

SPLiCE Phase 1 A methodology for Rapid Evidence Assessments

Output 2 from SPLiCE Phase 1



Report for Defra

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1 Introduction

A major transformation is underway to decarbonise UK energy generation and use in order to cut greenhouse gas emissions by 80% by 2050. Numerous potential pathways for achieving the 2050 emissions target each demand significant new energy infrastructure in various forms, as well as substantial increases in energy efficiency across the economy. For example, the alpha pathway in DECC's 2050 Pathways Calculator assumes that all sectors will help make the transition to a low carbon economy.

The Sustainable Pathways to Low Carbon Energy (SPLiCE) research programme seeks to provide significant information about the wide-ranging potential environmental, social and economic impacts of decarbonising the UK energy system. Information needs to be presented in a way that enables informed choices to be made about different configurations of the energy system framed within a wider context. The intention is that the programme would identify what is known and not known about the impacts of different energy supply and demand options and then fill any key evidence gaps, either directly or by encouraging others to do so.

The full SPLiCE Programme was planned to be delivered in two or three phases. The key research questions for the whole programme are:

- How can Government compare all the significant impacts of the energy decarbonisation options available, so that evidence-based choices can be made about the best mix of options to pursue?
- How can developers, planners and regulators access comprehensive and authoritative information about the impacts of energy infrastructure and other energy choices in order to make decisions about investment, deployment and impact mitigation?
- How can Government, industry and the research community present reliable, easy to understand information on impacts in order to improve public understanding and help engage the public and other interest groups to debate and build consensus around future energy options?

This report provides one output from SPLiCE Phase 1, namely a detailed written method for carrying out systematic evidence reviews on the environmental, social and economic impacts of energy supply and demand options.

2 Purpose of this report

The purpose of this report is to provide Defra and review teams commissioned in relation to SPLiCE with a standard methodology for carrying out Rapid Evidence Assessments (REAs) of the direct, indirect and cumulative impacts (positive and negative) of energy supply and demand options on the environment, society and the economy, based on published literature (both peer-reviewed and grey). REAs use methods developed for full Systematic Reviews, in order to ensure that they are systematic, transparent and repeatable, but limit the rigour of their application to reduce the time and expense of production.

The REA method described here will be used to ensure consistency when a rolling programme of reviews of impacts is undertaken in Phase 2. The intent is that the outputs of every REA will be produced, structured and presented in a consistent way to enable them to be compared by the wide range of possible end-users who wish to address specific questions in relation to the key research questions for the whole programme (above).

With respect to the question/s that each REA addresses, the outputs will provide an informed conclusion of the size and type of evidence available, a critical appraisal of the evidence and a subsequent summary of what that evidence indicates. In doing so, each REA will highlight where there are gaps in the evidence available or where improvements could be made to experimental/study design. The summary of all of the available evidence relating to a primary question may also help end-users to answer other questions they are working on.

3 Basis of the methodology

This methodology references Civil Service Guidance on REAs¹, Natural England's guidance on evidence reviews², the UK Energy Research Centre (UKERC) Technology and Policy Assessment (TPA) mission statement and framework³ and a "How to guide" on "The production of Quick Scoping Reviews and Rapid Evidence Assessments" by the Joint Water Evidence Group (JWEG)⁴. It builds upon the author's practical experience of undertaking REAs for government bodies and draws upon input and comments from a range of academic and policy stakeholders with experience of developing or referring to such reviews. The methodology was trialled on two case studies and subsequently revised to ensure greater clarity. The first case study examined the impacts (environmental, social and economic) of a single energy technology. The second case study evaluated the cumulative environmental, social and economic impacts of a mix of energy supply and demand options in one region. The form of the summary matrix of the significance of impacts of an energy supply or demand option also takes into account the separate development of a framework that is intended to value and compare the very different impacts of energy and demand options.

The JWEG guidance is generic and already synthesises many relevant methodologies, so has been used as a starting point and this methodology:

- Builds upon the key steps in JWEG's approach
- Identifies more detailed, additional or alternative practical methods for implementing each step that streamline or make more explicit what needs to be done
- Makes use of, builds upon, adapts or provides alternatives to JWEG's checklists and means of recording outputs associated with each step, as appropriate
- Pays heed to complementary elements of Natural England's guidance and UKERC's TPA.

The methodology is structured broadly in accordance with the JWEG guidance and explains reasons where it departs significantly from it. The entire process of undertaking an REA is outlined in Figure 1. Options for communicating the findings are being addressed by design of a knowledge gateway. A comprehensive report template is provided in Appendix 1 to ensure that all REAs are presented in a common format.

The JWEG guidance focuses on liaison with the Steering Group rather than with stakeholders more generally. However, UKERC TPA's guiding principles notably include: expert scrutiny and consideration of a wide range of perspectives; and full stakeholder participation and engagement. Similarly, Natural England's guidance is to engage stakeholders and independent experts throughout to arrive at robust evidential conclusions. If ambitions for SPLiCE are to be fulfilled and its outputs are to be useful in a range of contexts, as set out above in Section 1, then it makes sense for key stakeholders to have opportunity to input or comment and their involvement is considered at each stage of the process.

¹ <http://www.civilservice.gov.uk/networks/gsr/resources-and-guidance/rapid-evidence-assessment/>

² Stone, D.A. 2013. Natural England Evidence Reviews: guidance on the development process and methods (1st Edition 2013). Natural England Evidence Review, Number 001.

³ <http://www.ukerc.ac.uk/support/tiki-index.php?page=TPAFramework>

⁴ Collins, A., Miller, J., Coughlin, D. and Kirk, S. 2014. The Production of Quick Scoping Reviews and Rapid Evidence Assessments: A How to Guide - Joint Water Evidence Group April 2014, Beta Version 2

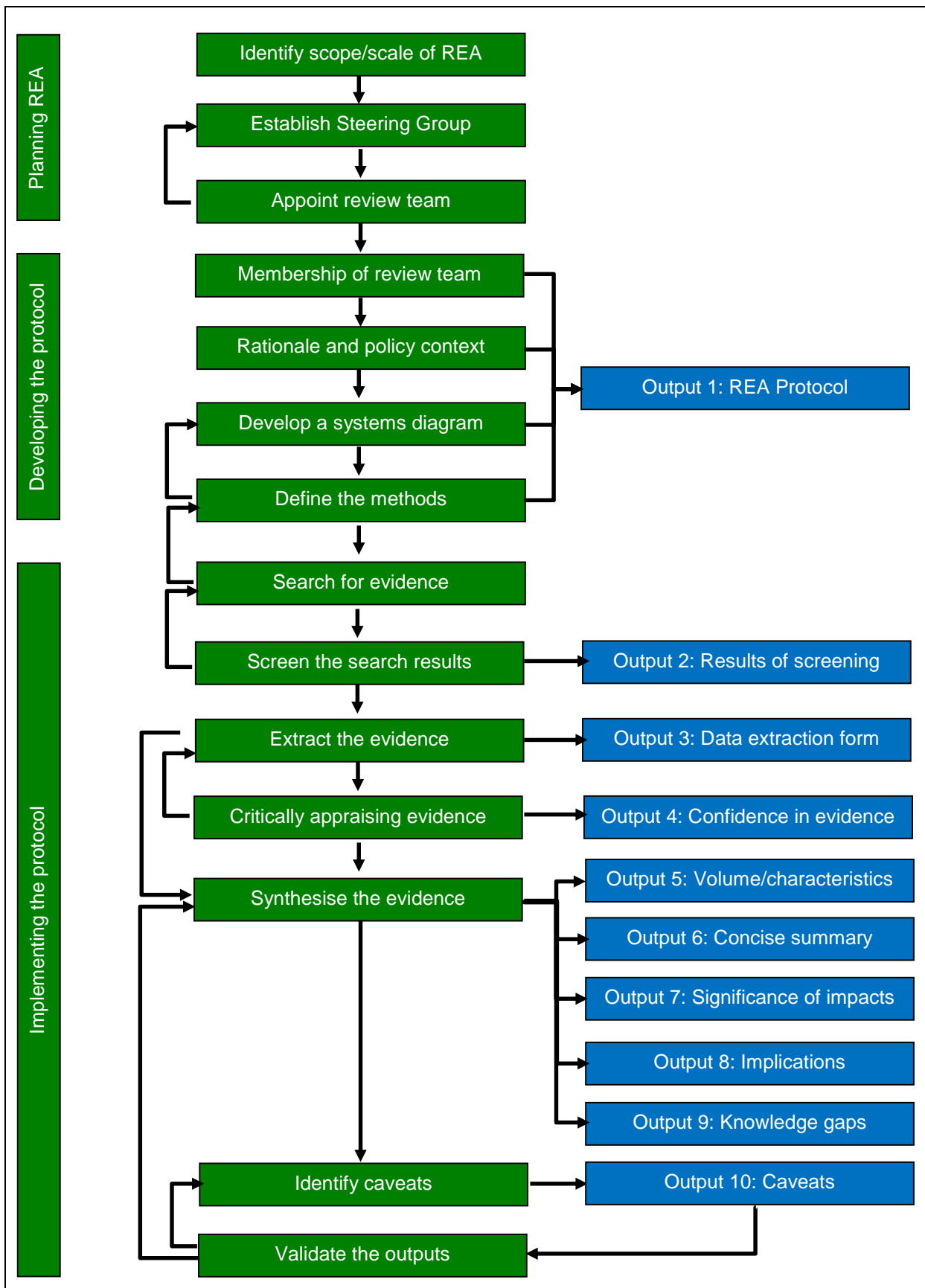


Figure 1. A flowchart of the outline process for REAs

4 Planning the REA

4.1 Identifying the scope and scale of the REA

Each REA should focus on the direct, indirect and cumulative impacts (positive and negative) of a specified energy supply or demand option(s) on the environment, society and the economy. It is recommended that REAs should usually address individual energy options at a UK scale to ensure that the review of all energy options can be reviewed efficiently and draw upon an adequate pool of evidence to reach robust conclusions. The evidence assembled and critically appraised by the REAs can then also help inform people considering specific regional or local issues. However, if desired, the subject or unit of study may be a specific region, location or energy facility.

4.2 Establishing the Steering Group

The individual(s) who has identified the scope and scale of the REA required will need to convene a steering group. This group can be small but should include representatives from Defra, other government departments and agencies, and stakeholders who will benefit from the REA's outputs. Additionally the Steering Group will benefit from an individual with experience of conducting Systematic Reviews, and ideally REAs, capable of challenging the direction of the review and its adherence to the REA guidance.

4.3 Appointing a review team

The review team should consist of individuals who have experience in systematically searching evidence and individuals who have good technical knowledge of the issues to be addressed, including its context and practicalities. The latter is important in searching, interpreting and communicating the evidence. The review team needs to have access to electronic databases that are able to search all relevant peer-reviewed articles and produce repeatable results (e.g., Web of Science or Scopus). Once a review team has been appointed the lead reviewer should join the Steering Group and provide a common point of contact.

5 Developing a protocol

A working protocol (**OUTPUT 1**) should be developed by the review team and agreed with the Steering Group to ensure that the approach to the REA is clear, transparent and achievable. The protocol should identify all aspects of the background to the REA, its objective(s) and details of the method that are specific to the individual REA, as detailed in Sections 5.1 – 5.5. The protocol should be maintained by the review team as a live document and updated during the review process, as appropriate, by agreement with the Steering Group.

5.1 Membership of the review team

Members of the review team undertaking the REA should be identified along with their roles and responsibilities in relation to each stage of implementing the protocol (i.e. Section 6), as shown in Table 1.

Table 1. Roles and responsibilities of individual members of the review team

Stage of implementing the protocol	Team member	Role	Responsibilities
Searching for evidence			
Screening the search results			
Extracting the evidence			
Critically appraising the evidence			
Synthesising the evidence			

5.2 Establishing the background rationale and policy context

The background should provide a concise, plain English outline of the rationale behind the REA, including the policy context (maximum 500 words).

5.3 Developing a systems diagram

A systems diagram or schematic of the elements of an energy supply or demand option(s) that can facilitate identification of their component drivers of impact and associated pressures should be developed. It may be provided when work is commissioned for subsequent review. Figure 2 provides a simple example from a case study on the impacts of small-scale district heating using biomass feedstocks, which was undertaken to pilot use of an earlier version of this REA guidance.

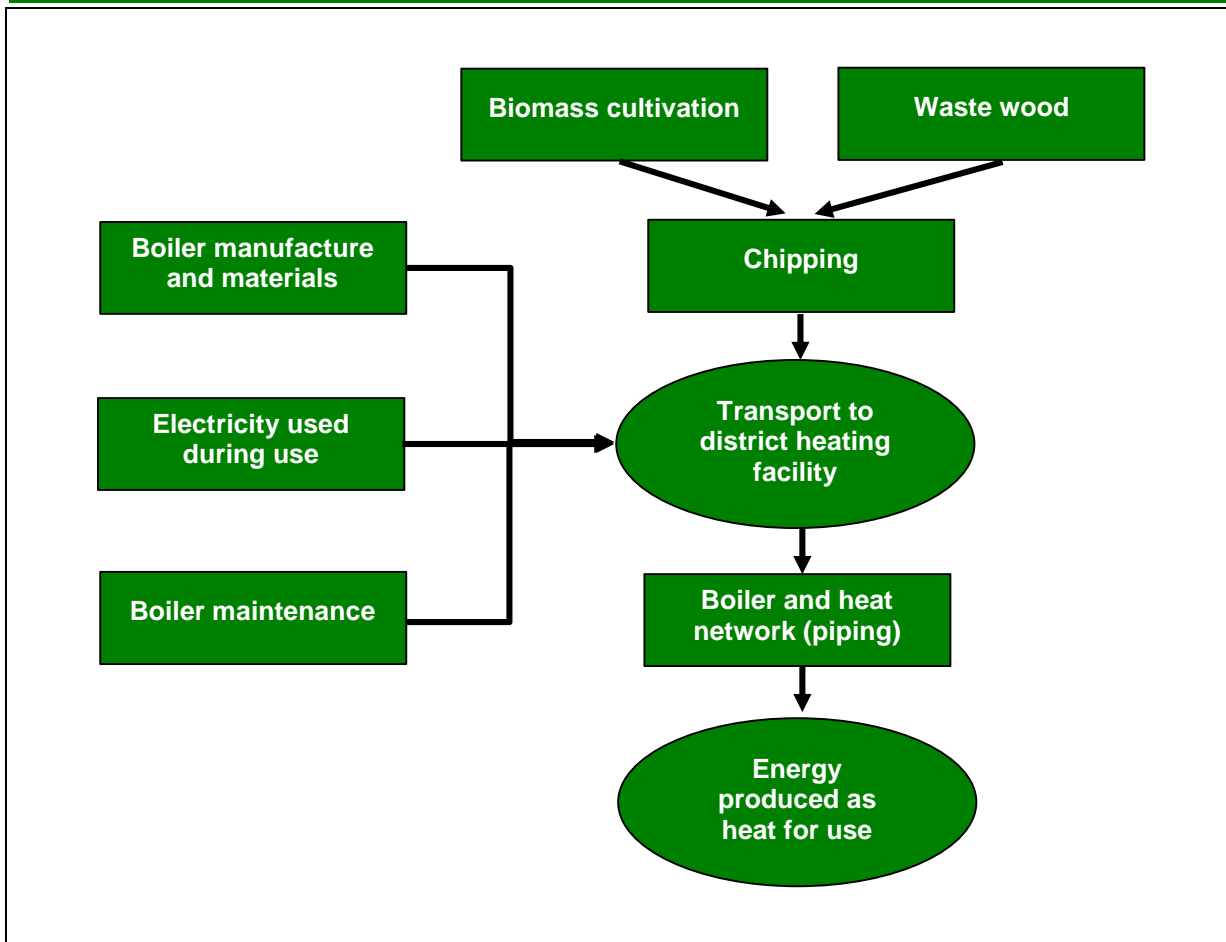


Figure 2. A schematic of the elements of a small district heating facility that may lead to direct, indirect and cumulative impacts (positive and negative) of energy supply and demand options on the environment, society and the economy.

5.4 Identifying the objective(s)

The systems diagram and policy context should be used to identify the primary question (an “impact question” assessing positive and negative impacts of a particular energy supply or demand option) that is to be the focus of the REA, e.g. “What are the life-cycle impacts of a small-scale district heating facility using biomass feedstocks?” Understanding the elements of the energy system that may lead to impacts and the policy context of an REA are essential in assuring that the review’s scope is not so narrow as to produce perverse results, e.g. a question that focuses on one particular element of the system from a wide range of inter-related elements may lead to its impacts being over-emphasised. Defining the question’s Population, Intervention, Control and Outcome (PICO) elements will help to ensure that the REA is clear and focused (Table 2).

Table 2. Defining the PICO elements of an REA question (adapted from the JWEG guidance)

PICO element	Definition
<i>Population</i>	The subject or unit of study. As noted in Section 4.1, it is recommended that this is always the UK. The evidence assembled and critically appraised by an REA can then also be considered by people who consult it to help inform specific regional or local issues. However, if desired, the subject or unit of study may be a specific region, location or energy facility.
<i>Intervention/exposure</i>	The proposed energy supply or demand option(s), their component drivers of impact and associated pressures, as informed by the framework. For example: <ul style="list-style-type: none"> • Drivers may relate to the stages of the life cycle, e.g. production of feedstock, construction, operation, infrastructure, and decommissioning • Pressures may relate to the use of land/resources, emissions, waste, and disturbance (physical, light, noise).
<i>Comparator</i>	It is recommended that this should always be the counterfactual, i.e. considering impacts of the energy supply or demand option in isolation of other energy options.
<i>Outcome</i>	The type(s) of direct, indirect and cumulative impacts (positive and negative) on the environment, society and the economy resulting from the proposed energy supply or demand option(s), their component drivers of impact and associated pressures

It may be helpful to produce a more detailed typology of the proposed energy supply or demand option(s) (and their component drivers of impact and pressures) in order to clarify the scope of the review, including the identification of search keywords (Section 5.5.2). However, it should not prejudice consideration of drivers of impacts or pressures not identified at this stage if they emerge during later stages of the review.

Similarly, it may be helpful to determine a more detailed typology of the impacts resultant from the drivers of impact and pressures. Although again, it should not prejudice consideration of impacts not identified at this stage if they emerge during later stages of the review. Example impact typologies can be found at Appendix 2.

There may be a desire to develop secondary questions in order to further qualify the primary question, if the proposed energy or demand option(s) or their potential impacts are diverse. However, the scope of questions should be carefully considered to ensure that the REA can be completed systematically within the time and resources available.

By agreement with the Steering Group, key stakeholders should be given opportunity to comment on the scope of the review: the policy context and the systems diagram, as well as the typology of the proposed energy supply or demand option(s) (and their component drivers of impact and pressures) and typology of the resultant impacts, if more detailed typologies are produced.

5.5 Defining the methods

5.5.1 Establishing a search strategy

A search strategy should be established to gather relevant peer-reviewed journal articles, grey literature (e.g. national and international government reports, studies published by industry and NGOs, theses and dissertations) and any unpublished evidence (e.g. unpublished reports or presentations and internal documents). All three types of evidence need to be considered in order to avoid publication bias and to address current issues where limited academic research has been undertaken.

Academic search engines able to search all relevant peer-reviewed articles and produce repeatable results, such as Web of Science or Scopus, should be used to identify relevant peer-reviewed from the UK, Europe and internationally. As some academic search engines, such as Web of Science provide a platform to other databases, the strategy should identify explicitly which databases are included (not all organisations have the same subscriptions). However, it must be borne in mind that no academic

search engine covers absolutely every journal, and peer-reviewed publications focus on research that has shown a significant effect, and are structured by discipline (i.e. cross-disciplinary studies are less frequently published).

The strategy should also provide a rationale for other places to be searched in order to ensure transparency, e.g. individual organisations’ websites, or CAB abstracts, (<http://www.cabi.org/publishing-products/online-information-resources/cab-abstracts/>, for theses and dissertations). Google Scholar or other such comprehensive search engines should not be used, as they do not produce repeatable results.

The strategy can be summarised simply as shown in Table 3.

Table 3. Search strategy

Type of evidence	Places searched	Rationale
Peer-reviewed journal articles		
Grey literature		
Unpublished evidence		

5.5.2 Identifying search keywords

The targeted searches should use primary, secondary and tertiary keywords, which can later be used to help categorise papers during data extraction (Section 6.3). Primary keywords should relate to the elements of the energy supply and/or demand options to be addressed and/or the associated drivers of impacts or pressures identified. Secondary and tertiary keywords should usually relate to the typology of the impacts resultant from the drivers of impact and pressures. Development of keywords needs to be an iterative process to balance the specificity of the search with the number of results returned. Each search engine has its own method for indicating “wildcards” (?*\$ etc.) to pick up multiple word endings and for implementing Boolean logic (i.e. the way in which keywords should be strung together with use of such terms as “AND”, “OR”, “NOT”). The latter should ensure that all possible combinations of primary and secondary and/or tertiary keywords are used in the search.

Table 4 provides example keywords for an REA from the case study on the impacts of small-scale district heating using biomass feedstocks, which was undertaken to pilot use of an earlier version of this REA guidance. In this case, the secondary keywords address types of biomass, the italicised secondary keywords are merely headings for sets of tertiary keywords relating to impacts. “Wildcards” are asterisked.

Table 4. Example keywords for an REA from a case study on the impacts of small-scale district heating using biomass feedstocks

Primary	Secondary	Tertiary
district heat*		
heat network*		
biomass	wood*, straw, crop*, forest*, waste	
bioenergy	wood, import*, residue*	
life-cycle	<i>land</i>	land-availab*, land-use change, DLUC, ILUC
	<i>soil</i>	erosion, compaction
	<i>climate change</i>	mitigation, abatement, emission*, greenhouse gas*, GHG, carbon dioxide, CO ₂ equivalent*
	<i>biodiversity</i>	species, habitat, disturbance, invasion, connectivity

Primary	Secondary	Tertiary
	<i>air quality</i>	particulate*, pollut*, volatile, organic compound*, emissions, combustion, ozone
	<i>water</i>	eutrophication, pollut*, flood*, water resource*, hydrology, flow*
	<i>noise</i>	ambient, impulsive
	<i>governance</i>	planning, "property right", contracts, "land use"
	<i>cultural</i>	"traditional lifestyle", spiritual, values, "visual impact", landscape
	<i>heritage</i>	"historic building", "historic structure", "historic site", "historic environment"
	<i>health</i>	stress, wellbeing, "air quality", mental, "local air pollut*", noise
	<i>cost</i>	"input costs", "energy cost", "R&D", "cost reduction", competition, market
	<i>revenues</i>	GVA, turnover, profit, income, operation, construction, growth, development
	<i>social justice</i>	allocation, "fuel poverty", unskilled, deprivation
	<i>employment</i>	job, unemployment, "job prospects",
	<i>transport</i>	traffic, HGV, freight, infrastructure

5.5.3 Pre-defining inclusion and exclusion criteria

In order to focus the review on the most relevant sources of evidence in a systematic way, a pre-defined set of inclusion/exclusion criteria should be established, which can be refined when the protocol is implemented, if necessary. These criteria will normally fall into the following categories:

- Geographic location, e.g. studies that include the UK and Europe
- Climatic conditions, e.g. temperate only
- Language restrictions (e.g. only published in English), which can be determined by the search engine
- Date restrictions (e.g. only evidence from post-2000), which can be determined by the search engine
- Restrictions relating to the typology of impacts.

5.5.4 Documenting potential conflicts of interest

In order to ensure transparency and avoid bias, it is important that members of the Steering Group and the review team (as well as any stakeholders consulted during the REA) are asked to declare all potential conflicts of interest. These may include personal conflicts, financial, political, academic and other interests; perhaps most commonly having:

- Authored relevant peer-reviewed papers or grey literature within the scope of the REA
- A potential interest in researching knowledge gaps that could be identified by an REA.

As the Steering Group and review team (as well as stakeholders consulted) need to include individuals who have good technical knowledge of the issues to be addressed by the REA, including its context and practicalities, it is to some degree inevitable that such conflicts will arise. Documenting them (Table 5) allows rigour to be imposed through appropriate quality assurance in this regard.

Table 5. Potential conflicts of interest

Individual	Role	Potential conflict of interest

5.5.5 Listing sources of information used in developing the protocol

A list of references to peer-reviewed and grey literature used in developing the protocol should be provided.

6 Implementing the protocol

6.1 Searching for evidence

Searches of the databases and other places explicitly identified in the protocol (Section 5.5.1) should be undertaken by individuals who have experience in systematically searching evidence. Application of the keywords should be checked by:

- An individual who has good technical knowledge of the issues to be addressed, including its context and practicalities
- The Steering Group in order to maintain common understanding about the scope of the review.

For each of the papers identified, the author(s), year, title of the document, and source (including hyperlink where available) should be recorded using a reference management programme that can be widely accessed or using a spreadsheet. The records of each search should then be combined to give a full list of the evidence found, removing any duplicates. If a reference management programme is used that can only be accessed by those with a valid subscription (e.g. Endnote) then all records should be transferred to a spreadsheet for the final output.

If the search keywords identify an unmanageable number of papers then systematic options that should be considered at this stage are to make the exclusion criteria more demanding or to review the REA's primary question. It is not appropriate to try to manipulate the number of papers identified by narrowing the scope of the keywords, so that they do not fully address the primary question.

6.2 Screening the search results

The full list of evidence should be screened in two phases, first, by reference to the title of each piece of evidence and, second, by reading the abstract or first paragraph of all those papers that remain. Screening of all the evidence should be undertaken by one person in order to ensure that the criteria are applied consistently. This should be someone with experience of systematically searching evidence.

The results of screening should be recorded in separate spreadsheets for phase one and phase two, listing all of the papers considered in each phase with each of the inclusion/exclusion criteria as column headers in addition to those column headers already required by Section 6.1 (i.e. author(s), year, title of the document, and source, including hyperlink where available) (**OUTPUT 2**). All those pieces of evidence that are excluded at this stage should be clearly identified in the spreadsheets. These spreadsheets are a valuable output, providing transparency, a starting point for any future re-investigation of the same impact question or related questions.

A second person with good technical knowledge of the issues to be addressed should independently screen a 10% sample of documents in order to check that there is no bias. If necessary, remedial actions should be taken to ensure the criteria are applied appropriately. Where one or more criteria have been applied inconsistently, the spreadsheets may enable the technical expert to identify which papers need to be reconsidered. However, at worst, it may be necessary for the whole screening process to be repeated. In such circumstances, it may be appropriate for the person who undertook the original screening to be briefed by the technical expert before re-screening selected papers, or for the technical expert or a third individual to re-screen all papers.

The Steering Group and key stakeholders should be given opportunity to review Output 2 in order to help avoid any bias and to identify if any key documents have been overlooked. Key stakeholders may include significant experts identified from the screening of results. Where additional documents are identified and included in the review, this should be noted under 'Source' in the data extraction form (Section 6.3).

6.3 Extracting the evidence

The next stage is to extract data from the remaining list of evidence relevant to the REA's primary question and any secondary questions, as appropriate. In order to ensure that data is extracted systematically and summarised in a way that is readily understood without needing to refer to the original source, the columns in the spreadsheets in Output 2 should be supplemented with additional column headers. As a minimum the resultant spreadsheet (**OUTPUT 3**) should include the following column headers:

- Author(s)
- Year
- Title of document
- Source (including hyperlink where available)
- Literature type: (drop-down box "Peer-reviewed", "Grey literature", "Unpublished")
- Location (drop-down box: "UK", "EU", "non-EU", "Global")
- Study type: "quantitative studies – experimental"; "quantitative studies – observational"; "qualitative studies"; "mixed studies"
- Scale of study (drop-down box: "Site level", "Local", "Country", "Region", "Global")
- Relevance to each primary and/or secondary keyword (to be simply ticked), plus each tertiary keyword (if appropriate, as the latter may make the data extraction form unnecessarily complex and unwieldy)
- Summary of all relevant quantitative evidence for the purposes of later searching, sorting and aggregating:
 - Subject detail (e.g. habitat type, economic sector), which will identify the subject of the impact. It may be quite broad (e.g. fisheries) or specific (e.g. a particular species).
 - Outcome variable(s), which have been specifically measured, observed or modelled (e.g. species abundance, diversity, unemployment rate).
 - Metric(s) (e.g. GBP, individuals per m²) for the outcome variable
 - Outcome detail, as reported in the study, rather than the review team's interpretation of it. This would be the number related to the metric, where recorded, or terms such as "significant", or "negligible" as used in the study.

Multiple rows should be completed per study where they consider more than one subject or variable. Some studies may not include clearly identifiable variables with associated metrics in which case those fields can simply be left blank.

- Summary of key messages in relation to the REA's impact question and any secondary questions, i.e. with regard to the energy supply or demand option(s), their component drivers, associated pressures and resultant impacts
- Summary of mitigation (i.e. alleviation of impacts) and enhancement measures (solely in relation to the key messages), which can later be synthesised (Section 6.5.3)
- Pedigree – individual studies (see Section 6.4.1)
- Pedigree – reviews (see Section 6.4.1).

Data extraction should be undertaken by people who have good technical knowledge of the issues to be addressed, including its context and practicalities. Dependent on the search engine and the way in which it is used, it may be possible initially to sub-divide the list of evidence by primary and/or secondary keywords, which will then allow delegation to individuals whose technical knowledge is specific to particular types of impacts resultant from the drivers and pressures. If review of the evidence is delegated in this way, then where papers span a range of impact types, they may need to be reviewed by more than one individual. Whether this stage of the review is undertaken by one person or delegated to a number of individuals, each individuals' data extraction should be reviewed on a 10% sample basis by another person with good relevant technical knowledge to check that there is no bias, so that remedial actions can be taken, if necessary. This quality control should be undertaken at regular intervals, as at worst, it may be necessary to repeat the whole process of data extraction for all papers considered up to that point.

For the sake of transparency and repeatability, use of text analysis or semantic tools to search papers and group documents is not advocated here. They have not previously been promoted for use in REAs by Civil Service guidelines, UKERC's TPA, NE guidelines or JWEG guidance.

The Steering Group and key stakeholders should be given opportunity to review Output 3.

6.4 Critically appraising the evidence

6.4.1 Evaluating the strength of evidence

It is essential to appraise the evidence critically in order to ensure that more reliable evidence is given greater consideration at the synthesis stage. The strength of evidence arising from individual studies and reviews should be assessed having due regard to any differences between the conditions under which the data were obtained and the situation addressed by the impact question. Evidence should be evaluated following the "data pedigree" approach. In some ways this approach is more systematic than that described in the JWEG guidance but is consistent with it. The approach is intended to accommodate the full range of study types (quantitative studies – experimental; quantitative studies – observational; qualitative studies; and mixed studies) while also being less onerous than using the collection of checklists advocated by Natural England's guidelines.

"Pedigree" is a description of the reliability of the information from which data have been derived. With regard to individual studies, it should consider the following aspects of the quality of information (van der Sluijs et al., 2002⁵):

- Proxy: is the value based on a direct measurement of the parameter in question, or on some other measurement that is correlated more or less well with the parameter?
- Empirical basis: is the value based on a large number of field measurements, a smaller number of field measurements, modelled values, estimates or speculation?
- Methodological rigour: is the data obtained using best practice, widely used approaches, laboratory or research tools, or is no information provided on these methods?
- Validation: can the data be cross-checked extensively, to a limited or indirect extent, or not at all?

The pedigree of each individual study (i.e. excluding reviews) should be evaluated by scoring key elements of the underlying data between 0 and 4 on the above four aspects, using the framework in Figure 3. Data pedigree should be established from the lowest score for any of the key inputs. A score of 0 – 4 will be described as poor; 5 – 8 moderate; 9 – 12 good; and 13 – 16 very good. These scores should also be recorded in Output 3 under the column header "Pedigree – individual studies".

⁵ van der Sluijs et al. 2002. Uncertainty assessment of the IMAGE/TIMER B1 CO₂ emissions scenario, using the NUSAP method. Report no: 410 200 104. Dutch National Research Programme on Global Air Pollution and Climate Change. Available at: <http://www.nusap.net/workshop/report/finalrep.pdf>

		Strength indicators			
		Proxy	Empirical	Method	Validation
Score	4	An exact measure of the desired quantity	Controlled experiments and large sample of direct measurements	Best available practice in well-established discipline	Compared with independent measurements of the same variable over long domain
	3	Good fit or measure	Historical/field data, uncontrolled experiments, small sample of direct measurements	Reliable method, common within established discipline, best available practice in immature discipline	Compared with independent measurements of closely related variable over shorter period
	2	Well correlated, but not measuring the same thing	Modelled data, indirect measurements	Acceptable method but limited consensus on reliability	Measurements not independent proxy variable with limited domain
	1	Weak correlation, but commonalities in measure	Educated guesses, indirect approximations, rule of thumb	Preliminary methods with unknown reliability	Weak and very indirect validation
	0	Not correlated and not clearly related	Crude speculation	No discernible rigour	No validation performed

Figure 3. Pedigree-matrix to evaluate data and evidence from selected individual studies

An analogous approach should be followed to assess the strength of evidence arising from reviews by scoring key elements of the underlying data using the framework in Figure 4. Data pedigree should be established from the lowest score for any of the key inputs. Scores should be described as: 4 – 6 poor; 7 – 9 moderate; 10 – 12 good. These scores should also be recorded in Output 3 under the column header “Pedigree – reviews”.

It is important to note that pedigree scores do not take account of authorship or whether studies are peer-reviewed, grey literature or unpublished, as these factors are not in themselves a determinant of the strength of evidence.

		Strength indicators			
		Research question	Search strategy	Weighting	Summary of results
Score	3	Clearly formulated question	Explicit, systematic search strategy	Systematic scoring of ‘data pedigree’ and confidence	Quantitative meta-analysis, caveats and assumptions detailed
	2	Research question broadly identified	Limited search strategy	Qualitative consideration of strength and quality of data	Qualitative analysis, caveats and assumptions detailed
	1	Research question not identified	Selected evidence only	Limited consideration of strength and quality of data	Limited analysis, difficult to trace evidence

Figure 4. Pedigree-matrix to evaluate data and evidence from selected reviews

Evaluation of pedigree should be undertaken by the same technical experts involved in data extraction. Whether it is undertaken by one person or delegated to a number of individuals, each individuals' scoring should be reviewed on a 10% sample basis to check that there is no bias, so that remedial actions can be taken, if necessary. Where pedigree scores are inconsistent, at worst, it may be necessary for the whole process to be repeated.

6.4.2 Ranking confidence in evidence across multiple papers

A methodology that builds upon one used in the Intergovernmental Panel on Climate Change's Fifth Assessment Report⁶ should be used to rank confidence in evidence across multiple papers in relation to each keyword or combination of keywords. Output 3 can be simply sorted and re-sorted to identify which papers are associated with each keyword or combination of keywords, i.e. associated with drivers, pressures and/or impacts. If a substantial amount of evidence has been located then it may be sensible to consider confidence in relation to drivers/pressures and impacts in combination. If there is limited evidence then only considering confidence with regard to individual impacts may make more sense.

Essentially, the following dimensions should be used to rank confidence:

- The number of studies and the strength of their evidence (summary terms: "limited," "medium," or "robust"), and
- The degree of agreement (summary terms: "low," "medium," or "high").

The amount and strength of evidence should be ranked by multiplying the number of papers associated with each keyword or combination of keywords by the mid-point of the pedigree scores. The ranking of agreement should be derived by counting the number of studies associated with a keyword, or combination of keywords, as a proportion of all studies. These dimensions should be combined using the matrix in Figure 5 to give an overall confidence rating (high, medium, low) for each key word or combination of keywords. Confidence increases towards the top-right corner of Figure 5, as suggested by the increasing strength of shading. Generally, evidence is most robust when there are multiple, consistent, independent lines of high-quality evidence.

HIGH						
Agreement	High agreement	Limited evidence	High agreement	Medium evidence	High agreement	Robust evidence
	Medium agreement	Limited evidence	Medium agreement	Medium evidence	Medium agreement	Robust evidence
	Low agreement	Limited evidence	Low agreement	Medium evidence	Low agreement	Robust evidence
LOW	Evidence (amount and strength of evidence)					HIGH

Figure 5. A depiction of evidence and agreement statements and their relationship to confidence

Ranking of confidence should be recorded in a separate spreadsheet (**OUTPUT 4**; Table 6).

⁶ Mastrandrea, M.D., C.B. Field, T.F. Stocker, O. Edenhofer, K.L. Ebi, D.J. Frame, H. Held, E. Kriegler, K.J. Mach, P.R. Matschoss, G.-K. Plattner, G.W. Yohe, and F.W. Zwiars, 2010. Guidance note for Lead Authors of the IPCC Fifth Assessment Report on consistent treatment of uncertainties. Intergovernmental Panel on Climate Change (IPCC). Available at: <http://www.ipcc.ch/pdf/supporting-material/uncertainty-guidance-note.pdf>

Table 6. Ranking of confidence

Keyword	No. of studies	Pedigree scores	Score no. of studies	Pedigree mid-point	Evidence	Agreement	Confidence

Care should be taken when ranking confidence to avoid undue account being taken of the same study published in more than one place. However, the common authorship of multiple papers should not in itself reduce ranking of confidence if they address different studies.

The methods employed in evaluating the strength of evidence from individual studies and reviews and ranking confidence in evidence across multiple papers should provide reassurance to stakeholders in the selected evidence and in the way it is used and interpreted. The Steering Group and key stakeholders should be given opportunity to review Output 4.

6.5 Synthesising the evidence

Synthesis of the evidence needs to describe:

- The volume and characteristics of the overall evidence base
- What the evidence indicates (i.e. the significance of impacts assessed in terms of their magnitude and confidence in the evidence)
- Implications for mitigation of negative impacts and enhancement of positive impacts
- Knowledge gaps and research needs.

6.5.1 Summarising volume and characteristics of the overall evidence base

The overall evidence base is summarised by Outputs 2, 3 and 4 from which the following summary statistics (**OUTPUT 5**) should be produced in relation to the total number of pieces of evidence (i.e. papers, reports etc):

- Initially identified
- After first phase of screening
- After second phase of screening
- Relevant to each primary and/or secondary keyword
- Relevant to each tertiary keyword
- In each of the following categories:
 - Type: Peer-reviewed, Grey literature, Unpublished
 - Location: UK, EU, non-EU, Global
 - Study type: “quantitative studies – experimental”; “quantitative studies – observational”; “qualitative studies”; “mixed studies”
 - Scale of study: Site level, Local, Country, Region, Global
- Relating to each pedigree ranking for individual studies
- Relating to each pedigree ranking for reviews.

The total number of pieces of evidence relevant to each primary and/or secondary keyword and tertiary keyword should be further broken down into the number of pieces of evidence in each of the following categories:

- Type: Peer-reviewed, Grey literature, Unpublished
- Location: UK, EU, non-EU, Global
- Study type: “quantitative studies – experimental”; “quantitative studies – observational”; “qualitative studies”; “mixed studies”
- Scale of study: Site level, Local, Country, Region, Global
- Each pedigree ranking for individual studies
- Each pedigree ranking for reviews.

6.5.2 Summarising what the evidence indicates

A concise, plain English summary (maximum 1,000 words) of the evidence should be produced (**OUTPUT 6**), drawing upon Outputs 3 (Data extraction form), addressing the REA’s primary question and any secondary questions with regard to the energy supply or demand option(s), their component drivers, associated pressures and resultant impacts, including cumulative impacts. This should incorporate a summary of all quantitative evidence. Due attention should also be given to capturing important qualitative insights, particularly from the social science domain. Wherever appropriate, individual conclusions should be accompanied by a confidence ranking’ drawing upon Output 4 (Confidence in evidence across multiple papers), also citing the ranking of levels of ‘evidence’ and ‘agreement’.

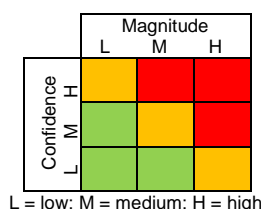
The summary should be supported by completion of a matrix from review of Outputs 3 and 4 in relation to the significance of the relevant impacts (**OUTPUT 7**). An example is provided as Table 7 from the case study on the impacts of small-scale district heating using biomass feedstocks.

“Magnitude” of impact should be determined subjectively as a product of “Extent”, “Duration”, “Reversibility” and “Frequency” of impact. Confidence in the magnitude of impact should again use the methodology associated with the Intergovernmental Panel on Climate Change’s Fifth Assessment Report (Section 6.4.2, Figure 5). The significance of an impact is then the product of its magnitude and confidence in the evidence underpinning this assessment.

Table 7. Significance of impacts of energy supply/demand option

Energy supply/demand option: <i>District heating</i>	Impact				
	<i>GHG emissions</i>	<i>Air quality</i>	<i>Biodiversity</i>	<i>Net employment creation</i>	<i>Cumulative impacts</i>
Pressure: Biomass/bioenergy					
Positive or negative (+/-)	+	-	+/-	+	+++/--
Extent (site level, local, national, regional, or global)	global	local	global	regional	generally larger scale
Duration (permanent, semi-permanent, or temporary)	semi-permanent	temporary	permanent	semi-permanent	longer term
Reversibility (irreversible, difficult to reverse, or reversible)	difficult to reverse	reversible	irreversible	reversible	mixed
Frequency (always, during construction and/or operation)	always	always	always	during construction and operation	always
Magnitude of impact (high, medium, low)	H	H	M	L	mixed
Confidence (high, medium, low)	H	H	M	M	mixed
Significance: magnitude x confidence (see key)					
Possible change in significance of impact with climate change (increase, decrease, or no change)	no change	no change	increase	no change	no change

Key to significance



In future, the magnitude of impacts from drivers and pressures associated with individual energy supply/demand options could change due to changes in the environment, the socioeconomic context, or the technology itself. Assessing such potential changes is to some degree imponderable, but subjective consideration should be given to whether the significance of impacts will vary as a result of climate change.

Unlike Natural England’s guidance, this methodology does not specifically rank the external validity of individual papers, i.e. the extent to which a study’s results are applicable or generalisable to the wider ‘population’ that is the focus of the review. Instead, Outputs 6 and 7 should consider the evidence as a whole, giving greater emphasis to more reliable evidence (i.e. with good or very good pedigree) and taking into account confidence in the evidence across multiple papers in relation to each keyword or combination of keywords (Output 4).

Outputs 6 and 7 should be produced by the same technical experts involved in data extraction (inclusive of scoring pedigree and ranking of confidence across multiple papers). If review of the evidence is delegated to more than one expert, as detailed in Section 6.3, then all experts involved should collectively develop Outputs 6 and 7. If these outputs are produced by a single technical expert, then another technical expert should review them to check that there is no bias, so that remedial actions can be taken, if necessary. The Steering Group and key stakeholders should also be given opportunity to comment on Outputs 6 and 7.

6.5.3 Summarising mitigation and enhancement measures

A plain English summary (maximum 500 words) of mitigation and enhancement measures should be produced from those identified in Output 3. It should be supported by completion of a matrix transcribing relevant references from Output 3 and relating them to the impacts associated with the energy supply or demand option(s) (**OUTPUT 8**). An example is provided as Table 8 from the case study on the impacts of small-scale district heating using biomass feedstocks.

The Steering Group and key stakeholders should be given opportunity to comment on Output 8 during its development.

Table 8. Mitigation of negative impacts and enhancement of positive impacts

Energy supply/demand option: <i>District heating</i>	Impact				
	<i>GHG emissions</i>	<i>Air quality</i>	<i>Biodiversity</i>	<i>Net employment creation</i>	<i>Cumulative impacts</i>
Mitigation	6, 7, 8			1,2	7
Enhancement	9		7	2,3,4,5	

References

1. T. Trink, C. Schmid, T. Schinko, K. W. Steininger, T. Loibnegger, C. Kettner, A. Pack and C. Toeglhofer (2010) Regional economic impacts of biomass based energy service use: A comparison across crops and technologies for East Styria, Austria, Energy Policy 38 (10) 5912-5926
2. K. W. Steininger and H. Voraberger (2003) Exploiting the medium term biomass energy potentials in Austria - A comparison of costs and macroeconomic impact, Environmental and Resource Economics, 24 (4) 359-377
3. O. Lehtonen and L. Okkonen (2013) Regional socio-economic impacts of decentralised bioeconomy: a case of Suutela wooden village, Finland, Environment Development and Sustainability 15 (1) 245-256
4. C. Panoutsou (2007) Socio-economic impacts of energy crops for heat generation in Northern Greece, Energy Policy, 35 (12) 6046-6059
5. NNfCC (2012) Jobs in the bioenergy sectors by 2020 - Publications - GOV.UK

6. DECC (2012) *An assessment of the carbon impacts of using different types of wood for bioenergy* <https://www.gov.uk/government/publications/an-assessment-of-the-carbon-impacts-of-using-different-types-of-wood-for-bioenergy>

7. DECC (2012) *UK Bioenergy Strategy* <https://www.gov.uk/government/publications/uk-bioenergy-strategy>

8. Ghafghazi et al (2011) Life cycle assessment of base-load heat sources for district heating system options *International Journal of Life Cycle Assessment* **16:3** 212-223 DOI:10.1007/s11367-011-0259-9

9. Gonzalez-Garcia et al (2013) Life cycle assessment of potential energy uses for short rotation willow biomass in Sweden *International Journal of Life Cycle Assessment* **18:4** 783-795 DOI:10.1007/s11367-012-0536-2

6.5.4 Identifying knowledge gaps and research needs

By recording in Output 3 (the data extraction form) the relevance of each document located to each primary and/or secondary keyword (plus each tertiary keyword, if appropriate), the spreadsheet should be simply sorted and re-sorted to identify where there are knowledge gaps relating to each keyword or combination of keywords from either the primary and/or secondary (and/or tertiary) themes. Other areas where further research is required should be identified by reference to those keywords or combination of keywords relating to either the primary and/or secondary (and/or tertiary) themes where confidence in the evidence across multiple papers is ranked as low. The list of areas where there are knowledge gaps or further research needs should be presented as **OUTPUT 9 (Table 9)**.

Table 9. Knowledge gaps and research needs

Knowledge gap	Research needs
Heading 1	Maximum 100 words
Heading 2	

6.6 Identifying caveats arising from the REA process

It is important that the outputs of every REA should be produced, structured and presented in the same ways to enable them to be uploaded to a knowledge gateway for access and comparison by the wide range of possible end-users. As a result of this standardised approach, any specific caveats that should be attached to the REA’s outputs should be provided as a series of short bullet points in plain English not exceeding 500 words in total (**OUTPUT 10**).

While it should be self-evident that any REA can only be based on evidence that has been published at the time of the review, one specific caveat that should be recorded in relation to all REAs is that, “The assessment of impacts is based on the built infrastructure technologies (e.g. construction materials and techniques) available when the REA was undertaken.”

6.7 Final outputs

All outputs from each REA are identified at relevant points in the methodology and listed in Table 10.

Table 10. Final outputs of each REA

Output	Description
1	The REA protocol
2	Results of screening all individual papers
3	Data extraction form
4	Confidence in evidence across multiple papers
5	Volume and characteristics of the overall evidence base
6	A concise summary of the evidence
7	Significance of impacts of energy supply/demand option

8	Mitigation and enhancement measures
9	A list of knowledge gaps and research needs
10	Caveats arising from the REA process

6.8 Validation

Although the Steering Group and, where appropriate, key stakeholders should have been given opportunity to review and comment on the development of all outputs during the course of the REA, they should be given a further opportunity to comment on all final draft outputs. New evidence or views on the evidence should be incorporated, as appropriate, or added as caveats arising from the REA process (**OUTPUT 10**).

6.9 Timescales and cost

REAs use search methods developed for full Systematic Reviews, but limit the rigour of their application to reduce the time and expense of production. The JWEG guidance on which this methodology is based estimates that individual REAs take 3-8 months to complete and cost in the region of £20,000-£50,000. It is not intended that this methodology should be any more onerous. Indeed, where this methodology identifies more detailed, additional or alternative practical methods for implementing each step it has been with the sole intent of streamlining and making more explicit what has to be done. As noted in Section 5.4, an important determinant of how long it will take to undertake an REA is the scope of the primary question (an “impact question” assessing positive and negative impacts of a particular energy supply or demand option) that is to be the focus of the REA. This should be borne strongly in mind when refining the primary question (Section 5.4) and considering potential secondary questions, while also being mindful that the question is not so narrow as to produce perverse results (e.g. does not give due consideration to inter-related impacts).

Appendices

Appendix 1: Report template

Appendix 2: Example impact typologies

Appendix 1. Report template

This report template should be reproduced in its entirety, with headings as identified. Wording should be completed where indicated in non-bold italics for each REA strictly in accordance with “A methodology for Rapid Evidence Assessments” (Smithers 2015). An asterisk signals a choice of words for deletion. The report should be clearly dated.

Introduction

This report has been produced strictly in accordance with a standard methodology (Smithers 2015) for carrying out Rapid Evidence Assessments (REAs) of the direct, indirect and cumulative impacts (positive and negative) of energy supply and demand options on the environment, society and the economy, based on published literature (both peer-reviewed and grey). REAs use methods developed for full Systematic Reviews, in order to ensure that they are systematic, transparent and repeatable, but limit the rigour of their application to reduce the time and expense of production.

The outputs of each REA produced using the standard methodology are structured and presented in a consistent way to enable their comparison by a wide range of possible end-users e.g. government policy advisers, regulators and enforcement bodies, local government planners and developers, non-governmental organisations and the general public.

The REA outputs contained in this report are as summarised in Table A1-1.

Table A1-1. A summary of the REA outputs

Output	Description	Summary
1	The REA protocol	The protocol identifies all aspects of the background to the REA, including: a concise, plain English outline of the rationale behind the REA and policy context; the primary question and any secondary questions addressed; and details of the method that are specific to the individual REA.
2	Results of screening all individual papers	A spreadsheet of all of the papers considered in each of two screening phases with column headers for: author(s); year; title of the document; and source, including hyperlink where available; and relevance to inclusion and exclusion criteria.
3	Data extraction form	A spreadsheet of all evidence extracted from each paper relevant to the REA’s primary question and any secondary questions. Column headers in Output 2 are supplemented by: literature type; location; study type; scale of study; relevance to each keyword; summary of quantitative evidence; subject detail; outcome variable(s) specifically measured, observed or modelled; metric(s); outcome detail, as reported in the study; summary of key messages in relation to the REA’s impact question and any secondary questions; summary of mitigation and enhancement measures; pedigree (the strength of evidence).
4	Confidence in evidence across multiple papers	Confidence in evidence across multiple papers in relation to each keyword or combination of keywords.
5	Volume and characteristics of the overall evidence base	Summary statistics in relation to the total number of pieces of evidence (i.e. papers, reports etc), also further broken down into the total number of pieces of evidence in a range of categories relevant to each keyword.
6	A concise summary of the evidence	A concise, plain English summary of the evidence which draws upon Outputs 3, addressing the REA’s primary question and any secondary questions with regard to the energy supply or demand option(s), their component

Output	Description	Summary
		drivers, associated pressures and resultant impacts, including cumulative impacts; supported by Output 7.
7	Significance of impacts of energy supply/demand option	A matrix of the significance of impacts assessed in terms of their magnitude and confidence in the evidence compiled from review of Outputs 3 and 4.
8	Mitigation and enhancement measures	A concise, plain English summary of mitigation and enhancement measures produced from those identified in Output 3, supported by a matrix transcribing relevant references from Output 3 and relating them to the impacts associated with the energy supply or demand option(s).
9	A list of knowledge gaps and research needs	Knowledge gaps relating to each keyword or combination of keywords where there is an absence of evidence or low confidence in the evidence across multiple papers and, hence, associated needs for further research.
10	Caveats arising from the REA process	Any specific caveats attached to the REA's outputs provided as a series of short bullet points in plain English.

Output 1: The REA protocol

Membership of the review team

The members of the review team who undertook this REA and their roles and responsibilities in relation to each stage of implementing the protocol are shown in Table A1-2.

Table A1-2. Roles and responsibilities of individual members of the review team

Stage of implementing the protocol	Team member	Role	Responsibilities
Searching for evidence			
Screening the search results			
Extracting the evidence			
Critically appraising the evidence			
Synthesising the evidence			

Background rationale and policy context

Maximum 500 words.

Figure 1. A systems diagram or schematic of the elements of (the energy supply or demand option(s))

Objective(s)

The primary question that was the focus of the REA was:

“xx xxxx xxxxxx xxxx xxxx”.

The primary question’s Population, Intervention, Control and Outcome (PICO) elements are provided in Table A1-3. A detailed typology of *the proposed energy supply or demand option(s)* and its/their*

component drivers of impact and pressures is provided in *Table a (OPTIONAL)*. A detailed typology of the impacts resultant from the drivers of impact and pressures is provided in *Table b (OPTIONAL)*. Secondary questions to further qualify the primary question were: *(OPTIONAL)*.

Table A1-3. The primary question’s PICO elements

PICO element	Definition
Population	
Intervention/exposure	
Comparator	
Outcome	

Methods

Search strategy

The search strategy adopted to gather relevant peer-reviewed journal articles, grey literature (e.g. national and international government reports, studies published by industry and NGOs, theses and dissertations) and any unpublished evidence (e.g. unpublished reports or presentations and internal documents) is outlined in Table A1-4.

Table A1-4. Search strategy

Type of evidence	Places searched	Rationale
Peer-reviewed journal articles		
Grey literature		
Unpublished evidence		

Search keywords

Targeted searches used primary, secondary and tertiary keywords (Table A1-5), which were later used to help categorise papers during data extraction for Output 3. Primary keywords were related to the elements of *the energy supply and/or demand options addressed* and/or the associated drivers of impacts or pressures identified. Secondary and tertiary keywords were related to the typology of the impacts resultant from the drivers of impact and pressures.

Table A1-5. Search keywords

Primary	Secondary	Tertiary

Inclusion and exclusion criteria

In order to focus the review on the most relevant sources of evidence in a systematic way, a pre-defined set of inclusion/exclusion criteria was established.

Inclusion criteria:

- aaaa
- bbbb

Exclusion criteria:

- cccc
- dddd.

Potential conflicts of interest

In order to ensure transparency and avoid bias, members of the Steering Group and the review team (as well stakeholders consulted during the REA) were asked to declare all potential conflicts of interest, including personal conflicts, financial, political, academic and other interests. As the Steering Group and review team (as well as stakeholders consulted) needed to include individuals who have good technical knowledge of the issues to be addressed by the REA, including its context and practicalities, it was to some degree inevitable that such conflicts would arise. Documenting them allowed rigour to be imposed through appropriate quality assurance in this regard.

Potential conflicts of interest identified were as detailed in Table A1-6.

Table A1-6. Potential conflicts of interest

Individual	Role	Potential conflict of interest

Sources of information used in developing the protocol

All references to be provided.

Output 2: Results of screening all individual papers

Searches of the databases and other places explicitly identified in the search strategy were undertaken by individuals who had experience in systematically searching evidence. Application of the keywords was checked by:

- An individual who had good technical knowledge of the issues to be addressed, including its context and practicalities
- The Steering Group in order to maintain common understanding about the scope of the review.

For each of the papers identified, the author(s), year, title of the document, and source (including hyperlink where available) was recorded. The records of each search were then combined to give a full list of the evidence found, removing any duplicates.

The full list of evidence was screened in two phases, first, by reference to the title of each piece of evidence and, second, by reading the abstract or first paragraph of all those papers that remain. Screening of all the evidence was undertaken by one person in order to ensure that the criteria were applied consistently. This was someone with experience of systematically searching evidence. A second person with good technical knowledge of the issues addressed independently screened a 10% sample of documents in order to check that there was no bias.

The results of screening were recorded in separate spreadsheets for phase one and phase two (*Table A1-7, which should be provided as an appendices*), which list all of the papers considered in each phase with each of the inclusion/exclusion criteria as column headers. All those pieces of evidence that were excluded at this stage are clearly identified. These spreadsheets are a valuable output, providing transparency, a starting point for any future re-investigation of the same impact question or related questions.

Table A1-7. Results of screening (phase one or phase two)

Author(s)	Year	Title	Source	Inclusion criteria 1	Inclusion criteria 2	Exclusion criteria 1	Exclusion criteria 2

Output 3: Data extraction form

Data was extracted from the remaining list of evidence following screening, as relevant to the REA’s primary question *and any secondary questions** (Table A1-8, which should be provided as an appendix). Data extraction was undertaken by people who had good technical knowledge of the issues to be addressed, including its context and practicalities. Each individuals’ data extraction was reviewed on a 10% sample basis by another person with good relevant technical knowledge to check that there was no bias.

Table A1-8. Data extracted

Author(s)	Year	Title	Source	Literature type	Location	Study type	Scale of study	Relevance to keyword 1	Relevance to keyword 2	Relevance to keyword 3	Subject detail	Outcome variable 1	Outcome variable 2	Outcome metric 1	Outcome metric 2	Outcome detail	Summary of key messages	Summary of mitigation/enhancement	Pedigree – individual studies	Pedigree – reviews

It was essential to appraise the evidence critically in order to ensure that more reliable evidence was given greater consideration at the synthesis stage. The strength of evidence arising from individual studies and reviews was assessed having due regard to any differences between the conditions under which the data were obtained and the situation addressed by the primary question. Evidence was evaluated following the “data pedigree” approach, which was intended to accommodate the full range of study types (quantitative studies – experimental; quantitative studies – observational; qualitative studies; and mixed studies).

“Pedigree” is a description of the reliability of the information from which data have been derived. With regard to individual studies, it considered the following aspects of the quality of information (van der Sluijs et al., 2002⁷):

- Proxy: is the value based on a direct measurement of the parameter in question, or on some other measurement that is correlated more or less well with the parameter?
- Empirical basis: is the value based on a large number of field measurements, a smaller number of field measurements, modelled values, estimates or speculation?
- Methodological rigour: is the data obtained using best practice, widely used approaches, laboratory or research tools, or is no information provided on these methods?

⁷ van der Sluijs et al. 2002. Uncertainty assessment of the IMAGE/TIMER B1 CO2 emissions scenario, using the NUSAP method. Report no: 410 200 104. Dutch National Research Programme on Global Air Pollution and Climate Change. Available at: <http://www.nusap.net/workshop/report/finalrep.pdf>

- Validation: can the data be cross-checked extensively, to a limited or indirect extent, or not at all?

The pedigree of each individual study (i.e. excluding reviews) was evaluated by scoring key elements of the underlying data between 0 and 4 on the above four aspects, using the framework in Figure 2. Data pedigree was established from the lowest score for any of the key inputs. A score of 0 – 4 was described as poor; 5 – 8 moderate; 9 – 12 good; and 13 – 16 very good. These scores were also recorded in Table A1-8 under the column header “Pedigree – individual studies”.

		Strength indicators			
		Proxy	Empirical	Method	Validation
Score	4	An exact measure of the desired quantity	Controlled experiments and large sample of direct measurements	Best available practice in well-established discipline	Compared with independent measurements of the same variable over long domain
	3	Good fit or measure	Historical/field data, uncontrolled experiments, small sample of direct measurements	Reliable method, common within established discipline, best available practice in immature discipline	Compared with independent measurements of closely related variable over shorter period
	2	Well correlated, but not measuring the same thing	Modelled data, indirect measurements	Acceptable method but limited consensus on reliability	Measurements not independent proxy variable with limited domain
	1	Weak correlation, but commonalities in measure	Educated guesses, indirect approximations, rule of thumb	Preliminary methods with unknown reliability	Weak and very indirect validation
	0	Not correlated and not clearly related	Crude speculation	No discernible rigour	No validation performed

Figure 2. Pedigree-matrix to evaluate data and evidence from selected individual studies

An analogous approach was followed to assess the strength of evidence arising from reviews by scoring key elements of the underlying data using the framework in Figure 3. Data pedigree was established from the lowest score for any of the key inputs. Scores were described as: 4 – 6 poor; 7 – 9 moderate; 10 – 12 good. These scores were also recorded in Table A1-8 under the column header “Pedigree – reviews”.

It is important to note that pedigree scores did not take account of authorship or whether studies were peer-reviewed, grey literature or unpublished, as these factors were not in themselves a determinant of the strength of evidence.

		Strength indicators			
		Research question	Search strategy	Weighting	Summary of results
Score	3	Clearly formulated question	Explicit, systematic search strategy	Systematic scoring of 'data pedigree' and confidence	Quantitative meta-analysis, caveats and assumptions detailed
	2	Research question broadly identified	Limited search strategy	Qualitative consideration of strength and quality of data	Qualitative analysis, caveats and assumptions detailed
	1	Research question not identified	Selected evidence only	Limited consideration of strength and quality of data	Limited analysis, difficult to trace evidence

Figure 3. Pedigree-matrix to evaluate data and evidence from selected reviews

Evaluation of pedigree was undertaken by the same technical experts involved in data extraction. Each individuals' scoring was reviewed on a 10% sample basis to check that there is no bias.

Output 4: Confidence in evidence across multiple papers

A methodology that builds upon one used in the Intergovernmental Panel on Climate Change's Fifth Assessment Report⁸ was used to rank confidence in evidence across multiple papers in relation to each keyword or combination of keywords. Essentially, the following dimensions were used to rank confidence:

- The number of studies and the strength of their evidence (summary terms: "limited," "medium," or "robust"), and
- The degree of agreement (summary terms: "low," "medium," or "high").

The amount and strength of evidence was ranked by multiplying the number of papers associated with each keyword or combination of keywords by the mid-point of the pedigree scores. The ranking of agreement was derived by counting the number of studies associated with a keyword, or combination of keywords, as a proportion of all studies. These dimensions were combined using the matrix in Figure 4 to give an overall confidence rating (high, medium, low) for each key word or combination of keywords. Confidence increases towards the top-right corner of Figure 4, as suggested by the increasing strength of shading. Generally, evidence is most robust when there are multiple, consistent, independent lines of high-quality evidence.

Ranking of confidence in evidence across multiple papers in relation to each keyword or combination of keywords is presented in Table A1.9.

⁸ Mastrandrea, M.D., C.B. Field, T.F. Stocker, O. Edenhofer, K.L. Ebi, D.J. Frame, H. Held, E. Kriegler, K.J. Mach, P.R. Matschoss, G.-K. Plattner, G.W. Yohe, and F.W. Zwiers, 2010. Guidance note for Lead Authors of the IPCC Fifth Assessment Report on consistent treatment of uncertainties. Intergovernmental Panel on Climate Change (IPCC). Available at: <http://www.ipcc.ch/pdf/supporting-material/uncertainty-guidance-note.pdf>

HIGH			
Agreement	High agreement Limited evidence	High agreement Medium evidence	High agreement Robust evidence
	Medium agreement Limited evidence	Medium agreement Medium evidence	Medium agreement Robust evidence
	Low agreement Limited evidence	Low agreement Medium evidence	Low agreement Robust evidence
LOW	Evidence (amount and strength of evidence)		HIGH

Figure 4. A depiction of evidence and agreement statements and their relationship to confidence

Table A1.9. Ranking of confidence across multiple papers in relation to each keyword or combination of keywords

Keyword	No. of studies	Pedigree scores	Score no. of studies	Pedigree mid-point	Evidence	Agreement	Confidence

Care was taken when ranking confidence to avoid undue account being taken of the same study published in more than one place. However, the common authorship of multiple papers did not in itself reduce ranking of confidence if they addressed different studies.

The methods employed in evaluating the strength of evidence from individual studies and reviews and ranking confidence in evidence across multiple papers should provide reassurance to stakeholders in the selected evidence and in the way it was used and interpreted.

Output 5: Volume and characteristics of the overall evidence base

The overall evidence base was summarised by Outputs 2, 3 and 4 from which a summary of statistics was produced in relation to the total number of pieces of evidence, i.e. papers, reports etc (Table A1.10).

Table A1-10. Summary statistics in relation to the total number of pieces of evidence

Stage/relevance	Total no.
Initially identified	
After first phase of screening	
After second phase of screening	
Relevant to keyword 1	
Relevant to keyword 2	
Type: Peer-reviewed	
Type: Grey literature	
Type: Unpublished	
Location: UK	

Stage/relevance	Total no.
Location: EU	
Location: Non-EU	
Location: Global	
Study type: "quantitative studies – experimental"	
Study type: "quantitative studies – observational"	
Study type: "qualitative studies"	
Study type: "mixed studies"	
Scale of study: Site level	
Scale of study: Local	
Scale of study: Country	
Scale of study: Region	
Scale of study: Global	
Pedigree ranking for individual studies: Poor	
Pedigree ranking for individual studies: Moderate	
Pedigree ranking for individual studies: Good	
Pedigree ranking for individual studies: Very good	
Pedigree ranking for reviews: Poor	
Pedigree ranking for reviews: Moderate	
Pedigree ranking for reviews: Good	

The total number of pieces of evidence relevant to each keyword was further broken down into the number of pieces of evidence in a range of categories (Table A1.11).

Table A1-11. Summary statistics in relation to the total number of pieces of evidence relevant to each keyword

Keyword	Relevance	Total no.
Keyword 1	Type: Peer-reviewed	
	Type: Grey literature	
	Type: Unpublished	
	Location: UK	
	Location: EU	
	Location: Non-EU	
	Location: Global	
	Study type: "quantitative studies – experimental"	
	Study type: "quantitative studies – observational"	
	Study type: "qualitative studies"	
	Study type: "mixed studies"	

Keyword	Relevance	Total no.
	Scale of study: Site level	
	Scale of study: Local	
	Scale of study: Country	
	Scale of study: Region	
	Scale of study: Global	
	Pedigree ranking for individual studies: Poor	
	Pedigree ranking for individual studies: Moderate	
	Pedigree ranking for individual studies: Good	
	Pedigree ranking for individual studies: Very good	
	Pedigree ranking for reviews: Poor	
	Pedigree ranking for reviews: Moderate	
	Pedigree ranking for reviews: Good	
Keyword 2		

Output 6: A concise summary of the evidence

A concise, plain English summary of the evidence (maximum 1,000 words), drawing upon Outputs 3, addressing the REA’s primary question and any secondary questions with regard to the energy supply or demand option(s), their component drivers, associated pressures and resultant impacts, including cumulative impacts. This should incorporate a summary of all quantitative evidence. Due attention should also be given to capturing important qualitative insights, particularly from the social science domain. Wherever appropriate, individual conclusions should be accompanied by a confidence ranking’ drawing upon Output 4, also citing the ranking of levels of ‘evidence’ and ‘agreement’.

Output 7: Significance of impacts of energy supply/demand option

Table A1.12 is intended to support the concise summary of the evidence (Output 6), and was completed from review of Outputs 3 and 4 in relation to the significance of the relevant impacts. “Magnitude” of impact was determined subjectively as a product of “Extent”, “Duration”, “Reversibility” and “Frequency” of impact. Confidence in the magnitude of impact was assessed using the methodology described in Output 4. The significance of an impact was then the product of its magnitude and confidence in the evidence underpinning this assessment.

In future, the magnitude of impacts from drivers and pressures associated with individual energy supply/demand options could change due to changes in the environment, the socioeconomic context, or the technology itself. Assessing such potential changes was to some degree imponderable, but subjective consideration was given to whether the significance of impacts would vary as a result of climate change.

The methodology did not specifically rank the external validity of individual papers, i.e. the extent to which a study’s results were applicable or generalisable to the wider ‘population’ that was the focus of the review. Instead, Outputs 6 and 7 considered the evidence as a whole, giving greater emphasis to more reliable evidence (i.e. with good or very good pedigree) and took into account confidence in the evidence across multiple papers in relation to each keyword or combination of keywords (Output 4).

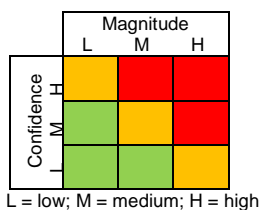
Outputs 6 and 7 were produced by the same technical experts involved in data extraction (inclusive of scoring pedigree and ranking of confidence across multiple papers). *All experts involved collectively*

developed Outputs 6 and 7 OR* These outputs were produced by a single technical expert, and another technical expert reviewed them to check that there was no bias.

Table A1-12. Significance of impacts of energy supply/demand option

Energy supply/demand option: XXXXXXXXXX	Impact				
	Impact 1	Impact 2	Impact 3	Impact 4	Cumulative impacts
Pressure: XXXXXXXX					
Positive or negative (+/-)					
Extent (site level, local, national, regional, or global)					
Duration (permanent, semi-permanent, or temporary)					
Reversibility (irreversible, difficult to reverse, or reversible)					
Frequency (always, during construction and/or operation)					
Magnitude of impact (high, medium, low)					
Confidence (high, medium, low)					
Significance: magnitude x confidence (see key)					
Magnitude of impact (high, medium, low) with climate change					
Confidence (high, medium, low) with climate change					
Significance with climate change					

Key to significance



Output 8: Mitigation and enhancement measures

A plain English summary (maximum 500 words) of mitigation and enhancement measures produced from those identified in Output 3.

Table A1.13 includes relevant references from Output 3 and relates them to the impacts associated with the energy supply or demand option(s).

Table A1-13. Mitigation of negative impacts and enhancement of positive impacts

Energy supply/demand option: xxxxx	Impact				
	<i>Impact 1</i>	<i>Impact 2</i>	<i>Impact3</i>	<i>Impact 4</i>	Cumulative impacts
Mitigation					
Enhancement					

References

1. xxxxxxxx
2. xxxxxxxx
- 3.

Output 9: A list of knowledge gaps and research needs

The spreadsheet in Output 3 recorded the relevance of each document located to each keyword. Thus, it was simply sorted and re-sorted to identify where there were knowledge gaps relating to each keyword or combination of keywords. Other areas where further research was required were identified by reference to those keywords or combination of keywords where confidence in the evidence across multiple papers was ranked as low. The list of areas where there were knowledge gaps or further research needs is presented in Table A1.14.

Table A1-14. Knowledge gaps and research needs

Knowledge gap	Research needs
<i>Heading 1</i>	<i>Maximum 100 words</i>
<i>Heading 2</i>	

Output 10: Caveats arising from the REA process

It is important that the outputs of every REA are produced, structured and presented in the same ways to enable their comparison by the wide range of possible end-users. As a result of this standardised approach, specific caveats attached to this REA’s outputs are:

- *A series of short bullet points in plain English not exceeding 500 words in total.*
- The assessment of impacts was based on the built infrastructure technologies (e.g. construction materials and techniques) available when the REA was undertaken.

Appendix 2. Example impact typologies

Table A2-1. Example impact typologies

Issue	Impacts
Air quality	<ul style="list-style-type: none"> • Greenhouse gases • Other gases • Heavy metals • Inorganic substances • Chlorinated organic substances • Other organic substances • Pesticides • Pollutant Release and Transfer Register (PRTR)
Biodiversity	<ul style="list-style-type: none"> • Gain/loss of habitat area • Disturbance • Chemical effects • Non-native species (incl. pathogens) • Habitat fragmentation/ connectivity • Cumulative effects
Geo-diversity	<ul style="list-style-type: none"> • Geological exposures • Mineral sterilisation
GHG emissions	<ul style="list-style-type: none"> • Direct emissions over lifetime
Land use	<ul style="list-style-type: none"> • Land-cover change • Land-use change • Fragmentation of land management units • Restrictions on land management • Chemical effects • Loss of crops • Indirect land-use change • Cumulative effects
Landscape	<ul style="list-style-type: none"> • Visual harm & landscape character • Historic elements (incl. archaeology) • Characteristic semi-natural vegetation • Tranquillity • Cumulative effects
Noise	<ul style="list-style-type: none"> • Air- impulsive noise • Air-ambient noise • Underwater-impulsive noise • Underwater- Ambient Noise
Scarce materials	<ul style="list-style-type: none"> • Dysprosium • Neodymium • Chromium • Copper • Manganese • Molybdenum

Issue	Impacts
Soil	<ul style="list-style-type: none"> • Nickel • Erosion • Soil organic matter • Contamination • Sealing • Compaction • Salinisation • Landslides • Cumulative effects
Waste generation and recycling potential	<ul style="list-style-type: none"> • Hazardous waste generation • Non-hazardous waste generation • Liquid waste generation • Recyclable materials • Cumulative effects
Water pollution	<ul style="list-style-type: none"> • Point-source pollution • Diffuse pollution • Ground water contamination • Marine pollution and impacts (Hydromorphology) • Cumulative effects
Water use	<ul style="list-style-type: none"> • Surface water flows and availability • Ground water abstraction and recharge • Flood frequency, intensity and risk • Cumulative effects.

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