UKERC

An assessment of evidence on the costs of intermittent power generation

Scoping note and assessment protocol

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An assessment of evidence on the costs of intermittent power generation:

What is the evidence on the costs and engineering impacts of intermittent generation on the UK electricity network, and how those costs are assigned?

PROJECT SCOPING NOTE AND ASSESSMENT PROTOCOL

Summary

This note provides an overview and guide to a process of assessment being undertaken by the UK Energy Research Centre Technology and Policy Assessment function (TPA), with support from the Carbon Trust.

The UKERC has consulted widely on the topics that the TPA needs to consider. It has chosen its preliminary topics carefully, in consultation with stakeholders and in accordance with defined criteria. Intermittency – used herein as shorthand for a range of issues that relate to the costs and electricity system impacts of the intermittent electrical output from wind, solar and some other forms of grid connected renewable generation – has emerged as one of two initial TPA assessment topics.

The TPA will undertake meta-analysis of existing work in order to seek gaps in knowledge, examine different modelling assumptions, and consider how well different pieces of work fit together. The assessment will seek to make clear where and why differences arise in terms of models, assumptions, scenarios and interpretation of findings. It will identify research gaps and provide a clear statement of the nature of the questions that remain.

A key goal is to achieve high standards of rigour and transparency. We have therefore set up a process that is inspired by the *evidence based* approach to policy assessment undertaken in healthcare, education and social policy, but that is not bound to any narrowly defined method or techniques. The approach entails tight specification of the means by which we will consult stakeholders and solicit expert input, highly specified searching of the relevant literature, and clear and transparent criteria against which relevant findings will be assessed. It is described in the Review Protocol, below.

An introduction to the subject matter and description of assessment activities are provided in this scoping note and protocol.

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Introduction

The UKERC technology and policy assessment (TPA) function 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.

The UKERC has consulted widely on the topics that the TPA needs to consider, through a workshop and a series of interviews with policymakers (see http://www.ukerc.ac.uk/content/view/55 and select "Paper on Initial Topic Selection"). It has chosen its preliminary topics carefully, in consultation with stakeholders and in accordance with defined criteria (Box 1). Intermittency – used herein as shorthand for a range of issues that relate to the costs and electricity system engineering impacts of the intermittent electrical output from wind, solar and some other forms of grid connected renewable generation – has emerged as one of two initial TPA assessment topics. This is an area where debate and controversy has been considerable. Yet it is a well studied area, with mounting evidence that should be sufficient to bring an end to at least some of the disagreement.

The TPA will undertake meta-analysis of existing work in order to seek gaps in knowledge, examine different modelling assumptions, and consider how well different pieces of work fit together.

The Carbon Trust has also considered the costs of intermittency[i], and in order to expand the scope and scale of work, the Carbon Trust is co-funding this assessment.

The purpose of this scoping note and protocol is to provide stakeholders an overview of the nature and approach the TPA assessment will take, how the assessment team will consult with experts and other interested parties and the timescale for assessment.

Subject matter

The study of intermittent generation in electricity systems

Research on the implications of intermittent generation for transmission and distribution system operation has a lengthy history. This begins with the work of the CEGB and other utilities in the late 1970s[ii], with much additional work during the 1980s and 90s by government funded laboratories, network operators and academics[iii]. Most recently, in the UK context, the system costs of additional renewables capacity were explored for the Energy Review[iv], and in a DTI study prepared for the Energy White Paper[v]. These findings were reviewed in the recent joint Carbon Trust/DTI networks impact study[vi]. In most cases the UK-based studies are focused upon wind power, as the most advanced and commercially viable intermittent source in the UK climate. Some (particularly early studies) also consider tidal barrage power.

Many of these studies appear to converge on certain findings – for example that transmission system impacts and costs are negligible at low penetrations of

intermittent generation (below around 5%), that penetration up to around 15% of peak output can be managed without significant change to network operation, and that geographical dispersal, interconnection with other regions and a diversity of generation types all reduce the costs of dealing with intermittency.

As 'real world' experience with renewables generation has increased, so has the potential for simulation models to utilise data from actual wind-farms and other installations. But important uncertainties remain – the UK currently has a rather modest installed capacity of wind generation. Much larger capacities exist elsewhere, for example in Denmark, Germany and Spain, but it is not clear that weather characteristics, plant location and electricity system operation translate well into a UK situation simulation.

Several aspects of the costs and impacts of intermittency are subject to debate and cost estimates vary widely[vii]. There is debate over how well some variables are captured in some of the simulations. For instance, that 'back up' costs are underestimated because the likelihood of low wind speeds across the UK coinciding with peak demand has not be properly factored into some work. Critics also take issue with the feasibility of some scenarios for plant mix, or geographical characteristics that are used in simulations. There is debate over how the system costs imposed by intermittent generation should be allocated – what is best attributed to wind generation alone and what 'smeared' across system output? There is also reporting in the mainstream media of a number of negative claims – that 'backup' costs are very large, and that the CO2 emissions associated with intermittency offset the savings from wind generation[viii]. Our consultations with policymakers have revealed a widespread perception that intermittency is particularly susceptible to manipulation by various lobby interests[ix].

Taking the debate forward

In light of the controversies identified in the previous section, it is important to deconstruct the modelling and simulation work that has been done in this area. The TPA will undertake a systematic and protocol based review of a broad range of existing analysis, UK based and international. This will use a transparent and consistent framework in order to provide clarity about what is known, what remains uncertain and the assumptions, calculations and judgements that lie behind different perspectives. It will seek to understand differences in assumptions, modelling approaches and allocation of costs.

The approach the TPA will take to all its work seeks to learn from a range of techniques referred to as *evidence based policy and practice* in fields such as healthcare, social policy and education, in particular the practice of *systematic review*, which has the following characteristics:

- Tight specification of the question to be addressed.
- Systematic and exhaustive searching of the available literature.
- Explicit criteria for the inclusion or exclusion of studies – with emphasis on empirical studies.
- Quality appraisal of the included studies using standardised criteria
- Synthesis of the results - using only those studies which are considered to be methodologically sound

- Disseminating the results effectively to the appropriate audiences.

An assessment of intermittency needs to take into consideration a range of inter-related engineering and economic factors, which include:

- The 'input assumptions' for each study – in most cases a future state will be simulated and overall system costs will be determined by network upgrades, distribution network impacts, system balancing and provision of plant margin. The following assumptions (or scenarios) are relevant:
  - Intermittent plant mix, location and operating characteristics – including scenarios of future plant location and electricity system evolution
  - Non-intermittent plant mix, availability of storage and degree of interconnection
  - The relationship between weather data, electricity demand and intermittent generation output
  - Future electricity demand
  - Requirements for and means of provision of system balancing services, to ensure frequency response and voltage stability over a range of timescales (instantaneous, spinning and standing reserve)
  - The level of plant margin needed to maintain security of supply
  - The contribution of intermittent generation to firm capacity (capacity credit)

- The 'modelling approaches' in terms of how simulation models represent the electrical engineering aspects and cost estimation requirements.
  - Different modelling assumptions, principles of operation, levels of aggregation and 'starting points' need to be explored and explained. This is sometimes referred to as 'opening the black box'

- Cost allocation methodologies also need careful analysis and consideration

Objectives

A clear, unequivocal, transparent and rigorous review of the evidence base, written in a style that is accessible to the non-specialist, ought to be able to overcome some of the controversy and conflict that surrounds this subject and move the debate forward. This assessment will seek to:

- Provide a clear overview of what is know, not known and uncertain
- Separate genuine uncertainties from misinformation
- Identify the origins of the divergence where informed studies come to different conclusions
- Identify research gaps
- Provide a clear statement of the nature of the questions that remain.

Protocol

This assessment 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 (click http://www.ukerc.ac.uk/content/view/55 and select the "Working Paper on the Role of Evidence in Energy Policy: What can be Learnt from Evidence Based Policy and Practise"). 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

This assessment will follow a generalised approach developed for all TPA work. 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, give rise to the specific process that we envisage for this study, outlined in Figure 1.

Figure 1 – process for TPA study on intermittent generation

	Scoping prospective issues	Solicit expert input	Define criteria for assessment	Review literature	Synthesis and analysis	Prepare draft report	Consult, peer review and refine	Publish and promote
Questions/issues	• What are key problems and issues?	• Need to reflect a range of informed opinion	• Ensure transparent, rigorous and replicable process	• Need to review literature thoroughly	• Need to apply rigorous criteria to evaluation of relevant studies	• Need to identify key issues and discuss initial findings with stakeholders	• Need to seek peer review and gain wide ranging criticism of initial work	• Need to ensure report reaches key audience
Actions	• Write scoping note • Seek feedback from AG • Seek feedback from online listing of initial scoping	• Appoint expert group • Hold expert/stake holder workshop	• Develop assessment protocols • Discuss with expert group and AG • Place protocols in public domain	• Apply protocol to literature search • Detailed and transparent 'trawl' • Identify relevant sources	• Apply protocol to evaluation and synthesis of literature • Detailed and transparent assessment of evidence base	• Write preliminary draft assessment	• Host stakeholder workshop to discuss draft report • Send draft report for peer review • Make appropriate revisions to draft report	• Design and graphics • Publication • Launch events
Outputs	• Scoping note	• Web publication of expert group	• Assessment protocols			• Draft report	• Final report	• Published report

Stakeholder engagement

The project will seek input and comment from interested parties within government, industry and NGOs. There will be two stakeholder workshops – one to invite comments on the project scope, and one to present emerging conclusions. The project scoping note will be published on the UKERC website.

Expert views

An expert group will be appointed, with a wide spectrum of views represented. The expert group will be consulted at three key stages: inception and specification of detailed question, preliminary findings and draft report. In each case detailed input will be sought – for example on the search terms to be deployed, to reveal key reports and studies and to review in detail emerging findings. The expert group is:

Prof Goran Strbac (University of Manchester, Supergen, UKERC)
Prof Michael Laughton (QMW College, Imperial College)
Mr David Milborrow (independent)
Mr Nick Hartley (Oxera)
Dr Lewis Dale (National Grid Transco)
Mr Phil Ruffles (RAEng)

Peer review

The draft report will be sent for peer review prior to finalisation and publication.

Core research team

This project will be undertaken by a team drawn from the EPSRC-funded SUPERGEN *Future Network Technologies* Consortium and the TPA function of the UK Energy Research Centre. Prof Jim Skea, UKERC Research Director, has overall responsibility for the TPA function. Dr Matt Leach and Dr Tim Green, both of the SUPERGEN Consortium, will be lead consultants. Robert Gross of UKERC will manage the project. Prof. Dennis Anderson is Senior Advisor to the TPA, and will provide high level comment. Researcher Assistants from Imperial College Electrical and Electronic Engineering and ICEPT will undertake the literature searching activity described below. Other members of the TPA team, based at ICEPT and SPRU, will provide input on evidenced-based policy and practice techniques and ensure consistency with other TPA activities.

Literature to be searched

A systematic review protocol covers the following details: provide a rationale for the choice of sources; list the main databases, bibliographies, catalogues, personal contacts and other sources that are to be employed; specify the years to covered; specify the search strategies be used (e.g. keywords; scanning reference lists; hand searching journals; etc.); and identify the mechanisms available for retrieving unpublished or less accessible documents.

The literature that is relevant to the intermittency debate includes:

- Peer reviewed academic journals in electrical engineering, economics and energy policy
- Working papers and PhD reports on electrical engineering, economics and energy policy
- Specialist electrical engineering and energy trade journals
- Technical reports produced or commissioned by electricity network operators, suppliers and former national and regional state electricity companies
- Technical and economic reports commissioned by government departments
- Reports and conference proceedings commissioned or produced by learned societies and institutes such as the Institute of Electrical Engineers and IEEE.

Following consultations with the expert group a full list of, and rationale for, the main databases, bibliographies, catalogues, expert recommendations and other sources that are to be employed will be published. This will specify the years covered; specify the search strategies be used (e.g. keywords; scanning reference lists; hand searching journals; etc.); and identify the mechanisms available for retrieving unpublished or less accessible documents. However, the main principles of, and preliminary list for the searches, are as follows:

- Manual searching of key documents and bibliographies (using the SCAR report and DTI Network Impacts study and recommendations from the expert group). This will lead to further reviews, academic papers, journals, books, policy publications, and policy consultation submissions.
    - Important to access as much 'Grey literature', notably evaluations of relevant policy programmes, plus relevant reports as possible.
- Database searches, using key words and search terms (see below).
- Databases to be searched will include:
    - 'ESTAR', the British Library's Electronic Storage and Retrieval System
    - 'SIGLE', the system for Information on Grey Literature in Europe, citations to reports and non-conventional literature published across EU member states since 1980.
    - Science Direct
    - Working papers, such as Cambridge working papers in economics
    - Engineering databases, such as IEEE Explore and IEE Inspec
- Searching specific journal archives not covered in the above
    - For example engineering journals, IEE conference proceedings
- Website searching (using the keywords combinations as below). Example sites:
    - DTI
    - NGT and Ofgem
    - Google
    - IEA
    - Wind energy associations
    - US DoE
    - NREL

Search terms

Key words will be determined in collaboration with the expert group and stakeholders. They are expected to include:

Intermittency AND Renewable
Intermittency AND Networks
Intermittency AND Electricity
Intermittency AND Generation
Renewable AND Network
System costs AND Power generation
Wind power AND network integration

Evaluation criteria

It is not uncommon for systematic reviews to exclude the vast majority of studies found during the search period[x]. In this assessment the intention is to include as much of the literature as possible, in order to highlight differences and begin to account for controversies and disagreements. It is therefore important that the criteria for inclusion are broad, but that evaluation focuses upon the different standards met by diverse studies.

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 do contain 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

Studies will be evaluated on the basis of the following criteria:

Clarity and assumptions
The assessment team will provide an overview of:

- The level of transparency and clarity in purpose and approach
- The level of transparency and clarity about assumptions made in developing models and/or scenarios
- The level of transparency and clarity about the strengths and weaknesses of the approach
- The level of transparency and clarity about assumptions made in interpretation of results
- The level of transparency about value judgements and viewpoints in all of the above

Rigour
The expert panel and expert team will review, assess and comment upon:

- The limitations and advantages of modelling techniques (engineering and economic)
- The limitations and advantages of scenarios and/or case studies
- The validity and appropriateness of assumptions made in both the above
- The limitations, advantages and consistency of interpretation of results

Quality control

The assessment team will provide an overview of the techniques used to ensure quality, including:

- Whether the study has been peer reviewed
- Whether the study has been overseen by an expert group or steering committee

Diversity of view and inclusiveness

The assessment team will also report on the extent to which reviewed studies sought to represent a spectrum of opinion and/or to address controversial aspects mindful of disparate views.

Publication and launch

It is important that this assessment reaches its intended audience in govt and industry. The TPA has an advisory group with representatives from govt, industry and NGOs. This group will be kept informed of progress with the assessment. The final report will be launched at an event for stakeholders. Email and other contact lists will be utilised to alert stakeholders to the assessment report. Press release and search engine submissions will also be made

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[i] DTI, Carbon Trust (2004), Network Impacts Study, available from www.thecarbontrust.co.uk

[ii] Eg Farmer (1980), the economics and dynamics of system lading and regulation. Int Conf on power system monitoring and control. June 1980.

[iii] Eg. Grubb (1991), Value of variable sources on power systems. IEE Proceedings, C, vol 138, No 2, March 1991

[iv] Milborrow, D (2001), PIU Working Paper on Penalties for Intermittent Sources of Energy, http://www.pm.gov.uk/output/Page4250.asp

[v] Ilex, 2002, Quantify the system cost of additional renewables in 2020, a report to the DTI http://www.dti.gov.uk/energy/developep/080scar_report_v2_0.pdf

[vi] Carbon Trust (2004), The Carbon Trust and DTI Network Impacts Study. http://www.thecarbontrust.co.uk/carbontrust/about/publications/Renewables%20Network%20Impact%20Study%20Final.pdf

[vii] RAEng (2004). The Cost of Generating Electricity. A study carried out by PB Power for The Royal Academy of Engineering.

[viii] See Wind Power Monthly, September 2004 for a review of media coverage of wind energy

[ix] See the TPA's user needs assessment report at http://www.ukerc.ac.uk/content/view/55

[x] Smith and Skea, 2003, Resource Productivity Innovation: Systematic Review. DTI, London

Box 1: UKERC Technology and Policy Assessment

Guiding principles

In order to achieve its goals the TPA will ensure:

- Full stakeholder participation and engagement, including
  - Appointment of an external advisory group
  - Wide ranging consultation on prospective assessment questions
  - Expert workshops 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 wide 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 throughout 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?