Imperial College London

Assessing whole-system costs of low-carbon generation technologies (GB/EU context)

G Strbac, M Aunedi, D Pudjianto
Imperial College London
2 October 2018

Imperial College London

Context

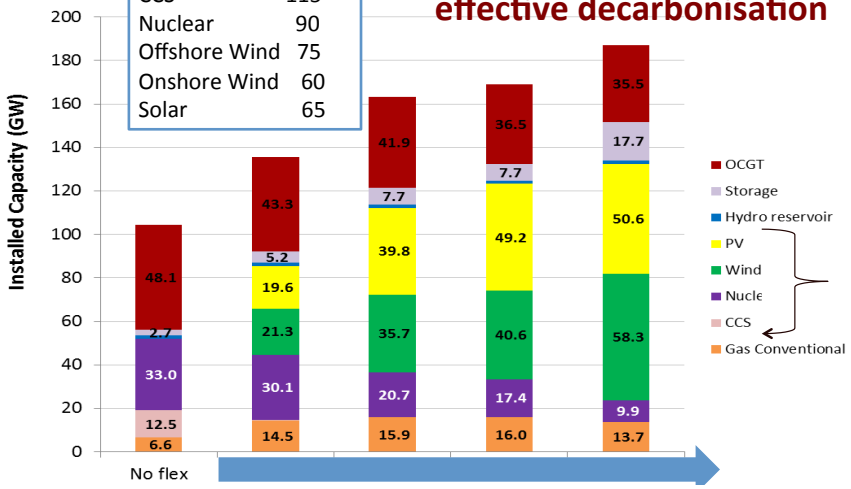
- Facilitating cost effective decarbonisation of electricity generation sector
  - *How do we compare cost of different low carbon technologies?*
  - *How to establish level playing field between different low carbon technologies?*
- Future renewable energy projects are expected to be profitable with little / no government support
  - *Carbon targets? Level of penetration of RES? Role of firm low carbon generation? Market design?*

LCOE = ***average price*** that generating asset must receive to break even over its lifetime

Imperial College London

LCOE (£/MWh)	
CCS	115
Nuclear	90
Offshore Wind	75
Onshore Wind	60
Solar	65

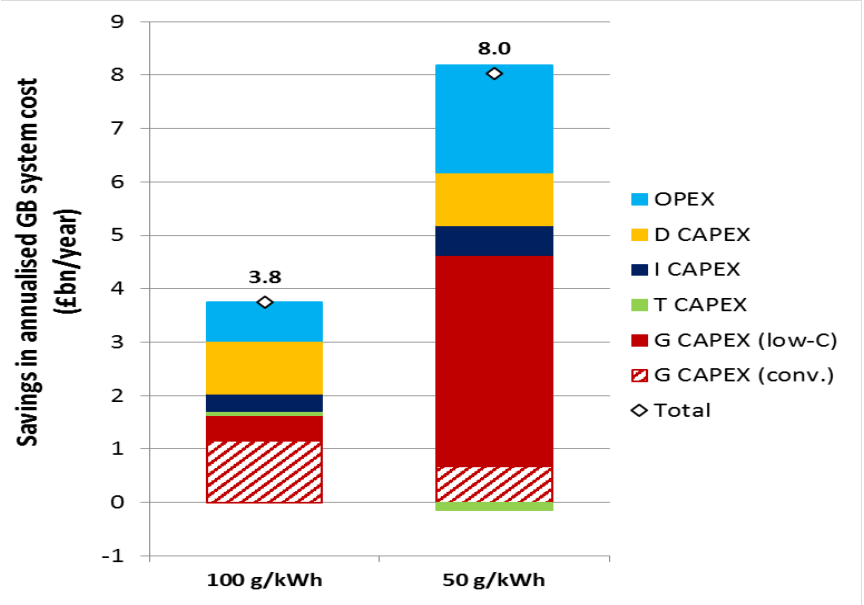
Flexibility – key driver for cost effective decarbonisation



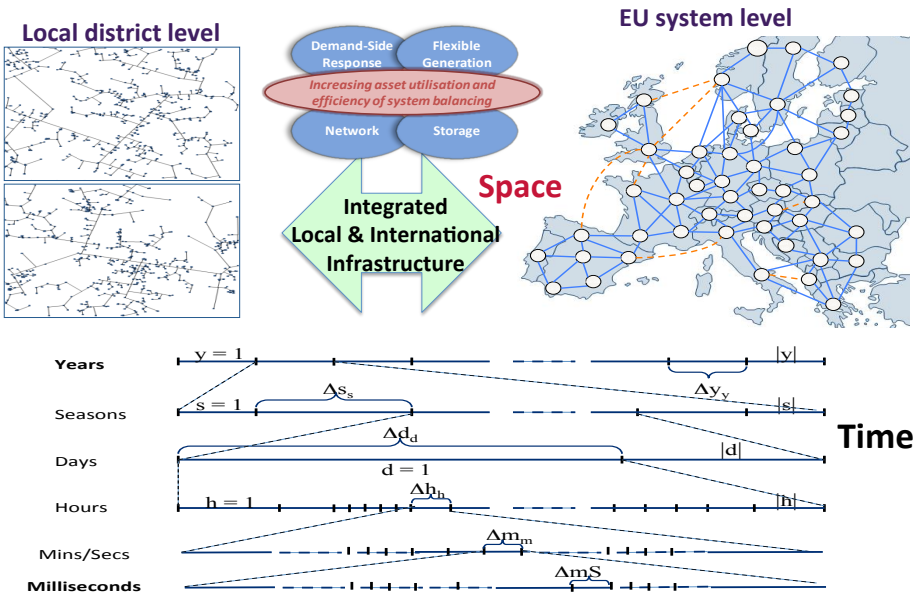
Flexibility

Imperial College London

Value of flexibility



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



System Integration Cost: *Concept*

- **Issue**: how to compare ***Levelized Cost of Energy/Electricity*** (LCOE) of different low carbon generation technologies?
- **Approach**: quantify Whole-system cost (WSC) of any generation technology representing the sum of the levelised cost of energy (LCOE) and the system integration cost (SIC):

$$WSC_{gen} = LCOE_{gen} + SIC_{gen}$$

- SIC components : *Increased balancing cost, network reinforcements, losses, Increased backup capacity cost, cost of maintaining system carbon emissions*

- **Definition**: *?*
- **Approach**: *Whole-system approach*

Imperial College London

Methods to determine System Integration Cost - *Examples*

Relative

- **Method 1**
  - Nuclear removed; model expands optimally wind/PV to meet carbon target (incremental)

→ *SIC [£/MWh] = change in total system cost ignoring the CAPEX/OPEX of two technologies involved, divided by substituted (nominal) generation output*

Absolute

- **Method 2**
  - Add nuclear, or wind, or PV or CCS; model allowed to re-optimise system

→ *Marginal benefit [£/MWh] = reduction in total system cost ignoring the CAPEX/OPEX of the low-C technology involved, divided by additional generation output*

Imperial College London

SIC & Flexibility

Flexibility

Scenario	No Flex	Low Flex	Mid Flex	Modern isation	Mega Flex
Year	2030	2030	2030	2030	2030
New storage (GW)*	0	5	10	10	15
DSR	0%	25%	50%	50%	100%
Interconnection (GW)**	7.5	9.9	11.3	11.3	15.0

** New storage capacity was optimally allocated across GB regions and network types.*
*** In all scenarios the model was allowed to add interconnection capacity (at a cost) if cost-efficient.*

LCOE (£/MWh)	
Nuclear	90
Offshore Wind	75
Onshore Wind	60
Solar	65

Modernisation

- Wind generators able to provide synthetic inertia and frequency response
- Wind generators able to provide reserve when curtailed
- Improved forecasting of wind
- Ability to procure frequency response services via interconnectors

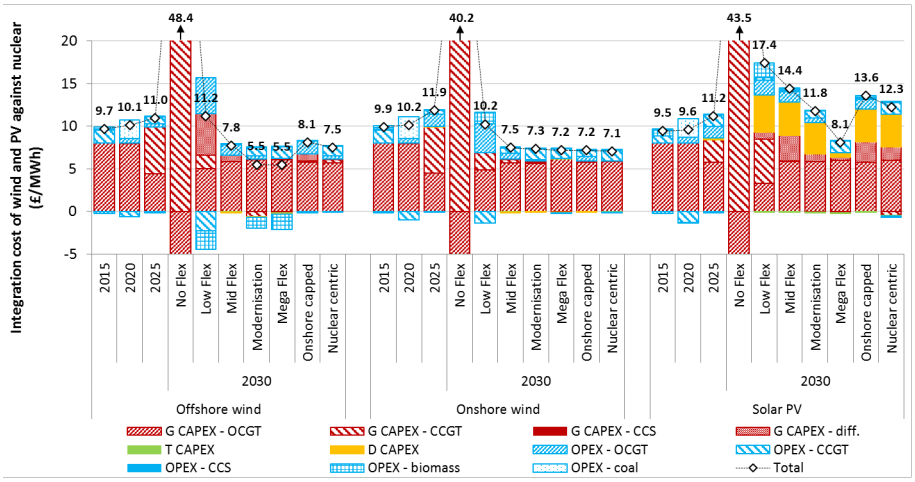
Imperial College London

Whole System Costs per scenario for three variable renewable technologies

Scenario name	No Flex	Low Flex	Mid Flex	Moderni-sation	Mega Flex		Onshore capped	Nuclear centric
				LCOE				
Nuclear	90	90	90	90	90		90	80
Offshore wind	75	75	75	75	75		70	80
Onshore wind	60	60	60	60	60		60	60
Solar PV	65	65	65	65	65		65	65
				SIC vs. nuclear				
Offshore wind	48.4	11.2	7.8	5.5	5.5		8.1	7.5
Onshore wind	40.2	10.2	7.5	7.3	7.2		7.2	7.1
Solar PV	43.5	17.4	14.4	11.8	8.1		13.6	12.3
				Whole-System Cost (WSC)				
Offshore wind	**123.4**	**86.2**	**82.8**	**80.5**	**80.5**		**78.1**	**87.5**
Onshore wind	**100.2**	**70.2**	**67.5**	**67.3**	**67.2**		**67.2**	**67.1**
Solar PV	**108.5**	**82.4**	**79.4**	**76.8**	**73.1**		**78.6**	**77.3**

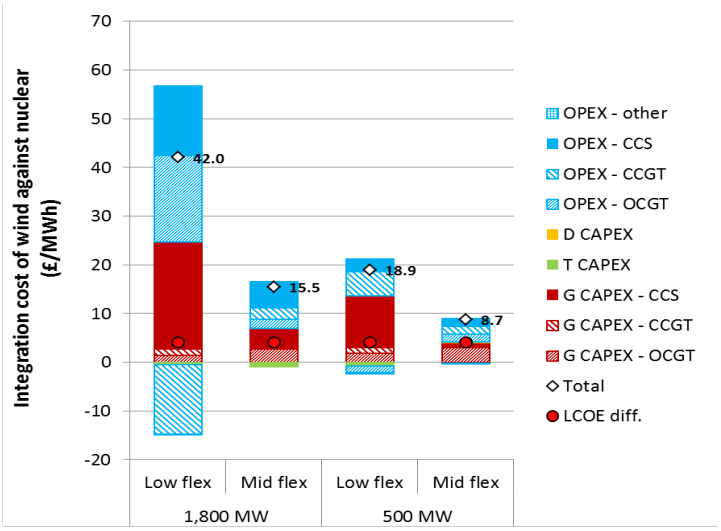
Imperial College London

System Integration Costs per scenario for three variable renewable technologies



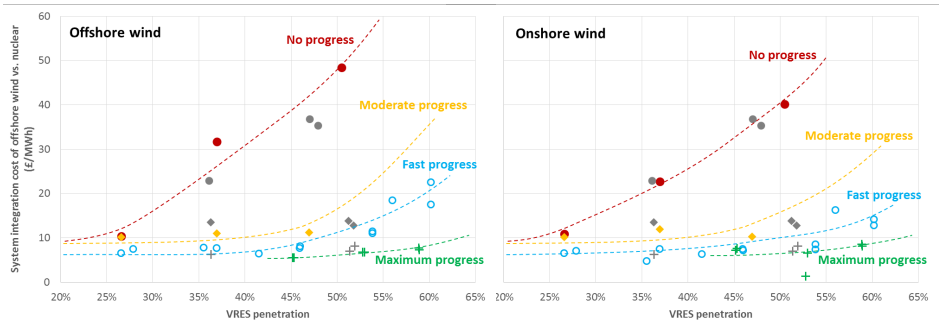
Imperial College London

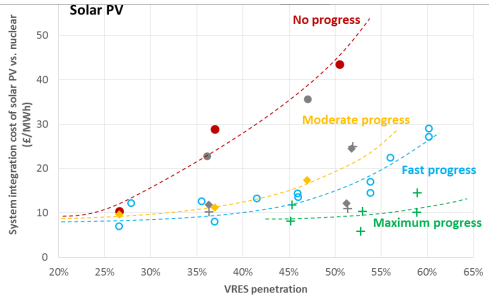
Impact of largest generator loss on SIC



SIC vs. RES penetration and flexibility

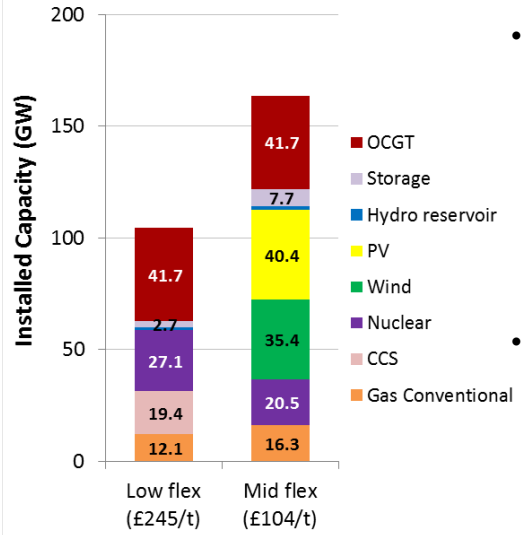
Imperial College London





Imperial College London

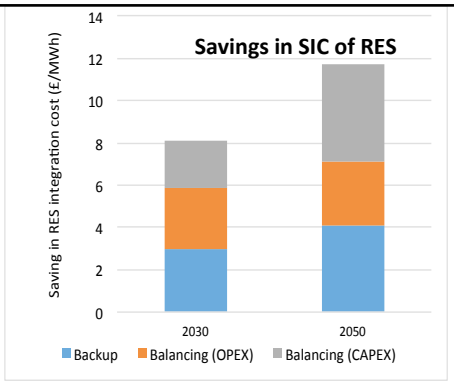
Required level of carbon price to reach decarbonisation objectives as function of flexibility

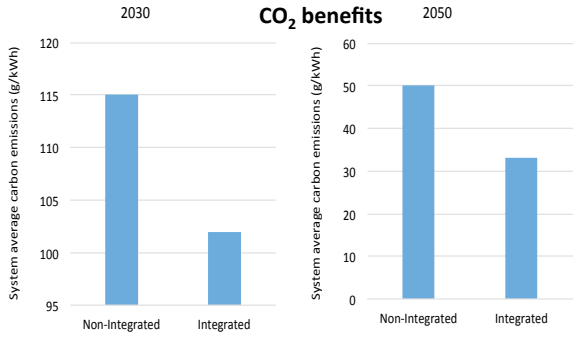


- Which carbon price would be needed to reach the intensity of 50 g/kWh in 2030 in the absence of explicit carbon emission constraint, for different flexibility levels?
- Presence of flexibility greatly reduces the required carbon price needed

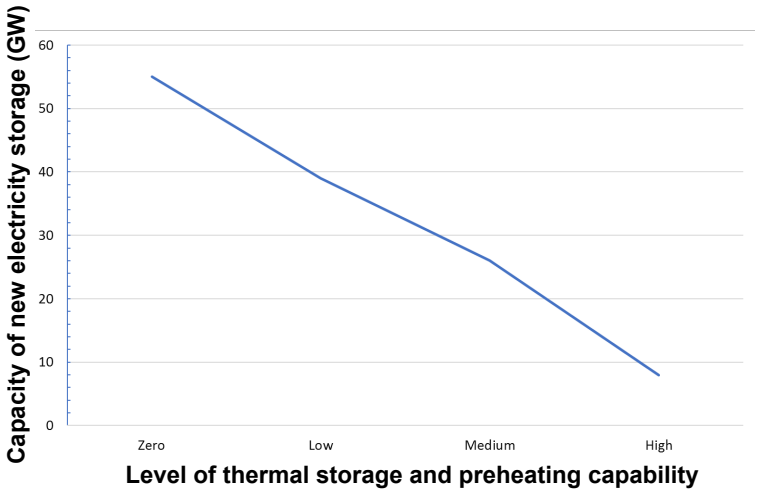
Imperial College London

Integrated operation of heat and electricity system reduces SIC of renewables and carbon emissions



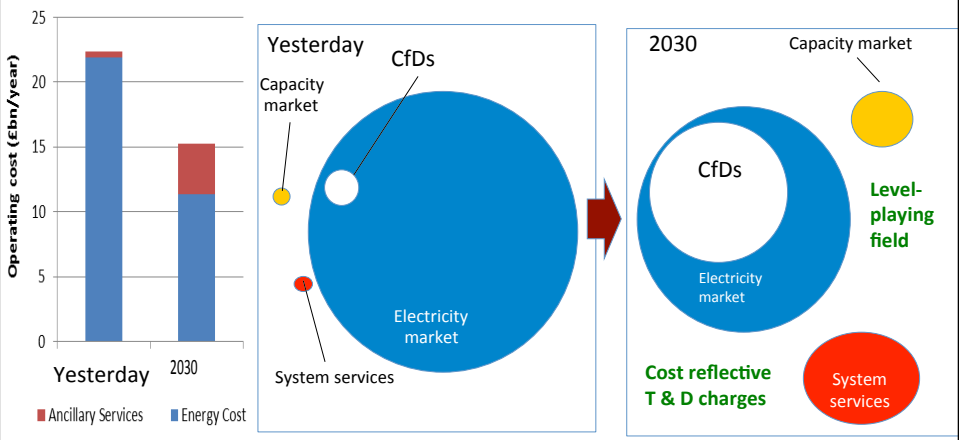


Thermal storage or electricity storage?



Imperial College London

Market (r)evolution



Historically, policy focus has been on the energy only:
Significant change is needed!

Imperial College London

Findings

- WSC & SIC are very much driven by system flexibility
  - Flexibility makes RES competitive against nuclear in 2030/2040 except if there is no progress in system flexibility
- SIC of RES increase significantly with level of penetration
  - Very low carbon target - firm low carbon generation (nuclear) or seasonal storage are needed
- If the market is cost reflective, low carbon technologies will be exposed to system integration cost
- Integrated energy system approach will reduce SIC of RES (multi-vector approach)
- Linking market design with decarbonisation objectives (meeting carbon target at minimum cost)

Imperial College London

Assessing whole-system costs of low-carbon generation technologies (GB/EU context)

G Strbac, M Aunedi, D Pudjianto
Imperial College London
2 October 2018