What can European climate services offer to the energy (and water resource) sector?

Prof. Alberto Troccoli
World Energy & Meteorology Council and University of East Anglia, Norwich, UK

APEC Climate Symposium
▪ The intimate relationship between Energy and Climate
▪ How Climate impacts Energy
▪ Climate Services and decision making in Energy Sector
Energy and meteorology go hand in hand

- Passing clouds: Drop in solar power
- Hurricanes: Disruptions to oil rig operations
- El-Niño: Changes in Demand Patterns
- Long term changes: Renewable Resource Assessment

Time scales:
- Seconds
- Minutes
- Days
- Months
- Seasons
- Years
- Decades
Energy Decisions & Meteorological Forecasts

Operations
- 'Weather' Forecast (hours-days ahead)

Maintenance
- Monthly forecasts (weeks ahead)

Management
- Seasonal Climate Forecasts

Investment/Planning
- Climate projections

Paul Langrock
Klaus Rockenbauer
Critical components of a prediction system

Model
(Physics/Statistics)

External factors
(Volcanoes, GHGs, Solar)

Observations
(Initial Conditions)

Time scale
The complexity of the Earth System
Critical components of a prediction system

Model
(Physics/Statistics)

External factors
(Volcanoes, GHGs, Solar)

Observations
(Initial Conditions)

Time scale

Model

Atmosphere

Land

Ocean

Ice

Importance

Days
Months
Years
Decades

Importance
WEMC primary goal is to enable improved

- **Sustainable energy**
  For a low carbon economy

- **Resilience**
  Of energy infrastructures

- **Efficiency**
  Of energy systems

Under ever changing weather and climate
1. The **dissemination of information** on products, practices, and experiences in Energy & Meteorology including the promotion of our members’ work

2. The **coordination of Special Interest Groups** leading to the production of reports, analyses and syntheses on key topics in Energy & Meteorology

3. The development and maintenance of **climate and energy demonstration tools** for the energy industry and the education of the general public

4. The **organisation of events** such as the International Conference Energy & Meteorology (ICEM), professional workshops, seminars and webinars
The energy industry has a multi-decadal experience in dealing with meteorological variables. So, what’s the big deal?

The landscape, in both climate and energy spaces, is changing rapidly.
Strong growth in renewables

GSR 2018 KEY FIGURES

Estimated renewable energy share of total final energy consumption, 2010

<table>
<thead>
<tr>
<th>Energy Type</th>
<th>Share</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fossil fuels</td>
<td>79.5%</td>
</tr>
<tr>
<td>Nuclear energy</td>
<td>2.2%</td>
</tr>
<tr>
<td>Traditional biomass</td>
<td>7.8%</td>
</tr>
<tr>
<td>Modern renewables</td>
<td>10.4%</td>
</tr>
<tr>
<td>Hydropower</td>
<td>3.7%</td>
</tr>
<tr>
<td>Biomass/solar/geothermal</td>
<td>4.1%</td>
</tr>
</tbody>
</table>

REN21 (2018)
Impressive growth in Wind and Solar

Wind Power Global Capacity and Annual Additions, 2007-2017

Solar PV Global Capacity, 1st Country Partition, 2007-2017

REN21 (2018)
CO$_2$ emissions and temperature

IPCC AR5 (2013)
Disasters due to natural events

EM-DAT (2016)

See also Diffenbaugh et al. (2017, PNAS)
Percentage difference in monthly solar radiation in El Niño relative to La Niña

Winter (JJAS)  Summer (DJFM)

Davy and Troccoli (2012)
Global changes in streamflow projections

Change in streamflow for RCP8.5, 2040–2069 (2050s) vs 1971–2000

Reductions in usable capacity for 61–74% of the hydropower plants

van Vliet et al. (2016)
Global changes in water temperature projections

Change in water temperature for RCP8.5, 2040–2069 (2050s) vs 1971–2000

Reductions in usable capacity for 81–86% of the thermoelectric power plants

van Vliet et al. (2016)
Addressing the ever variable nature of climate
Increasing share of power supply from variable renewable energy (RE) sources. Demand variability is also increasing. The transformation is taking place against a variable and changing climate.
The Copernicus Climate Change Services (C3S) European Climatic Energy Mixes (ECEM) developed a demonstrator to assess how well different energy supply mixes in Europe will meet demand, over different time horizons, focusing on the role climate has on the mixes.
European Climatic Energy Mixes (ECEM)

Calibrated Climate Variables
- Temperature
- Rainfall
- River Discharge
- Wind Speed
- Solar Radiation
- Cloud Cover
- Others

Energy Variables
- Hydro Power
- Demand
- Wind Power
- Solar Power
- Thermal Power

+ Ancillary

Define models & transfer functions
Select / Gather relevant datasets

+ Extreme Events Case Studies

- Skill & Reliability
- Assessment of Seasonal Forecasts of Energy Variables
- Sub-Country Scale
- Historical Period
- Seas. Fcst
Stakeholder Engagement: Workshops
## Seasonal Forecasting systems used in C3S ECEM

<table>
<thead>
<tr>
<th>Originator</th>
<th>Forecast System</th>
<th>Model</th>
<th>Spatial resolution</th>
<th>Hindcast period</th>
<th>Hindcast ensemble size</th>
<th>Forecast ensemble size</th>
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</thead>
<tbody>
<tr>
<td>ECMWF</td>
<td>System 4</td>
<td>IFS Cyc36r4</td>
<td>T255 L91 (~80 km)</td>
<td>1981–2010 (30 years)</td>
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<td>Météo-France</td>
<td>System 5</td>
<td>Arpege-IFS Cyc37</td>
<td>T255 L91 (~80 km)</td>
<td>1993–2014 (22 years)</td>
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<tr>
<td>Met Office</td>
<td>GloSea5-GC2</td>
<td>HadGEM3-GC2</td>
<td>N216 L85 (~60 km)</td>
<td>1993–2015 (23 years)</td>
<td>28</td>
<td>42</td>
</tr>
</tbody>
</table>

Seasonal forecasting skill: correlations for summer

### Seasonal forecast: summary table skill for Summer

#### JJA skill:

Where a skill score is significantly greater than zero, it is marked with a **C** (correlation), **B** (Brier skill score) or **R** (ROC skill score). **Colours**: 1 score, 2 scores, 3 scores

Skill is diverse across models, variables and seasons.

Having more significant skill scores can add confidence, but the behaviour of the models should be examined in detail for each use case.

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<table>
<thead>
<tr>
<th>Country Code</th>
<th>Country</th>
<th>Met Office</th>
<th>ECMWF</th>
<th>Météo-France</th>
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</tbody>
</table>

**Table 3: Summary table for skill of JJA forecasts from each model, for predicting ERAI data. Entries are high, medium and low skill (i.e. 1, 2, 3 scores) and are marked with **C**, **B** or **R** depending on whether the skill is significant (correlation), Brier or ROC, respectively.**
Correlation predicted solar radiation vs PV CF

Figure 7: Map of the correlation skill between DJF solar PV generation and irradiance from the ECMWF system. Countries where the skill is indistinguishable from zero at the 95% confidence level are obscured by cross-hatching. Bett et al (2017)
Seasonal Forecast of PV CF

Figure 5: Standardised time series of forecasts of DJF solar PV capacity factor, using irradiance as the predictor. Top: results from the Met Office system, for Lithuania (left) and Sweden (right). Bottom: Similar forecasts for Ireland, using the Météo-France system. In each panel, the hindcast is shown in red, and the ECEM historical energy data is shown in black, in standardised units (see equation 2). The correlation skill $r$ is shown in the legend with 95% confidence intervals; an asterisk * indicates significance based on these intervals.
Climate Projection – France | Summer (JJA/Jun–Aug)

Air Temperature [°C]

- adjERA-I
- WFDEI
- RCP 8.5
- RCP 4.5

Produced by the ECEM Demonstrator Vn2.2 (http://ecem.climate.copernicus.eu/demo)
Climate Projection time series – Precip and Wind

Climate Projection – Spain | Summer (JJA/Jun–Aug)
- adjERAI
- WFDEI
- RCP 8.5
- RCP 4.5

Climate Projection – Germany
- adjERAI
- WFDEI
- RCP 8.5
- RCP 4.5

Produced by the ECEM Demonstrator Vtn2.2 (http://ecem.climate.copernicus.eu/demo)
Climate Projection time series – Solar Rad & Power

Produced by the ECEM Demonstrator Vn6.1 (http://ecem.climatem europen)
Projected changes in Solar Rad. Global vs Regional models

<table>
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<tr>
<th>GCM</th>
<th>RCM</th>
<th>GCM</th>
<th>RCM</th>
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<td>HadGEM</td>
<td>RCA4 0.44</td>
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<td>GFDL</td>
<td>RCA4 0.44</td>
<td>NORESM</td>
<td>RCA4 0.44</td>
</tr>
</tbody>
</table>

Fig. 2 Annual projected changes in SSR in the RCA4 regional model and in different driving GCMs. The changes are defined as the difference between the future projections for RCP8.5 (2071–2100) and the historical simulation (1971–2005).

Fig. 3 Annual changes in SSR in individual RCMs (first name on x axes) and in GCM applied as boundary conditions (second name on x axes) over the European domain. Blue columns depict changes for RCMs with 0.11° resolution, orange columns depict changes for RCMs with 0.44° resolution, and grey columns depict changes in GCMs. The changes are defined as the difference between the future projections of RCP8.5 (2071–2100) and historical simulation (1971–2005).
Projected changes in Solar Rad.
Global vs Regional models

<table>
<thead>
<tr>
<th>GCM</th>
<th>RCMs</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>CNRM</td>
<td>ALADIN (0.44)</td>
<td>RCA(0.44)</td>
</tr>
<tr>
<td>IPSL</td>
<td>WRF (0.44)</td>
<td>RCA(0.44)</td>
</tr>
</tbody>
</table>

Bartok et al (2016)
An online interactive tool to test energy mixes

http://ecem.wemcouncil.org
General Documentation and Key Messages

EUROPEAN CLIMATIC ENERGY MIXES (ECEM)

KEY MESSAGES

ECEM KM 01

A warming Europe

Key messages: A warming Europe

- Temperatures have risen consistently across Europe over the last ~40 years
- In countries such as Germany the warming has been strongest in winter whereas in Spain, for example, it is strongest in summer
- At the same time, variability from year-to-year and day-to-day persists, and cold events have continued to occur in recent years
- Temperature is a major driver of the ECEM models for energy demand and of solar and hydro supply thus these trends and patterns of variability will impact estimates of these energy variables

How do we know Europe is warming?

Warming trends are evident in time-series plots of historic air temperature data (°C) for 1979-2016 including those for the seven countries shown here (Sweden, UK, France, Italy, Spain, Germany and Romania). The plot below shows the trends for summer (June, July and August).

For more information visit www.ecem-climate.copernicus.eu or contact the ECEM team at support@ecem-climate.copernicus.eu

Date of publication: 25 June 2017

A series of Key Messages for the European energy sector based on the analysis of data in the ECEM Demonstrator.

Using the demonstrator

- Introduction
- Getting started
- Help menu
- Creating and modifying the map
- Creating and modifying time series
- Time slider and map legend
- Date range and temporal resolution
- Downloading data
- Downloading and printing graphs
- Zooming and resetting
- Absolute values and anomalies
- Thresholds

EUROPEAN CLIMATIC ENERGY MIXES

Using the demonstrator

- Countries
- Time Period
- Historical
- Variables
- Climate
- Select variables

Country

New graph

Reset Map
### Variables and Event Case Studies Fact Sheets

**EUROPEAN CLIMATIC ENERGY MIXES (ECEM)**

**EVENT CASE STUDY**

**ECEM CS 001**

**High demand in winter 2009/10**

**Boosting Decision Making**

1. Winter 2009/10 saw high power demand due to extremely cold temperatures across much of northern Europe, as seen in the ECEM demonstrator.

2. The impact of another winter similar to 2009/10 is likely to be greater today because of the increase of weather-sensitive renewables such as wind in the energy mix. For the UK, the ECEM historical dataset shows a significant drop in wind power if 2009/10 conditions occurred today.

**Scientific/Technical Advances**

1. ECEM has brought together credible data from the climate and energy communities, processed in a consistent way over a range of time scales.

2. The demonstrator tool provides valuable insight into the winter 2009/10 event and can be used to study the impact of other extreme weather events on European power systems.

3. Analysis of the ECEM datasets has revealed dependencies and risks across European countries and between energy and climate variables.

**Key Lessons**

1. The ECEM historical dataset allows:
   - Investigation of an event in the context of recent history
   - ‘What if’ questions to be assessed based on today’s energy mix and the climate drivers

2. The demonstrator can help anticipate future risks through:
   - Seasonal forecasts
   - Climate projections

---

### 1 General

1.1 Description
1.2 Units
1.3 Links
1.4 Data format
1.5 Keywords
1.6 Contact

### 2 Dataset coverage

2.1 Geographic area
2.2 Temporal resolution
2.3 Time period
2.4 Spatial resolution

### 3 Usage

3.1 License conditions
3.2 Citation(s)

### 4 Lineage statement

4.1 Original data source
4.2 Tools used in production of indicators

### 5 Data quality

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**For more information visit**: [http://ecem.climate.copernicus.eu](http://ecem.climate.copernicus.eu)

**Date of publication**: 12 June 2017

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**Version 4, Date of publication**: 4 December 2017

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**EUROPEAN CLIMATIC ENERGY MIXES (ECEM)**

**VARIABLE FACT SHEET**

**ECEM VFS E01**

**Energy demand**

A series of fact sheets which provide metadata for the climate and energy variables produced by ECEM

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**For more information visit**: [www.ecem.climate.copernicus.eu](http://www.ecem.climate.copernicus.eu) **or** contact the ECEM team at support@ecem.climate.copernicus.eu
Want to learn more about C3S ECEM?

For more information about C3S ECEM please visit: 
http://ecem.climate.copernicus.eu

and the demonstrator can be accessed at:
http://ecem.wemcouncil.org
How can seasonal climate forecasts help your business?

The SECLI-FIRM project has received funding from European Union's Horizon 2020 Research and Innovation Program under Grant Agreement 776868.
Nine cases for Europe and S. America will be investigated. These represent recent seasons with anomalous climate conditions leading to problematic and quantifiable impacts for the energy and/or water industry. They will be co-designed by industrial and research partners.
Use of seasonal forecasts by the UK National Grid Operator

Case Study 8
Winter weather & energy system balancing

The objective is to illustrate the benefits of using seasonal forecast information to better predict the UK winter mean electricity demand and wind power.
To download it (it’s free!), please visit:
https://link.springer.com/book/10.1007%2F978-3-319-68418-5 or
http://www.wemcouncil.org/wp/resources/
Energy and Meteorology are closely connected.

Energy systems are already experiencing sizeable climate impacts, which are likely to become more severe.

Climate services (with seasonal climate forecast, climate projections, but also reconstructions of the past) are emerging as useful tools for Energy planning, and operations/maintenance.

Despite emerging use of climate in energy (and other) sectors, there is a strong need:
- to improve knowledge of meteorological data and processes
- to improve access to meteorological and energy data for improved products
Thank You