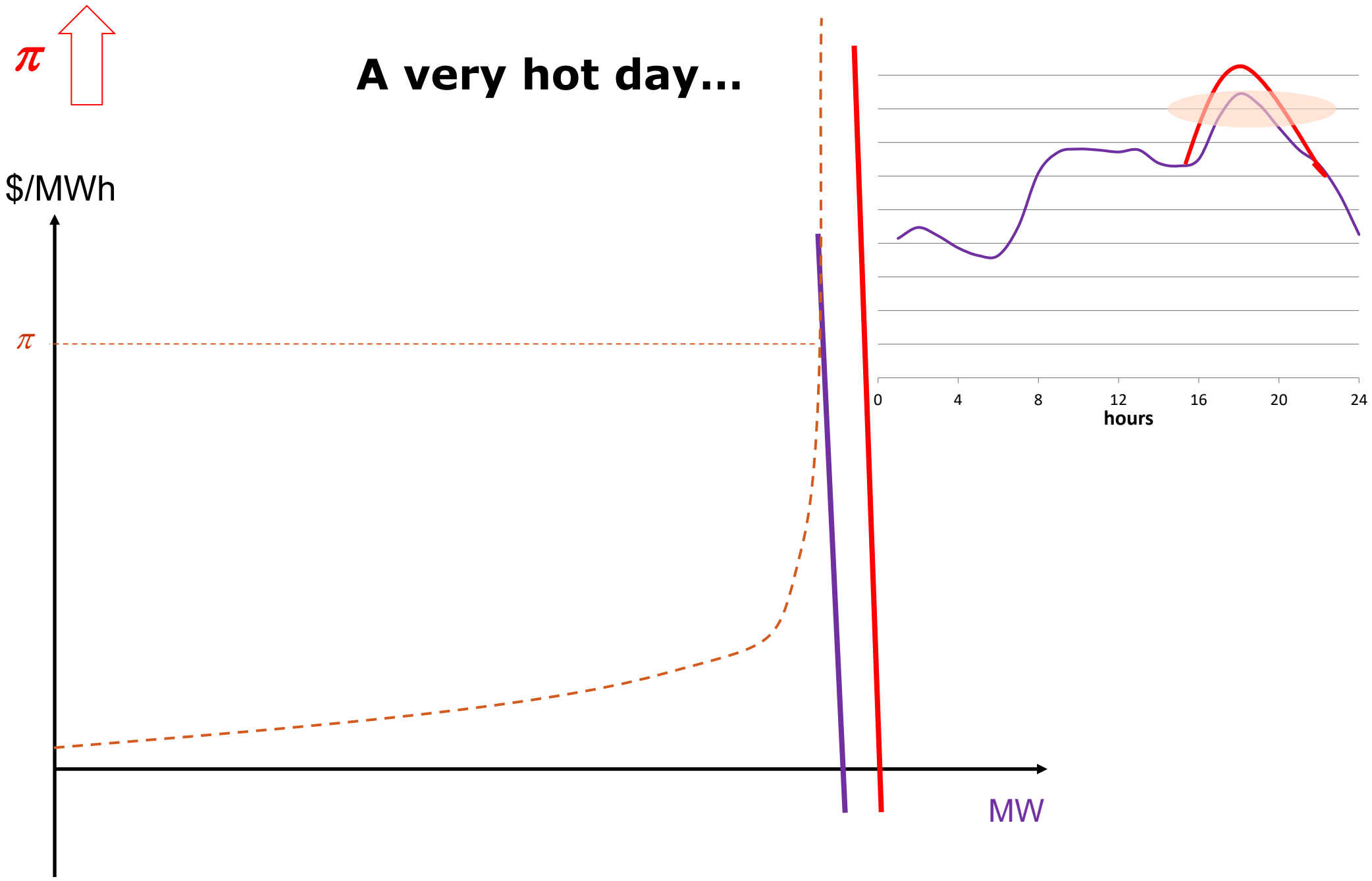


Price elasticity of demand

- **Demand elasticity** to prices has historically been very **weak**
  - ***"Inelastic"*** *demand*
  - Often small proportion of the total costs
  - Electricity is indispensable
  - Historically electricity is expected to be always available
- *But benefits of "**demand response**" may be significant, especially under extreme conditions*

Demand response:
Customer adapting their *consumption* to dynamic (or time varying) electricity prices or other signals

A very hot day…



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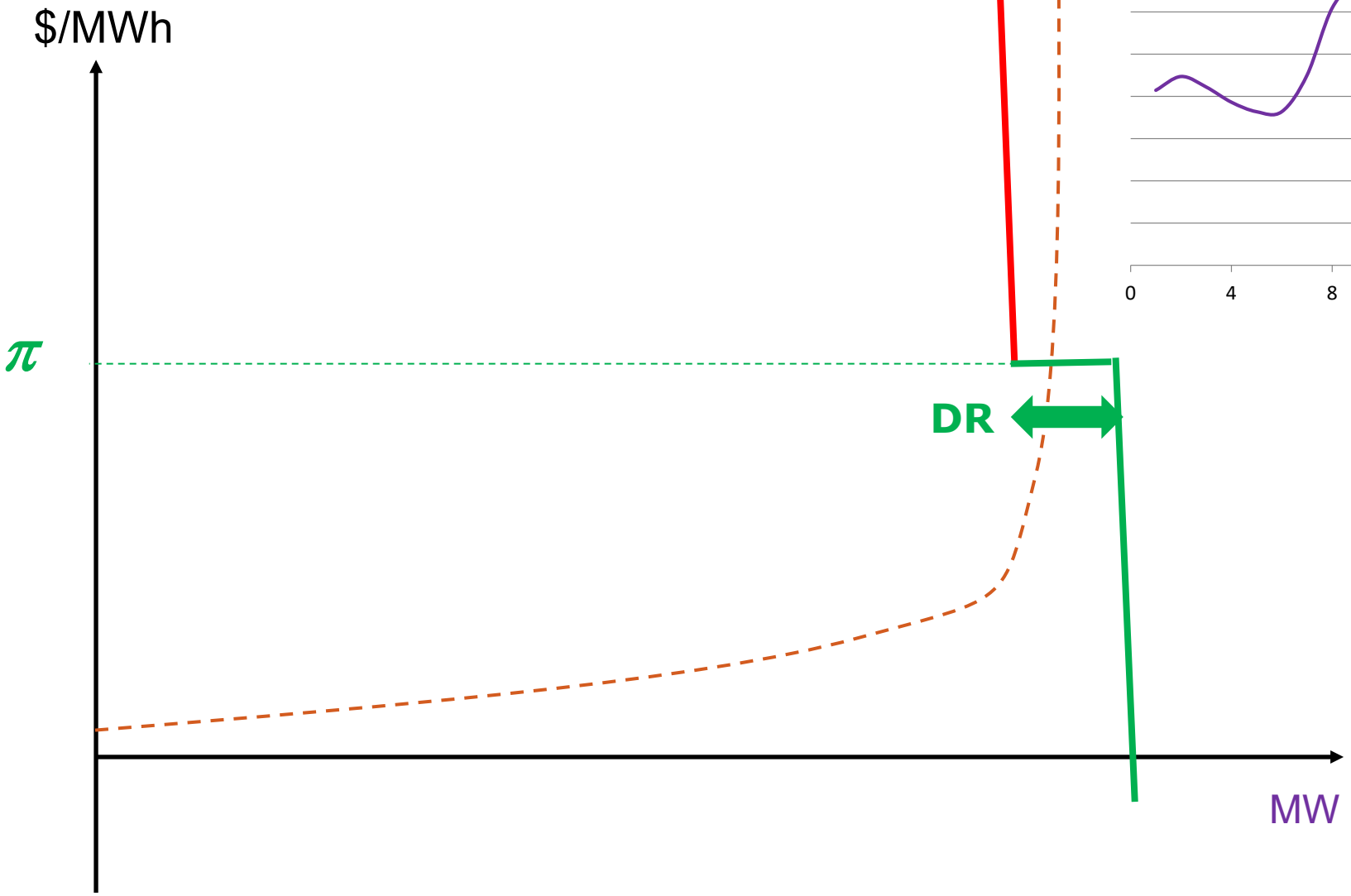
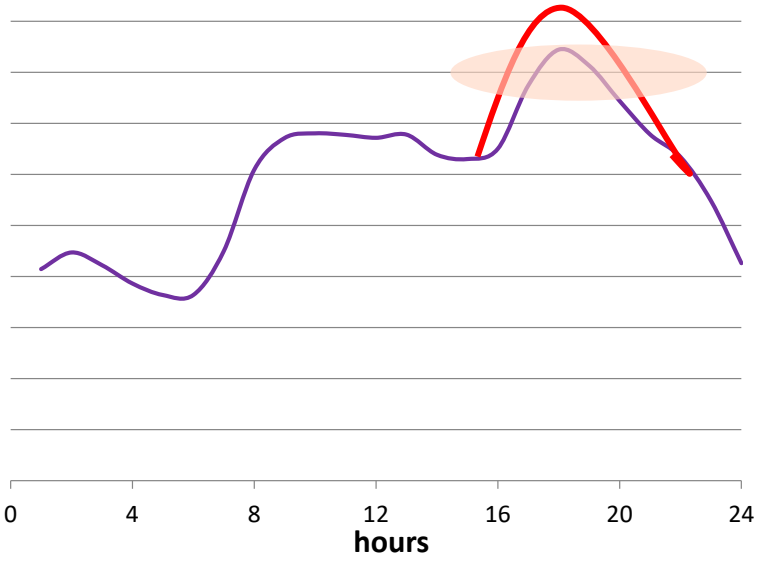
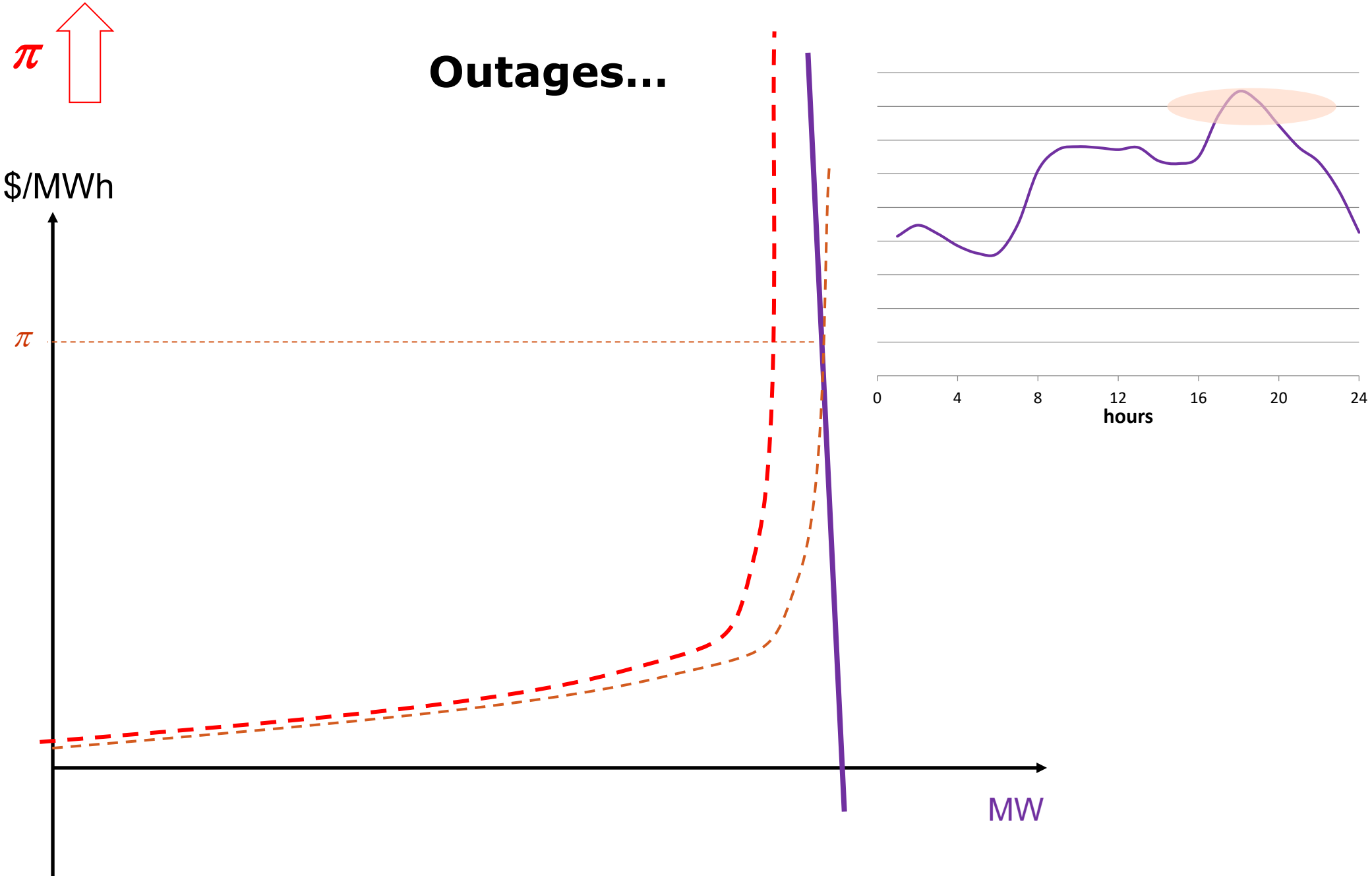




Outages…



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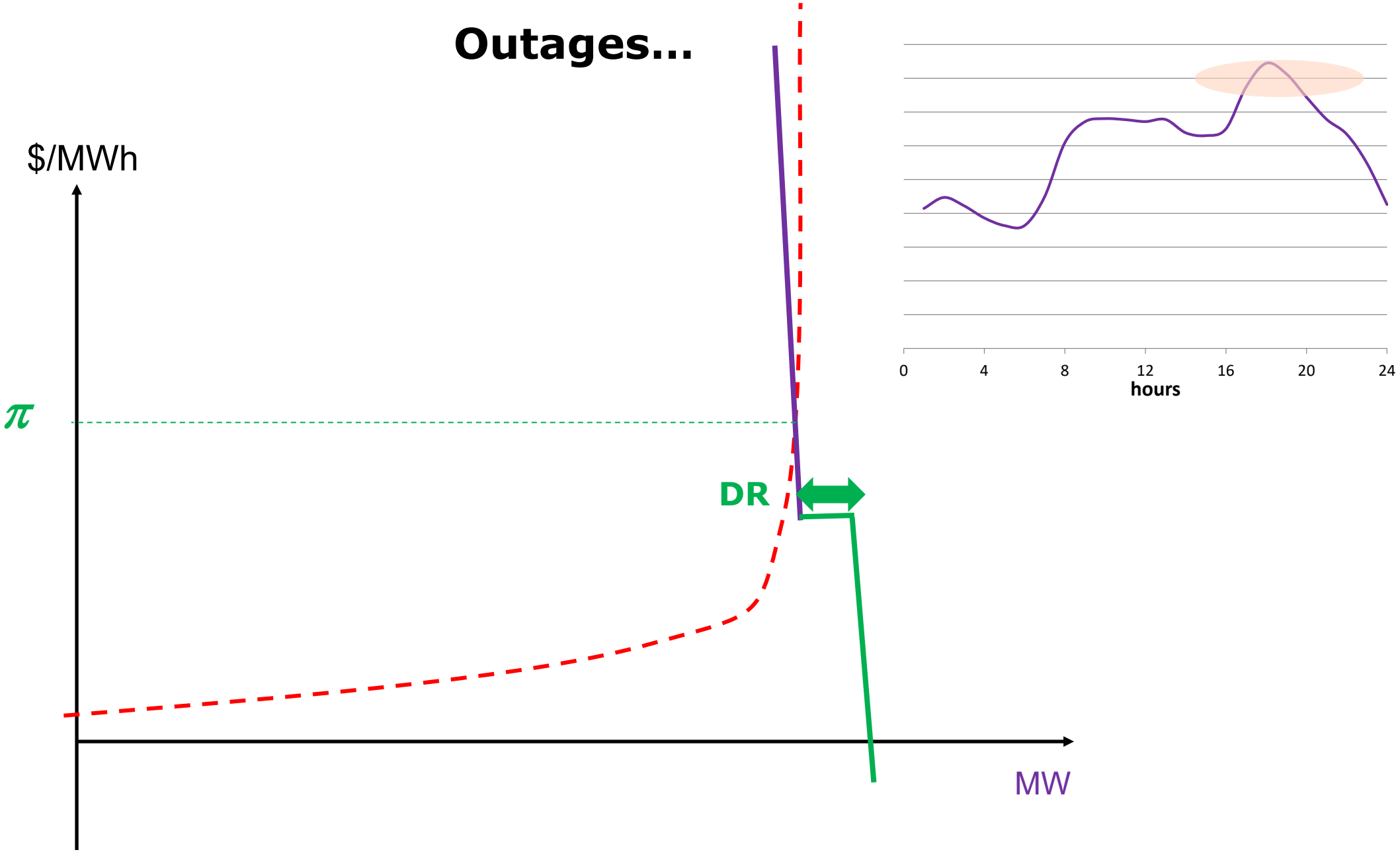

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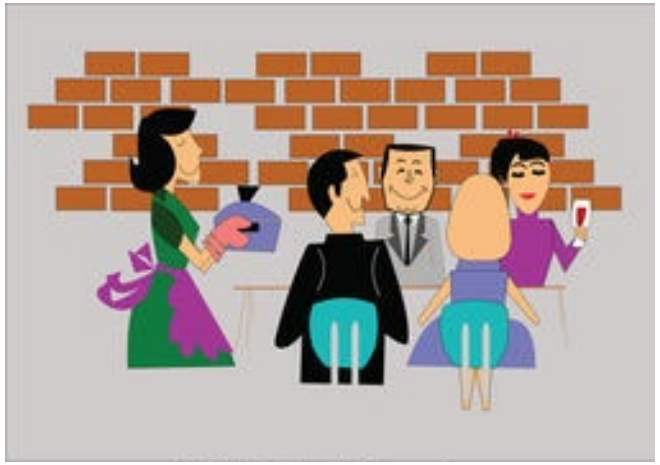
- *But benefits of "**demand response**" may be significant, especially under extreme conditions*
- So why not to do it?
  - Foregoing consumption is possible only for few activities
  - Shifting consumption is only possible if storage (in different forms) is available

Demand response and (consumer) flexibility

	Deferrable		Curtailable	
	Nonflexible	Flexible	Partially	Fully
TV				
Playstation				
Microwave oven				
Kettle				
Hob				
Oven				
Laptop				
Lighting				
Washing machine				
Dishwasher				
…				

Based on: S. Altaher, *et al.*, Automated Demand Response from Home Energy Management System under Dynamic Pricing and Power and Comfort Constraints, IEEE Transactions on Smart Grid, January 2015

Storing flexibility in clothes and dishes



(Images sourced from the internet)

Storing emotions?
July 17th, 1994

(Images sourced from the internet)

Demand response and (consumer) flexibility

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Playstation				
Microwave oven				
Kettle				
Hob				
Oven				
Laptop				
Lighting				
Washing machine				
Dishwasher				
…				

Flexibility has primarily to do with consumers, not with technology!

But a game changer is knocking at the door…

Demand response and (consumer) flexibility

	Deferrable		Curtailable	
	Nonflexible	Flexible	Partially	Fully
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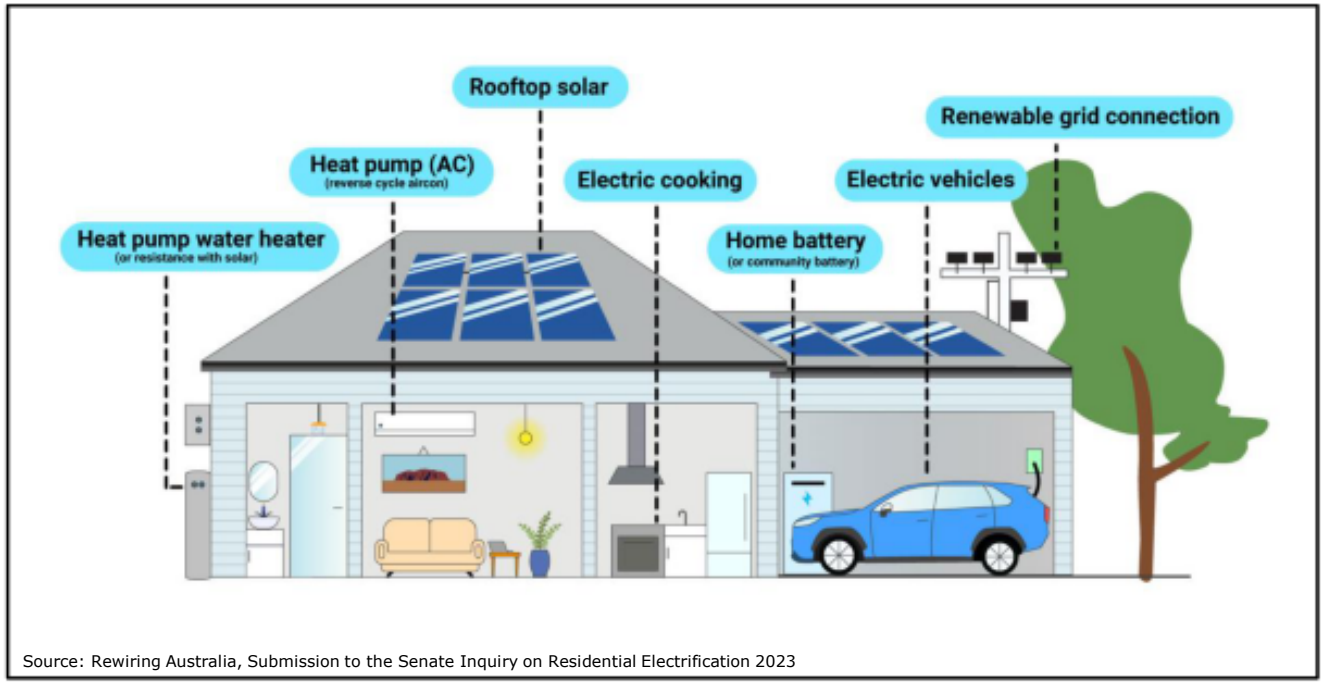
Playstation				
Microwave oven				
Kettle				
Hob				
Oven				
Laptop				
Lighting				
Washing machine				
Dishwasher				
Water heater				
Electric heat pump				
HVAC				
Electric vehicle				
Battery				
...				

Electrification!



Source: Rewiring Australia, Submission to the Senate Inquiry on Residential Electrification 2023

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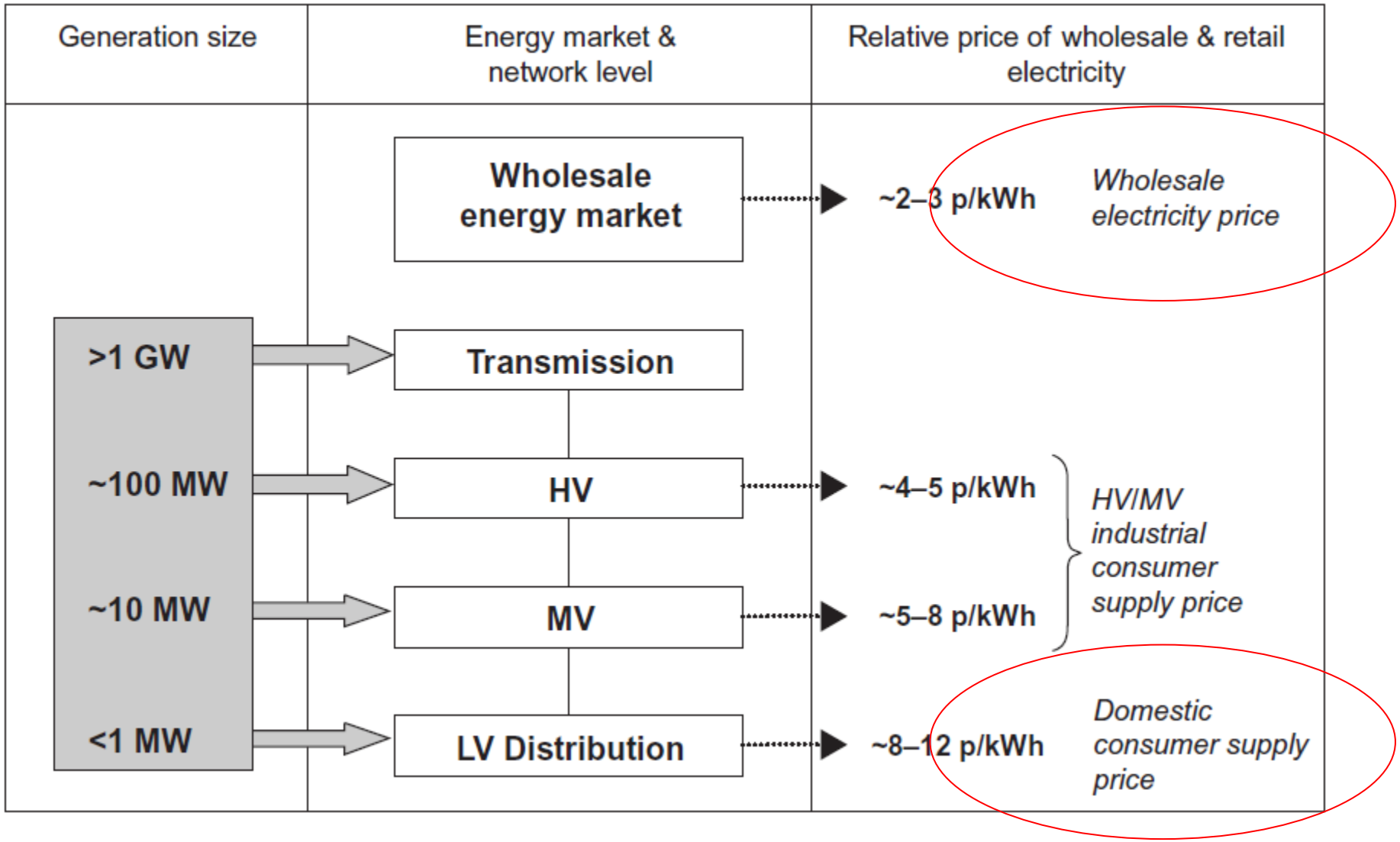
  - Shifting consumption (in different forms) is available
  - What else?

The historical value chain and prices



Source: N. Jenkins, J.B. Ekanayake, G. Strbac, "Distributed generation", IET, 2010

A typical electricity bill

Am I incentivised to be any flexible?

BREAKDOWN OF CHARGES **BILLING PERIOD: 28 DEC 22 - 27 MAR 23 (90 DAYS)**

A detailed breakdown of your new charges.

Your electricity charges

Your rate: General Usage

Charge description	Bill days	Meter no.	Previous read	Current read	Usage (kWh)	Charge (incl GST)	Amount (incl GST)
General Usage	90				301.769	21.700 c/kWh	$65.48
Daily Supply	90					116.230 c/Day	$104.61
(A = Actual, E = Estimated)						**Total electricity charges**	$170.09

Flat rate tariffs further reinforce price inelasticity of demand!

What is needed to unlock DR?

Price elasticity of demand

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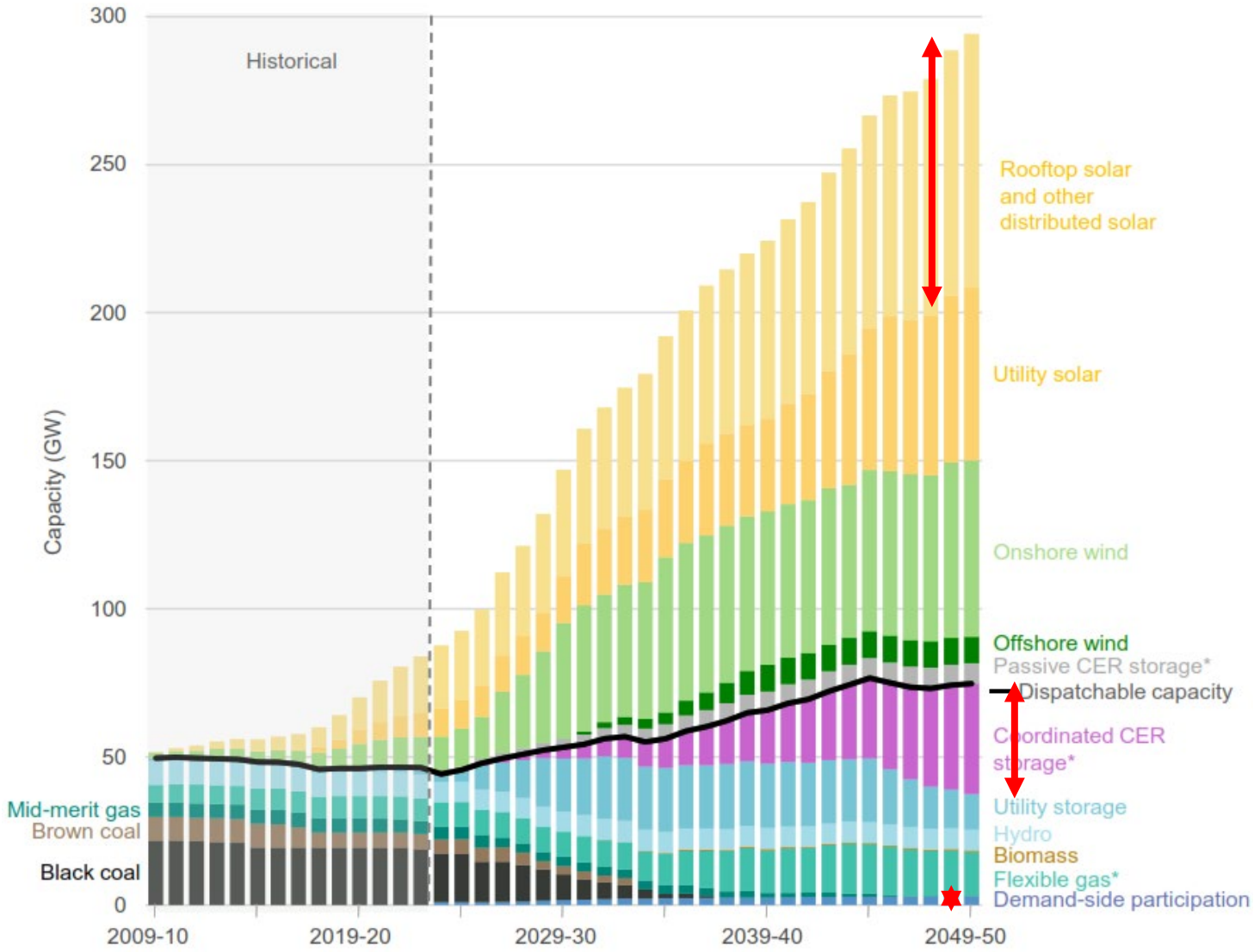
  - What else

Time-varying retail pricing and smart metering are essential to enable demand side flexibility

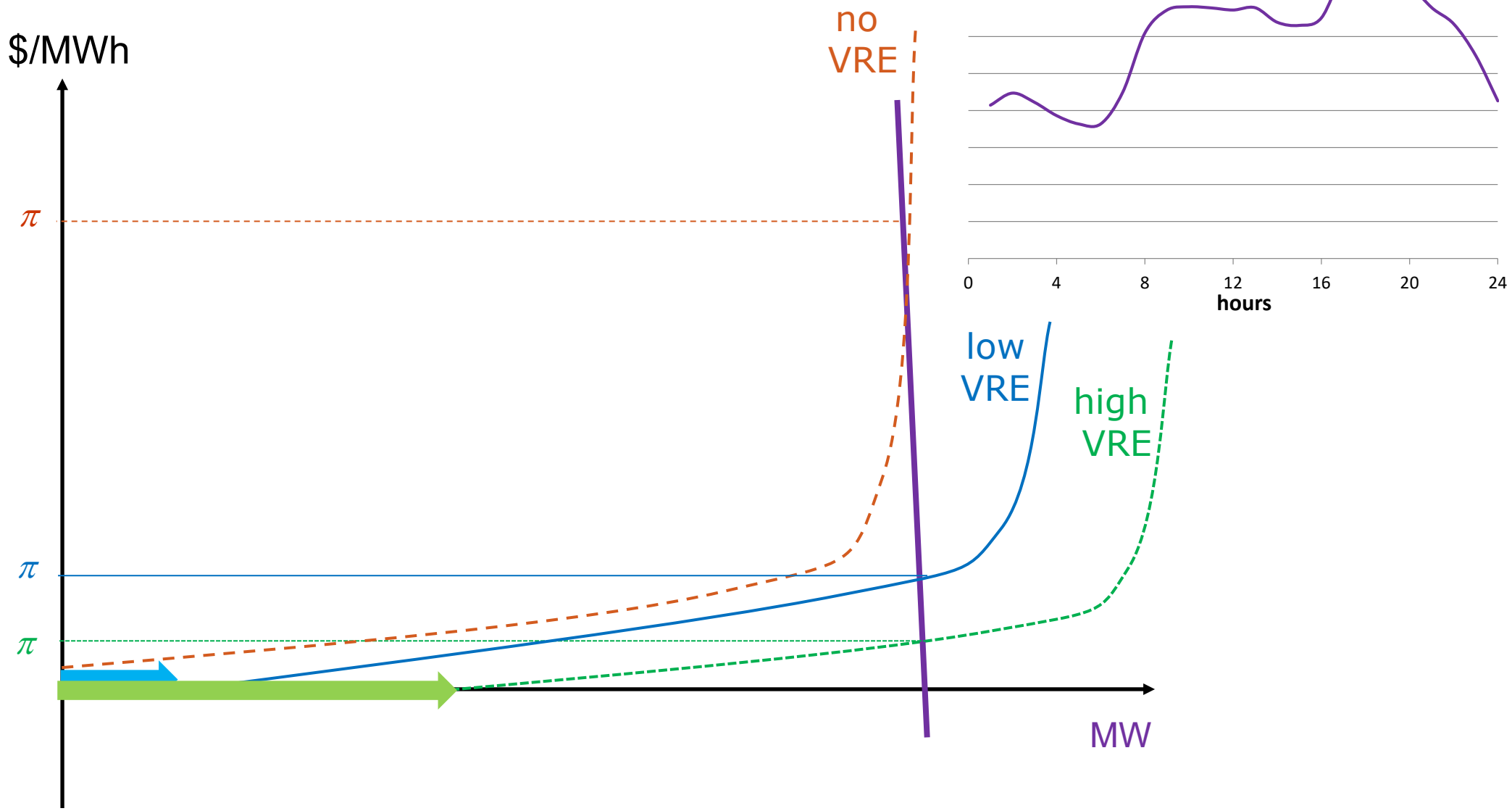
What is the role of demand side flexibility in the future?

Installed generation capacity, "Step change" scenario



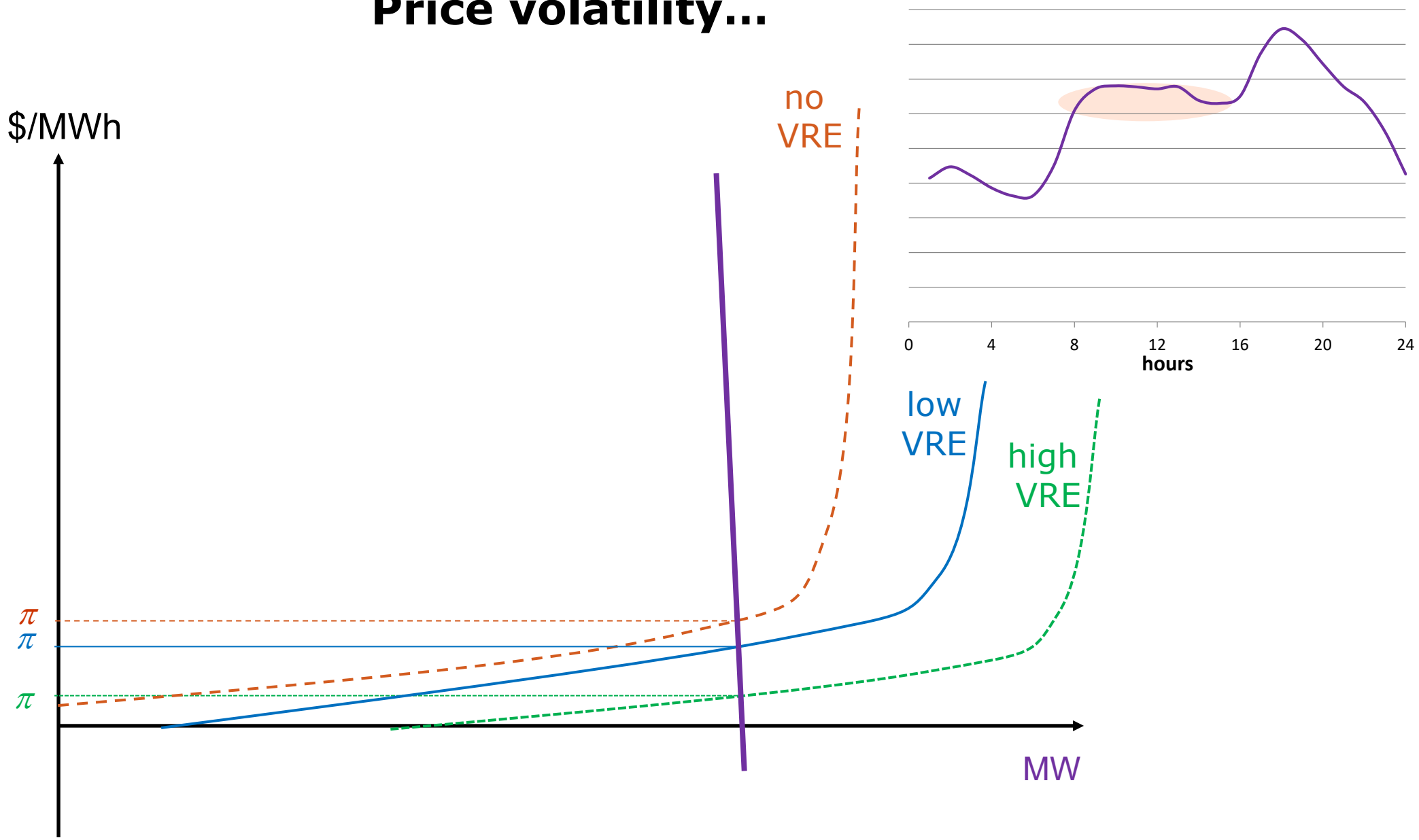
Source: AEMO, ISP 2024

Price volatility…



VRE=Variable Renewable Energy

Price volatility…



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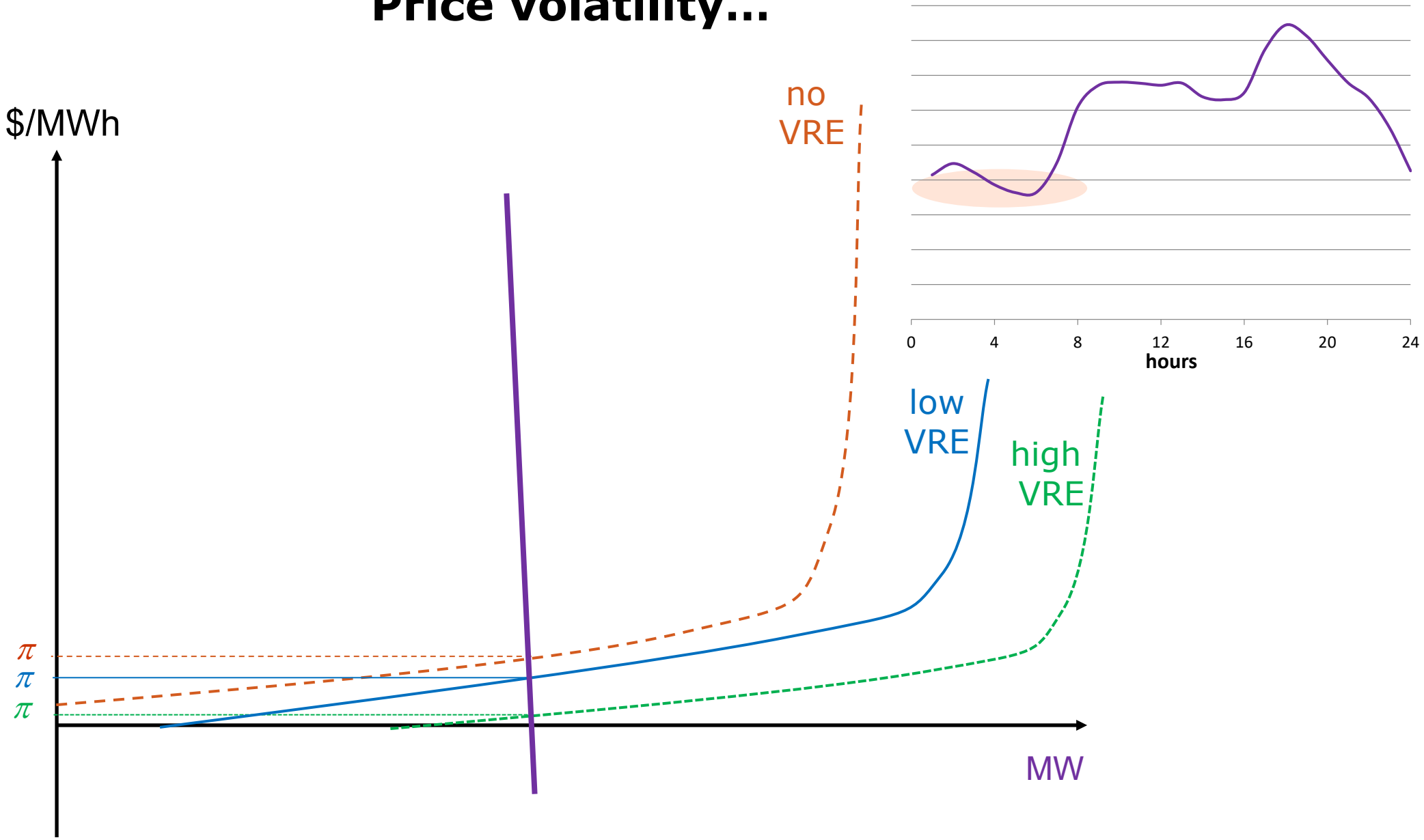
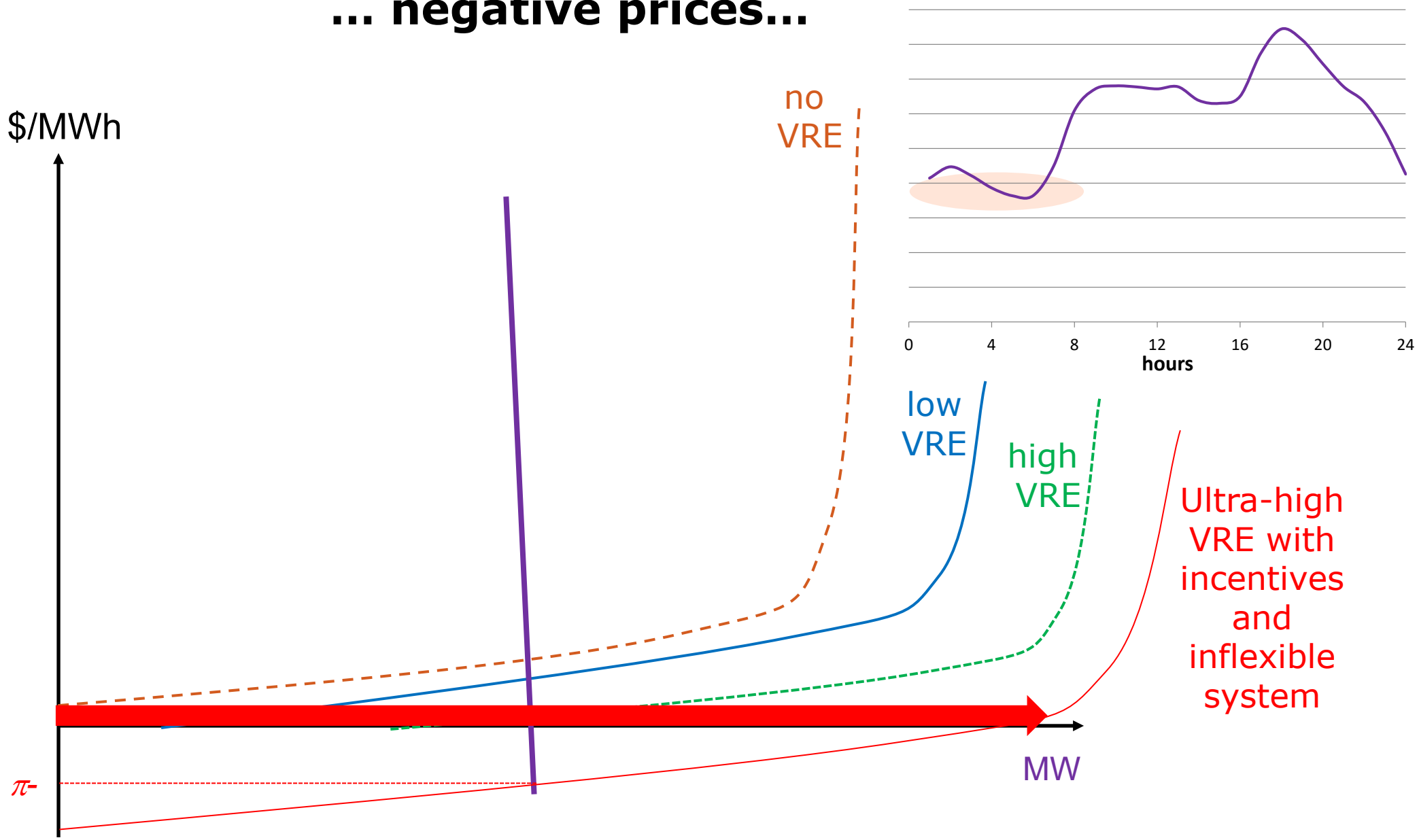


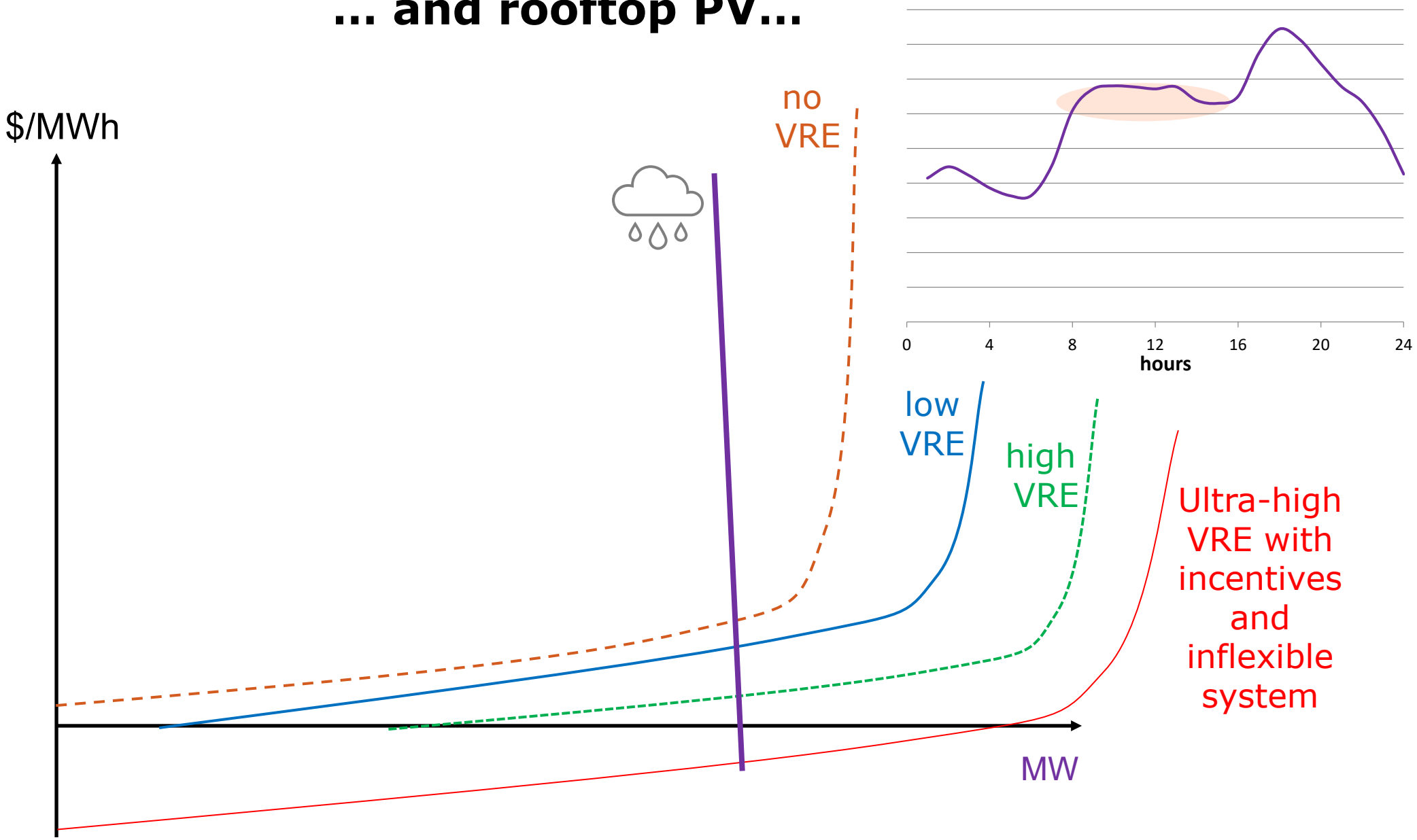
VRE=Variable Renewable Energy

… negative prices…



VRE=Variable Renewable Energy

… and rooftop PV…



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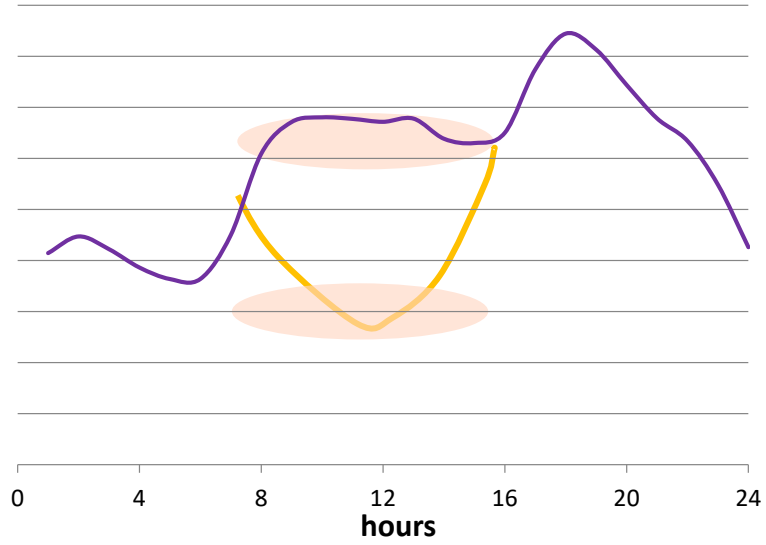


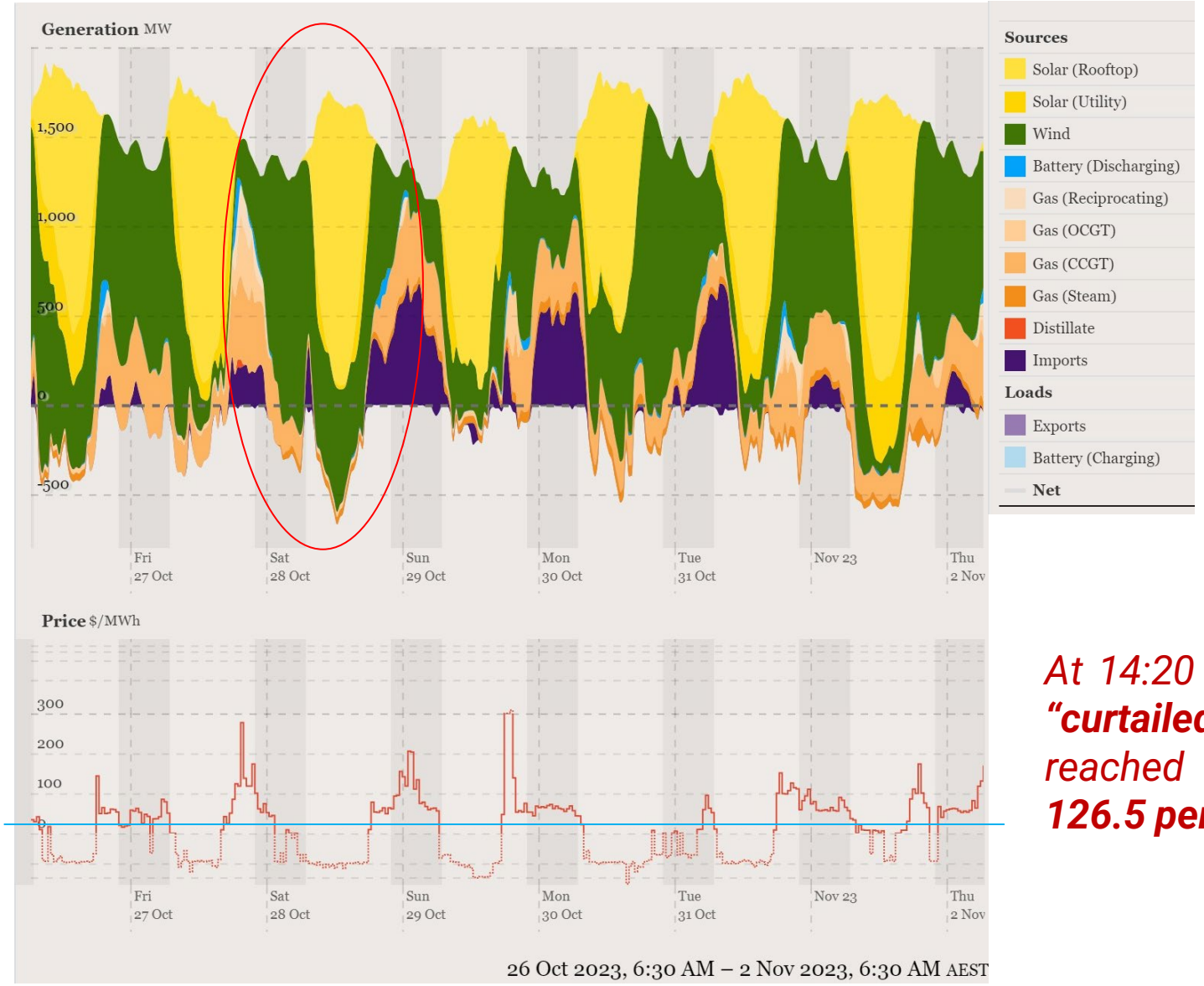
Negative prices!
That's all we wanted!

Is it really so?

VRE=Variable Renewable Energy

The full(er) picture…

*"Utility scale solar contributed just 4.2 per cent, but that's because the bulk of its **450MW** of installed **large scale solar capacity** in the state was **curtailed** most of the time by negative prices"*



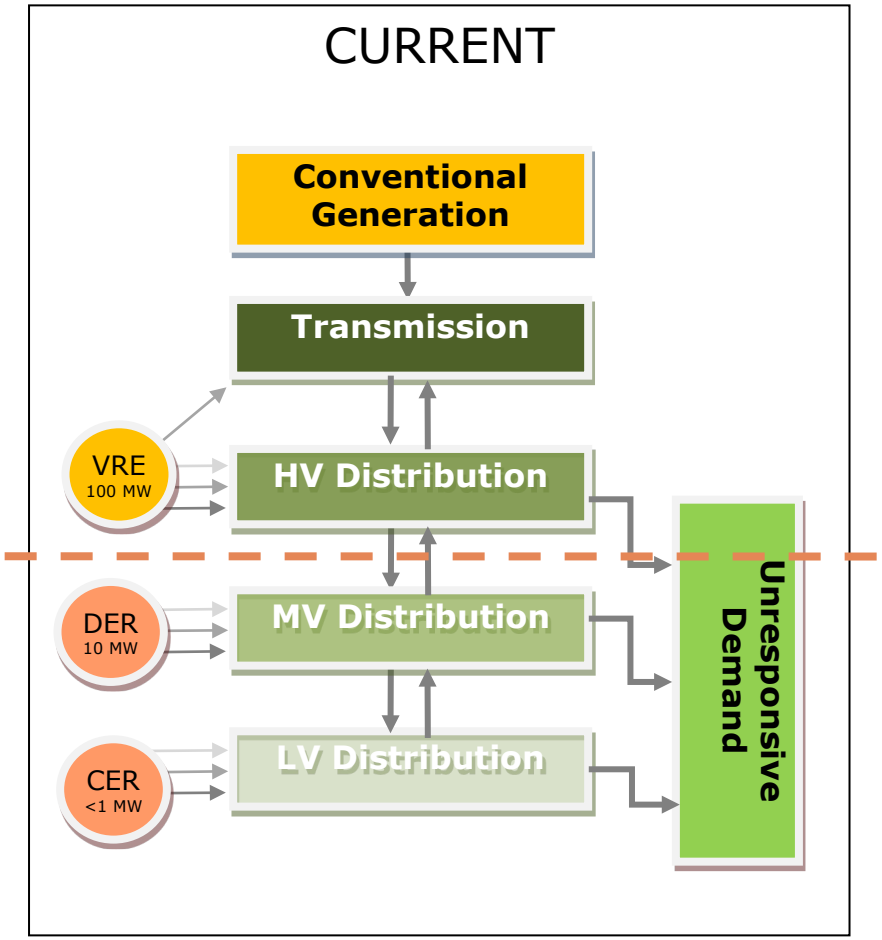
*At 14:20 AEST on Saturday **"curtailed" wind and solar** reached a phenomenal **126.5 per cent**"*

Source: OpenNEM

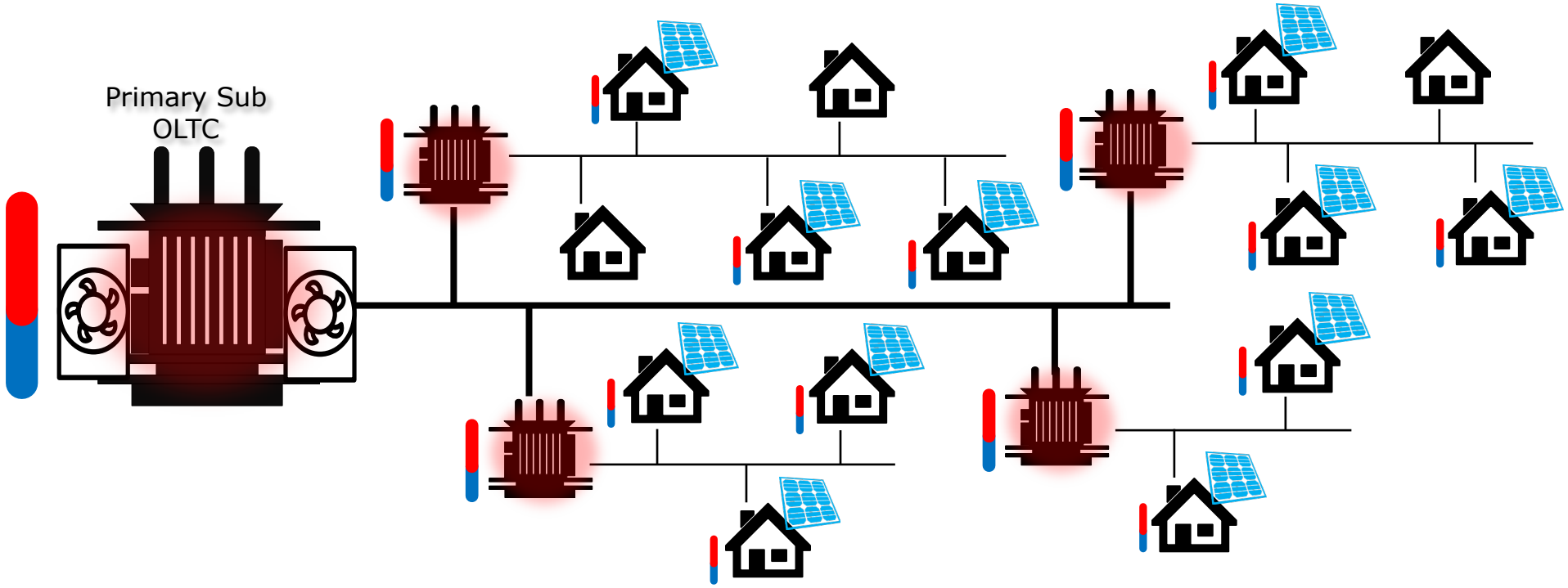
System and market issues with a "Fit & Forget" paradigm

Visible generators = "dispatchable" and "controllable"

Invisible **embedded generation** = "non-dispatchable" and "non-controllable"



Network issues with uncontrolled embedded generation

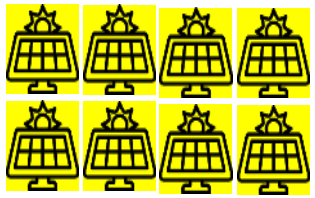


Source: M. Liu *et al.*, "Grid and market services from the edge", *IEEE Power and Energy Magazine*, July/August 2021

System balancing in the future

Supply side

Large scale, centralised generation



MARKET SERVICES

INFLEXIBLE CONSUMPTION

Demand side

IMPORTED FLEXIBILITY

- INTECONNECTIONS
- AC LINES
- HVDC

(Images sourced from the internet)

System balancing in the future

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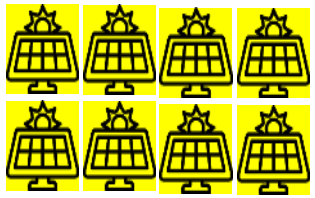

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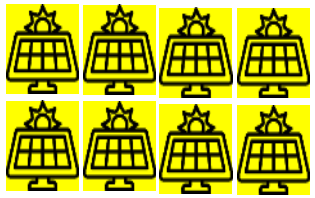

Supply side

Large scale, centralised generation

MARKET SERVICES

INFLEXIBLE CONSUMPTION

IMPORTED FLEXIBILITY

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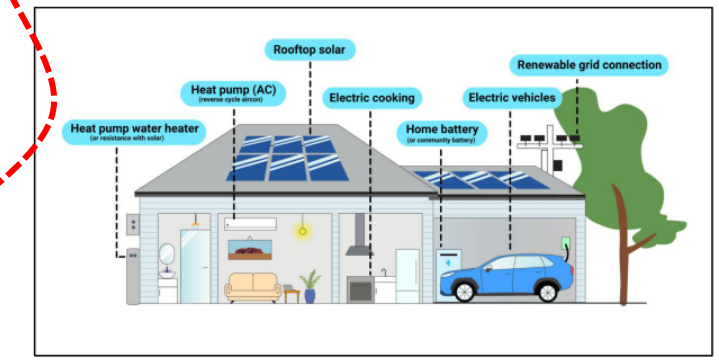
Demand side

New, huge opportunities for DER



Source: Rewiring Australia, Submission to the Senate Inquiry on Residential Electrification 2023

(Images sourced from the internet)

From DR to DER to CER

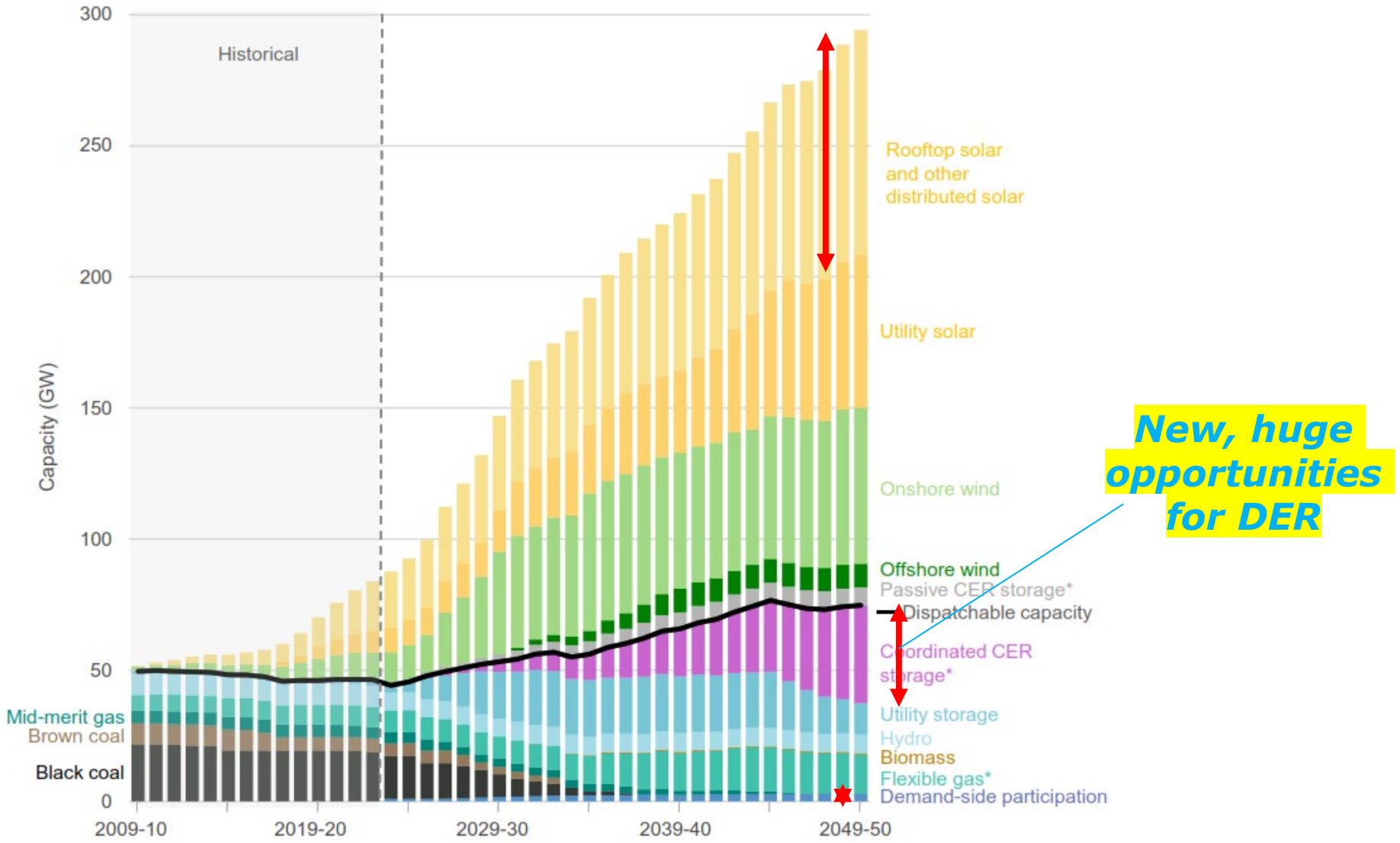
- Rooftop PV and electrification mean we are witnessing the dawn of **distributed energy resources**

- **DER** refers to any active resource connected to distribution networks:
  - Distributed Generation (**DG**)
  - Demand Response (**DR**) from flexible consumption
  - Different forms of **storage**

- DER often refer to **"behind-the meter"** appliances belonging to consumers
  - "*Prosumers*" = producers + consumers
  - Consumer energy resources (**CER)**

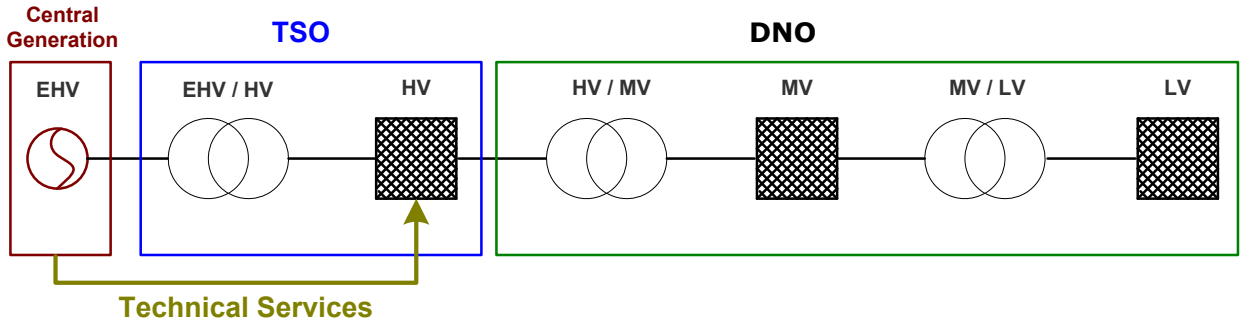
What is the role of demand side flexibility in the future?

Installed generation capacity, "Step change" scenario



Source: AEMO, ISP 2024

A changing paradigm for flexibility provision

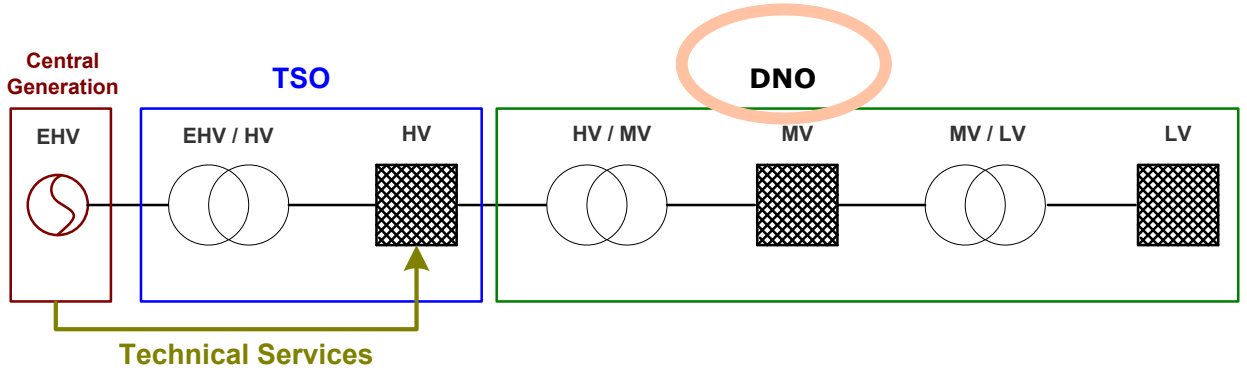


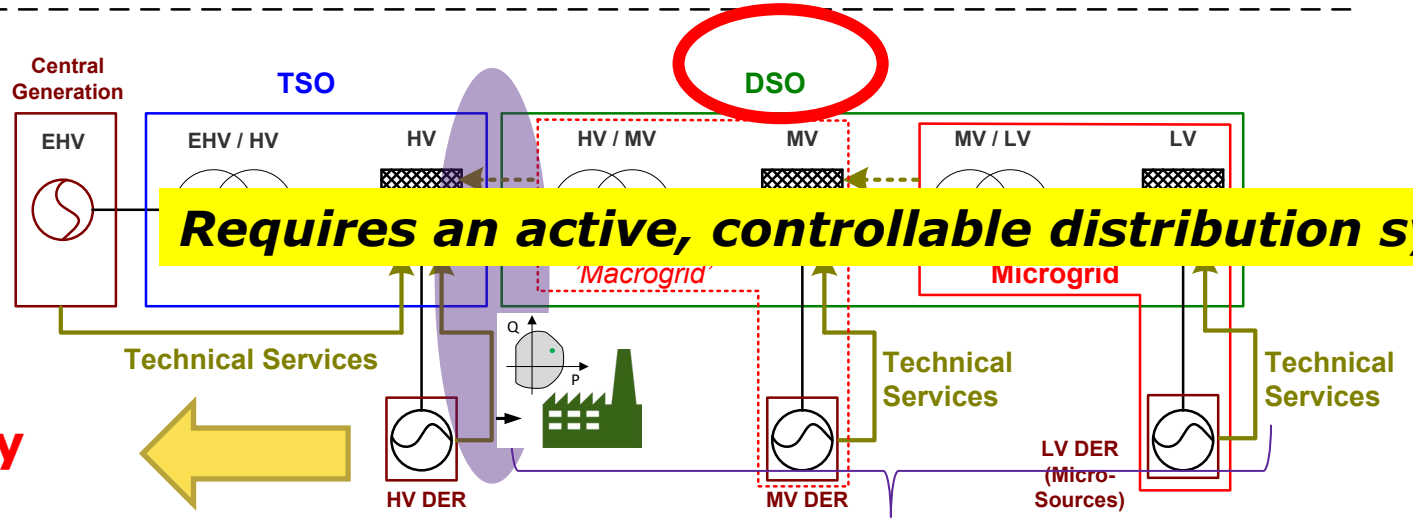
Past

Flexibility → **Inflexibility**

Source: More Microgrids project, 2010

A changing paradigm for flexibility provision

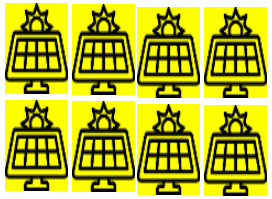




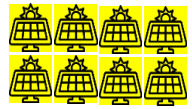
Requires an active, controllable distribution system

Future

Inflexibility



DER, VPP, Communities, Microgrids

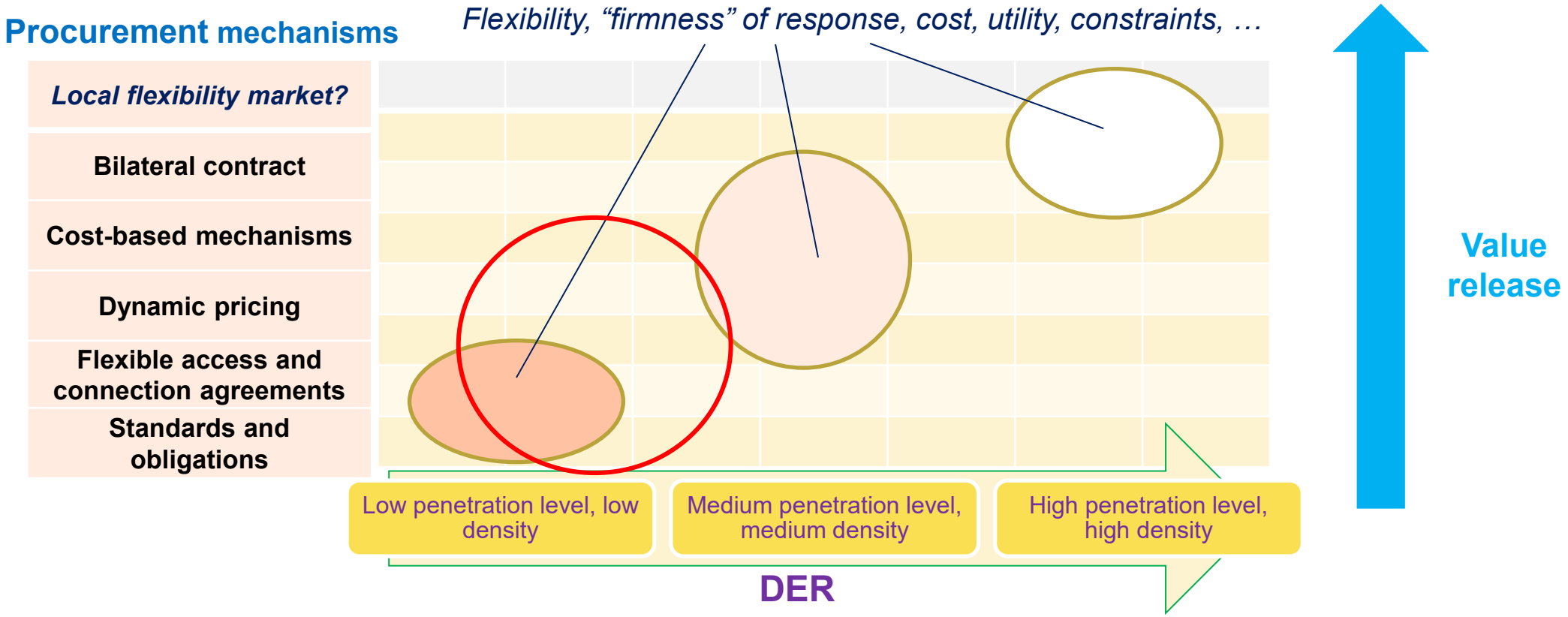


Flexibility

Source: More Microgrids project, 2010

(Images sourced from the internet)

Enabling DER:
From standards to markets



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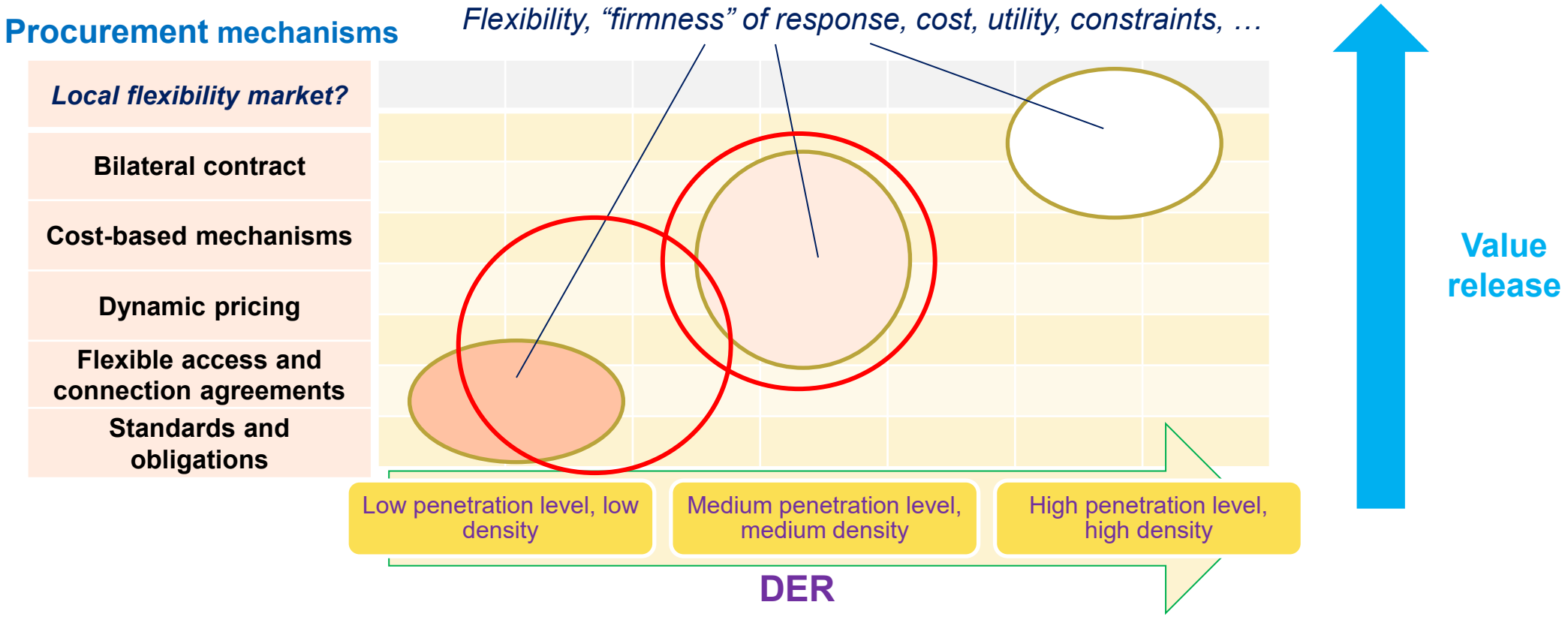
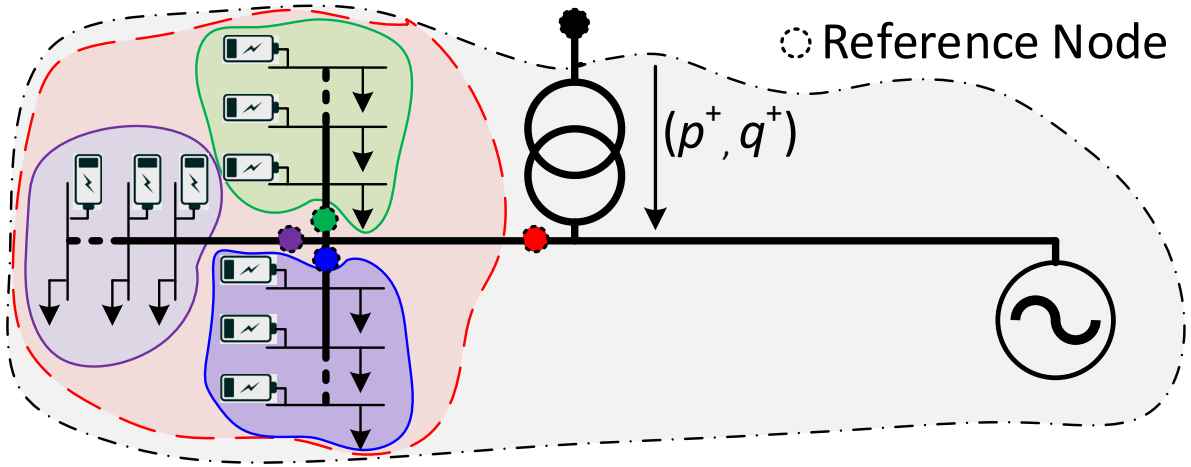


Aggregation and orchestration benefits: *virtual power plants (VPPs)*



Source: S. Riaz *et al*, "Modelling and characterisation of flexibility from distributed energy resources", *IEEE Transactions on Power Systems*, July 2021

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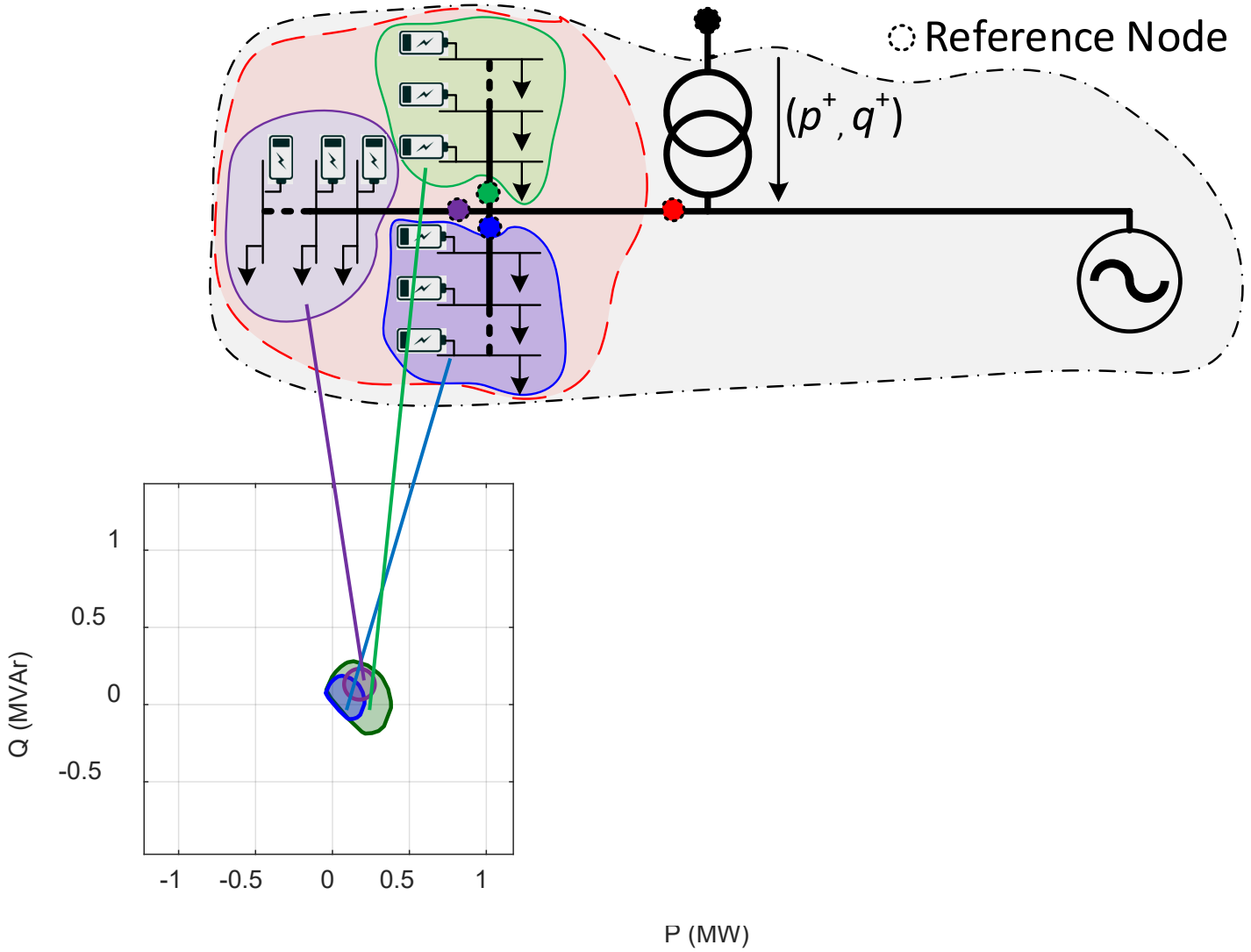

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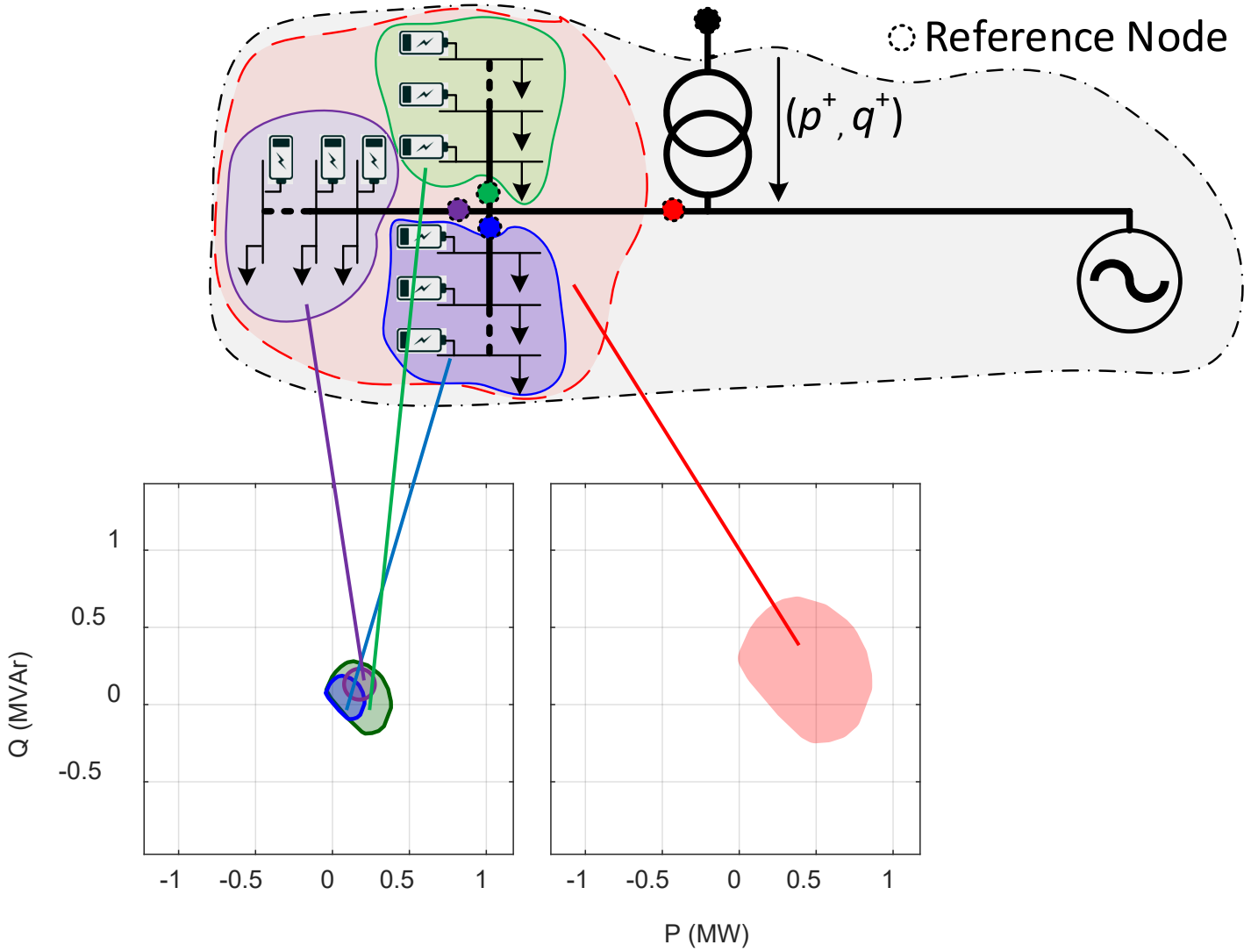

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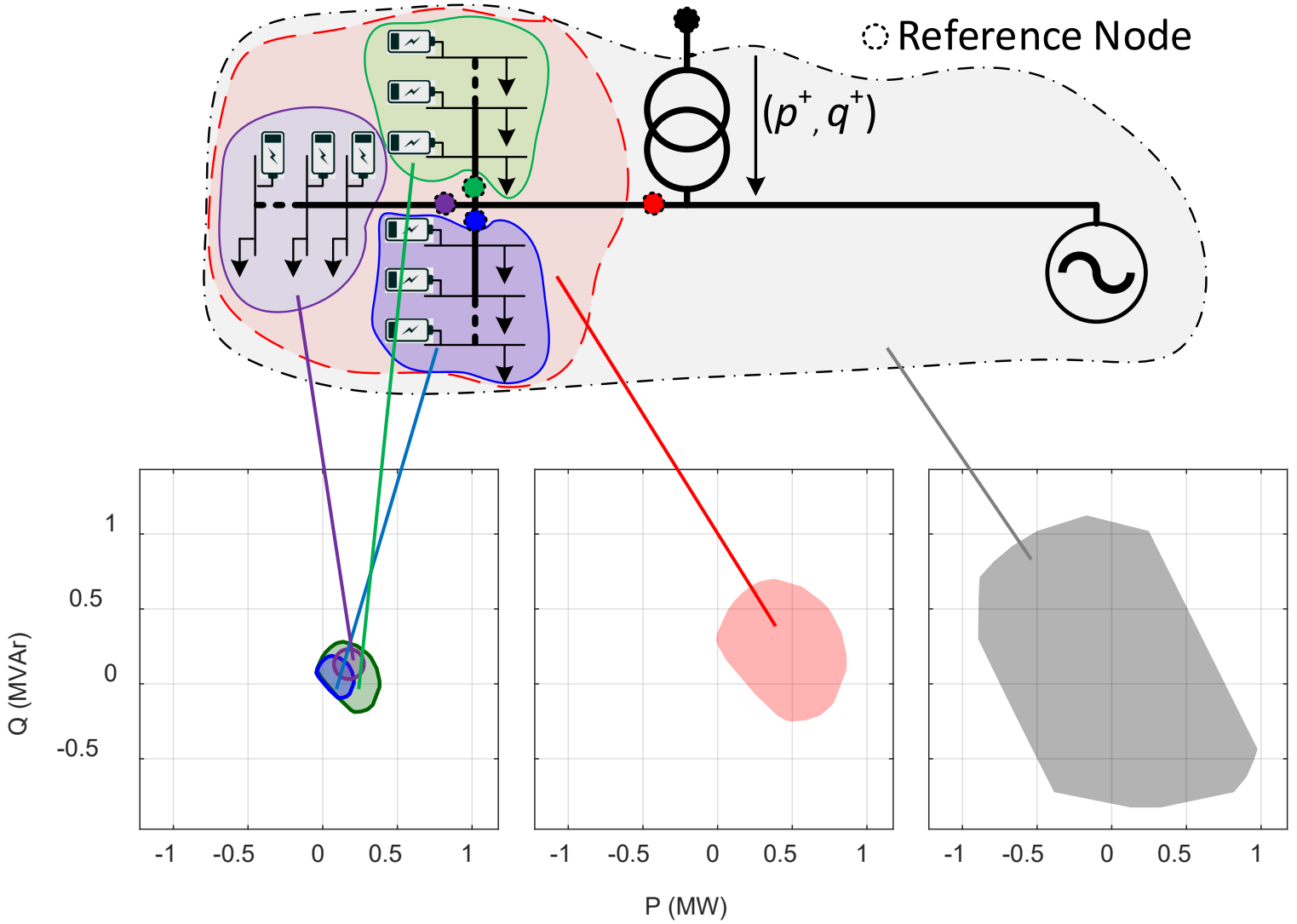
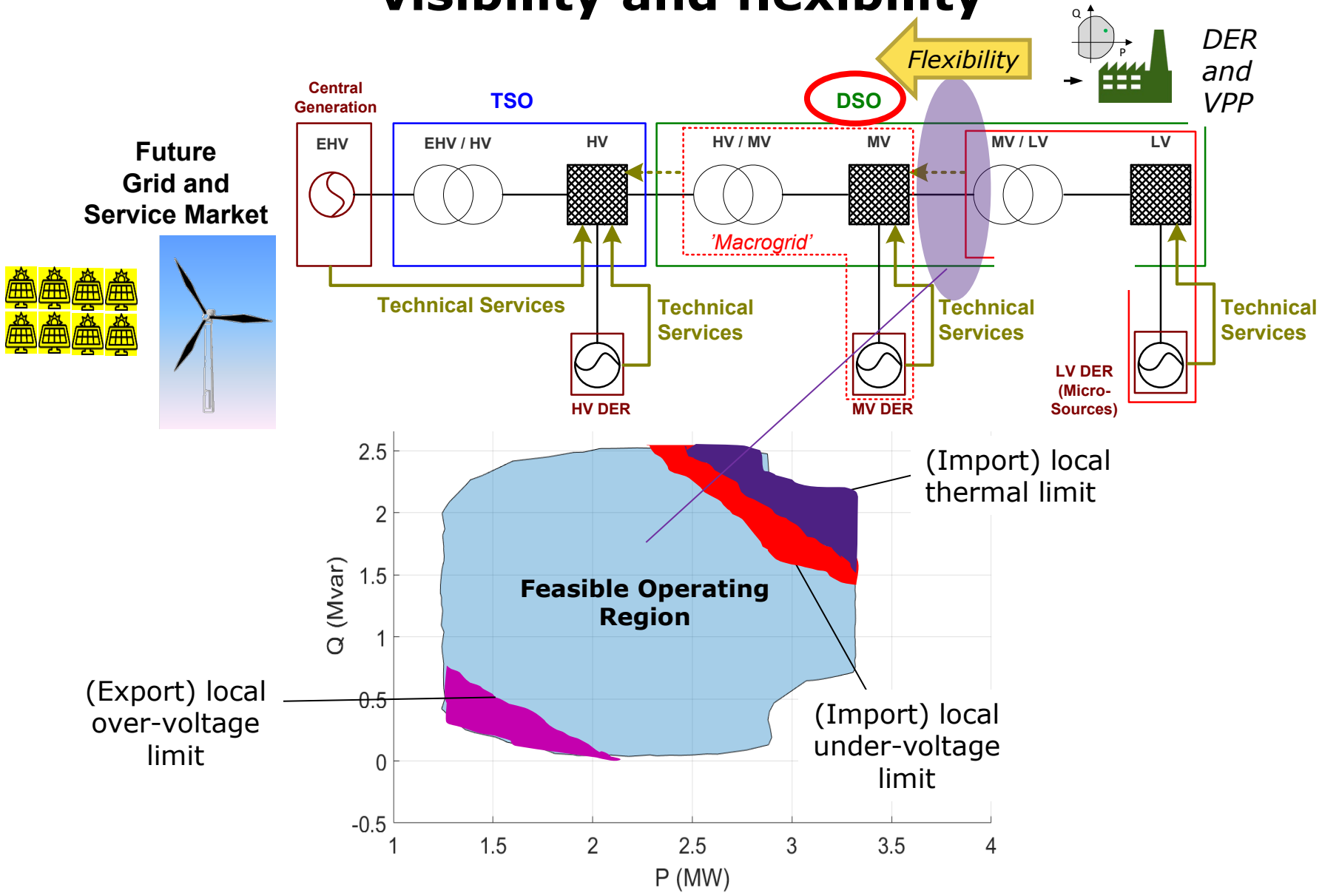


Maths of DER aggregation:
1+1>2
☺

Source: S. Riaz *et al*, "Modelling and characterisation of flexibility from distributed energy resources", *IEEE Transactions on Power Systems*, July 2021

Network-aware local and system-level visibility and flexibility



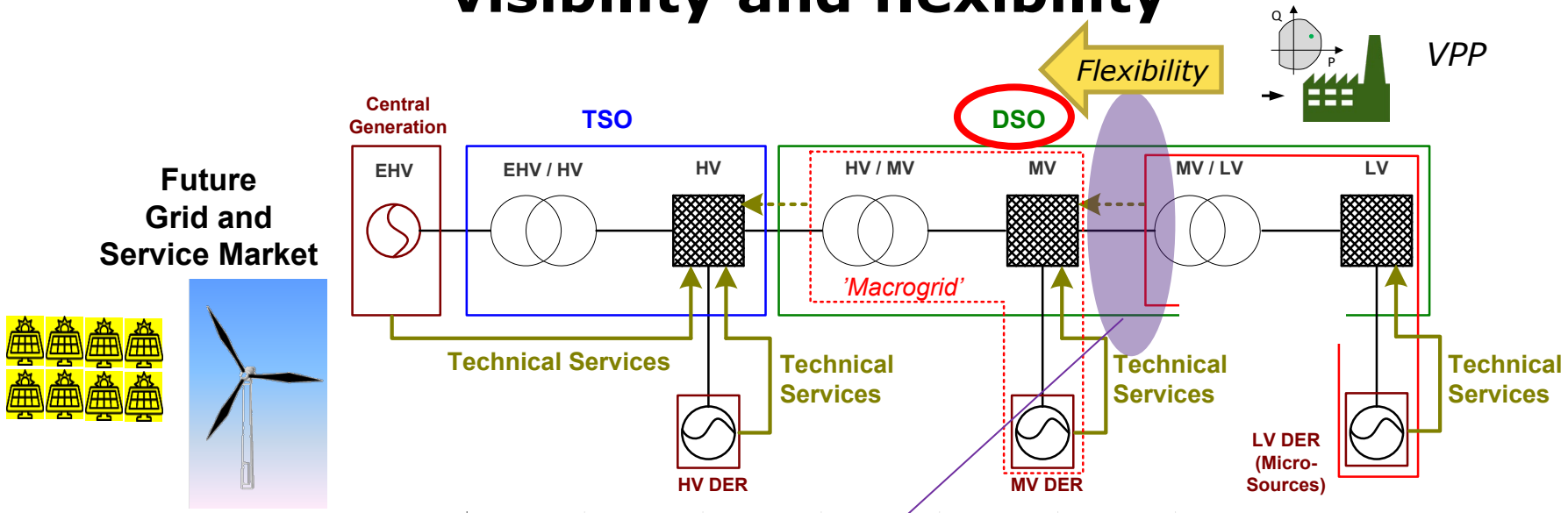
Lack of DER visibility and system security

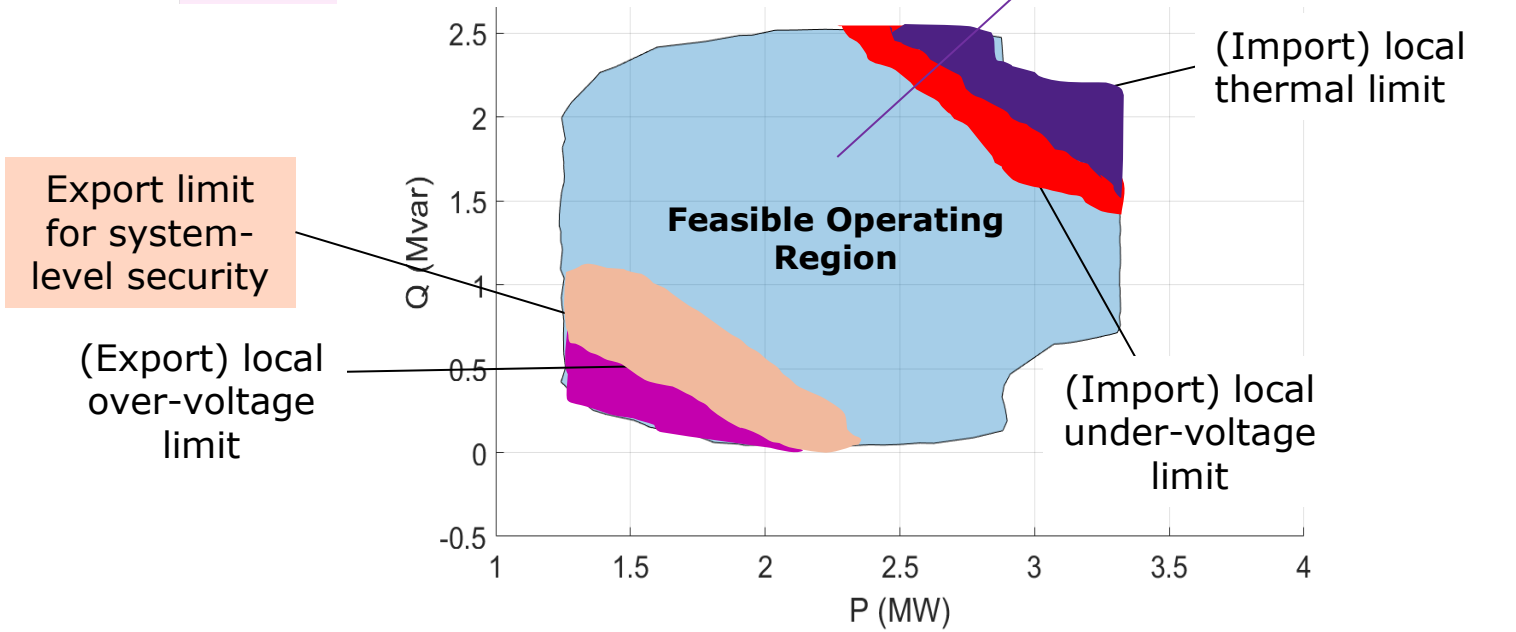
Electricity provider authorised to switch off rooftop solar in SA in emergencies

This is the consequence of DER not being visible/dispatchable/controllable in a relatively weak grid

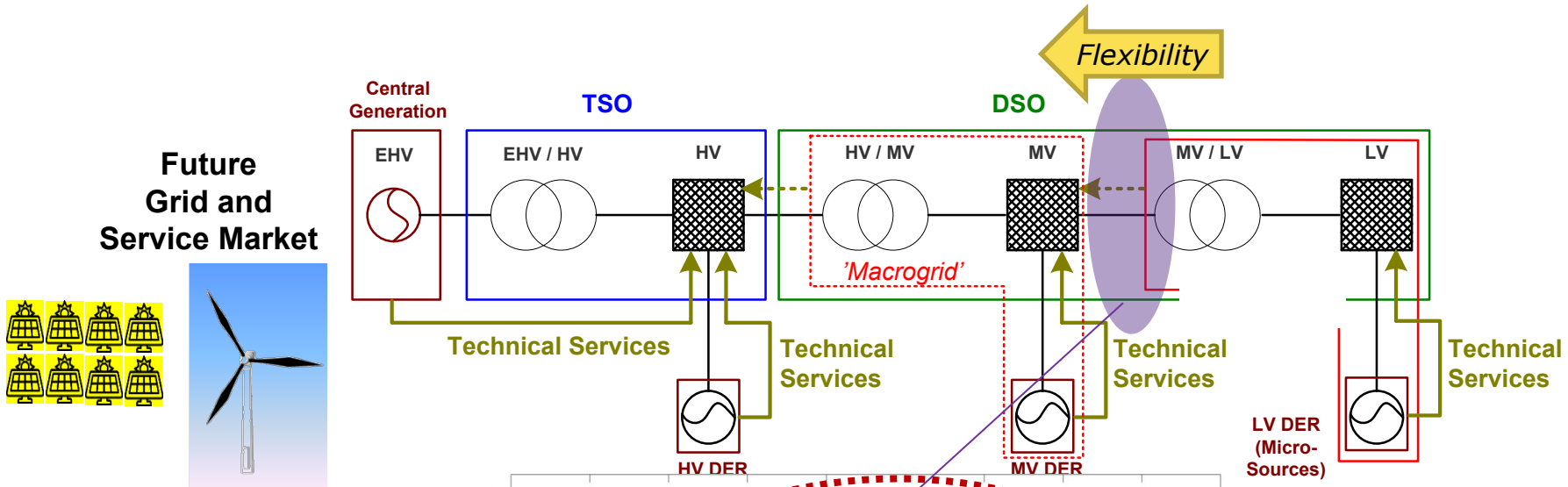
Source: *ABC News*, 27 August 2020

Network-aware local and system-level visibility and flexibility



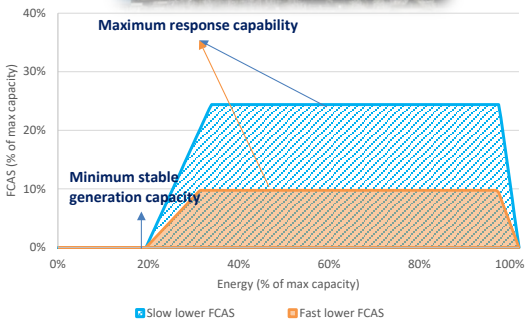


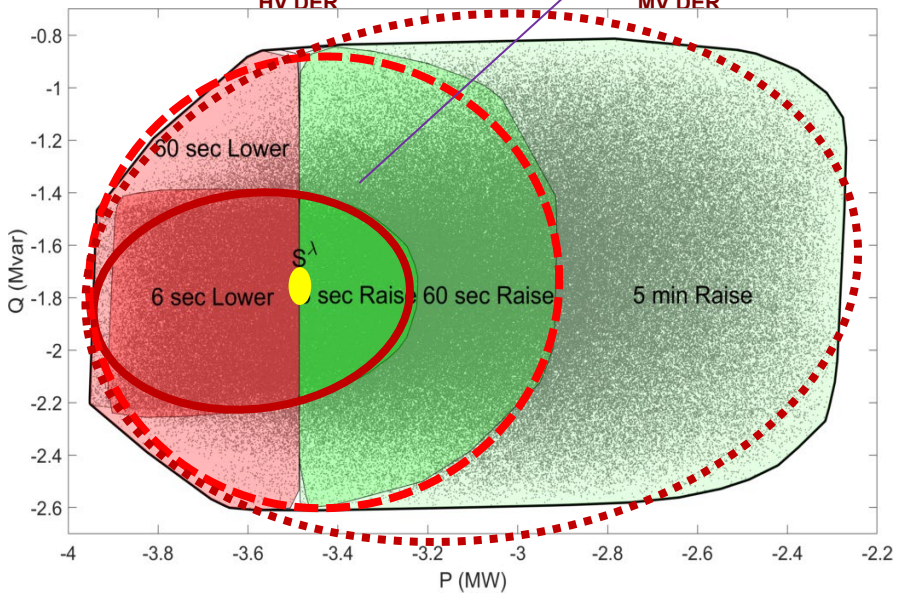
Not only energy flexibility



Future Grid and Service Market

CCGT



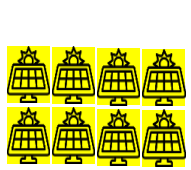


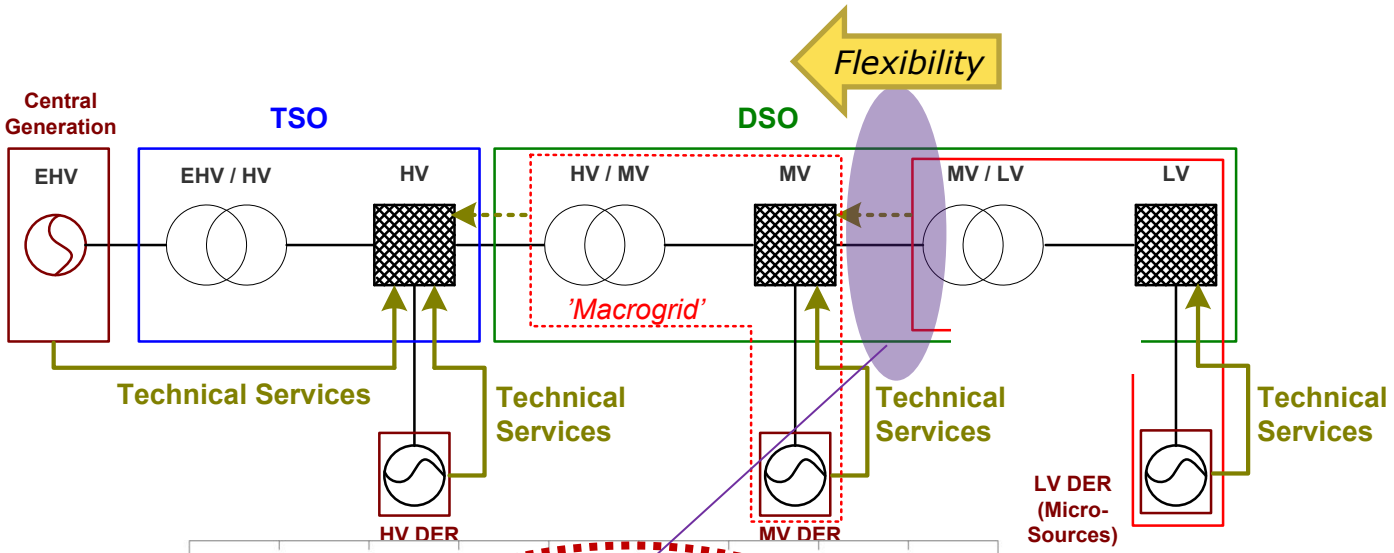
As part of aggregation schemes, network-constrained DER could provide flexibility and grid services, including for system security

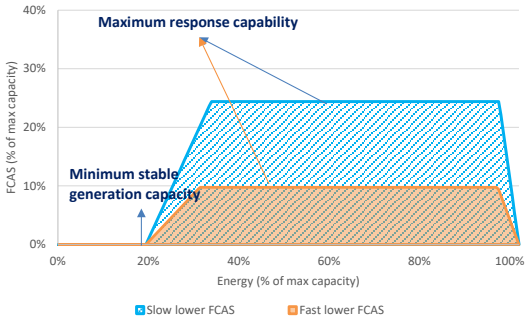
Source: H. Wang, *et al*, "Integrated Techno-economic Modeling, Flexibility Analysis, and Business Case Assessment of an Urban Virtual Power Plant with Multi-market Co-optimization", *Applied Energy*, 259, 1 February 2020, 114142.

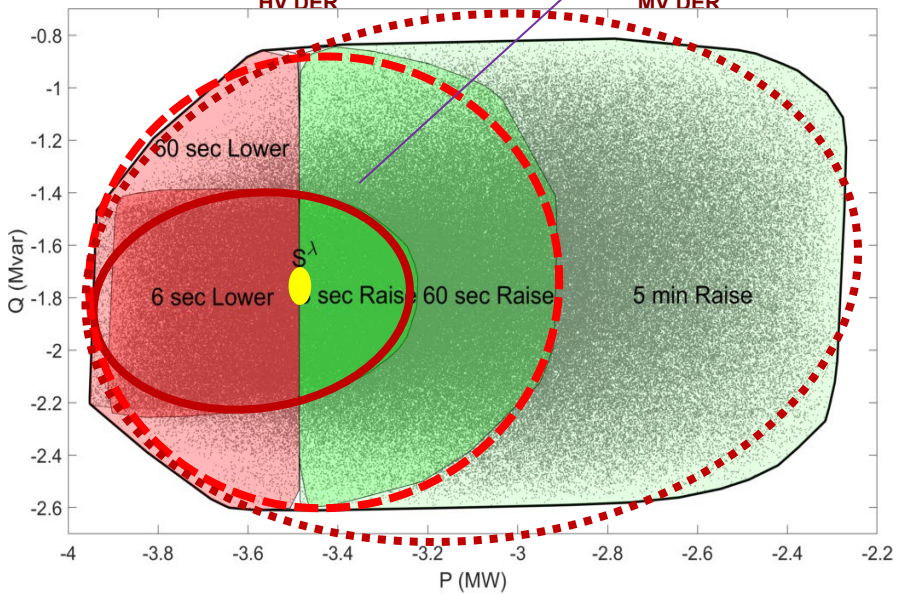
Not only energy flexibility

Future Grid and Service Market







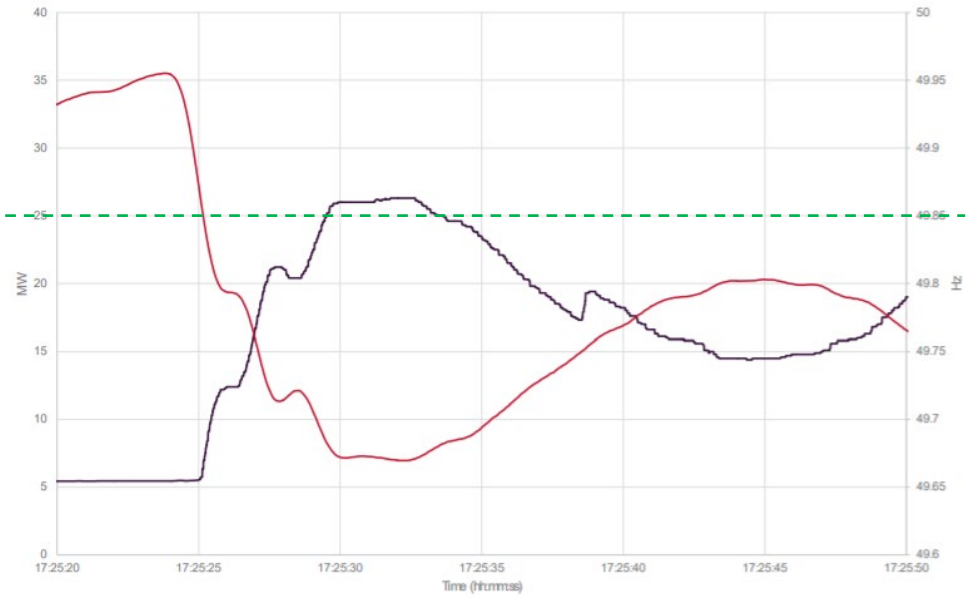


As part of aggregation schemes, network-constrained DER could provide flexibility and grid services, including for system security

Source: H. Wang, *et al*, "Integrated Techno-economic Modeling, Flexibility Analysis, and Business Case Assessment of an Urban Virtual Power Plant with Multi-market Co-optimization", *Applied Energy*, 259, 1 February 2020, 114142.

Does size matter?

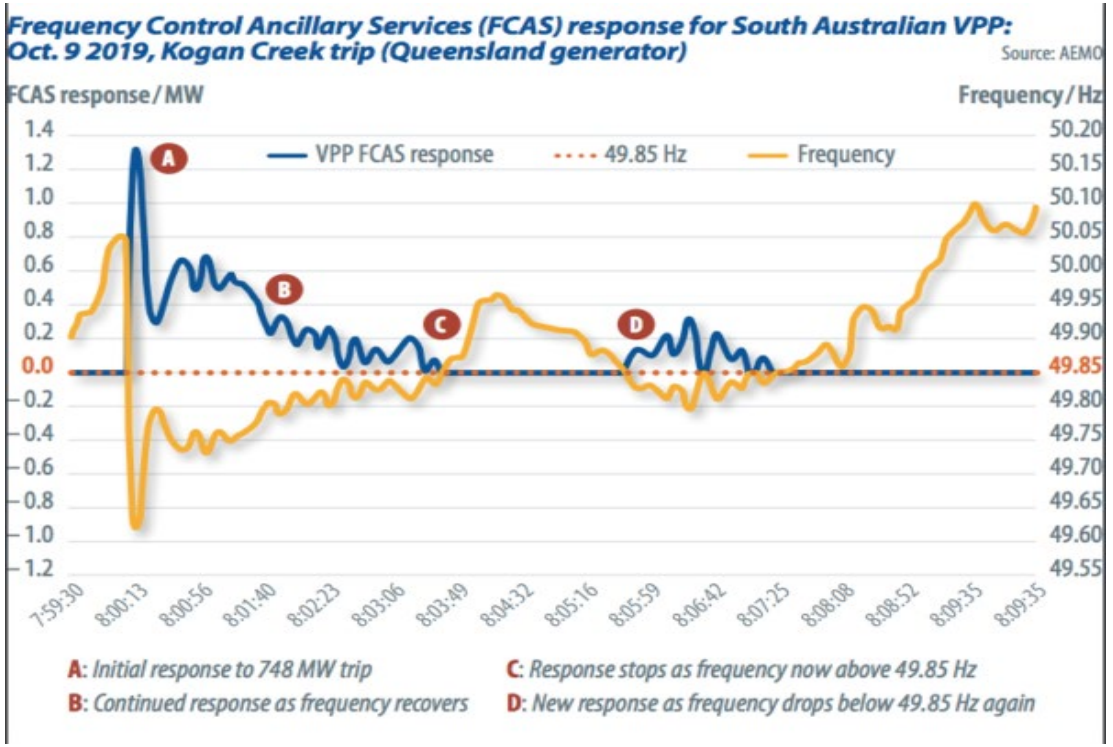
"Big battery"



Frequency Battery MW

Hornsdale Power Reserve response to trip of generation in NSW, 18 Dec 2017

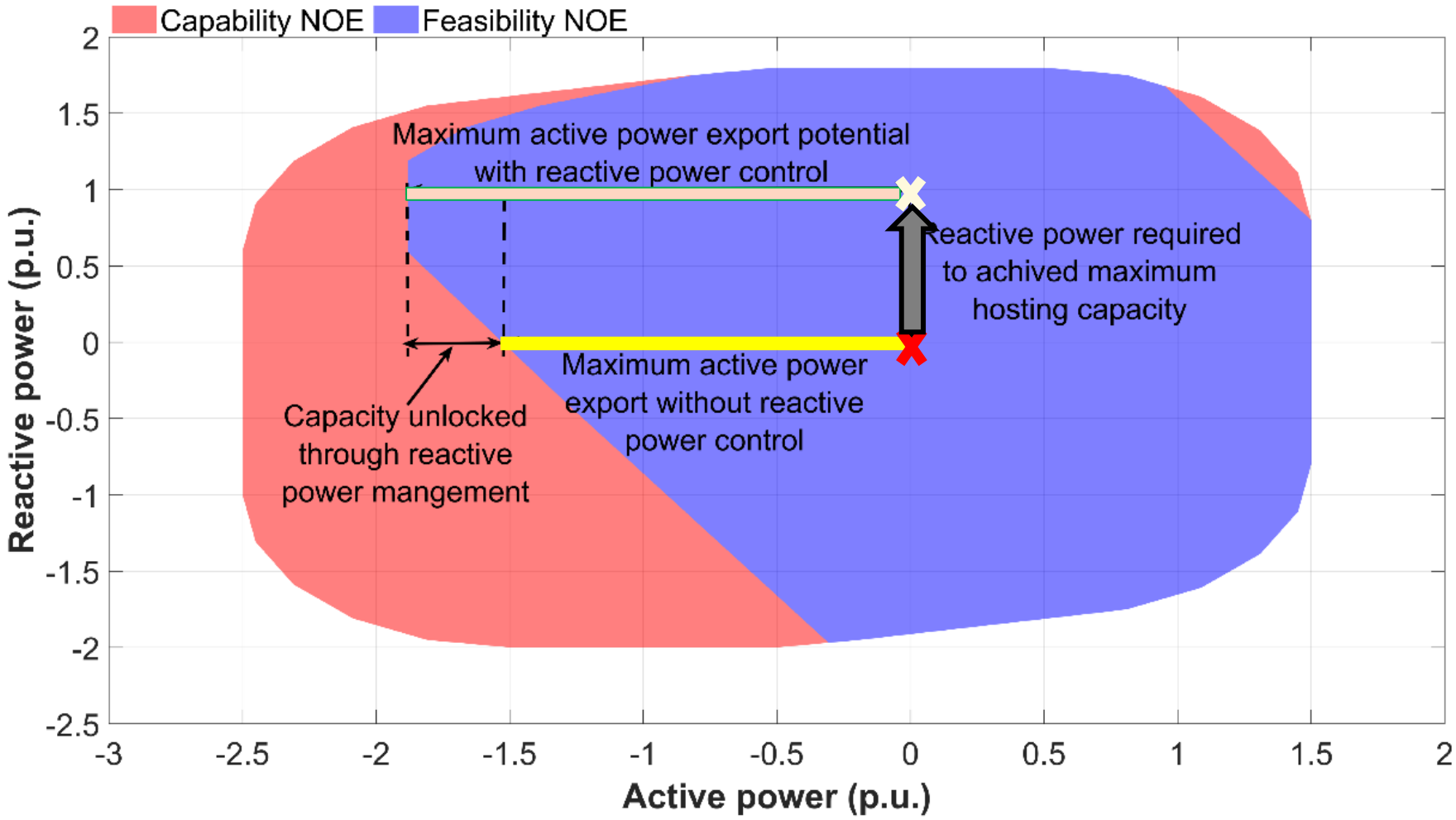
VPP



South Australia VPP response to trip of Kogan Creek, 9 Oct 2019

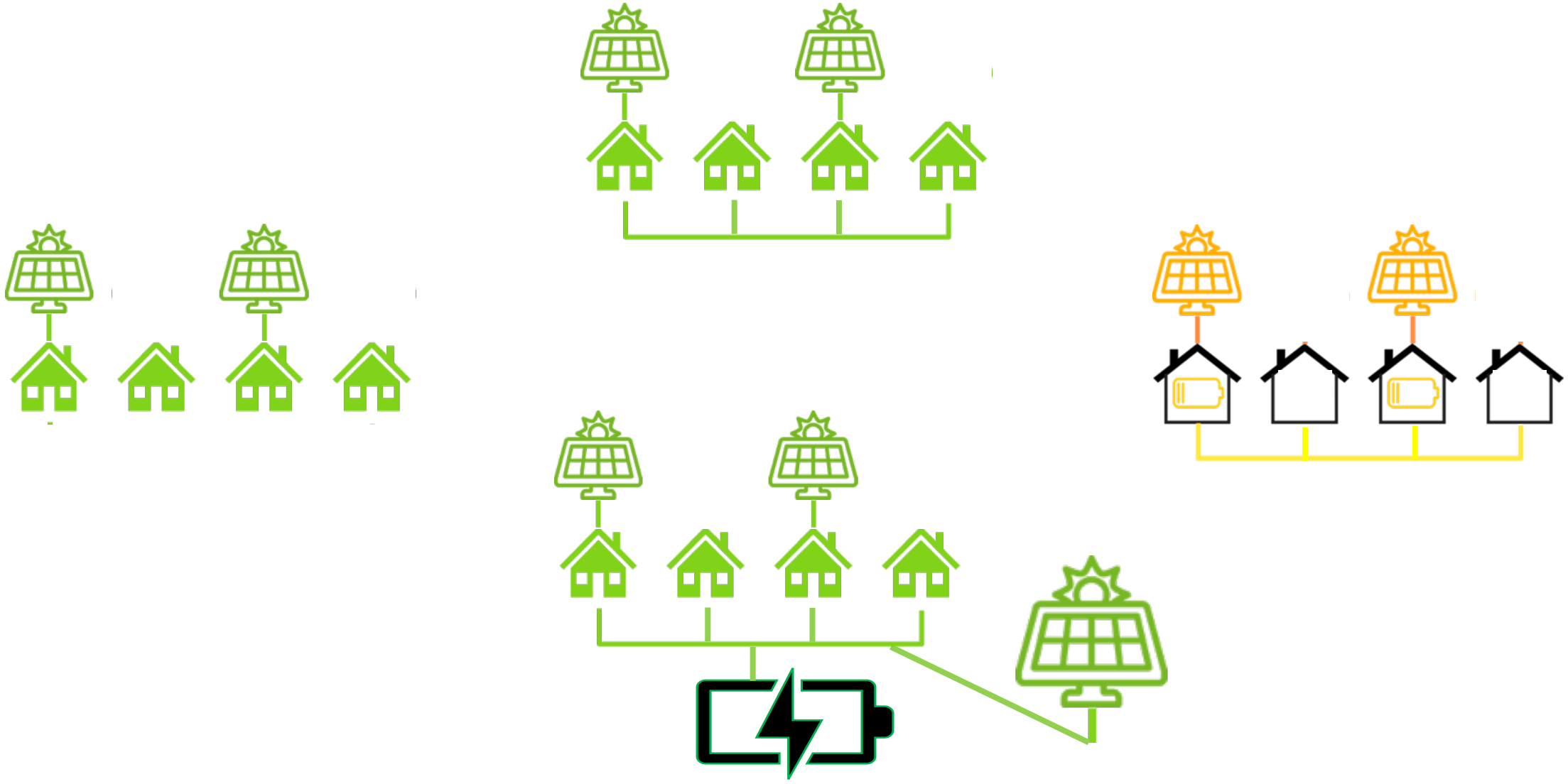
Sources: "Initial operation of the Hornsdale Power Reserve Battery Energy Storage System" *AEMO*, April 2018; https://www.pv-magazine-australia.com/2020/04/04/long-read-orchestral-support-for-an-evolving-energy-system/ and AEMO.

Integrated provision of local and system services



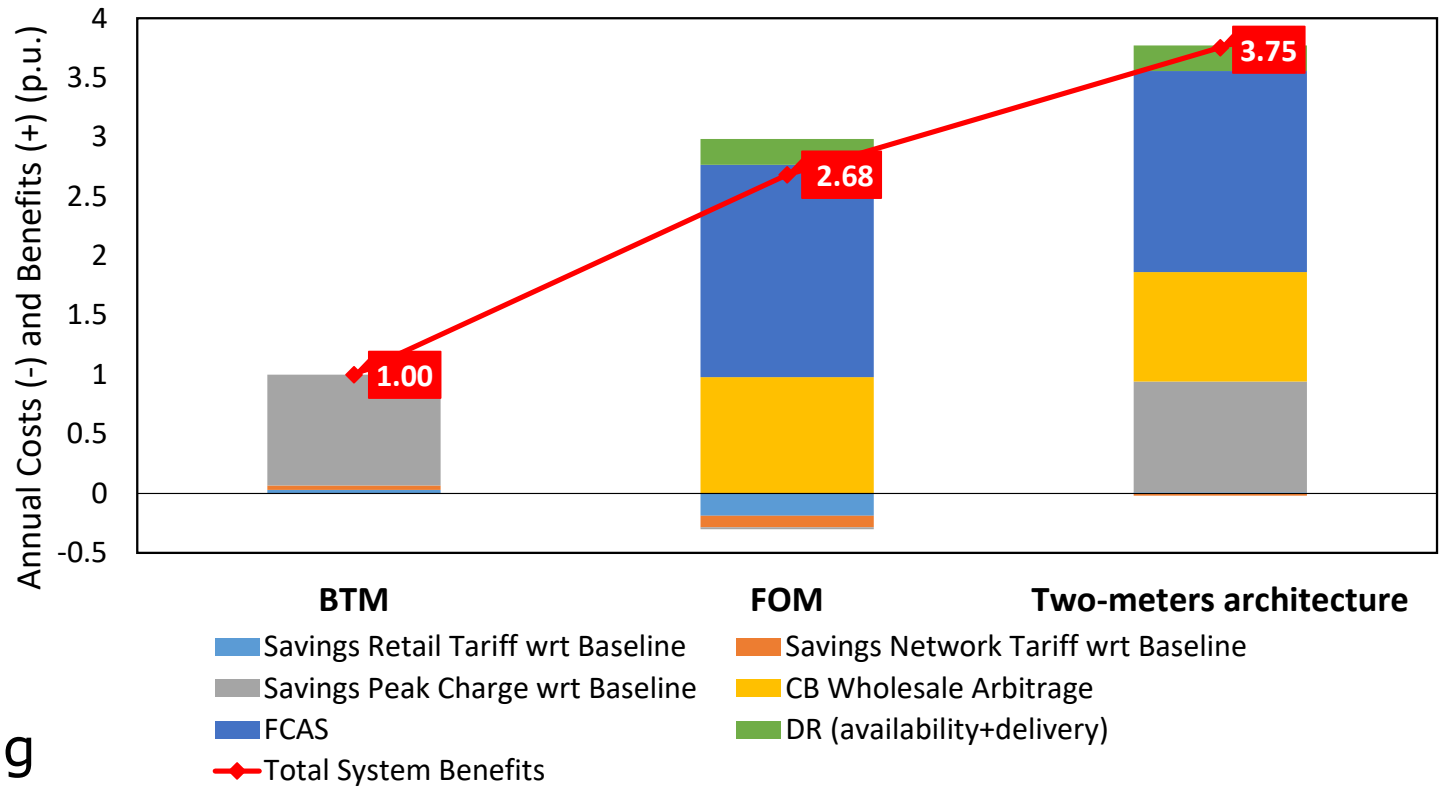
Source: M. Liu *et al.*, "Grid and market services from the edge", *IEEE Power and Energy Magazine*, July/August 2021

Creating value for and from communities



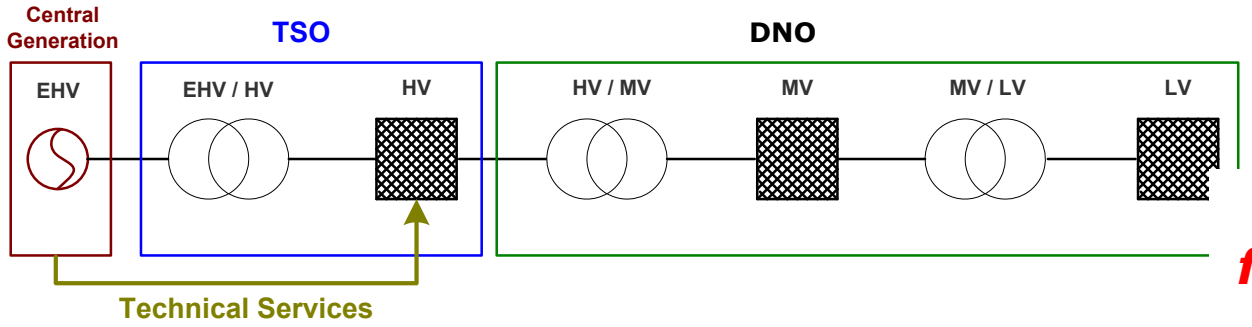
Crating value for and from communities: the "Power Melbourne" project

- Orchestrate a **network of community batteries** installed in different commercial buildings and community premises
- Physical and virtual resource sharing
- Hybrid BTM and FOM model!



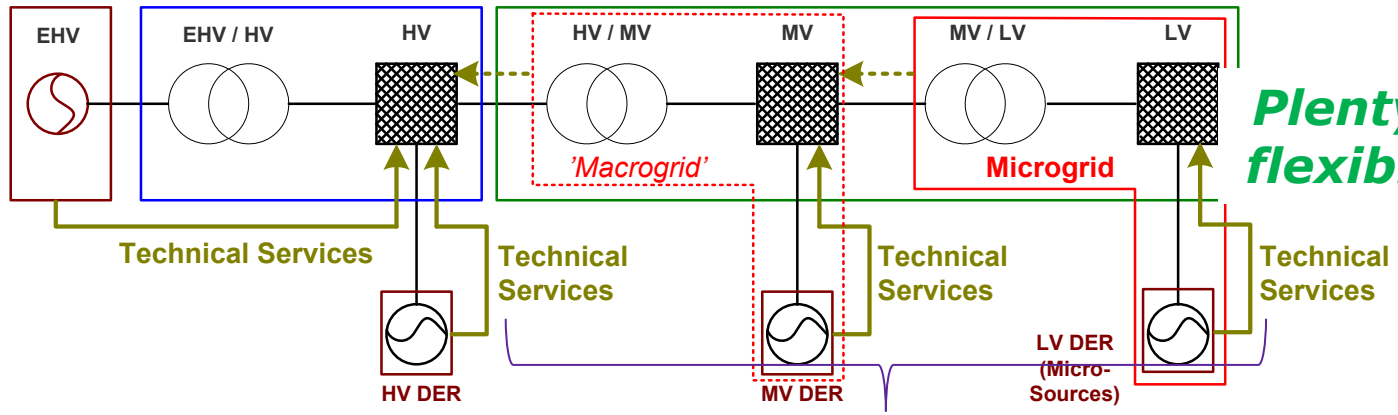
C. Bas Domenech, *et al.*, "Co-optimization of Behind-the-meter and Front-of-meter Value Streams in Community Batteries", *Journal of Modern Power Systems and Clean Energy,* 2024

A changing paradigm for flexibility provision



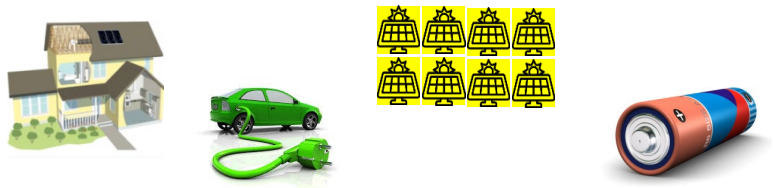
No flexibility

How much redundancy do we need in the two systems?



Plenty of flexibility

DER, VPP, Communities, Microgrids

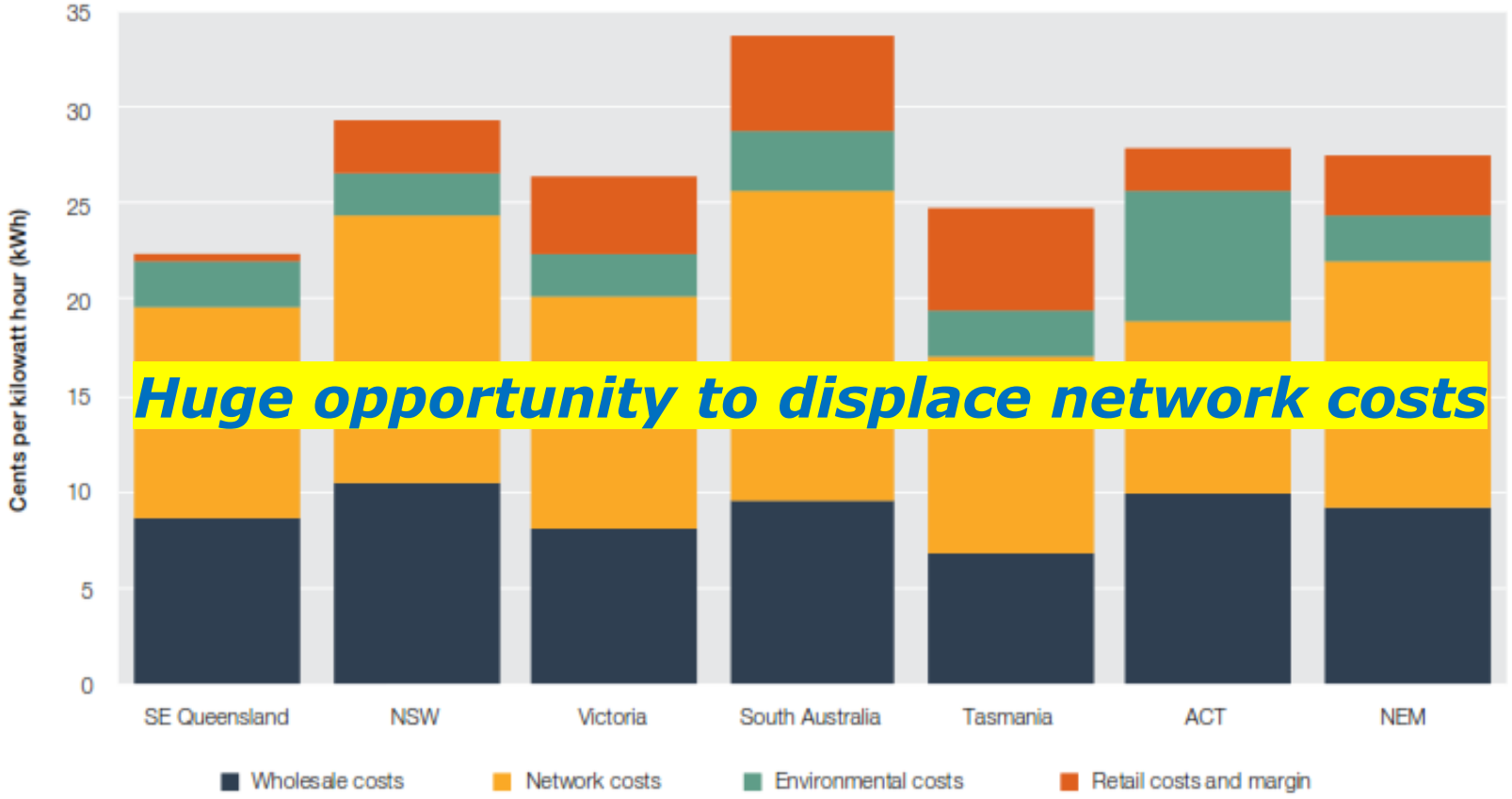


Source: More Microgrids project, 2010

(Images sourced from the internet)

Residential electricity bill cost components

Figure 6.2 Composition of a residential bill – electricity



Huge opportunity to displace network costs

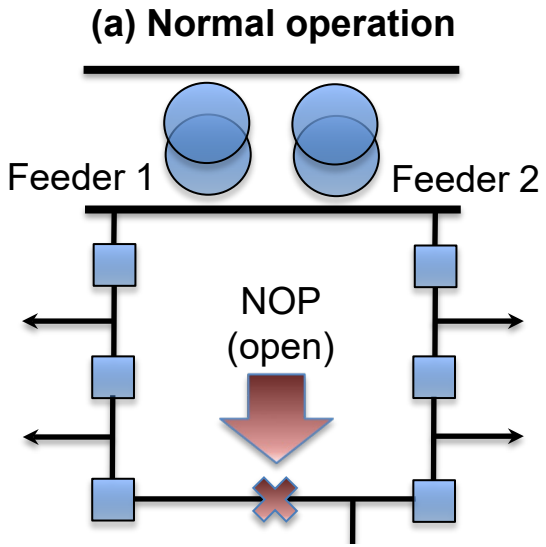
Note: Cost components for the average residential customer in 2021–22, excluding GST Calculated using tends in supply chain components for each jurisdiction and national trends.

Source: AEMC, *Residential electricity price trends 2021*, 25 November 2021 (using data from Energy Made Easy and Victorian Energy Compare on 17 September 2021).

Source: https://www.aer.gov.au/publications/reports/performance/state-energy-market-2022

Network security and (premium) reliability services from the demand side

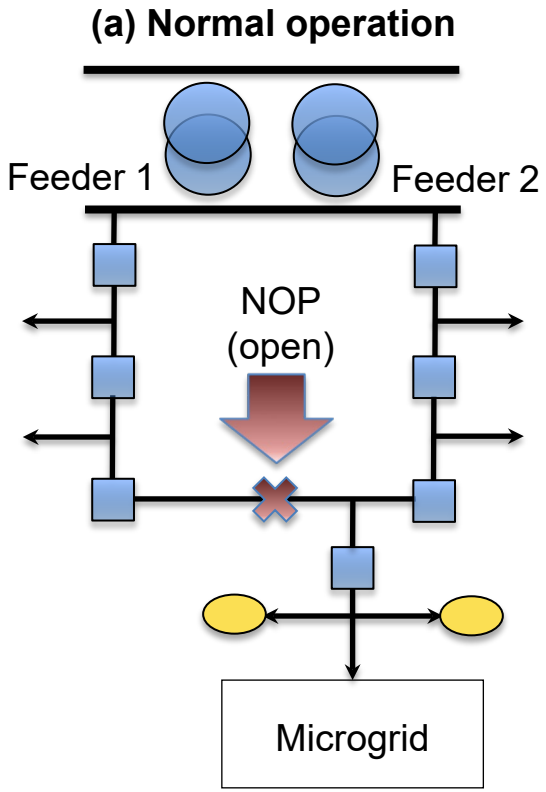
N-1 redundancy



E. A. Martínez Ceseña, N. Good, A. L. A. Syrri, P. Mancarella, "Techno-economic and business case assessment of multi-energy microgrids with co-optimization of energy, reserve and reliability services," *Applied Energy*, 2018

A. L. Syrri and P. Mancarella, "Reliability and Risk Assessment of Post-Contingency Demand Response in Smart Distribution Networks", SEGAN, 7, 1-12, 2016

Network security and (premium) reliability services from the demand side



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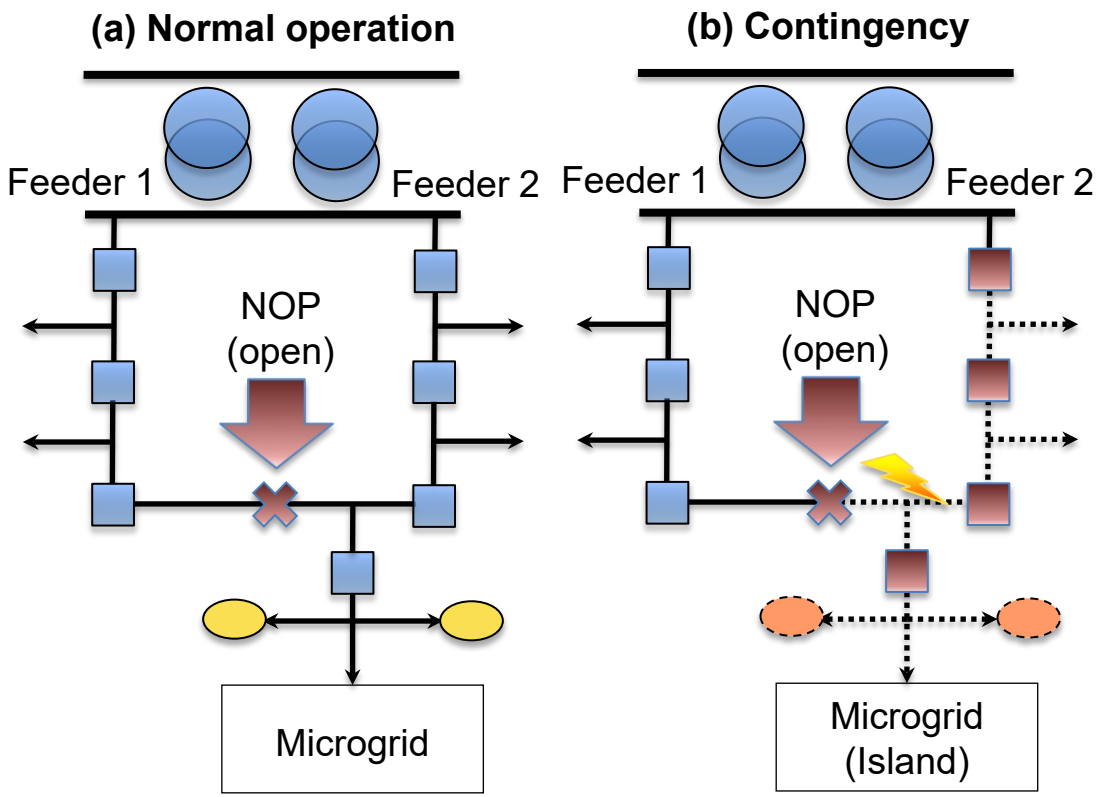

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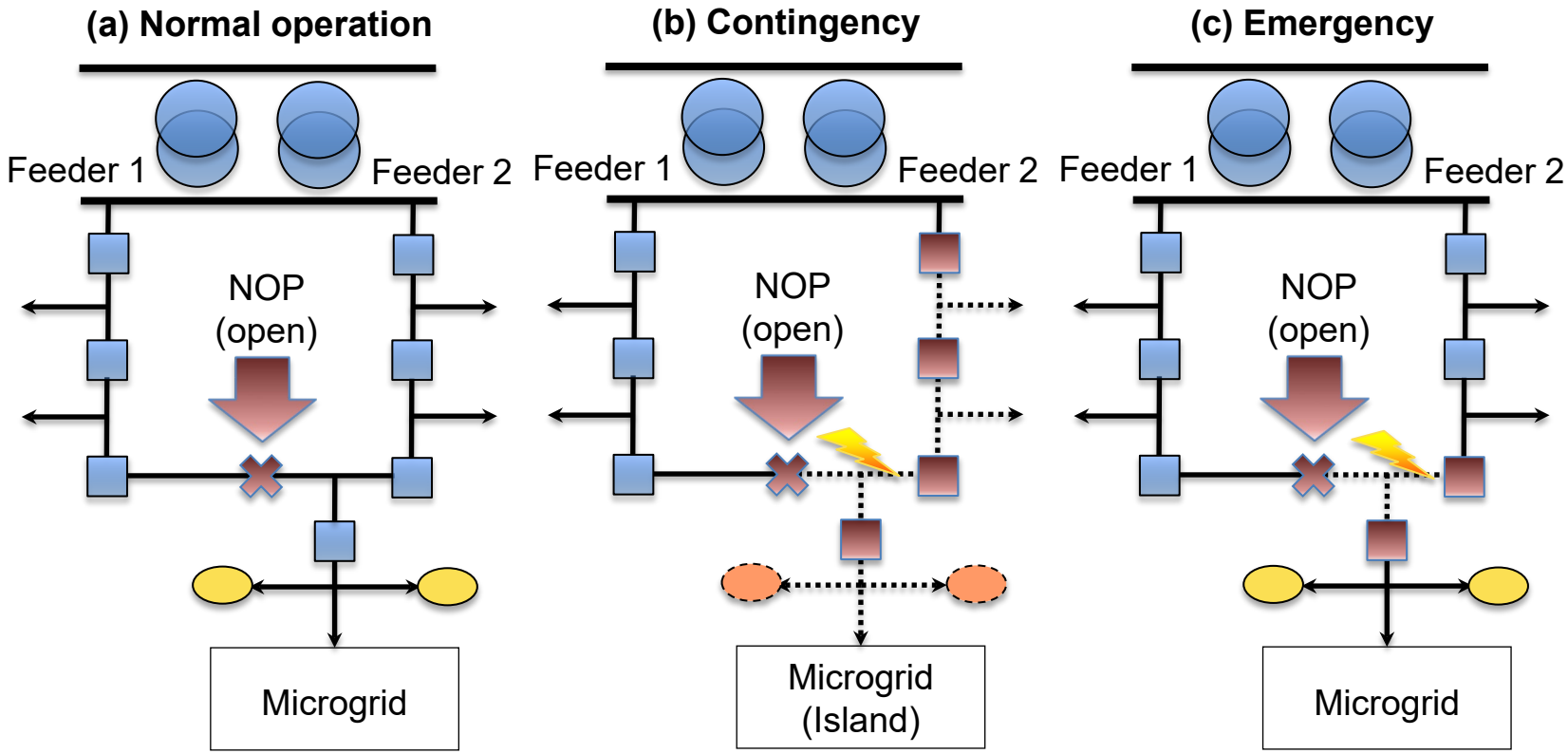
Network security and (premium) reliability services from the demand side

- With DER, ***no or less N-1 redundancy is needed***
- Microgrids could then also supply islanded customers during emergency conditions



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A. L. Syrri and P. Mancarella, "Reliability and Risk Assessment of Post-Contingency Demand Response in Smart Distribution Networks", SEGAN, 7, 1-12, 2016

Extracting the true value of DER: a regulatory matter

Creator: mphillips007 | Credit: Getty Images/iStockphoto

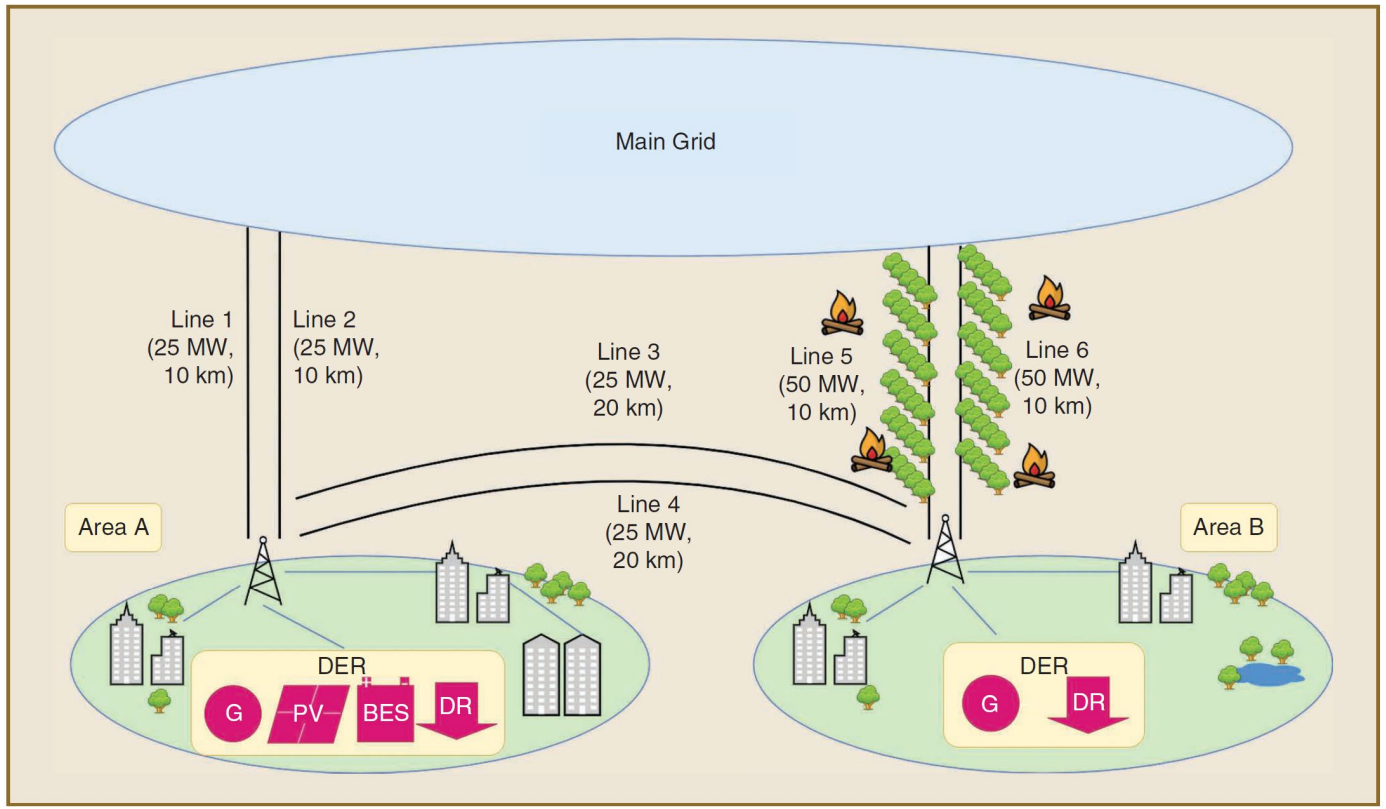
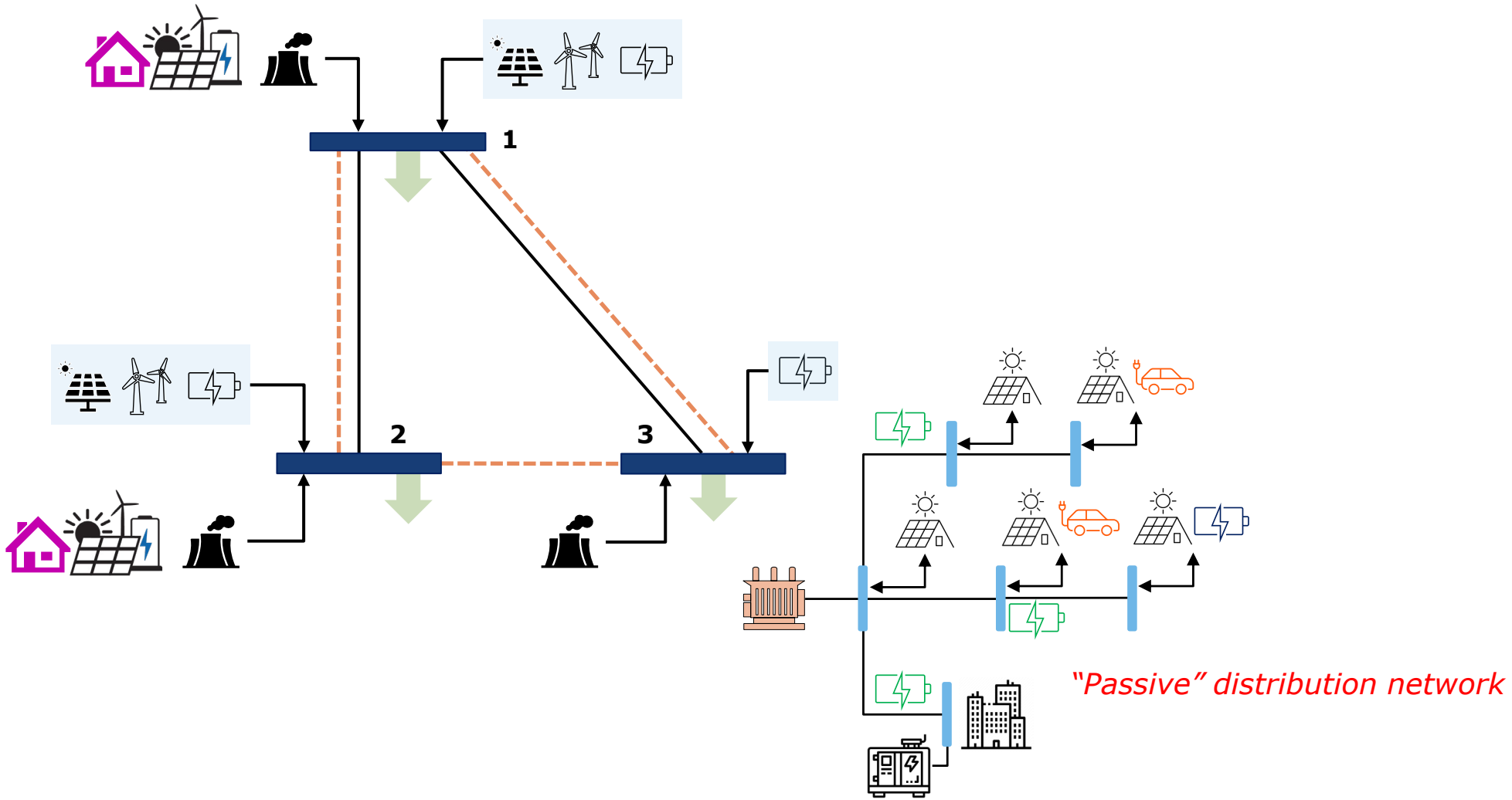


figure 8. The electricity network and DER candidates along with areas exposed to wildfires. BES: battery energy storage.

Moreno, R., et al. (2022). Microgrids Against Wildfires: Distributed Energy Resources Enhance System Resilience. IEEE Power and Energy Magazine, 20(1), 78-89.

Next:
Integrated planning of transmission and distribution



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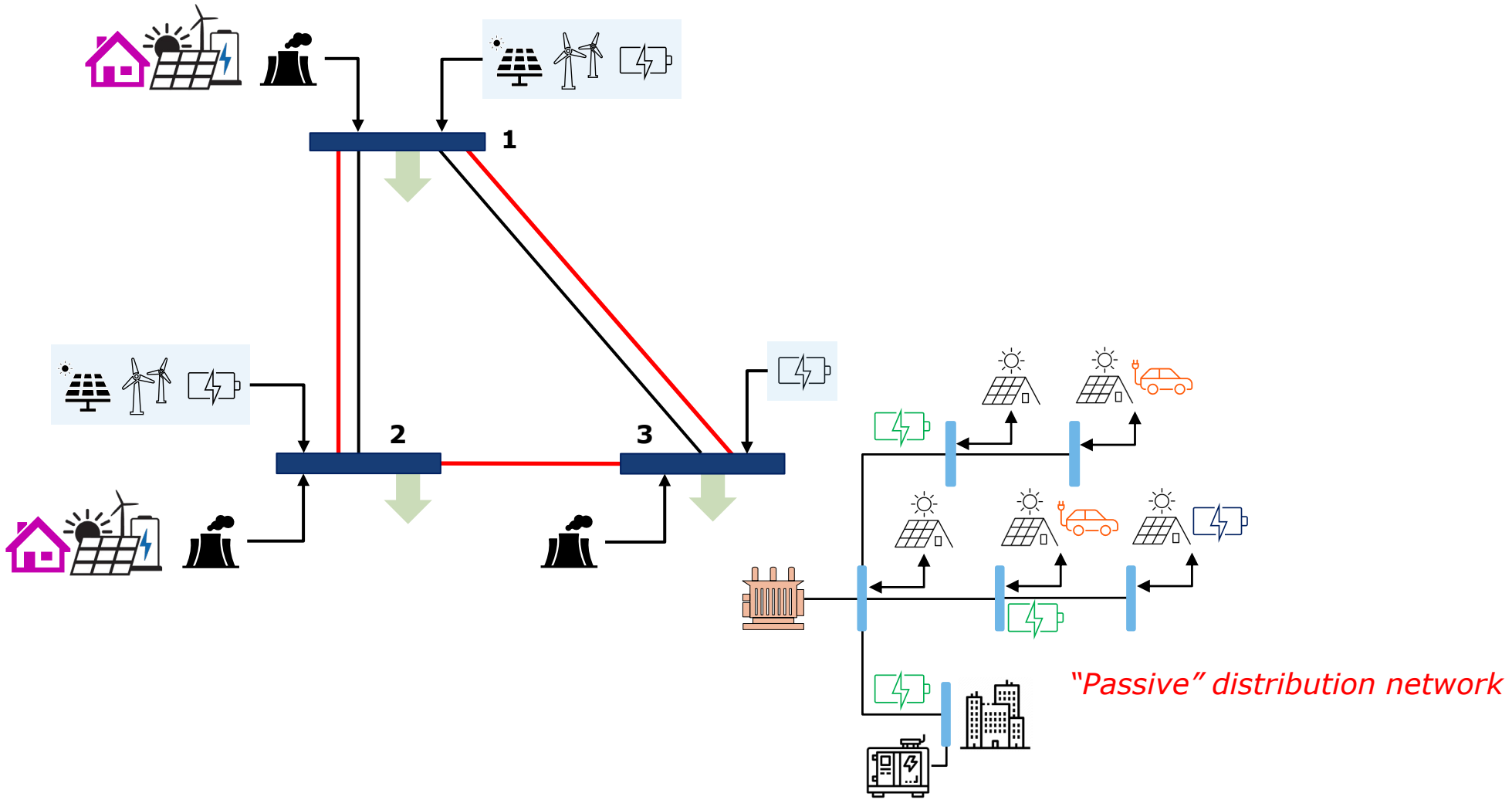

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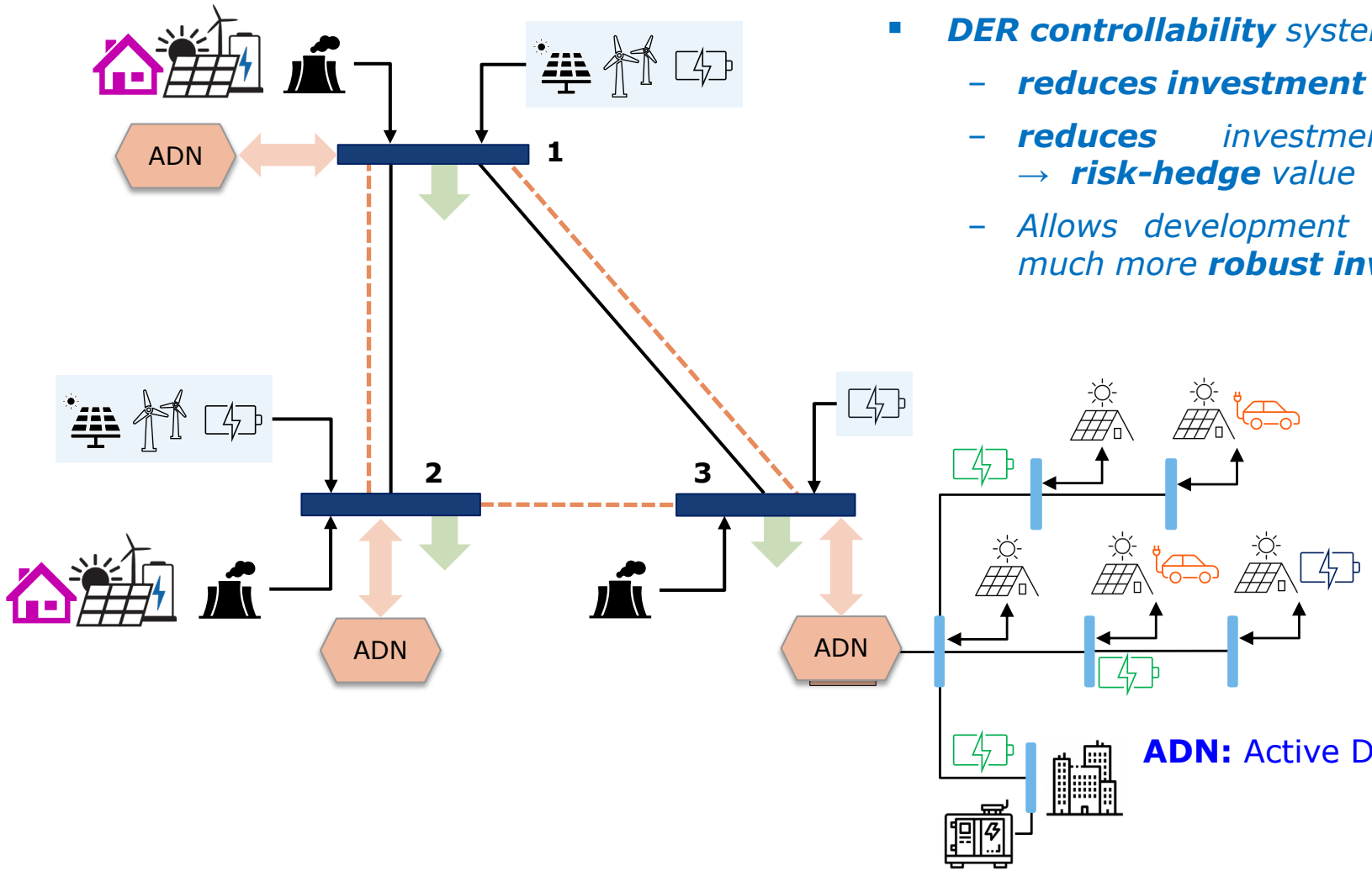

- ***DER controllability*** *systematically:*
  - ***reduces investment*** *requirements*
  - ***reduces*** *investment* ***uncertainty*** *→* ***risk-hedge*** *value*
  - *Allows development of a clearer and much more* ***robust investment path***

P. Apablaza *et al.*, "Assessing the Impact of DER in the Expansion of Low-Carbon Power Systems Under Deep Uncertainty", *Electric Power System Research*, 2024

DER rights and responsibilities

Should DER be remunerated for providing security (and resilience) services?

Or is it rather a social responsibility?

ELSEVIER

The Electricity Journal

Volume 36, Issue 4, May 2023, 107265

Give a little to get a little: A DER Bill of Rights and Responsibilities provides the social license for participation and control in DER-dominated grids - an Australian example

N.N. Lal [a], L. Brown [b]

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LIFE MATTERS →

How to make rooftop solar work for everyone

Broadcast Wed 7 Jun 2023 at 9:06am

ABC RN

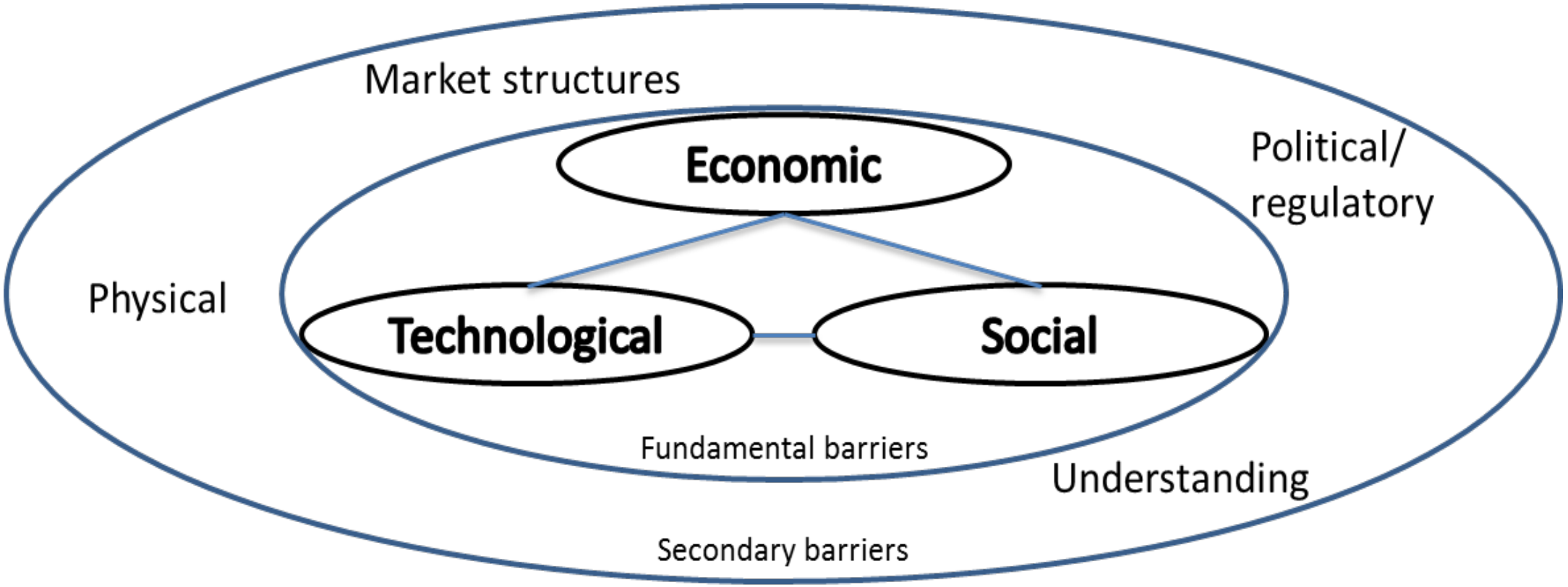
Australia is leading the way on rooftop solar uptake, but can the grid keep up? *(ABC News: Curtis Rodda)*

Guests:

Dr Alan Finkel, author *Powering Up: Unleashing the Clean Energy Supply Chain*

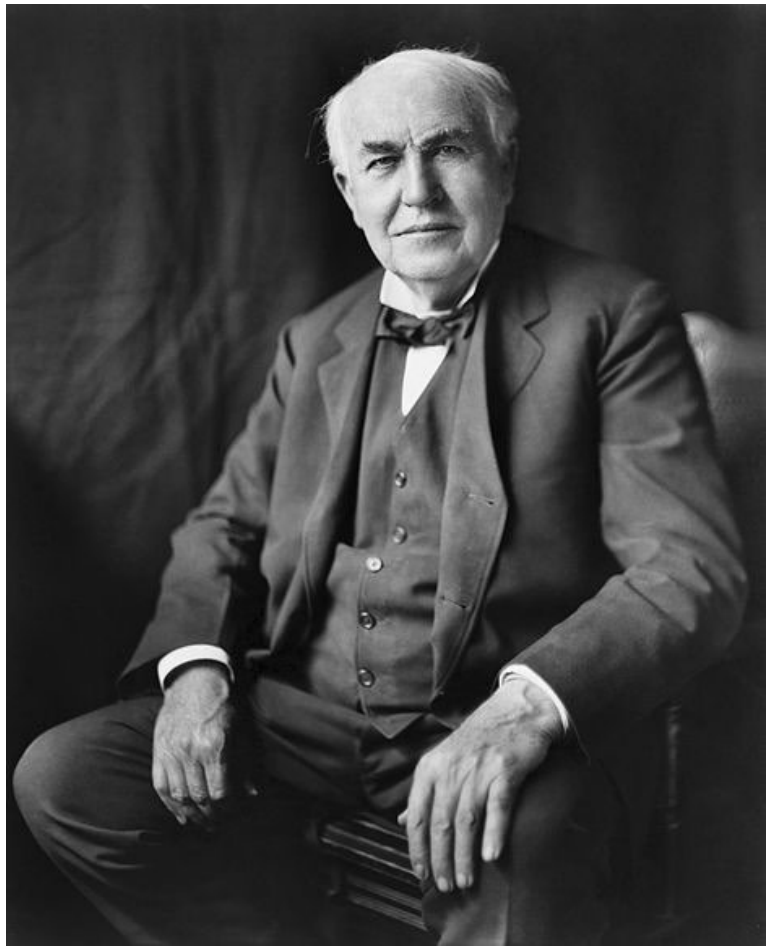
Dr Niraj Lal, Visiting Fellow at the ANU Centre for Sustainable Energy Systems

Harnessing DER flexibility:
Overcoming multi-dimensional barriers



N. Good, et al., "Review and classification of barriers and enablers of demand response in the smart grid", *Renewable and Sustainable Energy Reviews*, vol. 72, pp. 57-72, May 2017

Back to the future



"We will make electricity so cheap that only the rich will burn candles"

Thomas Edison, 1878

Acknowledgements

- C4NET for the *"ESP-V"* project
- The City of Melbourne and the Vic Government for the "*Power Melbourne*" project
- CSIRO, AEMO and the GPST consortium
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- *veski* and the Victorian Government for my 2017 *veski* Innovation Fellowship
- The "*Future Fuels*" CRC
- The UK EPSRC for the *"MY-STORE"* and *"TERSE"* projects
- The European Commission for the *"ADDRESS"*, *"COOPERATE"*, *"DIMMER", "H2ME2", "ATTEST", "EUniversal"* projects
- The incredible work of my incredible team

Thank you!
Any question?