ENERGY INSTITUTE

UCL

5th International Conference on Smart Energy Systems
Copenhagen, 10-11 September 2019
#SESAAU2019

A METHOD FOR MODELLING GENERATION COSTS IN A SYSTEM WITH RENEWABLES AND LARGE SCALE GRID STORAGE FOR USE IN ENERGY SYSTEM MODELS

SALMAN SIDDIQUI

PHD CANDIDATE, UCL ENERGY INSTITUTE

SUPERVISORS

PROF. MARK BARRETT, DR. CATALINA SPATARU, JOHN MACADAM

Powered by

AALBORG UNIVERSITY DENMARK

reINVEST

sEEnergies

Fonden Energi- & Miljødata
www.emdfonden.dk

4DH

UN environment

DISTRICT ENERGY IN CITIES INITIATIVE

Innovation Fund Denmark

Background

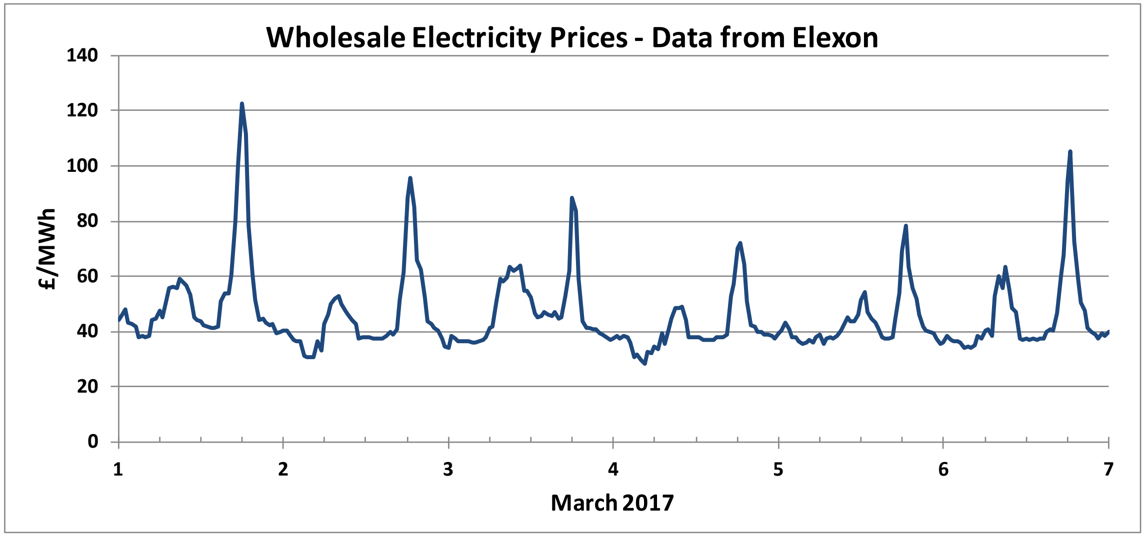
Balancing is essential for security of the grid, dispatchable thermal power plants – provide flexibility but must be phased out.

Net zero emission target increases dependency on renewables and nuclear. Fossil fuels with CCS cannot be used on a large scale.

Battery storage (li-ion) is a leading proposition to providing flexibility and grid balancing.

An increase in variable renewable power generation will potentially lead to greater volatility in electricity prices.

- Electricity prices patterns for large half-hourly consumers have generally been predictable following daily variances between peak and off-peak times (below)
- To aid planning of future electricity based investments and operation such as heat pumps, it is necessary to understand the future price patterns of electricity.
- This may present synergies between certain demand vectors such as heating and heat storage that can efficiently utilise low electricity prices
- The cost of batteries must also be factored into the cost of electricity if decisions are to be made on investment in other forms of energy storage.



METHOD

- A simplified representation of the electricity network is constructed
- Hourly historic demand data is scaled for future demand scenarios
- Hourly renewable data is extrapolated for future energy scenarios from corresponding historic timeseries data from Renewables Ninja [1,2]
- Power generation is disaggregated via generator type rather than each generator i.e. Offshore Wind Power as a total rather than each individual Wind Farm
- Storage and Dispatchable generation are assumed to be the main grid balancing methods available
- No constraints modelled - such as transmission and power constraints
- Only electricity (battery) storage modelled
- Merit order of carbon intensity - Dispatchable (thermal) generation only used if renewable generation + storage reserves are insufficient to meet demand

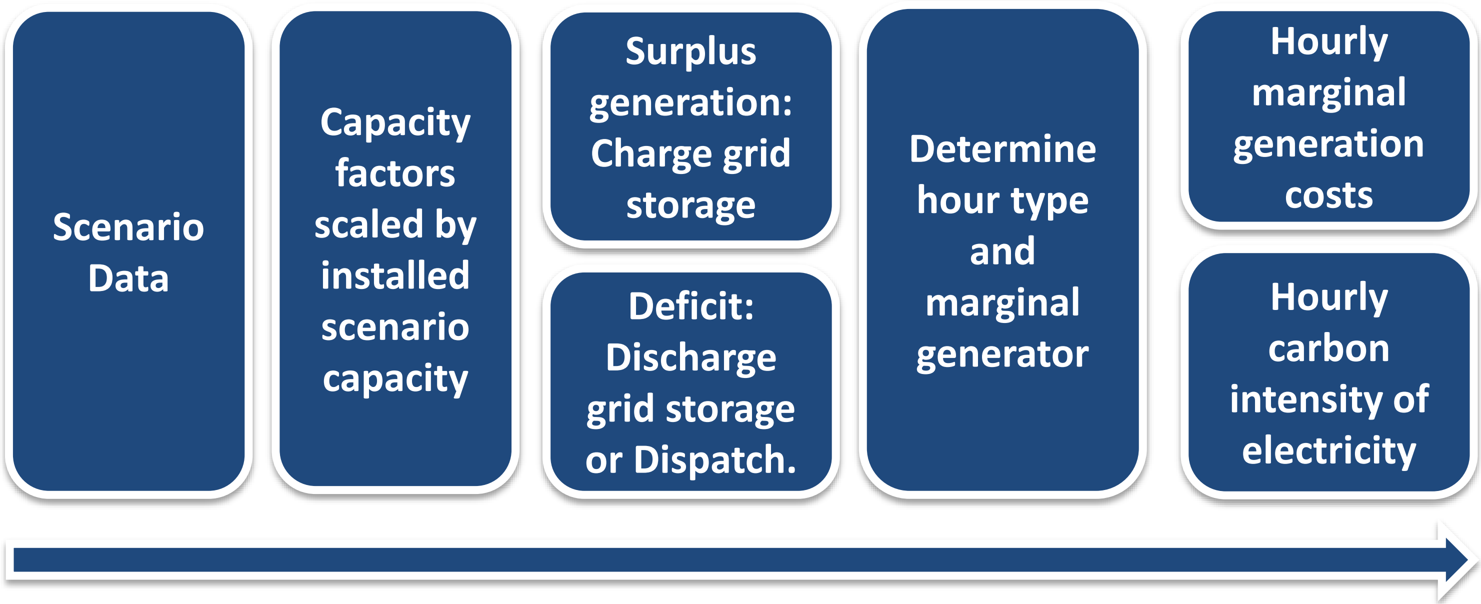
[1] Pfenninger, Stefan and Staffell, Iain (2016). Long-term patterns of European PV output using 30 years of validated hourly reanalysis and satellite data. Energy 114, pp. 1251-1265. doi: 10.1016/j.energy.2016.08.060
[2] Staffell, Iain and Pfenninger, Stefan (2016). Using Bias-Corrected Reanalysis to Simulate Current and Future Wind Power Output. Energy 114, pp. 1224-1239. doi: 10.1016/j.energy.2016.08.068

Four Hour Types:

1. **Surplus Generation** – Hours where supply exceeds demand and storage capacity
2. **Charge Hours** – Hours where storage is charged with surplus generation
3. **Discharge Hours** – Hours where storage is discharged
4. **Dispatch Hours** – Hours where backup dispatchable generation is required

- Charge and Discharge hours subdivided into part and full-cycles
- Dispatch hours subdivided into off-peak and peak (≈3% highest dispatch) hours

- Different algebraic expression to calculate marginal costs of each hour type
- Mixed hour types weighted accordingly


Scenario Data
Capacity factors scaled by installed scenario capacity
Surplus generation: Charge grid storage
Deficit: Discharge grid storage or Dispatch.
Determine hour type and marginal generator
Hourly marginal generation costs
Hourly carbon intensity of electricity

Surplus Hours Cost =

f (

- **Variable costs** of Marginal Renewable Generator
- Cost of Constraining Marginal Renewable Generator

)

Charge Hours Cost =

f (

- Fixed costs of storage
- Variable costs of storage
- Fixed costs of Marginal Renewable Generator
- Variable costs of Marginal Renewable Generator
- **Charge amount**
- Storage Capacity
- **Capacity factor** of Marginal Renewable Generator

)

Discharge Hours Price =

f (

- **Cost of charging storage capacity**
- Discharge amount
- Storage efficiency

)

Off-peak Dispatch Hours Price =

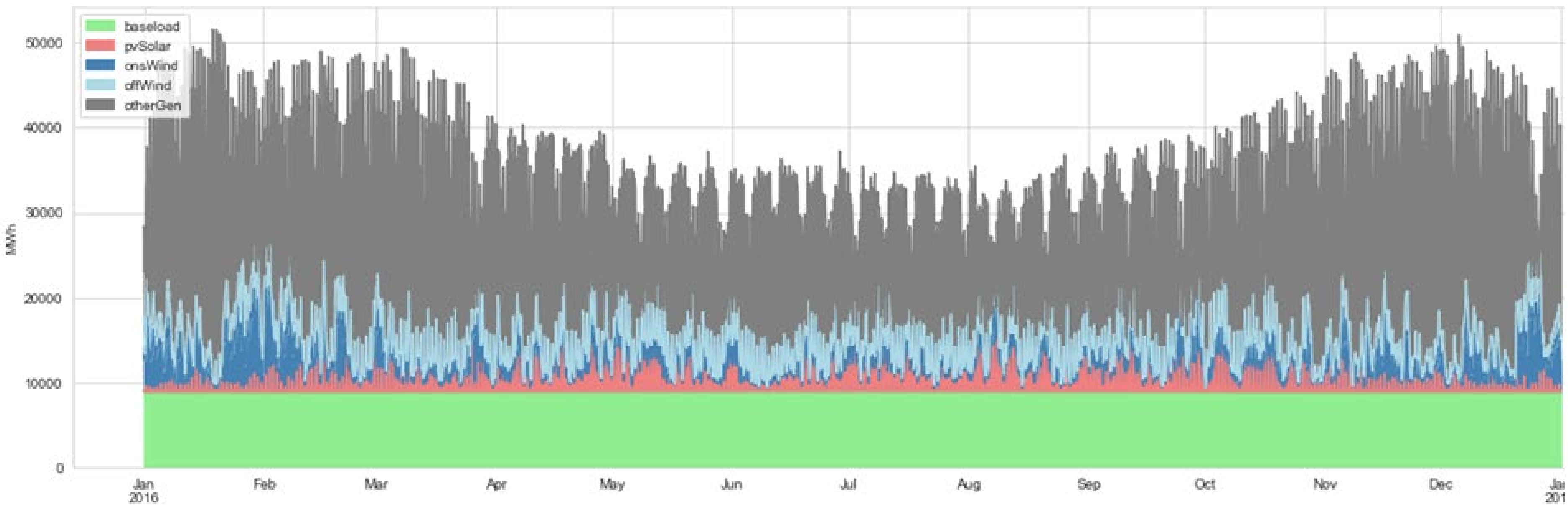
f (
- Variable operating costs of Dispatchable Generator
)

Peak Dispatch Hours Price =

f (
- Variable operating costs of Dispatchable Generator
- **Fixed operating costs** of Dispatchable Generator
- Capacity of Dispatchable Generation
- Outage Rate
- Hourly Dispatchable Generation
)

Comparison to 2016 data

	Dispatchable TWh	All Renewables TWh	Daily wholesale costs £		
			min	mean	max
2016 Actual Data	140.84	47.78	22.11	41.12	166.63
2016 Simulated	148.15	51.36	22.25	58.30	160.08

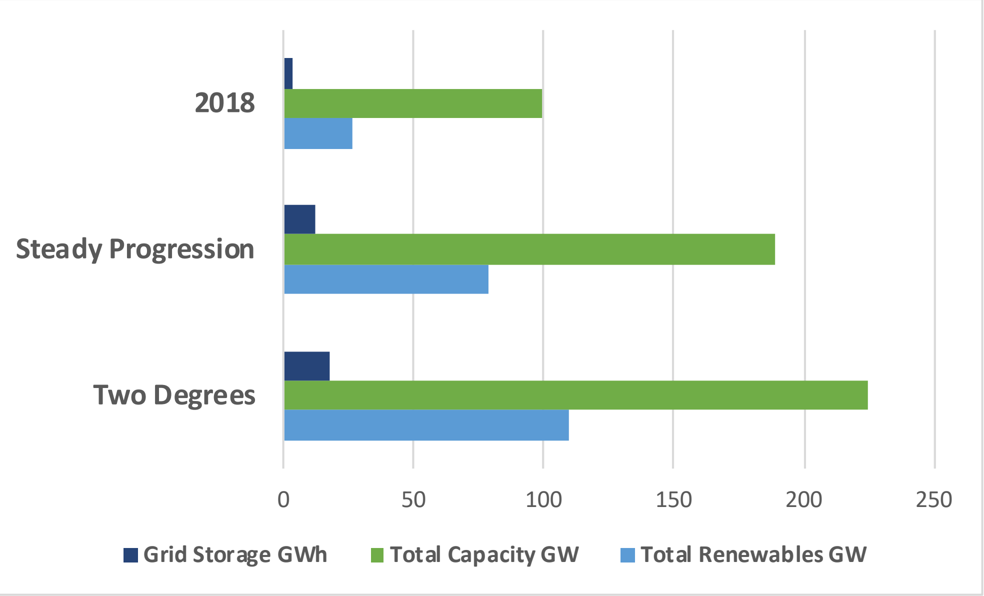


nationalgrid

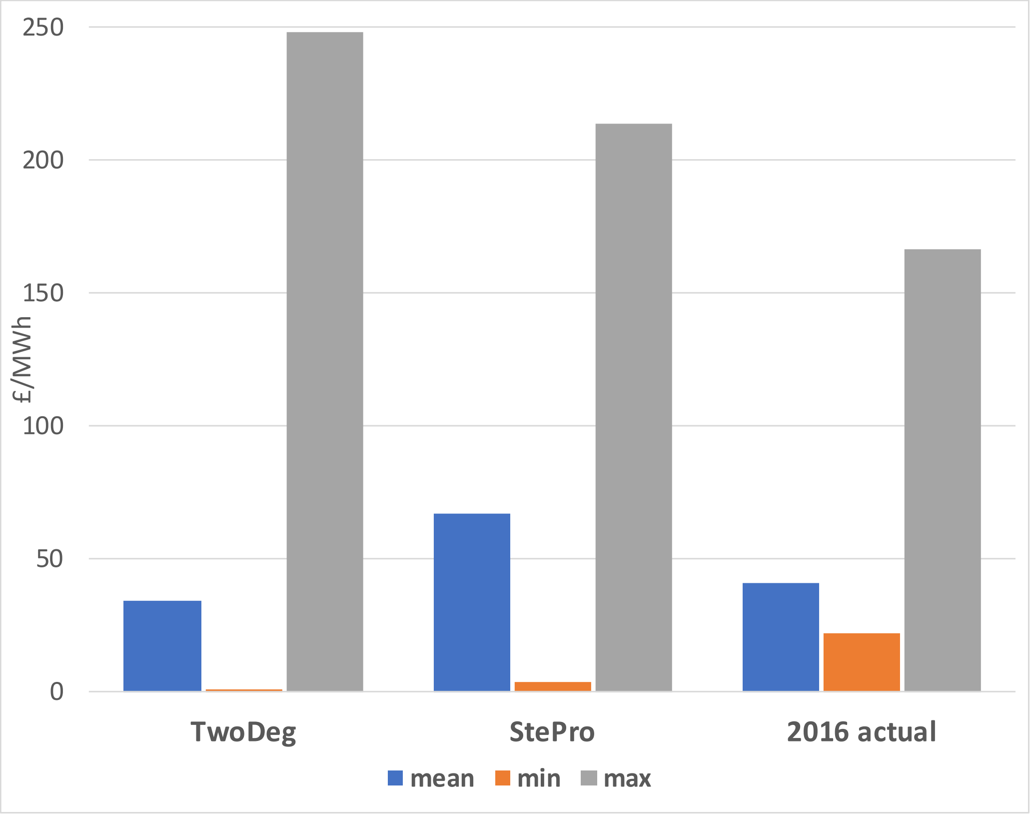
Future Energy Scenarios

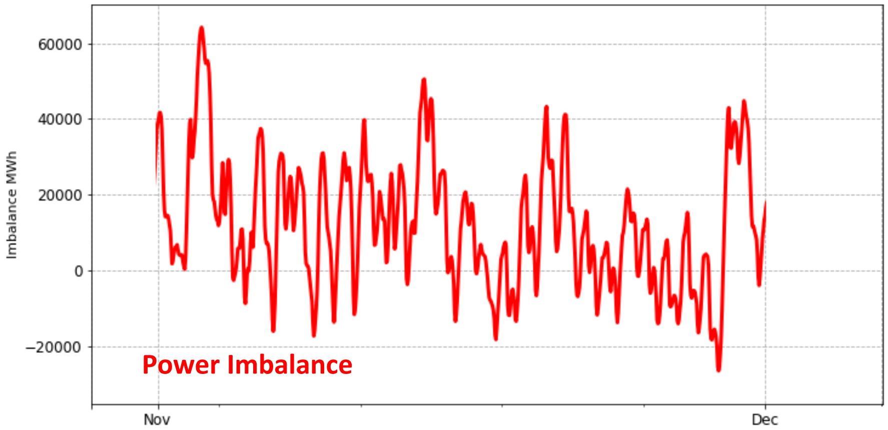
- Annually updated report on projections for UK
- Four scenarios accounting for prosperity and ambition

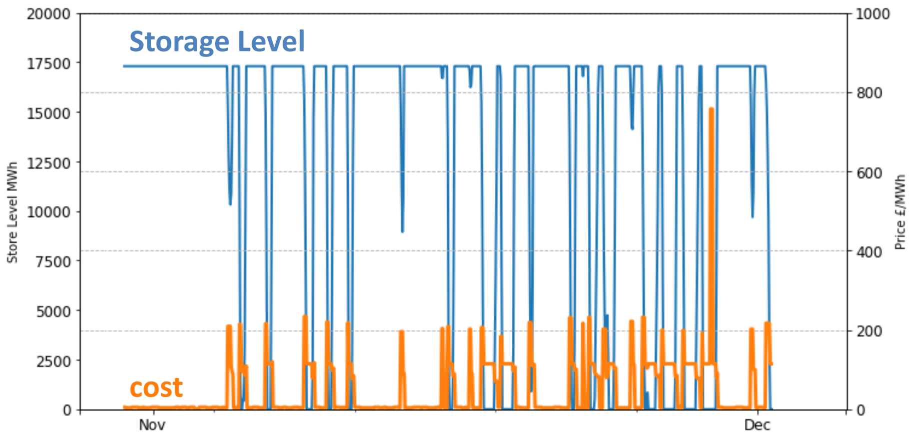
- “Steady Progression” + 30% Demand
  “Two Degrees” + 25% Demand
  (relative to 2018)



- Higher renewables scenario had lower mean costs – even less than current
- And lower minimum cost
- But higher maximum costs – fewer dispatch hours
- Owing to increased cost volatility





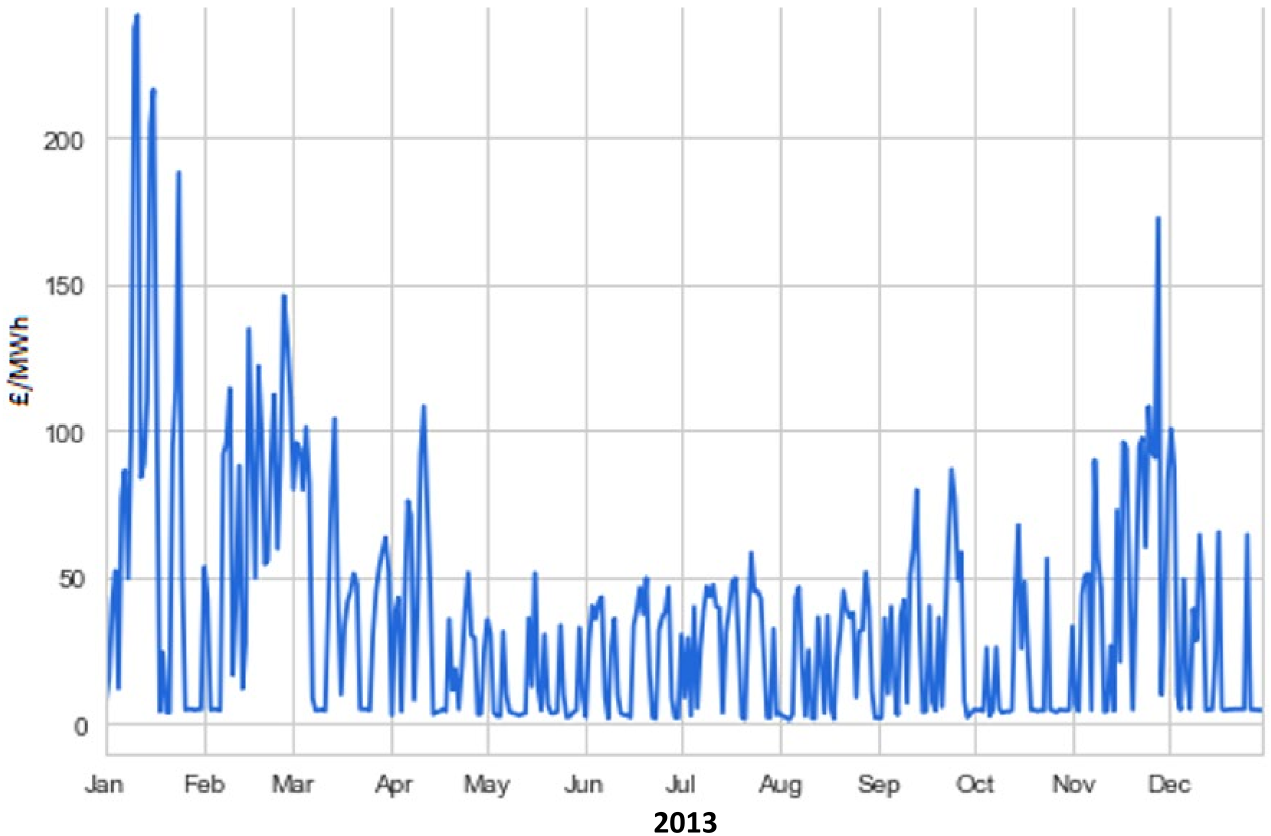


TwoDegree Scenario:

- Store Capacity - 17.5 GWh
- Renewable Capacity – 109 GW
- Demand +25% (rel. to 2017)

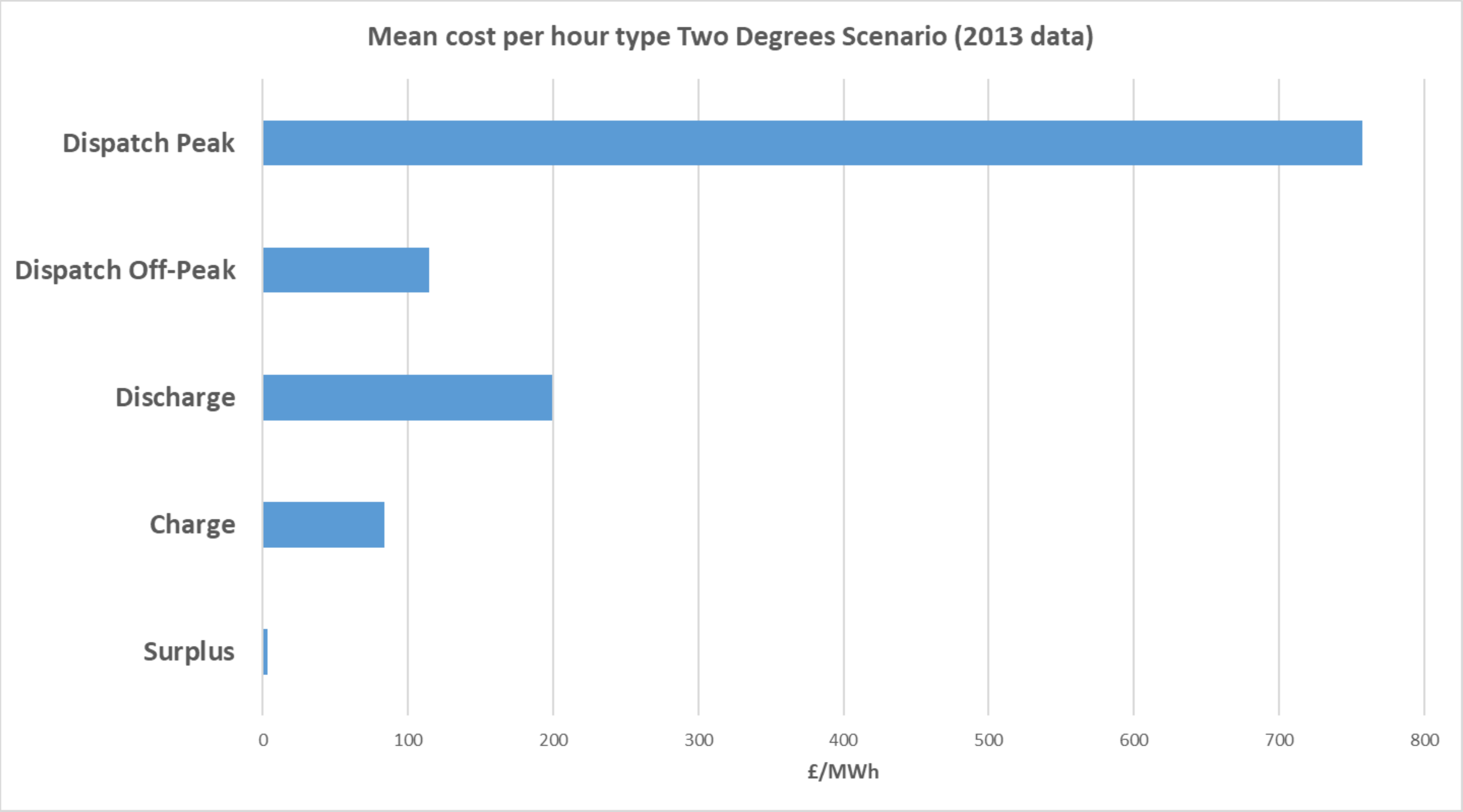
- High cycling of storage between charge and discharge cycles
- Dispatchable generation frequently required due to depleted storage
- Very low costs for surplus hours due to low operating costs of renewable generators
- Higher cost for discharge than off-peak dispatchable (assuming CCGT))

MODELLED DAILY MARGINAL GENERATION COSTS FOR TWO DEGREES SCENARIO



Powered by

AALBORG UNIVERSITY DENMARK
reINVEST
sEEnergies
Fonden Energi- & Miljødata www.emdfonden.dk
4DH
UN environment
DISTRICT ENERGY IN CITIES INITIATIVE
Innovation Fund Denmark


Mean cost per hour type Two Degrees Scenario (2013 data)
Dispatch Peak
Dispatch Off-Peak
Discharge
Charge
Surplus
0
100
200
300
400
500
600
700
800
£/MWh

Conclusions

- While renewable generators have very low marginal costs, the higher marginal costs of including electricity storage to integrate renewables must be considered
- Battery storage projections add a significant cost to power generation
- Dispatchable/thermal generators are still cheaper than li-ion storage, even considering carbon costs
- High renewable capacity leads to increase cost volatility
- Depending on dominant renewable generator, high degree of seasonality in mean generation costs.

Future Work

- Comparison to other forms of storage (thermal energy storage with electrified heating)
- Publication in IJSEPM

5th International Conference on Smart Energy Systems
Copenhagen, 10-11 September 2019
#SESAAU2019

Thank You

Questions?

Powered by
AALBORG UNIVERSITY DENMARK
reINVEST
sEEnergies
Fonden Energi- & Miljødata www.emdfonden.dk
4DH
UN environment
DISTRICT ENERGY IN CITIES INITIATIVE
Innovation Fund Denmark