MODELLING IMPACTS OF CLIMATE CHANGE ON ENERGY SYSTEMS: A CRITICAL REVIEW

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Overview

Climate change affects energy systems (demand profiles and supply) in many ways. As these impacts could potentially affect the price and security of energy, and thus welfare, they should be accounted for in long-term energy system modelling and analysis. This poster outlines a critical review of the literature on this subject.

Potential impacts of climate change on the energy system include changes to demand patterns, primary resources, access to fuels, the efficiency of conversion and transportation technologies and downtime due to extreme events (Ebinger and Vergara, 2011). A range of engineering and economic models have been used to study climate-energy impacts. The studies primarily cover impacts on demand rather than supply, and focus on economically developed regions (Ciscar and Dowling, 2014).

Gaps in the literature include: a thorough examination of the impact of extreme events, the impacts of increasing water competition and variability of renewable resources, the representation of climate impacts on supply side processes and their integration as feedback loops in energy system models.

The review systematically covered: relevant text books, impact summary reports by governmental organisations, journal papers, empirical analyses, modelling studies and previous reviews. The results are relevant to the field of energy system integrated assessment modelling (IAM). Specifically, this review has been completed in preparation for the integration of these impacts in TIAM-UCL, a bottom-up least cost optimisation energy system model (Anandarajah et al, 2011). With this in mind, the results are tabulated and comments provided on their relative importance.

Methods

A systematic search and critical review of literature was completed, covering the following areas:

- Climate change impacts on demand patterns
- Long-term impacts on supply technologies – resources and efficiencies
- Impacts of increased frequency and severity of extreme events
- Modelling tools and approaches.

A wide range of literature was examined:

- Reviews by governmental organisations
- Journal papers on regional impact studies, sector/technology-specific studies, literature reviews
- Text book chapters describing energy system modelling theory.

The results are presented in two tables. The first categorises the impacts according to the relevant climate/weather element, impact type (resource/efficiency/access/downtime) and significance in the context of energy system modelling. The second lays out the features, strengths, weaknesses and climate uses of relevant IAMs.

Results

Potential long-term impacts of climate change on the energy system include:

- Changing demand for heating and cooling due to rising temperatures
- Changes to wind, solar and hydropower resources – long term averages and variability
- The effect of rising temperatures on access to fossil fuels due to melting sea ice and permafrost
- The effect of rising temperatures on the efficiency of thermal and nuclear power plant cooling systems
- Reduction of transmission line and PV panel efficiencies due to rising temperatures.

Potential impacts of increasingly frequent and severe extreme events include:
- Damage to coastal infrastructure by floods
- Damage to power lines by storms
- Increased downtime of offshore wind farms due to access being restricted by high winds and waves
- Downtime of thermal and nuclear power stations due to heat waves and droughts.

Further related impacts include:
- Increased competition for water as temperatures rise and precipitation patterns change, exacerbated by the increased requirement for carbon capture and storage and biomass crops.

Principal findings from the review of modelling approaches:
- Both top-down (economic) and bottom-up (engineering) models have been used
- Climate change impacts are incorporated exogenously and endogenously to varying degrees
- More work has been done in this field for economically developed countries
- Quantitative studies on these subjects are largely performed at national or regional scale
- Studies have employed a wide range of climate change scenarios.

Some important gaps in the literature remain, including:
- The effect of increased variability of wind/solar/hydropower resource on investment
- The impacts of increasingly frequent and severe extreme events on energy supply and price
- The compound effect of simultaneous and successive impacts
- Comprehensive modelling of the impacts of increased water competition
- Integration of adaptation techniques in energy system IAMs
- Representation of climate impacts as feedback mechanisms.

Conclusions

Studies indicate that these impacts are likely to vary significantly between geographical regions. They are projected to affect the cost of energy and, in the case of extreme events, security of supply. Work has so far focussed largely on regional studies of the impacts of changes in average temperatures and water availability. More studies on the impacts of extreme events (singly and in combination), the increasing variability of renewable energy resources and increasing water competition would be especially useful. Examination of the literature indicates that the omission of climate impacts from integrated assessment models could potentially result in biases such as overestimation of the thermal and nuclear power plant efficiency and overestimation of the uptake of biomass, biofuels and CCS due to water competition. Significant work remains to integrate climate impacts as feedback loops in energy system IAMs.

References

- Ebinger and Vergara (2011), *Climate Impacts on Energy Systems*, World Bank
- Ciscar and Dowling (2014), *Integrated Assessment of Climate Impacts and Adaptation in the Energy Sector*, Energy Economics, Issue 46, p531-538
- Anandarajah et al (2011), *TIAM-UCL Global Model Documentation – Working Paper,* UKERC