Workshop on Smart Grid Technologies and Implications for Inclusive Development in Sri Lanka

3-4 April 2018 • Galle, Sri Lanka

Smart grid methodologies and models to address affordability, sustainability and system reliability and resilience

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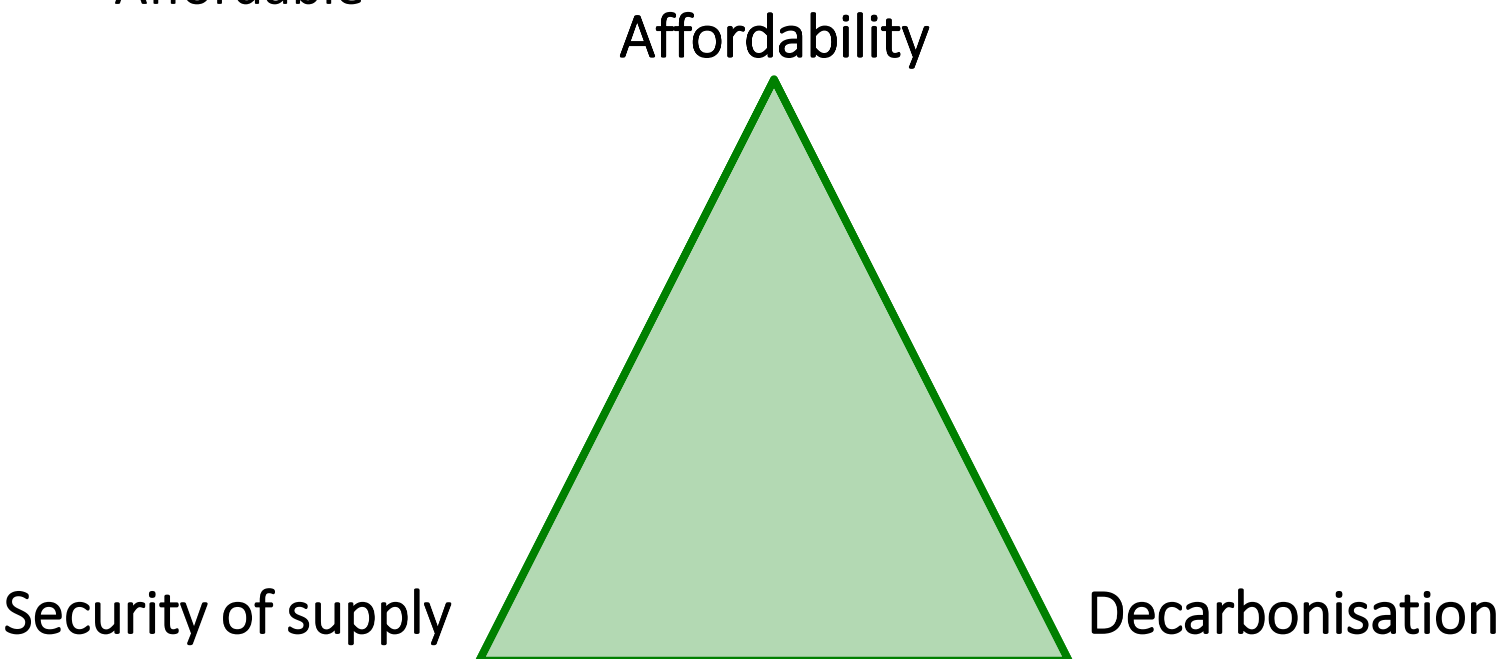
Why are we worried about delivering a low-carbon energy system?

Low-carbon energy

What are the issue with the energy trilemma?

- How will we deliver energy that is
  - Sustainable (low to almost zero carbon)
  - Reliable and secure
  - Affordable

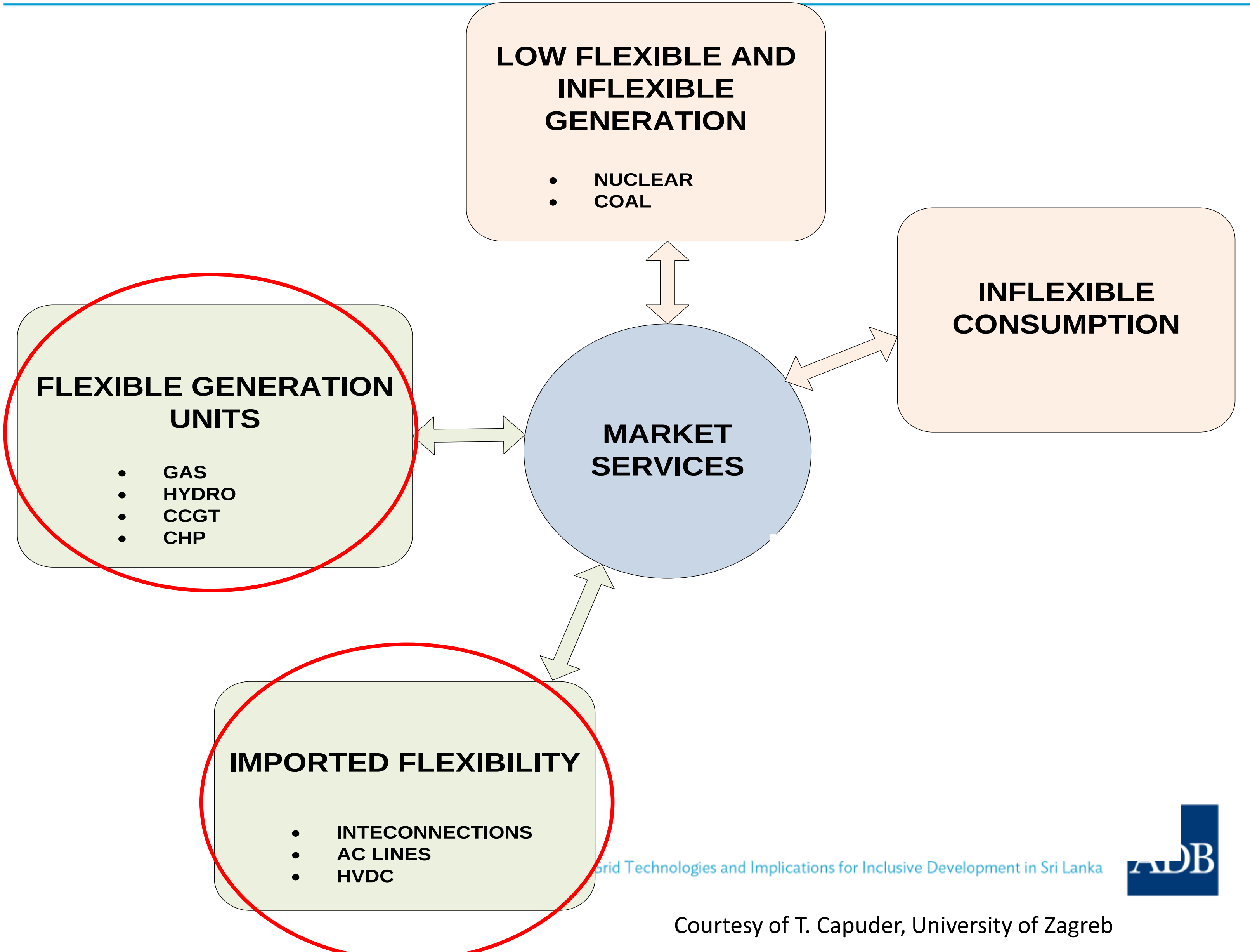


Let's focus on reliability

- Adequacy
  - Do I have enough capacity in planning?
- Security
  - Do I have enough capacity in operation?

- Flexibility
  - Do I have fast enough capacity in operation?
- Resilience
  - Do I have enough capacity in the case of extreme events?

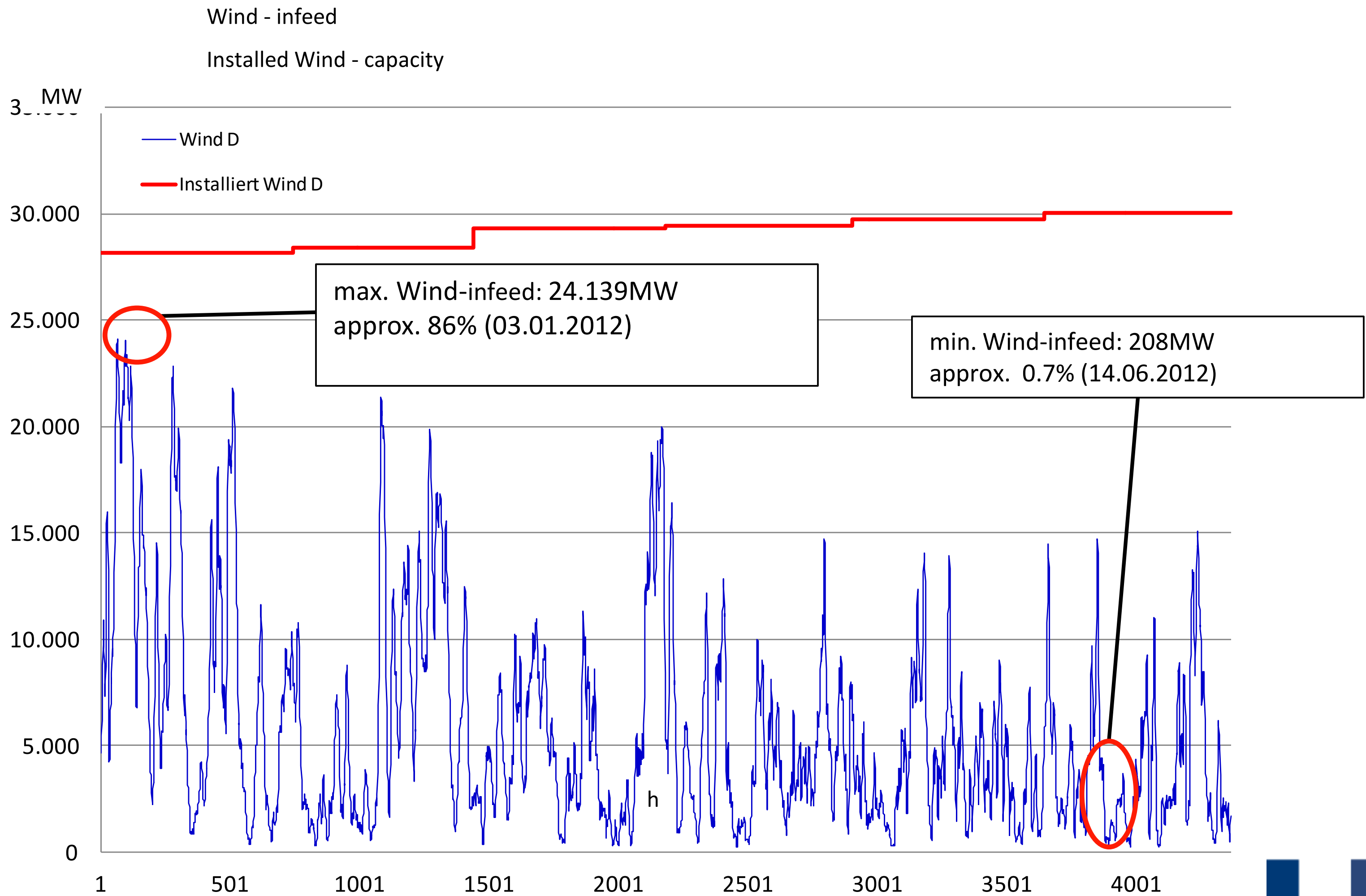
Who provides reliability today?



Courtesy of T. Capuder, University of Zagreb

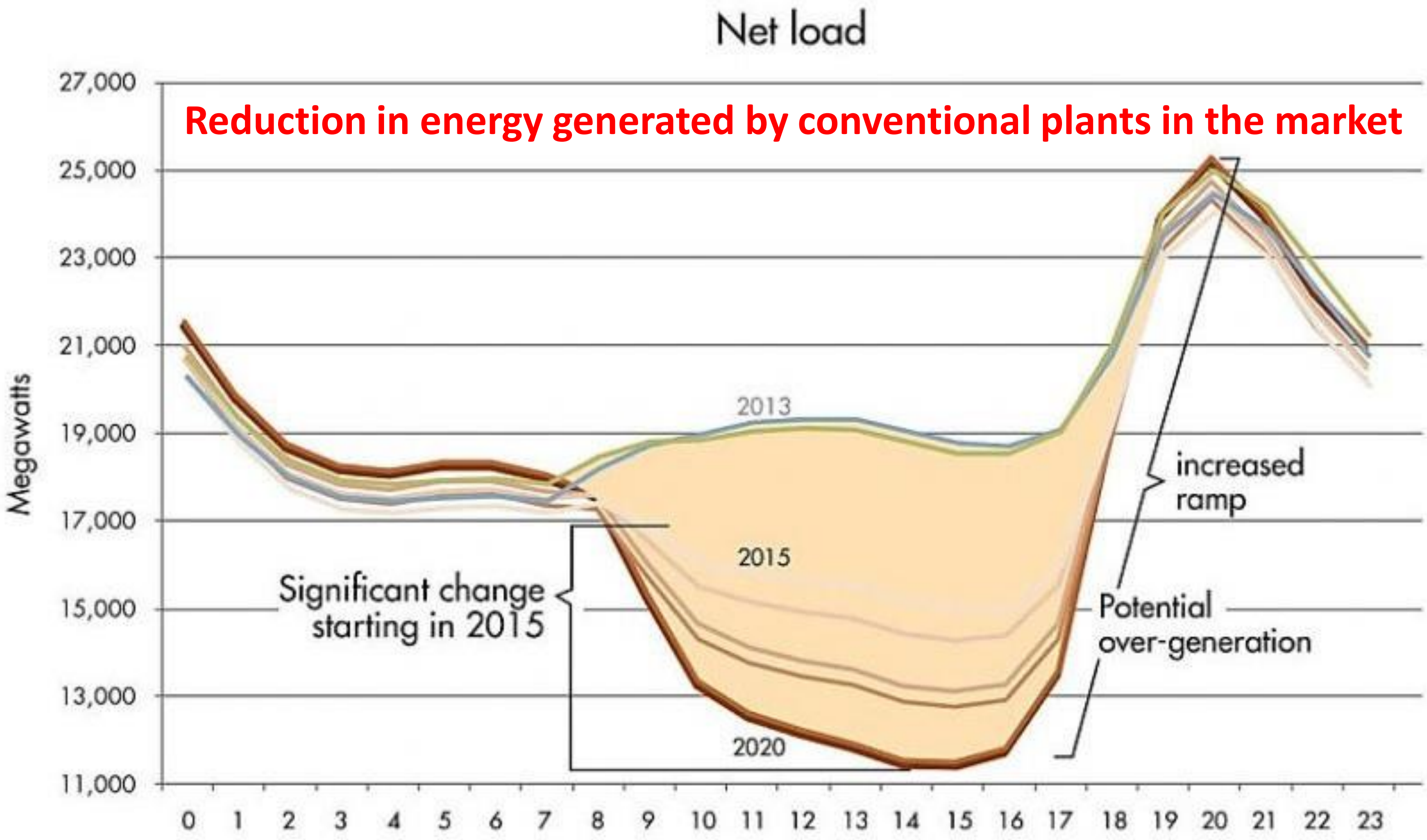
Renewables and reliable capacity (*adequacy*): an example from Germany

Reduction in energy generated by conventional plants in the market



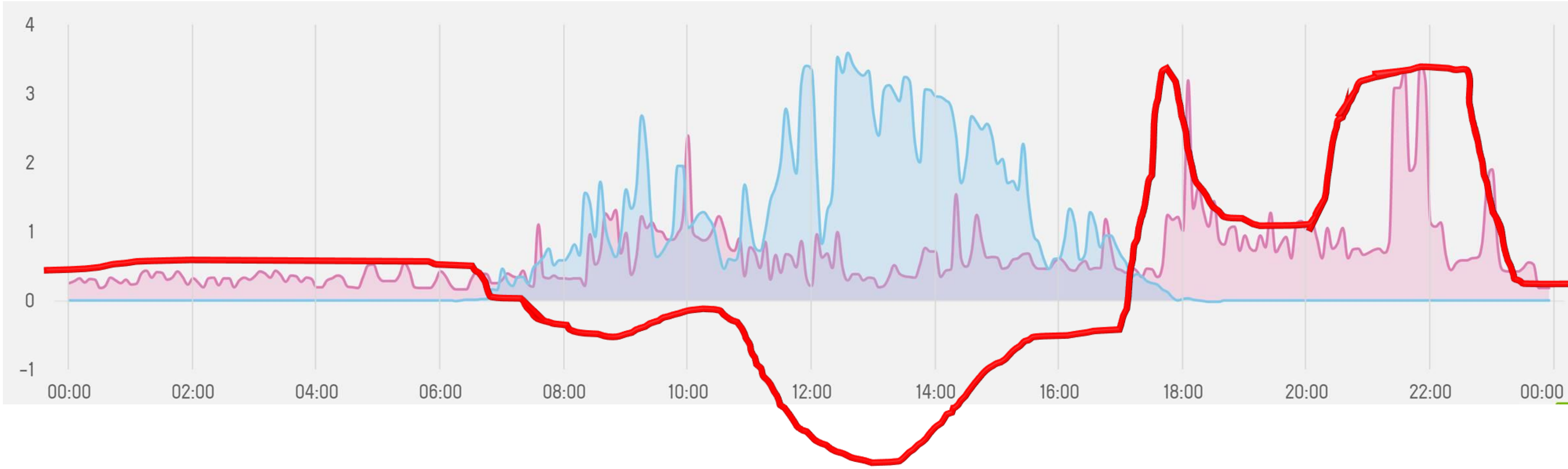
Courtesy of J. Vanzetta (Amprion) and M. Paolone (EPFL)

Renewables and *flexibility*: the Californian "duck" curve

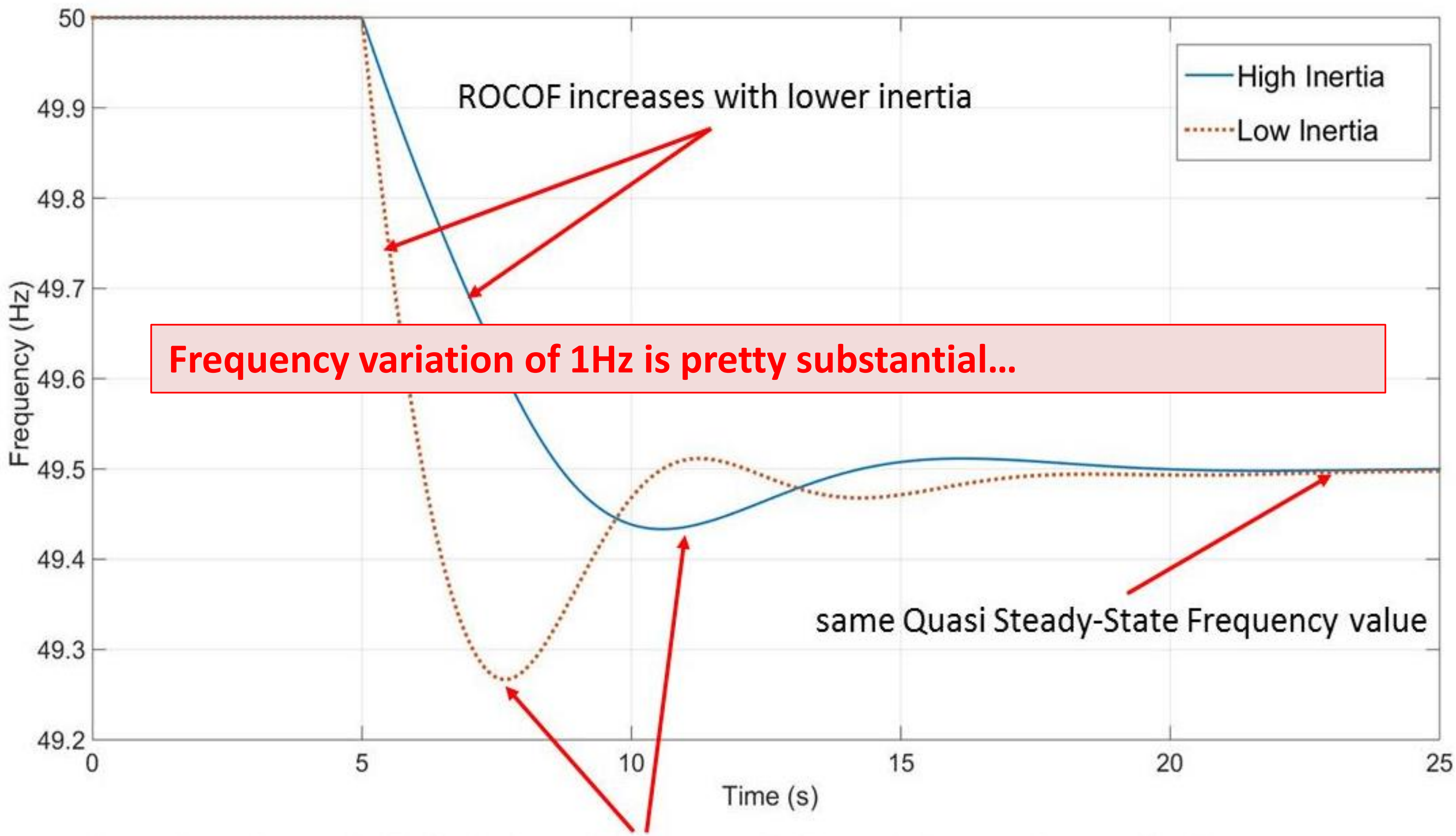


(source: CAISO)

What animal do you have at home?



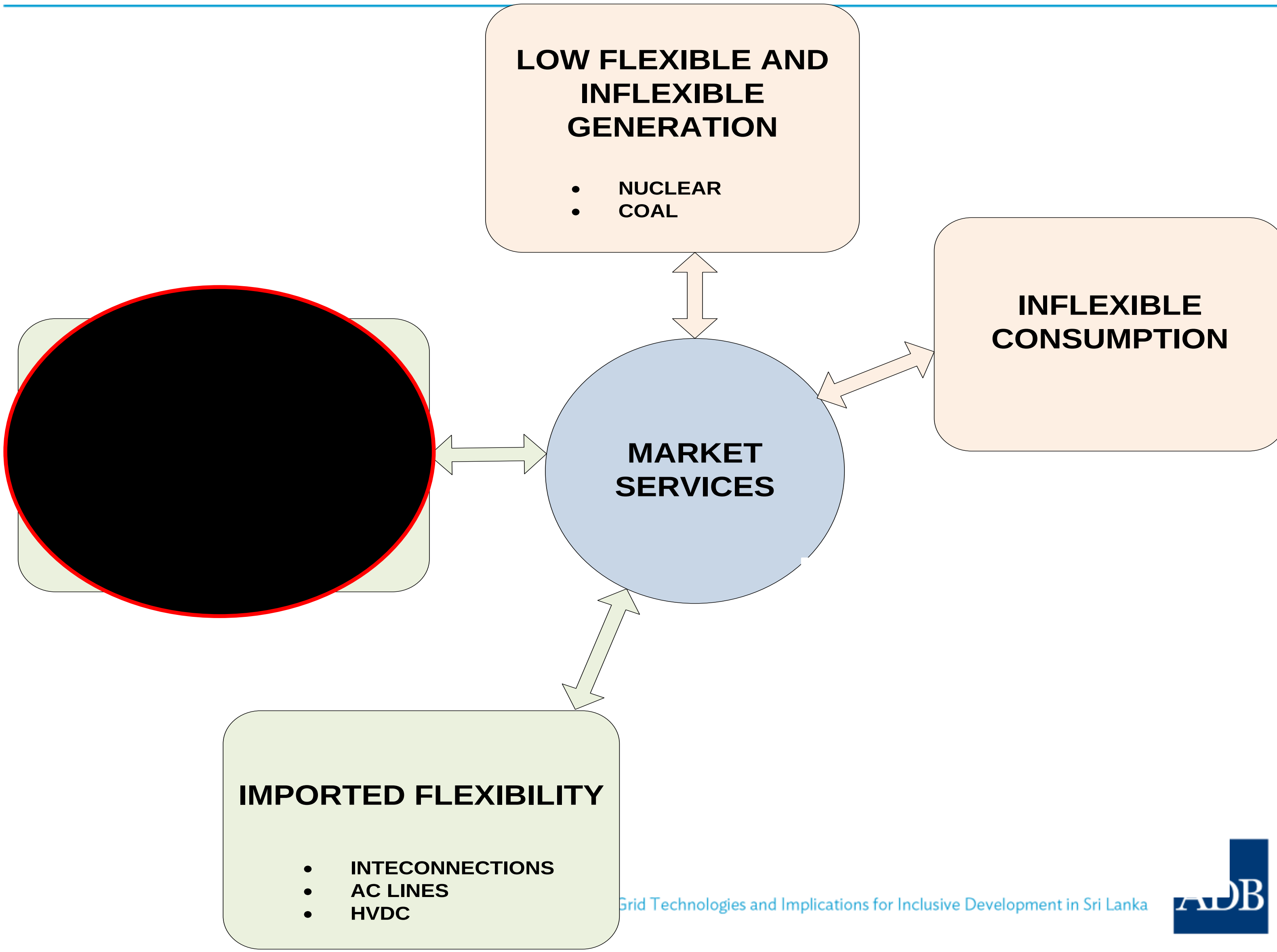
Renewables and *security*: illustrative example for Australia



lower inertia results in both lower frequency Nadir and shorter time to Nadir

P. Mancarella et al., "*Power system security assessment of the future National Electricity Market*", Report in support of the "Finkel Review", June 2017

Who provides reliability today?



Courtesy of T. Capuder, University of Zagreb

Can we make a low-carbon system secure? Modelling for the "Finkel Review"

Power system security assessment of the future National Electricity Market

A report by the
Melbourne Energy Institute
at the
University of Melbourne
in support of the

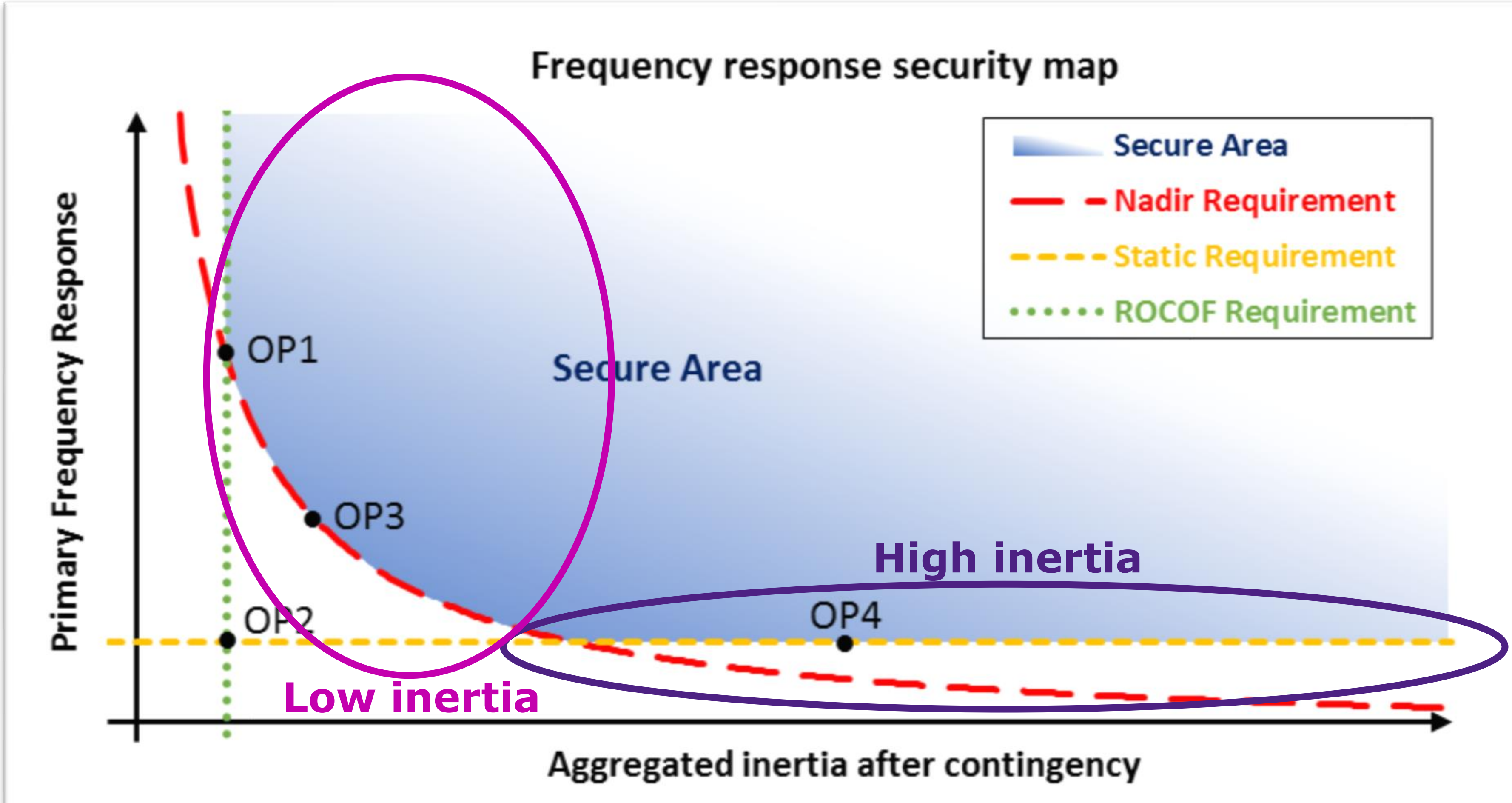
'Independent Review into the Future Security of the National Electricity Market'

June 2017

http://www.environment.gov.au/system/files/resources/1d6b0464-6162-4223-ac08-3395a6b1c7fa/files/power-system-security-assessment.pdf

http://www.environment.gov.au/energy/publications/electricity-market-final-report

Frequency Response Security Maps



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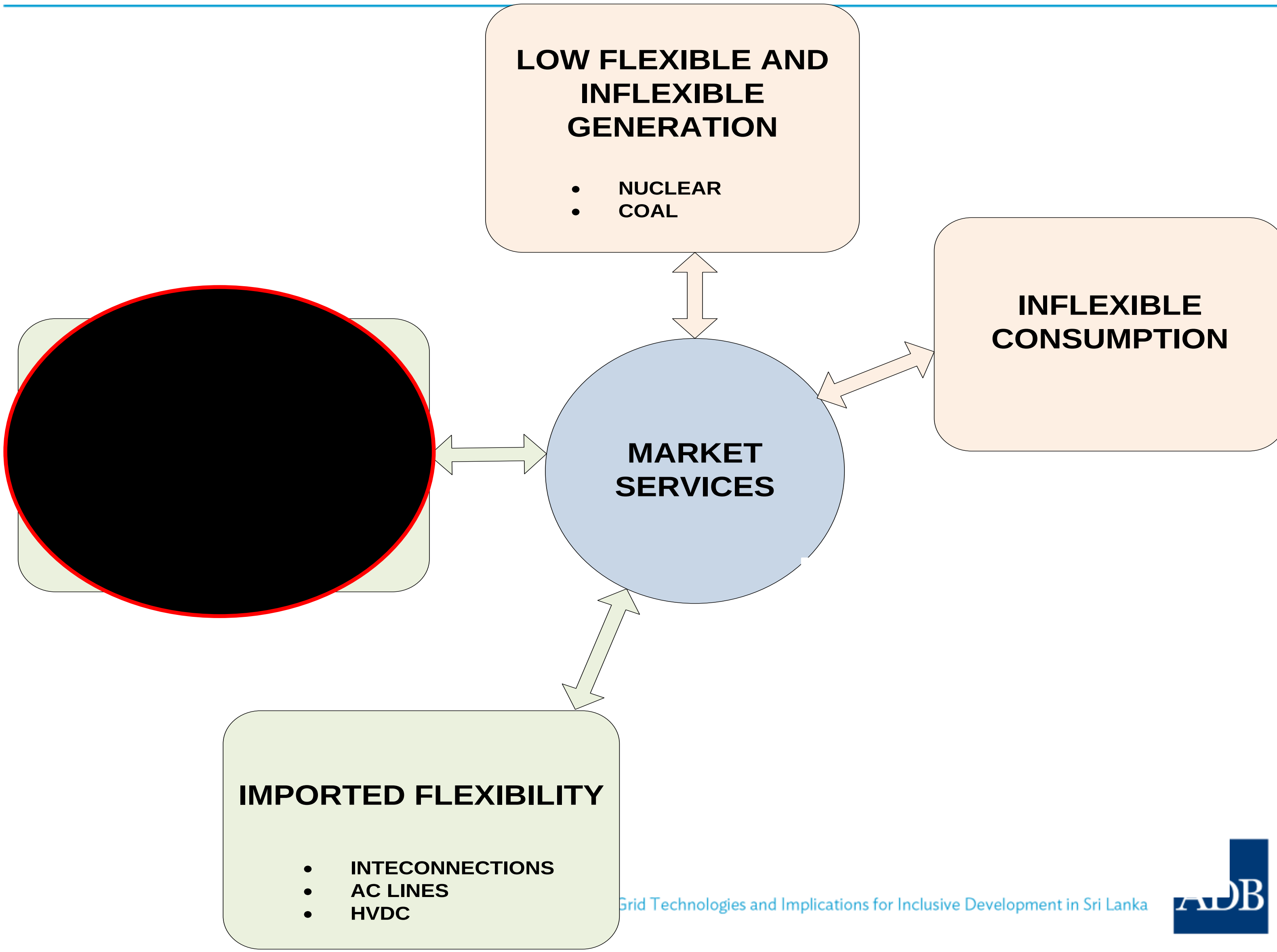
Who will provide reliability tomorrow?



Who will provide reliability tomorrow?

LOW FLEXIBLE AND INFLEXIBLE GENERATION

- NUCLEAR
- COAL

INFLEXIBLE CONSUMPTION

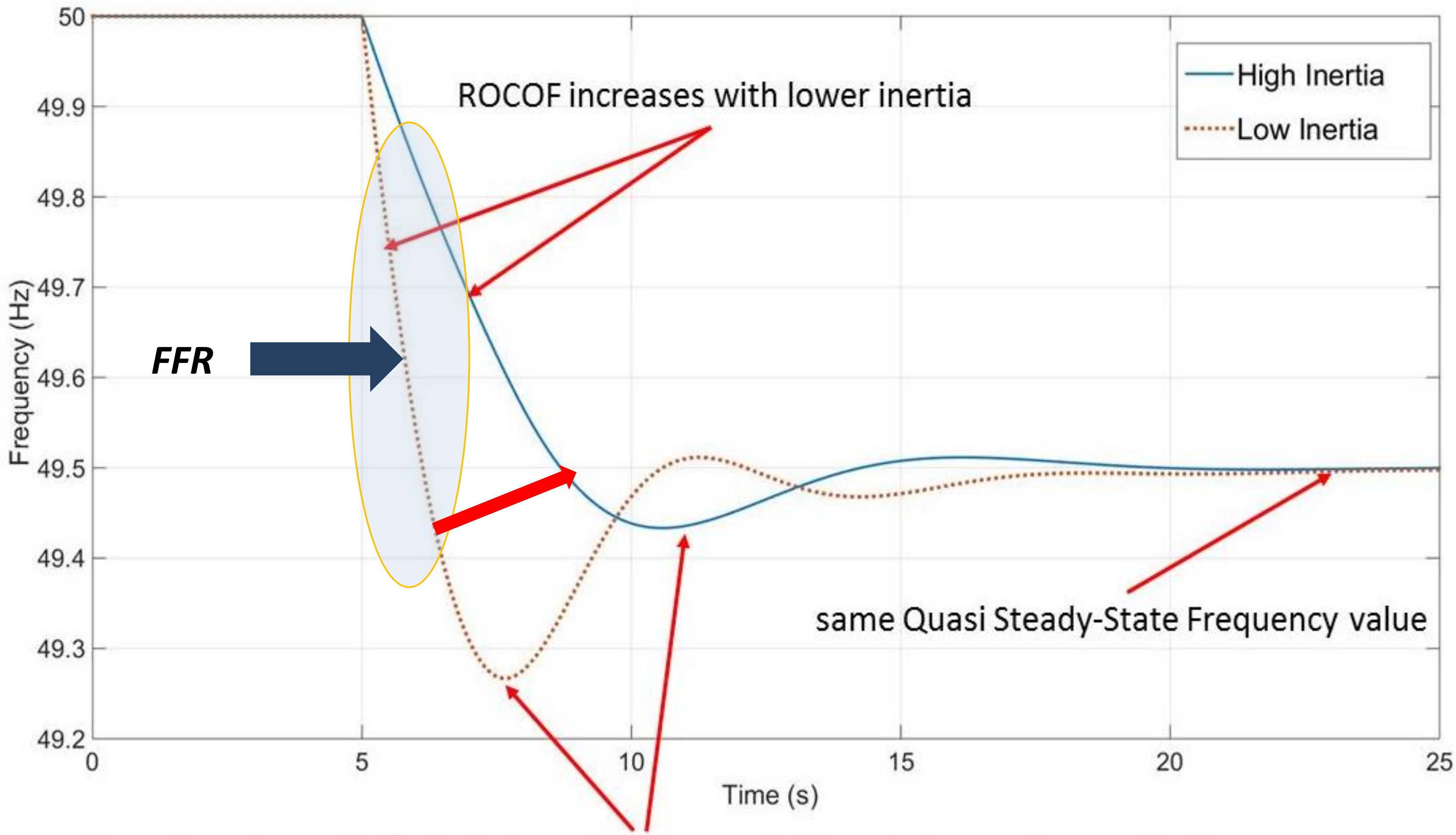
[redacted]

MARKET SERVICES

IMPORTED FLEXIBILITY

- INTECONNECTIONS
- AC LINES
- HVDC

Fast Frequency Response (FFR) to support low-carbon system operation



lower inertia results in both lower frequency Nadir and shorter time to Nadir

P. Mancarella et al., *"Power system security assessment of the future National Electricity Market"*, Report in support of the "Finkel Review", June 2017

Do we really need batteries?

LOW FLEXIBLE AND INFLEXIBLE GENERATION

- NUCLEAR
- COAL

INFLEXIBLE CONSUMPTION

FLEXIBLE GENERATION UNITS

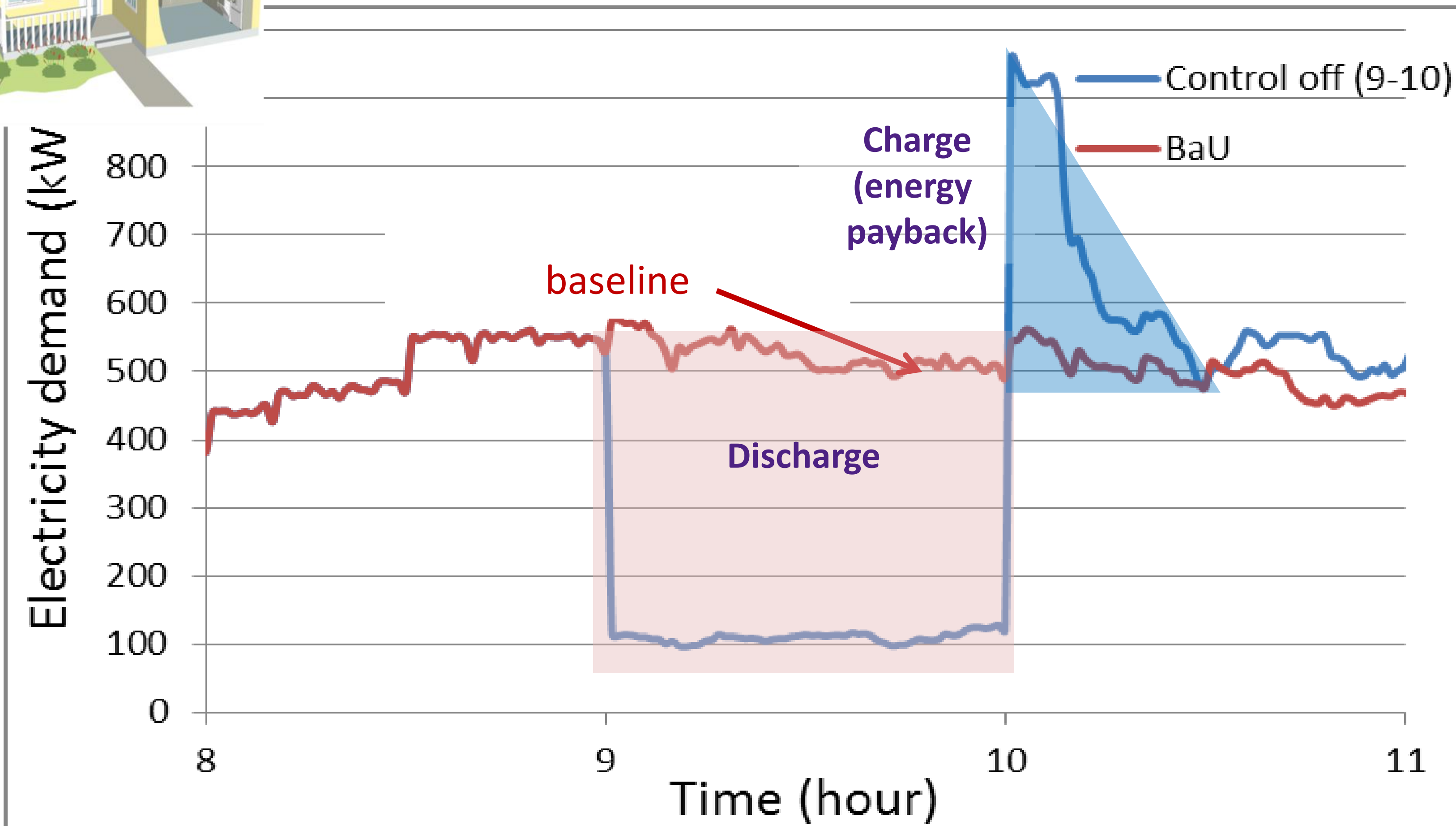
- GAS
- HYDRO
- CCGT
- CHP

MARKET SERVICES

IMPORTED FLEXIBILITY

- INTECONNECTIONS
- AC LINES
- HVDC

"Virtual storage" in buildings: up-flexibility



… or could we do this?

LOW FLEXIBLE AND INFLEXIBLE GENERATION

- NUCLEAR
- COAL

INFLEXIBLE CONSUMPTION

FLEXIBLE GENERATION UNITS

- GAS
- HYDRO
- CCGT
- CHP

MARKET SERVICES

IMPORTED FLEXIBILITY

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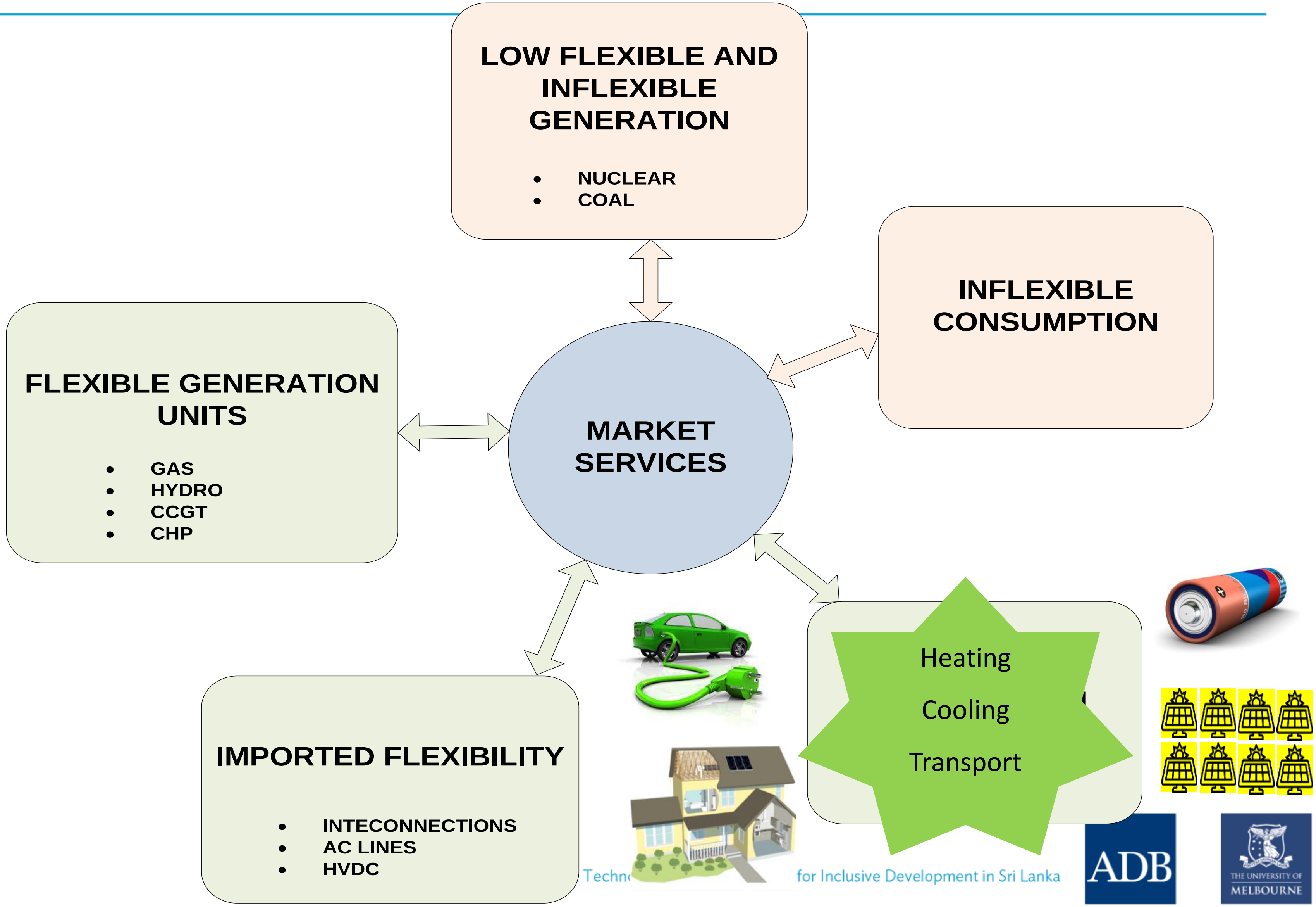
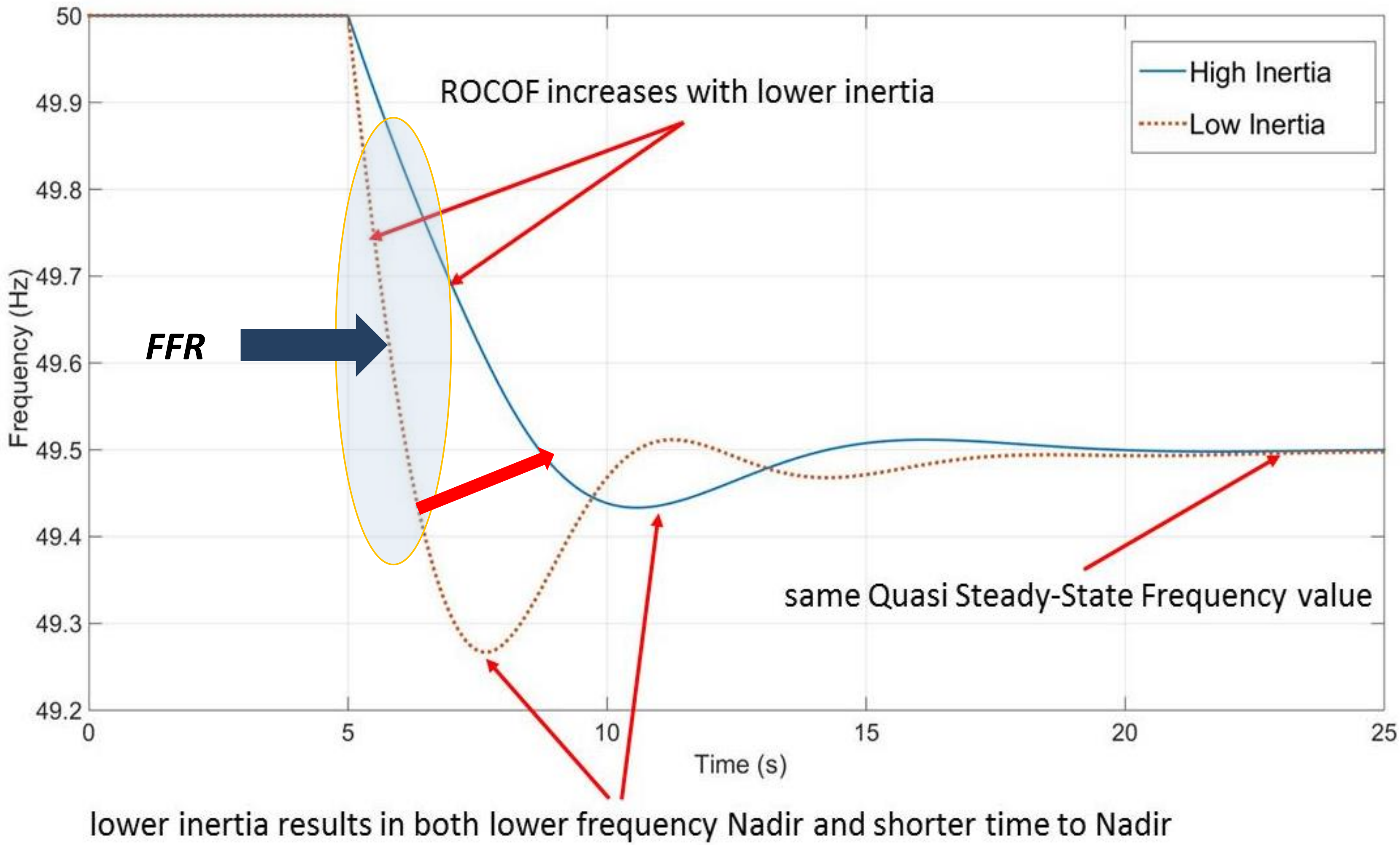
… and finally this?

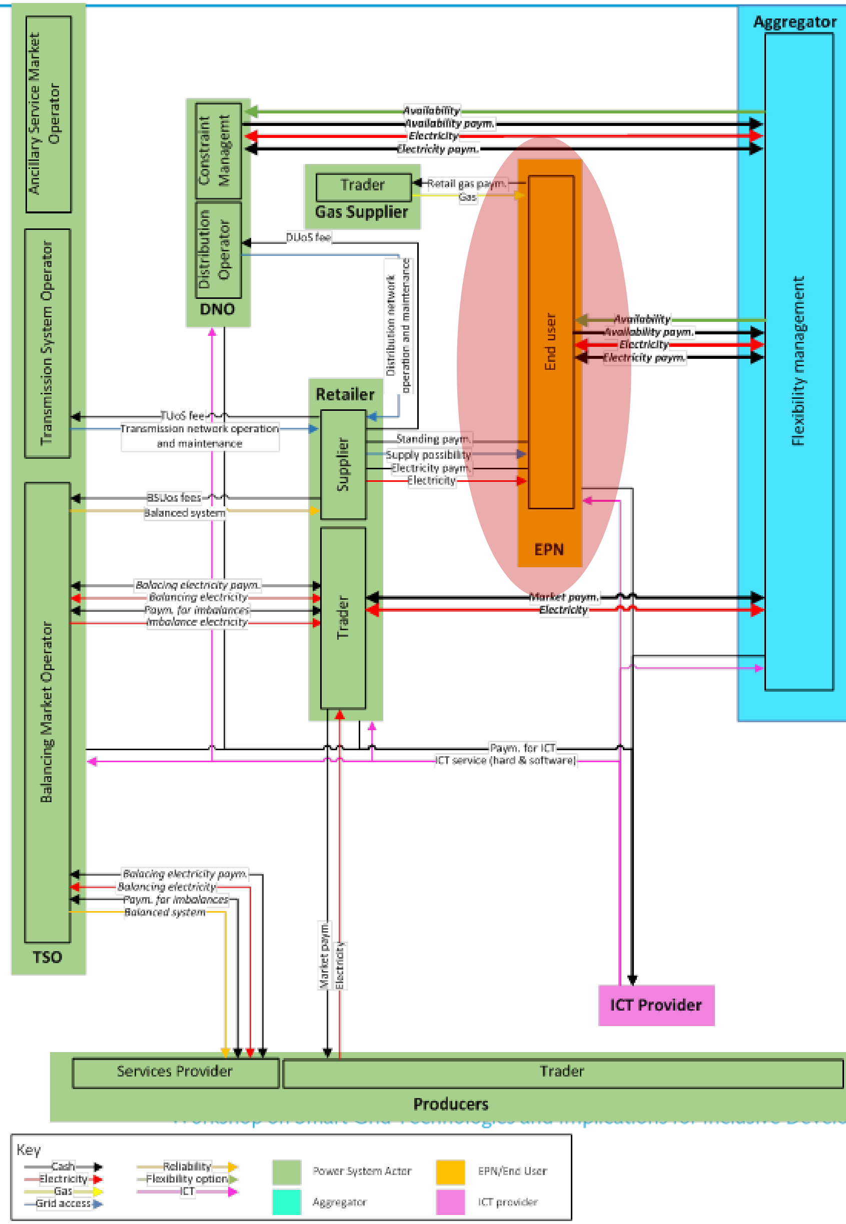


Operational tools:
Frequency response security constrained OPF



P. Mancarella et al., "*Power system security assessment of the future National Electricity Market*", Report in support of the "Finkel Review", June 2017

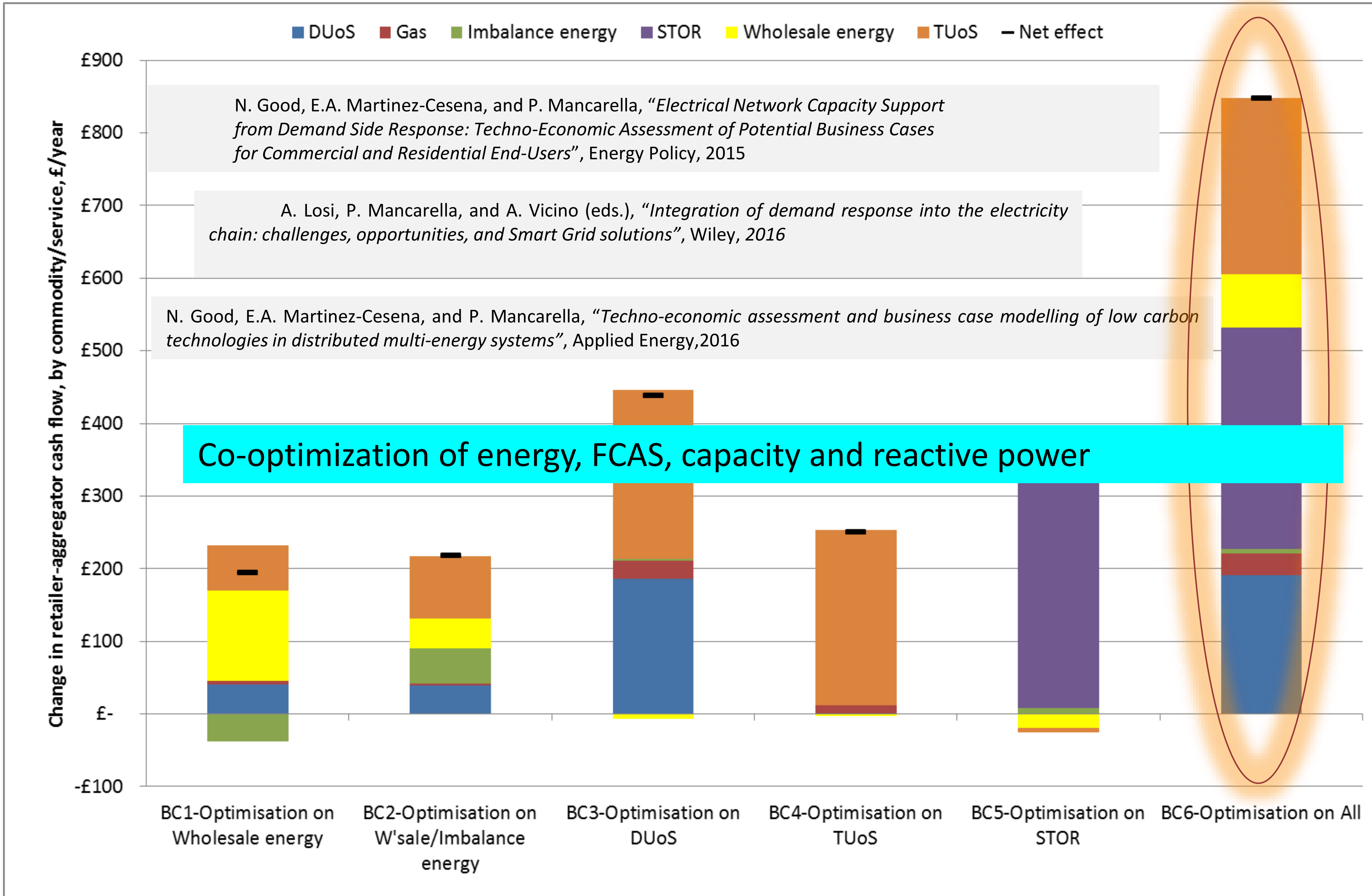
Techno-economic tools:
Is this commercially viable?



Distributed energy at edge of the value chain: Challenges & Opportunities

A. Monti, D. Persch, K. Ellis, K. Kouramas, and P. Mancarella (eds.), “*Energy positive neighborhoods and smart energy districts: methods, tools and experiences from the field*” , Elsevier, September 2016

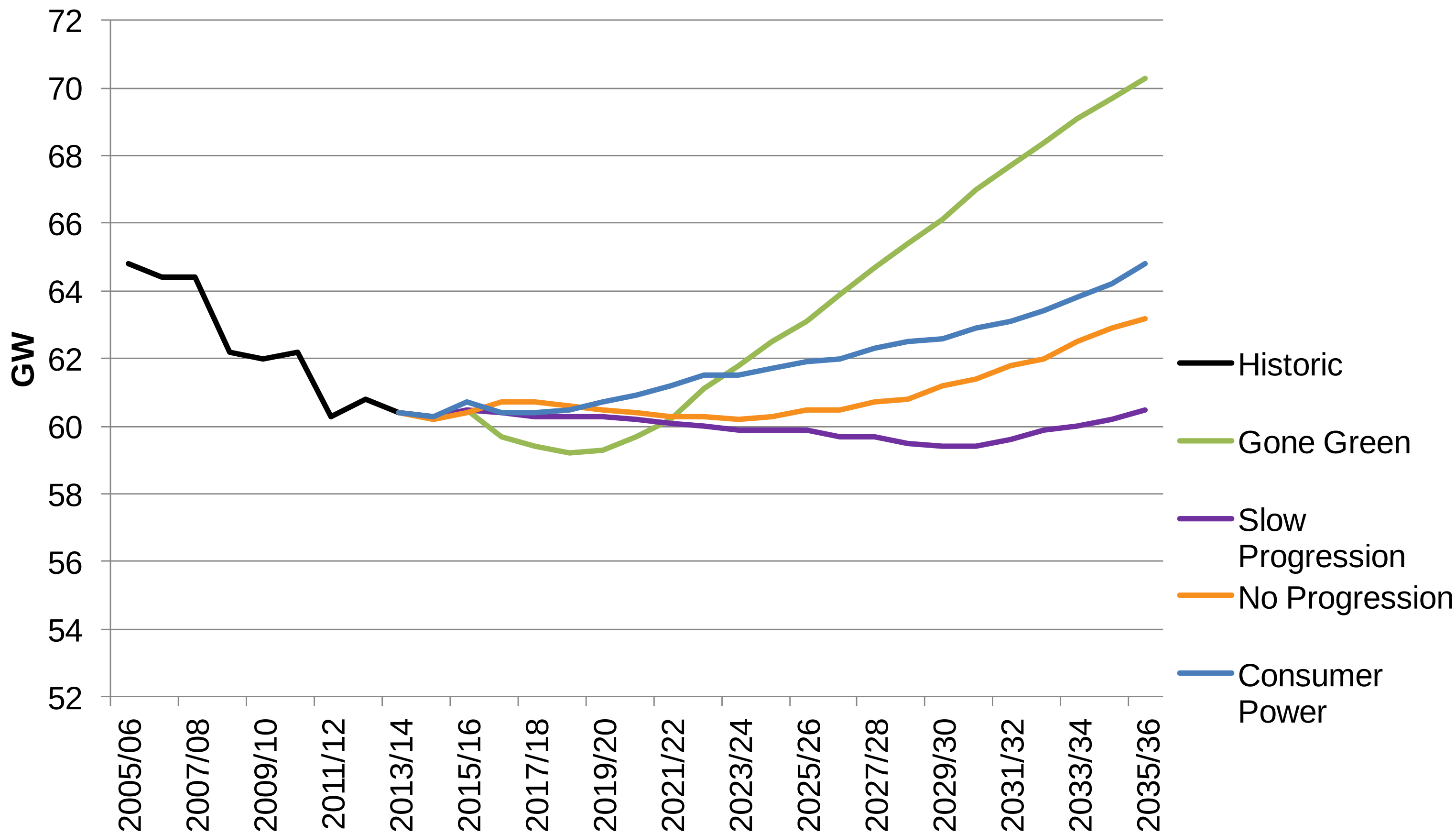
Techno-economic tools: multi-service optimization



Planning against uncertainty (and complexity): What future do we plan for?

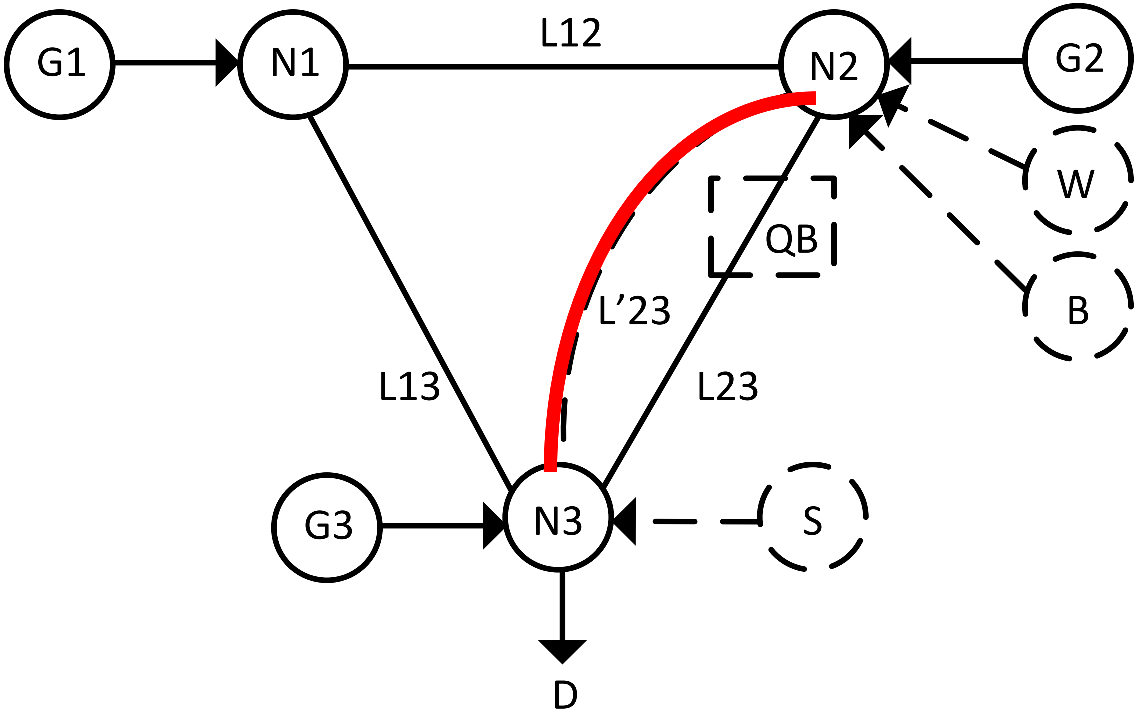
Average cold spell peak demand

National Grid Future Energy Scenarios – July 2015



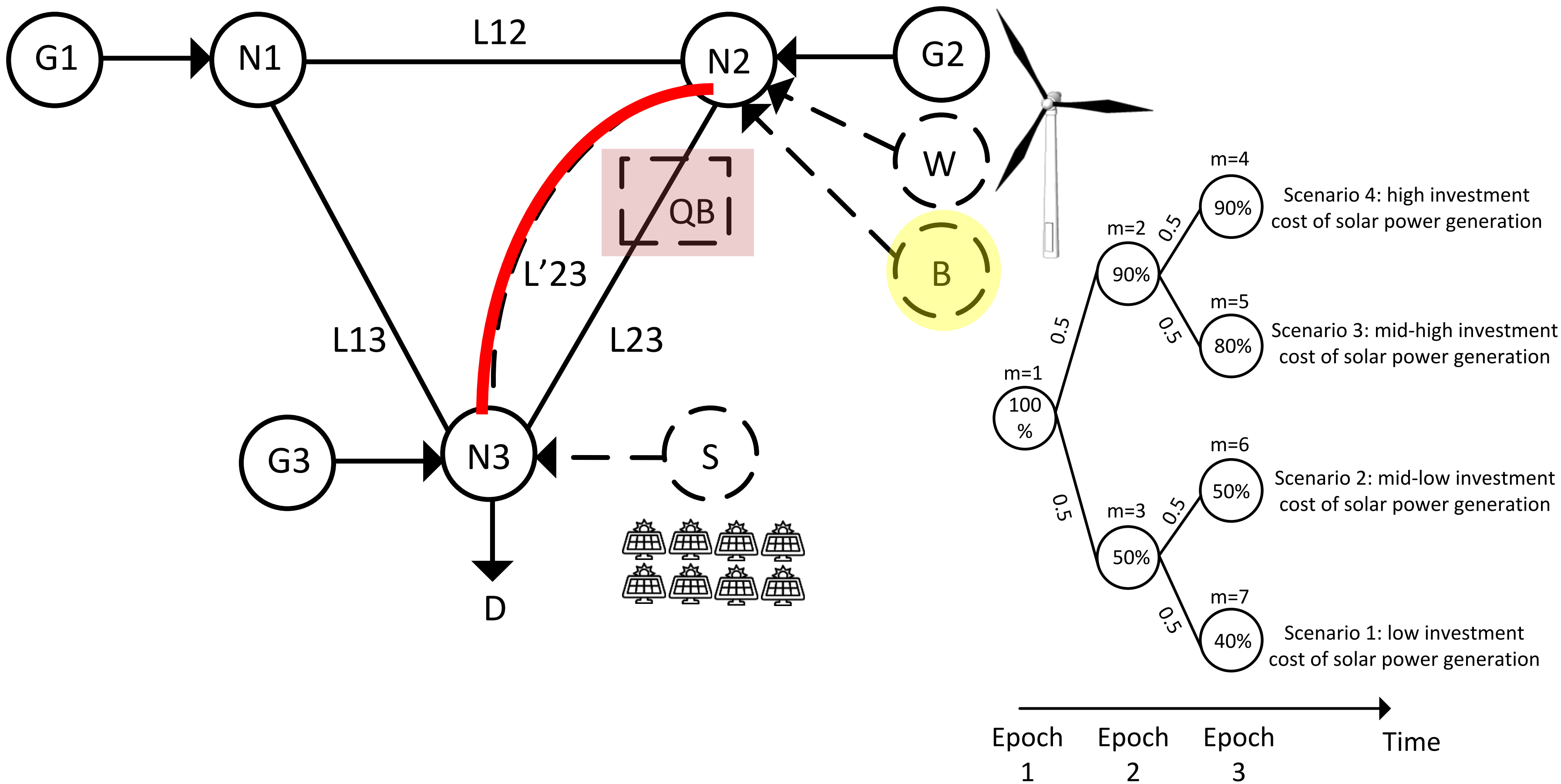
(courtesy of R Shaw, Electricity North West)

Planning the Smart Grid:
Need for new Energy Policy modelling tools



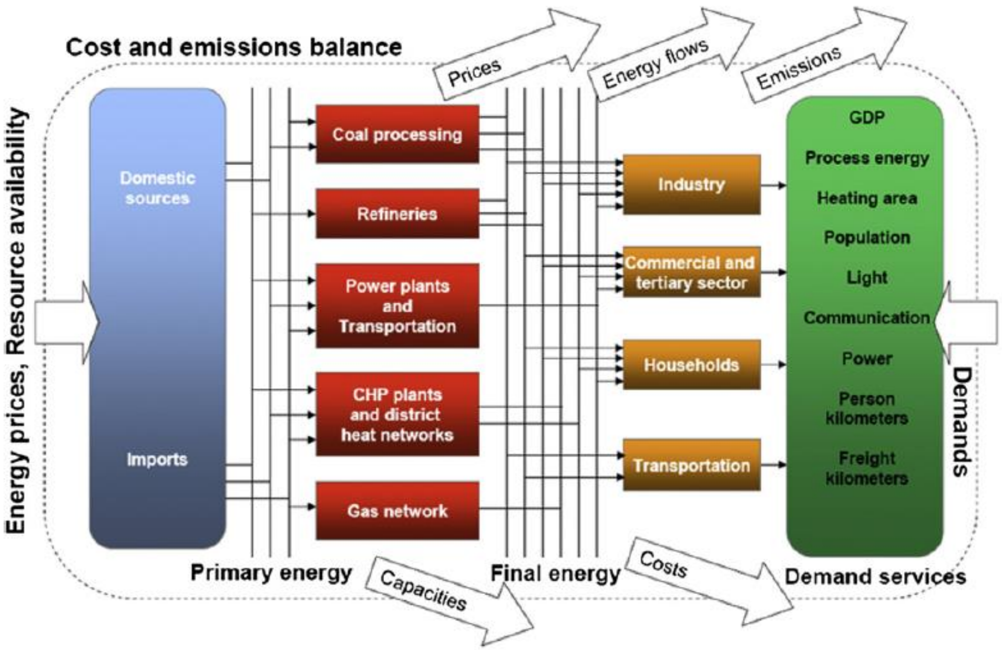
R. Moreno, A. Street, J.M. Arroyo, and P. Mancarella, "Planning Low-Carbon Electricity Systems under Uncertainty Considering Operational Flexibility and Smart Grid Technologies", *Philosophical Trans. Royal Society A*, June 2017

Planning the Smart Grid:
Need for new Energy Policy modelling tools



R. Moreno, A. Street, J.M. Arroyo, and P. Mancarella, "Planning Low-Carbon Electricity Systems under Uncertainty Considering Operational Flexibility and Smart Grid Technologies", *Philosophical Trans. Royal Society A*, June 2017

Planning the whole energy system:
Need for new Energy Policy modelling tools



R. Loulou and M. Labriet, “ETSAP-TIAM: the TIMES integrated assessment model Part I: Model structure,”
Comput. Manag. Sci., vol. 5, no. 1–2, pp. 7–40, Feb. 2008

Remme U. “Overview of TIMES: parameters, primal variables & equations”, Proc. vETSAP Workshop November 2007

Example of end-use demand in TIMES

	Code	Unit
Transportation segments (15)		
Autos	TRT	Billion vehicle-km/year
Buses	TRB	Billion vehicle-km/year
Light trucks	TRL	Billion vehicle-km/year
Commercial trucks	TRC	Billion vehicle-km/year
Medium trucks	TRM	Billion vehicle-km/year
Heavy trucks	TRH	Billion vehicle-km/year
Two wheelers	TRW	Billion vehicle-km/year
Three wheelers	TRE	Billion vehicle-km/year
International aviation	TAI	PJ/year
Domestic aviation	TAD	PJ/year
Freight rail transportation	TTF	PJ/year
Passengers rail transportation	TTP	PJ/year
Internal navigation	TWD	PJ/year
International navigation (bunkers)	TWI	PJ/year
Non-energy uses in transport	NEU	PJ/year
Residential segments[a] (11)		
Space heating	RH1, RH2, RH3, RH4	PJ/year
Space cooling	RC1, RC2, RC3, RC4	PJ/year
Hot water heating	RWH	PJ/year
Lighting	RL1, RL2, RL3, RL4	PJ/year
Cooking	RK1, RK2, RK3, RK4	PJ/year
Refrigerators and freezers	RRF	PJ/year
Cloth washers	RCW	PJ/year
Cloth dryers	RCD	PJ/year
Dish washers	RDW	PJ/year
Miscellaneous electric energy	REA	PJ/year
Other energy uses	ROT	PJ/year
Commercial segments[a] (8)		
Space heating	CH1, CH2, CH3, CH4	PJ/year
Space cooling	CC1, CC2, CC3. CC4	PJ/year
Hot water heating	CHW	PJ/year
Lighting	CLA	PJ/year
Cooking	CCK	PJ/year
Refrigerators and freezers	CRF	PJ/year
Electric equipments	COE	PJ/year
Other energy uses	COT	PJ/year
Agriculture segment (1)		

P. Mancarella et al., “Modelling of integrated multi-energy systems: drivers, requirements, and opportunities”, 19th Power Systems Computation Conference (PSCC), Genova, Italy, June 2016. *Invited Plenary Contribution*

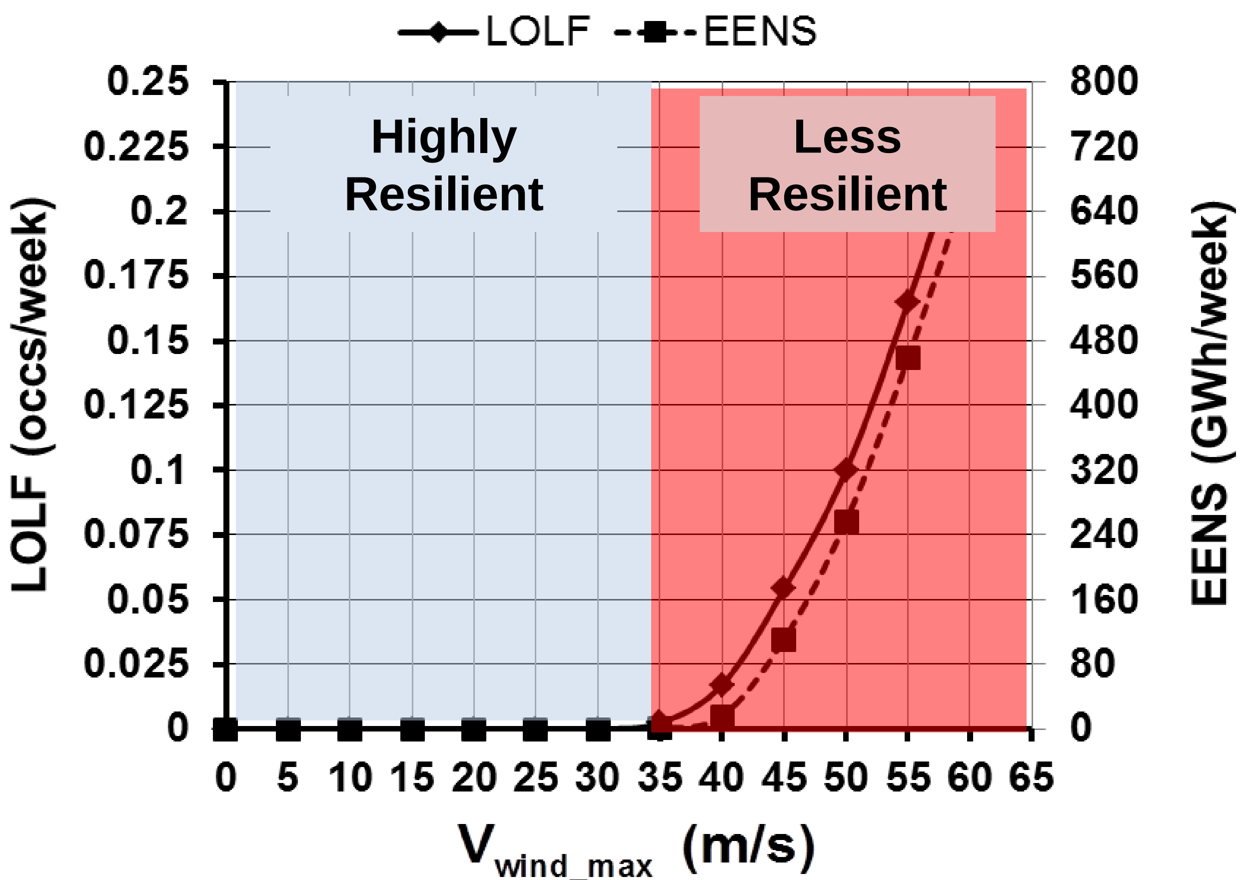
Planning against the extreme: Reliability or resilience?

Reliability Vs Resilience

Reliability	Resilience
High probability, low impact	Low probability, high impact
Static	Adaptive, ongoing, short and long term
Evaluates the power system states	Evaluates the power system states and transition times between states
Concerned with customer interruption time	Concerned with customer interruption time and the infrastructure recovery time

M. Panteli and P. Mancarella, The Grid: Stronger, Bigger, Smarter? Presenting a conceptual framework of power system resilience, *IEEE Power and Energy Magazine,* May/June 2015*, Invited Paper*.

Can we define a resilience threshold?



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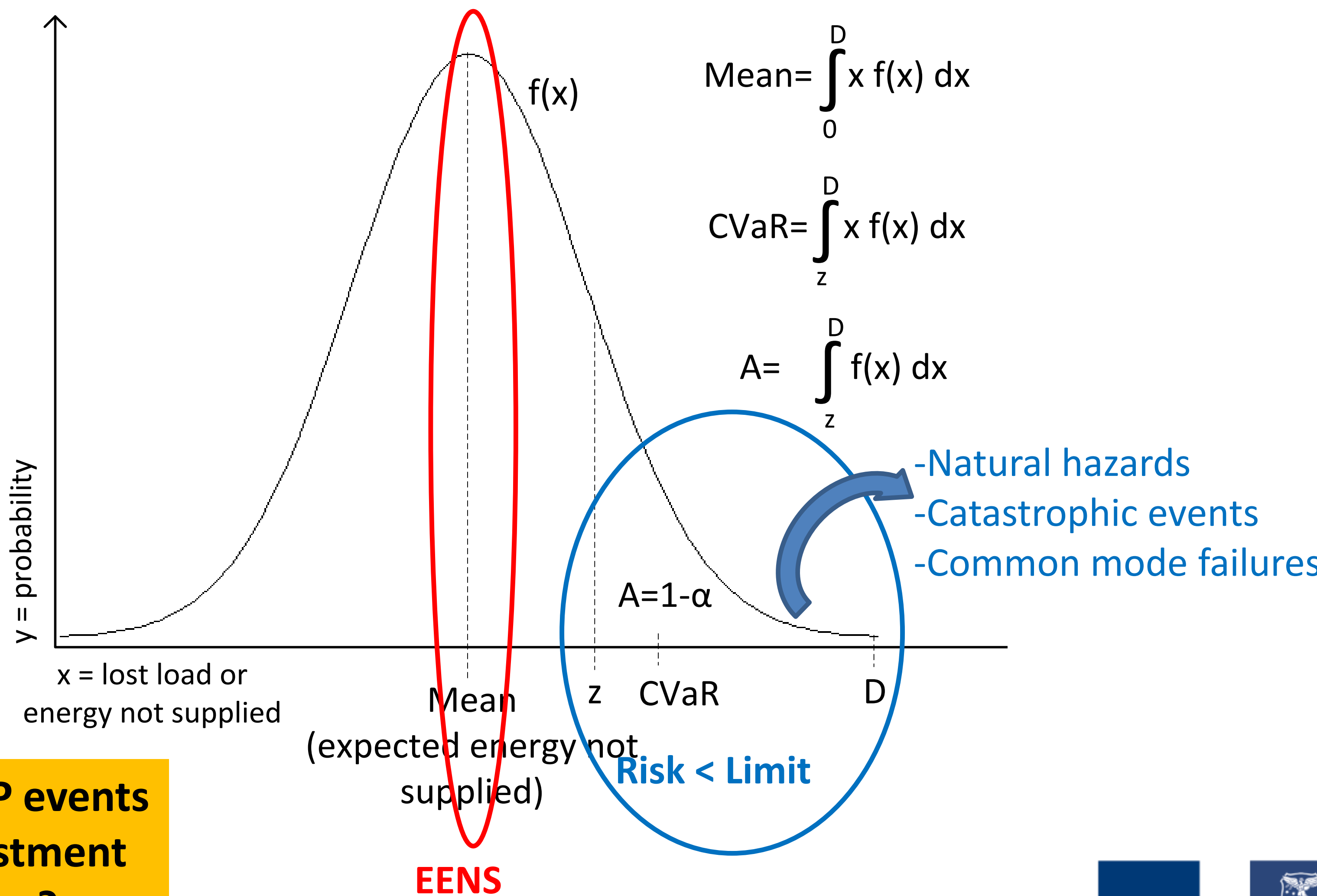
Rethinking fundamental approaches to planning: From "average" to "risk" indicators



How do HILP events affect investment decisions?

The Resilience Trilemma

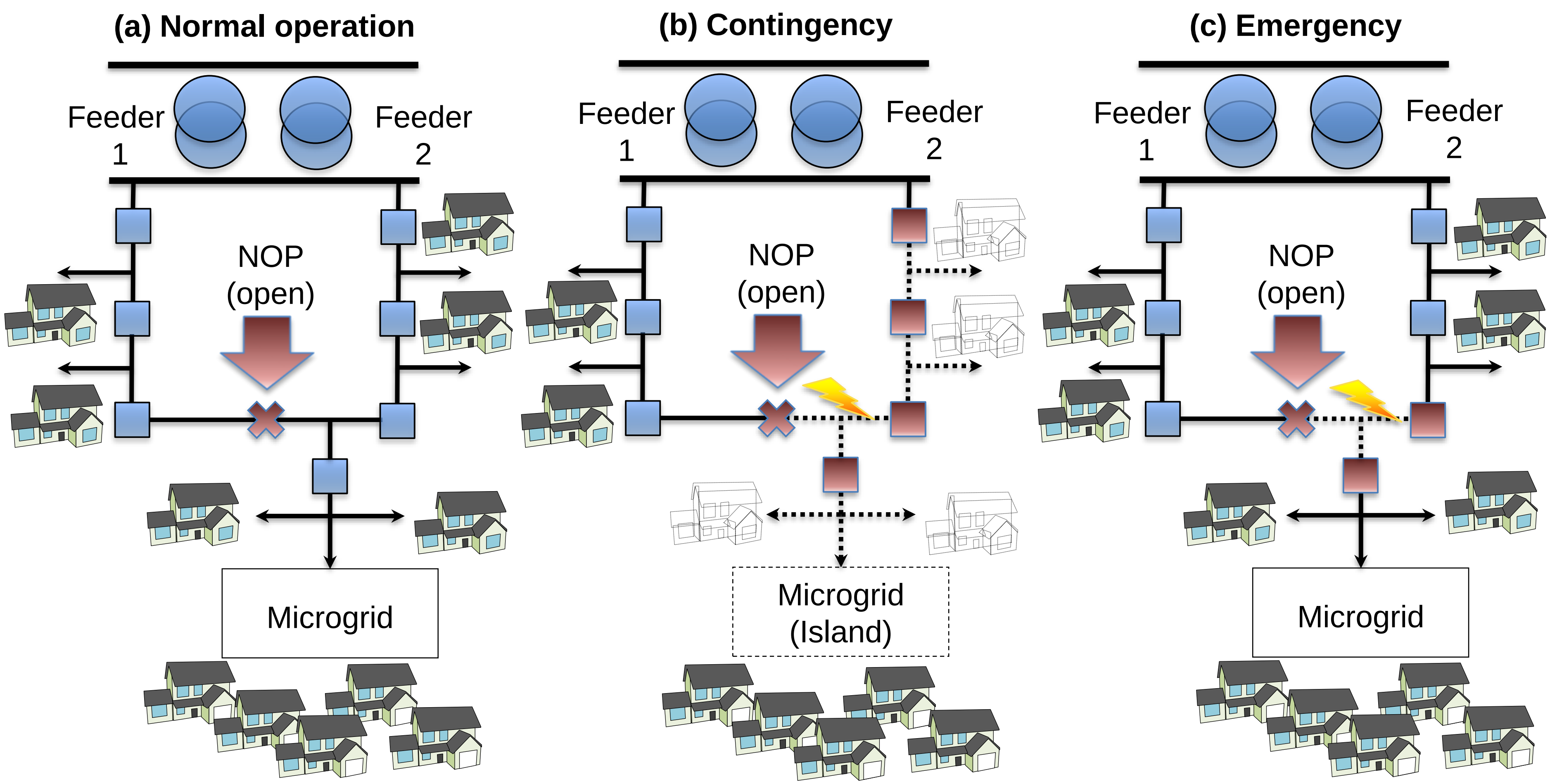
M. Panteli and P. Mancarella, The Grid: Stronger, Bigger, Smarter? Presenting a conceptual framework of power system resilience, *IEEE Power and Energy Magazine,* May/June 2015*, Invited Paper*.

Make the network more responsive (e.g. faster restoration), self-adaptive, resourceful, etc.

Upgrade existing infrastructure, asset life extension, etc.

Build new infrastructure, e.g. transmission lines, substations, etc.

Distributed energy resources, reliability and resilience



How about "social" resilience?

- The role of communities can be crucial to lessen the impact of severe power blackouts.
- Critical period: Insufficient capacity to deal with the event (72 hours)
- Communities are often overlooked in both proactive and reactive phases of emergency management
- Need for redefining technical vs. social models

Social resilience aspects and pictures are courtesy of and elaborated from J. Moreno, University of Manchester.
Work performed within the Newton-Picarte UK-Chile project "Disaster management and resilience in electric power systems", 2015-2017

"Disaster management and resilience in electric power systems"

Participants:

UNIVERSIDAD DE CHILE

The University of Manchester

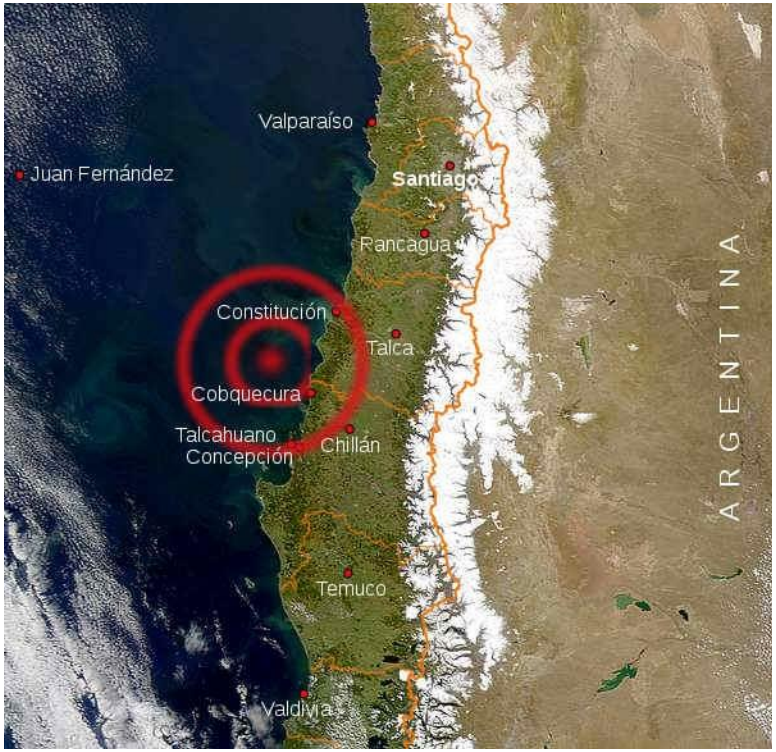
Funders:

CONICYT
COMISIÓN NACIONAL DE INVESTIGACIÓN CIENTÍFICA Y TECNOLÓGICA

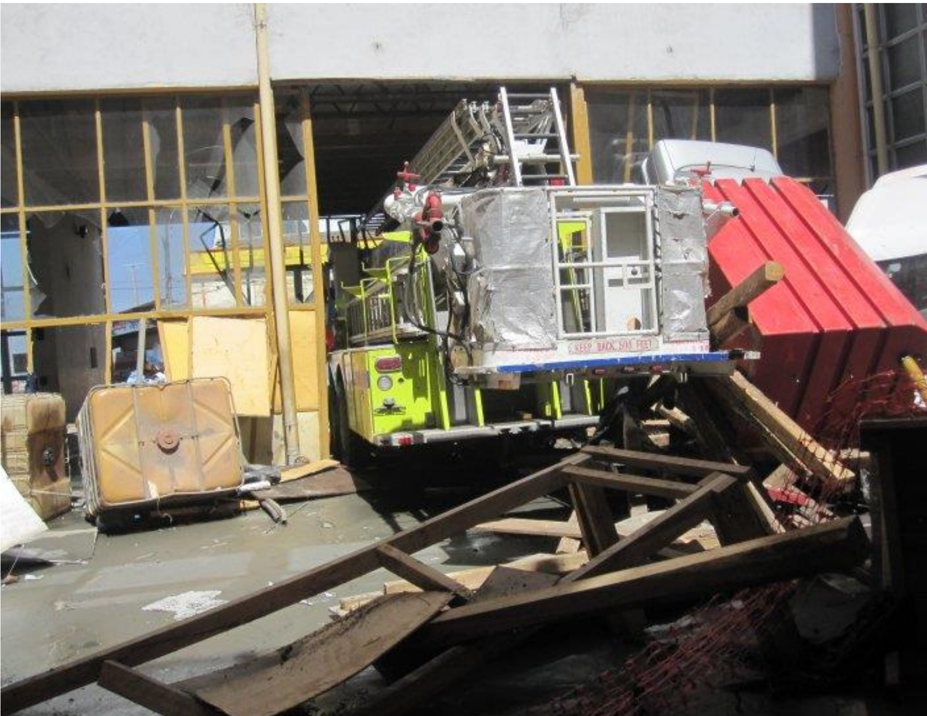
EPSRC
Engineering and Physical Sciences Research Council

- *Multi-disciplinary research: Electrical engineering, civil engineering, operations research, social science and economics*

The 2010 Chile earthquake and tsunami, 8.8 Mw




VALPA RAISO
SAN VI CENTE

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“Negative” resilience


PARIS

“Positive” resilience

- Community resilience:

“The capacity of communities to cope with and recover positively from disasters, learning from such stress, activating their inner resources and performing better in future in the face of adversity”

Positive resilience

- Cooperation and solidarity
- Organisation
- Social networks
- Alternatives to electricity
- Use of natural sources of energy

An integrated socio-technical assessment: key findings

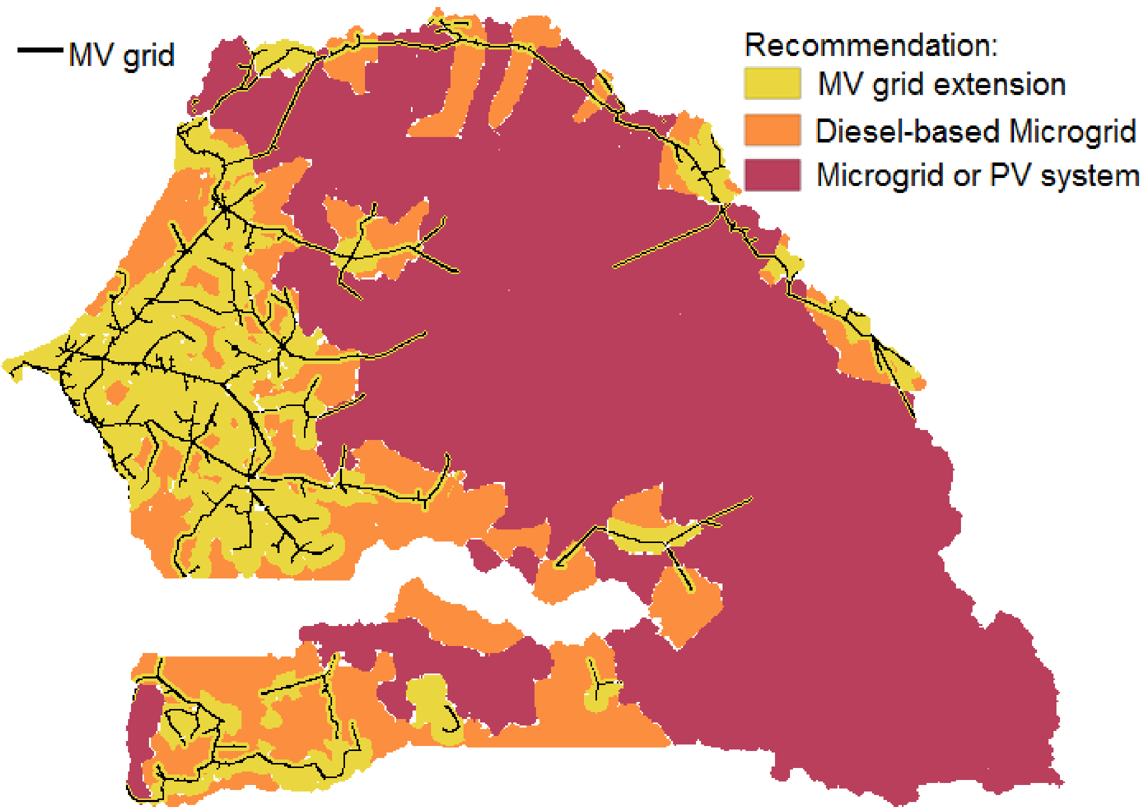
- Social aspects may change (dramatically) the technical perspective
- Need for integrating social aspects in technical modelling:
  - **Repair time after event**
  - **Customer damage function during event**, and therefore
  - **Value of Lost Load**

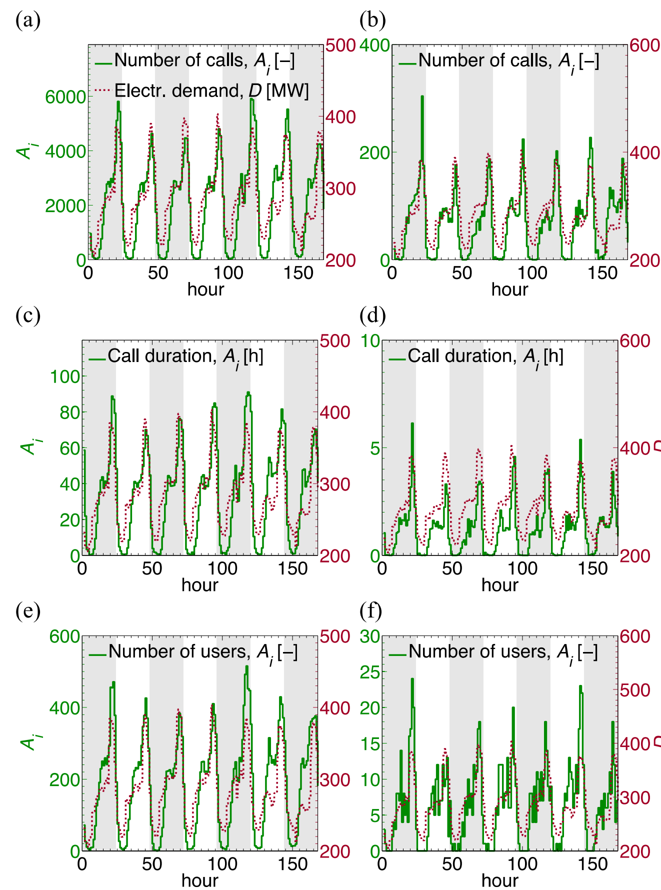
Resilience vs Reliability is not only HILP vs LIHP, but requires a more fundamental rethinking of the parameters involved in the technical modelling, besides the modelling itself

New project in South East Asia

- **TERSE: Techno-economic framework for Resilient and Sustainable Electrification**
- USD 1.7M UK-China-Malaysia project, led by the University of Manchester
- Integrating reliability and resilience in planning from a techno-economic perspective
- Integrating impact of distributed energy resources
- Integrating social aspects into the technical framework
- **Collaborations welcome ☺**

Optimal electrification plan for a whole-country





Dakar Rural area

E.A. Martinez-Cesena, P. Mancarella and M. Schapfler, Using mobile phone data for electrification planning, D4D Competition, MIT Media Lab, April 2015, Double Award Paper

Concluding remarks

- Low-carbon technologies bring challenges and opportunities
- Need for new operational and planning tools to support decisions of policy makers and regulators to fully address the energy trilemma and truly value Smart Grid technologies
- Need for integrating reliability and resilience in planning from a techno-economic perspective
- Need for integrating social aspects into techno-economic models
- **Towards development of comprehensive socio-technical operational and planning frameworks**

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3-4 April 2018 • Galle, Sri Lanka

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