Climate Change and The UK Solar Energy Resource

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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 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
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
Conversion of Sunshine Duration to Solar Irradiation

- Method used Suehrcke (2000), based on widely used Angstrom-Prescott equation.

\[ f_{\text{clear}} = \left( \frac{\overline{K}}{K_{\text{clear}}} \right)^2 \]

where

- \( f_{\text{clear}} \) = time fraction that no significant clouds block the sun
- \( \overline{K} \) = monthly average daily clearness index
- \( K_{\text{clear}} \) = 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 extraterrestrial radiation

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

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

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

Comparison of Solar Irradiation Monthly Mean Resource Maps to actual measured Solar Irradiation

June

(W/m²)

Measured Irradiation
Irradiation converted from UKCIP gridded sunshine duration

UK Solar Resource
present and future

Comparison of Solar Irradiation Monthly Mean Resource Maps to actual measured Solar Irradiation
January

(W/m²)

Measured Irradiation
Irradiation converted from UKCIP gridded sunshine duration
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

Solar Irradiation - Percentage Change 2050s Medium Scenario
Summer Months (June, July, August)

Change (%)
- 17.4 - 20.0
- 14.8 - 17.3
- 12.1 - 14.7
- 9.4 - 12.0
- 6.8 - 9.3
- 4.1 - 6.7
- 1.4 - 4.0
- -1.2 - 1.3
- -3.9 -- 1.3
- -6.8 -- 4.0
- -9.2 -- 6.7
- -12.0 -- 9.3

10% of Probability Distribution  50% of Probability Distribution  90% of Probability Distribution
UK Solar Resource
present and future

Solar Irradiation - Percentage Change 2050s Medium Scenario

Change (%)
- 17.4 - 20.0
- 14.8 - 17.3
- 12.1 - 14.7
- 9.4 - 12.0
- 6.6 - 9.3
- 4.1 - 6.7
- 1.4 - 4.0
- -1.2 - 1.3
- -3.9 -- 1.3
- -6.8 -- 4.0
- -9.2 -- 6.7
- -12.0 -- 9.3

Probability of change being less than (%)
UK Solar Resource
present and future

Baseline Solar Radiation
Winter Average (Dec, Jan, Feb)

Solar Radiation Change from Baseline in 2050
Winter Average (Dec, Jan, Feb)
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

Baseline Solar Radiation
Annual Average

Solar Radiation Change from Baseline in 2050
Annual Average

(Maps of the UK showing solar radiation and change from baseline in 2050.)
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
Global irradiation and solar electricity potential
Horizontally mounted photovoltaic modules

Global irradiation and solar electricity potential
Optimally-inclined photovoltaic modules

Yearly sum of global irradiation [kWh/m²]

Authors: M. Ers, T. Clevenger, T. Mold, E. D. Doney
JRC 6- European Commission, 2004-2006
http://jrc.ec.europa.eu/energy/