ELECTRICITY NETWORK TRANSFORMATION ROADMAP 2017-27

Exploring the Beneficial Integration of Distributed Energy Resources & Digital Market Platforms for Energy – DAY 1

7- 8 July 2016
Energex, Brisbane

energy networks association

CSIRO

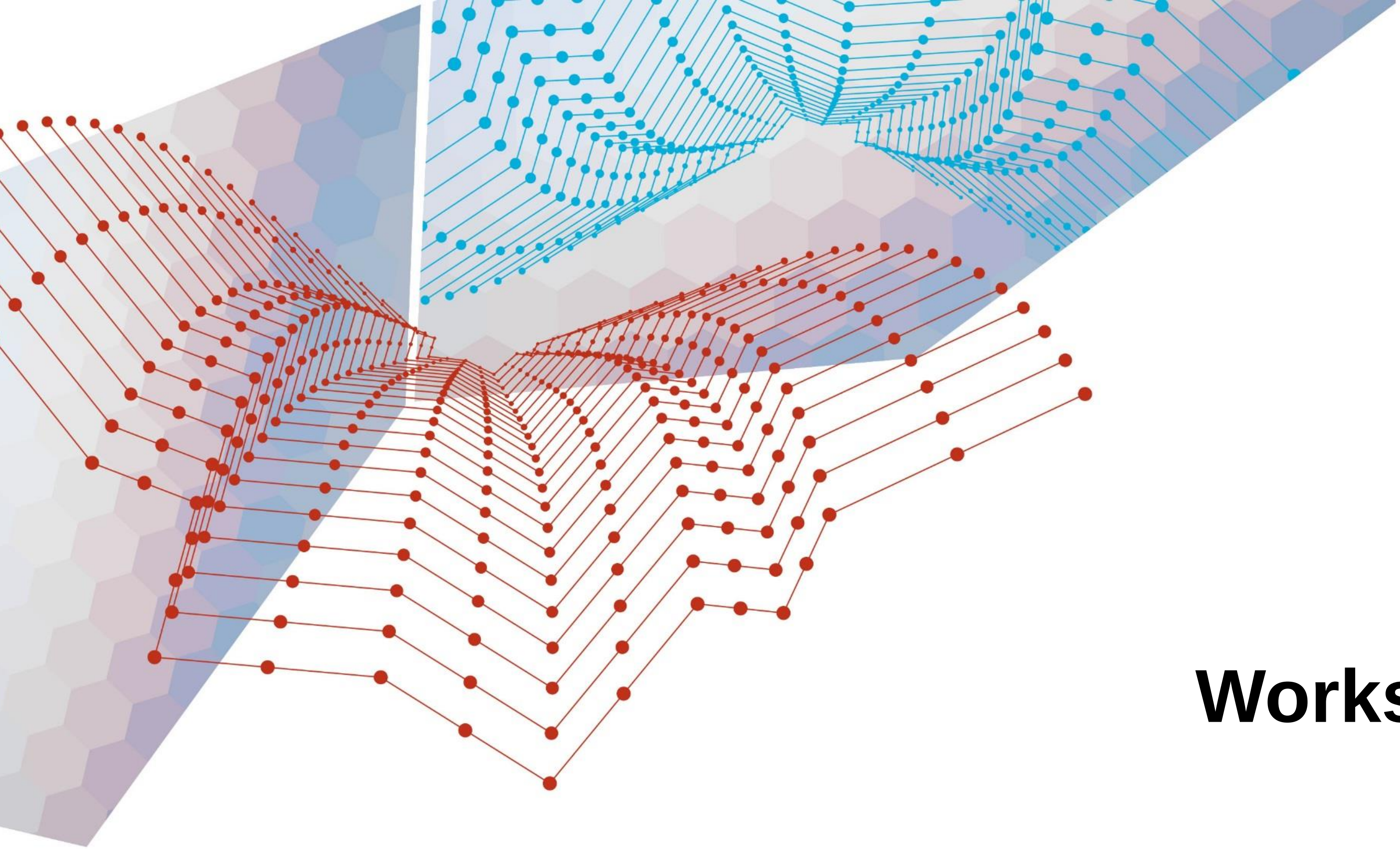
Important Notices

- **These slides are solely for workshop purposes only. The contents are designed to foster a diversity of thinking about future possibilities in Australia. They do not represent the official position of either the Energy Networks Association or CSIRO.**
- ‘Chatham house’ rules apply
- Competition and Consumer Act provisions apply
- Participants to make their own call on sharing commercially sensitive material

Acknowledgement

CSIRO and ENA wish to recognise the ongoing contributions of the following global thought-leaders:

Tabors Caramanis Rudkevich



ELECTRICITY NETWORK TRANSFORMATION ROADMAP

2017-27

Workshop Introduction

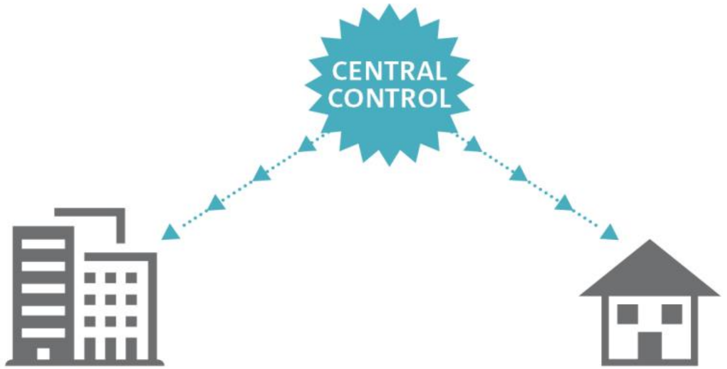
Mark Paterson, CSIRO

ena energy networks association

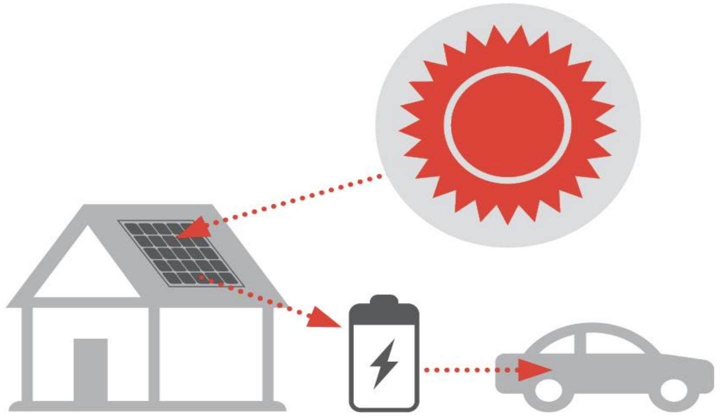
CSIRO


Welcome to
2027
SPACEBITS

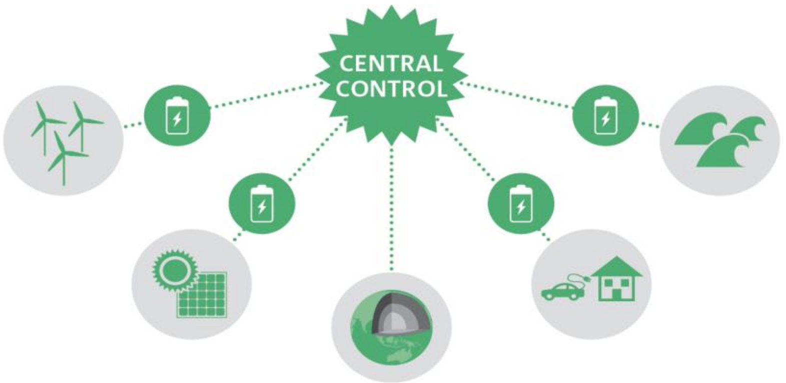
Global electricity systems are profoundly changing



Set and forget


Leaving the grid

Rise of the ‘Prosumer’



Renewables thrive

Six major commonalities shared by all 2050 scenarios

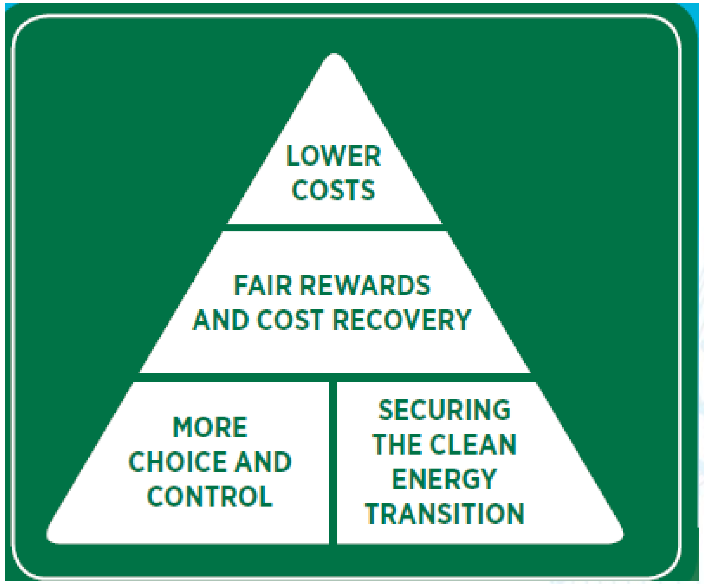
1. Network-centric → Customer-centric decision power
2. Centralised → Hybrid/Decentralised technological architecture
3. Dispatchable FF generation → Increasing decarbonisation (with dispatchability, intermittency and inertia challenges)
4. Regulated natural monopoly → Increasing exposure to competitive forces and product substitution.
5. 30 – 50% of Australia's electricity volume (MWh) served by distributed generation
6. Under every scenario, electricity networks continue to play a critical set of roles in 2050

Roadmap Vision / Outcome

Australia’s electricity systems in 2027 and beyond are **resilient to all of the divergent futures described by the four Future Grid Forum 2050 scenarios**.

This resilience will be underpinned by systems that enable:

- A ‘balanced scorecard’ of long-term customer, societal and environmental value creation;
- Whole-of-system efficiency, reliability, safety and flexibility; and,
- Millions of end-users participating in and sharing the benefits of whole-of-system optimisation through open, vibrant markets and appropriate protections.



Workshop Agenda - Day 1

9:00 – 9:45	Introduction
9:45 – 10:30	The Value and Opportunity of DERs
10:30 – 10:45	**Morning Tea**
10:45 – 12:15	Future Grid Characteristics & Functionality
12:15 – 12:45	**Lunch**
12:45 – 2:30	Optimal Grid Operation in a High DER Future
2:30 – 2:45	**Afternoon Tea**
2:45 – 4:55	Grid Architecture I
4:55 – 5:00	Conclude Day 1
5:00 – 6:00	**Post workshop drinks & canapes**

Workshop Agenda – Day 2

9:00 – 9:15	Open Day 2
9:15 – 11:15	Grid Architecture II
11:15 – 11:30	**Morning Tea**
11:30 – 12:45	Integrating & Incentivising DER Services
12:45 – 1:15	**Lunch**
1:15 – 3:00	Exploring Technical & Economic Platforms in the Australian context
3:00 – 3.15	**Afternoon Tea**
3:15 – 3.45	Next Generation Platform – Next Steps
3:45 - 4:00	Bringing it all together – Conclude Workshop

The ‘DNA’ structure of the Roadmap project

A. Customer Orientated Networks (WP 1 & 2)

- Transformation Drivers
- FGF Update
- Customer Reorientation

B. Revenue and Regulatory Enablers (WP 3 & 4)

- Business Models
- Regulatory Frameworks – Risk Sharing; Scope of Service; Customer Protection

C. Pricing and Incentives (WP 5)

- Cost-Reflective Pricing
- “Second Wave” Incentives
- Value of New services including Micro-grids, Ancillary Services

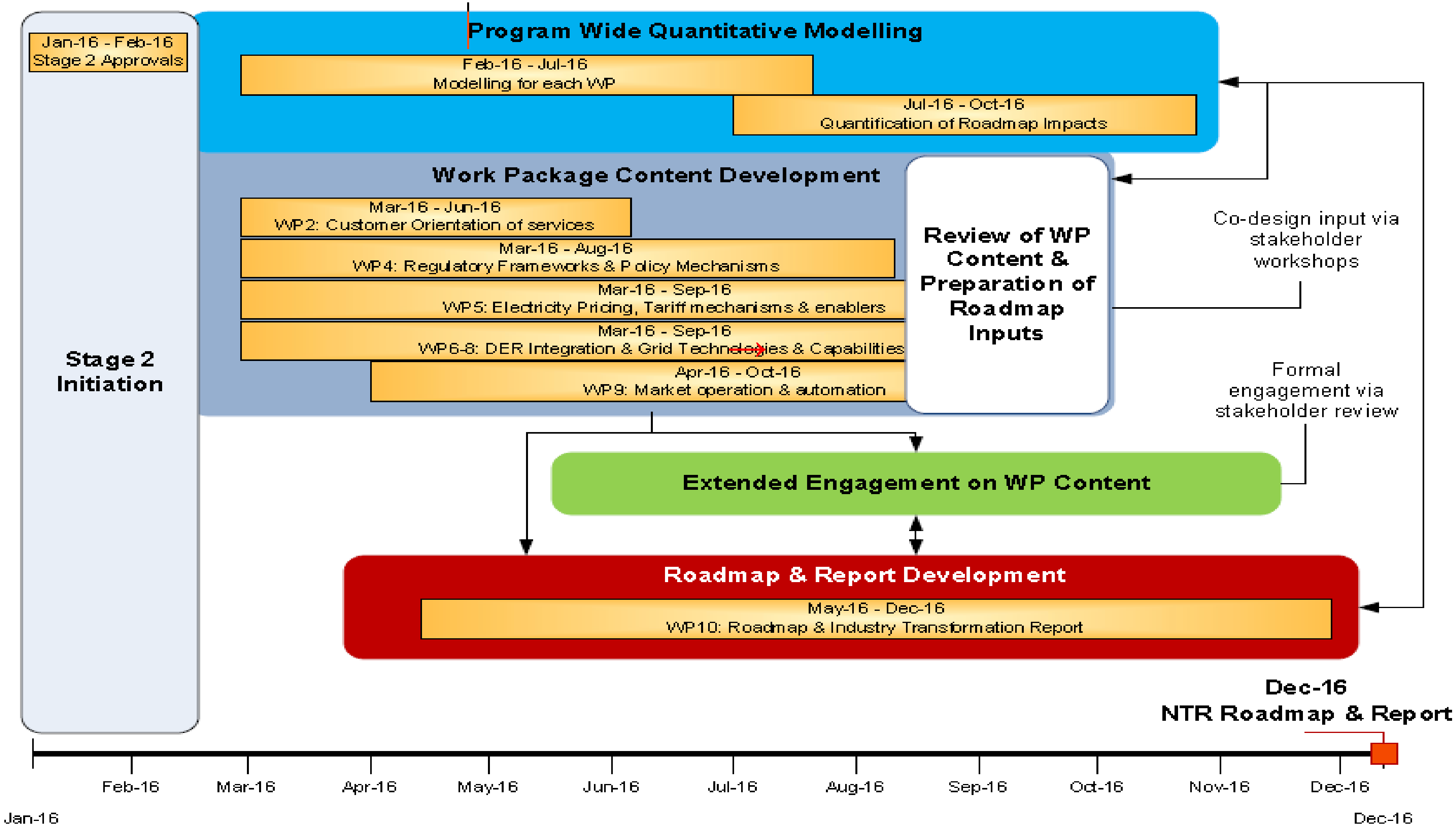
D. Technological Enablers (WP 6 – 8)

- Standards, operating platforms
- Advanced Power System Operations, Reliability and Security
- Grid-side technologies and innovation
- Future Workforce requirements

E. Next Generation Platform (WP 9)

- Transactive Energy models
- Institutional frameworks

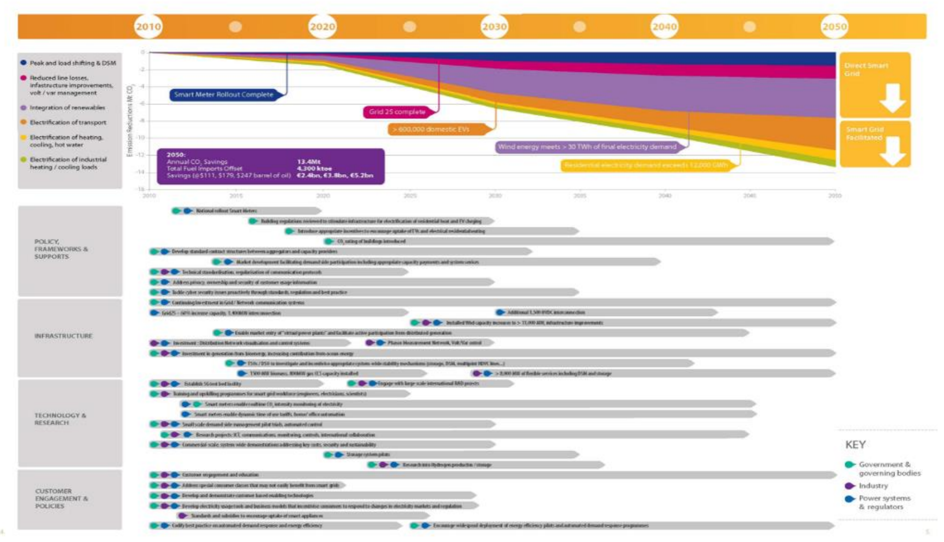
Stage 2 Schedule



Roadmap construction

The 2017-27 Roadmap will concisely set out:

- An integrated set of ‘no regrets’ actions spanning all Domains (or ‘swim lanes’);
- The sequence, interrelationships and milestones for actions across the decade; and,
- Nominated primary and secondary responsibilities for each action.



In-scope / Out-of-scope

This workshop is intended to be:

- Exploratory and consultative; and,
- Designed for both shared learning and seeking stakeholder feedback on a range of quite technical matters.

In addition to transcending current issues, for efficiency the following are out-of-scope:

- Electricity Pricing (refer ENTR workshop on 25 July);
- Regulatory Frameworks (upcoming ENTR paper); and,
- Considerations of ‘who’ might perform new distribution system functions required in a High-DER future

Engagement Principles

The Electricity Network Transformation Roadmap project will help guide the transformation of Australia's electricity networks over the 2017-27 decade toward a customer-oriented future.

General Principles

- Stakeholders will be provided with opportunities to reflect upon, contribute to and provide feedback on Work Packages informing the Roadmap.
- Participants will be provided with a summary of the stakeholder feedback received.
- A diversity of legitimate perspectives will be considered on all of the Roadmap topic areas to inform electricity network transformation.
- As a process involving a wide range of stakeholders, all participants are expected to engage respectfully, proportionately and in good faith

Engagement Principles (Con't)

Guidelines for Seeking Consensus

- While placing a high priority on the principle of co-design and the pursuit of consensus, the ENA and CSIRO also recognize that not all stakeholders will agree with all decisions made or content developed.
- Given the finite Roadmap development schedule, in such cases the ENA and CSIRO have outlined a process for advancing and making transparent unresolved points of difference in the Engagement Principles.

ELECTRICITY NETWORK TRANSFORMATION ROADMAP 2017-27

Introduction to Work Package 6/8: Technical Enablers

Stuart Johnstone, ENA

ena energy networks association

CSIRO

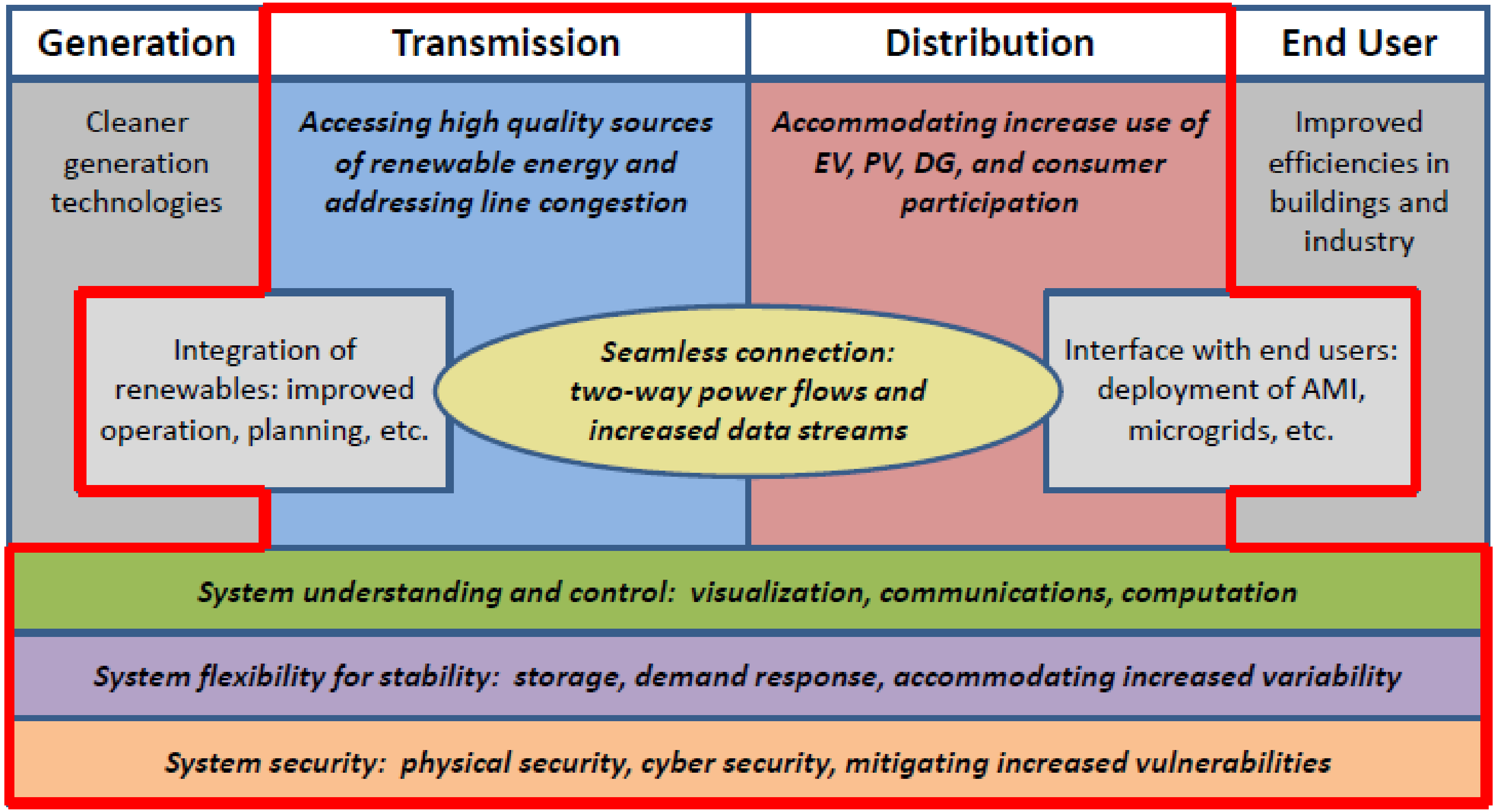
Stage 1 of the Roadmap project explored the challenges and opportunities of integrating DERs

The mass integration of Distributed Energy Resources requires a careful operational response to challenges such as voltage management, frequency regulation and network stability.

However, well-integrated DERs can also provide solutions for addressing these network challenges and improving network efficiency. This is likely to require:

- **New regulatory frameworks**
- **New business models**
  - Commercial responses which unlock the potential of energy storage, demand response services and power electronics solutions.
- **Enhanced standardisation**
  - For example Standards for: Storage, Electric Vehicles, Inverters, Protection Relay, Smart Meters, intelligent control architecture
- **Smart Control and Storage**
  - The addition of smarter control, and/or better storage to DER enhances their benefits and improves voltage control, power quality and increases their reliability.
- **Adaptive Systems – Demand Response and Prediction:**
  - Critical to predicting and controlling network loads in the integrated grid.

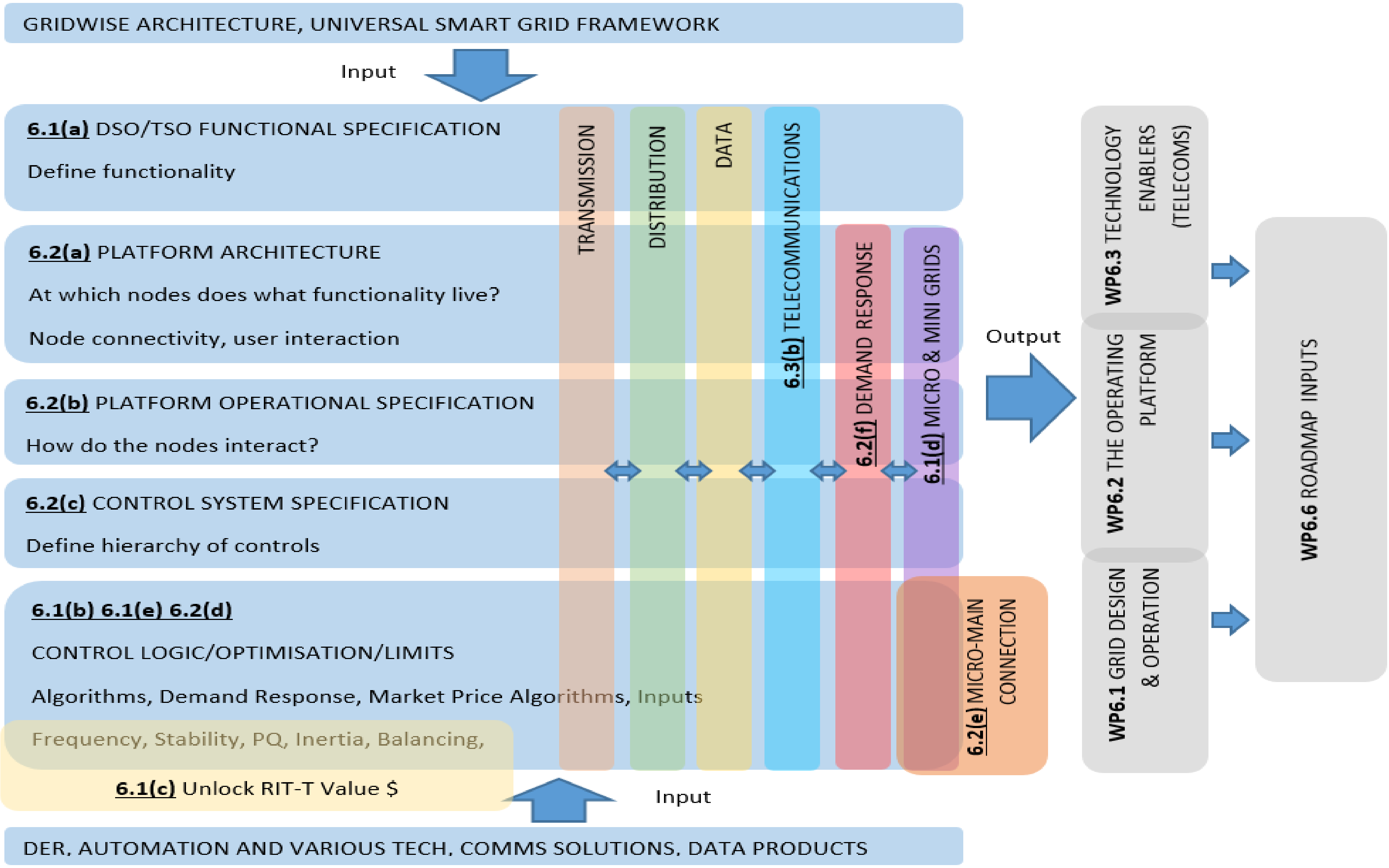
Conceptual Future System Operability



The technological focus of Stage 2 includes:

1. **System operation**
   - Develop a functional description/specification of DSO functionality that are likely to be inherent in future network services
2. **Operating platform**
   - Develop the most effective operating platform that allows full optimisation and coordination of the diverse range of connected demand side services
3. **Technical enablers**
   - Identify gaps in industry standards and guidelines
   - Establish what communication requirements are required
4. **Innovation**
   - Identify the key gaps in research and development
5. **Future Industry Workforce Requirements**
   - Establish a strategy to identify and facilitate the changes required to service the future skills and training requirements

WP 6.1/2/3 - Future Grid Architecture



Deliverable - Future Grid Architecture

- Develop a functional description/specification of DSO functionality that are likely to be inherent in future network services
- Establish what is the optimum design and operating parameters of an inverter dominated power system of the future to allow for the likely reduction in the level of synchronous generation and the increase in non-synchronous generation.
- Identify the solutions to efficiently design, control, and operate grid connected and islanded/non-connected microgrids/minigrids.
- Balancing demand side response.
- network operation and control that alleviates the technical impacts and maximise the benefits of new demand side technologies
- Establish the optimal controls required to maximise overall system performance and maintain system stability and global optimisation.

Smart Grid Architecture Model

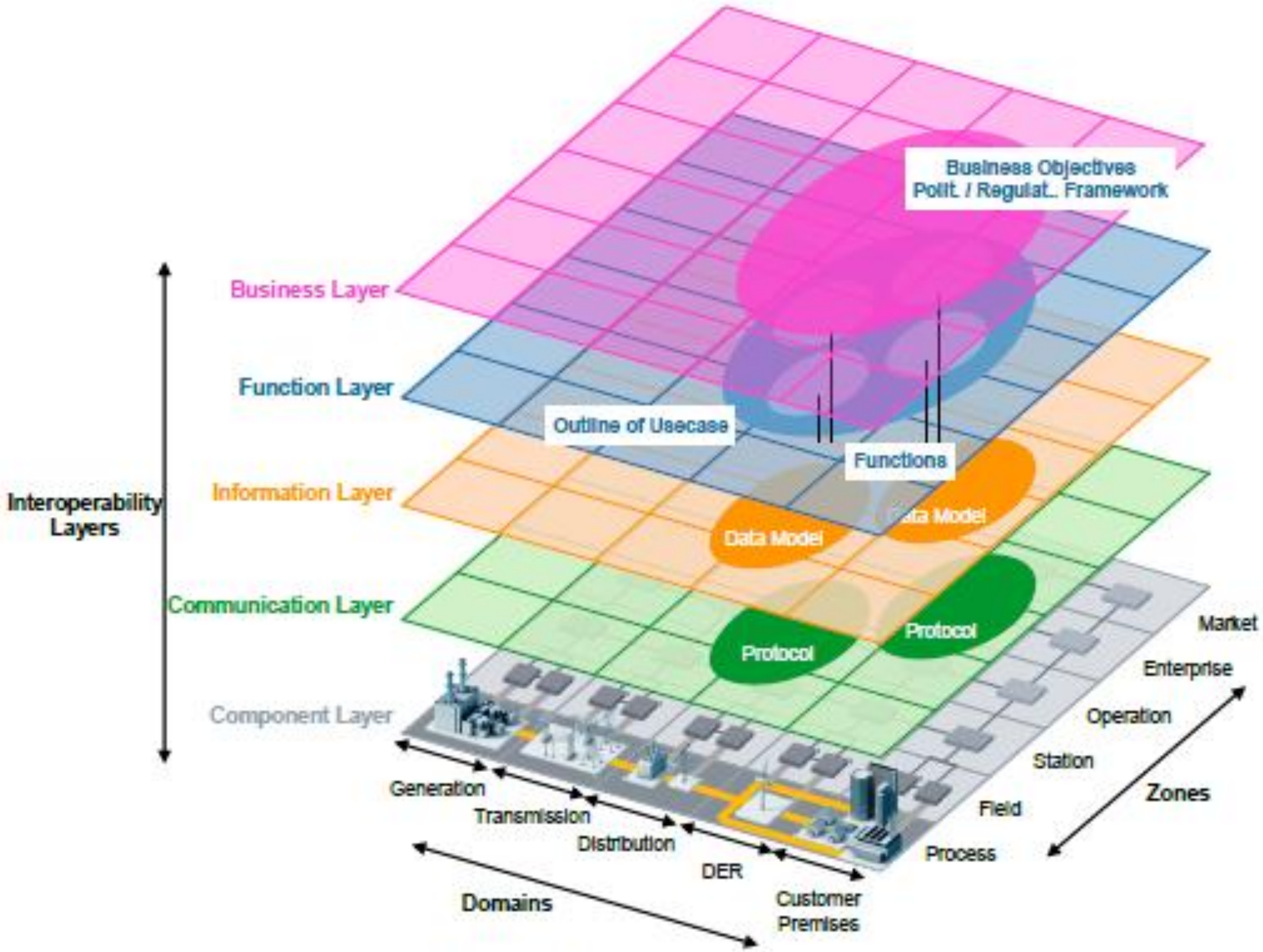
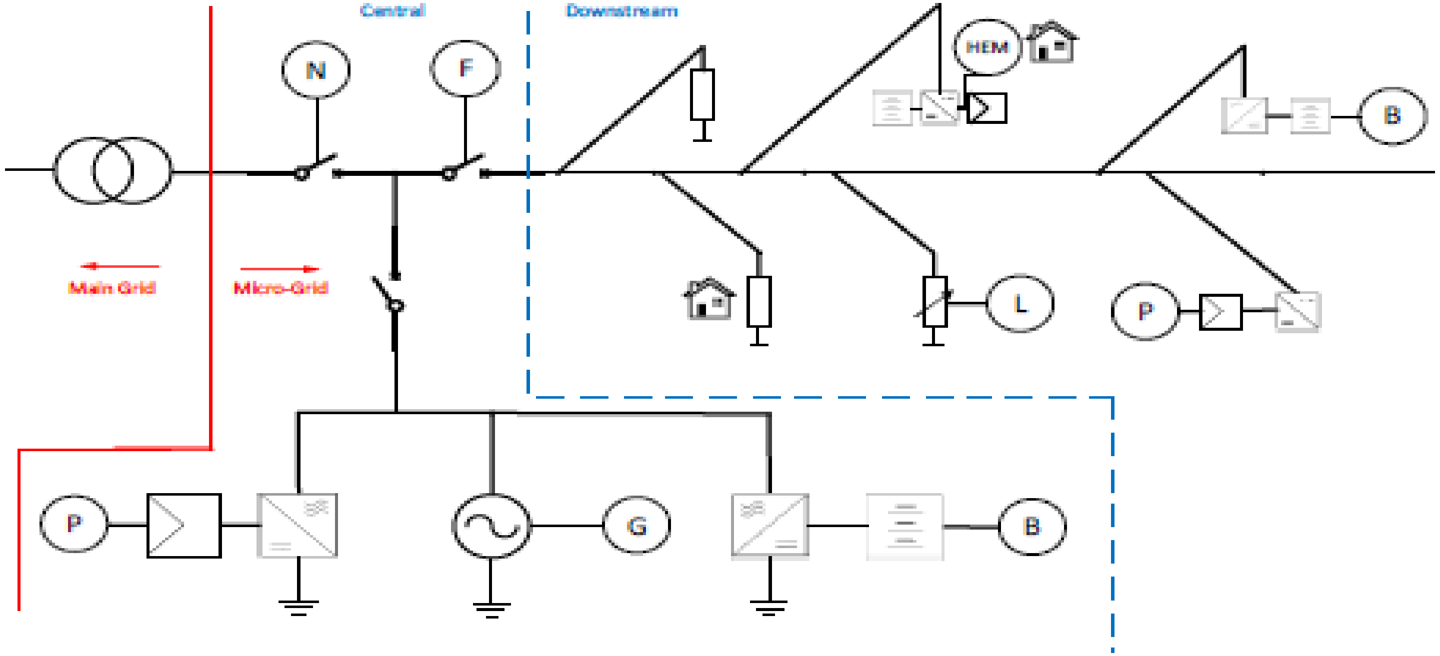


Figure 8: SGAM framework

View of what the future DSO model architecture could look like, and the ways on which the different layers of the distribution network interact and can be utilised.

Micro-grid Design and Function



The generic model of a Microgrid/minigrid could contain any or all of the following components or power assets that can be deployed, started up, shut down, connected or disconnected multiple times a day and/or have continuously controlled power generation or consumption

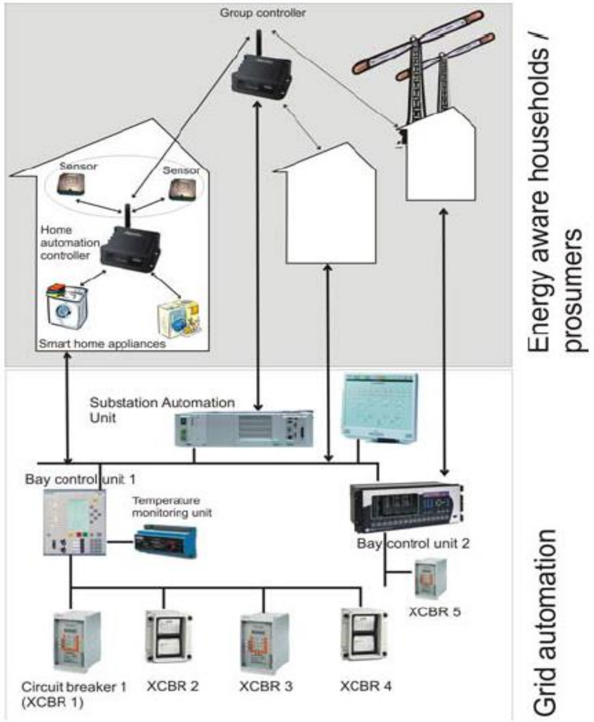
Why are Standards required?

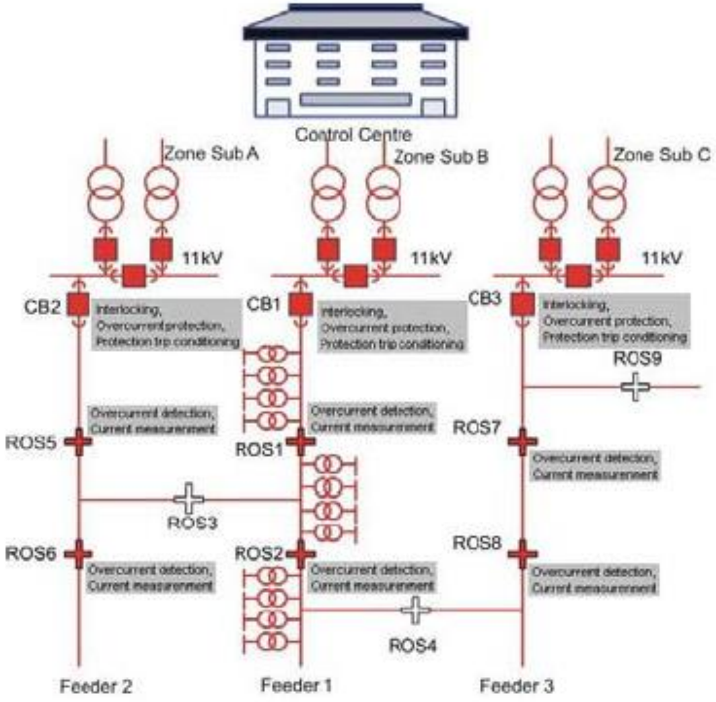
- The developing nature of the Energy Supply Industry brings significant risks for government, industry, and the wider community.

- Standards can be used to provide a guiding framework that can be used to manage key consumer risks and minimise early commercialisation risks for business and industry

Deliverable – Standards Roadmap

If we want to build interoperability and intelligent control systems as part of the future Energy System we need to ensure we have appropriate standards to facilitate this transition.





Framework of the approach that is being pursued by the NTR for development of a prioritised plan on Standards

Why Standards?	What priorities and why?	What specific Standards and when?
Objective	**Priorities for Standards**	**Standard Topics**
Prioritised plan to deal with gaps in industry standards and guidelines	Priority Area 1	Action 1.1 Action 1.2
	Priority Area 2	Action 2.1 Action 2.2
	Priority Area 3	Action 3.1 Action 3.2

Deliverable – Future Workforce Requirements

Drivers of change

- What changes are expected to asset design, technical support equipment and organizational processes in the next 15 years?
- How will these developments affect the role of maintainers and their day-to-day tasks?

Training of maintainers

- How maintainers are currently trained in Australia?
- What are the enablers and barriers to ensure an appropriate maintenance workforce for the future?

Technicians/ trades in Australia

1.4m people considered as technician or trades worker in Australia

252,626 electrical/ electronic/ ICT/ telecommunications technicians (electrical trades) in Australia

16,908 electrical trades in the Electricity, Gas, Water and Waste Services sector

Data from ABS 2011 Census and NCVER

How do we expect asset design, technical support equipment and organizational processes to change?

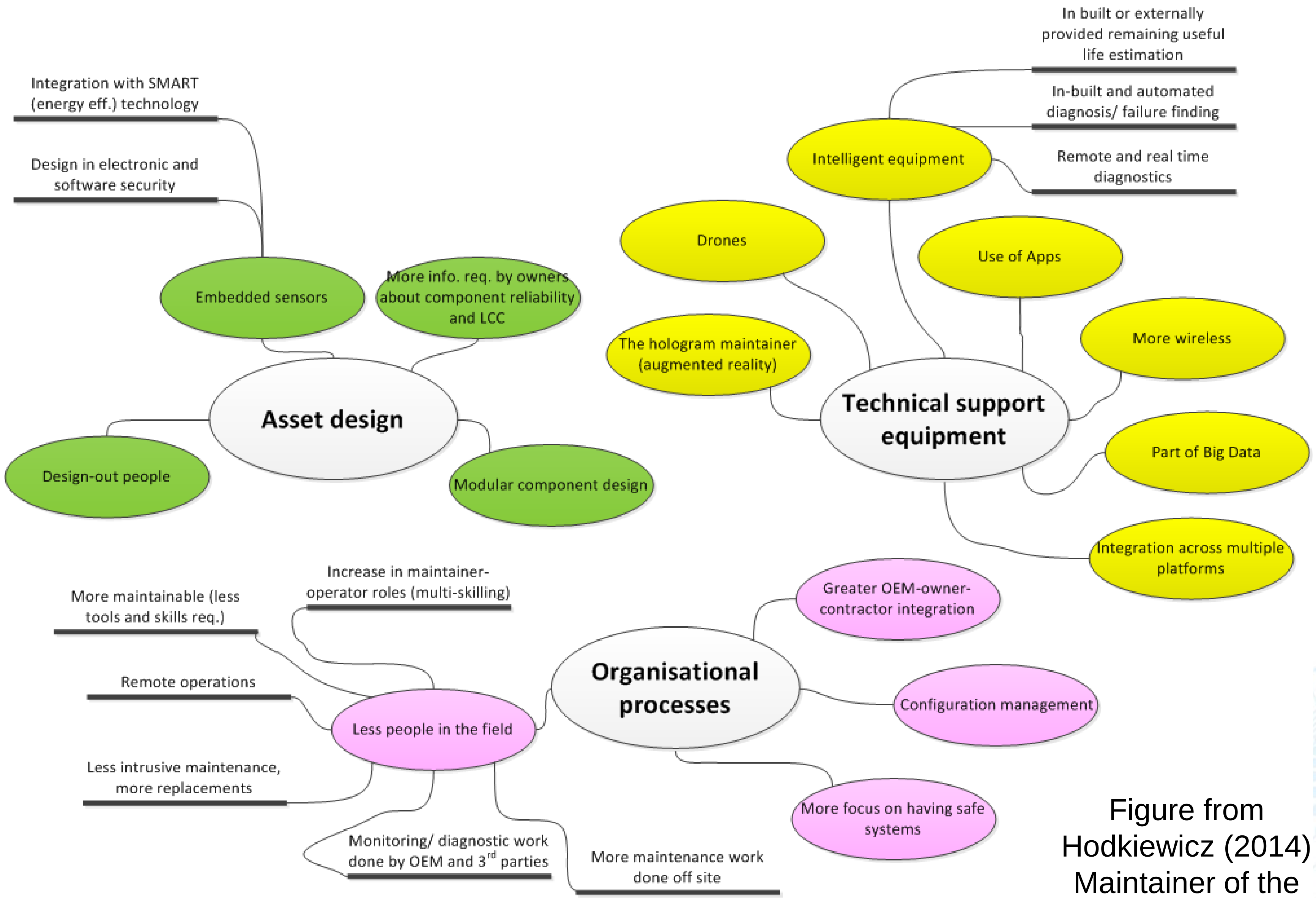


Figure from Hodkiewicz (2014) Maintainer of the

STANDARDS AND THE FUTURE OF DISTRIBUTED ELECTRICITY

Standards as technical enablers for all possible distributed electricity futures

Part of the ENA and CSIRO Electricity Network Transformation Roadmap

Jessica Curtis, National Sector Manager

7 July 2016

PROCESS

- Reference groups: Scope and topics
- Discussion paper: Background for feedback
- Identification of:
  - State of Standards
  - Priorities
  - Dependences
- August: Workshop
- September: Standards paper published
- December: NTR published

Standards and the Future of Distributed Electricity

OVERVIEW OF TOPIC AREAS

MARKET SYSTEMS AND OPERATIONS

- Market Systems
- Electrical System Operation

GOVERNANCE AND SERVICES

- Asset management
- Security
- Cyber Security
- Critical Infrastructure Resilience
- Terminology

GENERATION: DISTRIBUTED AND CENTRALISED

- General Generation
- Solar
- Marine
- Wind
- Hydro
- Thermal Power Plants

TRANSMISSION AND DISTRIBUTION

- Substations
- Switchgear
- Transformer
- Protection Relays
- Cable and Overhead Lines
- Grid Size Energy Storage
- Distributed Energy Coordination

PROSUMERS

- Building Management System
- Customer Energy Management
- Process Automation Systems
- Demand Response Management Equipment
- Advanced Metering
- Local Energy Storage
- Electric Vehicles
- Inverters
- Microgrids

SUPPORTING TECHNOLOGIES

- Communications
- Electromagnetic Compatibility
- Power Quality

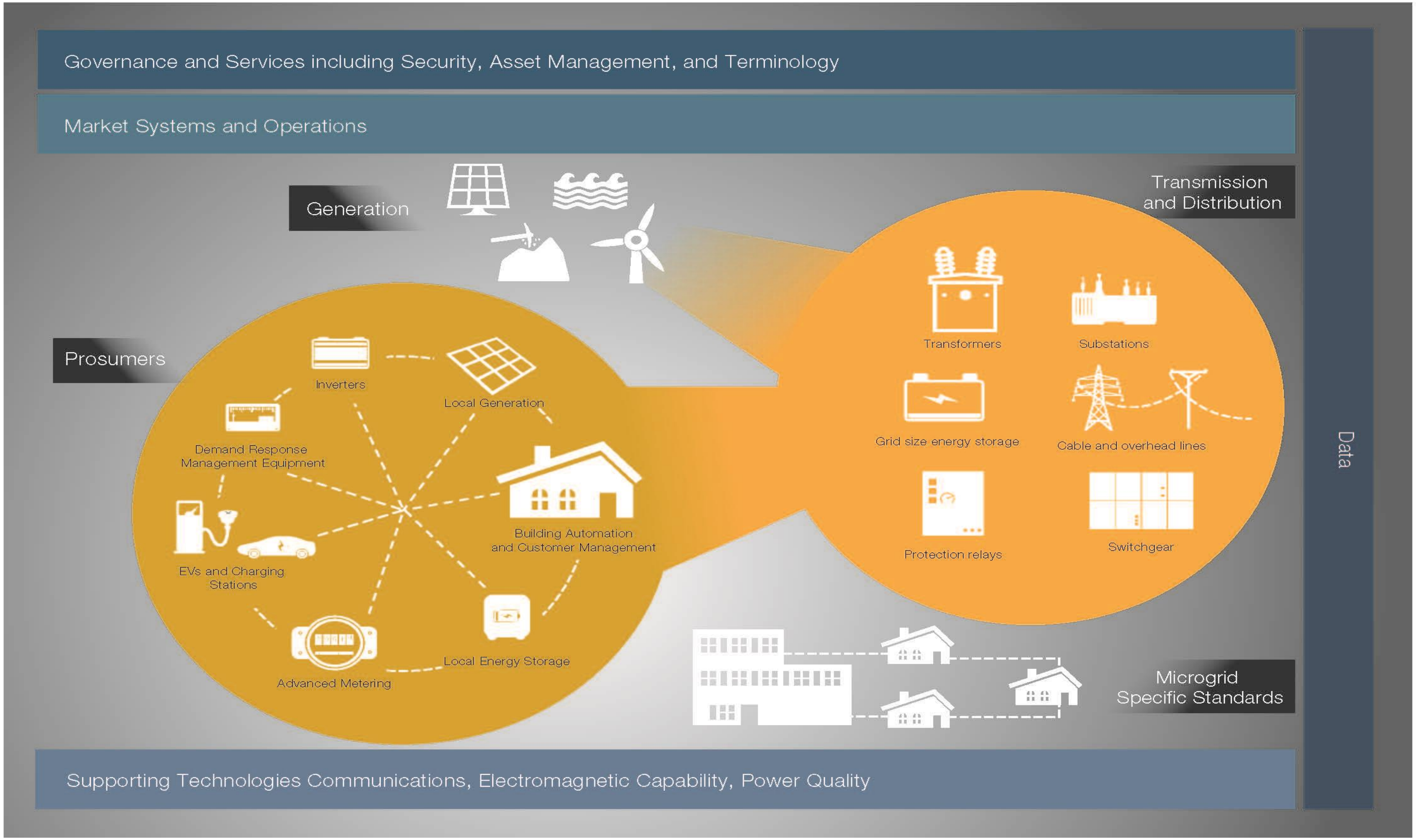
DATA

- Frameworks
- Privacy

STANDARDS Australia

Jessica Curtis, National Sector Manager

Standards and the Future of Distributed Electricity



Discussion paper

- Providing background information
- Asking for:
  - Feedback on information
  - Identification of problem areas
  - Urgent work needed
  - Timeline of priority work
  - Dependencies

What could be the unintended consequences of changes to the standards in each topic?

How might changes to the standards in each topic impact privacy or security? How should this be considered when creating or revising these documents?

The layout for each functional area is as follows:

Functional area	This is the overarching topic area we are asking for your feedback on	
Description	• How we have defined this topic area	
Sub Topics	• Where possibly unclear, a list of possible topics which may fall into this area • *If you identify any additional sub topics which could be considered a part of this area, please include this in your response.*	
Committees Operating in this Functional Area	**Standards Australia Committees**	**International Committees**
	• Relevant Standards Australia committees. (A) signals Active, (I) signals Inactive.	• Relevant IEC comimttees. • If they are mirrored by a relevant Australian committee, they will be in the same row. (P) signals Participating Australian relationship, (O) signals Observing Australian relationship. • If they are mirrored by an Australian committee which is not directly relevant to the topic area, that committee will not be shown.
	• Full list of mirror relationships, subcommittees and other details available in the Appendix. • *Australian Committees: Do you feel that the committees are operating well in managing this area, are appropriately representative, and are their areas of work/ functional scopes clear.* • *If you would like further information, including the nominating organisations which sit on them, you can find that on our Standards Development Public Portal: www.sdpp. standards.org.au* • *IEC Committees: We ask you to provide your input on Australian participation on these committees – if we are currently contributors, do you feel we are active enough? If not, should stakeholders consider proposing that Australia should mirror that committee?* • *If you would like further information on the IEC committees, the IEC's website provides work programs and scopes:www.iec.ch.*	
Australian Standards in this functional area	• Significant Australian or Australian/New Zealand specific standards which have been developed in this area, in addition to international standards which have been adopted here (either directly or modified for the Australian environment). • • *Are these standards current and appropriate? Do they allow for innovation?* • *Please also consider if there are any additional standards which should be considered in the topic area.*	
IEC Standards in this functional area	• Series of IEC standards which have been identified as being significant to this area. • *Has Australia adopted sufficient IEC standards in this area?* **Please also consider if there are any additional standards which should be considered in the topic area.**	

ELECTRICITY NETWORK TRANSFORMATION ROADMAP

2017-27

Mapping DER Services to Value

John Phillpotts, CSIRO

ena energy networks association

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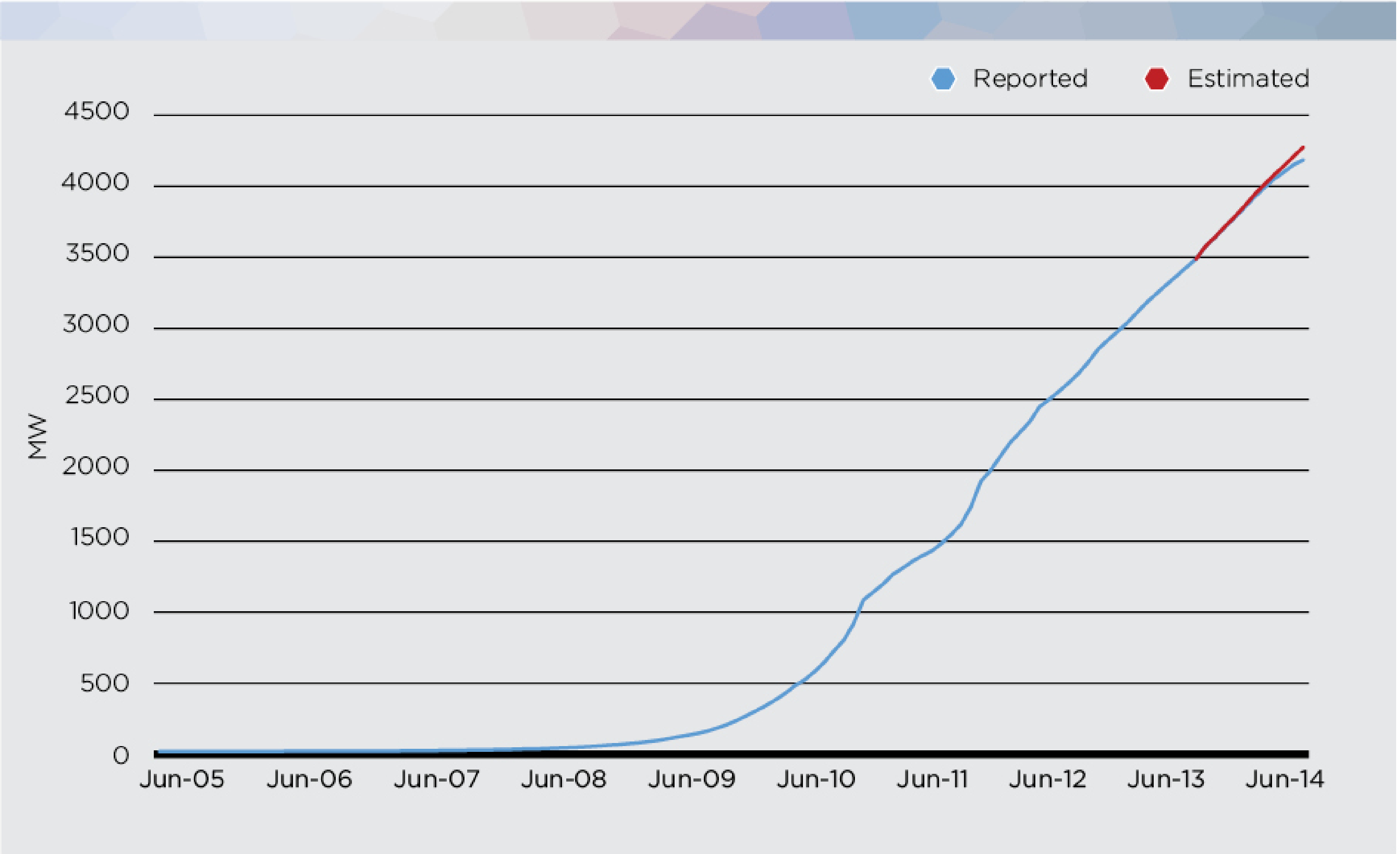
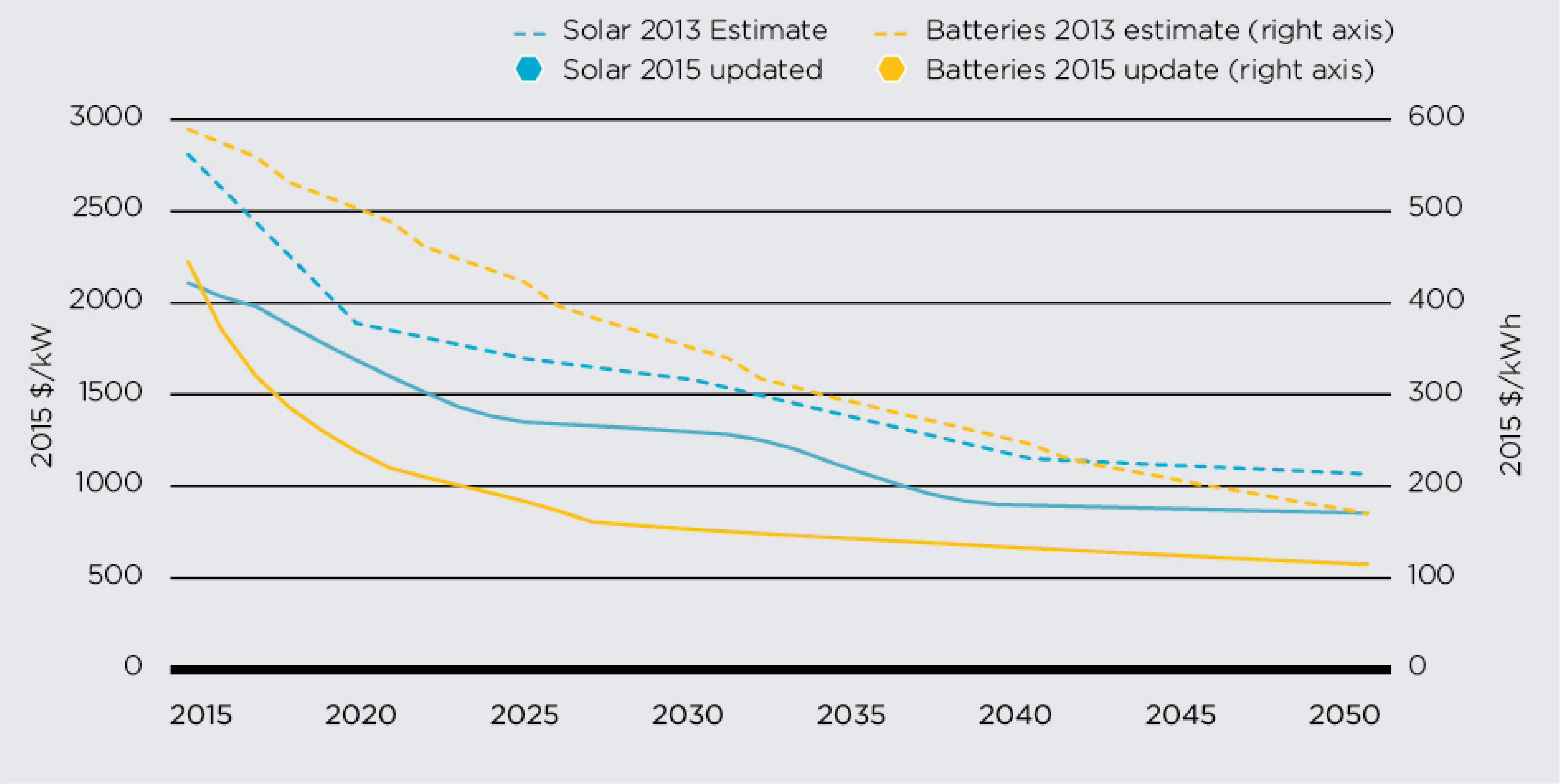
Customer needs and wants are changing:
National cumulative installation of Solar PV Panels



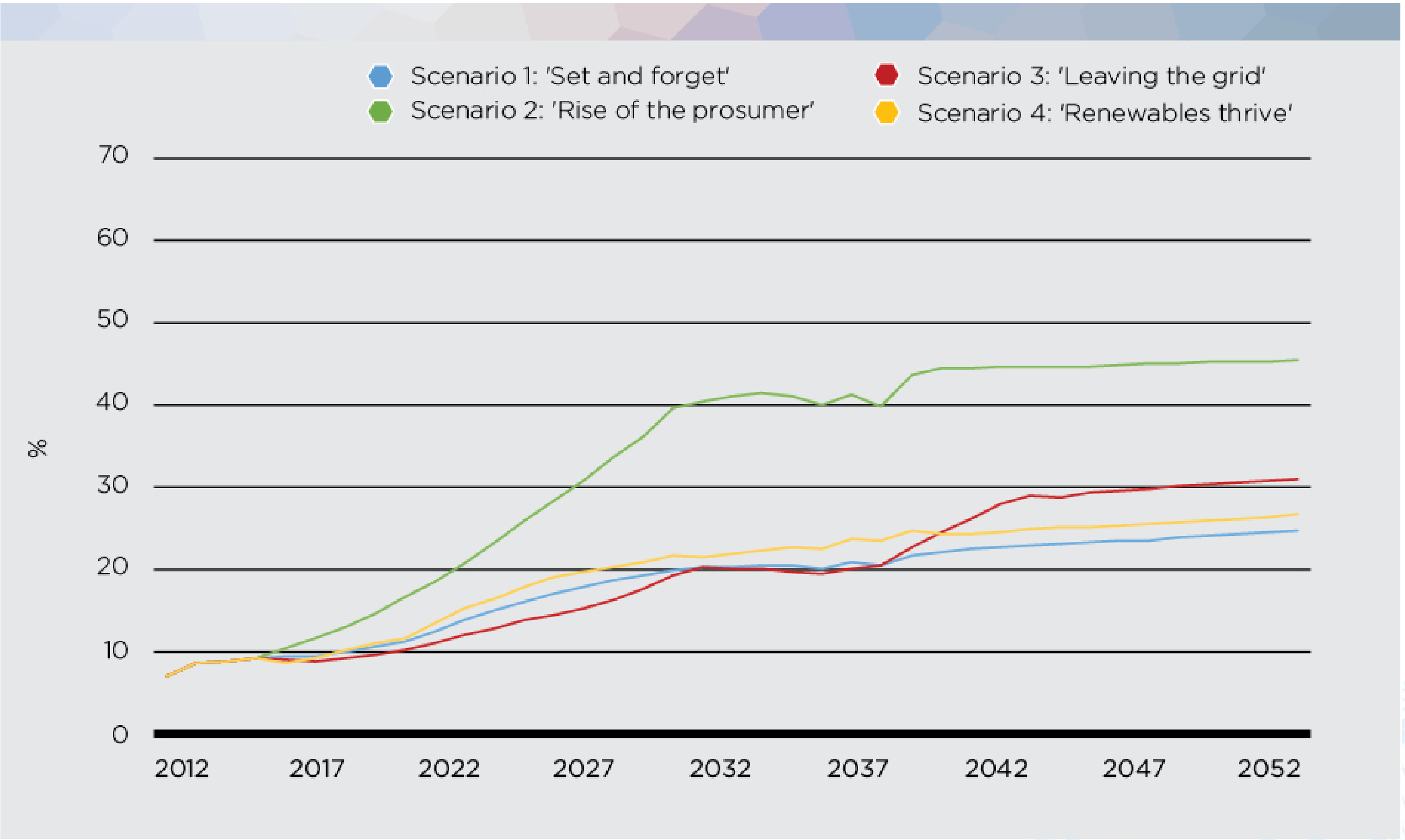
Source: Australian Photovoltaic Institute 2015.

Customer needs and wants will continue to change: High levels of solar panels and storage are *more* plausible

The key transformation drivers – competitive on-site generation and storage – have each strengthened their competitive position since 2013 by about 20%

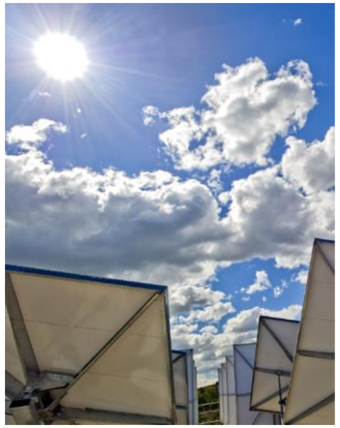


Customer needs and wants will drive industry (& grid) transformation: Changing customer Projected share of Distributed Generation (mostly rooftop Solar PV systems) by FGF scenarios



Distributed Energy Resources

Distributed RE Generation



Power Electronics

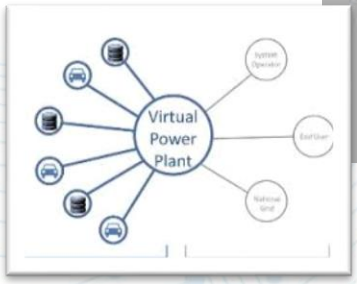
Energy Storage

Demand Management & Load Matching

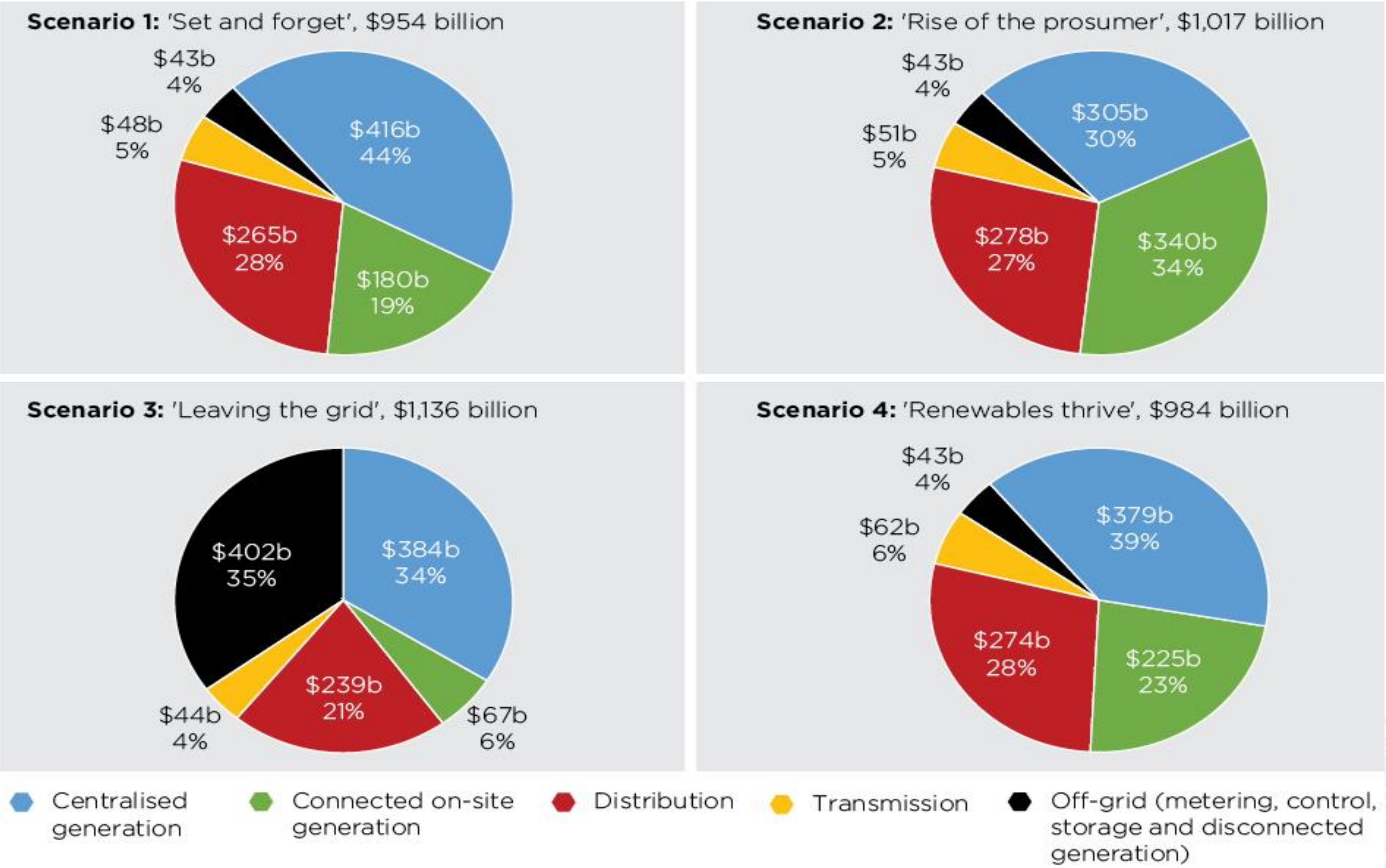
Distributed FF Generation

Electric Vehicles

Microgrids & Virtual Power Plants



Potential cumulative system expenditure outcomes



20th Century Grid Design Principles

- Generation is dispatchable
- No significant energy storage in the grid
- Power must be kept in balance
- Generation follows load
- Distribution can be treated as a passive load depending from Transmission
- Real power flows in one direction only in distribution
- Voltage, reactive power, and system frequency are regulated
- Designed for reliability, not economy

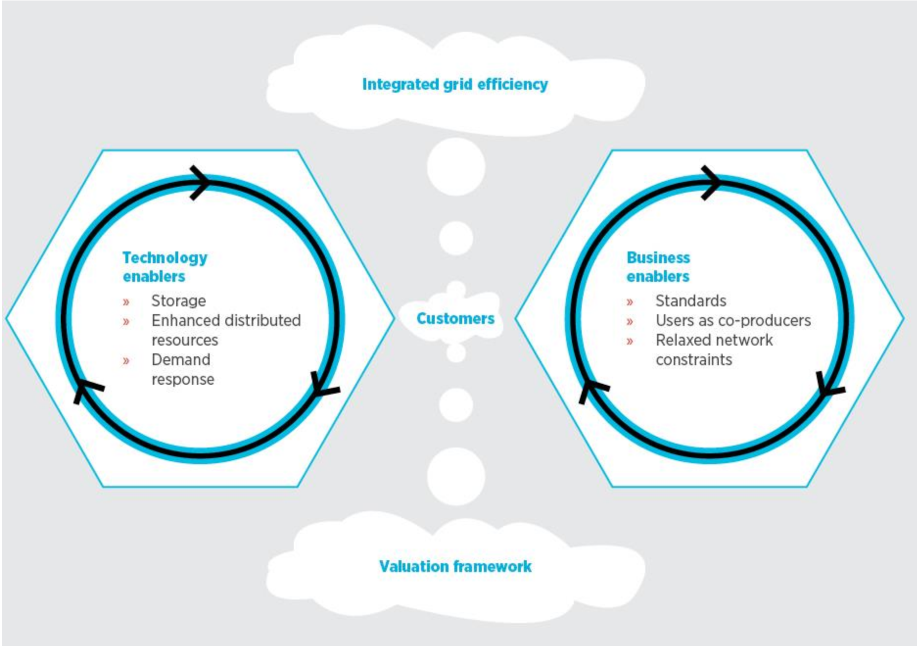
We are in the process of violating most of these principles!

Electricity Network Transformation Roadmap Interim Report (2015): Challenges and Opportunities of Distributed Energy Resources

Integration of Distributed Energy Resources requires a careful operational response to challenges such as voltage management, frequency regulation and network stability.

However, well-integrated DERs can also provide solutions for addressing these network challenges and improving network efficiency. This is likely to require:

- New regulatory frameworks;
- Enhanced standards; and
- Commercial responses which unlock the potential of energy storage, demand response services and power electronics solutions.



What is the ‘value’ of the distribution grid with high DER and greater system decentralisation?

To understand potential value of DER for the system, need to first consider the value of the system first.

Trends in ‘economics of defection’ plus growing desire for ‘independence’ raise this question – why stay connected?

- Current electricity networks evolved from local microgrids to capture value of diversity and economies of scale, which remain relevant
- Value of multi-directional, transactive network increases in proportion to the number of interconnected entities / facilities
- How can grid evolution build upon the value of the current grid to capture the potential network benefits seen in other sectors?

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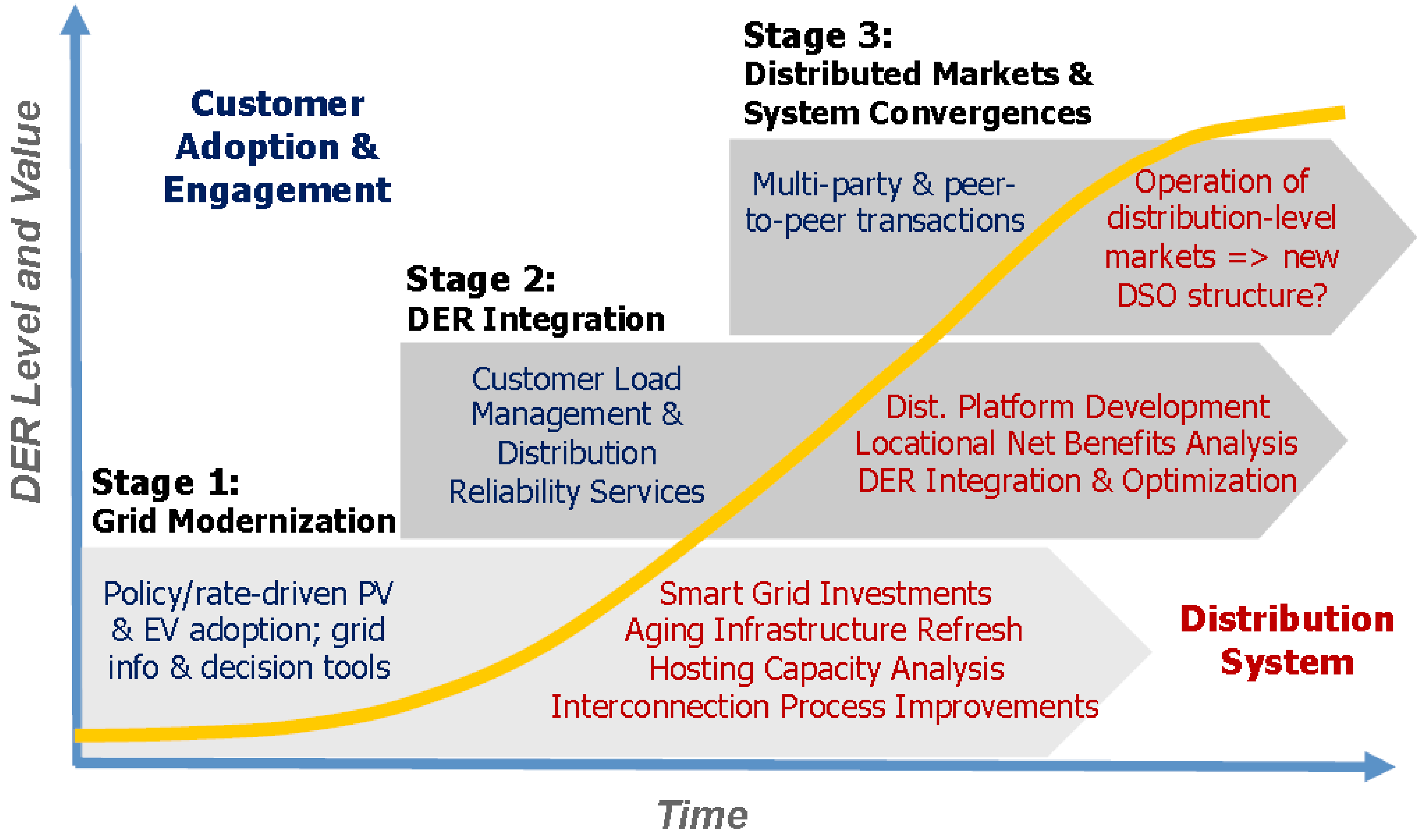
Customer & Distribution Grid Evolution



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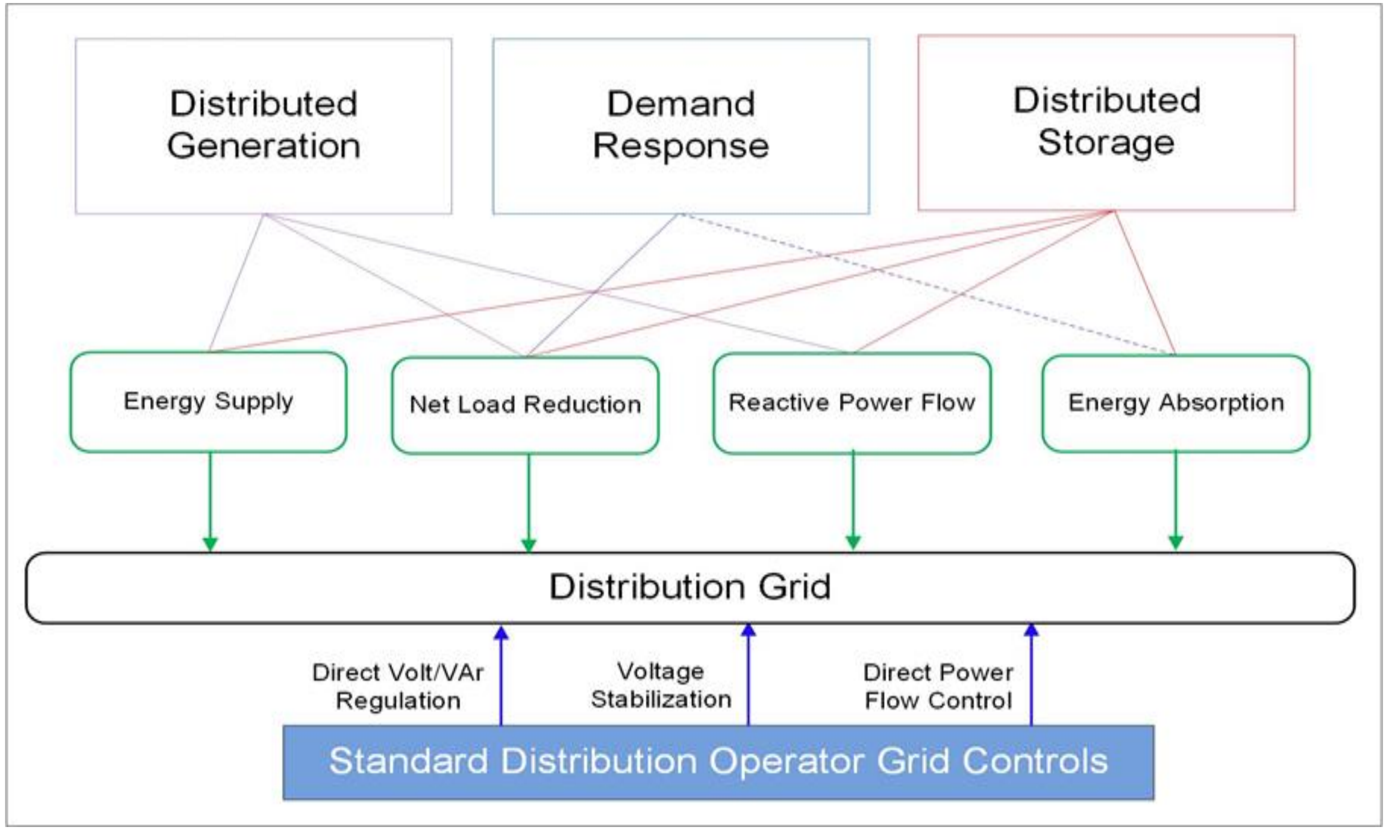
The Mixed DER Coordination Challenge

- Functional capabilities overlap for some DER
- Not all DER perform the same way
- How should mixed DER be allocated/dispatched?



Courtesy of: Jeffrey D. Taft, PhD, Chief Architect for Electric Grid Transformation
Pacific Northwest National Laboratory

Pacific Northwest NATIONAL LABORATORY

Core Electric Products – Examples

		Energy	Reactive Power	Reserves
	Demand Response	★		★
 	Distributed Generation	★	★	★
 	Distributed Storage	★	★	★

Mapping DER Services to Value

Table 1. Technical Ability of DER Technologies to Provide Core Electric Products

Market Product		Demand Response	Photo voltaic	DG (fossil)	EV Charging	Storage
DA Energy	Delivered		Today	Today		Today
	Reduced (DR)	Future	Today	Today	Future	Today
	Time Shifted	implicit		Today	implicit	Today
RT Energy	Delivered		Today	Today	Future	Today
	Reduced	Today	Today	Today	Future	Today
	Time Shifted	implicit			implicit	Today
Wholesale Ancillary Services	Spinning Reserve	Future		Future	Future	Future
	Frequency Regulation (traditional)	future reg down only		Today	Future	Today
	Black Start		Future	Today		Future
Reactive Power	Var Support		with advanced inverters	with advanced controls	future with advanced inverters	Future with advanced inverters
	Voltage Control		with advanced inverters	with advanced controls	future with advanced inverters	
Reserves	Up			Today		Future but requires charge state held aside
	Down (DR)	Today		Today		

Locational Net Value of DER

Requires alignment of several planning processes inside & outside utility

	Value Component
Wholesale	Bulk Power System Benefits
	System Energy Price
	Wholesale Energy
	Resource Adequacy
	Flexible Capacity
	Wholesale Ancillary Services
	RPS Generation & Interconnection Costs
	Transmission Capacity
	Transmission Congestion + Losses
	Wholesale Market Charges
Distribution	Subtransmission, Substation & Feeder Capacity
	Distribution Losses
	Distribution Power Quality + Reactive Power
	Distribution Reliability + Resiliency
	Distribution Safety
Customer & Societal	Customer Choice
	Emissions (CO_2, Criteria Pollutants & Health Impacts)
	Energy Security
	Water & Land Use
	Economic Impact

Table source: More Than Smart

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ELECTRICITY NETWORK TRANSFORMATION ROADMAP 2017-27

Future Grid Purpose & Characteristics

Stuart Johnstone, ENA

ena energy networks association

CSIRO

Challenges facing the Networks

- Significant changes: more distributed and more complex devices & services

- Many are ‘cross-system’ from Transmission to Distribution and to Consumers and their devices

- We should expect a rising tide of sensors, data, automation & intelligence

- Seamless, interoperable and secure operation is essential – no interference or system crashes

- Technical governance today is not directed to ensuring ’whole-system’ integration, with 3rd parties

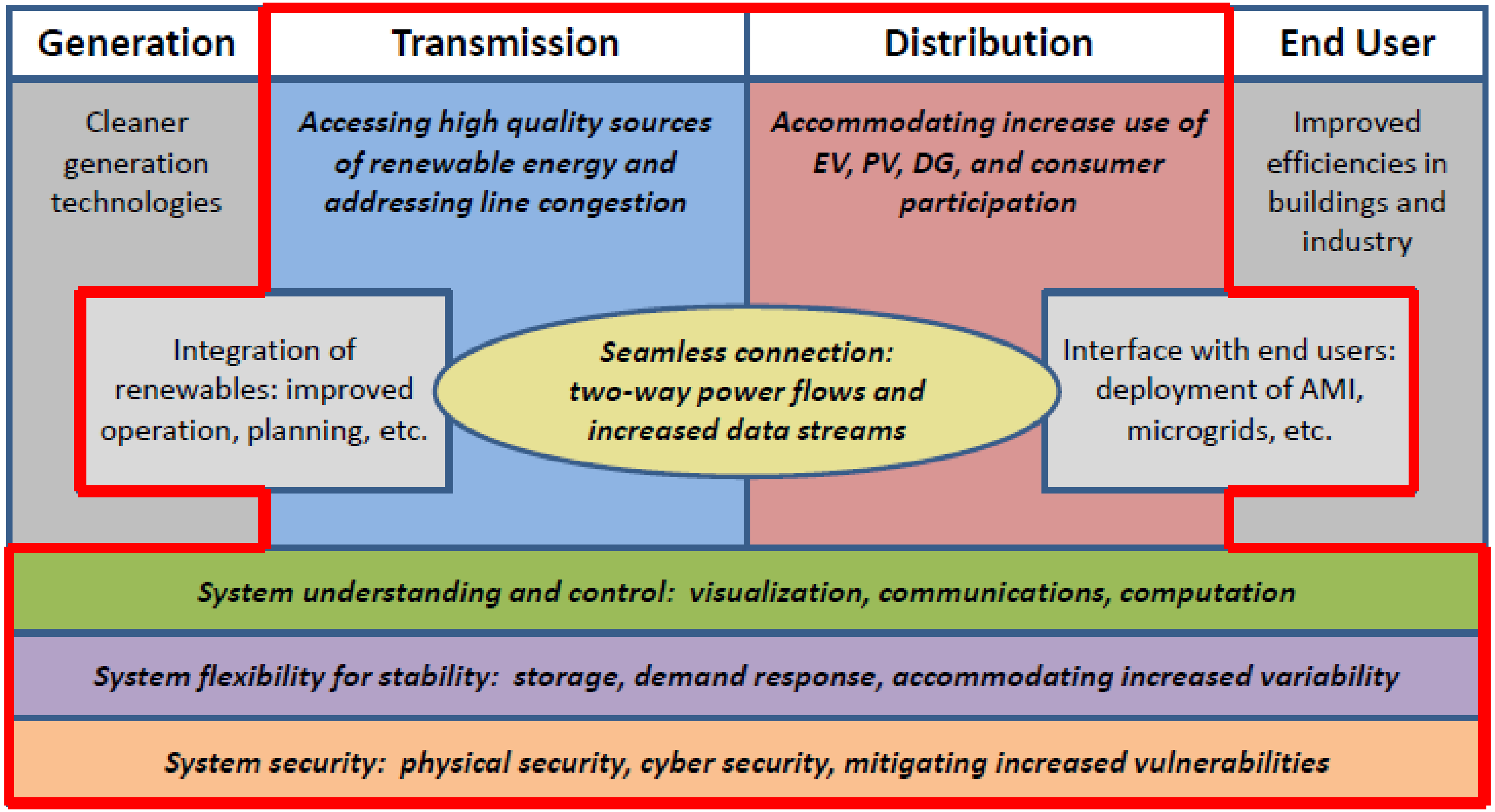
If Challenges not met - System Failure???

Vision for the Grid of the future will need to address multiple Goals

Enable a seamless, cost-effective electricity system, from generation to end use, capable of meeting the clean energy demands and capacity requirements of this century, while allowing consumer participation and electricity use as desired:

- Significant scale-up of Clean Energy
- Allows 100% customer participation and choice (including distributed generation, demand-side management, electrification of transportation, and energy efficiency)
- A 100% holistically designed system (including potential AC-DC hybrid configurations)
- Competitiveness and value creation
- A reliable, secure, and resilient Grid

Priority Needs and Focus



Note: There are institutional issues/solutions that must be considered in conjunction with these technology needs.

Renewable Integration

What is the challenge?

- Variable renewables and their impacts on planning and operations
- Impact of renewables (PV) on the distribution system
- Deliver from DER locations to load (transmission)

Where are we today?

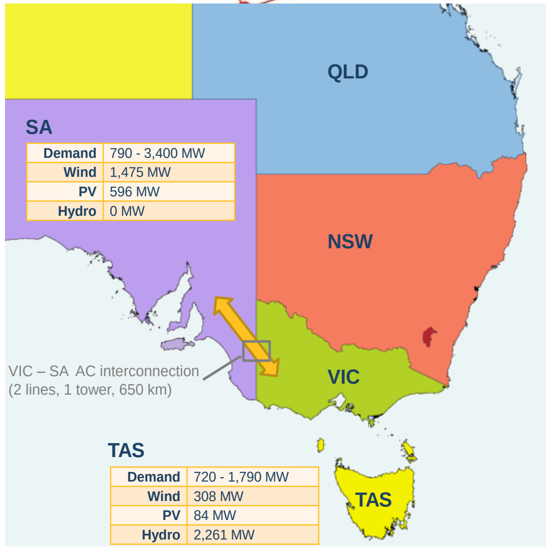
- Traditional generation is being displaced by renewable energy, not only at the utility scale but also at the residential level.
- In South Australia over 45% of the 4,300 MW installed capacity is from wind and rooftop photovoltaic (PV) plant. This is accompanied by loss of brown coal fired generation.

Need for collaboration?

- Regional transmission & distribution planning
- New algorithms to support advanced modelling; Dynamic analysis
- Tool development (situational awareness, forecasting, storage)
- Higher penetration integration studies
- Market design analysis

Where are we going?

- Increasing penetration rate of variable generation – 50%... 80%... 100%?
- Seamlessly integrated DG, EVs, DR
- Resource-focused planning
- Allow better customer participation, choice and value



QLD

Demand	3,940 - 8,900 MW
Wind	0 MW
PV	1,336 MW
Hydro	652 MW

NSW

Demand	5,160 - 14,740 MW
Wind	649 MW
PV	1,035 MW
Hydro	2,650 MW

VIC

Demand	3,600 - 10,580 MW
Wind	1,168 MW
PV	759 MW
Hydro	2,237 MW

NEM total

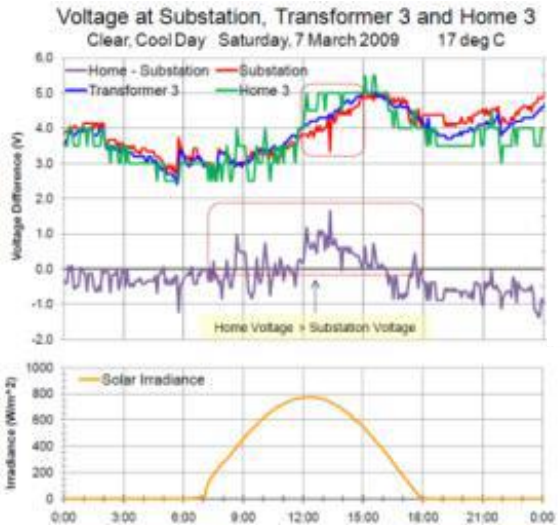
Demand	15 GW – 30 GW
Wind	3,600 MW
PV	3,810 MW
Hydro	7,800 MW

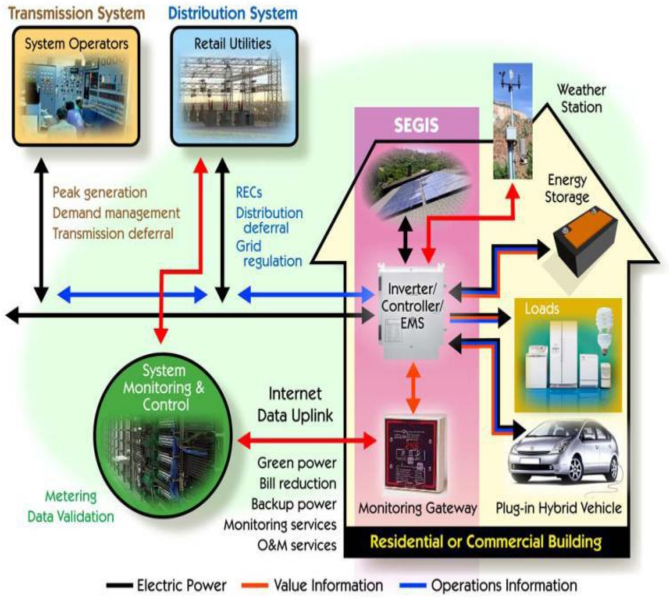
Installed capacity in the NEM

Source: AEMO

Renewable Integration - Considerations

- Integration studies
- Power system modelling tools
- Transmission utilisation analysis
- Active power controls development
- Reserves analysis





Smart Grid

What is the challenge?

- Implement two way communication to inform consumers and grid operators
- Integrate PEVs, DER and DR while better managing load
- Improve electric system efficiency and reliability

Where are we today?

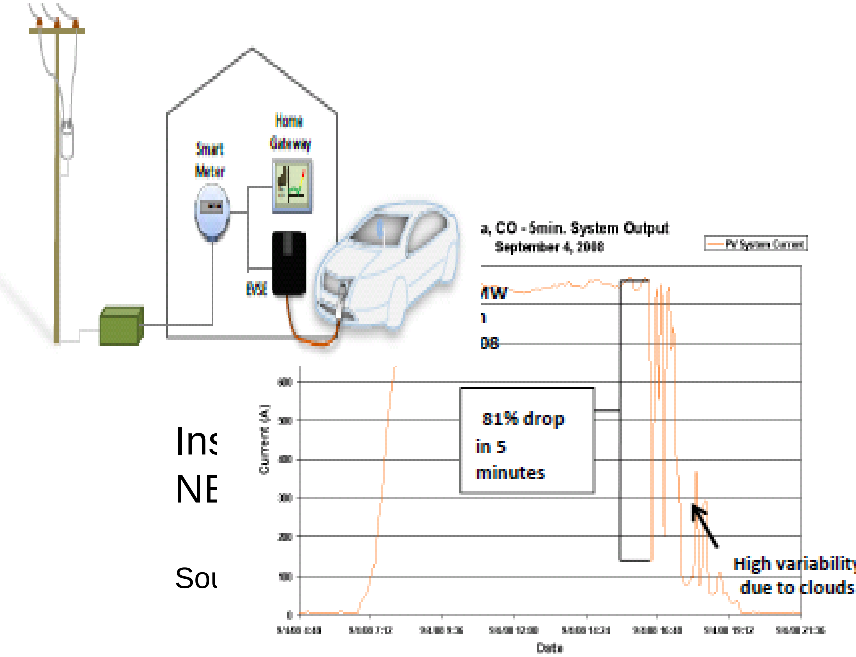
- Increasing penetration of intermittent renewables and DR into T&D, emerging PEVs with aggressive penetration targets

Need for collaboration?

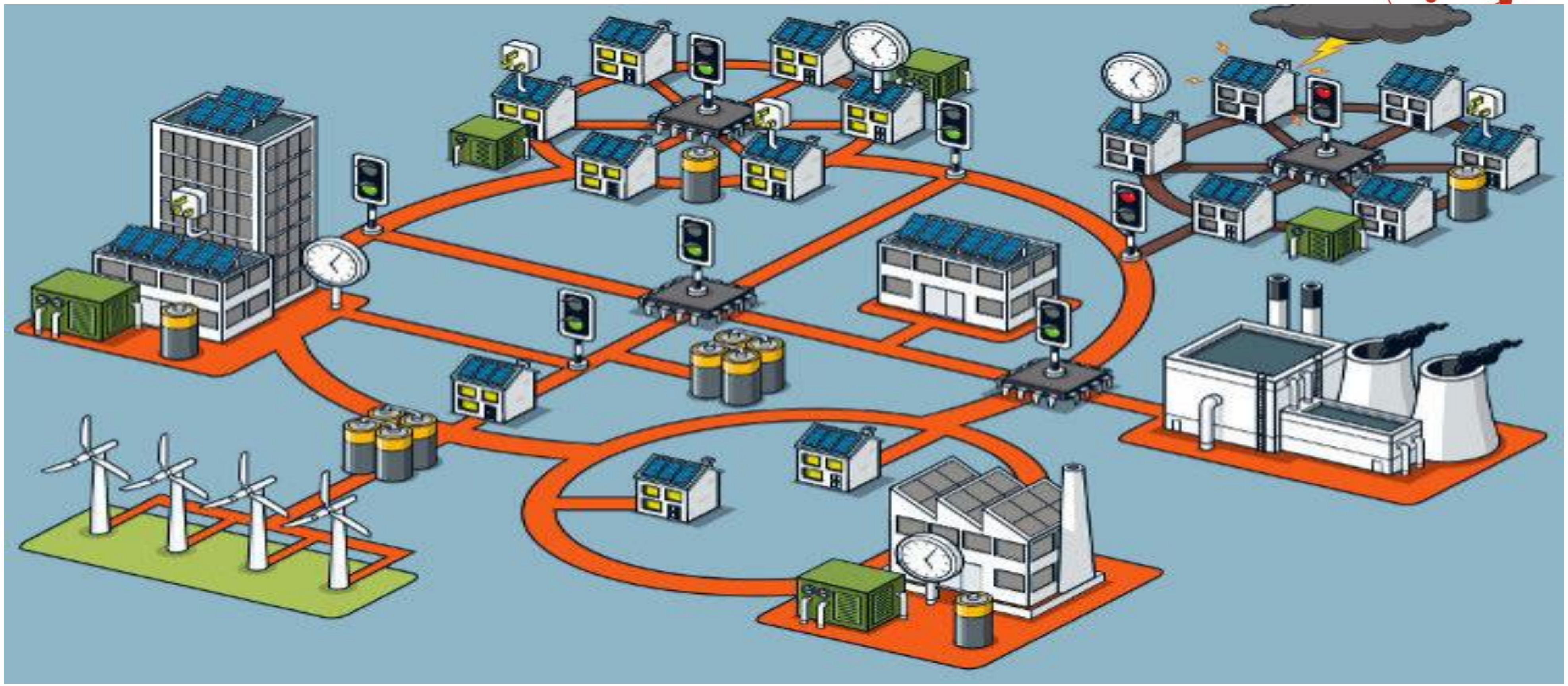
- Protection coordination of multiple DER operations
- R&D in power electronics, energy storage, smart PEV charging, and system integration
- Multi-objective microgrid
- Hybrid AC/DC structure????
- Standards

Where are we going?

- Distribution automation
- Expanded integration of DER/DR/PEV
- Cost-effective microgrid development
- Integrated T&D modelling and analysis
- IEEE standards implementation



Future Smart Grid?



Advanced Modeling

What is the challenge?

- Future generation resource mix unknown and load profiles uncertain
- Breadth and depth of “smart grid” data (data overwhelm); vulnerabilities continually emerging
- Boundary seams (planning, modelling, and operations) critical for effective integration with legacy systems

Where are we today?

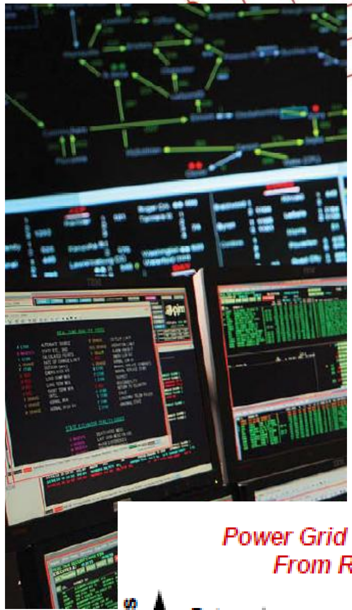
- Real-time system monitoring by operators is supported by offline engineering analysis (high latency)
- Operator trying to make control decisions, especially quickly during a disturbance, based on incomplete data
- Inconsistencies in planning and operations assumptions/models

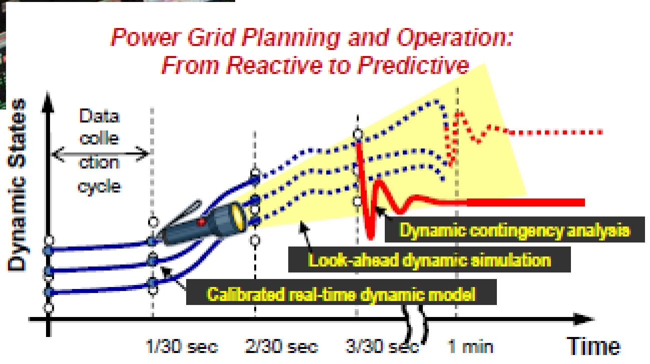
Need for collaboration?

- Strategic modelling approach for the holistic understanding and design of a complex system of grid systems
- New algorithms, techniques, and computational approaches
- Validation and verification of tools, techniques and models on actual power system problems (and data)

Where are we going?

- New models, planning, and operational tools that are well integrated and used by industry for real-time system control
- Improved flexibility and reliability through better system understanding
- Address a variety of market structures; increased engagement (services and roles)





Cyber Security

What is the challenge?

- Reliable energy delivery depends on cyber-security in the modernised energy sector's complex communication architectures that transmit real-time data and information for operations
- Increasingly sophisticated cyber-threats directly target the energy sector

Where are we today?

- Cyber-resilience of DER devices varies
- Some entities have sophisticated capabilities to detect, prevent and respond to cyber-incidents but still evolving in complex IT landscape
- Cyber security standards are still evolving

Need for collaboration?

- All energy sector stakeholders, public and private sector, must actively engage
- Accelerate frontier cyber-research into real-world energy sector operations
- Stay ahead of emerging threats, vulnerabilities and consequences
- Interoperable cyber security standards

Where are we going?

- Resilient energy delivery systems are designed, installed, operated and maintained to survive a cyber incident while sustaining critical functions.

Energy Storage

What is the challenge?

- Costs of energy storage systems
  - Cost/Benefit ratio too low
- Lack of data for projects
  - Questions about reliability
- Utilities are generally conservative
- Regulatory treatment of energy storage

Where are we today?

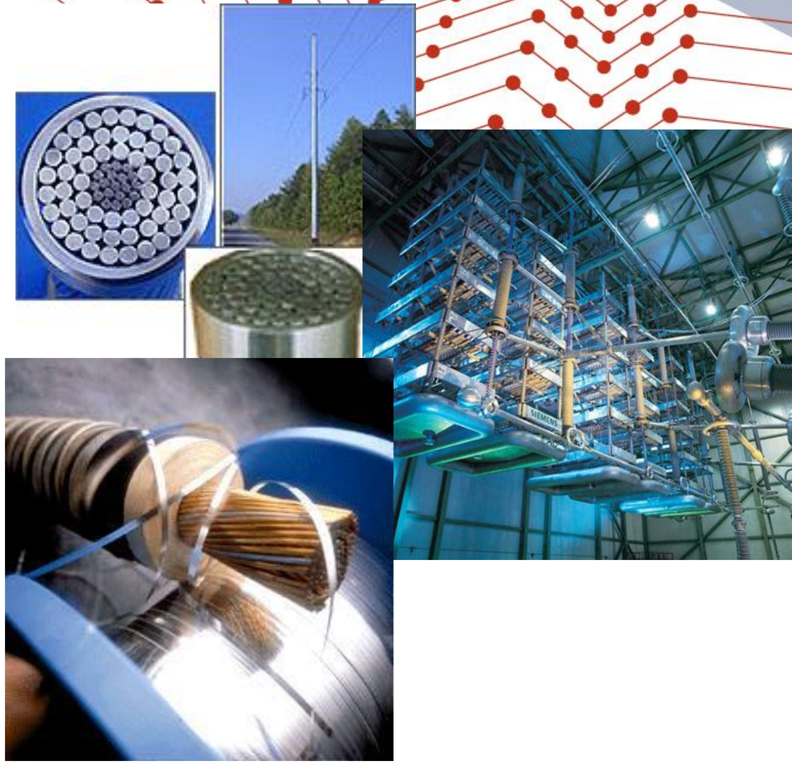
- Energy storage is still in infancy in Australia, however new technology being developed and adopted – advanced batteries, Tesla power wall, flow batteries, flywheels

Need for collaboration?

- Complementary approaches needed to accelerate breakthroughs
  - Basic electrochemistry
  - Device development
  - Bench and field testing of systems
  - Standards

Where are we going?

- Reduced grid storage costs
- Develop multiple commercial technologies for multiple applications
- Develop new materials and technologies to revolutionise energy storage
- Develop value proposition for storage applications



- What analysis should we do to support industry?
- What balance of research, device development, and field testing is appropriate?
- How can we work more closely with industry to bring energy storage to deployment?

Power Electronics/Materials

What is the challenge?

- Increased need for energy conversion and power flow control
- Capabilities for efficient, long-distance or off-shore energy transfers
- Materials, devices, and systems that can handle high power and extreme operating conditions

Where are we today?

- The material backbone of the electricity delivery system hasn't changed
- R&D in wide band gap semiconductors have shown improved performance over silicon

Need for collaboration?

- Understanding fundamental material properties and novel functionalities
- Reducing the costs of wide band gap semiconductors and the associated devices and systems
- Identifying new applications for novel materials
- Standards

Where are we going?

- High-performance, cost-effective power electronic systems
- Materials for self-healing, embedded sensing, and dynamic reconfigurations
- Enhanced material properties for insulators, conductors, magnetics, etc.
- Standards

- Will power electronics be a critical asset to manage a more asynchronous grid with higher penetrations of variable renewables?
- What functionalities or material properties are desired for the future grid?

Comparison

EXISTING GRID	Future GRID
Electromechanical	Digital
One way communication	Two way communication
Centralized Generation	Distributed Generation
Few Sensors	Sensors Throughout
Manual monitoring	Self monitoring
Manual Restoration	Self Healing
Failures & Blackouts are possible	No Blackouts

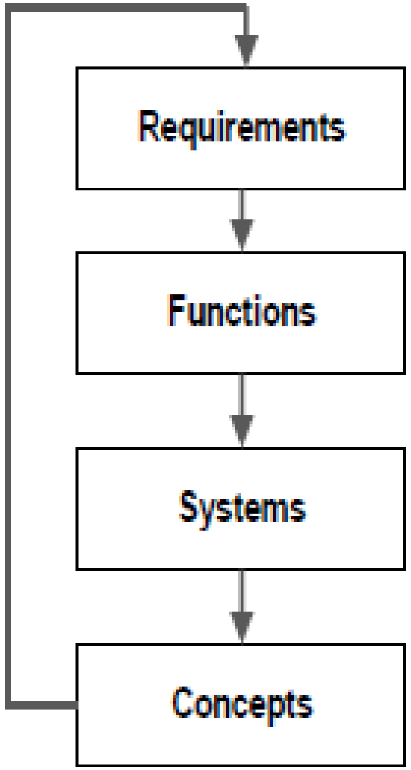
Summary of Future Grid Requirements

- **Grid operations will be increasingly complex.** Large penetrations of distributed generation will significantly increase the complexity of grid operations.
- **The grid will leverage two-way power flows across the system,** and greater visibility and predictability will be needed from transmission down to the end device. Information will be exchanged in near real time with low latency. Tools and software will exist that enable the grid to operate in an optimised cost environment with more distributed assets.
- **There will be more interaction between the distribution and transmission systems.** Operations will blur and information will be exchanged between the two systems in near real time, with more integrated coordination between the two. The vertical exchange of information will be automated, enabled, optimised, and regulated by the development of interface standards.
- **The integration and synchronisation of distributed generation and microgrids** will become key components of distribution system operations. Seamless transitions and interfaces will be needed.

Summary of Future Grid Requirements

- **Operations will be more predictive rather than reactive**. Increased data—measured and verified with greater granularity—will provide more insight into the behaviour of the grid. This will support the forecasting of both energy production and energy demand.
- **A shift will occur away from traditional inertial energy storage and toward new battery/energy storage technologies.**
- **Changing customer behaviour**, values and service requirements will continue to change.
- **The grid will operate as a centralised-decentralised hybrid, and the distribution system may be the heart of the future grid**. Central generation and microgrids/distributed generation will complement each other. The grid will feature decentralised control and operational “brains” (distributed intelligence) scattered along the system. Utilities will play the coordination role in the decentralised grid.
- **There will be vertical-horizontal integration**. Operations within an organization’s/utility’s (vertical) domain are expected to collaborate with other (horizontal) entities that also interact with the grid (e.g., microgrids).

Questions to Consider



- What issues and challenges does the existing system face?
- What do the multiple system stakeholders require from the system?

- What functions must be provided in the system to meet the requirements?
- What services can be provided by stakeholders?
- What measures of performance are relevant?

- What infrastructure or systems are needed to deliver the functions?
- What data exchange, interface and interoperability provisions are needed?

- How can the overall system be configured to best meet the requirements?
- What is needed to ensure an integrated system?
- How can the requirements be best satisfied?

ELECTRICITY NETWORK TRANSFORMATION ROADMAP 2017-27

Energex reflections on services customers may demand in a High-DER Future

Peter Price, Energex

energy networks association

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What I'll cover

- Customer Context
- Insights into DER in SEQ
- Next steps in the Energex Operational Technology Roadmap
- Questions to be addressed

EXISTING GRID	Future GRID
Electromechanical	Digital
One way communication	Two way communication
Centralized Generation	Distributed Generation
Few Sensors	Sensors Throughout
Manual monitoring	Self monitoring
Manual Restoration	Self Healing
Failures & Blackouts are possible	No Blackouts

What's missing?

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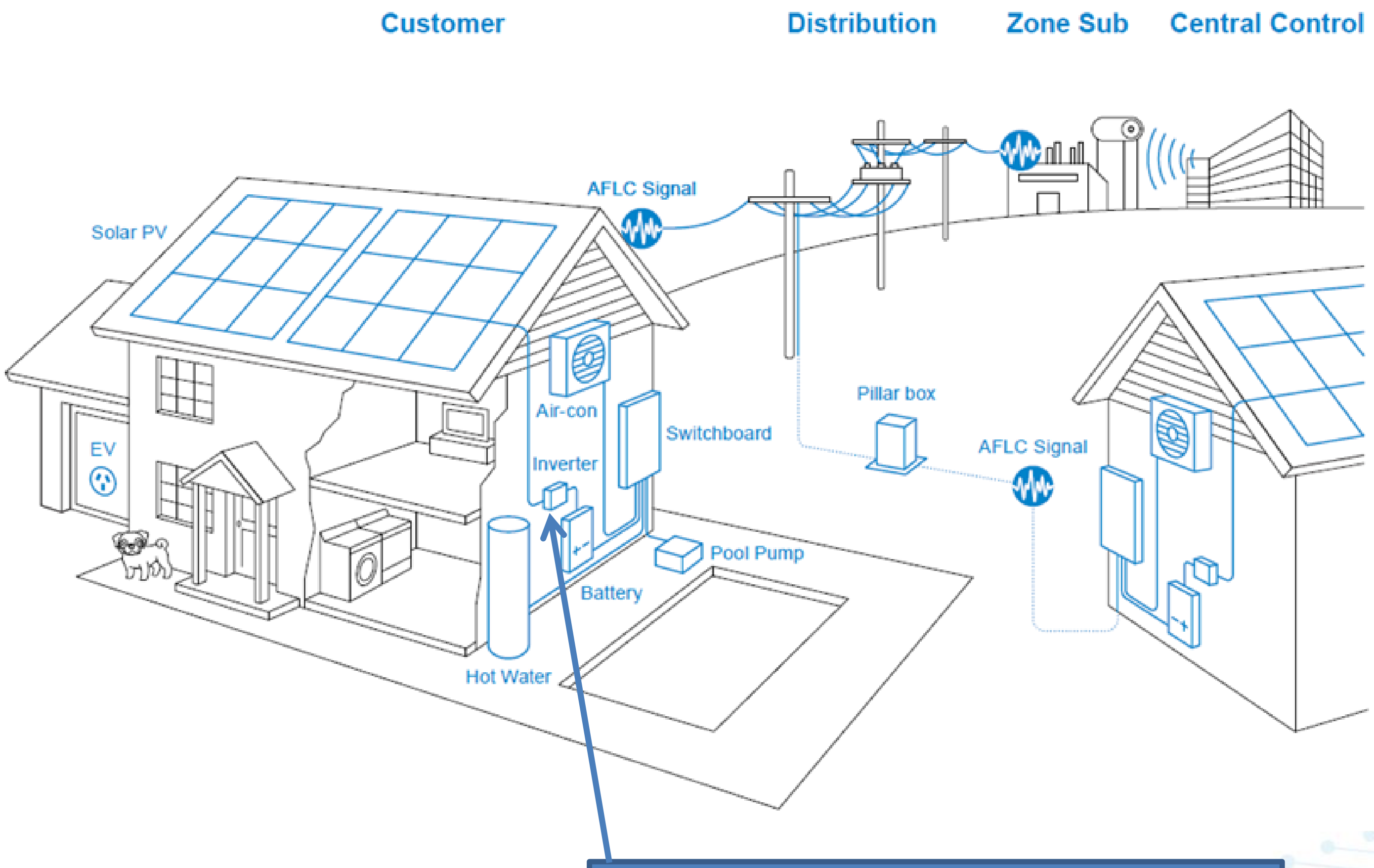
energex positive energy

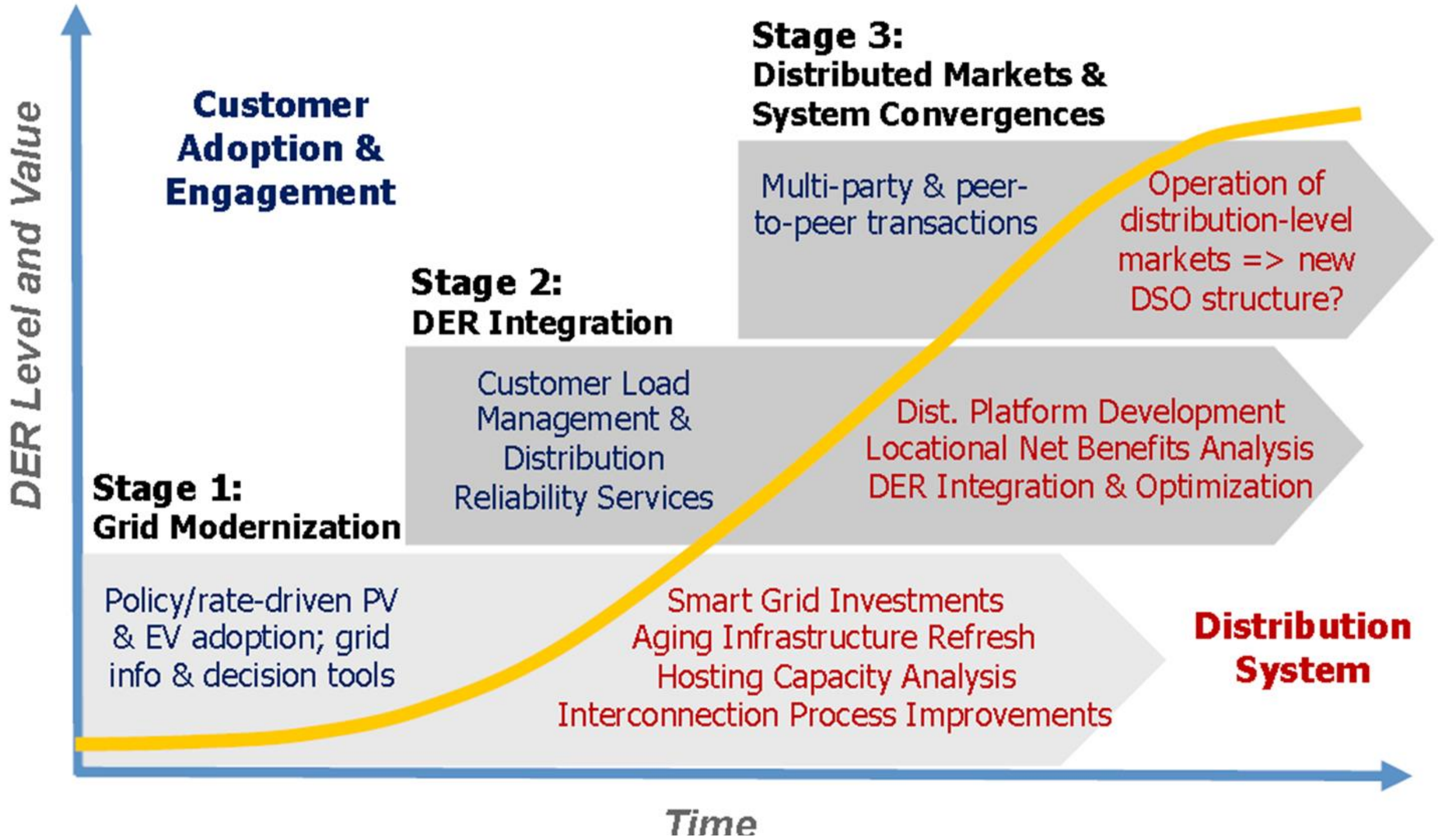
The Customer Must be the Focus for DSO of 2027



HEMS are here now

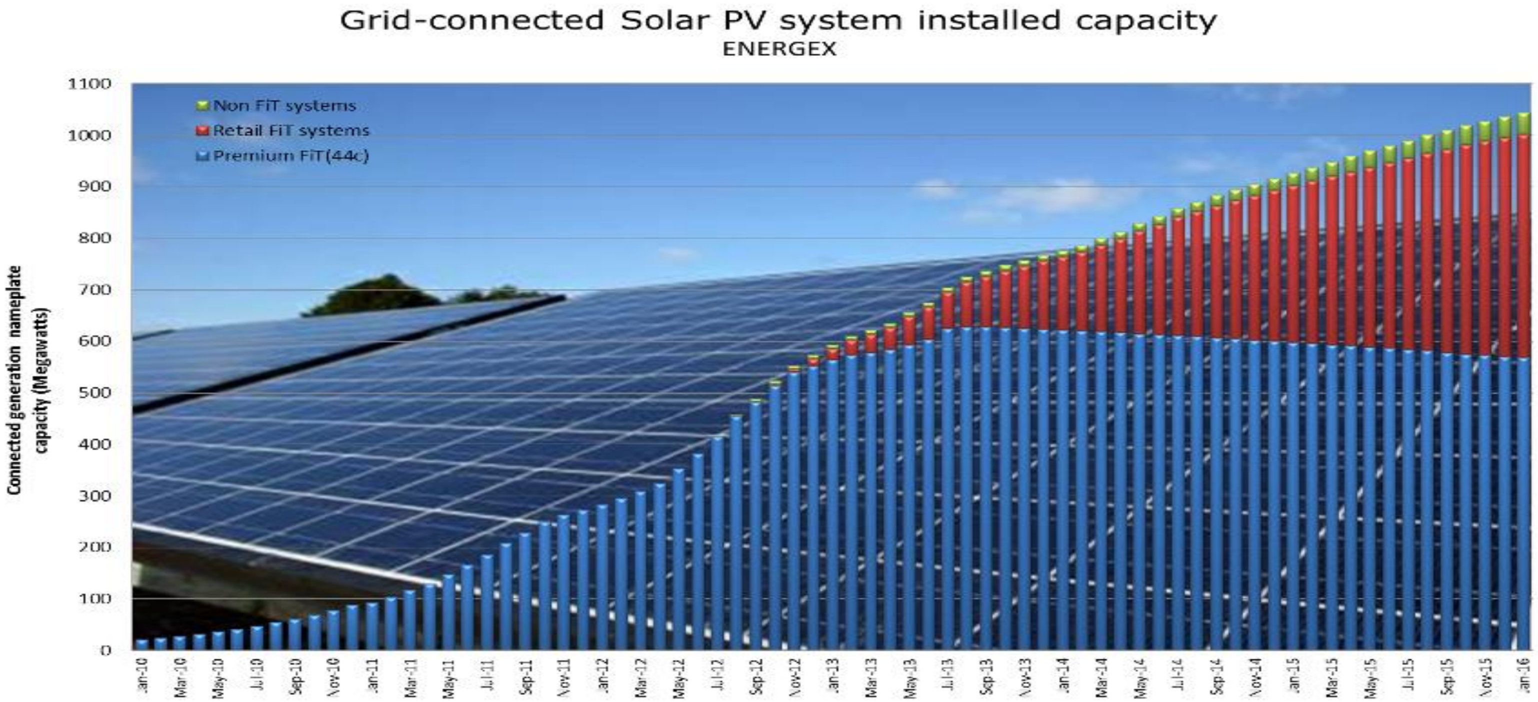
The DSO will provide the market mechanisms needed to empower consumers, prosumers, and DERs to optimize system operation, offer and exchange DER energy services, and achieve an integrated grid
https://prosumergrid.com/project/dso/

As customers increasingly embrace distribution system operation must evolve

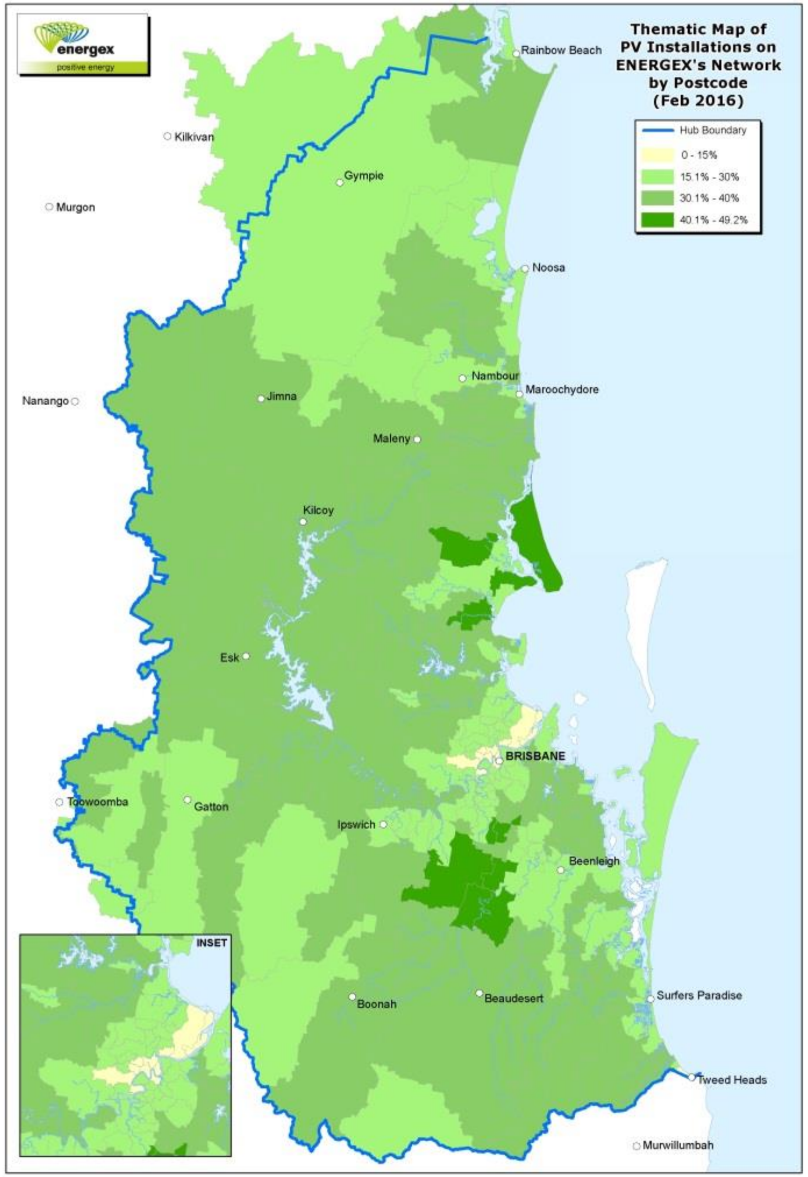


Future Electric Utility Regulation / Report No. 2

Customers continue to install rooftop PV



~1100MW on installed domestic PV capacity in a ~5000MW network. In some postcodes >40% of customers have PV. Total energy delivered is ~ 7% (1438GWh) of total

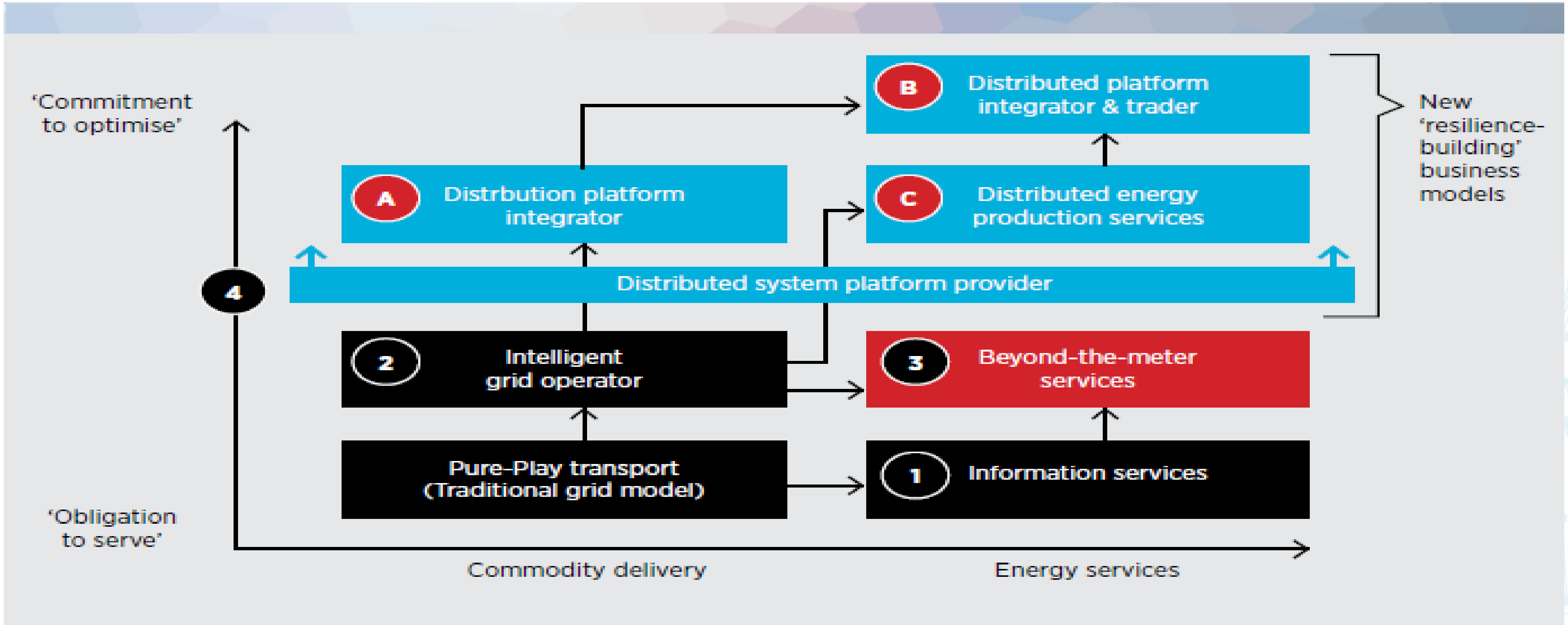


1 Million Solar Homes or 3GW of PV

15 megawatt (MW) solar farm

~700kW solar matched to building load

Optimal Grid Operation in a High DER Future will require new approaches to system operation – a new technology platform



Source: Accenture 2015, *Network business model evolution: an investigation of the impact of current trends on DNSP business model evolution*, Accenture, Melbourne, p. 12.

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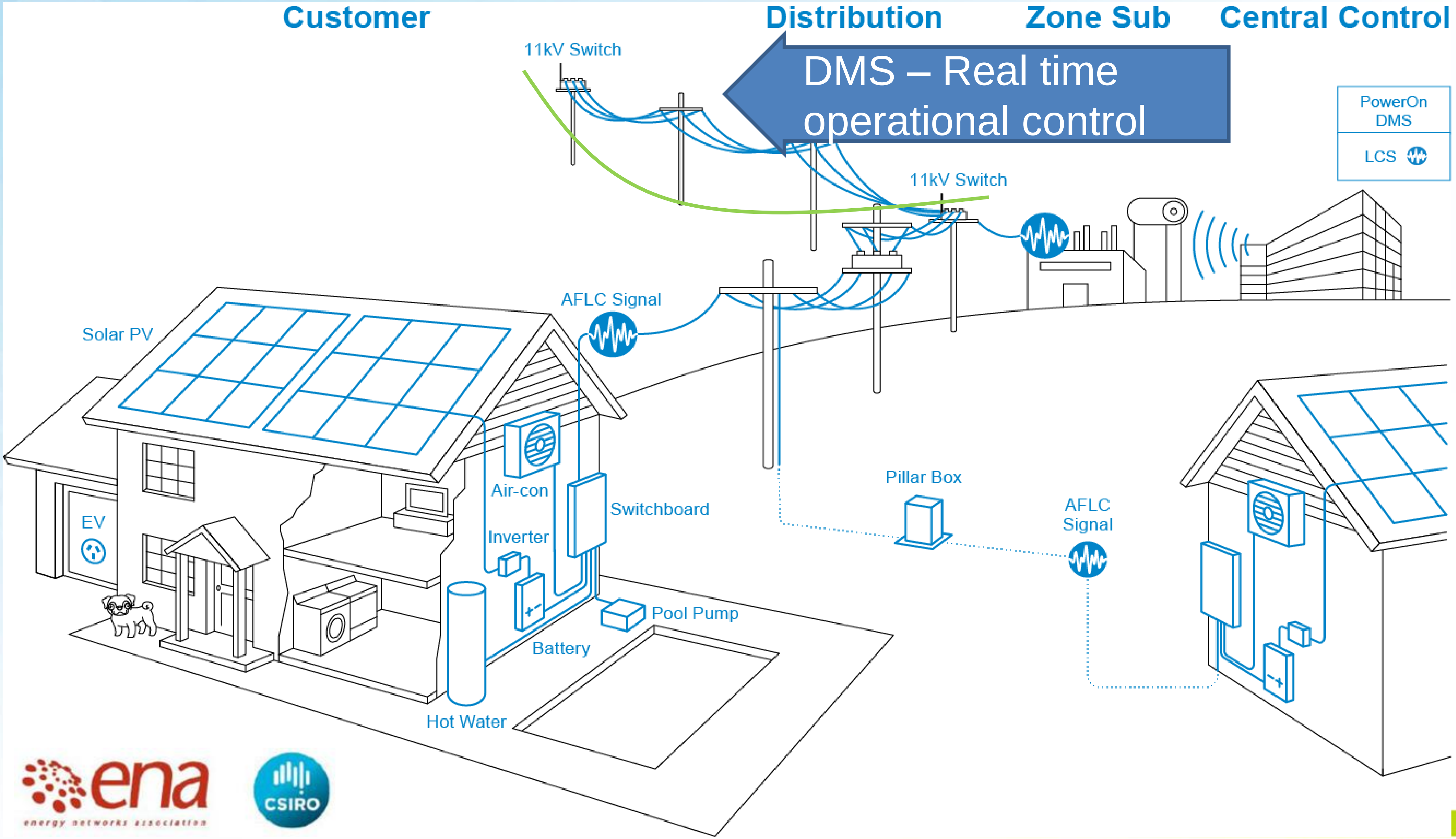
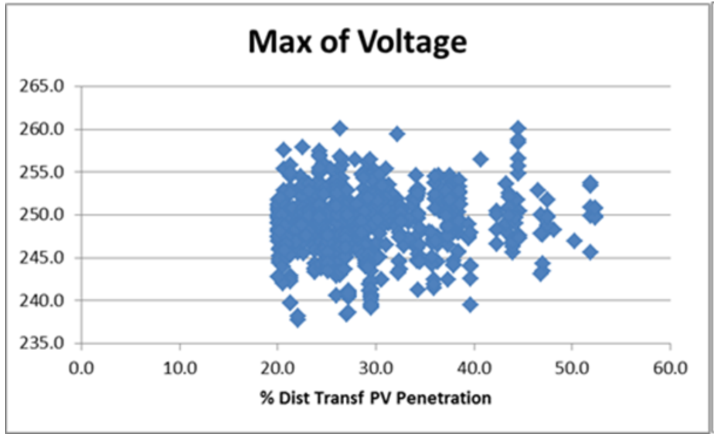
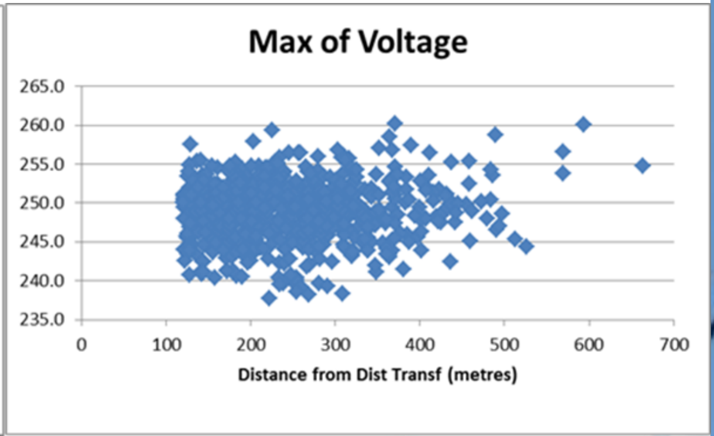
Next iteration of the Energex Smart Grid



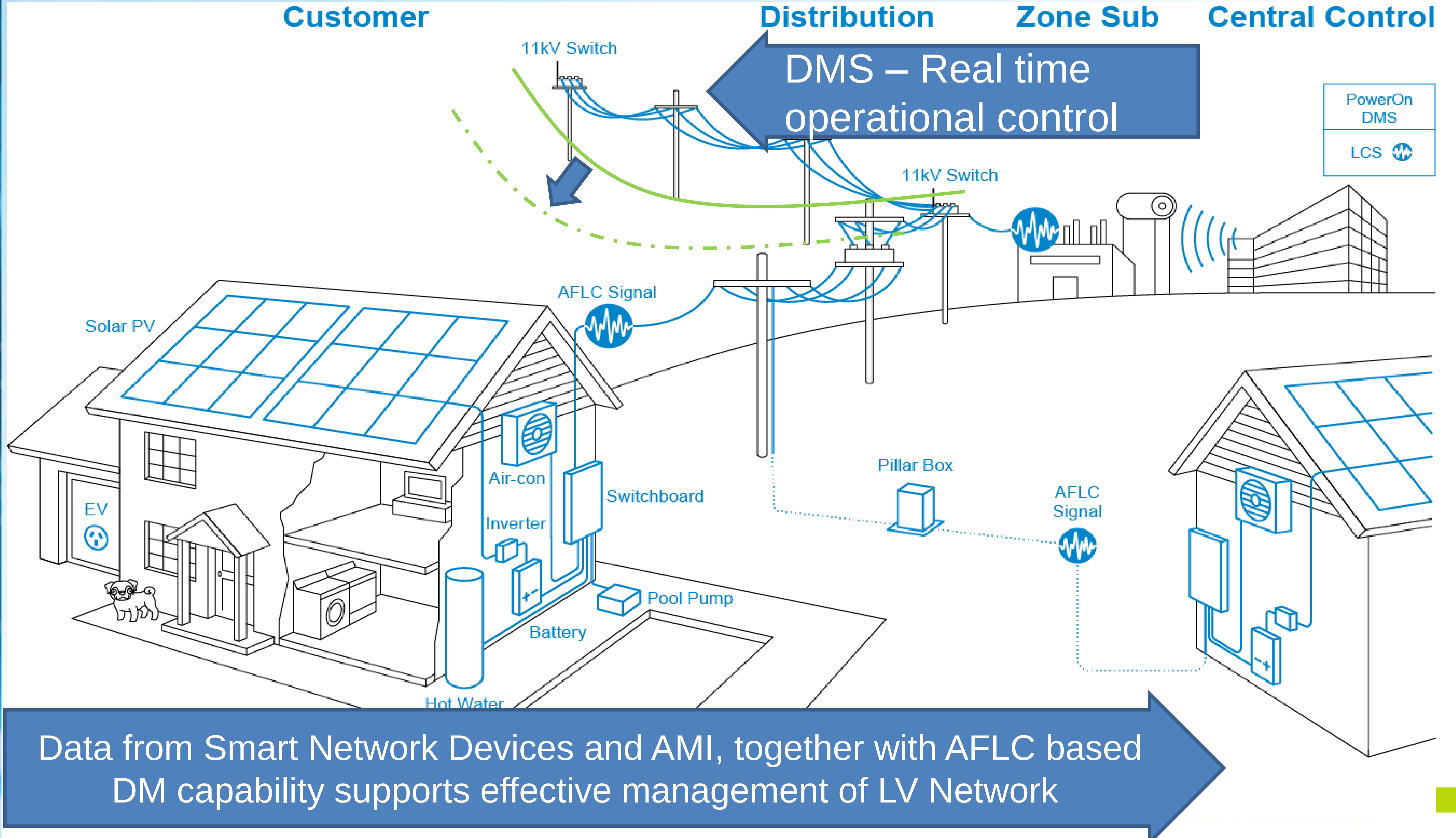
Transformer monitoring – the next step

- 11,000 Power Quality Meters on Distribution Transformers
- Remote collection of PQ data
- Data imported into Energex's Distribution Monitoring Analytics software to allow analysis
- Key outputs:
  - Voltage
  - Phase balance
  - Distortion
  - Loss of phase alarms (not yet fully operational)





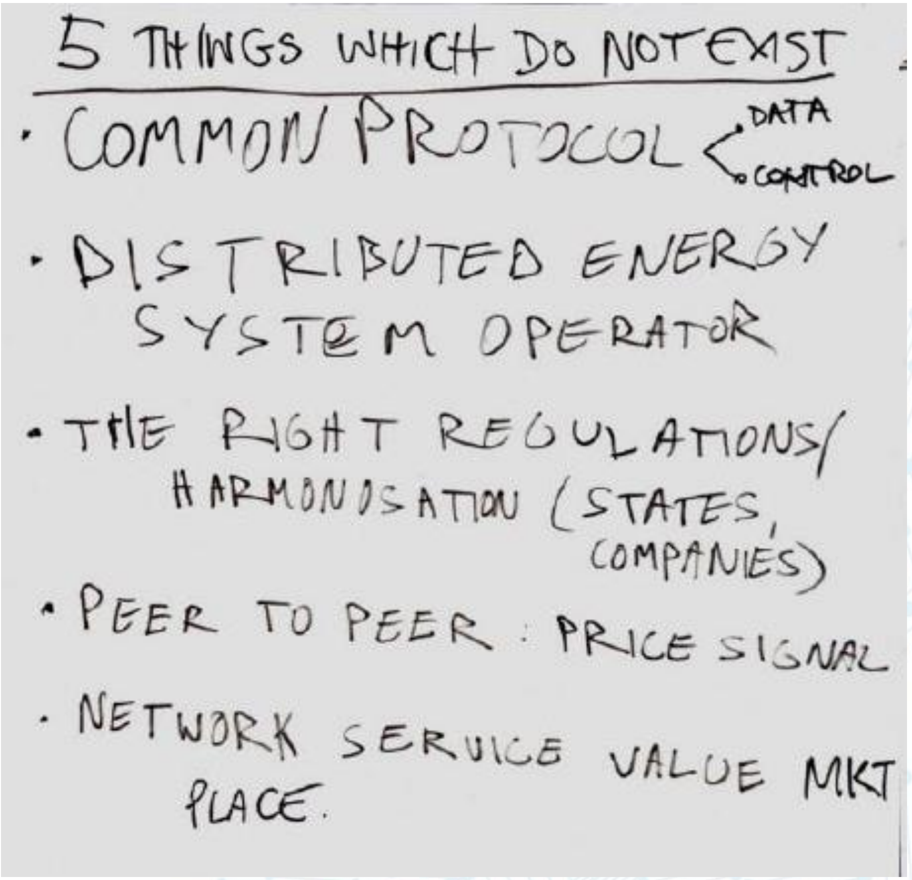
Next iteration of the Energex Smart Grid



Data from Smart Network Devices and AMI, together with AFLC based DM capability supports effective management of LV Network

Questions for Discussion

- What functionality is required to enable prosumer's energy needs?
- Centralised v decentralised?
- End to end interoperability? Day ahead, Near real time or Real time?
- How do we align the technology roadmap with the other market enablers?
- What are the longer lead time actions required to enable the 2027 future?



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ELECTRICITY NETWORK TRANSFORMATION ROADMAP

2017-27

Optimal Grid Operation in a High-DER Future

Tom Bakker, CSIRO

energy networks association

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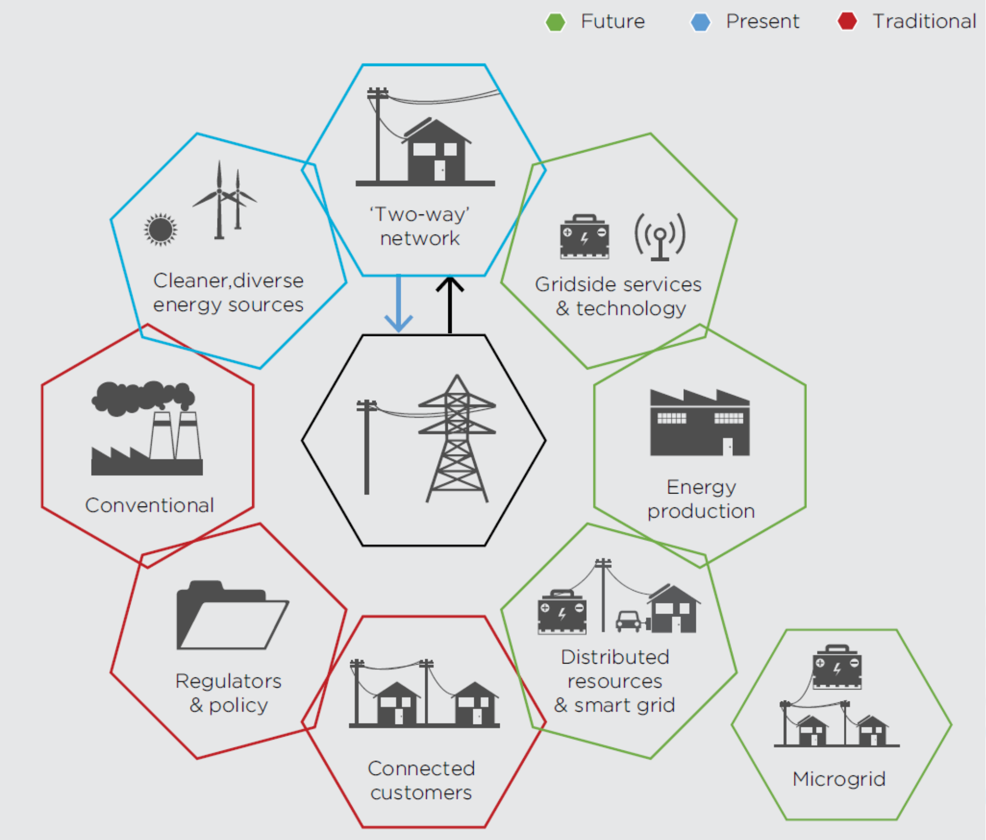
Why does anything need to change?

We currently have utilities who operate network systems effectively

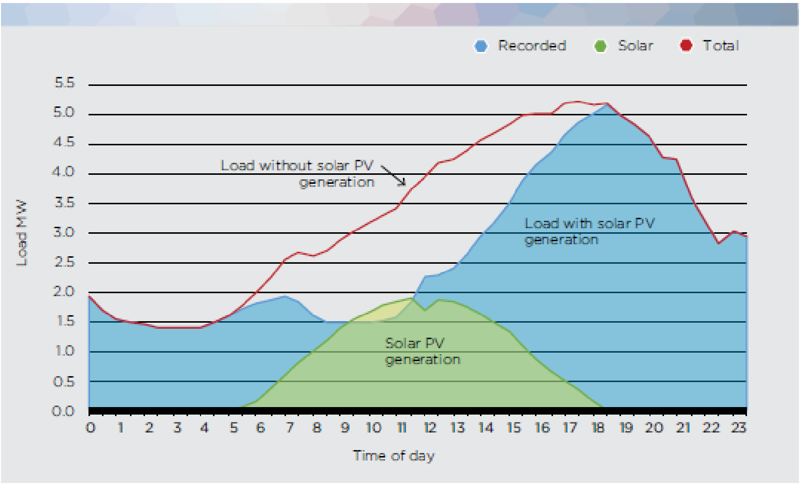
BUT:

DER are proliferating and affecting everything!

- Operation
- Planning
- Business models
- Customer interaction with grid
- Power quality and flows



Source: ENTR IPR Report



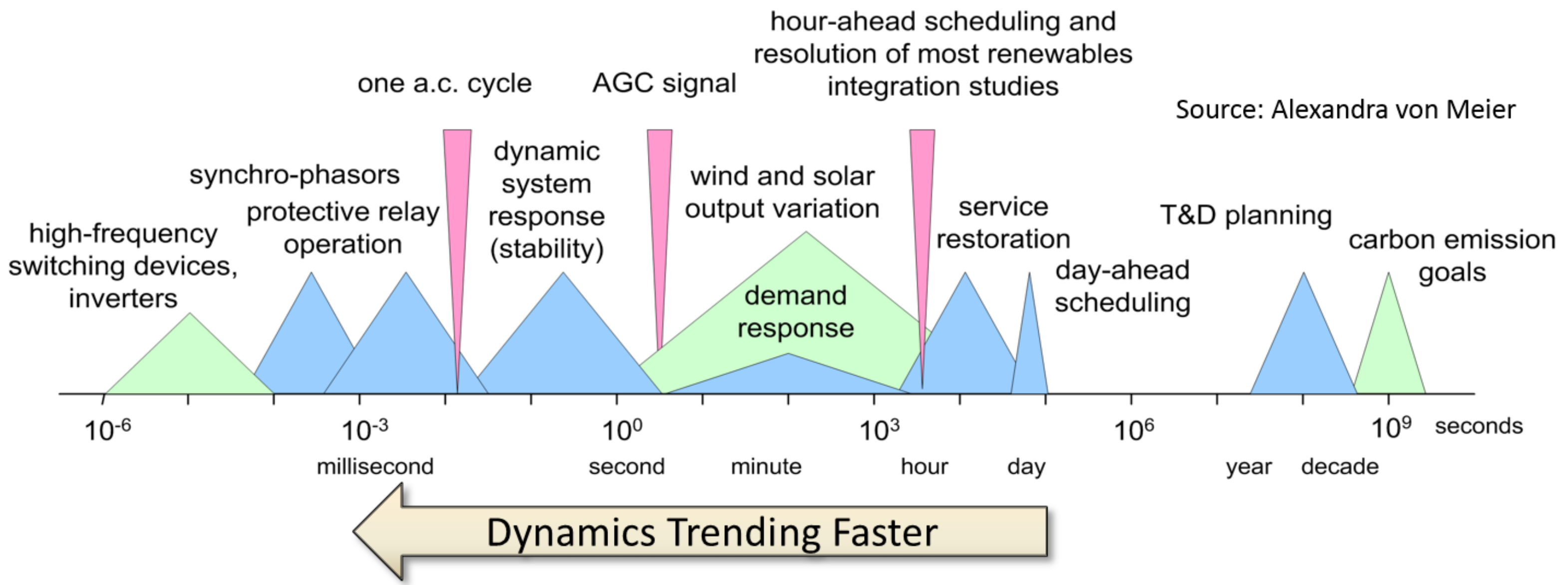
Source: Energex, *Distribution Annual Planning Report*, 2015

Already High Complexity, only Increasing

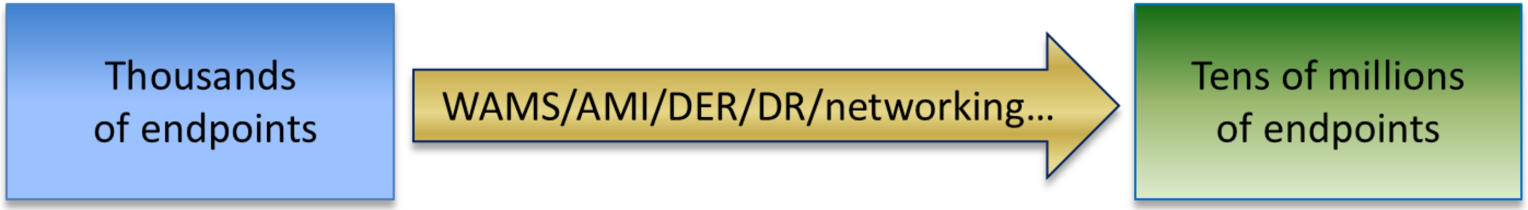
Low Complexity — Medium Complexity — High Complexity — Ultra-Large Scale Complexity

Grid complexity that was already massive, is increasing even further

Less Time, More Data, More Endpoints



- Increasingly faster device/system dynamics
- Moving from slow data sampling to fast streaming data
- Massive numbers of sensing and control endpoints



Courtesy of A. Meier, J. Taft and

Changing Customer Expectations, Same Physics

20th Century Electric Utility Mission:

21st Century Electric Utility Mission:

Pacific Northwest NATIONAL LABORATORY

Emerging need for a Distributed Energy Resources coordinator

- With increased complexity across the energy system the distribution system needs to be **well managed and coordinated** to ensure the efficient flow of electricity and the stability of the system.

- Typically, the party responsible for **coordinating DER** in a manner that ensures stability and unlocks systemic efficiencies is referred to as the **Distribution System Operator (DSO)**

- Maximise **Value for Customers** and **Efficiency of Grid**

Markets vs Controls

- Two extreme views:

<u>Market economists:</u>
Just get the right market rules and prices and everything will work

<u>Control engineers:</u>
Just set up and the right optimization equations and everything will work

- In fact each group needs the other!
- Markets do not adequately account for the physical grid – control systems are needed
- Control systems cannot get all the necessary data to drive their algorithms

- <u>Better Point of View</u>: Both mechanisms are needed – the architectural question is how they must be structured to interact and support each other

Centralised vs Decentralised

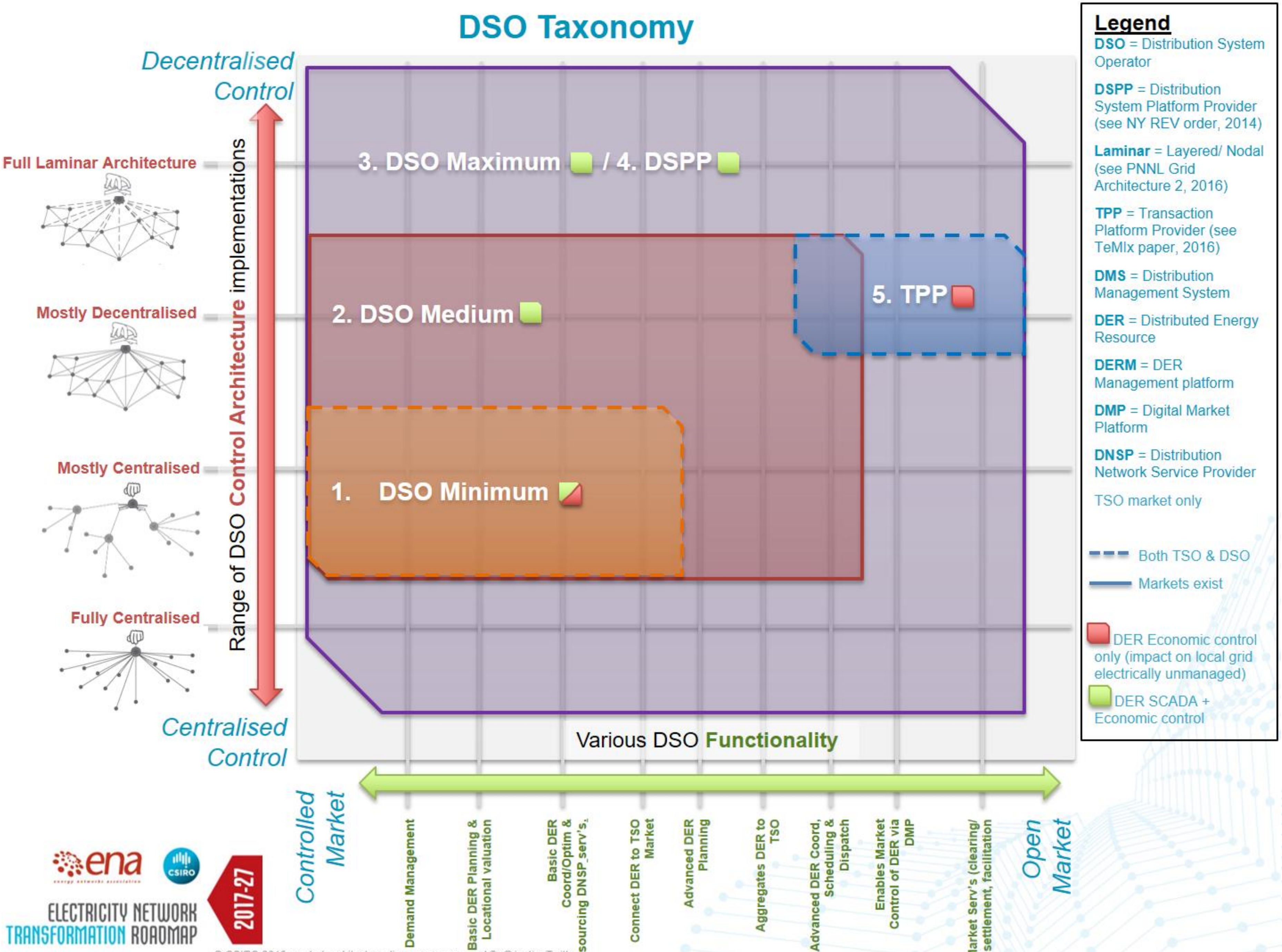
- Two extreme views:

<u>Grand central optimisation:</u> Bring all data to one location (control center) and issue all dispatch and control from there

<u>Distributed System:</u> Put intelligence in everything, operate on local data, and let each object function as an independent agent

- Each approach has pluses and minuses
- Central schemes have scalability and security challenges
- Distributed schemes have deployment and diagnostic challenges

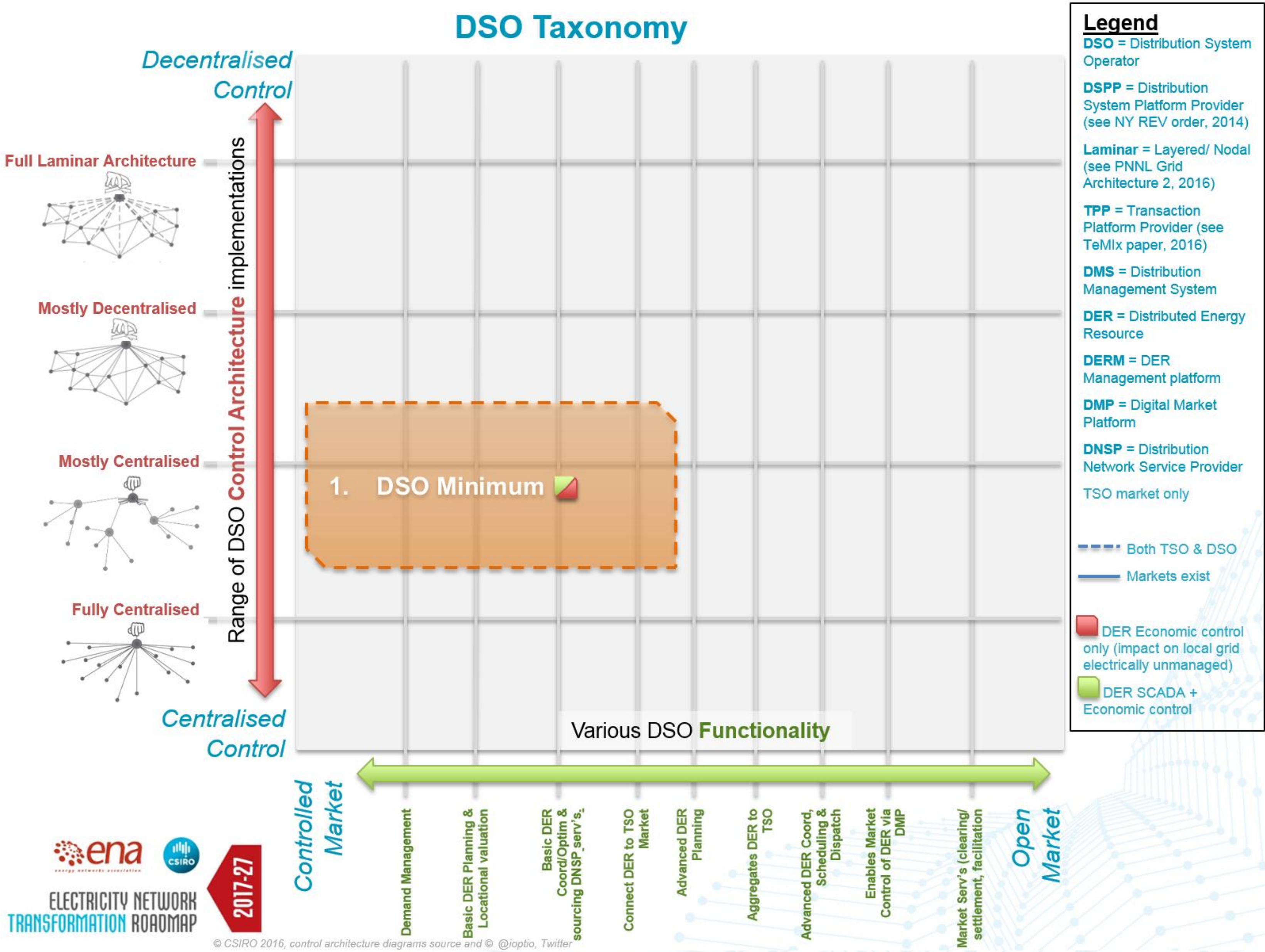
- <u>Better point of view</u>: use a hybrid approach with well-defined structural properties



- Not “Who”, but rather a definition of bundles of functions
- Control methodologies mapped against DER “value animating” functions
- 5 possible main “bundlings”

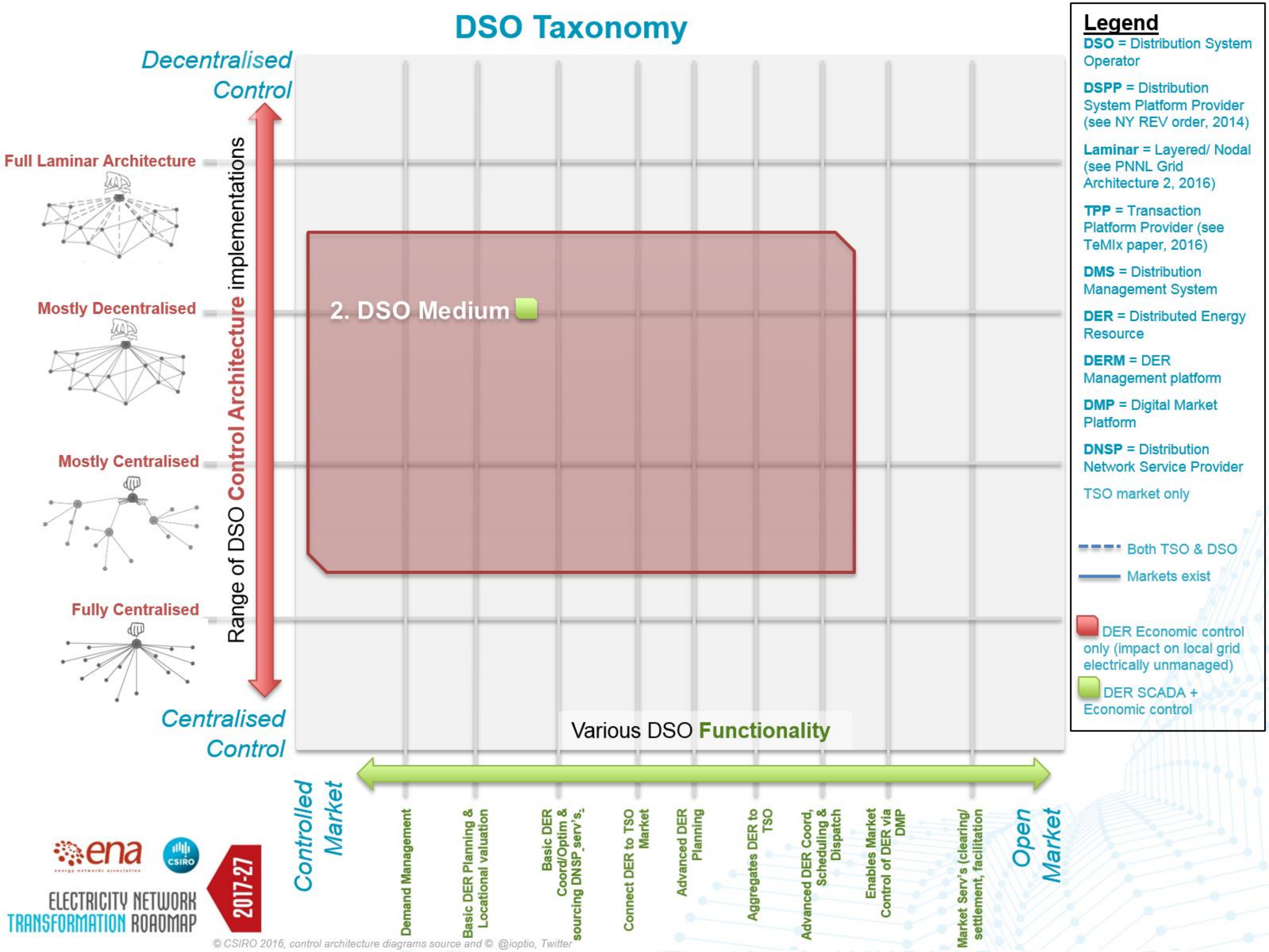
1. DSO Minimum / Lite

- Demand Management
- Basic DER Planning & Locational Valuation
- Basic DER Coordination, optimisation and sourcing of DNSP services
- Connect DER to TSO Market
- Exists today (Energex + 3rd party example)



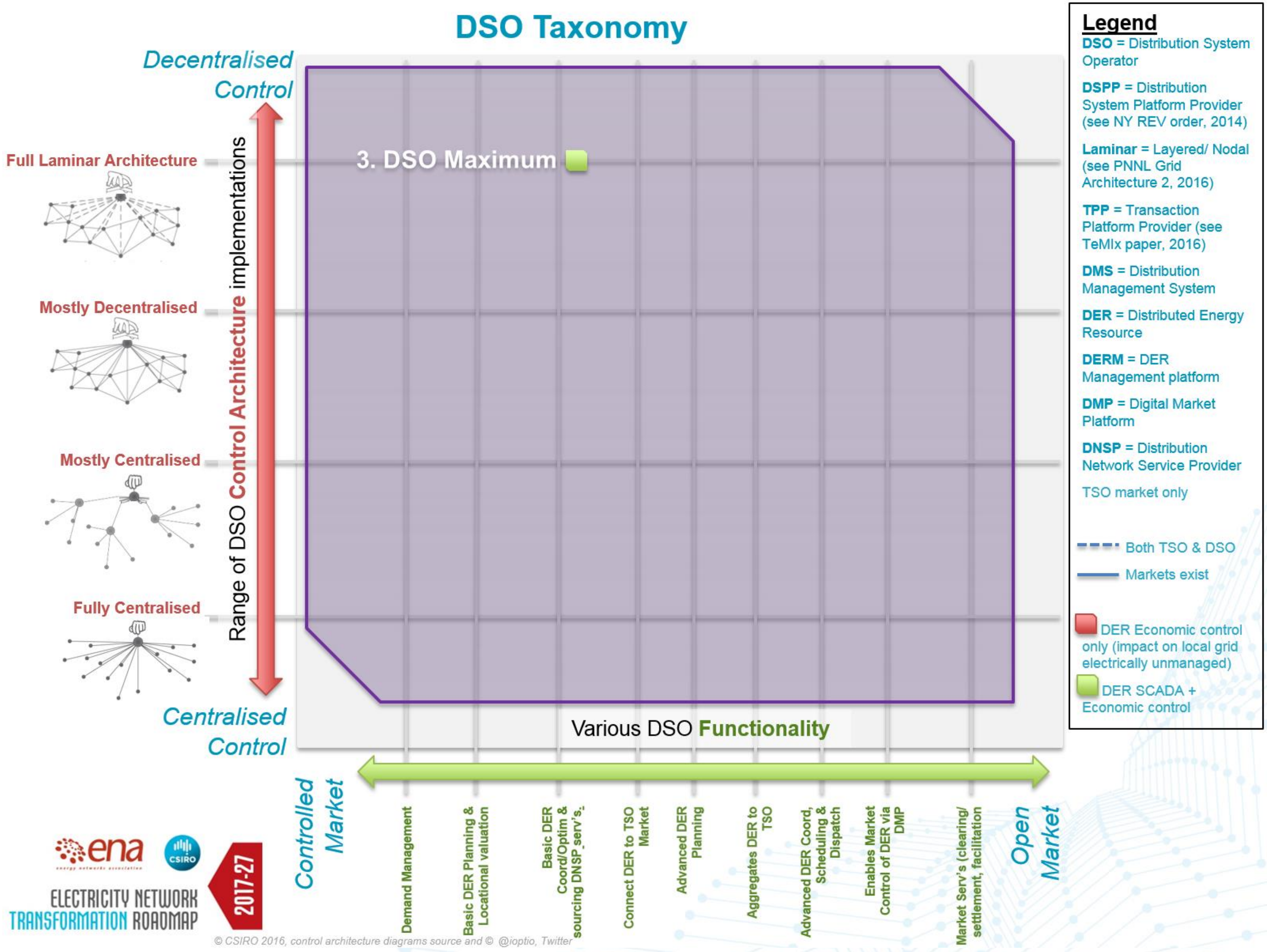
2. DSO Medium / Comprehensive

- DSO Min, plus
- Advanced DER Planning
- Aggregates DER to TSO
- Advanced DER Coordination, Scheduling & Dispatch
- Operates a DERM



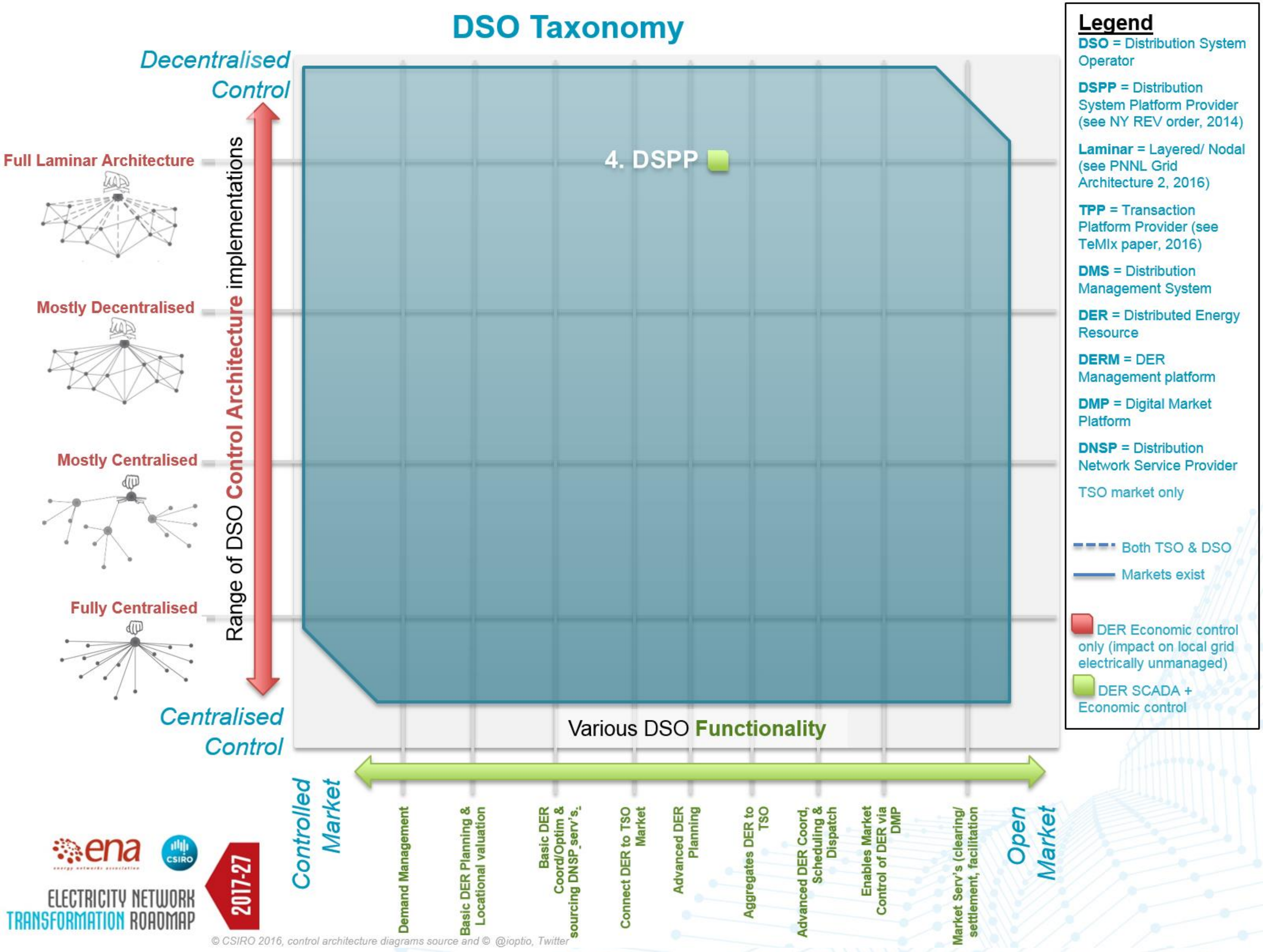
3. DSO Maximum

- DSO Med plus
- Primarily "controls" driven model
- Enables Market Control (and monetisation) of DER via market platform



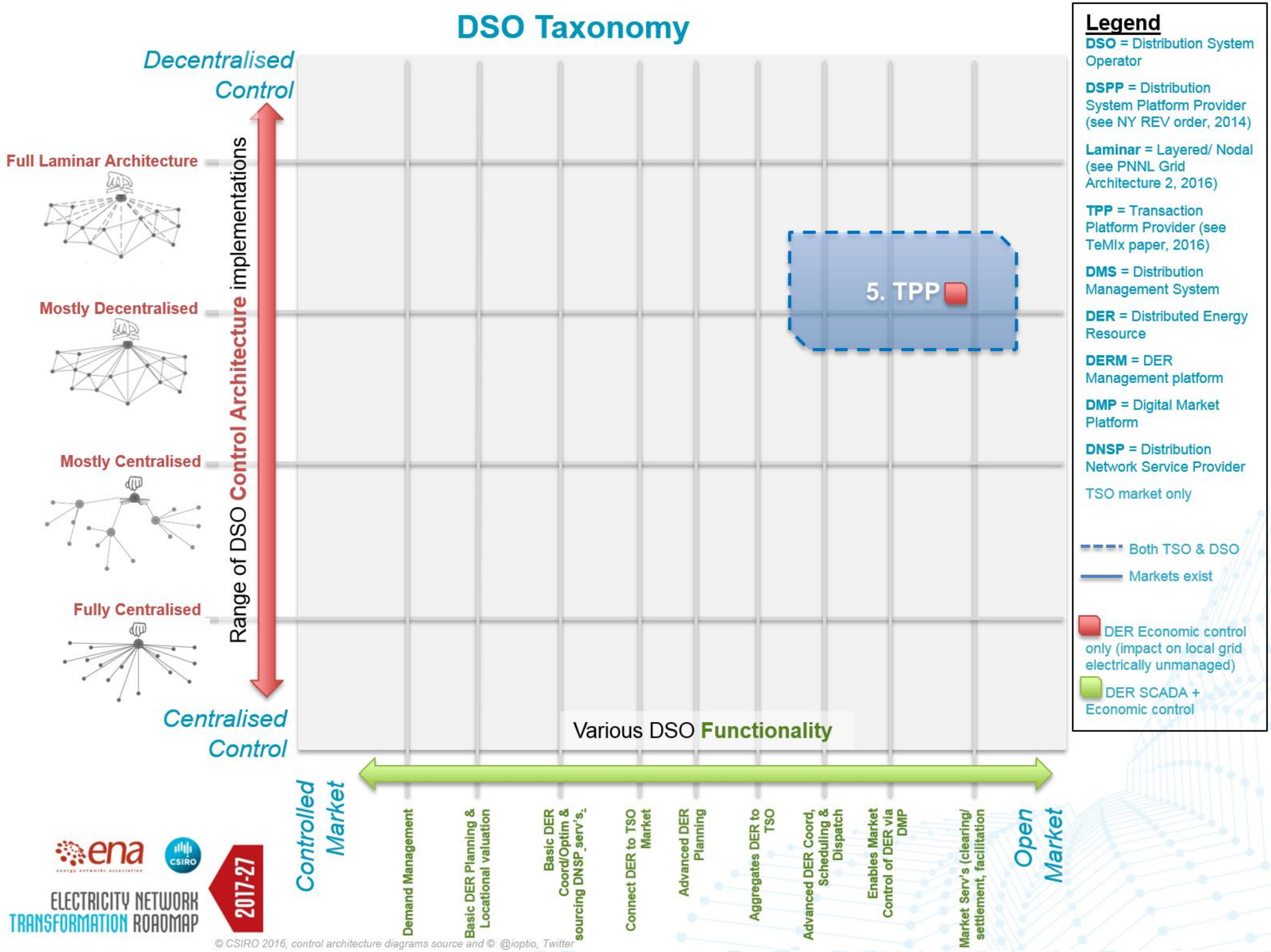
4. Distribution System Platform Provider (DSPP)

- Specific DSO Max, defined by regulator in New York "Reforming the Energy Vision" (NY REV) proceeding
- Market Services (clearing, settlement, facilitation).
- Primarily "markets" driven model



5. Transaction Platform Provider (TPP)

- Software platform for trading DER and Transport Services
- Advanced DER Coordination, Scheduling & Dispatch
- Enables Market Control (and monetisation) of DER via DMP
- Market Services (clearing, settlement, facilitation).
- No SCADA interface



Workshop Session

Key Questions

1) Do we need a DSO?

2) What is the most beneficial DSO function?

3) What other DSO functions may unlock additional value?

Clarifying our workshop discussion about system operation in a High-DER future

1. Thinking about **technological** requirements in a High-DER future, will we need someone to operate the distribution system in 2027 and beyond? **The workshop agreed that we will.**

2. In addition to the basic functions DNSPs are providing today, **what additional technological functions** be needed by 2027 and beyond? **We agreed this is an area that needs to be explored in the Australian context.**

ELECTRICITY NETWORK TRANSFORMATION ROADMAP

2017-27

Grid Architecture & Control I

Stuart Johnstone, ENA

Safer, Stronger, Smarter Networks

Electricity Network Transformation Roadmap

ENTR Grid Architecture Workshop

7th July 2016

www.eatechnology.com

EA Technology

We support energy networks to become more cost-effective and reliable through:

- Power Engineering Consultancy
- Specialist Electrical Engineering Services
- Power Skills Training Services
- Products

We understand network businesses, and drivers from the assets up. We understand how DNOs operate, talk the language and we help implement outputs.

- Employee-owned
- Values-led
- Innovation focused
- SME

Innovation
Portfolio of innovation projects

MY ELECTRIC AVENUE

Customer-Led Network Revolution

Low carbon LONDON
Energising change

LCN Fund
Low Carbon Networks

The Smart Grid Architecture Model (SGAM) Framework

SGAM – Smart Grid Architecture Model

Framework

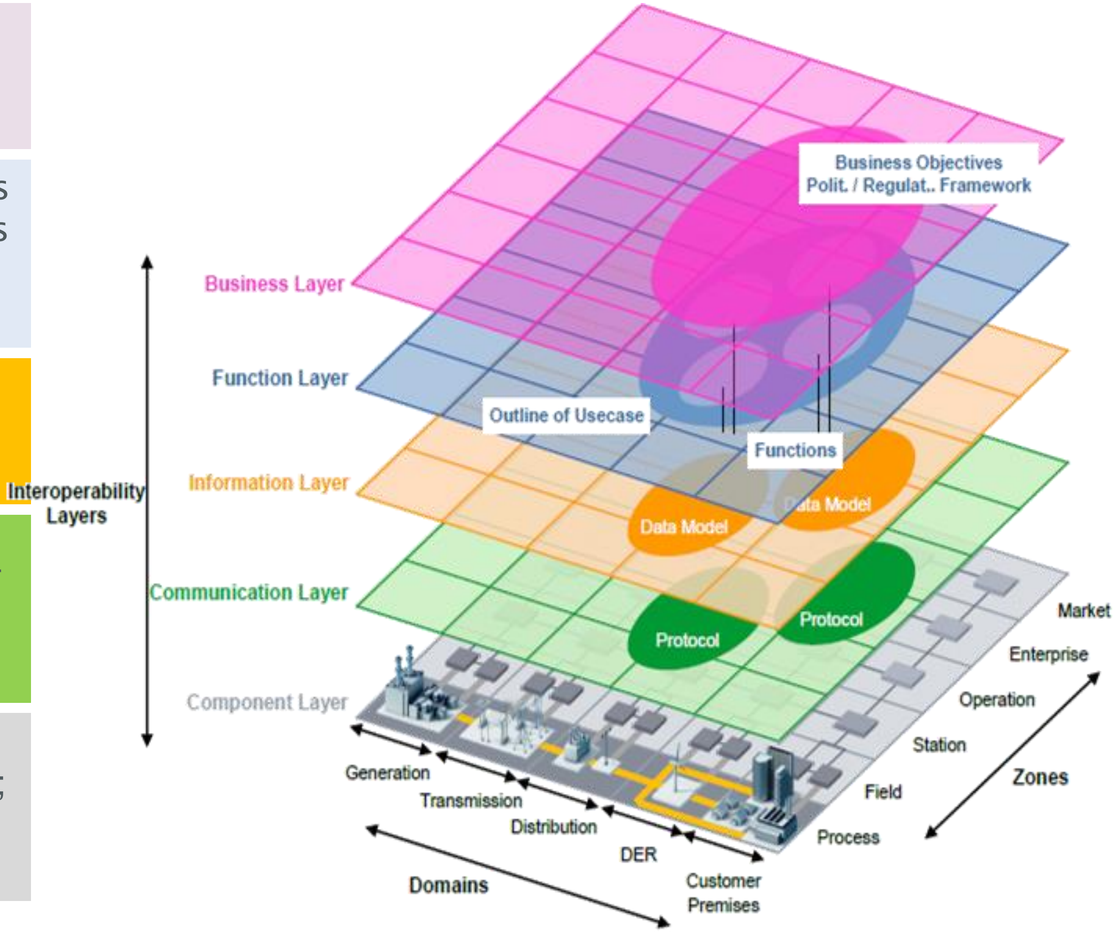
The business layer identifies the macro-level impacts of changes to the electricity sector on different businesses.

The function layer describes the key options for solutions to meet the business case. It is independent from information, communication and physical components.

The information layer describes the type of information that is being passed to achieve the required function.

The communication layer describes the protocols for the interoperable exchange of information, functions, service or data between components.

The component layer is the **physical** distribution of all participating components; including power system assets, protection, connections and computers.

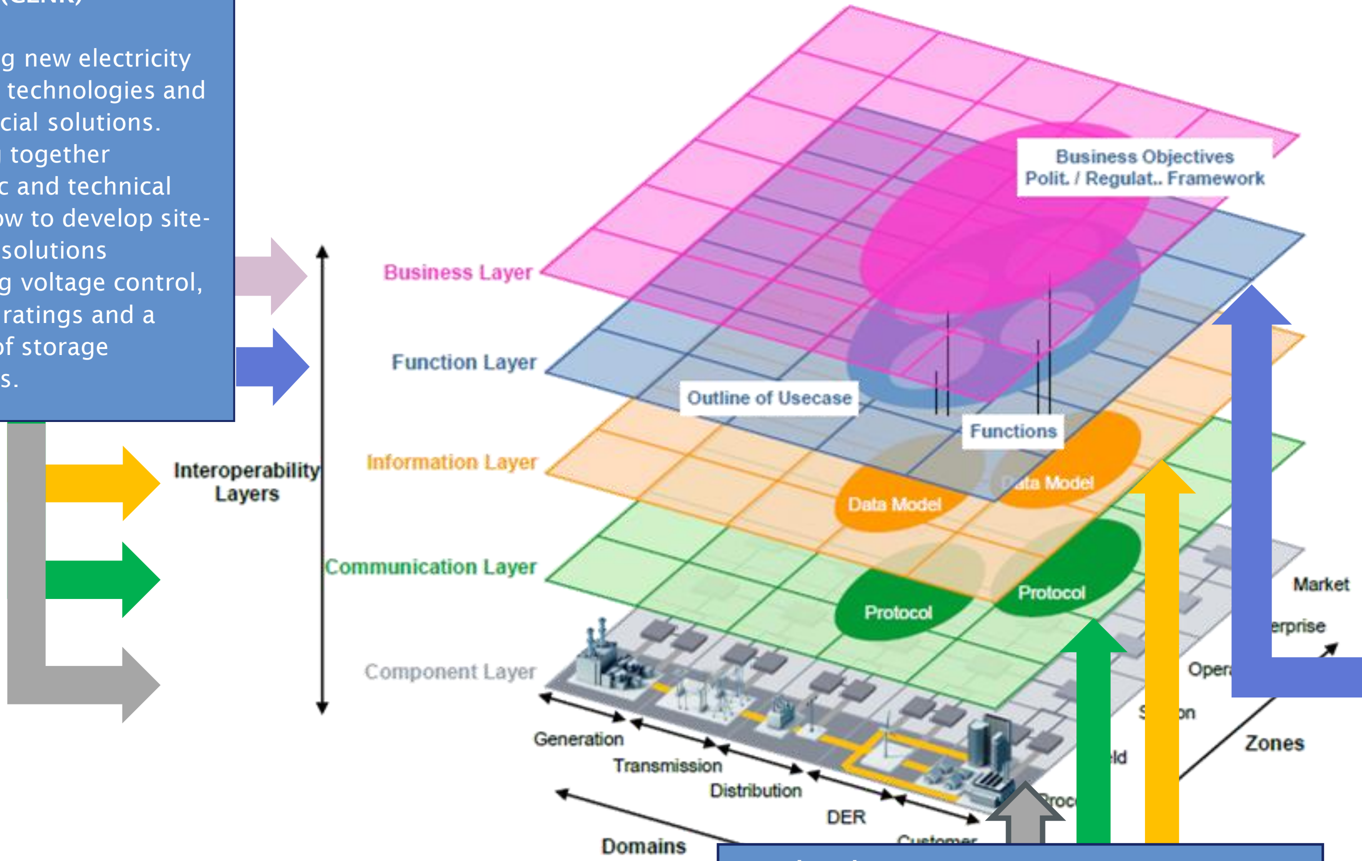


SGAM Framework

EA Technology's experience within SGAM framework

The Customer Led Network Revolution (CLNR)

- Exploring new electricity network technologies and commercial solutions.
- Bringing together scientific and technical know-how to develop site-specific solutions including voltage control, thermal ratings and a variety of storage solutions.



Transform Model

A techno-economic modelling tool to allow Government, Regulators and Network Operators to understand the level of investment required in order to integrate disruptive technologies such as distributed energy resources.

My Electric Avenue

Innovative project that provided a solution to the potential impact that the recharging of electric vehicles (EVs) will have on the local electricity network.

Example of using SGAM framework

Network Control of Customer Load

- The ‘use case’ here is the ability for a network operator to manage customer demands via some remote control of large loads
- Control techniques are used across the world for loads such as heating, cooling, pool pumps etc
- In its simplest form, the actors here are the network operator and the customer (with no intermediaries)
- It needs to be done in a way which is enduring, lower cost than the alternative reinforcement, and does not significantly affect the customer’s experience (i.e. it is acceptable to the customer)
- Various options are available in terms of the communications media used, where the control and decision making sits etc

Example of using SGAM framework

Load control

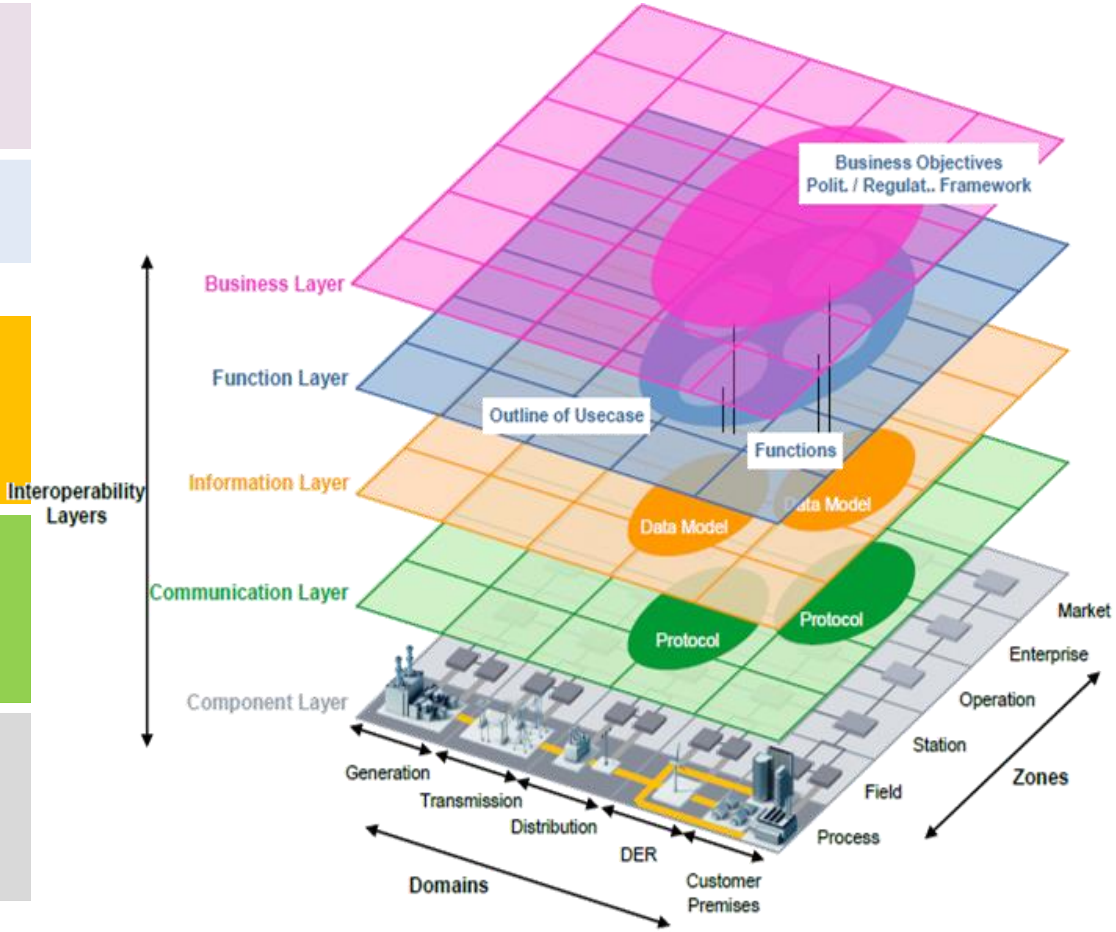
The business case for load control, better asset utilisation, energy market, risk management.

The actors, process and functionality required to realise the business objectives.

Information exchanged might include the state of the customer devices (on/off). The required levels of latency, security and data storage are probably low.

Communication could be via network operator channels: power line carrier or private radio, or could be via third party comms links (such as hiring of telecomms)

Remote control switches at customer premises. Head end devices to send out switching commands (could be installed at local level or centrally).



ELECTRICITY NETWORK TRANSFORMATION ROADMAP

2017-27

Grid Architecture & Control I Workshop

energy networks association

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Template for Workshop

Step through selected Use Cases

1. Describe high level characteristics or outcomes required

2. What are the key components the system may need to enable those characteristics (prioritise)

3. What are the key Functionalities that will be required to enable those characteristics (prioritise)

4. What type of information will need to be stored by or passed between actors for these characteristics (prioritise)

5. How will these components and various actors need to communicate to enable these characteristics

6. Supporting Questions: a) Challenges/risks; b) Gaps in current tech/innovation; c) which actors do we need to consider; d) Other enablers we need to consider

Table No:	Use Case Description:	Layer:					
Describe the key characteristics required?							
What components are necessary to facilitate this?		Priority	1	2	3	4	5
		Priority	1	2	3	4	5
		Priority	1	2	3	4	5
		Priority	1	2	3	4	5
What functionality and interoperability will be required?		Priority	1	2	3	4	5
		Priority	1	2	3	4	5
		Priority	1	2	3	4	5
		Priority	1	2	3	4	5
What type and level of information needs to be stored and passed between actors?		Priority	1	2	3	4	5
		Priority	1	2	3	4	5
		Priority	1	2	3	4	5
		Priority	1	2	3	4	5
What gaps in innovation need to be addressed?		Priority	1	2	3	4	5
		Priority	1	2	3	4	5
		Priority	1	2	3	4	5
		Priority	1	2	3	4	5
How do these components need to communicate with each other?							
What challenges does this scenarios pose to the network and other stakeholders?							
List the actors which could have roles to play in delivering this scenario for the industry?							
What Enablers need to be considered? Community & Awareness Standards & Regulations Facilities & Infrastructure Skills & Education Finance & Investment Partnerships & Collaboration							

Use Cases for Workshop

1. Demand Response
2. Dynamic Load Balancing
3. Electric Vehicle to Grid Interaction
4. Coordination of Electric Vehicles
5. Distributed Energy Generation/Injection
6. Home Area Network to Grid Interaction
7. Enable DER Market Operations
8. Energy Storage
9. Dynamic Asset Optimisation
10. Peer to Peer trading
11. Customer/Grid Interface Infrastructure systems
12. Microgrid Management & Grid Interaction

Use Case Example

Dynamic Load Balancing - Monitoring and display of power-system components and performance across interconnections and over large geographic areas in near real-time. Provide automated and secure management of demand, generation and other energy resources and auxiliary services with a focus on expected dynamic load and generation balancing that will be required as renewable penetration increases.

- **Rationale:** The goals of situational awareness are to understand and ultimately optimise the management of power-network components, behaviour, and performance, as well as to anticipate, prevent, or respond to problems before disruptions can arise.

How to fill out Worksheet

Describe the key characteristics required?	• Optimise the management of power-network components • Enable energy market, • Mitigate risk

What components are necessary to facilitate this?	Remote Control Switches	Priority	1	[redacted]	3	4	5
	Head end devices	Priority	1	2	3	[redacted]	5
		Priority	1	2	3	4	5
		Priority	1	2	3	4	5

What functionality and interoperability will be required?	Monitoring and display of power-system components and performance across	Priority	1	[redacted]	3	4	5
	Manage demand response	Priority	[redacted]	2	3	4	5
		Priority	1	2	3	4	5
		Priority	1	2	3	4	5

How to fill out Worksheet

What type and level of information needs to be stored and passed between actors?	Real time data – but also describe levels that may be required, security and if it (how long and where)	Priority	1	[redacted]	3	4	5
		Priority	1	2	3	4	5
		Priority	1	2	3	4	5
		Priority	1	2	3	4	5

What gaps in innovation need to be addressed?	Head end devices currently have limited functionality to provide required	Priority	[redacted]	2	3	4	5
		Priority	1	2	3	4	5
		Priority	1	2	3	4	5
		Priority	1	2	3	4	5

How do these components need to communicate with each other?	• Power line carrier • Private radio • Via third party comms links

List the components, but also describe how this communication will need to take place

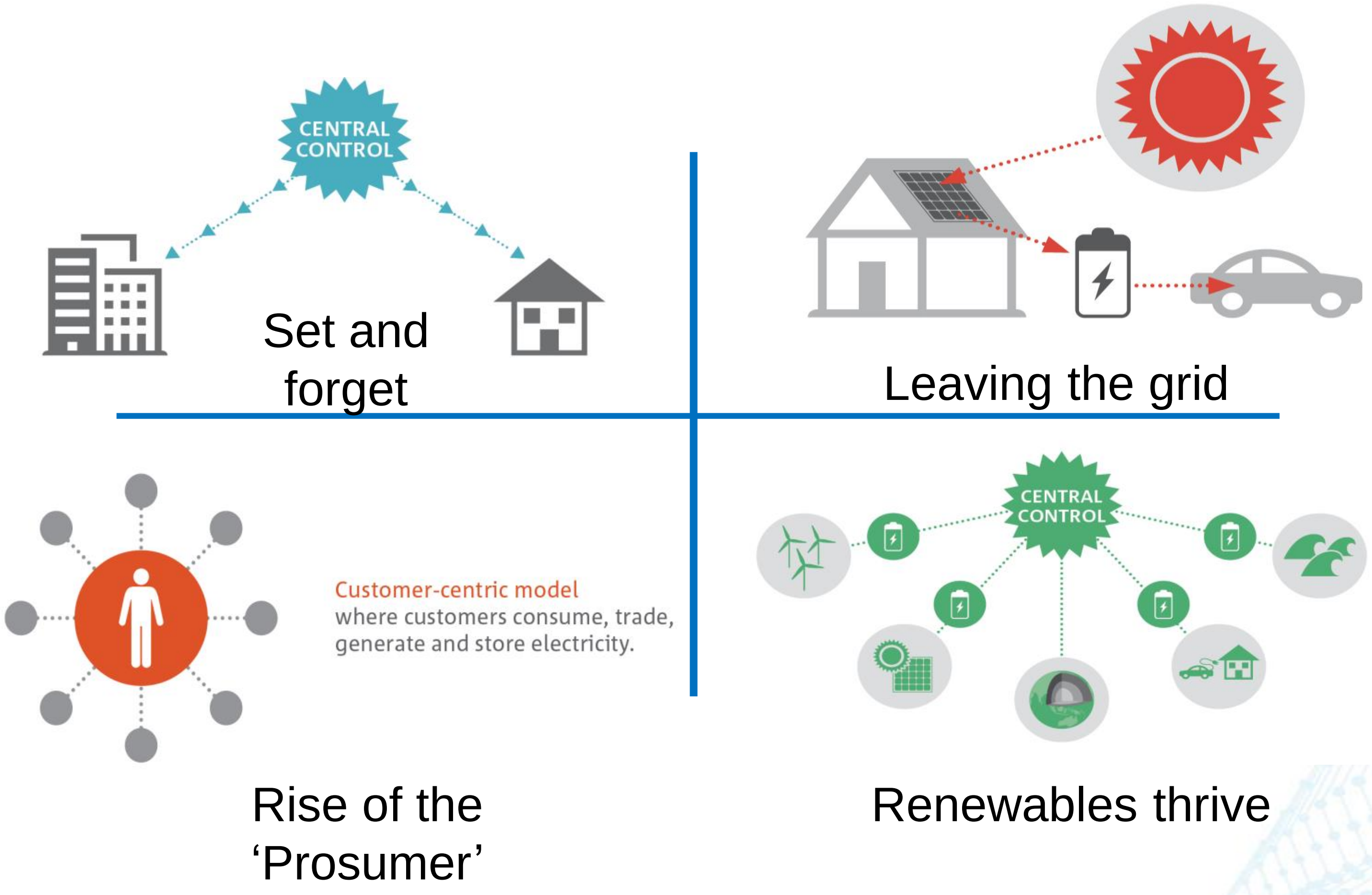
How to fill out Worksheet

What challenges does this scenarios pose to the network and other stakeholders?	• Cyber security List the challenges/risks, but also describe how this could be mitigated

List the actors which could have roles to play in delivering this scenario for the industry?	• DNSPs • TNSPs • Third parties etc….. • AEMO • DSO?

What Enablers need to be considered? Community & Standards & Facilities & Skills & Education Finance & Investment Partnerships &	• Standards – i.e. what areas? Priority? New or update existing • New Training requirements – i.e.. list what areas or job types and the skills that may be required • Potential partnerships or collaboration to enable these functions

And Finally I would like to test if the priority of the use case changes across the different Future Grid Forum Scenarios



Scenario applicability	Set and Forget	Rise of the Prosumer	Leaving the Grid	Renewables Thrive
Use Case XXXX	5	3	1	4

SGAM – Component Layer

SGAM – Smart Grid Architecture Model

Framework

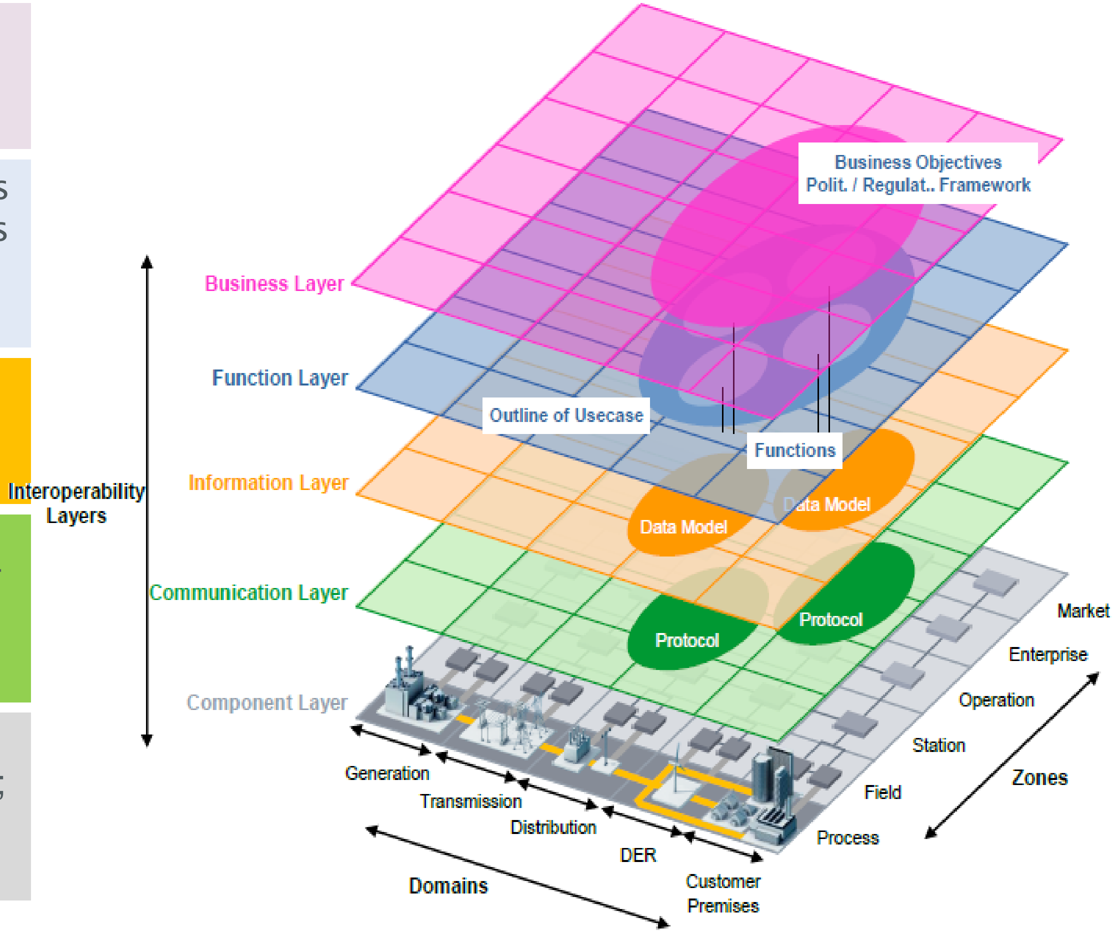
The business layer identifies the macro-level impacts of changes to the electricity sector on different businesses.

The function layer describes the key options for solutions to meet the business case. It is independent from information, communication and physical components.

The information layer describes the type of information that is being passed to achieve the required function.

The communication layer describes the protocols for the interoperable exchange of information, functions, service or data between components.

The component layer is the **physical** distribution of all participating components; including power system assets, protection, connections and computers.



SGAM - Component Layer

An overview:

- The emphasis of the component layer is the **physical** distribution of all participating components in the smart grid.
- This includes system actors, applications, power system equipment (typically located at process and field level), protection and tele-control devices, network infrastructure (wired / wireless communication connections, routers, switches, servers) and any kind of computers.
- Components can sit anywhere on the SGAM plane depending on the function they are required to carry out.

SGAM - Component Layer

Developing the Component layer

- The approach to developing the component layer should be two fold; it should first consider the involved actors and then the required components derived from the use case and function information.
- The actors should be any entity/stakeholder responsible for the completion of a subtask within the overall use case.
- The components can be devices, applications and systems or any other physical entity (hardware).
- All actors and components should then be mapped to the appropriate domain and zone.

SGAM – Functional Layer

SGAM – Smart Grid Architecture Model

Framework

The business layer identifies the macro-level impacts of changes to the electricity sector on different businesses.

The function layer describes the key options for solutions to meet the business case. It is independent from information, communication and physical components.

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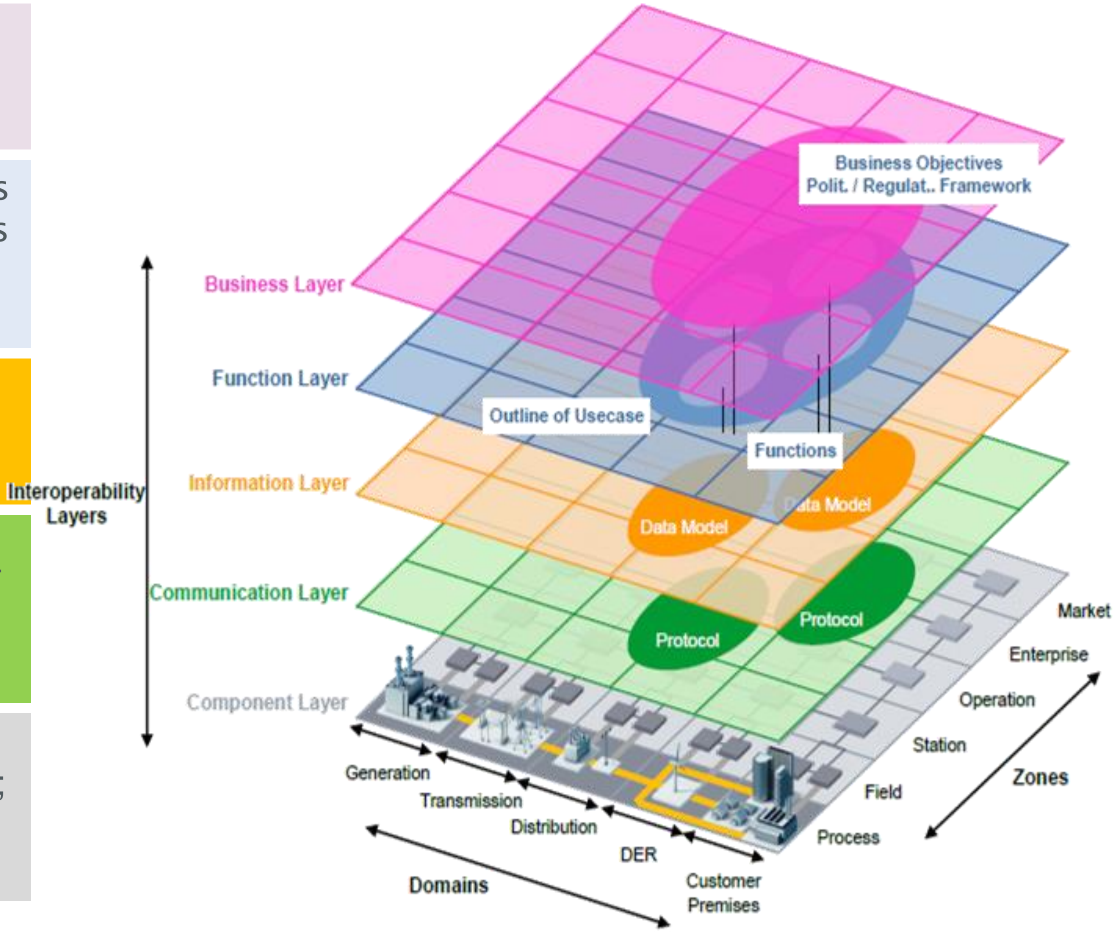

SGAM - Functional Layer

An overview:

- The functional architecture is intended to describe the functional elements of a system.
- It should include IT-oriented, technology neutral descriptions of Smart Grid use cases, their functions and required technical services
- The relationships between system elements should be described independently from physical implementation, applied technology or assigned actors.
- This allows for functions to mapped flexibly across the SGAM plane.
- In the context of Smart Grid a functional architecture consists of

SGAM - Functional Layer

Functions map flexibly onto Smart Grid Plane:

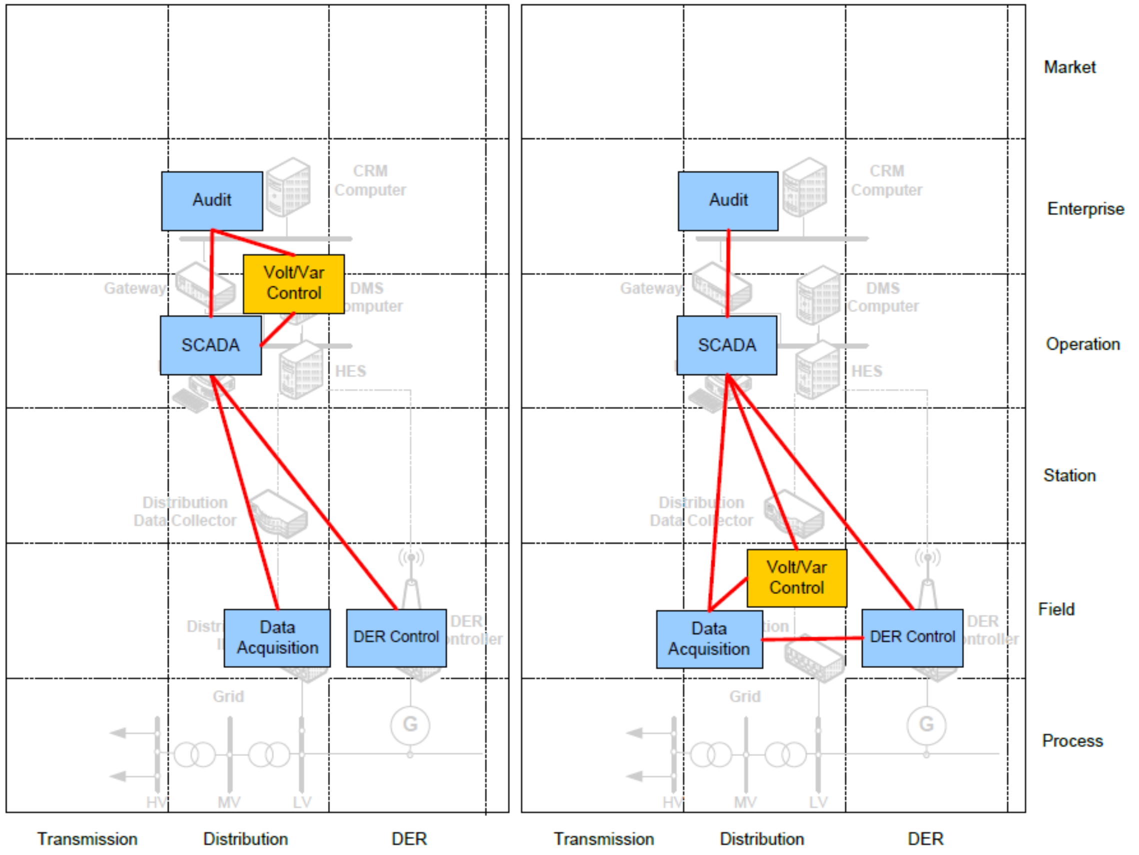

Figure 17: Flexibility for assignment of function "Volt/Var Control" to SGAM segments, case A - in operation zone, case B - in field zone

- The example of Volt/Var control is shown in two zones of the plane; centralised (left) and de-centralised (right).
- Either scenario will have a different impact on other SGAM layers.
- But the function can sit in either situation, illustrating the flexibility in this layer

ea technology

Safer, Stronger, Smarter Networks

SGAM - Functional Layer

Functional Examples

- Enabling the network to integrate users with new requirements
- Enhancing efficiency in day-to-day grid operation
- Ensuring network security, system control and quality of supply
- Enabling better planning of future network investment
- Improving market functioning and customer service
- Enabling and encouraging stronger and more direct involvement of consumers in their energy usage and management