

System Services for a 100% Renewable Power System

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Wind in the Electricity Market in Ireland

Mark O'Malley,
Electricity Research Centre, University College Dublin

Paul Smith, EirGrid

23 Oct 2006

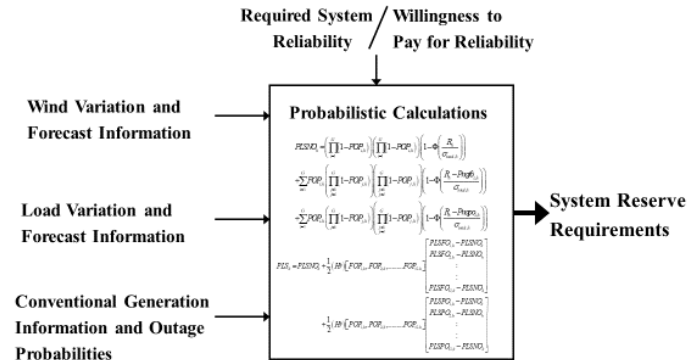
UWIG, Oklahoma City, USA

Impact of wind on generation reserve requirements in Ireland

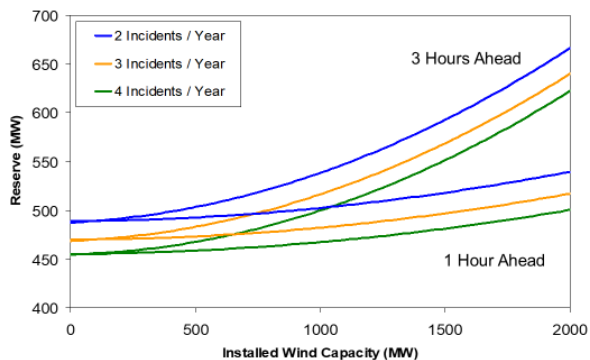
Mark O'Malley, Electricity Research Centre, University
College Dublin

25th October 2006
UWIG, Oklahoma City, USA

Outline of Methodology



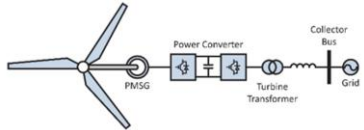
Operating reserve required



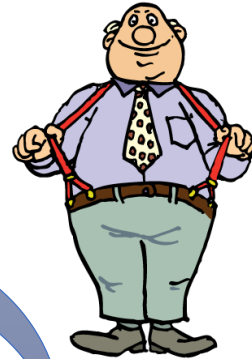
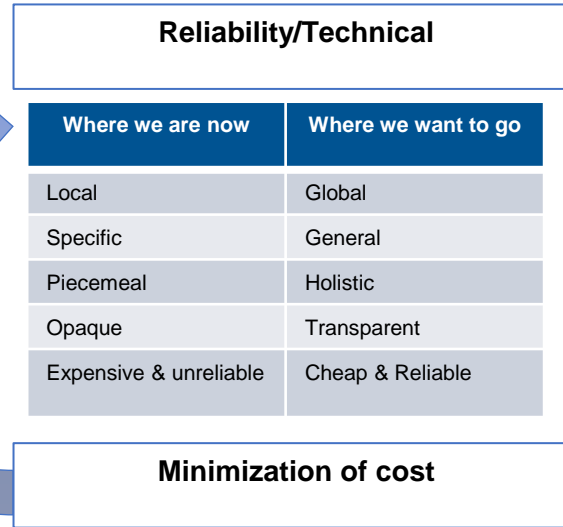
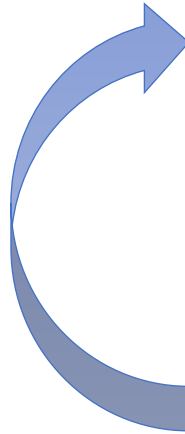
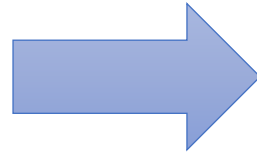
| Where we were then | Where we wanted to go |
|--------------------------|-----------------------|
| Local | Global |
| Specific | General |
| Piecemeal | Holistic |
| Opaque | Transparent |
| Expensive & unreliable ? | Cheap & Reliable ? |

| Research Program | Description | Number of Questions |
|-----------------------------------|--|---------------------|
| <i>Inverter Design</i> | Development of capabilities, services , design methodologies and standards for IBRs. | 10 |
| <i>Tools and Methods</i> | New tools and methods required to ensure reliability, security, and stability in power systems. | 9 |
| <i>Control Room of the Future</i> | Development of new technologies and approaches for enhanced real-time visibility and analysis in power system operator control rooms. | 17 |
| <i>Planning</i> | New planning metrics, methods, and tools to capture the characteristics and influence of a changing resource mix. | 15 |
| <i>Black Start</i> | Creating new procedures for black starting and restoring a power system with high or 100% IBR penetrations. | 1 |
| Services | Quantifying the technical service requirements required of future power system to maintain the supply-demand balance reliably and at least cost. | 7 |

Cost reliability trade off



Type IV



IBRs replacing Synchronous Machines



**GLOBAL PST
CONSORTIUM**

System Needs and Services for Systems with High IBR Penetration

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University of Newcastle, UK*

*Thomas Bowen
NREL, USA*

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Imperial College London, UK*

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ESIG, USA*

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Imperial College London, UK*

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GE, USA*

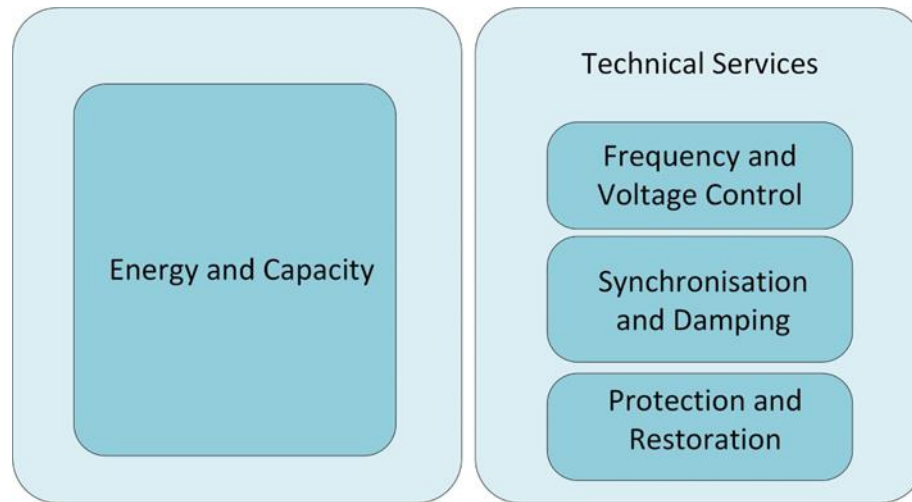
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ERCOT, USA*

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HickoryLedge, USA*

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ESIG, Ireland*

*Deepak Ramasubramanian
EPRI, USA*

October 8th, 2021



← Major programs

Fast Frequency Response

Very Fast FCAS Market Commencement

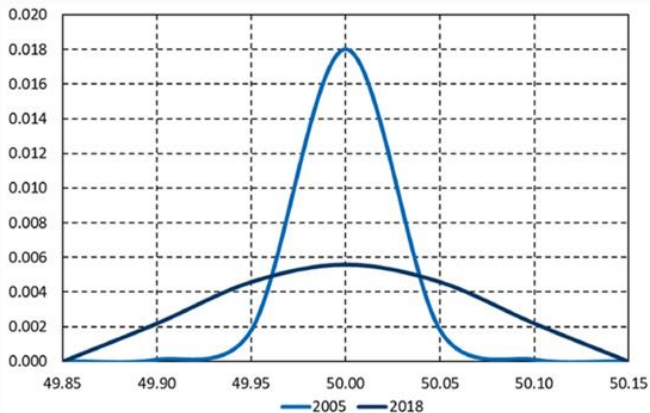
On the 15 July 2021, the AEMC made a [final rule](#) to introduce two new market ancillary services in the NEM under the existing Frequency Control Ancillary Services (FCAS) arrangements, the very fast raise and very fast lower FCAS markets.

Following consultation with stakeholders and work undertaken by AEMO, the very fast raise and very fast lower FCAS markets opened on **Monday 9 October 2023 at 1.00pm (Market Time)**.

Very Fast FCAS Market Commencement – Go for Monday 9 October 2023



Figure 1: Frequency distribution within the normal frequency operating band in the NEM (2005 Snapshot vs. 2018 Snapshot)



Source: AEMO, Removal of disincentives to the provision of primary frequency response during normal operating conditions – Electricity rule change proposal, 1 July 2019, p.14.

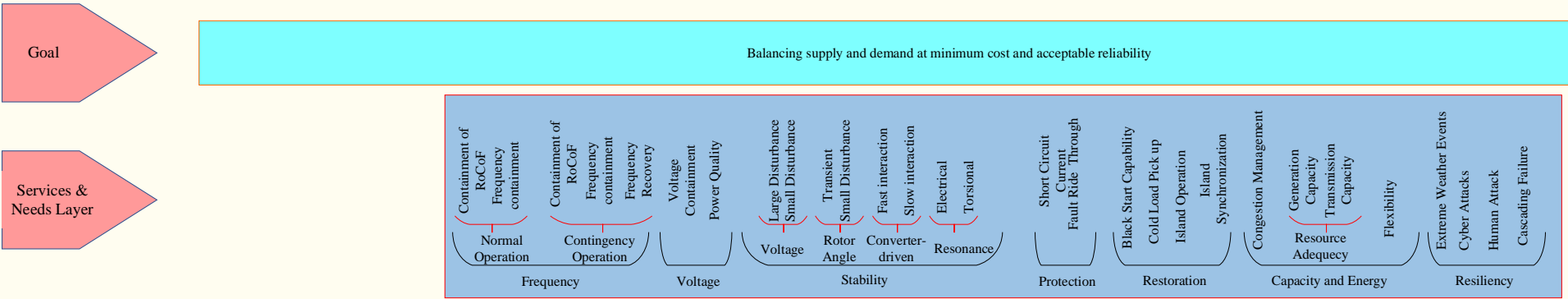
Framework: Primary layer



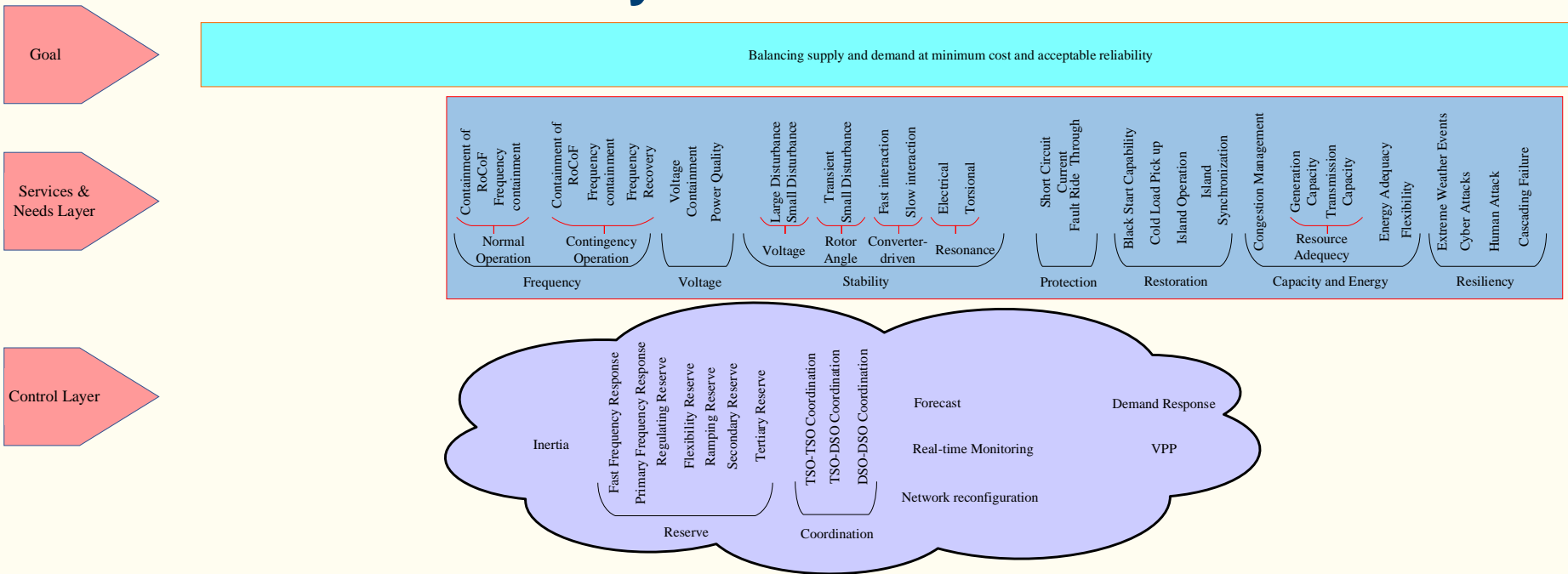
Goal

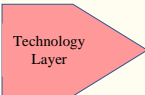
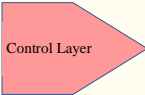
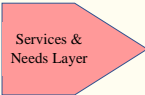
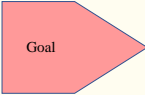
Balancing supply and demand at minimum cost and acceptable reliability

Framework: Services and needs layer

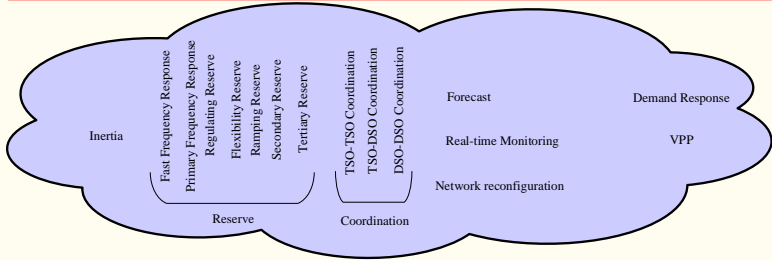
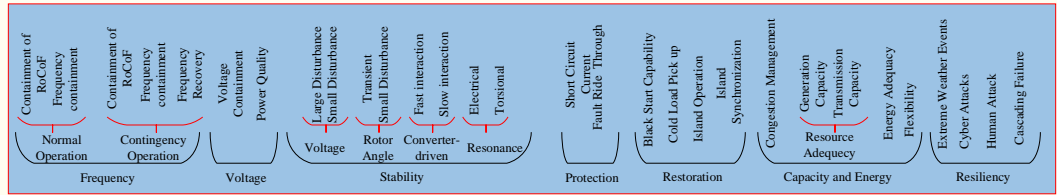


Framework: Control layer





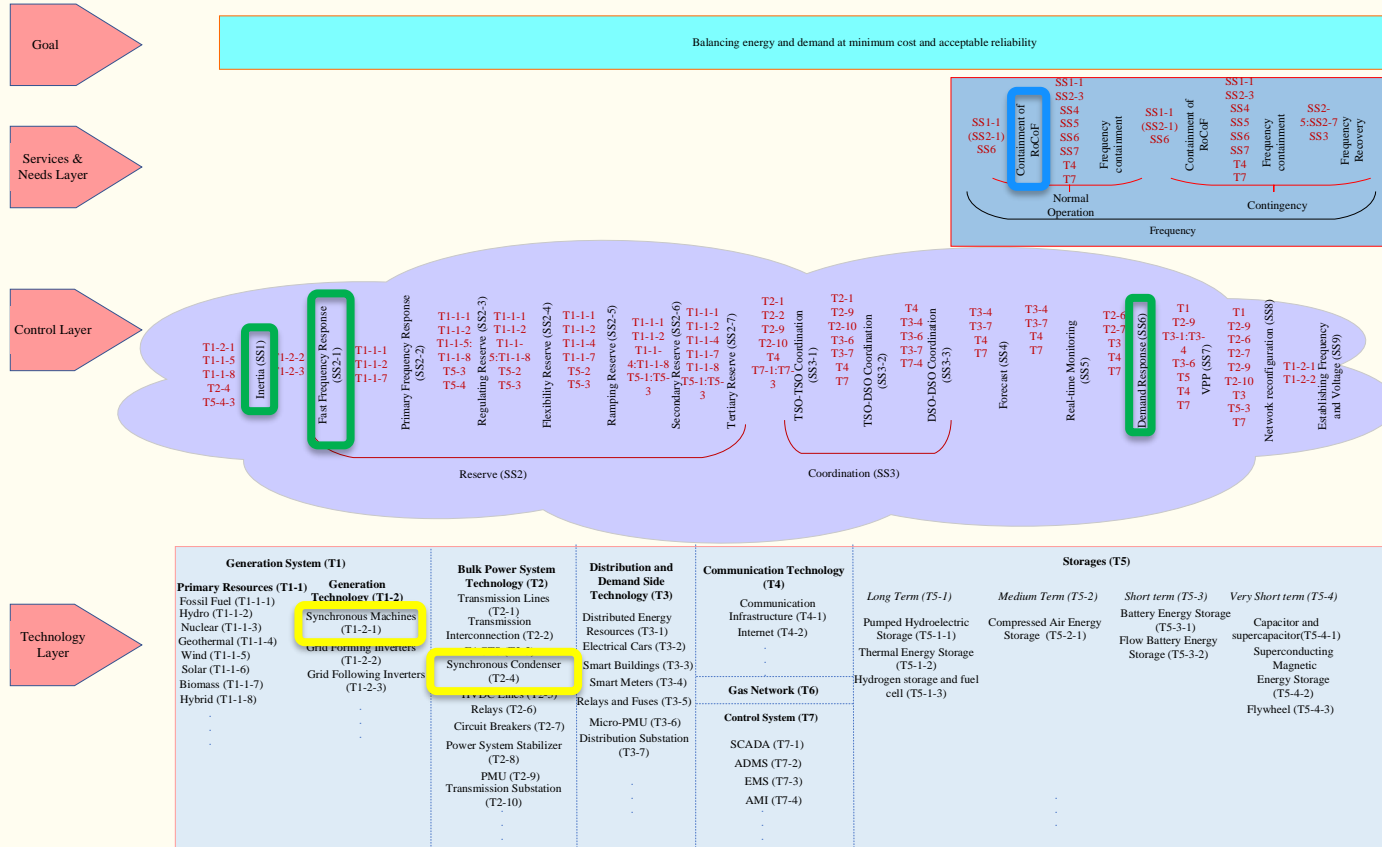
Balancing supply and demand at minimum cost and acceptable reliability



| Generation System | | Bulk Power System Technology | Distribution and Demand Side Technology | Communication System | Storages | | | |
|--------------------------|------------------------------|------------------------------|---|------------------------------|--------------------------------|-------------------------------|-----------------------------|------------------------------|
| Primary Resources | Generation Technology | Transmission Lines | Distributed Energy Resources | Communication Infrastructure | <i>Long Term</i> | <i>Medium Term</i> | <i>Short term</i> | <i>Very Short term</i> |
| Fossil Fuel | Synchronous Machines | Transmission Interconnection | Electrical Cars | Internet | Pumped Hydroelectric Storage | Compressed Air Energy Storage | Battery Energy Storage | Capacitor and supercapacitor |
| Nuclear | Grid Forming Inverters | FACTS | Smart Buildings | . | Thermal Energy Storage | . | Flow Battery Energy Storage | Superconducting |
| Geothermal | Grid Following Inverters | Synchronous Condenser | Smart Meters | Gas Network | Hydrogen storage and fuel cell | . | . | Magnetic Energy Storage |
| Wind | . | HVDC Lines | Relays and Fuses | Control System | . | . | . | Flywheel |
| Solar | . | Relays | Micro-PMU | SCADA | . | . | . | . |
| Biomass | . | Circuit Breakers | Distribution Substation | ADMS | . | . | . | . |
| Hybrid | . | Power System Stabilizer | PMU | EMS | . | . | . | . |
| . | . | Transmission Substation | . | AMI | . | . | . | . |
| . | . | . | . | . | . | . | . | . |
| . | . | . | . | . | . | . | . | . |

Framework: Technology layer

Framework example- Containment of RoCoF



Bring it all together Institutionally for Transformation of the Global Power System

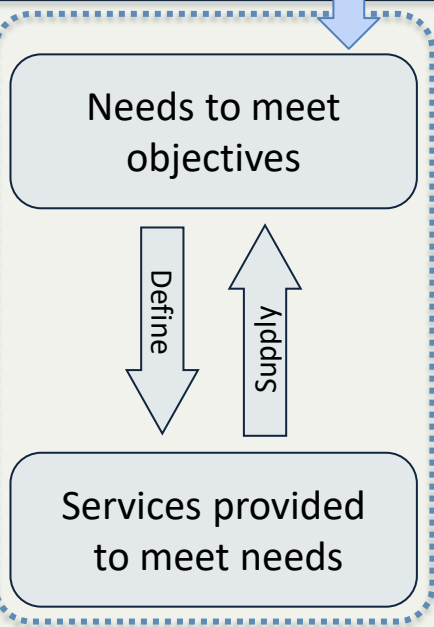
Operational & Commercial Mechanisms

nationalgridESO
EIRGRID GROUP
ENERGINET
AEMO
California ISO

Objective to maintain reliable supply at least cost

Balance of reliability and cost

Political Economy
Government, policies, market outcomes, consumers, investors, etc.



Characteristics of the Electricity Grid

Electricity Grid
Interconnection of multiple sub-systems and devices with a market

Physical properties and constraints of subsystems & devices

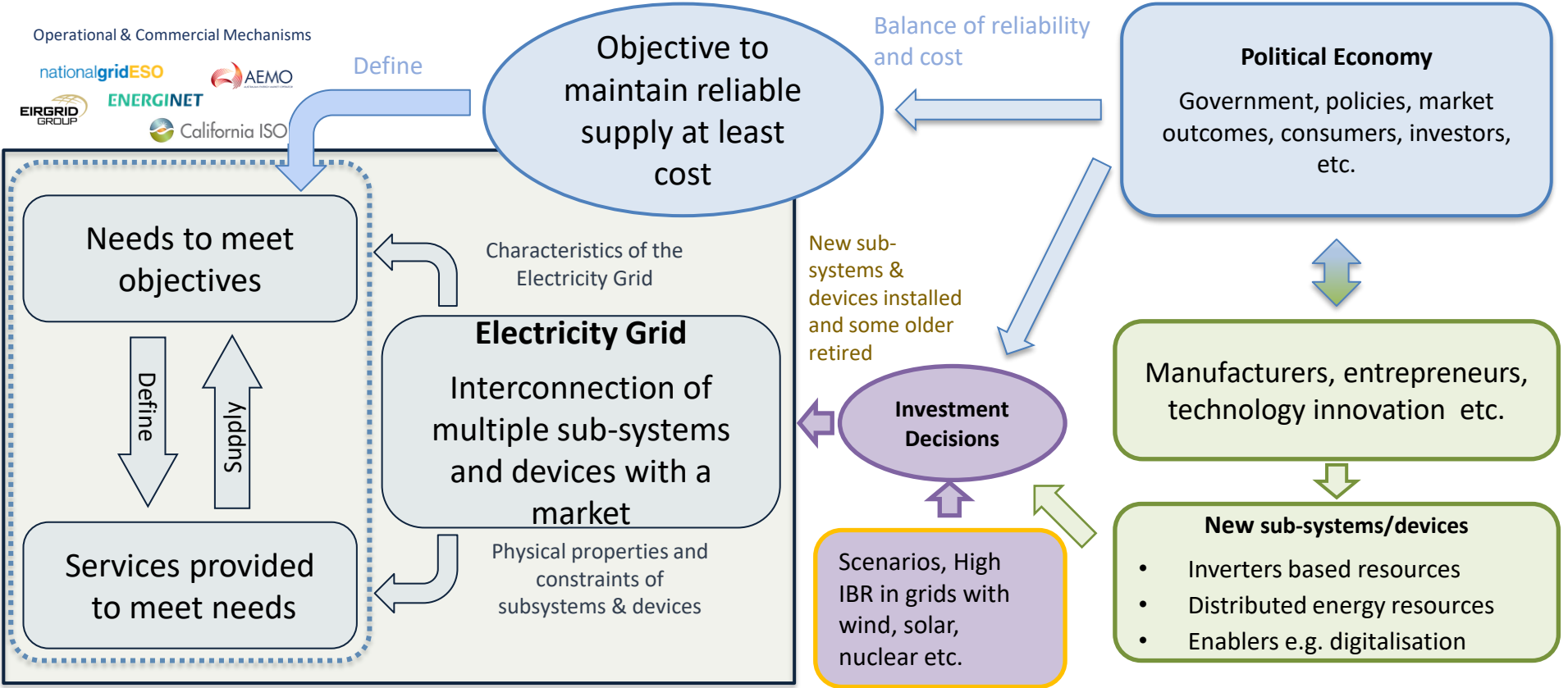
New sub-systems & devices installed and some older retired

Investment Decisions

Scenarios, High IBR in grids with wind, solar, nuclear etc.

Manufacturers, entrepreneurs, technology innovation etc.

- New sub-systems/devices**
- Inverters based resources
 - Distributed energy resources
 - Enablers e.g. digitalisation



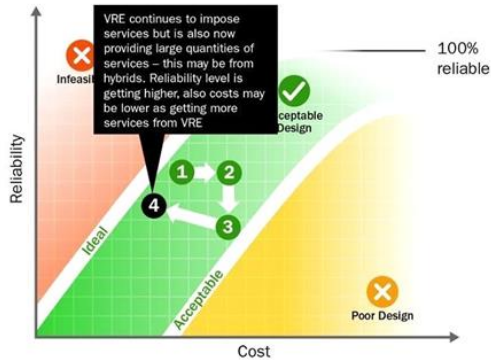
Framework needs much more work



A



B



D



C

O'Malley et al., "Grand challenges of Wind Energy Science – Meeting the needs and services of the power system", Wind Energy Science, in review.

Conclusion

- Significant detailed system level work needed to gain generalisable insights (ongoing)
- Managing needs and services due to IBRs replacing SMs we to have a rigorous process/methodology
- Need a framework to do this ?
- Have made a start – more to be done

Acknowledgements & Further Reading

- Leverhulme Trust International Professorship

Further Reading

- <https://globalpst.org/>
- <https://www.esig.energy/>