Space and Time Analysis of Irradiation variation across the UK: A 10 Year Study of Solar Farm Yield

Diane Palmer, Elena Koubli, Tom Betts, Ralph Gottschalg

Outline

- Obtaining the Yield Data.
- Analysis by Distribution Network Operator Area (DNO).
- Analysis by grid supply point.
- Temporal trends.
- Achievement of Nameplate Capacity.

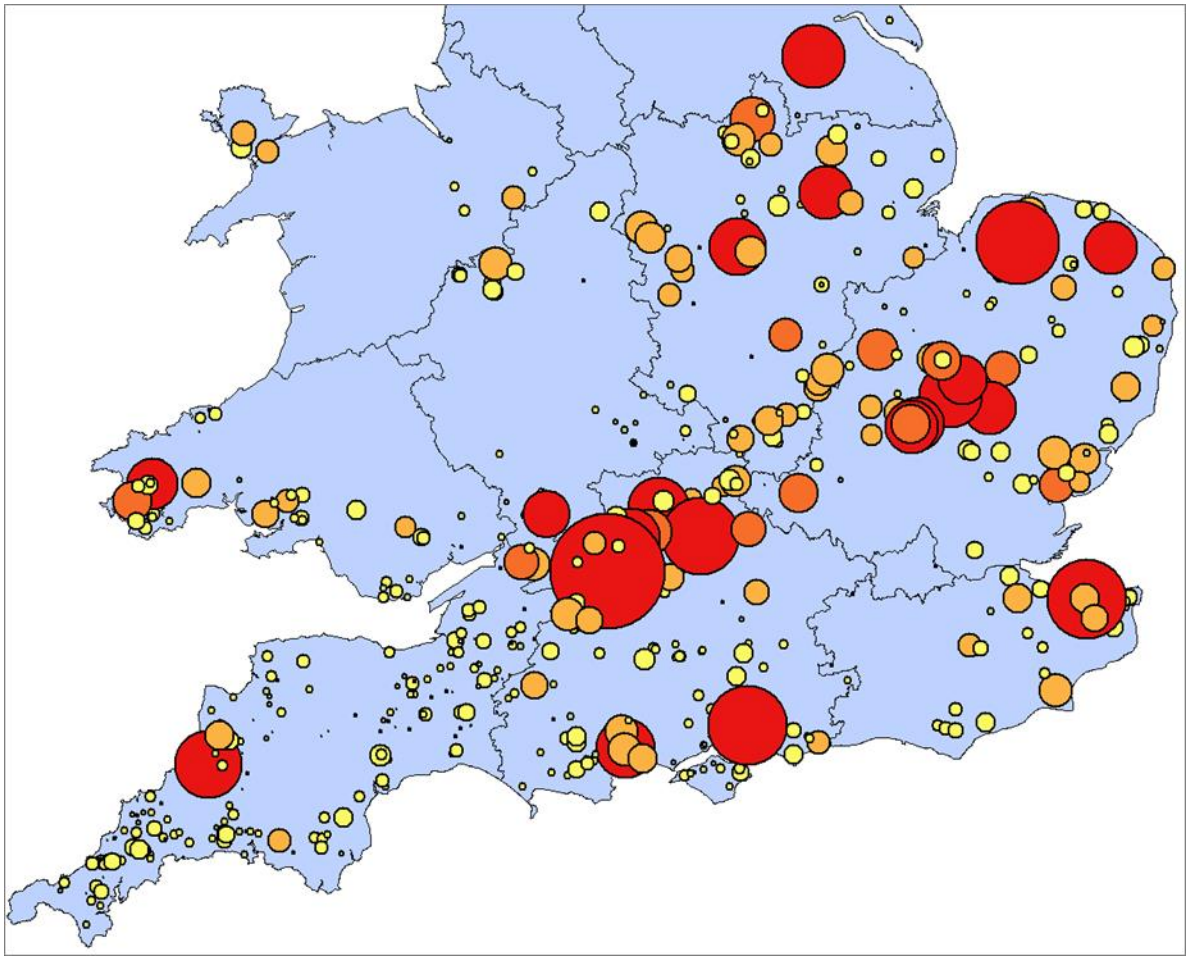
Purpose of Research

Determine impact of PV on the Grid:

- How to measure it
- When
- Where

Location of installations

The larger and hotter the circle, the greater the capacity of the solar farm



Department of Climate Change Renewable Energy Planning database, REPD 2015 (575 x 1-50MW installations at September 2015)

Available data for ground mounted installations:

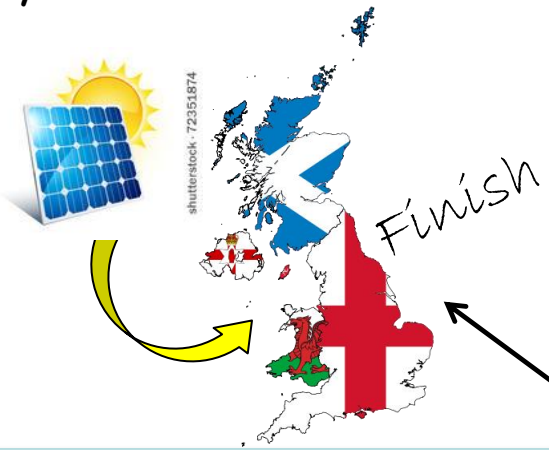
- Nameplate capacity
- Location
- Date production commenced

Assumptions:

- Inclination angle: 22^{o}
- Orientation: South
- Module Type: c-Si

Calculation of Solar Farm Output Data

Output for any solar farm anywhere in the UK



Finish

Start

Kriging of Met. Office
Data: 80 weather stations

UK-Wide Map of Global Horizontal Irradiation

↓

Global Horizontal Irradiance + time/date + lat/long + Tilt + Azimuth = Tilt Irradiation

King model for the maximum power point P(G,T) with adjusted coefficients

Ross thermal model

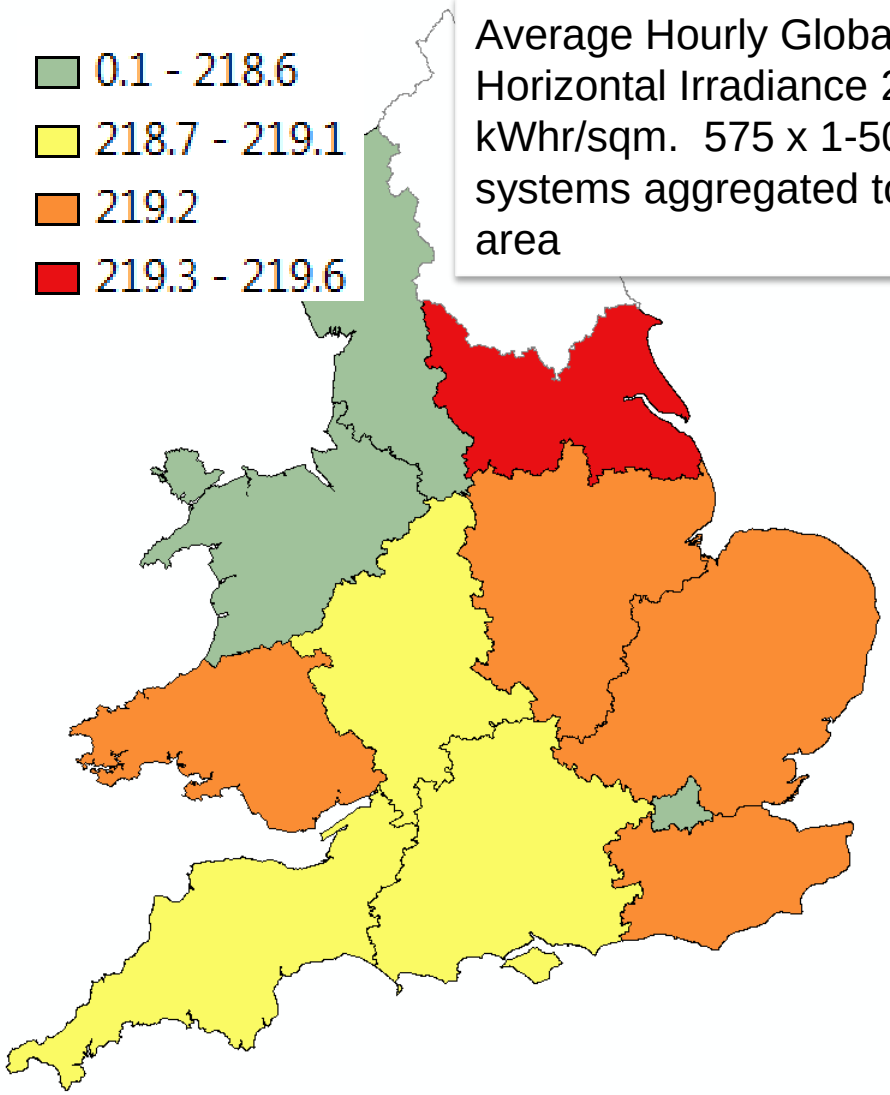
Models that take as input irradiance and temperature (the only available information)

Plane-of-array irradiance for each solar farm

Separation:
BRL model

Translation:
Hay &McKay with Reindl's correction

Aggregation by DNO: Problems



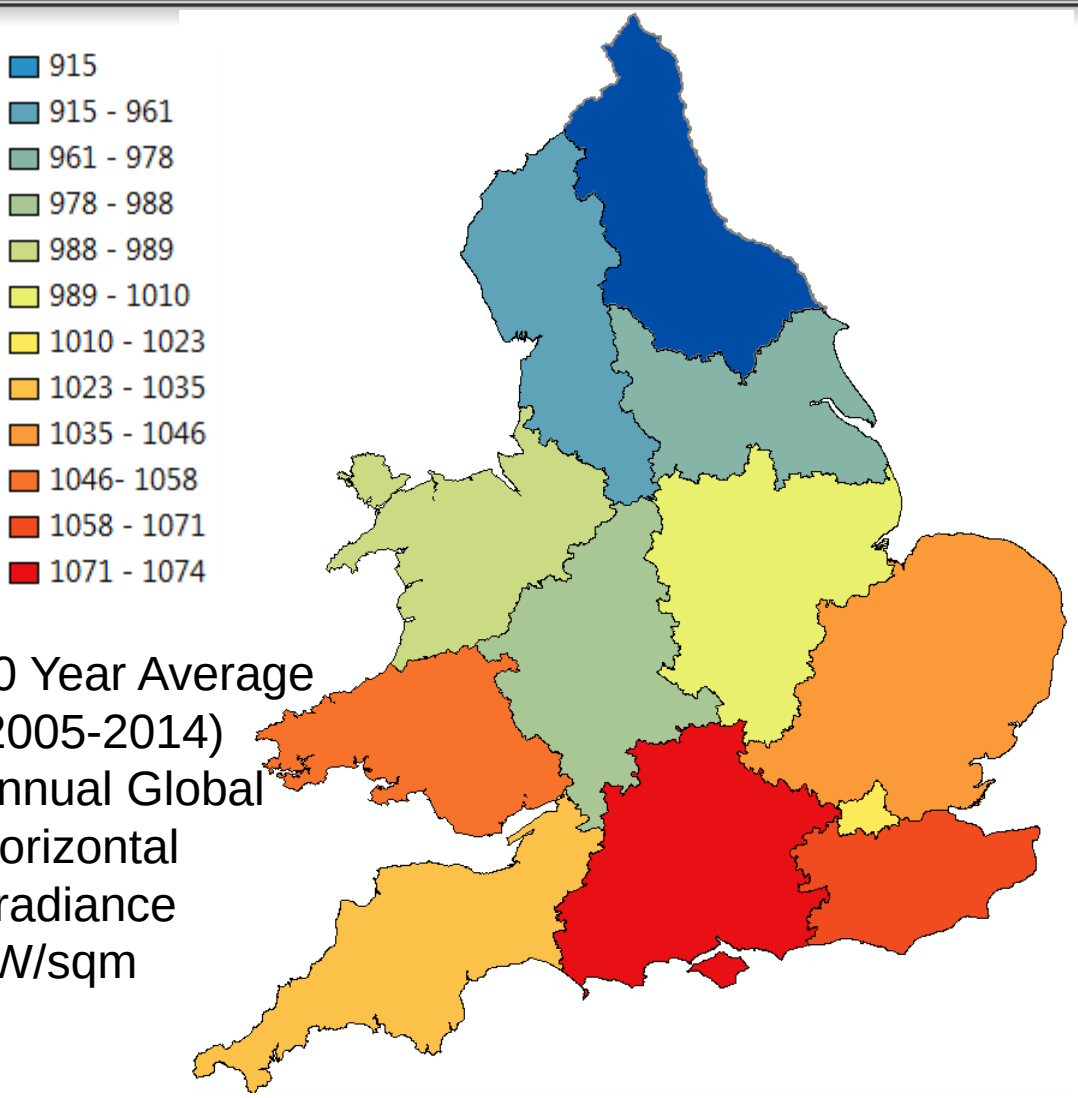
Average Hourly Global Horizontal Irradiance 2014 kWhr/sqm. 575 x 1-50 MW systems aggregated to DNO area

Modifiable Area Unit Problem:

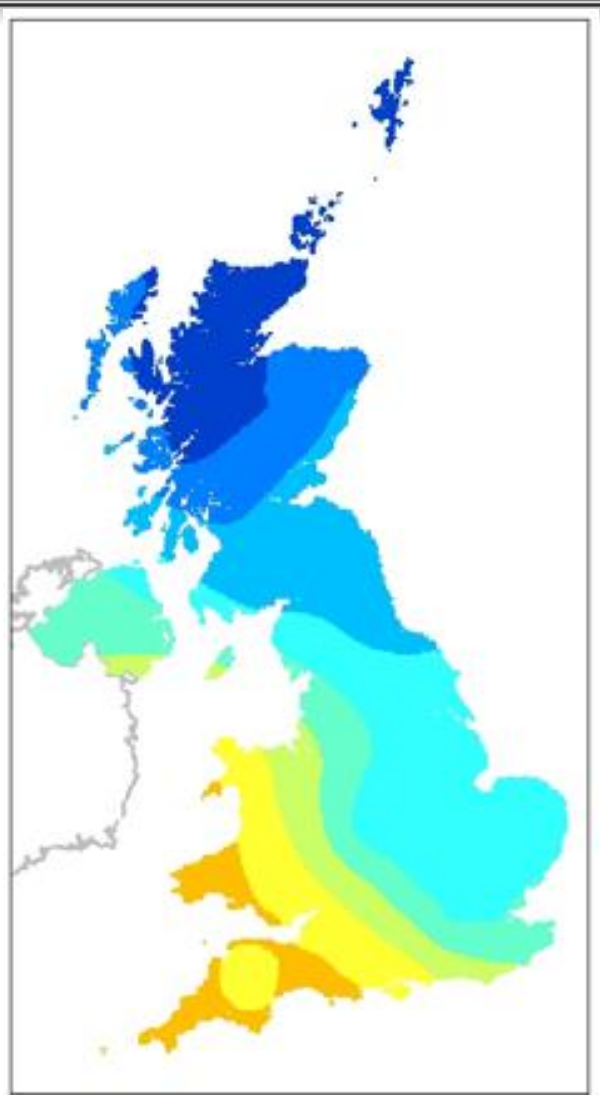
- A source of bias
- Occurs when points are aggregated into districts
- Results vary according to how area boundaries are drawn.

Solution	Advantages	Disadvantages
EITHER: Use irradiance of centre point of DNO ✓	Latitude of specific point used calculating POA irradiance	Single central point taken as representative of area – improvement because of central location of point
OR: Use average irradiance of DNO	Overcomes MAUP	Averaged input supplied to POA algorithm.

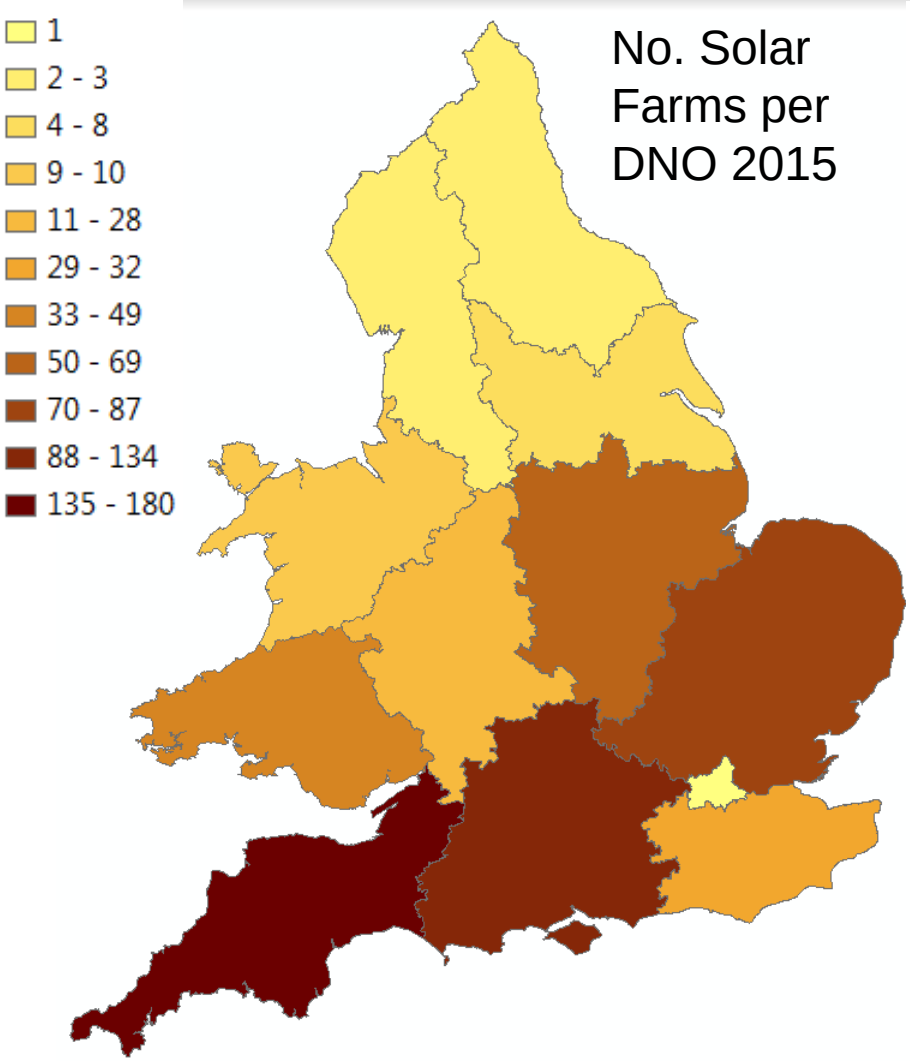
Annual Global Horizontal Irradiance per DNO



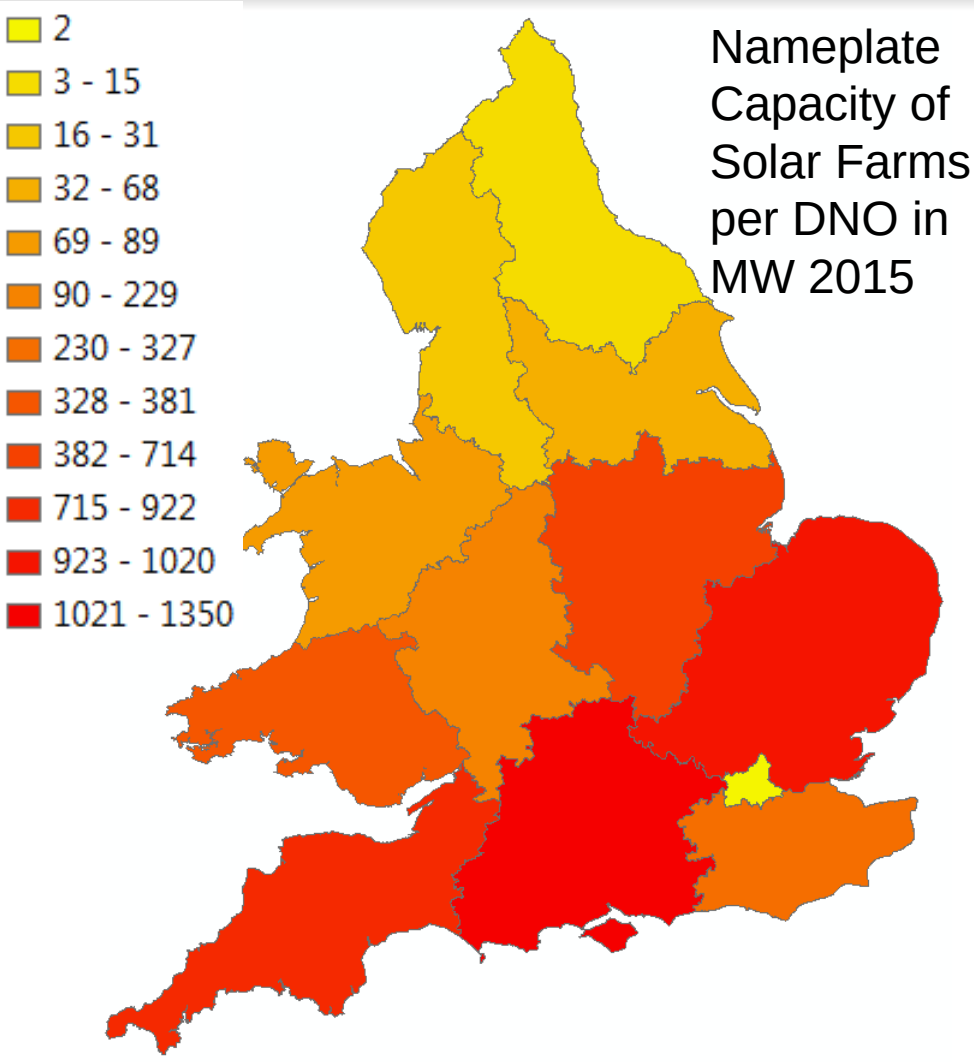
10 Year Average (2005-2014) Annual Global Horizontal Irradiance kW/sqm



Solar Farm Distribution at the DNO Level

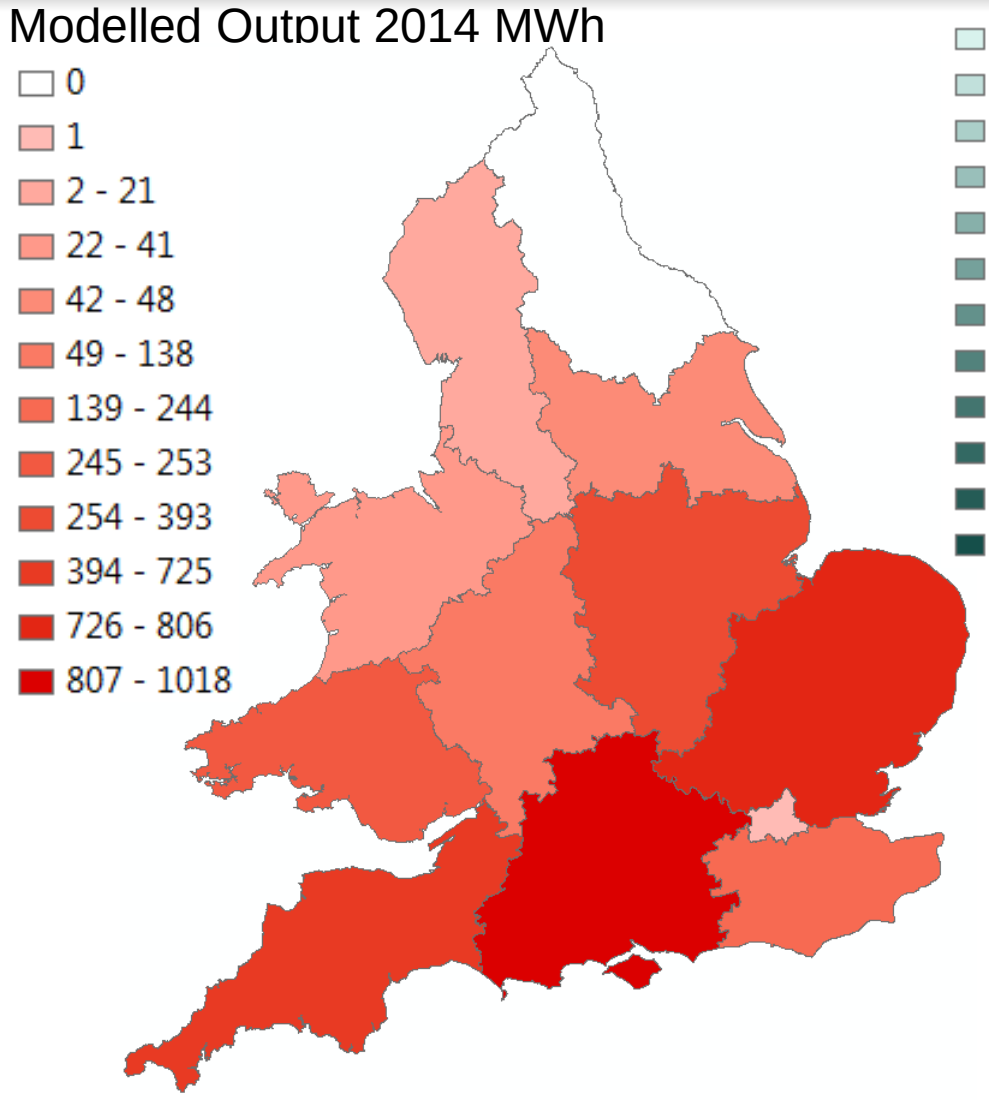


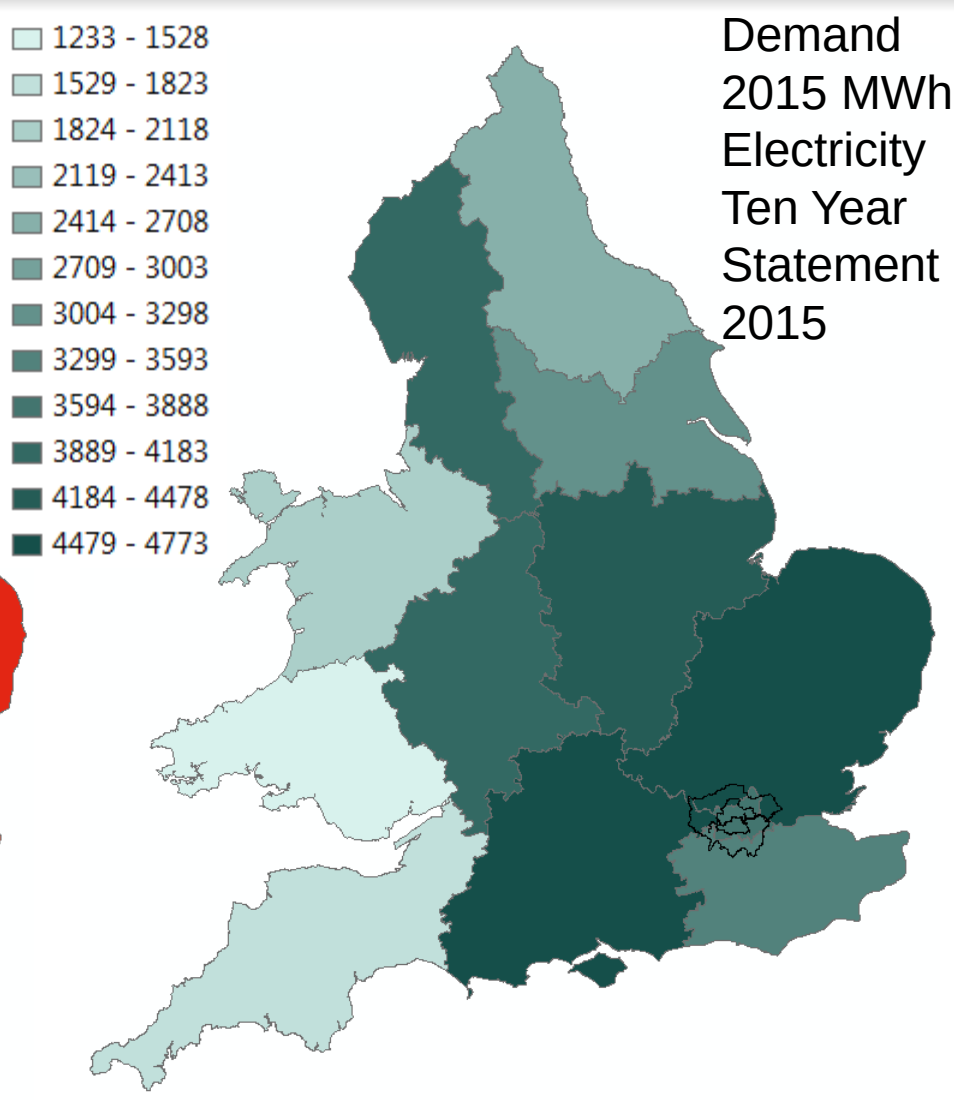
No. Solar Farms per DNO 2015



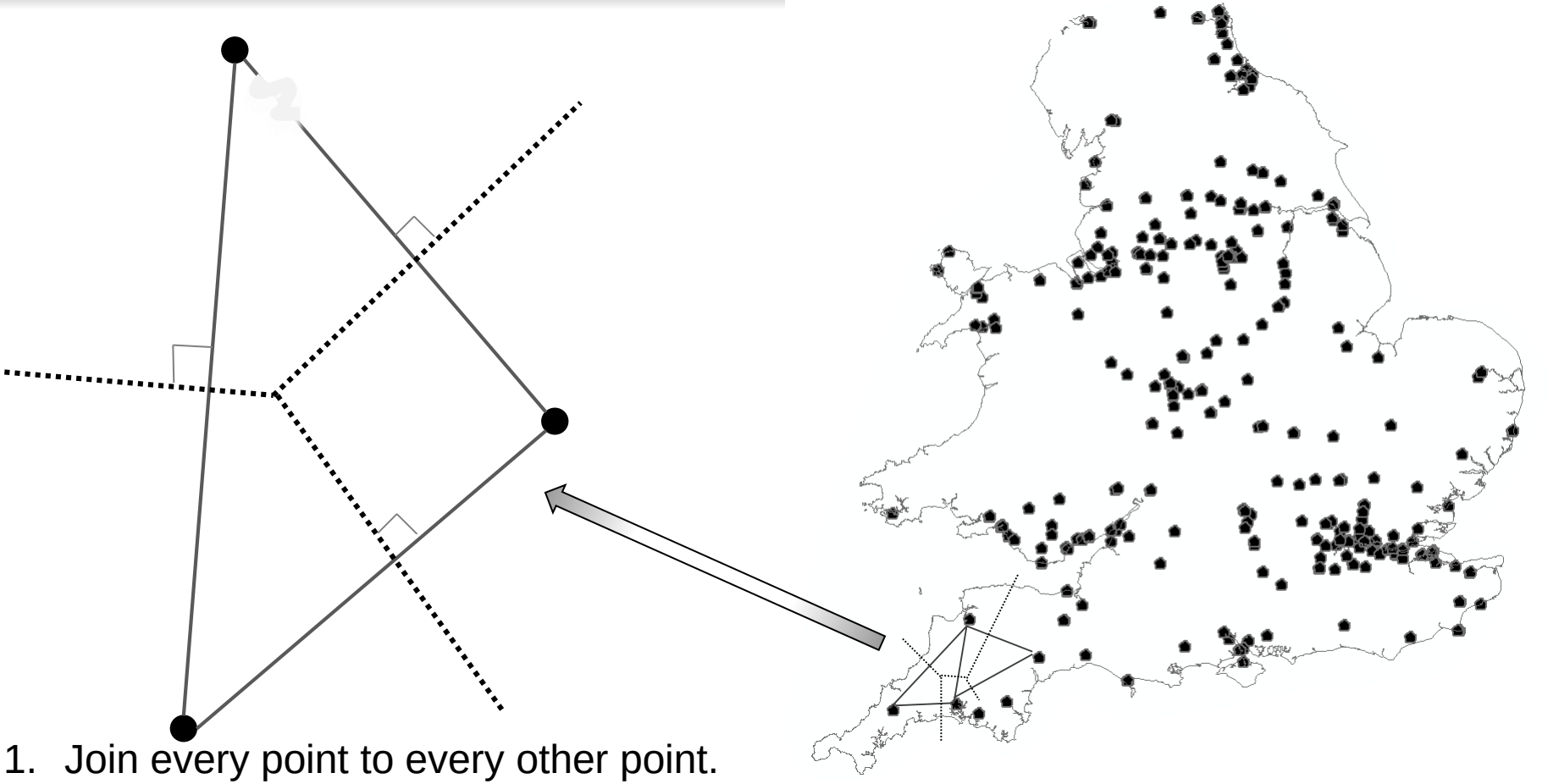
Nameplate Capacity of Solar Farms per DNO in MW 2015

Solar Farms Production and Demand per DNO



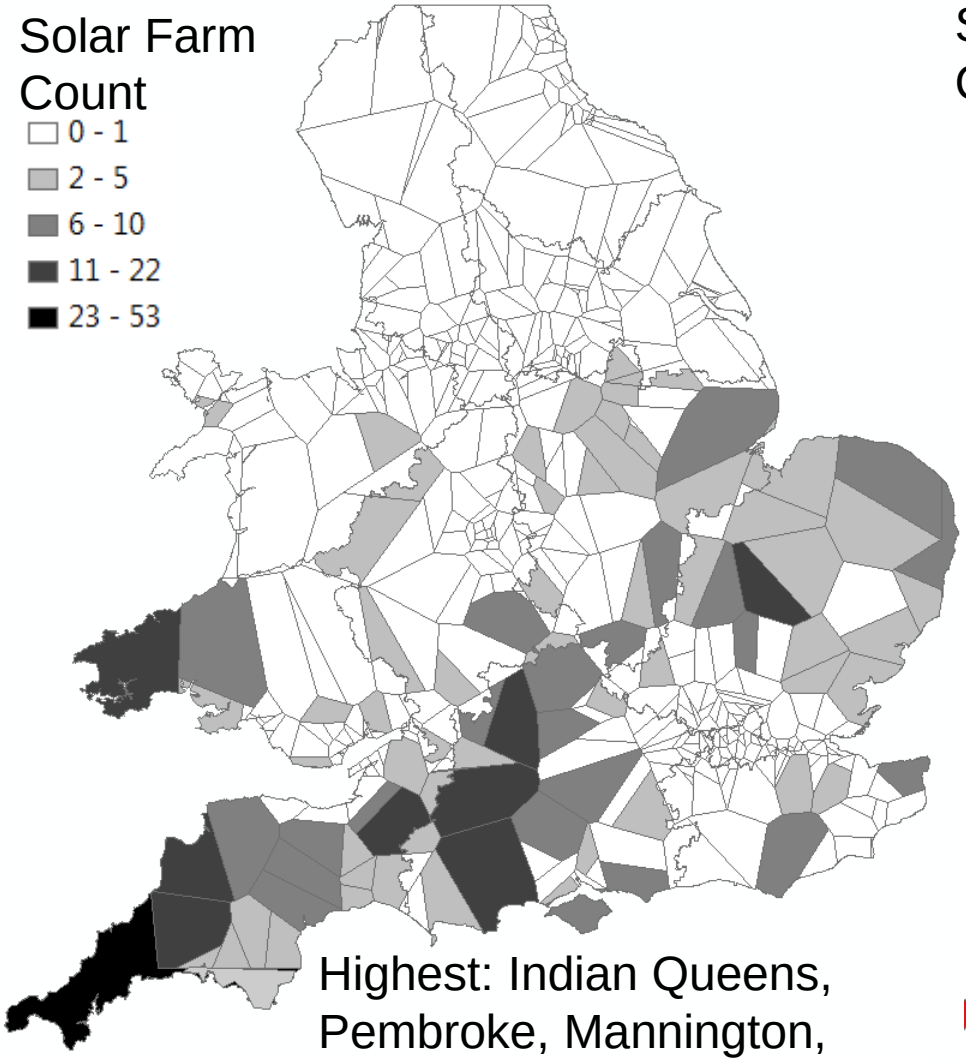


Create Grid Supply Point Areas: Voronoi

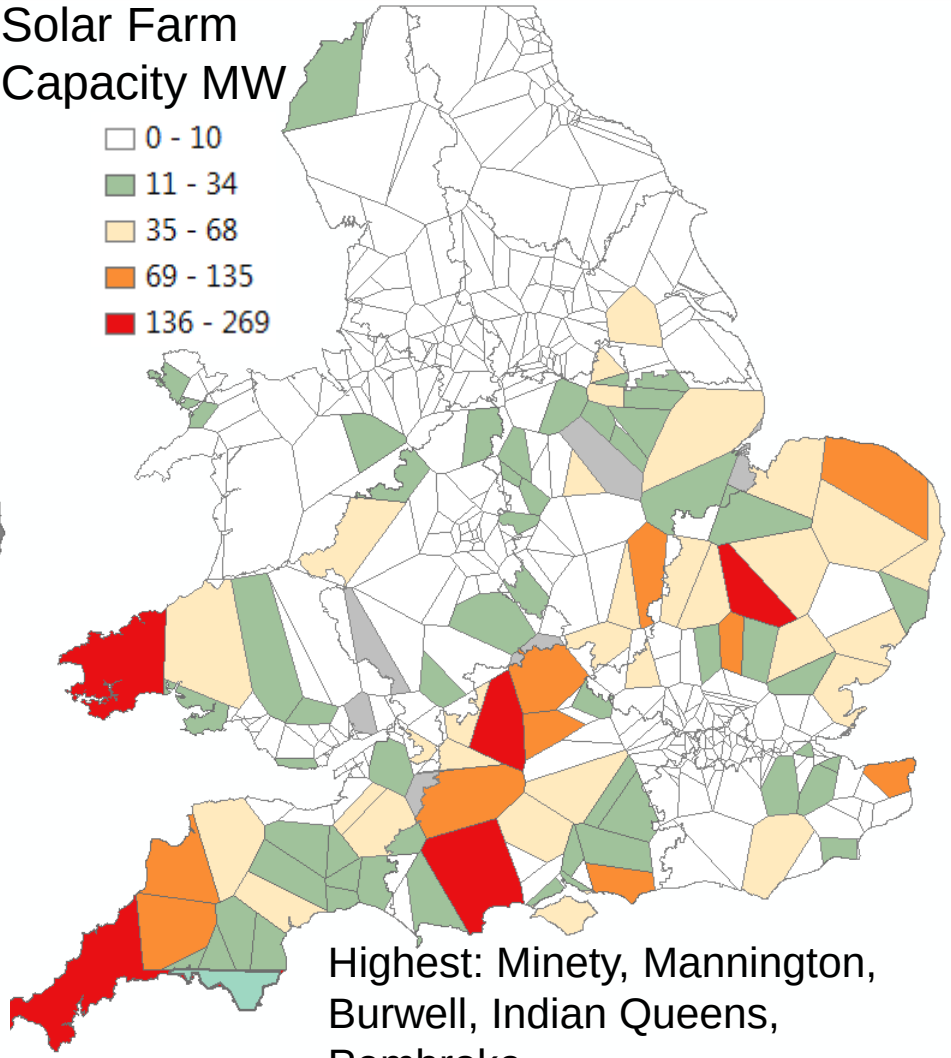


1. Join every point to every other point.
2. Draw a line half-way along each joining line at right angles to it (the perpendicular bi-sector).
3. Join the bi-sectors and erase original joins.

Analysis at Grid Supply Point Level



Highest: Indian Queens, Pembroke, Mannington, Alverdiscott, Bridgwater

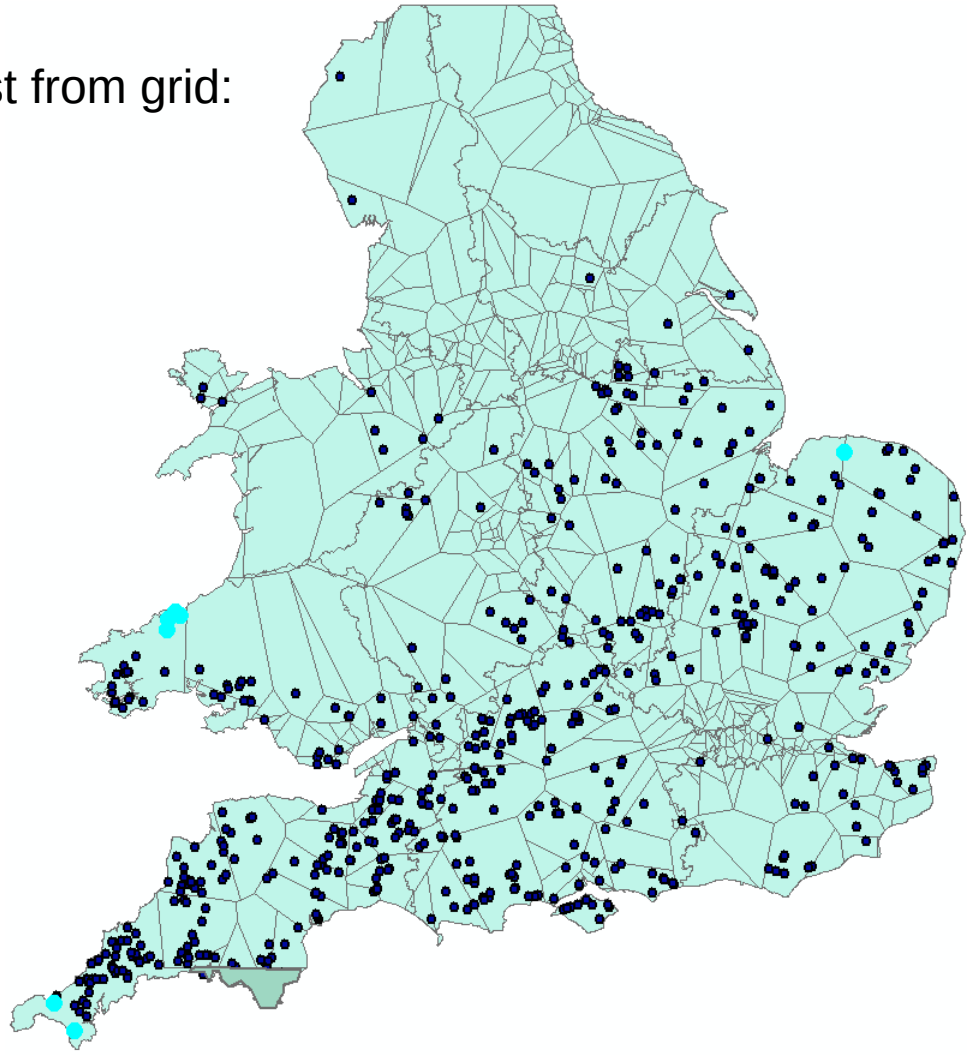


Highest: Minety, Mannington, Burwell, Indian Queens, Pembroke

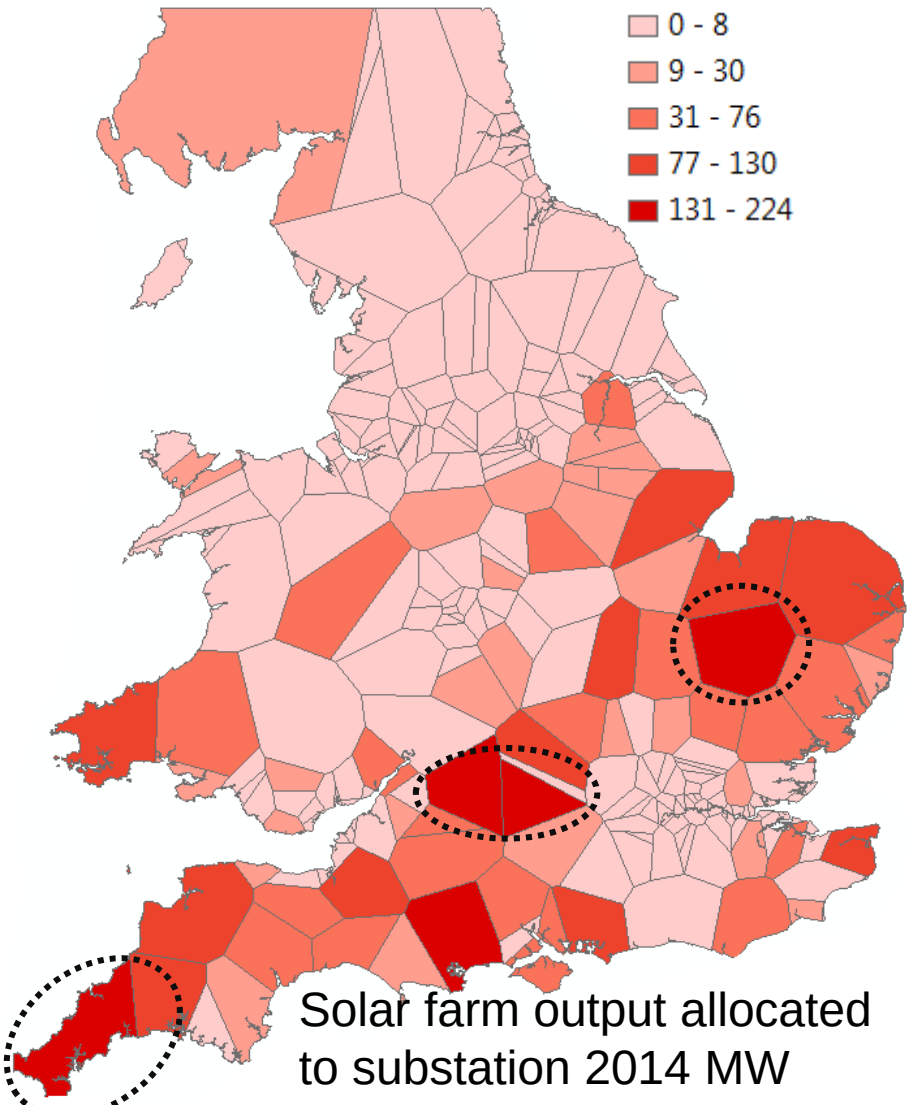
Distance to the Grid

Solar farms furthest from grid:

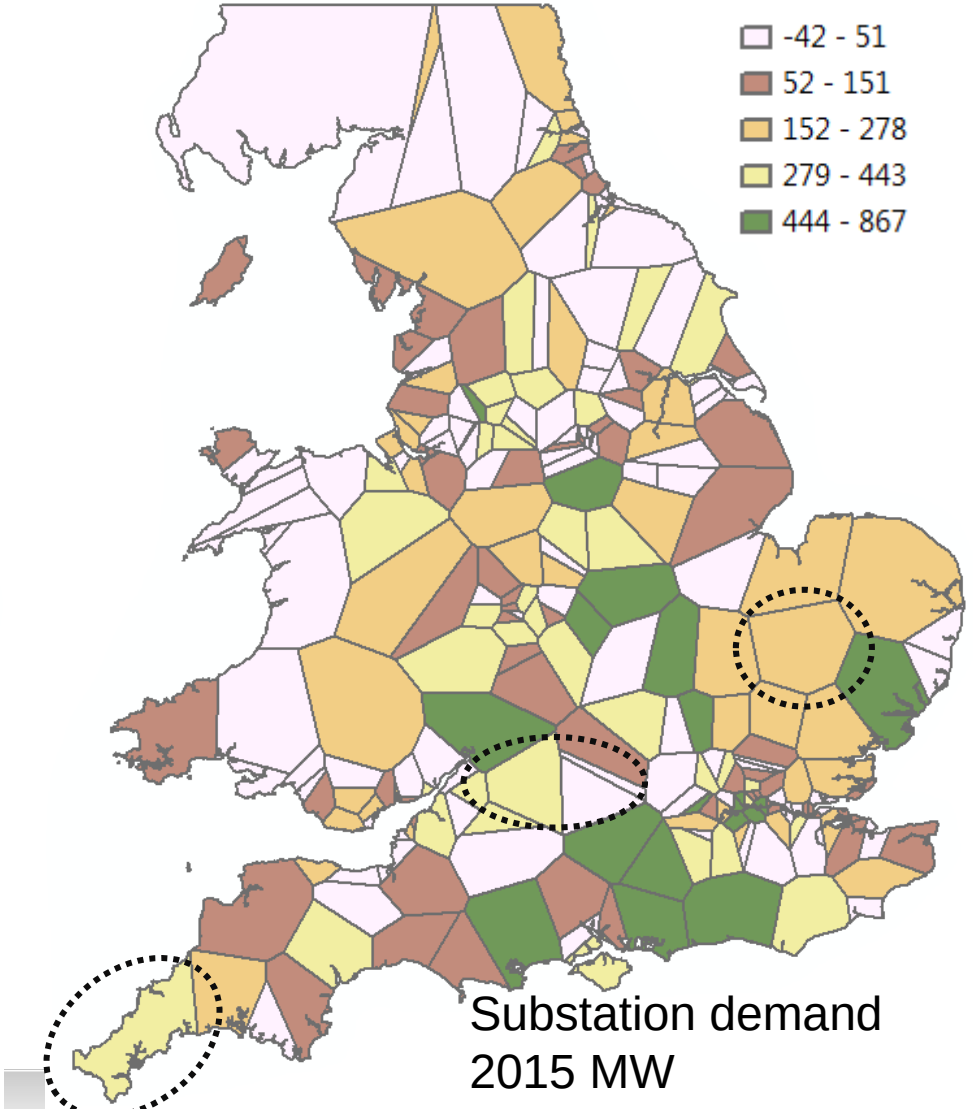
- Indian Queens
- Pembroke
- Norwich Trowse



Production and Demand: Grid Supply Point Analysis

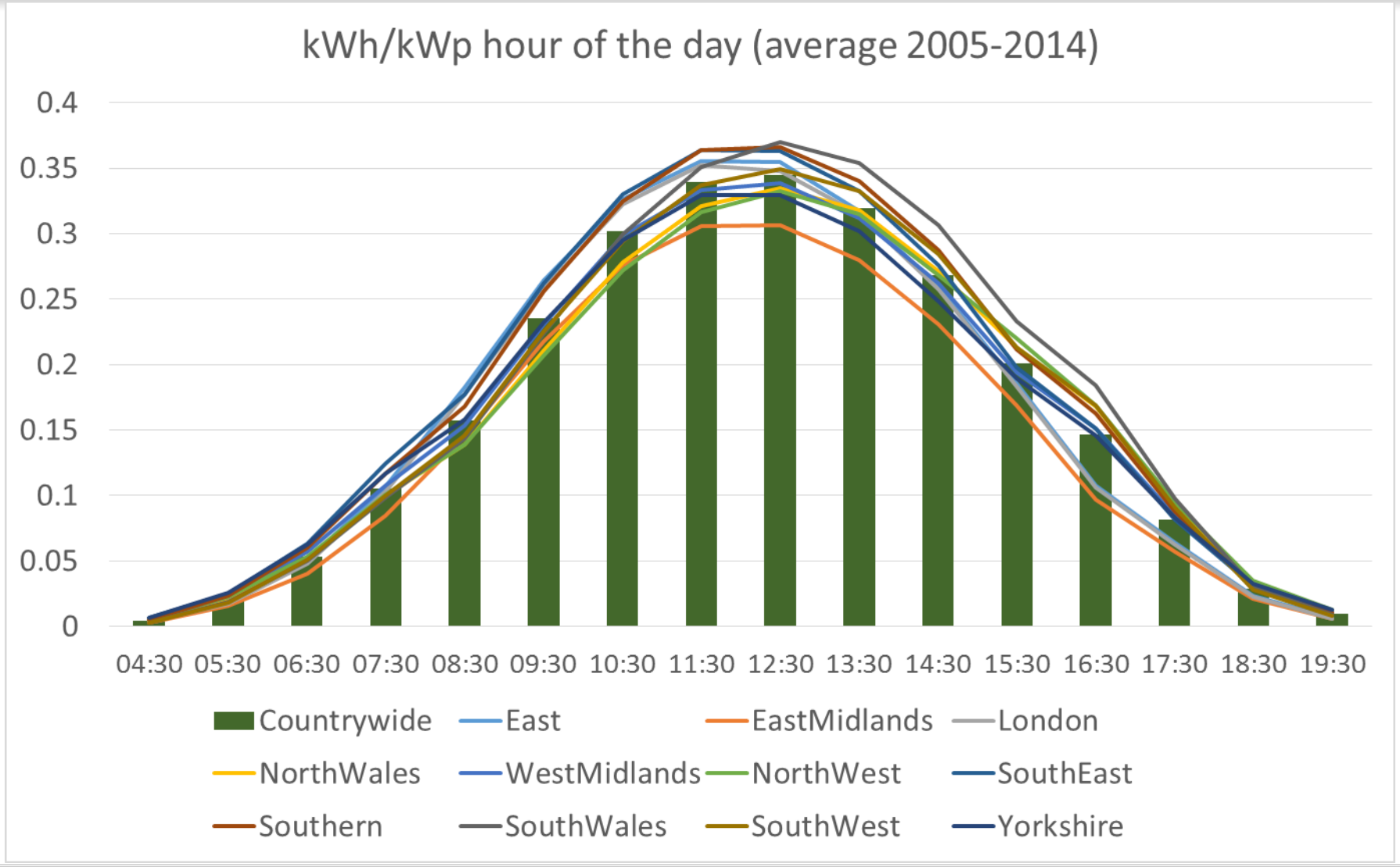


Solar farm output allocated to substation 2014 MW

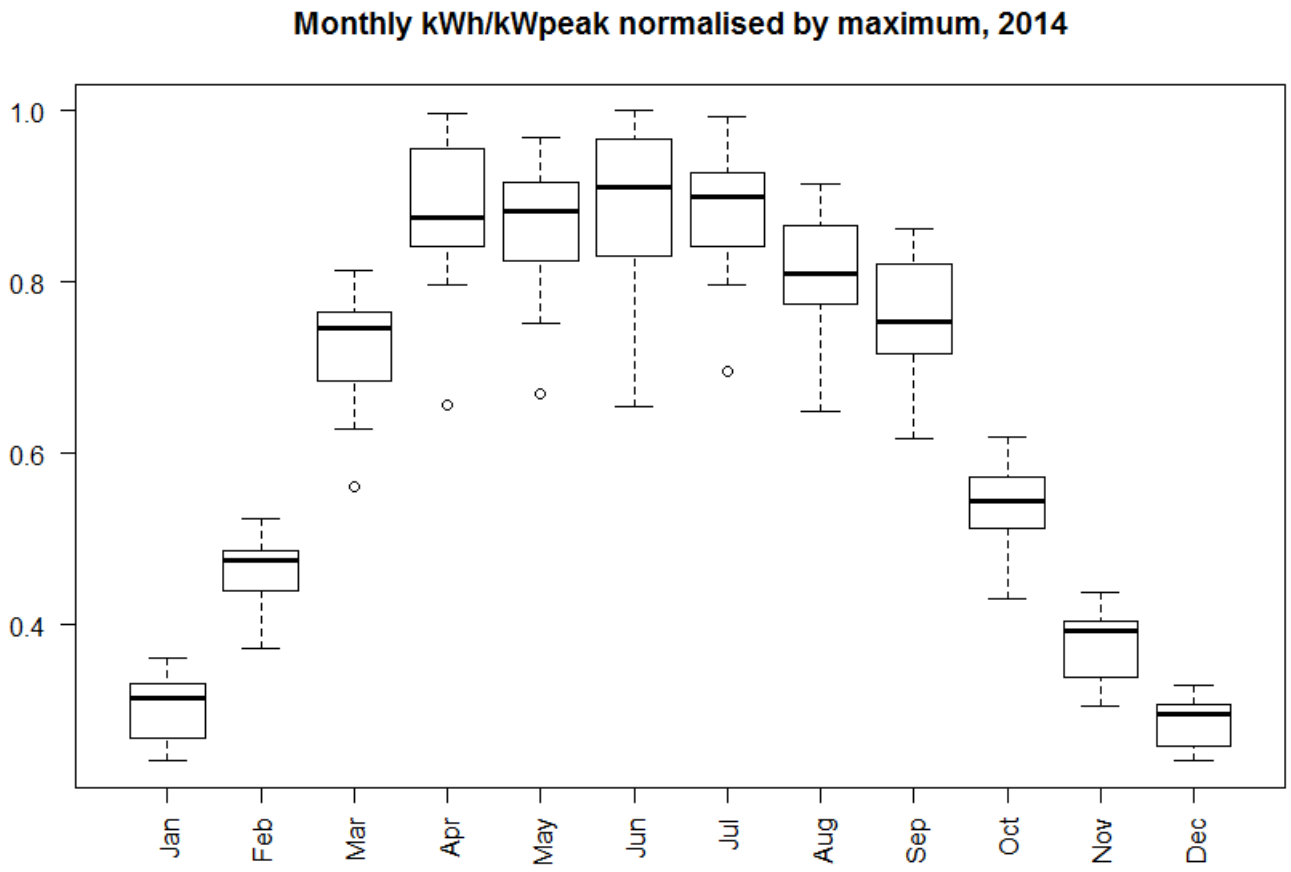


Substation demand 2015 MW

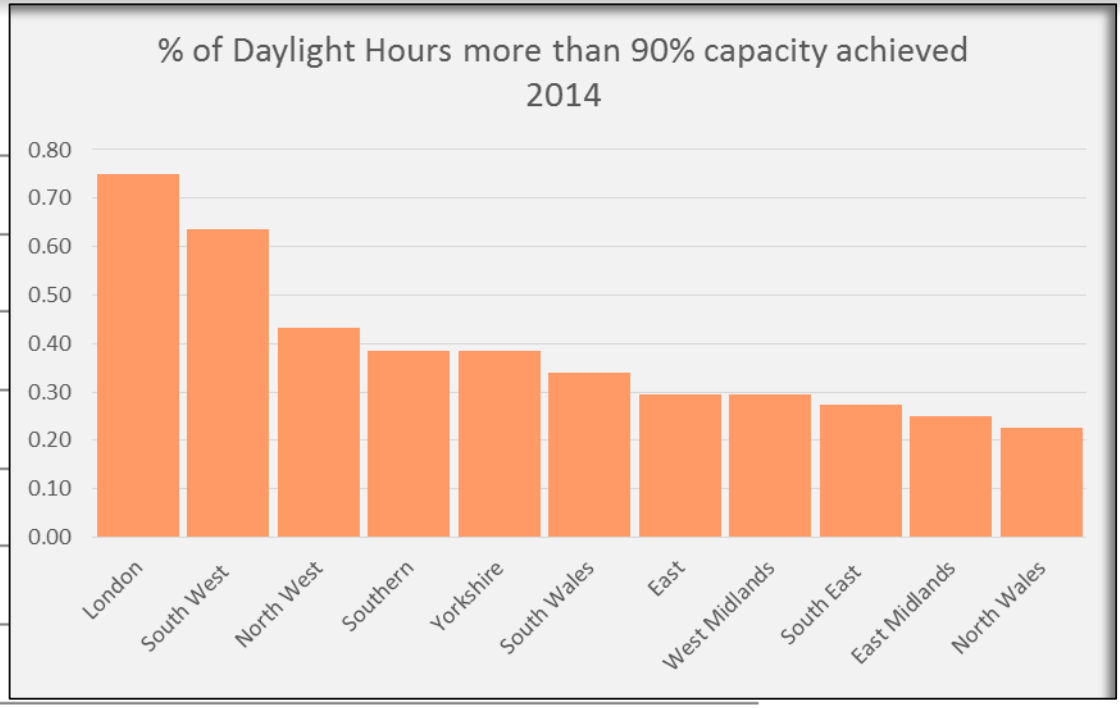
Countrywide Variations in Output - hourly



Countrywide Variations in Output - monthly



Achievement of Nameplate Capacity



No more than 93% capacity ever achieved

NB. Oversizing: Ratio of array nameplate capacity at STC to inverter's rated AC output e.g. 1:25

Conclusion

- Grid stresses:
  - Highest number of solar farms
  - Highest solar farm capacity
  - Distance to nearest grid connection point
  - Imbalance of supply and demand
- But
  - Capacity seldom achieved
  - Variability in output:
    - East / West
    - Hourly
    - Monthly