

4th International Symposium on Smart Grid- Methods, Tools, and Technologies

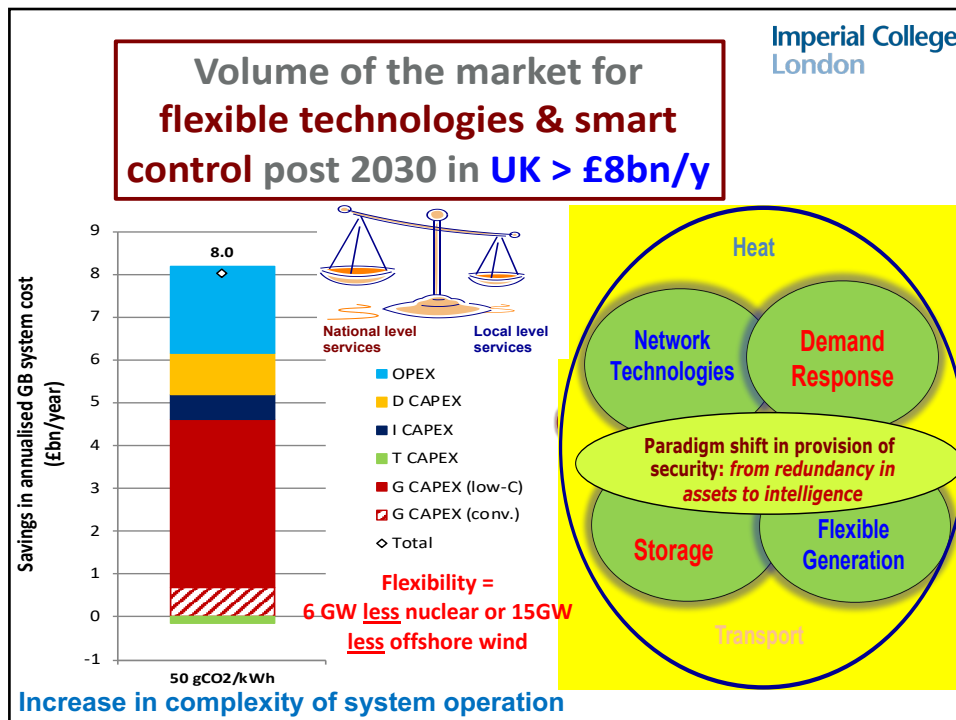
Challenges and opportunities for cost effective energy system decarbonisation

Imperial College London

Goran Strbac

D Pudjianto, P Djapic, X Zhang, M Aunedi, H Ameli, S Giannelos, F Teng

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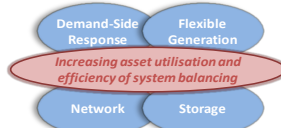
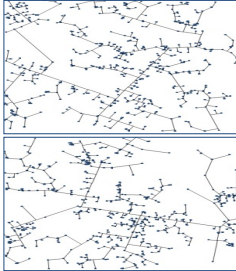


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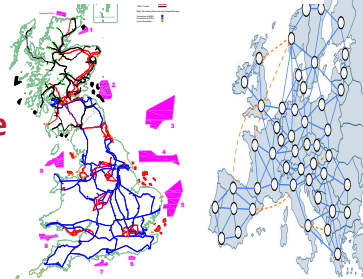
Whole-system modelling critical for capturing **Time** and **Location** interactions in *low carbon systems*

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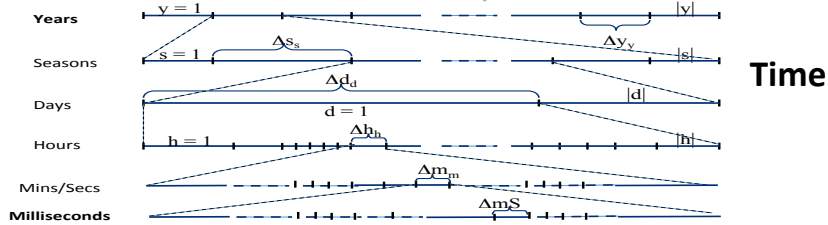
Local district level



National / International level



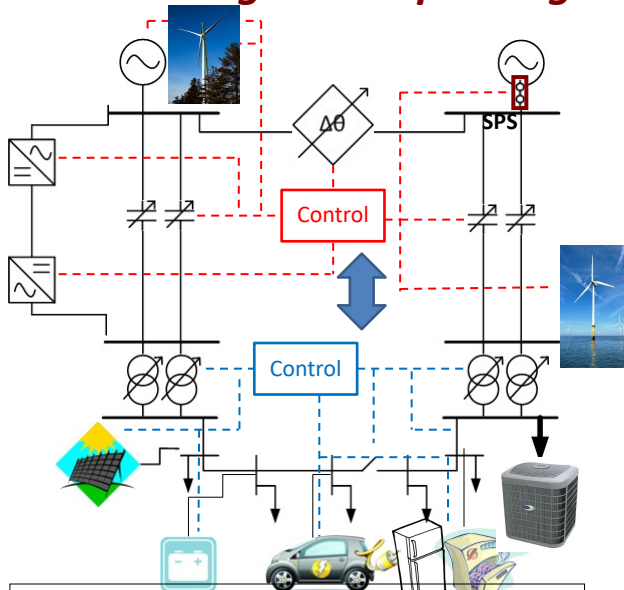
Space



Time

3

Operational challenge: *towards digitalised paradigm*



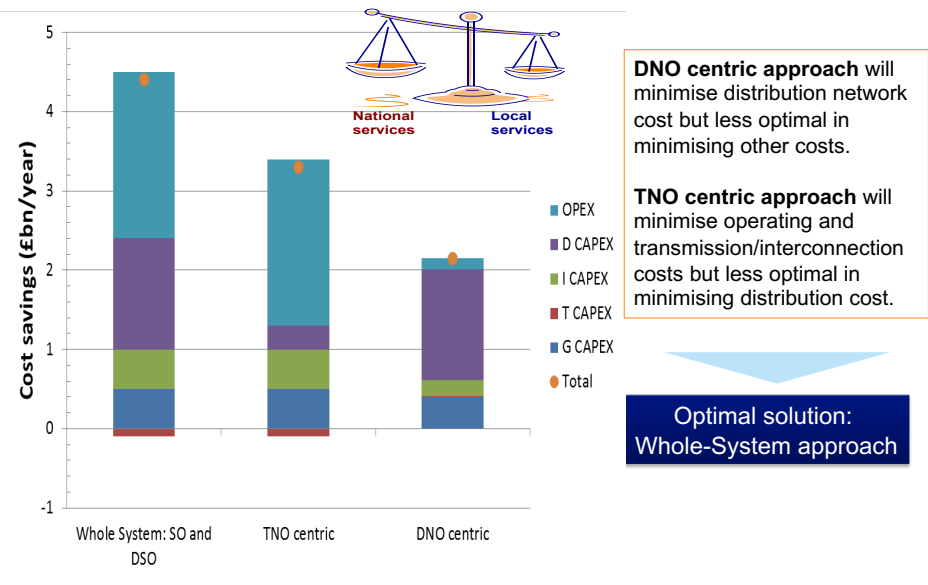
Paradigm shift in delivering security of supply: *from redundancy in assets to Energy Intelligence*

Integrated DSO & TSO operation
Energy Integration

Managing risks & uncertainties

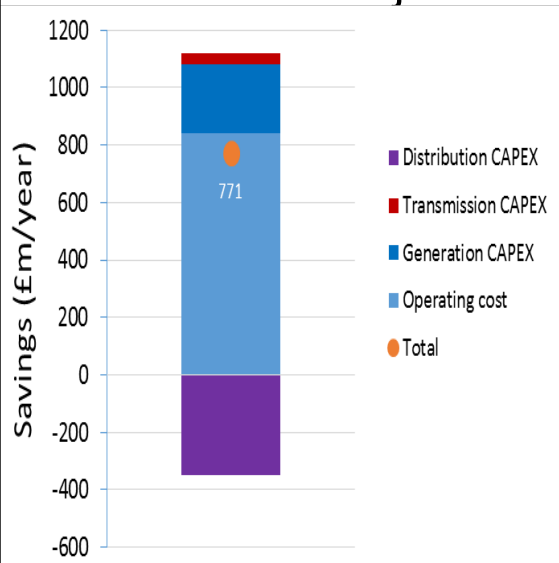
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Flexibility: focus on local or national level operation and infrastructure management ?



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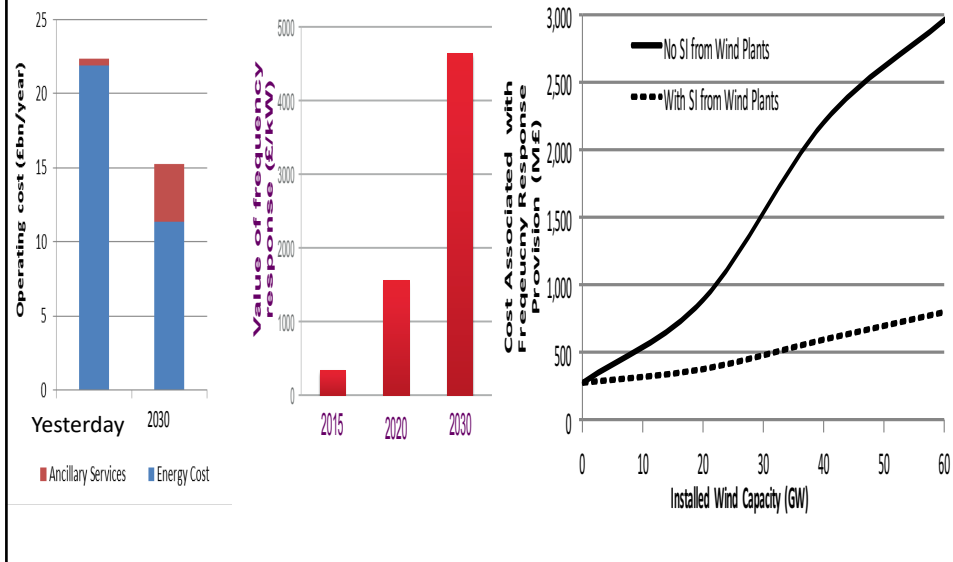
Balancing national and local objectives



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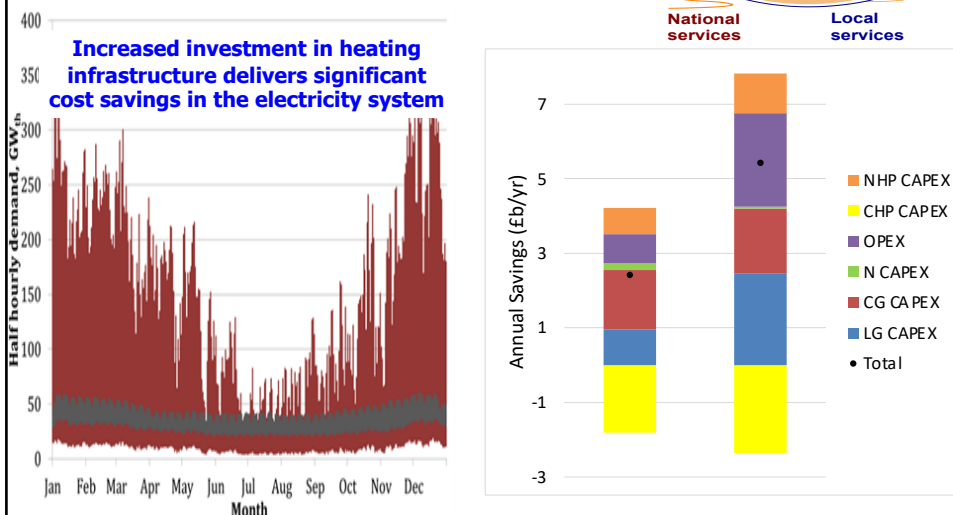
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Value of frequency response and Synthetic Inertia provided by wind generation



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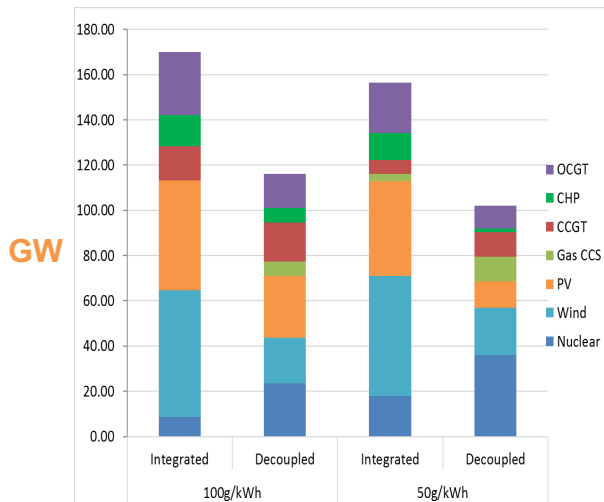
How important is the integration of heat, gas electricity, sectors?



Flexibility - significant opportunity from integrating heat / cooling, gas, electricity, transport, water infrastructure

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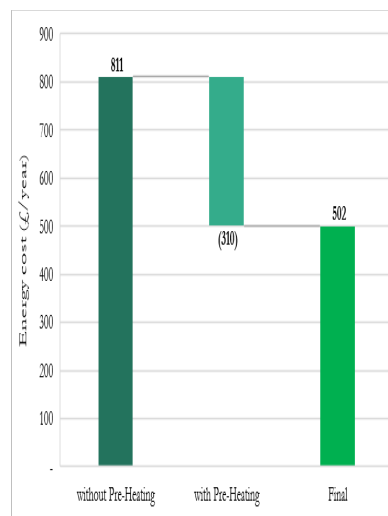
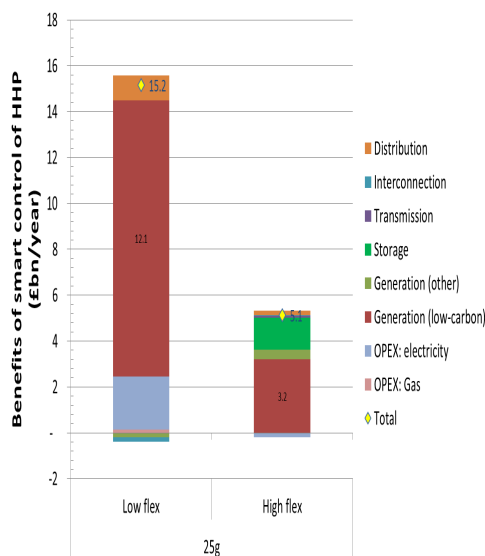
Importance of flexibility – impact on Electricity Generation mix



Cross vector flexibility improves the system ability to integrate variable RES

Optimal generation portfolio very dependant on cross-vector flexibility

System and consumer benefits of smart control of HHP



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Flexibility in combined gas/H₂ & electricity system

Volume of gas will reduce but the value of gas will increase

Importance of integrated operation paradigm: cost effective integration of renewables will require coordinated operation of gas & electricity systems.

Investing in flexibility in gas/H₂ system will provide savings in electricity system

Multi-directional compressors: reduction in operating cost of >£600m/y

Value (£/MWh)

Wind Penetration	Value (£/MWh)
20% Wind	~120
40% Wind	~250
60% Wind	~320

Legend

- Compressor
- Valves
- Pipelines
- Gas Flow

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Thermal storage or electricity storage ?

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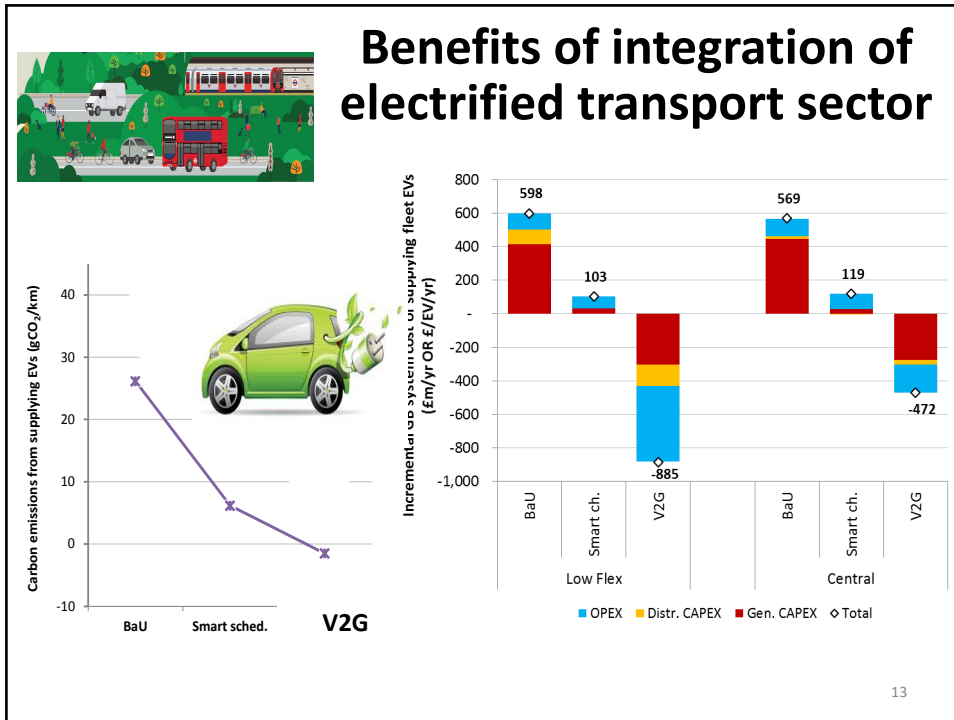
Multi-energy coupling also creates competition for flexibility resources across energy sectors

What are the appropriate commercial and regulatory frameworks ?

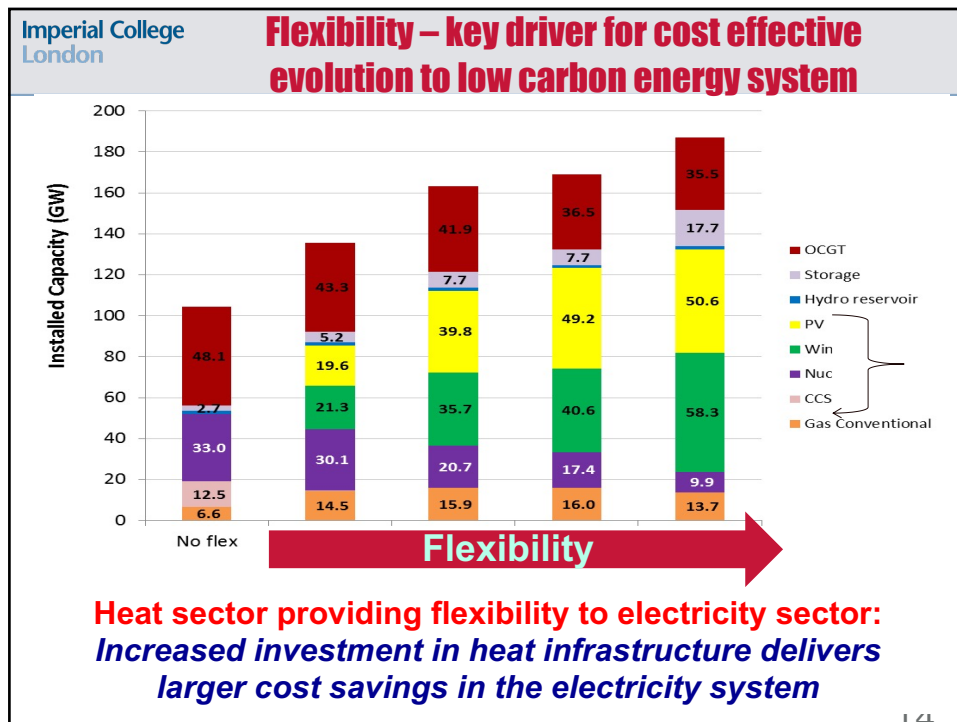
Capacity of new electricity storage (GW)

Level of thermal storage and preheating capability	Capacity of new electricity storage (GW)
Zero	~55
Low	~40
Medium	~25
High	~10

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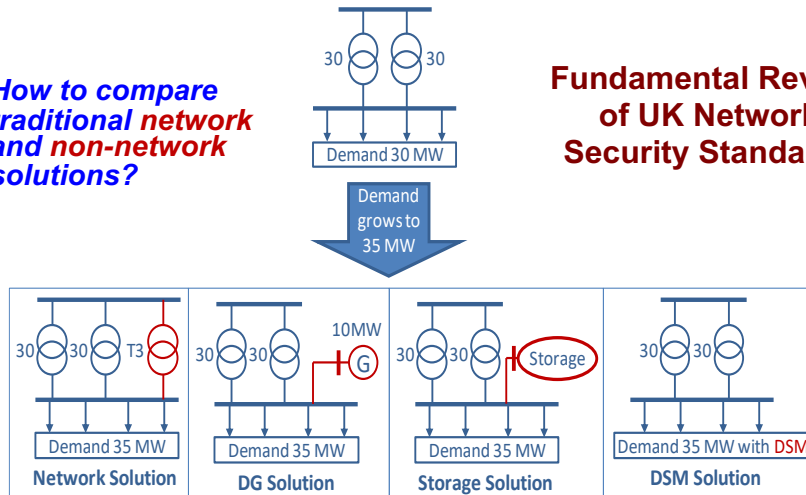


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Non-network solutions dealing with network problems Imperial College London

How to compare traditional network and non-network solutions?

Fundamental Review of UK Network Security Standards



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Paradigm shift in delivering security of supply: from redundancy in assets to smart control

VoLL = 17£/kWh

2 x 5 MW 2 x 5 MW 2 x 5 MW

5 MW 7.5 MW 10 MW

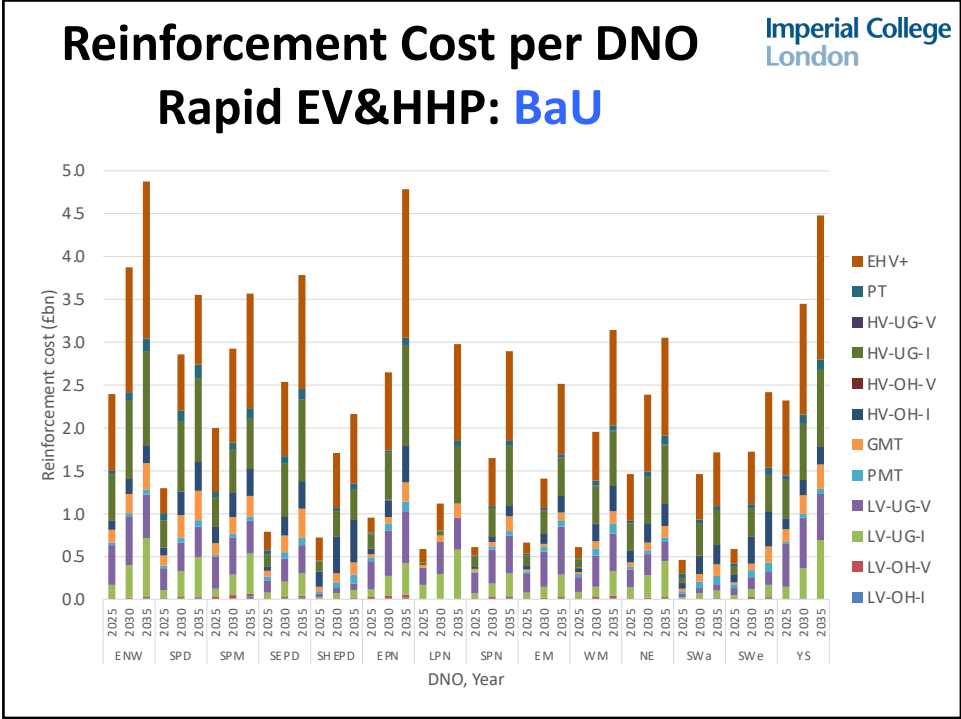
N-1 **N-0.5** **N-0**

Network Reliability	Security Level	BaU	Smart
Low	N-0.75	8.8	875.0
	N-0.5	3.4	182.1
	N-0.25	1.5	59.0
	N-0	0.7	21.5
High	N-0.75	90.2	9296.9
	N-0.5	35.4	1961.5
	N-0.25	15.2	625.0
	N-0	7.4	229.7

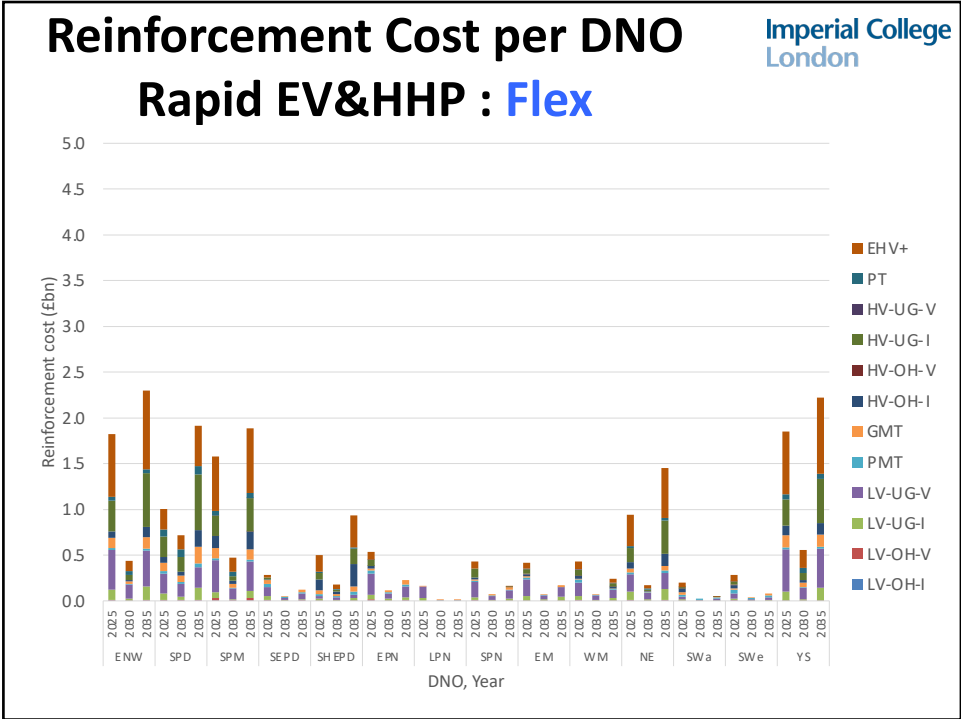
Potential savings of £5bn in reducing distribution network reinforcement at the GB level by 2030

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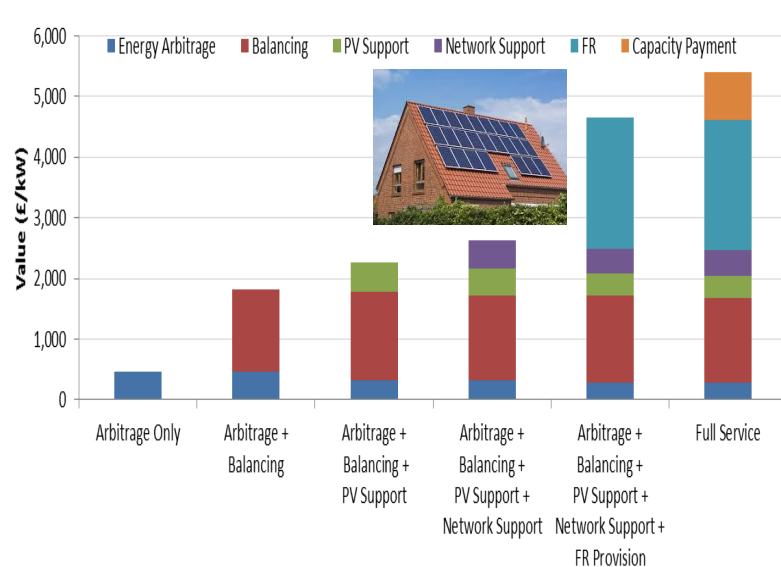
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System benefits of flexible distributed energy resources - multi-service provision

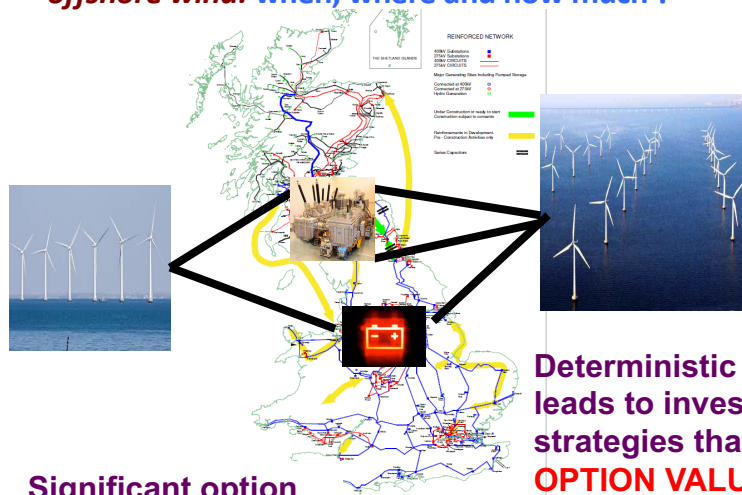
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Dealing with uncertainty in future development of offshore wind: when, where and how much?

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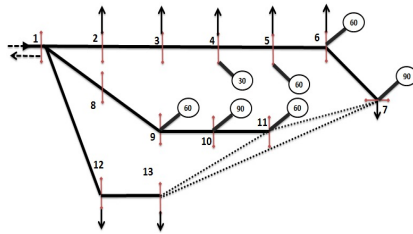


Significant option value of flexible technologies

Deterministic planning leads to investment strategies that may ignore **OPTION VALUE** of flexible technologies and favour conventional investments

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Investment under uncertainty managing EV - driven constraints – Option Value of SOP

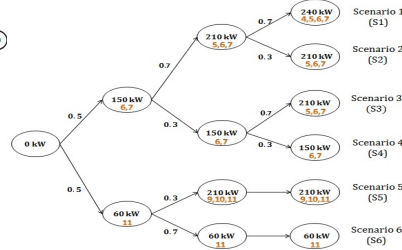


- Smart Options:**
 (a) Soft Open Points
 (b) Coordinated Voltage Control
 (c) Demand Side Response

STOCHASTIC APPROACH – SIGNIFICANT OPTION VALUE OF SMART

	Stage1	Stage2	Stage3	Stage4
S1	-	• DSR • SOP	• SOP • Conventional	-
S2	-	• DSR • SOP	• SOP • Conventional	-
S3	-	• DSR • SOP	-	• SOP
S4	-	• DSR • SOP	-	-
S5	-	-	• CVC • SOP	-
S6	-	-	-	-

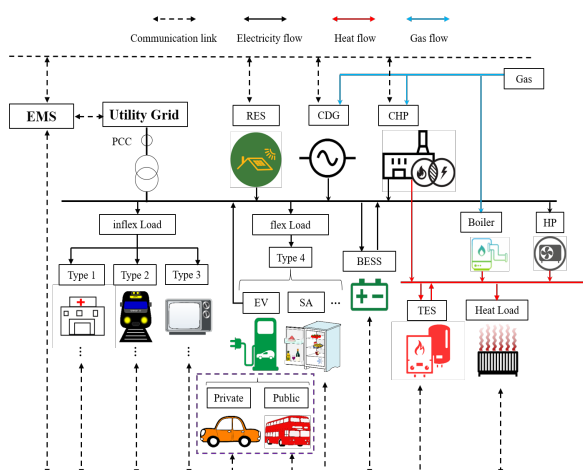
Uncertainty: Location and volume of EVs



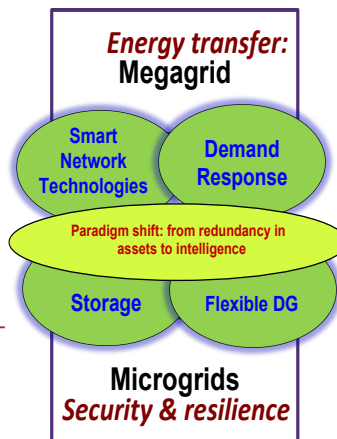
DETERMINISTIC APPROACH

	Stage1	Stage2	Stage3	Stage4
S1	• Conventional	-	• DSR	-
S2	• Conventional	-	• DSR	-
S3	• Conventional	• DSR	• Conventional	-
S4	• Conventional	• DSR	-	-
S5	-	• Conventional	-	-
S6	-	-	-	-

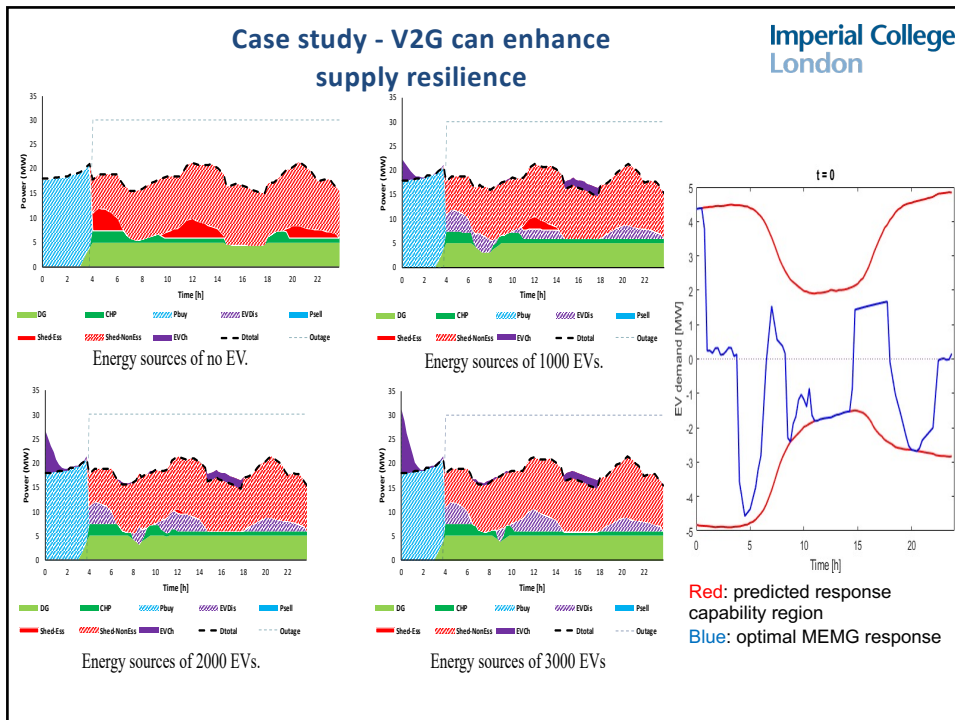
Enhancing energy supply resilience through digitalisation



Multi-energy Micro-grids providing resilience to Mega-grids



From Incremental to Strategic thinking



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From Centralised to Decentralised Control, Trading, Operation

gridmates
Connect with energy.™

**SOLUTIONS:
THE P2P ECONOMY**

HOME SMART

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Will investment in flexibility be commercially viable?

**Access to all benefits and corresponding revenue streams –
Market reform**

- **Access to balancing services**
 - ✓ Participate in balancing market
- **Access to Ancillary Services market**
 - ✓ Primary/secondary / tertiary frequency regulation services, inertia, voltage, stability, etc.
- **Access to capacity market**
 - ✓ Reducing need for peaking plant – contribution to capacity market
- **Access to network management market**
 - ✓ Reducing need for network reinforcement
- **Reducing need for low carbon generation**
 - ✓ Meeting carbon targets with minimum LC generation
- **Access to option value**
 - ✓ Providing flexibility to deal with uncertainty

Smart network technologies

Demand Response

Paradigm shift in delivering security of supply: from redundancy in assets to intelligence

Storage

Flexible Generation

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Linking demand and supply through **Integrated Marketplace**

Yesterday

Emerging Smart Future

Climate change

Energy Security

Technology

Aging assets

Markets

Whole-Systems approach needed

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Many thanks!!

**4th International Symposium on Smart Grid-
Methods, Tools, and Technologies**

*Challenges and opportunities for cost
effective energy system decarbonisation*