Climate Change and The UK Solar Energy Resource

Dougal Burnett – PhD Student
Dr Gareth Harrison – Senior Lecturer

Institute for Energy Systems
The University of Edinburgh

UKERC

PhD Research

PhD Title: Climate Change and Renewable Energy Portfolios

- **A study of the potential impact of climate change on renewable energy resource and optimal electricity generation portfolio mixes in the UK.**

- **Uses ‘mean variance portfolio theory’ to explore optimal electricity generation portfolios for the present and future climate scenarios.**

Presentation

- **Objective:**
  - **To investigate UK solar resource of the present climate and the potential impact that climate change could have on the resource.**

- **Outline:**
  - **Solar Energy and Technologies**
  - **UK Present & Future Solar Resource**
  - **Results and Conclusions**
  - **Further Work**

Solar Technologies

Solar

Solar PV

Solar Thermal Panel

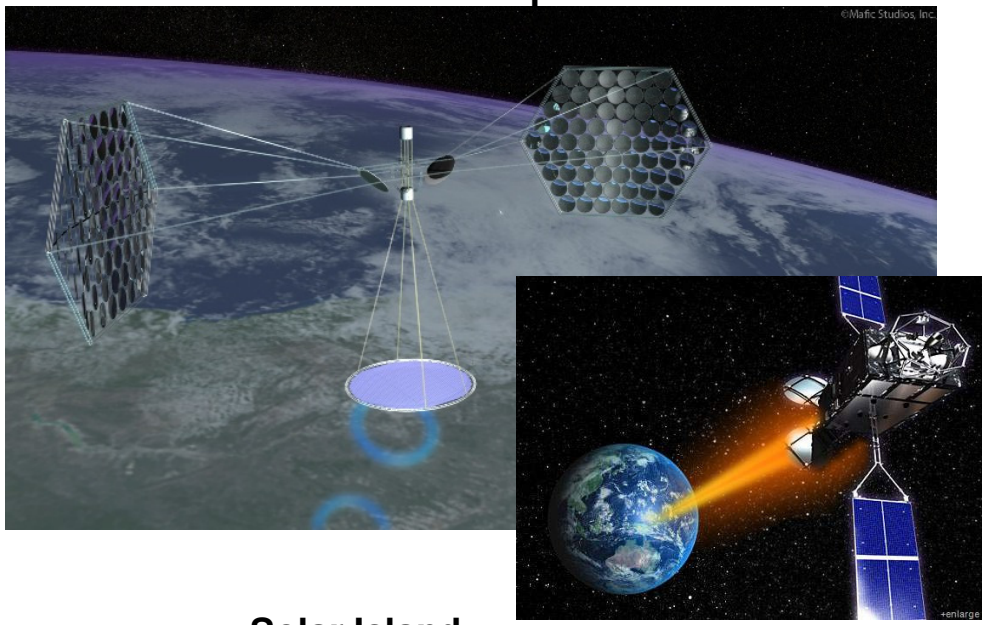
Passive Solar Heating

Solar Beam Concentrators

Solar Technologies

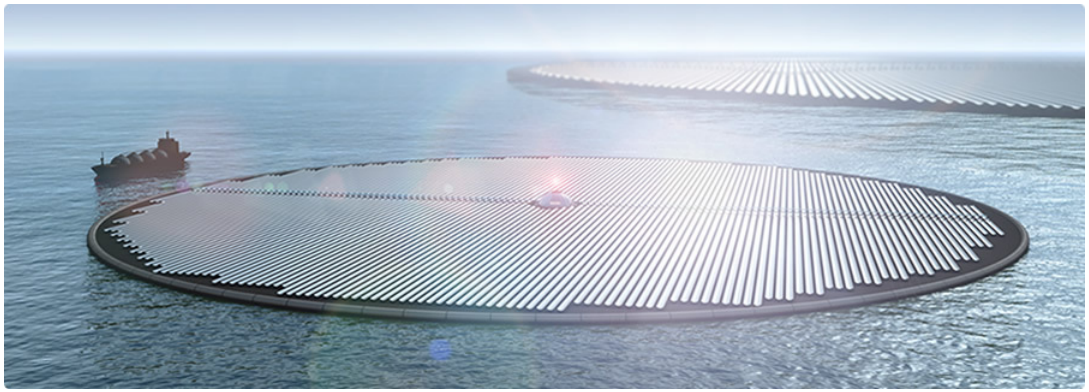
Solar Tower

Space Based Solar



Solar

Solar Island



Solar Technologies

Some novel (and not so novel) applications

UKERC

UK Solar Resource

present and future

Data for present climate (baseline) and future solar climate variability

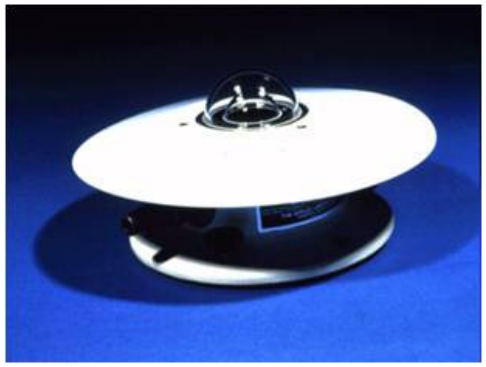
- **World Meteorological Organization (WMO) recommend a climate average to be over 30 year period (1961-1990).**
- Sources of Solar Irradiation Data
  - **Met Office Land Surface Observed Data Sets**
  - **UK Climate Impact Program**
    - **Observed Gridded Data Sets**
    - **UKCP09 Projections**
  - Photovoltaic Geographical Information System (PVGIS).
  - Other sources GCM's, RCM's, reanalysis, satellite…

UK Solar Resource

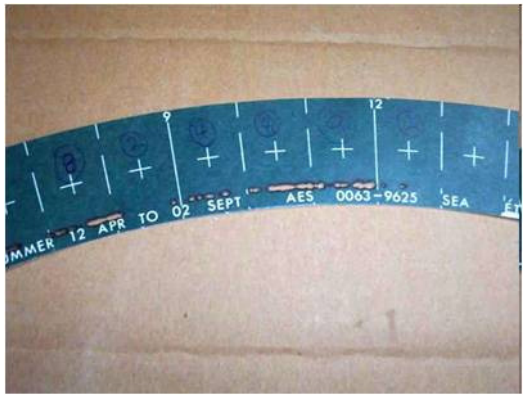
present and future

Measurement of Solar Irradiation

- Weather stations use pyranometers and pyrheliometers



- Campbell-Stokes Recorder - measures sunshine duration

UK Solar Resource

present and future

Conversion of Sunshine Duration to Solar Irradiation

- **Method used Suehrcke (2000), based on widely used Angstrom-Prescott equation.**
  - **Relates the sunshine fraction to monthly average solar radiation**

$$f_{clear} = \left(\frac{\overline{K}}{\overline{K}_{clear}} \right)^2$$

where

f_{clear} = time fraction that no significant clouds block the sun

$\overline{K}$ = monthly average daily clearness index

$\overline{K}_{clear}$ = monthly average clear sky clearness index

$$\overline{K} = \left(\frac{\overline{H}}{\overline{H}_O} \right)$$

where

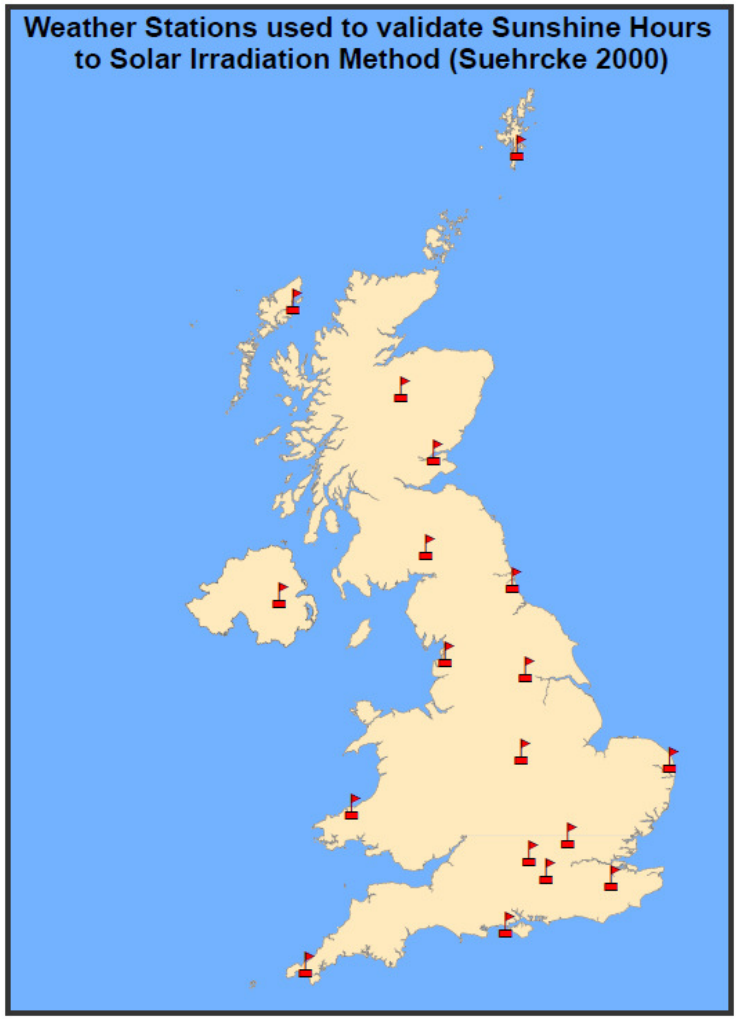
$\overline{H}$ = monthly average of daily horizontal surface radiation (beam + diffuse)

$\overline{H}_o$ = monthly average of daily horizontal surface extraterrestial radiation

  - **Lots of lower level calculations required: sun–earth variables, latitude, day hours, solar declination, extra-terrestrial irradiation, sunset hour angle…**

UK Solar Resource

present and future



Validation of Suehrcke Method

- **Identify weather stations that measure both 'sunshine hour duration' and 'solar irradiation' with sufficient historical data.**
- **Convert the measured 'sunshine hour duration' to 'solar irradiation' using the Suehrcke method.**
- **Compare the measured 'solar irradiation' with the Suehrcke derived 'solar irradiation.**

OUTCOME

- **18 weather stations identified with at least five years of historical data for each data set.**
- **Comparison showed excellent agreement at all locations.**

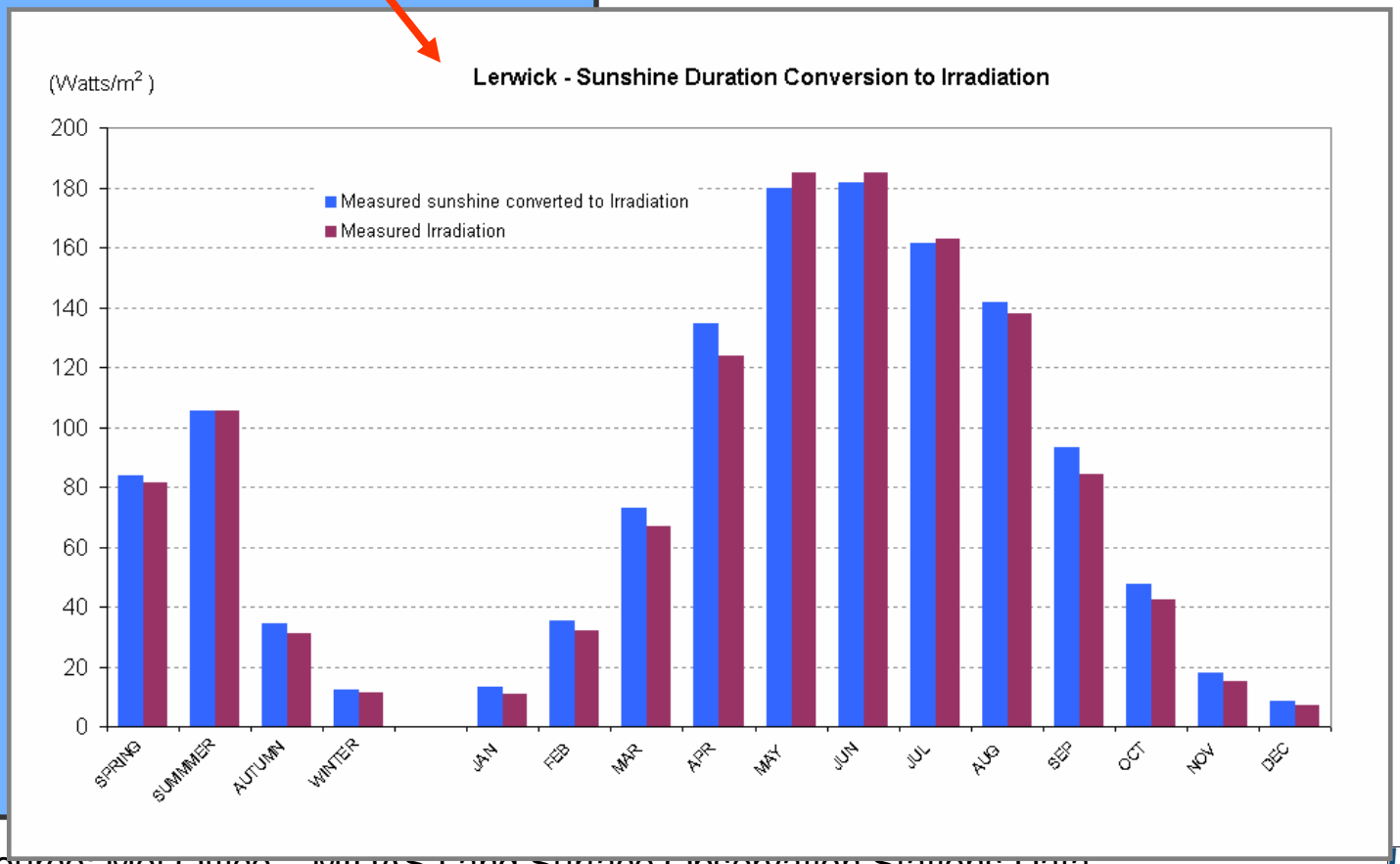
Data Source: Met Office – MIDAS Land Surface Observation Stations Data

UK Solar Resource

present and future

Weather Stations used to validate Sunshine Hours to Solar Irradiation Method (Suehrcke 2000)

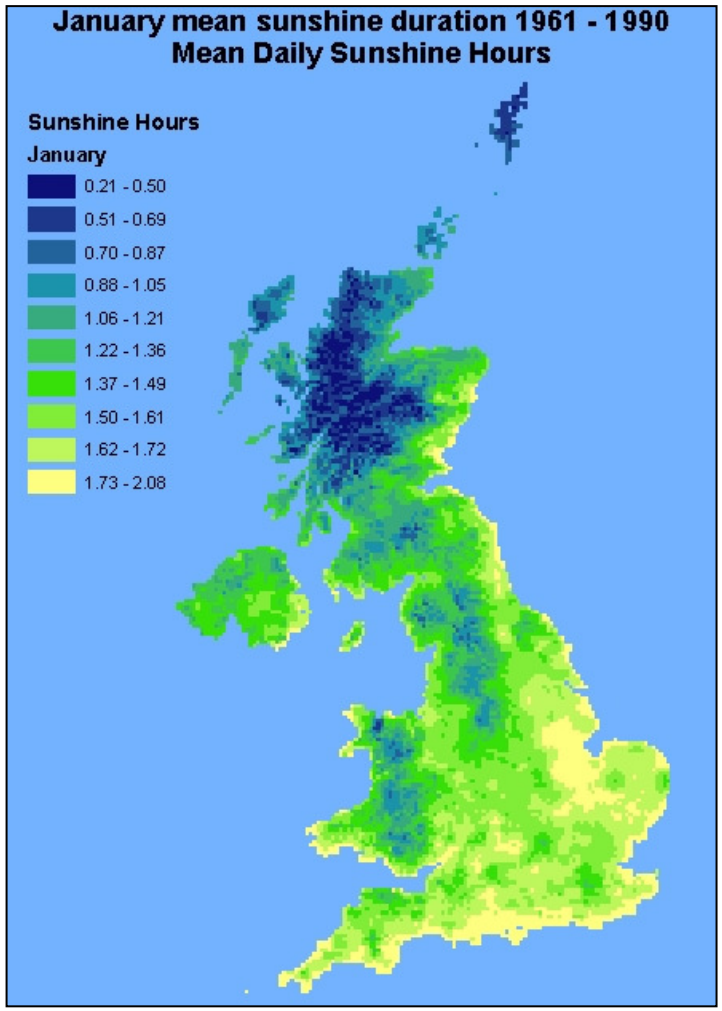
Validation of Suehrcke Method



Data Source: Met Office – MIDAS Land Surface Observation Stations Data

UK Solar Resource

present and future



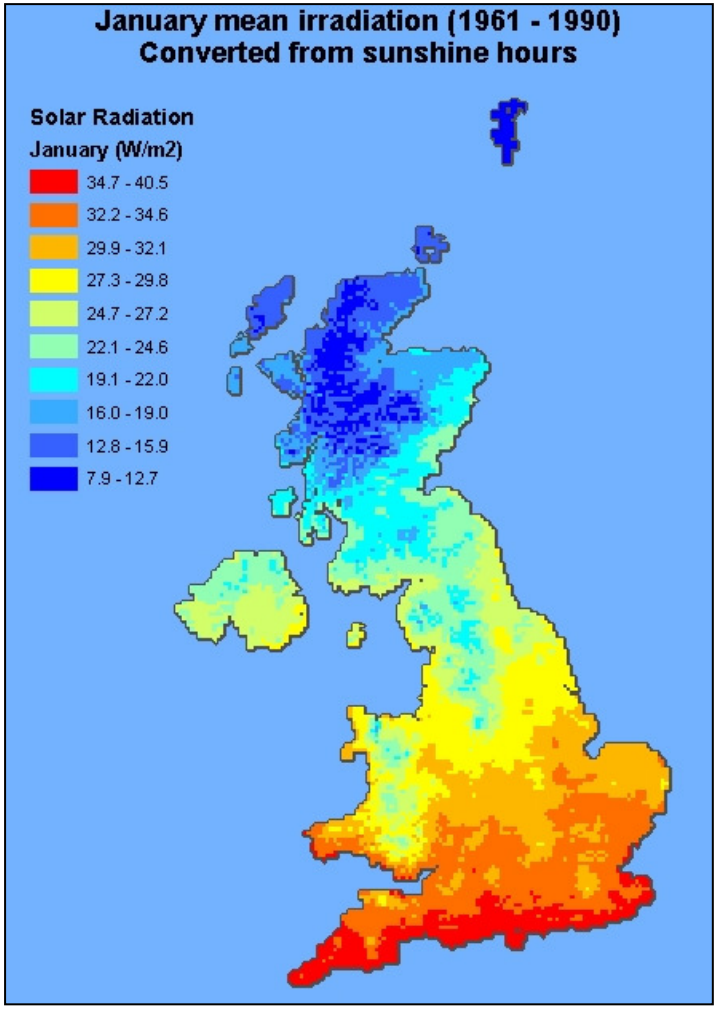
Sunshine Hours - Baseline Resource

- **UKCP09: Gridded Observation Data Sets**
- **Based on surface observations from many weather stations**
- **Values generated using interpolation and regression**
- **Takes into account factors such as altitude, terrain, land use, latitude, longitude**
- **Conversion process from Sunshine Hours to Solar Irradiation**

Data Source: UKCP09 gridded data set observed data (5km x 5km)

UK Solar Resource

present and future



Sunshine Hours to Solar Irradiation

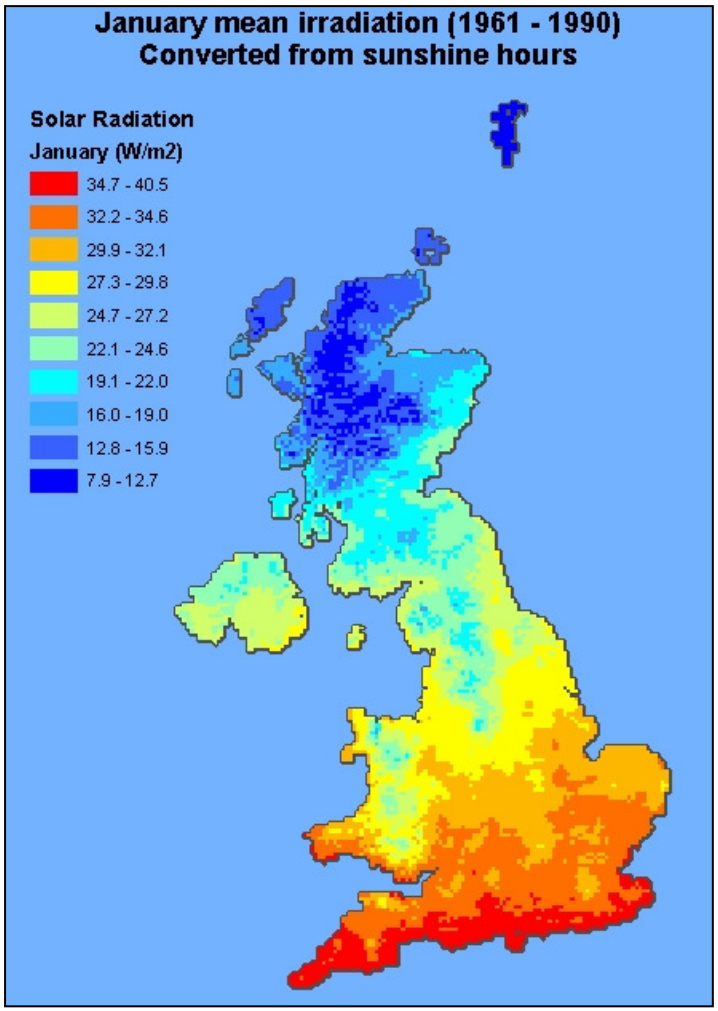
- Suehrcke conversion method
- Performed conversion on each grid cell for each month of each year from 1961 to 1990
- Averaged the results for each month and season

Solar Irradiation Monthly Mean Baseline Resource Map Created…

Data Source: UKCP09 gridded data set observed data (5km x 5km)

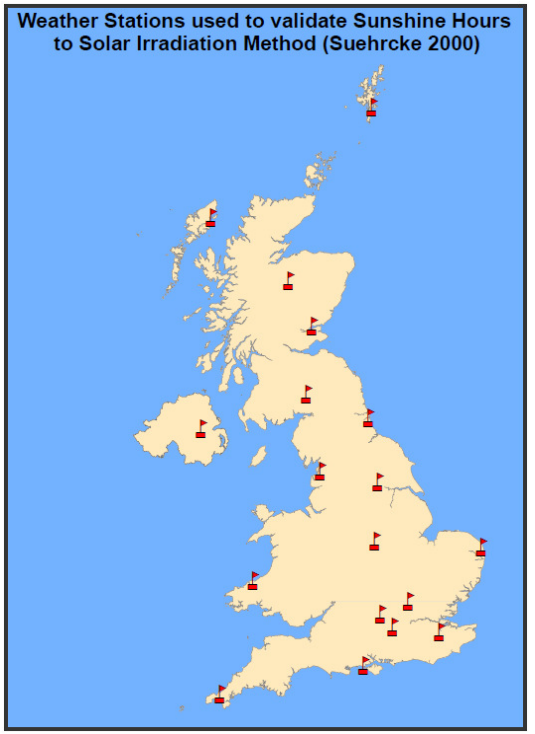
UK Solar Resource

present and future



Validation of Solar Irradiation Monthly Mean Baseline Resource Map

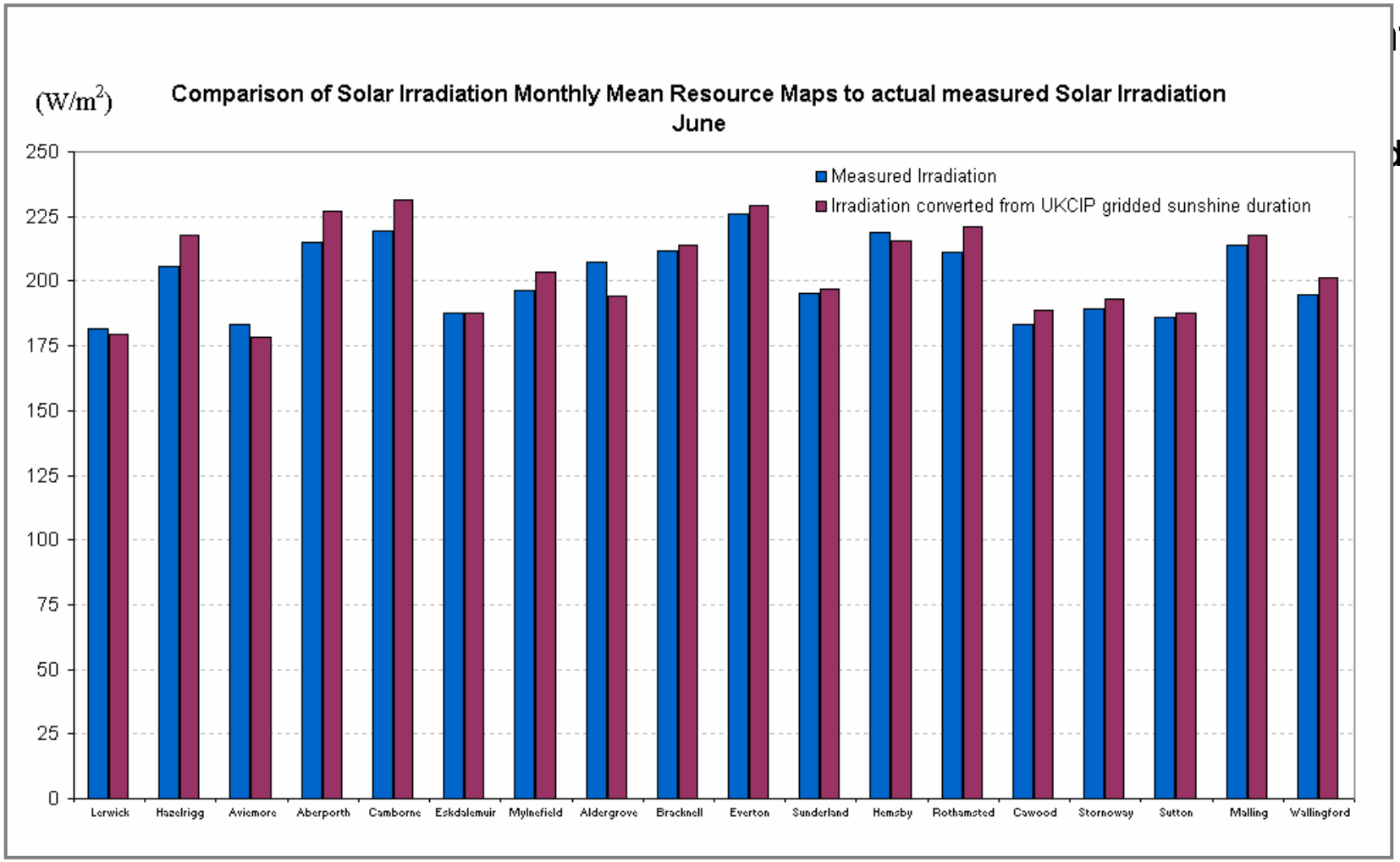
- **Compare with actual solar irradiation data measured over the same time period**



Data Source: UKCP09 gridded data set observed data (5km x 5km)

UK Solar Resource

present and future

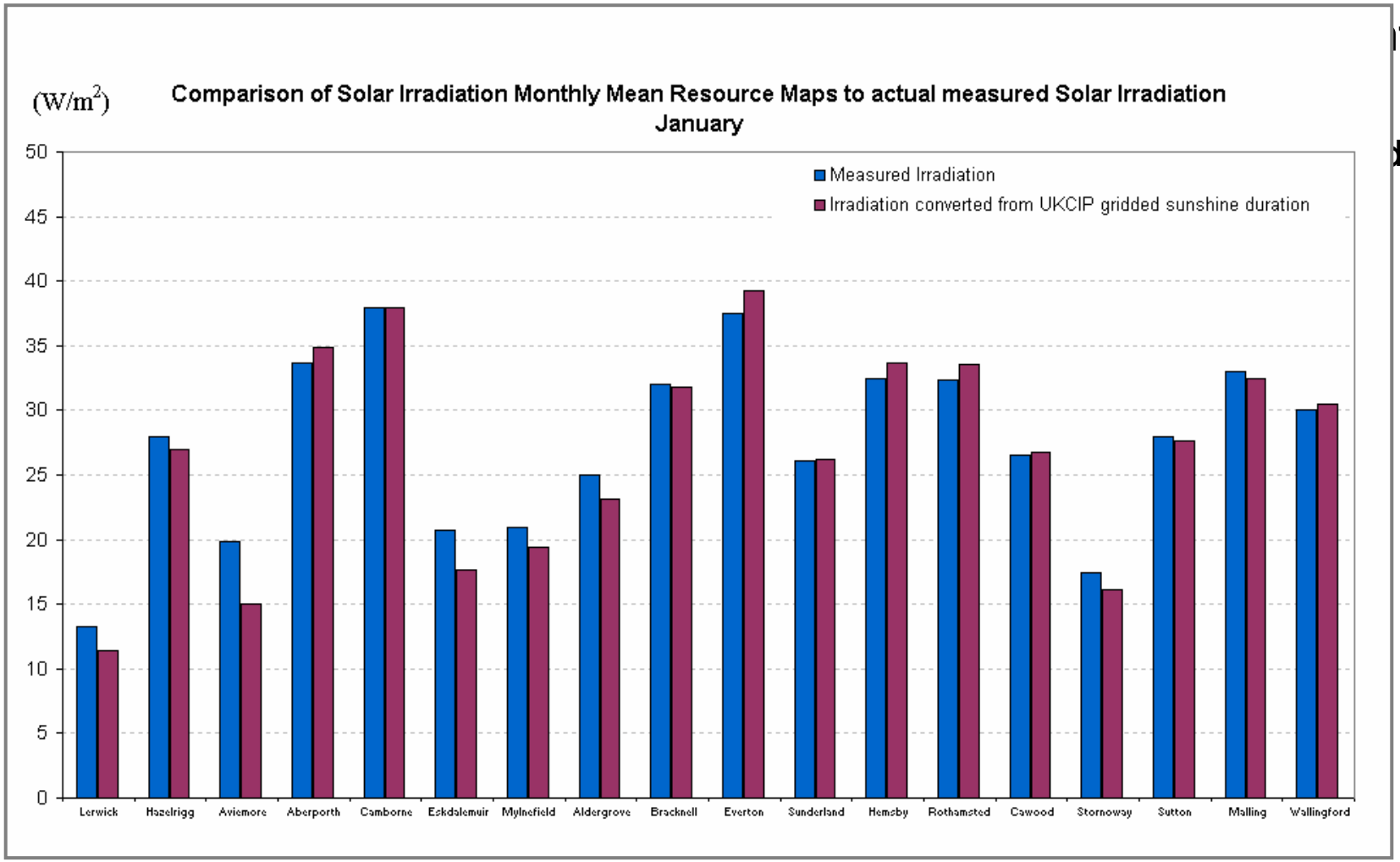


thly

data

UK Solar Resource

present and future



thly

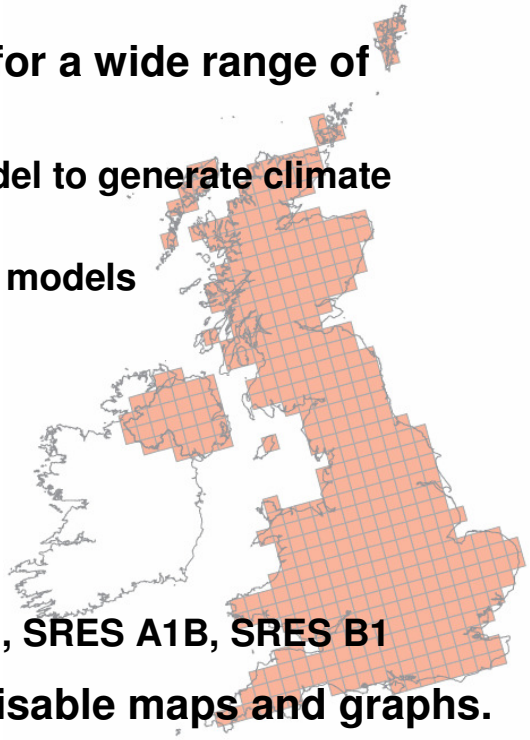
data

UK Solar Resource

present and future

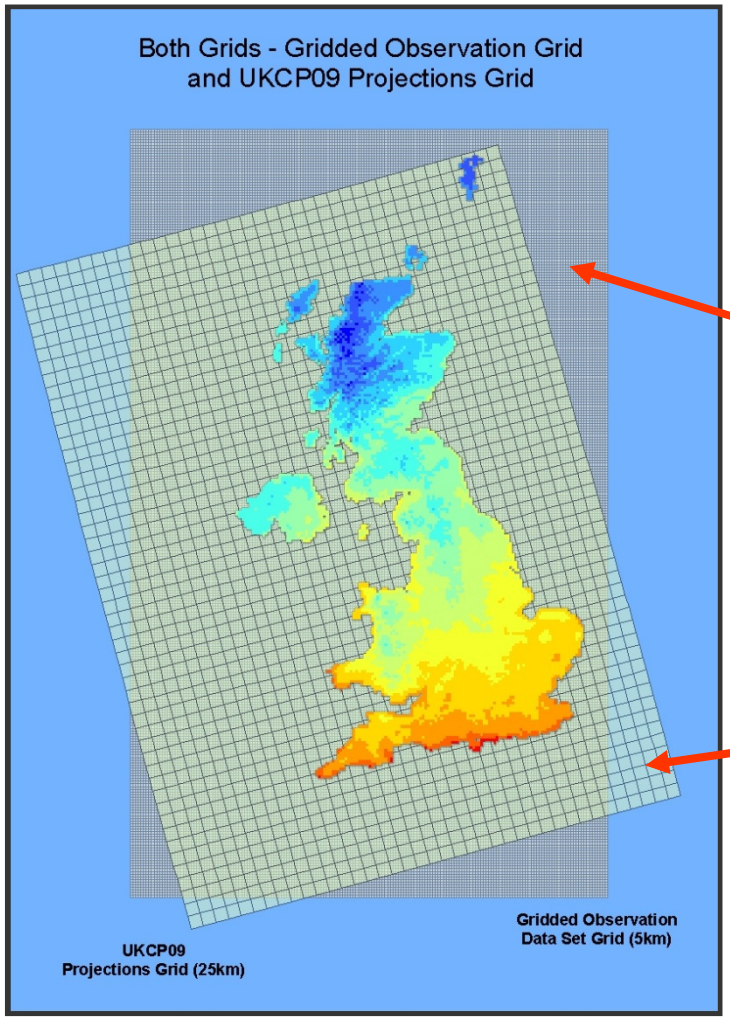
Future solar irradiation climate variability

- **UKCP09 Climate Projections**
- **Provides Probabilistic Projections of Climate Change for a wide range of climatic variable**
  - **Uses perturbed physics ensembles (PPE) of HadCM3 model to generate climate projections**
  - **Projections also include the results of other IPCC climate models**
  - **Downscaled using ensemble of HadRM3 model**
  - **Quantifies known sources of uncertainties.**
- **Projections for seven 30 year time periods (2010-2099)**
- **Three future emission scenarios: (low, medium, high)**
  - **Comprise of three IPCC Emissions Scenarios: SRES A1FI, SRES A1B, SRES B1**
- **User Tools: user interface, weather generator, customisable maps and graphs.**



UK Solar Resource

present and future



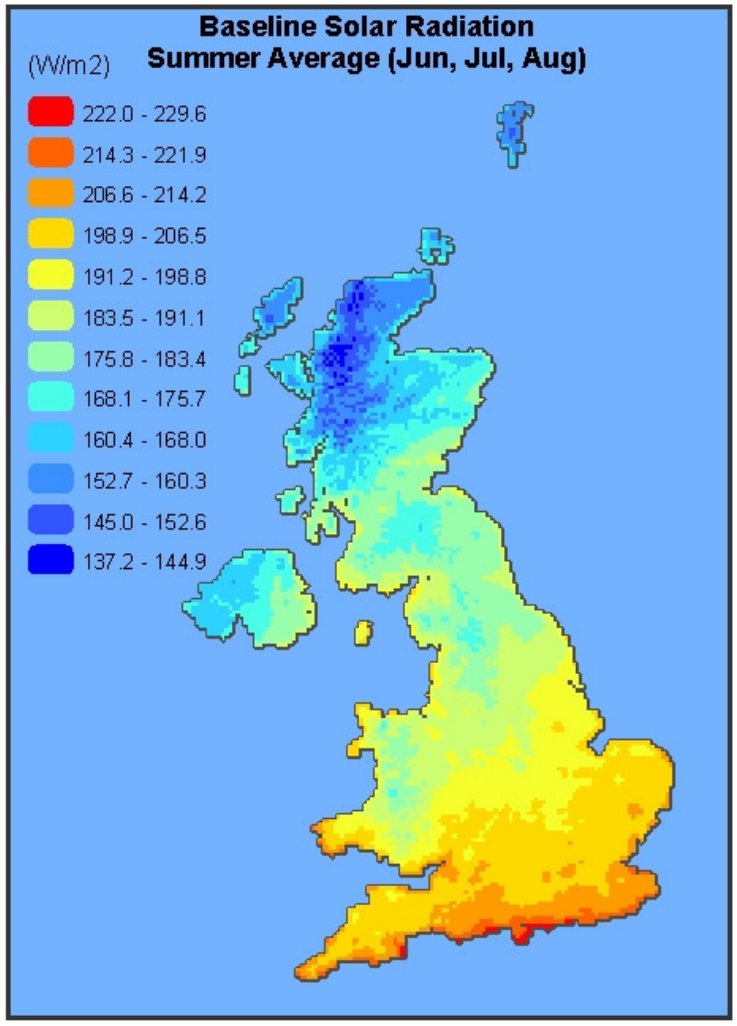
Projecting the UKCP09 anomalies onto the baseline mode

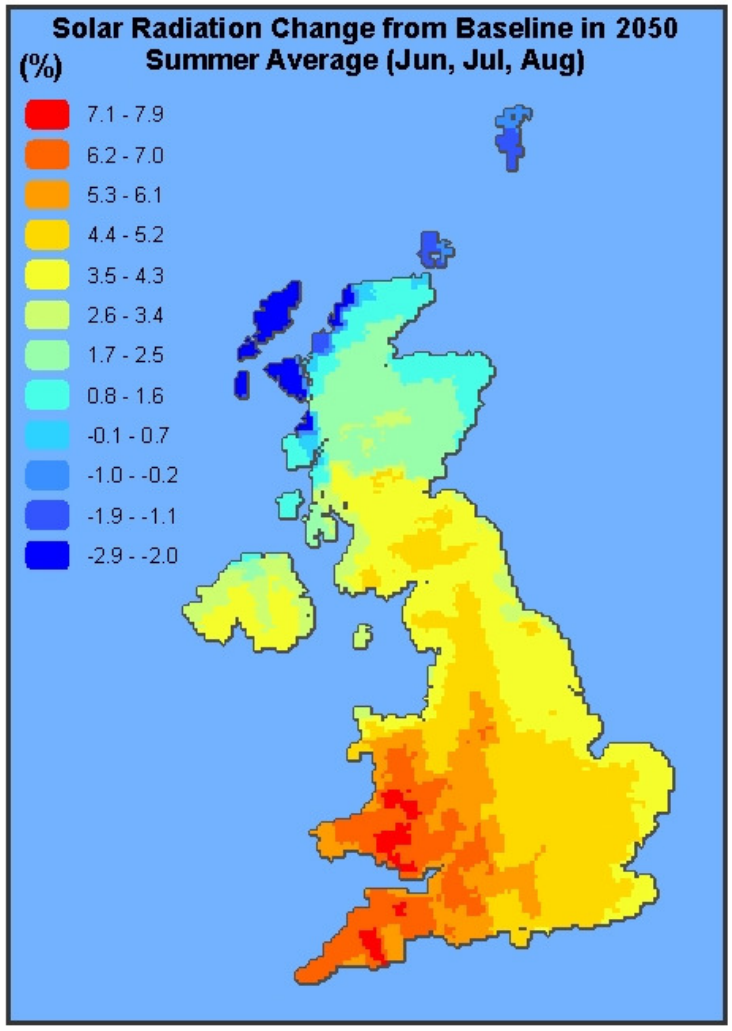
Present climate grid (5km x 5km)

Future projections rotated grid (25km x 25km)

UK Solar Resource

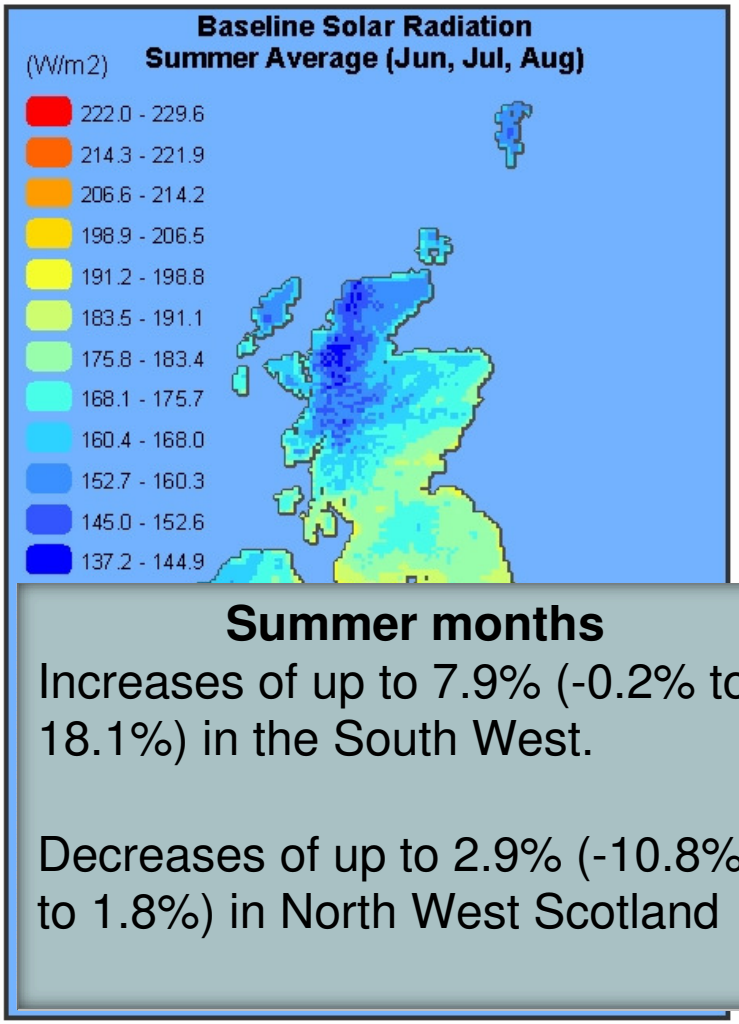
present and future

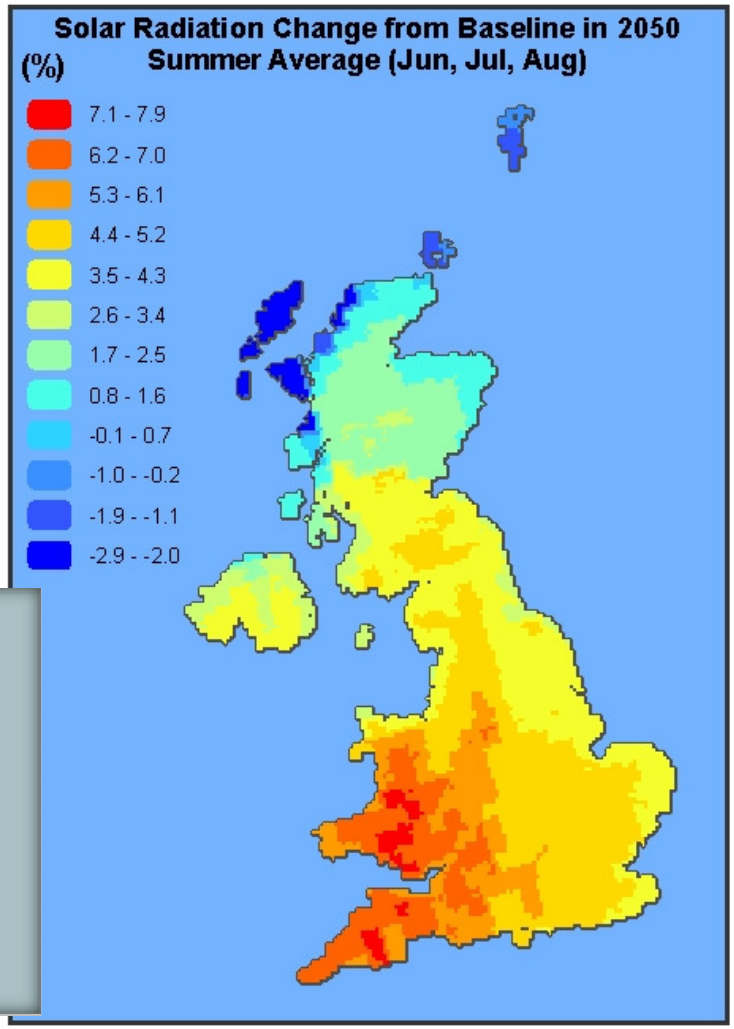




UK Solar Resource

present and future





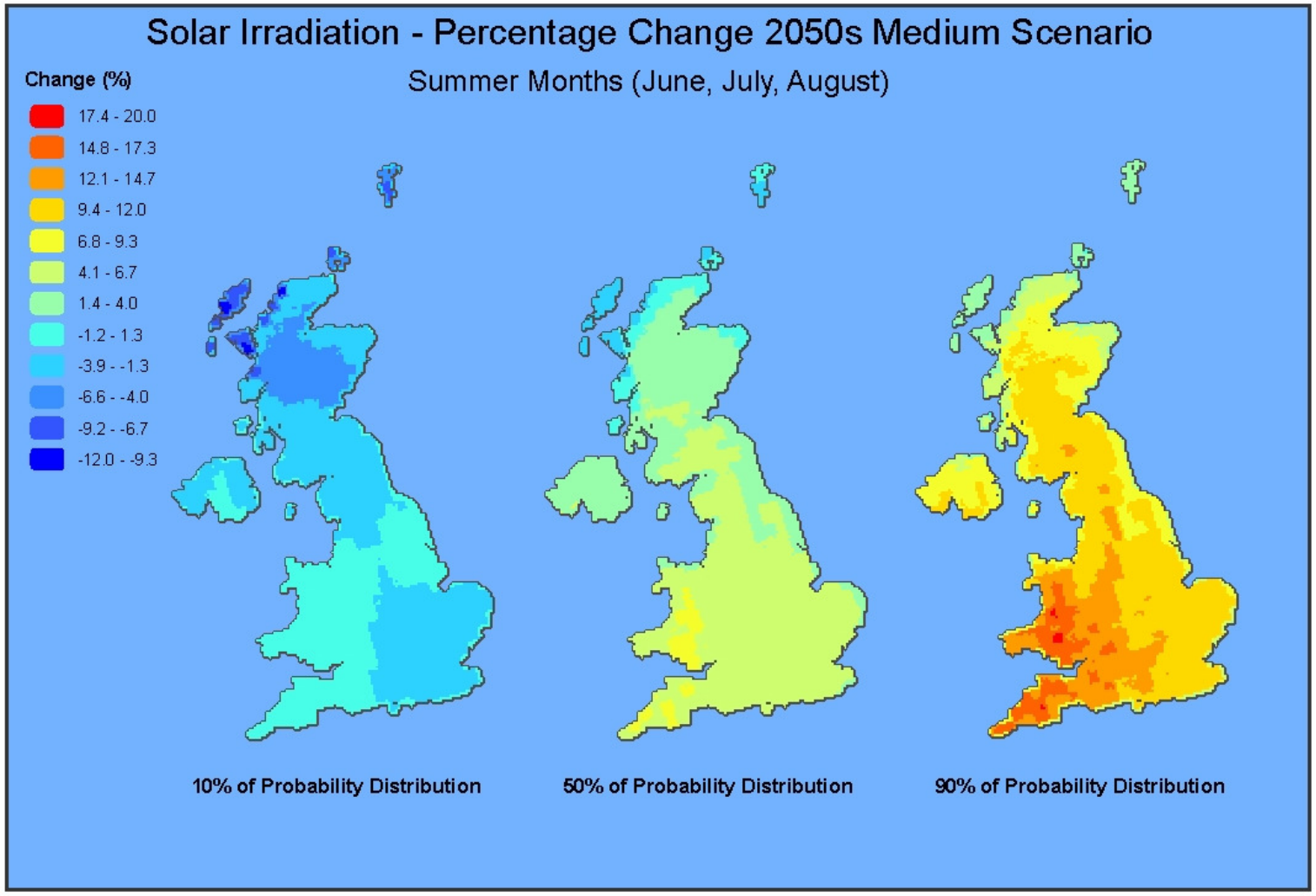
Summer months

Increases of up to 7.9% (-0.2% to 18.1%) in the South West.

Decreases of up to 2.9% (-10.8% to 1.8%) in North West Scotland

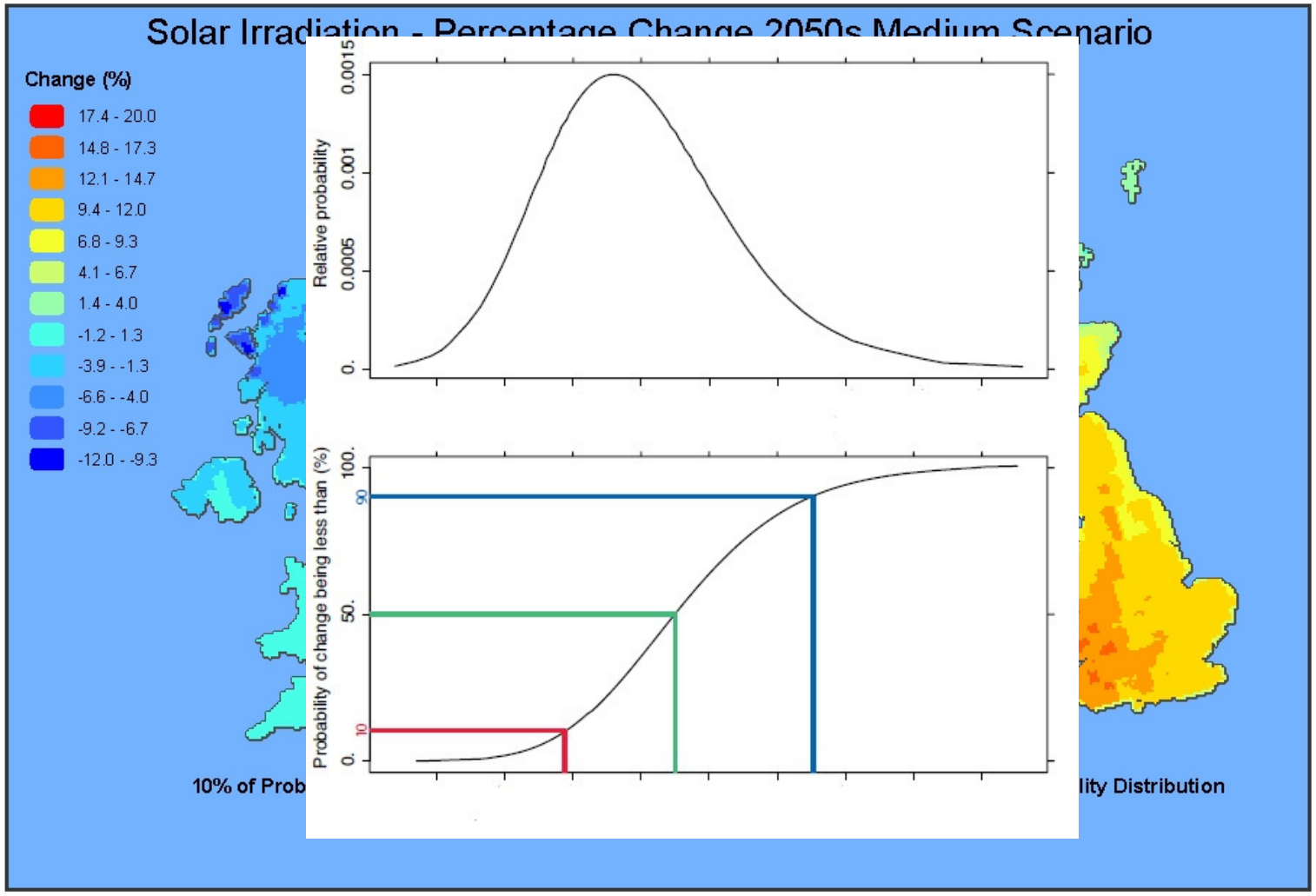
UK Solar Resource

present and future



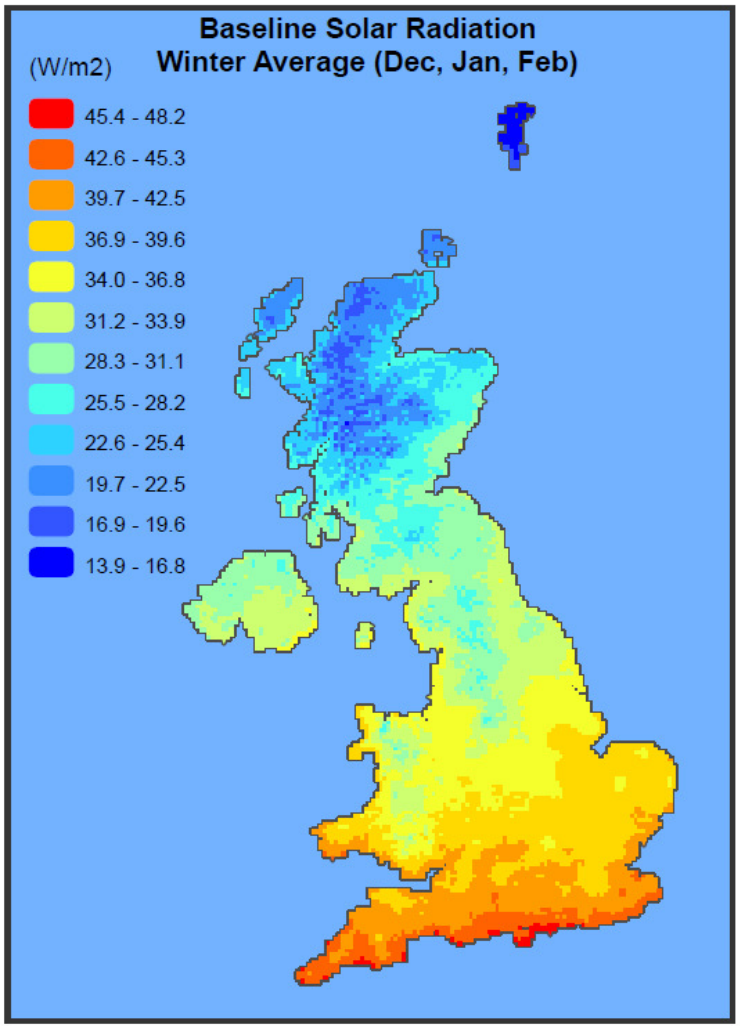
UK Solar Resource

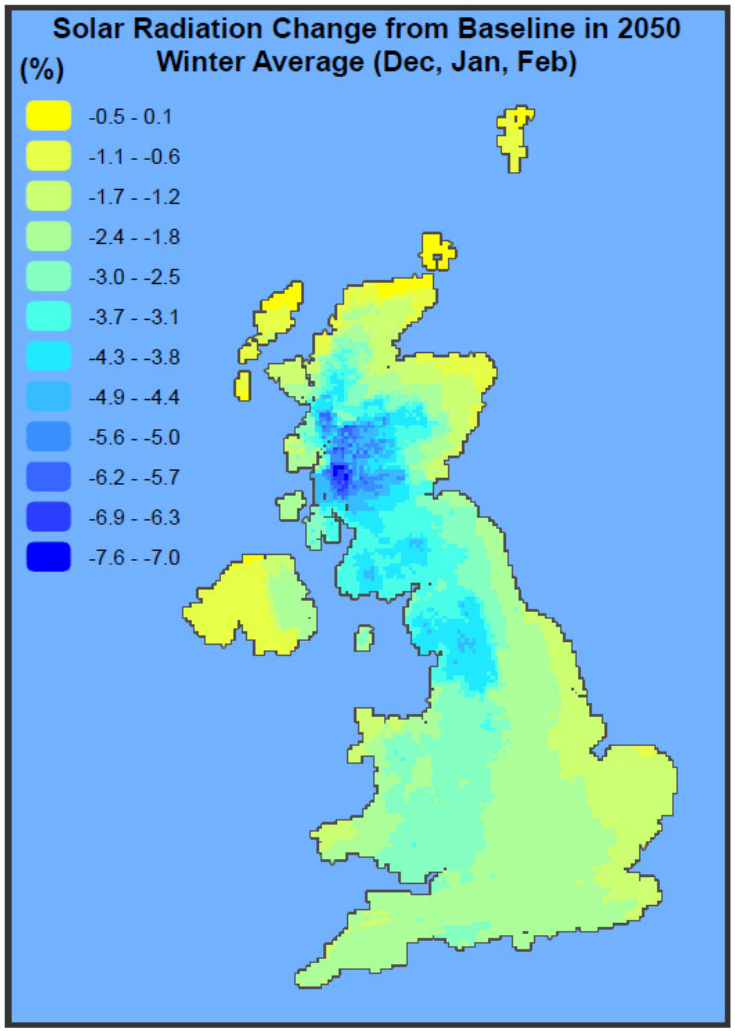
present and future



UK Solar Resource

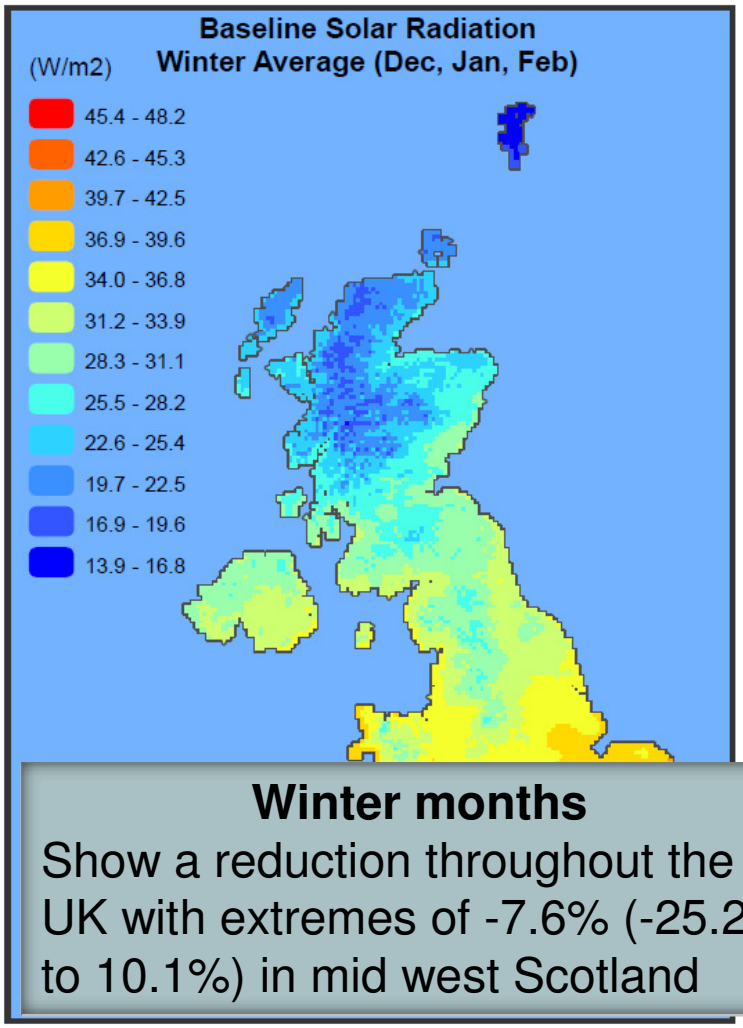
present and future

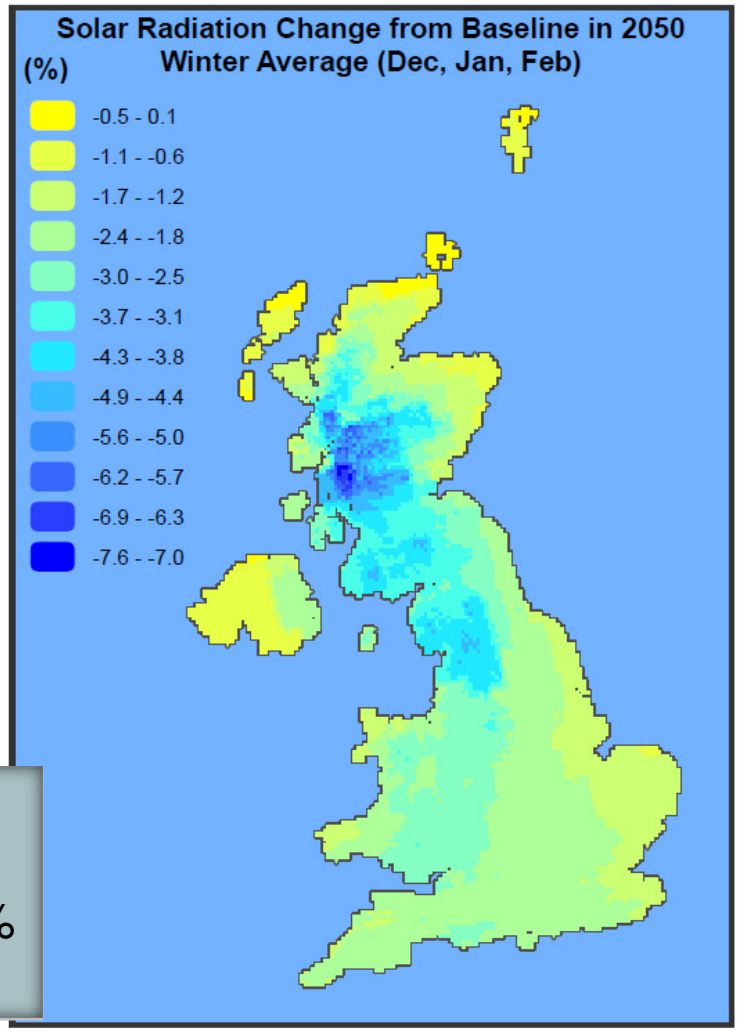




UK Solar Resource

present and future



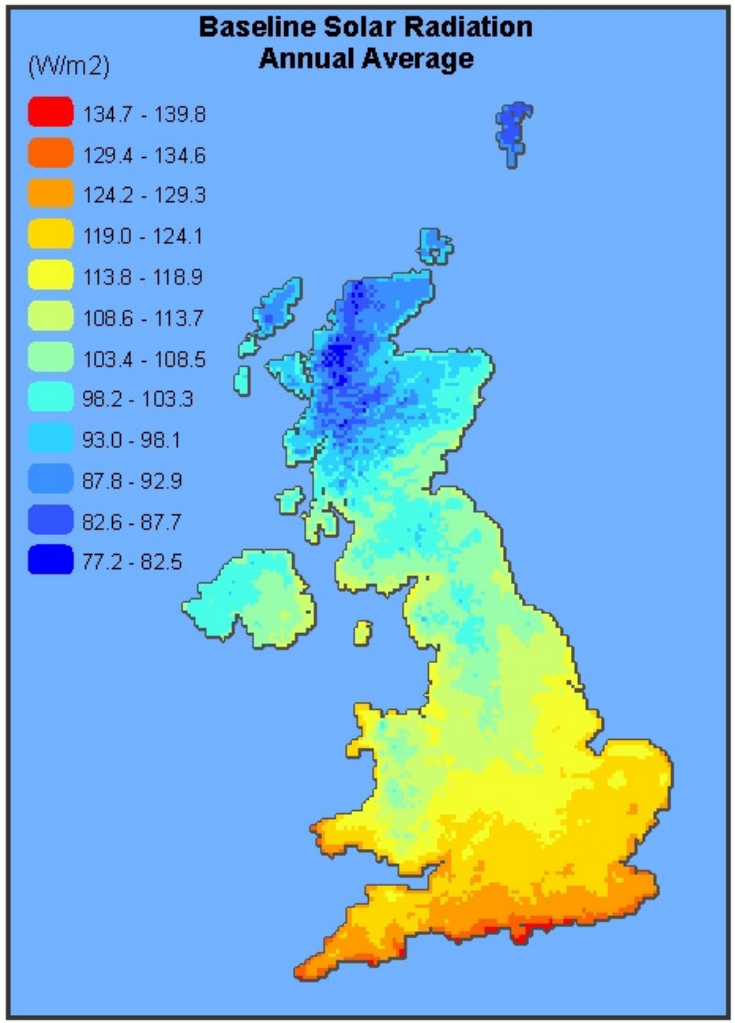


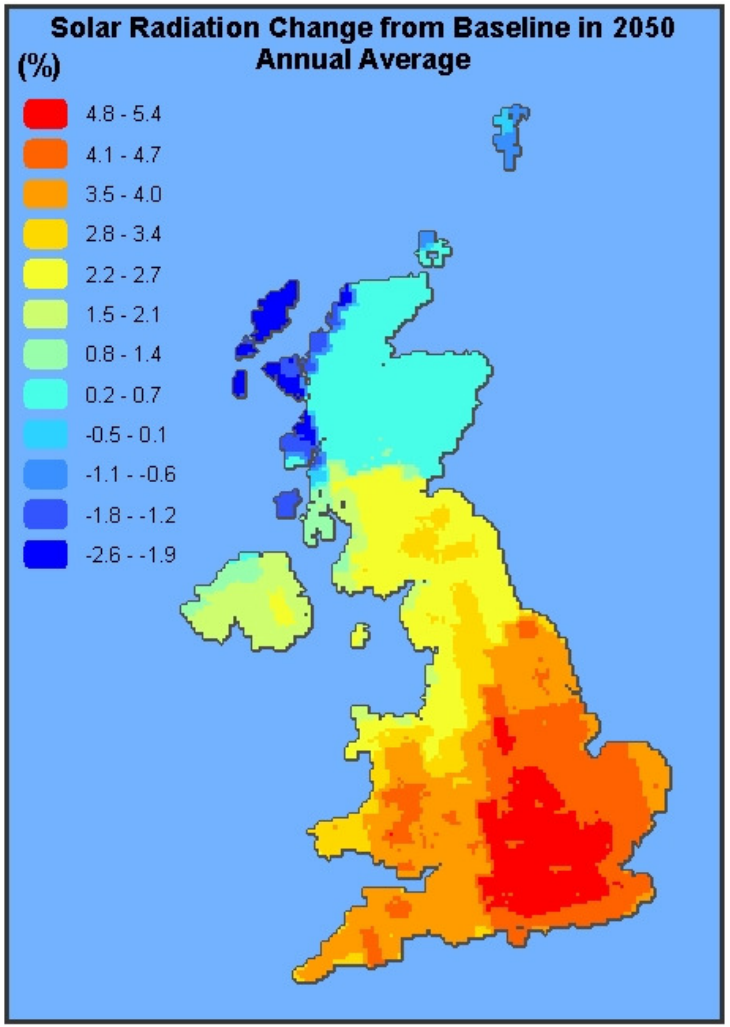
Winter months

Show a reduction throughout the UK with extremes of -7.6% (-25.2% to 10.1%) in mid west Scotland

UK Solar Resource

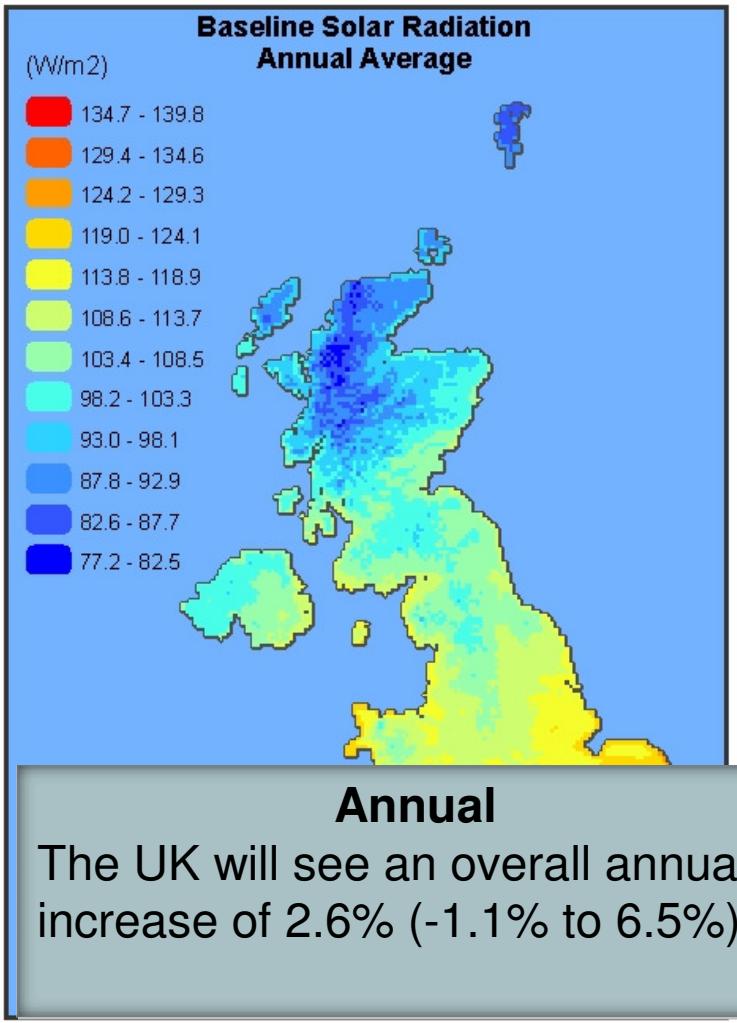
present and future

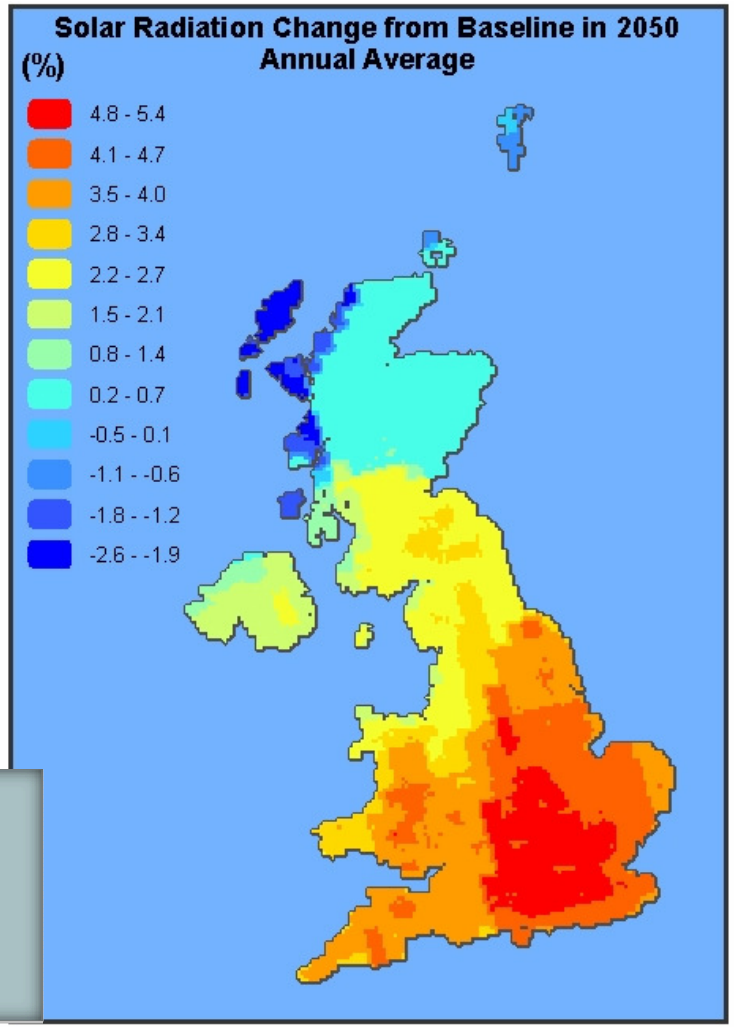




UK Solar Resource

present and future





Annual

The UK will see an overall annual increase of 2.6% (-1.1% to 6.5%)

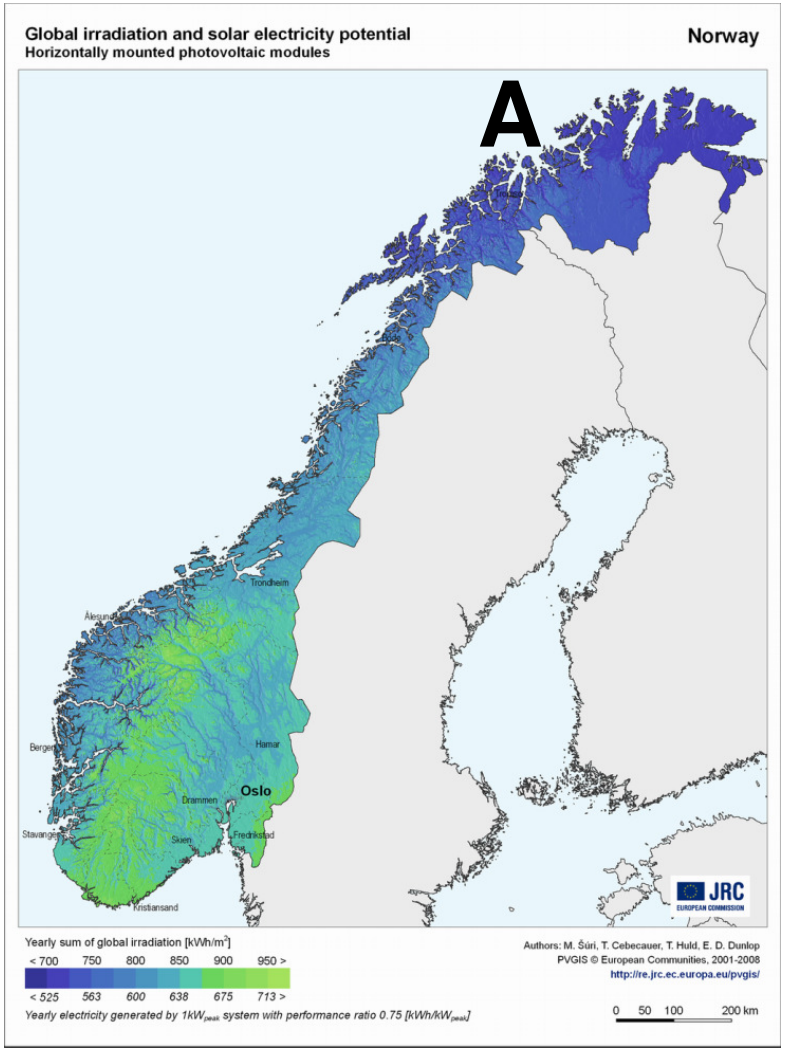
Conclusions

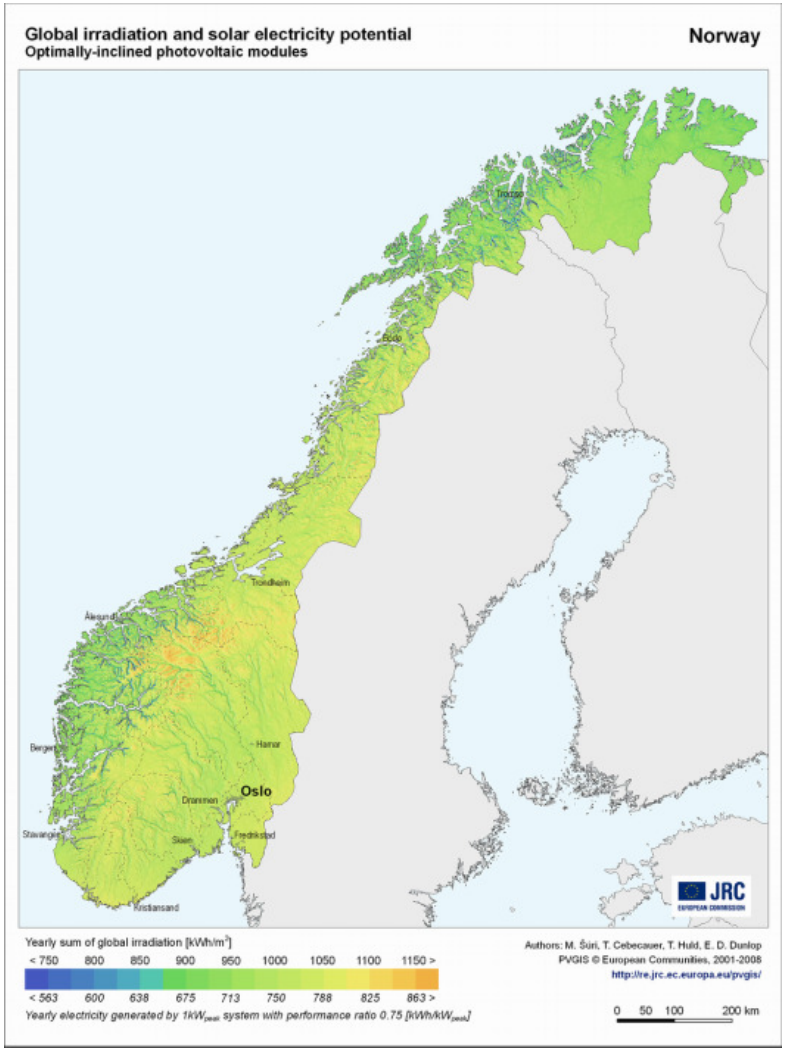
- Assessed the seasonal solar resource of the UK and investigated the impact climate change could have on the resource by the 2050s for a medium emission scenario.
- Summer months - most parts of southern UK will get sunnier and benefit from increased solar energy resource in summer, while the relatively poor resources in the north will decrease slightly.
- Winter months - all regions in will have increased cloud cover and slightly reduced solar energy resource.
- The UK will see an overall annual increase of 2.6% (-1.1% to 6.5%)
- Positive news for the viability of solar technologies, particularly in southern regions.
- Correlates well with increased use of air cooling systems due to the increased temperatures.
- However, the resource will be more seasonally variable and regional resource differences will be further reinforced.

Further Work

- **Add south facing inclination to solar resource assessment calculations.**
  - **More calculations**
  - **Need ratio of direct and diffuse irradiation levels**
- **Projected costs and efficiency of a generic PV technology**
- **Geographical Economic Assessment**
  - **Cost and Risk Analysis**
- **Include results in PhD thesis**

Solar


Global irradiation and solar electricity potential
Horizontally mounted photovoltaic modules
Norway
A
Trondheim
Bergen
Hamar
Oslo
Drammen
Stavanger
Skien
Fredrikstad
Kristiansand
JRC
EUROPEAN COMMISSION
Yearly sum of global irradiation [kWh/m²]
< 700 750 800 850 900 950 >
< 525 563 600 638 675 713 >
Yearly electricity generated by 1kW peak system with performance ratio 0.75 [kWh/kW peak]
Authors: M. Šúri, T. Cebecauer, T. Huld, E. D. Dunlop
PVGIS © European Communities, 2001-2008
http://re.jrc.ec.europa.eu/pvgis/
0 50 100 200 km


Global irradiation and solar electricity potential
Optimally-inclined photovoltaic modules
Norway
Trondheim
Bergen
Hamar
Oslo
Drammen
Stavanger
Skien
Fredrikstad
Kristiansand
JRC
EUROPEAN COMMISSION
Yearly sum of global irradiation [kWh/m²]
< 750 800 850 900 950 1000 1050 1100 1150 >
< 563 600 638 675 713 750 788 825 863 >
Yearly electricity generated by 1kW peak system with performance ratio 0.75 [kWh/kW peak]
Authors: M. Šúri, T. Cebecauer, T. Huld, E. D. Dunlop
PVGIS © European Communities, 2001-2008
http://re.jrc.ec.europa.eu/pvgis/
0 50 100 200 km