Data Challenges for Analysing the Water-Energy Nexus

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Background

• Researcher at DTU within hydrology + climate science
• Same department as ‘Energy Systems Analysis’ (Kenneth’s group)
• Fairly new to energy-water couplings and in particular energy system specifics
• Here to learn, interact and get feedback – possibly shorter presentation and longer discussion round afterwards
• Personal dream of doing dynamically coupled water-energy nexus modelling studies – I have done this previously between hydrology/climate models.
• Present result (or rather points raised) from review type paper currently under review in ‘Science of the total Environment’
Abstract paragraph 1 – setting the scene

Water is paramount for the operation of energy systems as well as securing food supply, industries, and municipalities. Water demands across sectors can negatively affect regions of water scarcity by e.g. power plants shutdowns, poor agricultural yields, and lack of potable water. Future economic and population growth as well as climate change is likely to exacerbate these patterns. However, the models used for energy system management and planning in general do not properly include water availability which can lead to improper representations of water-energy interlinkages.

Analogue to the situation for climate/hydrology models app. 10 years ago
Introduction statements – setting the scene (a bit more)

- Resolving the highly interlinked and interdependent nexus of water, energy and food systems presents a formidable challenge for sustainable development (World Water Assessment Programme/UNESCO)

- The importance of taking a nexus approach in policy and planning is highlighted in the development and implementation of the Agenda 2030 and its 17 Sustainable Development Goals (United Nations General Assembly, 2015)

- To properly analyse the coherence and competing demands of this nexus, not only at different temporal and spatial scales but also across sectors and climatic conditions, calls for integrated, systematic approaches and tools (Allan et al., 2015; Howells et al., 2013).
The challenge

Under review - please do not distribute
Abstract paragraph 2 – the aim

1) The present paper initially aims to highlight water withdrawals and consumption rates for current technologies within electricity and fuel generation and potential future technologies.

2) Secondly, the paper presents a review of currently available data on current and future projected water resources as well as data on energy statistics relevant to water-energy nexus studies.

3) Finally, the paper highlights some of the main challenges in studying the linkage between water and energy (in terms of data).
Methodology

• Water-energy aspects related to the production of electricity

• For comparison and to highlight emerging technologies aspects of the following is included: biomass, liquid fuels, energy resource extraction, CO\textsubscript{2} capture/storage, energy storage, recycling and waste treatment.

• Freshwater

• Distinguish between withdrawal (total) and consumption (net)

• Operational/production side – no LCA, establishment/decommissioning etc.

• Environmental issues not addressed

• Satellite data sources not considered

• No: jurisdiction, geographical variations, and end-user water-energy interactions
Withdrawal/consumption and thermal power plant cooling

Water use* varies not only with energy source but also with (e.g. cooling) technology

*Absolute values and share between withdrawals and consumption rates

Figure 1. Water withdrawal and consumption definition (a) and cooling technologies in thermal power plants (b).
Water withdrawal rates

- Withdrawal rates dependent on cooling technology
- Also for ‘renewables’:
  - Biopower

Non-renewables

- Nuclear
  - (tower) [2]
  - (pond) [2]
  - (OT) [2]

- Gas
  - (tower) [1]
  - (pond)
  - (OT) [1]

- Gas comb cycle
  - (tower)
  - (pond)
  - (OT)

- Coal
  - (tower) [1]
  - (pond) [1]
  - (OT)

Renewables

- Biopower
  - (tower/pond) [1]
  - (OT)

Oil production

- Oil
  - (OT) [2]
  - (recycled) [2]
  - (hybrid) [2]
  - (dry)
Water consumption rates

Renewables in terms of GHGs is not necessarily renewable in terms of water recourses.
## Water resources data

<table>
<thead>
<tr>
<th>Name</th>
<th>Association</th>
<th>Content</th>
<th>Temporal Information</th>
<th>Reference</th>
<th>Data availability*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flow Regimes from International Experimental and Network Data</td>
<td>UNESCO</td>
<td>River discharge, 162 countries divided into eight regions</td>
<td>Temporally similar to GRDC. (Daily)</td>
<td>(Henny et al., 2014)</td>
<td>Free to use – ordered through GRDC</td>
</tr>
<tr>
<td>The Global River Discharge Database (RivDis)</td>
<td>Supplied by the Oak Ridge National Laboratory</td>
<td>1018 stations</td>
<td>1807-1991 Monthly</td>
<td>(Vörösmarty et al., 1996)</td>
<td>Free to use</td>
</tr>
<tr>
<td>Coordinated Regional climate Downscaling Experiment (CORDEX) – (see figure 4)</td>
<td>The World Climate Research Program (WCRP) project supported by WMO, UNESCO etc.</td>
<td>Regional climate model output (14 domains) Historical and future (RCP based)</td>
<td>From 3h to monthly</td>
<td>(Giorgi and Gutowski, 2015)</td>
<td>Free to use</td>
</tr>
<tr>
<td>Global Earth Observation System of Systems (GEOSS Portal)</td>
<td>Maintained by the European Space agency (ESA)</td>
<td>Numerous data sets and providers User-friendly map based GUI</td>
<td>'Conglomerate'</td>
<td>(Giuliani et al., 2011)</td>
<td>Free to use</td>
</tr>
<tr>
<td>WATCH</td>
<td>EU project (many partners)</td>
<td>Multiple global hydrology</td>
<td>1901-2100</td>
<td>(Harding et al. 2011)</td>
<td>Free to use</td>
</tr>
</tbody>
</table>
The CORDEX regional climate model experiment framework

Highly ambitious and streamlined in terms of general conventions:

- **Forcing (RCPs and boundary models)**
- **Periods + timesteps**
- **Domain/geography + model grids**
- **Output variables**

**Result:** Ease of use and interoperability
Figure 4. Historical and projected future water (and climate) data from the CORDEX database (Giorgi and Gutowski, 2015). Shown here for Europe is a three-model mini-ensemble (for illustrative purposes and with randomly selected models) of yearly distributed means for historical precipitation, evapotranspiration and total runoff (1976-2005) as well as projected residuals (2071-2100, using the RCP4.5 scenario) extracted for the European domain in approx. 12.5 km resolution. The ensemble includes the MPI-ESM-LR/CCLM4, EC-Earth/RCA4 and EC-Earth/RACMO22 GCM/RCM global/regional climate models.
## Energy data (1)

<table>
<thead>
<tr>
<th>Name</th>
<th>Association</th>
<th>Content</th>
<th>Temporal resolution</th>
<th>Reference</th>
<th>Data availability</th>
<th>Link to water</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Global</strong></td>
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</tr>
<tr>
<td>Resource (The Renewable Energy Source of Information)</td>
<td>IRENA</td>
<td>Power production per technology type</td>
<td>Annual</td>
<td>(IRENA, 2017)</td>
<td>Free to use</td>
<td>Power production from thermal and hydro power plants</td>
</tr>
<tr>
<td>DataBank – (see figure 5)</td>
<td>World Bank</td>
<td>Power production by fuel</td>
<td>Annual (from 1967)</td>
<td>(World Bank, 2017)</td>
<td>Free to use</td>
<td>Power production from thermal and hydro power plants</td>
</tr>
<tr>
<td>OECD Data</td>
<td>OECD</td>
<td>Power production divided into nuclear and non-nuclear</td>
<td>Annual</td>
<td>(OECD, 2017)</td>
<td>Free to use</td>
<td>Power production from nuclear plants</td>
</tr>
<tr>
<td>Global Energy Statistical Yearbook – (see figure 5)</td>
<td>Enerdata</td>
<td>Gross annual power production</td>
<td>Annual</td>
<td>(Enerdata, 2017a)</td>
<td>Free to use</td>
<td>No</td>
</tr>
</tbody>
</table>

### Either

1) **No water linkages**

2) **Too aggregated, i.e. no spatio-temporal details such as plant level intake/re-ejection amounts, time/space information, quality (temperature/chemistry), source (river name, location, and aquifer depth etc.)**

3) **If this information is acquired (not free), then it is not in a readily usable format (too specific)**

4) **Some information is not available due to commercial interests**
Figure 5. Electricity production shares (%) for all EU28 countries (total) for different fuel sources for 1967-2014 and corresponding absolute electricity production (TWh) for 1990-2016 (left) (Enerdata, 2017a; IEA, 2017; World Bank, 2017). Electricity production shares (%) for each EU28 country based on all renewable sources (upper right) as well as renewable sources excluding hydropower (lower right) for 1990-2014 (IEA, 2017; World Bank, 2017).
Energy data (2)

Figure 6. Withdrawal and consumption rates (L/MWh) for selected US power plants of varying fuel sources (coal, nuclear, gas, wood/waste/biomass and municipal solid waste) and cooling types (OT/REC etc.) for 2014-2015 (USEIA, 2017).
Abstract paragraph 2 – the findings

We conclude that despite the existence of detailed energy data in some regions, there is a **substantial gap in the availability, access and quality** of proper regional and global data usable for detailed **quantitative analyses**. We also identify a need for improved **standardization of formats** and **data collection methodologies** across different uses of the data. An **effort** towards a coordinated, transparent, and sustained open-access data framework holding energy sector water usage information at fine spatio-temporal scales alongside hydro-climatic observational and modelled data using common forcings, scenarios and assumptions for future projections is therefore recommended for improved future detailed quantitative water-energy nexus studies.

1. Without this framework, aggregated assumption-heavy data must be used.

2. Additionally: Sustainable energy often refers to GHGs alone but is in essence not aligned with water sustainability – or even other resources.
Open questions

• Do we already have something resembling such a (data) framework?
• Or someone working towards it (who)?
• What is needed?
  
  *Suggestion*:
  • Initially the database could include water and energy (model) data separately
  • At a later stage, output from dynamically coupled (climate)-water-energy models could be included

• What are the constraints?
  • Commercial interests
  • Other?...

*Thanks*