UKERC Technology and Policy Assessment

Intermittency II Project

Scoping note and review protocol

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The UK Energy Research Centre is the focal point for UK research on sustainable energy. It takes a whole systems approach to energy research, drawing on engineering, economics and the physical, environmental and social sciences.

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The Technology and Policy Assessment (TPA) Theme of UKERC

The TPA was set up to inform decision-making processes and address key controversies in the energy field. It aims to provide authoritative and accessible reports that set very high standards for rigour and transparency. Subjects are chosen after extensive consultation with energy sector stakeholders and upon the recommendation of the TPA Advisory Group, which is comprised of independent experts from government, academia and the private sector.

The primary objective of the TPA is to provide a thorough review of the current state of knowledge. New research, such as modelling or primary data gathering may be carried out when essential. It also aims to explain its findings in a way that is accessible to non-technical readers and is useful to policymakers.
Introduction

The UKERC technology and policy assessment (TPA) team was set up to address key controversies in the energy field and to provide authoritative inputs to decision-making processes through accessible and credible reports that set very high standards for rigour and transparency. The principles by which the TPA will ensure these standards are described in Box 1 below:

Box 1: UKERC Technology and Policy Assessment Guiding Principles

In order to achieve its goals the TPA will ensure:

- Appropriate stakeholder participation and engagement including
  - Appointment of an external advisory group
  - Consultation on prospective assessment questions
  - Consultation on emerging findings

- Clarity and transparency of analysis, including
  - Clear, published criteria for choosing and refining questions
  - Protocols that can be readily criticised and replicated

- Expert scrutiny and the consideration of a range of perspectives, including
  - Selection of an expert team to work on each assessment
  - Appointment of advisors to bring a range of perspectives to each assessment
  - The solicitation of commentary and input during the assessment process
  - Exposure of findings to peer review

TPA question selection criteria

The TPA management team and UKERC Research Director, in consultation with the TPA advisory group and other UKERC Directors, will select questions according to the following criteria:

- Does the question reflect the concerns of users?
- Is the question relevant to current energy policy debate and/or the objectives of the UKERC and UK energy policy?
- Are there important areas of conflict or confusion that a TPA assessment could help overcome?
- Can the question be made sufficiently concise as to allow it to be addressed within the timeframe and resource limits of the TPA?
- Is the question amenable to a synthesis assessment based on existing evidence? For example, is the question sufficiently tightly defined? Is an adequate evidence base both available and accessible?
The subject of this TPA project

Introduction: the subject and its importance

In 2006 the UKERC TPA team completed its first assessment of the evidence on the costs and impacts of intermittent generation on the British electricity system (Gross et al. 2006). The conclusion from that study was that the additional system costs imposed by intermittent generation would be relatively modest, adding around £5–£8 per MWh to the cost of the renewable electricity generated (ibid). This was based on a review of the available evidence, most of which did not envisage (and therefore did not model) more than 20% of electricity to be sourced from intermittent renewables.

Since then, the UK’s targets for renewable generation have been set considerably higher than this (DECC 2011), and a number of significant new studies have been carried out into the likely effects of a much higher proportion of renewable electricity in the UK mix (Poyry 2009, Poyry 2011a, Strbac et al. 2012), and other work is also currently in progress (RAEng 2014).

This project will provide an update to the original 2006 UKERC report, reviewing the new evidence for the costs and impacts associated with higher shares of renewable generation and assessing how projected impacts may have changed. For the purposes of this project ‘new evidence’ is defined as that which has emerged since the previous UKERC project undertook its review in late 2005/early 2006. In conjunction with the project Expert Advisors, the project team will also consider whether the study should review all the new evidence, or limit the analysis to findings relevant to penetration levels greater than, for example, 20%1. The primary research question proposed for this project is:

What new evidence has come to light since UKERC reviewed the costs and impacts of intermittency in 2006 and what does the available evidence now suggest about the costs and impacts of intermittent generation (including relatively high penetrations of 20% and above)?

1 We use this to mean 20% of annual electricity demand being met by intermittent renewables but we recognise that other definitions exist, for example some studies define penetration levels as a percentage of peak system load.
Context

A key outcome of the 2006 UKERC report was conceptual clarification associated with how to account for the capacity contribution of intermittent output (Skea et al. 2008). The report also quantified impacts on short term system-balancing. Other impacts were found to be negligible. However as penetrations rise the prospects of curtailment increase considerably, whilst the average load factors of conventional plant could fall to levels well below the current norm (Strbac et al. 2012). Both these effects have important implications for the total costs of the electricity supply system, and bear upon the attractiveness of the investment proposition of renewables and conventional thermal plant.

The previous UKERC work reviewed and categorised over 200 studies related to the impacts of intermittent generation, and there has been a substantial addition to the literature since then. A search of academic journals and the grey literature to inform this scoping note and guide the project team’s initial thinking identified more than 50 papers, studies and reviews, the majority of which were found to be directly relevant.

Examples of work undertaken by, or on behalf of, industry and governments include the Poyry studies of 2009 and 2011 (Poyry 2009, 2011a, 2011b) which focus on the effect of high wind penetrations on the electricity market and thermal generators, the potential levels of curtailment at very high penetrations of intermittent generation, and the level of conventional generation required to ensure security of supply. Of particular note is that the (2011b) work found that 'It is the strong conclusion of this study that in Northern Europe the overall output of the renewable generation will be highly variable, and will not average out because of weather and geography.' and 'heavy reinforcement of interconnection doesn't appear to offset the need for very much backup plant', whilst Strbac et al. (2012) aim to 'illustrate the potential contribution that alternative balancing technologies can make to meeting the balancing challenge'.

The work of EnerNex Corporation (2011) has a US perspective, assessing integration costs for four scenarios up to a 30% penetration level, and Holttinen et al. (2013) provide a summary of the results of long-running work under the auspices of the International Energy Agency, whilst the discussions covered in UKERC (2012) are focused on the potential role of the demand side in managing intermittency.

In the academic literature, Milligan et al. (2011) discuss the difficulties in correctly calculating integration costs, concluding that whilst the calculation methodologies are

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2 Where generators are forced to limit their output because of insufficient demand or grid capacity.
well developed the resultant integration costs are very dependent on the ‘balancing’ technology chosen by the analyst. The work of Apt (2007) is somewhat complimentary to this, presenting a technical analysis of wind characteristics that then draws general conclusions over the optimal characteristics (and therefore by implication the technology) of wind-balancing plant.

There are also a number of papers such as Smith et al. (2007) and DeCesaro et al. (2009) which consolidate or summarise integration costs and impacts data from other studies. Whilst these types of papers can provide very useful cross–checks to ensure the coverage of the search terms used, it is important to ensure that the numbers presented are not double counted in the UKERC project’s outputs.

The work of Hirth (2013) draws attention to a potential impact that did not feature to any significant extent in the evidence renewed by the UKERC 2006 study. Hirth models the effect on the market value of renewable generation as penetration levels increase, concluding that there is a very significant reduction in the market value of such output at higher penetration levels. Depending on the market design and regulation, and the support mechanisms employed, this could have significant implications for the projected revenue stream of renewable generators.

A striking characteristic of the debate surrounding intermittent generation is the very wide range of views as to whether such generation creates significant system impacts and increases costs, or indeed whether the CO₂ savings envisaged by a significant penetration of renewables will be offset by the actions required to deal with intermittency. At one end of this spectrum are those such as Henney and Udo (2012) and Hughes (2012) who argue that CO₂ savings from wind generation will be much smaller than others envisage. Taylor and Tanton (2012) also suggest that integration costs have been either ignored or under–reported. Others rebut these contentions (Gross et al. 2012) and present evidence that CO₂ savings are only offset to a very minor degree (National Grid 2012). Ueckerdt et al. (2013) emphasise the importance of including all system integration costs in LCOE³ estimates, an approach which has its supporters but is by no means universally accepted. At the other end of the spectrum, Swinand and Godel (2012) use an econometric cost function approach to calculate UK wind integration costs and conclude that costs are very low, whilst Harrison (2013) and Milborrow (2013) also emphasise that integrating intermittent generation into electricity systems is both well understood and the costs relatively modest.

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³ Levelised Cost of Electricity – a commonly used metric, often expressed in £/MWh, that aims to capture all the costs involved in building and operating a power plant and allocate those costs over the lifetime output of the plant (IEA 2005).
Research questions

This expanded and broadened evidence base suggests that, in addition to updating the findings of the UKERC 2006 work, a range of impacts which were not quantified in the earlier study need to be investigated so that the scale of their implications can be assessed. The value of management options such as interconnection, demand response and storage may increase and this needs to be discussed and quantified where appropriate.

Therefore, this project will consider the impact on curtailment, the electricity market implications, the effect (both technical and economic) of the reduced load factor of the thermal plant, as well as the balancing and reliability impacts that the original UKERC work focussed on. The project team have drawn up an initial set of research questions (see below) to guide their thinking, which will be refined in discussion with the project Expert Advisors and other stakeholders as required.

The overarching question which this project will address is:

- What new evidence has come to light since UKERC reviewed the costs and impacts of intermittency in 2006 and what does the available evidence now suggest about the costs and impacts of intermittent generation (including relatively high penetrations of 20% and above)?

From which a series of supplementary questions follow:

- What are the full range of impacts and associated costs of intermittency that are identified in the literature, and how do these impacts and costs compare to the evidence that was available in 2006?
- Has the range of impacts expanded, and if so, why?
- Which categories of impact are the focus of interest?
- To what extent is there a consensus within the current body of evidence on the size and range of the cost and impacts of intermittency?
UKERC TPA Approach

The TPA approach learns from the practice of systematic review, which aspires to provide more convincing evidence for policymakers and practitioners, avoid duplication of research, encourage higher research standards and identify research gaps. This *evidence based* approach is common in areas such as education, criminal justice and healthcare.

The goal is to achieve high standards of rigour and transparency. However, energy policy gives rise to a number of difficulties for prospective systematic review practitioners and the approach is not common in energy. We have therefore set up a process that is inspired by the evidence based approach, but that is not bound to any narrowly defined method or techniques.

This assessment protocol describes this process in detail. It provides a specification of the means by which we will consult stakeholders and solicit expert input, specifications for searching the literature, and criteria against which relevant findings will be assessed.

**Assessment sequence**

The TPA has identified a series of steps that need to be undertaken in each of its assessments. These steps, derived from the practise of *systematic review* in non-energy policy analysis, are outlined in Figure 1 below.

**Figure 1 – typical process for TPA studies**

<table>
<thead>
<tr>
<th>Scoping prospective issues</th>
<th>Solicit expert input</th>
<th>Define criteria for assessment</th>
<th>Review literature</th>
<th>Synthesise and analysis</th>
<th>Prepare draft report</th>
<th>Consult, peer review and refine</th>
<th>Publish and promote</th>
</tr>
</thead>
<tbody>
<tr>
<td>Questions/issues</td>
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<tr>
<td>What are key problems and issues</td>
<td>Need to reflect a range of informed opinion</td>
<td>Ensure transparent, rigorous and replicable process</td>
<td>Need to review literature thoroughly</td>
<td>Need to apply rigorous criteria to evaluation of relevant studies</td>
<td>Need to identify key issues and discuss initial findings with stakeholders</td>
<td>Need to seek peer review and gain wide-ranging criticism of initial work</td>
<td>Need to ensure report reaches key audience</td>
</tr>
</tbody>
</table>

**Actions**

<table>
<thead>
<tr>
<th>Write scoping note</th>
<th>Appoint expert group</th>
<th>Develop assessment protocols and AGT</th>
<th>Apply protocol to literature search</th>
<th>Identify relevant sources</th>
<th>Write preliminary draft assessment</th>
<th>Host stakeholder workshop to discuss draft report</th>
<th>Design and graphics</th>
<th>Publication Launch events</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seek feedback from advisory group</td>
<td>Hold expert/stakeholder workshop</td>
<td>Discuss expert group and AGT</td>
<td>Detailed and transparent ‘trow’</td>
<td>Draft report for peer review</td>
<td>Make appropriate revisions to draft report</td>
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<tr>
<td>Seek feedback from online listing of initial scoping</td>
<td>Place protocols in public domain</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Outputs</th>
<th>Scoping note</th>
<th>Draft report</th>
<th>Published report</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Web publication of expert group</td>
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<tr>
<td></td>
<td>Assessment protocols</td>
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Whilst this project will follow this generalised approach, developed for all TPA work, it will be adapted to reflect the fact that the primary aim in this instance is to update the
UKERC 2006 report, which may mean that some of the steps in Figure 1 are not appropriate or may need to be revised. The project team will also adapt the approach so that it is consistent with the compressed timescale in which this project will be completed. In doing so, they will draw upon recognised approaches to delivering high quality evidence reviews that do not involve a full-scale systematic review (GSR and EPPI Centre).

Stakeholder engagement

The project will seek input and comment from relevant stakeholders in the academic, policy-making and industrial communities. Semi structured interviews with relevant experts may also be held. The project scoping note will be published on the UKERC website.

Expert Advisors

The project team will engage with a small team of expert advisors who can bring their experience and perspectives to bear on the subject. The expert advisors will be asked to comment on the scope of the project and the proposed approach, advise and assist the project team in the selection of relevant evidence sources, and review draft results. The expert advisors will be announced in due course and will be listed in the main project report.

Research sources

A systematic review protocol typically provides a rationale for the choice of sources and lists the main databases, bibliographies, catalogues, personal contacts and other sources that are to be searched. It will also specify the years to be covered and the search criteria that will be used. As identified in the Assessment Sequence section above, the project team will adopt an approach that is consistent with the available timescale.

The literature that is relevant to the intermittency debate will be drawn from:

- Peer reviewed academic journals in electrical engineering, economics and energy policy
- Working papers on electrical engineering, economics and energy policy
- Specialist electrical engineering and energy trade journals
- Technical reports produced or commissioned by electricity network operators, suppliers, regulators, and former national and regional state electricity companies, national energy labs, international agencies e.g. National Grid, Ofgem, NREL, IEA
• Technical and economic reports commissioned by government departments e.g. DECC, BERR, US DoE
• Reports and conference proceedings commissioned or produced by learned societies and institutes such as the IET, IEEE and RAEng
• Specialist consultancies (e.g. Oxera, Poyry, Parsons Brinckerhoff, Mott MacDonald)

This study will include sources which:

• Are relevant, as far as possible, to the key issues captured in the question
• Cover either engineering or economic aspects of electricity system operation
• Contain primary evidence from modelling, and/or real world experience
• Contain modelling but also reviews of modelling and/or empirical studies
• Contain expert views or represent the opinion of professional bodies/societies
• Contain material which is as relevant as possible to the UK context

The initial set of key words, search terms and evidence categorisation are described below. These may be revised following discussion with the Expert Advisors, and input from stakeholders where appropriate.

**Search Terms**

<table>
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<tr>
<th>Technologies</th>
<th>Infrastructure</th>
<th>Descriptors</th>
<th>Markets</th>
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<tbody>
<tr>
<td>Wind</td>
<td>Network</td>
<td>Intermittent</td>
<td>Wholesale market</td>
</tr>
<tr>
<td>Solar</td>
<td>Grid</td>
<td>Intermittency</td>
<td>Power market</td>
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<tr>
<td>Storage</td>
<td>Transmission</td>
<td>Variable Generation</td>
<td>Electricity pool</td>
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<td>Renewable</td>
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<td>Capacity credit</td>
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<td>Thermal</td>
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<td>Capacity margin</td>
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<td>System reserve</td>
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<td>Load factor</td>
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<td>Ramp rates</td>
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<td>Inertia</td>
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<td>Backup</td>
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**Combination of search terms**

1. Wind AND (intermittent OR intermittency OR variable generation)
2. Solar AND (intermittent OR intermittency OR variable generation)
3. Storage AND (intermittent OR intermittency OR variable generation)
4. Renewable AND (intermittent OR intermittency OR variable generation)
5. Network AND (wind OR solar OR storage)
6. Grid AND (wind OR solar OR storage)
Databases / sources

Google scholar

Note that searches using Google scholar have been demonstrated to include the relevant journal paper databases such as ScienceDirect and IEEE.

Google

Documents published by the following institutions will be searched by using the combinations of search terms described above plus adding the name of the institution as an extra search term:

- DECC / Ofgem
- National grid
- IEA / OECD
- British / American / European Wind Association
- European Commission
- Energy Network Association (ENA)
- European Network of Transmission System Operators for Electricity (entsoe)
- Frontier Economics
- Poyry
- NERA economic consulting
- EIA
Categories for quantitative findings

1. Reserve requirements
2. Reserve costs
3. Capacity credit
4. Cost equivalent for capacity credit
5. Impacts on fuel and emission savings (less efficient use of thermal plants)
6. Energy spilling, curtailment (restriction of intermittent generation)

Relevance ratings

A relevance rating will be assigned to each piece of evidence and additional categorisation of references may take place following the initial search process. The initial relevance ratings are:

1. Article shows clear data on at least one of the terms above
2. Article shows clear data on at least one of the terms above, however, misses some data or uses an uncommon metric
3. Article mentions at least one of the terms above, however, does not include relevant data
4. Irrelevant article or duplicate
References


National Grid 2012. Submission to the Scottish Parliament’s Economy, Energy and Tourism Committee providing clarity from National Grid on whether “reducing the carbon intensity” of the grid takes account of electricity which is generated from thermal plant but, due to despatch decisions, does not make it as far as the grid. The Scottish Parliament. Edinburgh.


Poyry 2011a. Analysing technical constraints on renewable generation to 2050 – A report to the Committee on Climate Change. Committee on Climate Change. London.


