RICARDO-AEA

SPLiCE Phase 1
Rapid Evidence Assessment Case Study 1: Small-Scale District Heating Using Biomass Feedstocks

Output 2a for SPLiCE Phase 1

Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

Environmental Change Institute

PML Plymouth Marine Laboratory

UCL ISR

University of Sussex
SPRU – Science Policy Research Unit

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Executive summary

This is a rapid evidence assessment (REA) with the intention of testing a draft REA protocol produced in Work Stream 2 of the Sustainable Pathways to Low Carbon Energy (SPLiCE) project to allow high quality, consistent reviews of published literature (Smithers, 2015). To test the method in a reasonable timeframe the initially wide question was narrowed quickly to look at a few technologies. The method produces results in 10 output Excel workbooks to ease entry into a prospective Knowledge Gateway. These outputs were used to produce this report and the document indicates where text is derived from those outputs or where those outputs should be referred to separately. A complete list of the output workbooks can be found in Appendix 1.

The remainder of the main text of this document presents a REA as prepared following the draft REA protocol. Lessons learned that informed the development of the REA method are given in Appendix 2.

Please note that, as the purpose of this case study is to test a draft REA method, it is not, and is not intended to be taken as, a full REA covering the research question.

Primary Question

Question	***What are the life-cycle impacts of a small-scale district heating facility using biomass feedstocks***
Population The subject or unit of study	*UK: environment, economy and society*
Intervention/exposure The proposed energy supply or demand option(s) (and their component drivers of impact and pressures)	*Small district heating unit (50-300 kW) consuming biomass feedstocks, typical of developments currently used in Britain. Life-cycle includes construction, commissioning, operation, decommissioning & interactions with other sectors.*
Comparator	*No installation of district heating*
Outcome The type(s) of impacts resultant from the drivers of impact and pressures	*Direct, indirect and cumulative impacts on the environment, society and the economy (positive, negative and neutral)*

Evidence summary

There is considerable literature on the use of district heating (DH) including references to the use of a range of forms of biomass as feedstocks. However, much of the material is not relevant to issues surrounding the potential development of small-scale DH using biomass in the UK. Several levels of filter were applied before eventually identifying 34 publications from which detailed information was drawn. The evidence can be divided into material derived from two distinct disciplines environmental science and socio-economics. This report describes the results presented in 10 **[Output]** tables defined in the REA protocol (Smithers, 2015) and are presented in Excel format to ease entry into the Knowledge Gateway. These are cited in the text and should be referred to for further details and additional notes for qualification.

Environmental

- There is broad agreement from the studies that DH fuelled by biomass has a significantly lower impact on the climate and lower greenhouse gas (GHG) emissions than DH using fossil fuel (with natural gas, heating oil and coal as comparators). For example, GHG reduction potentials quoted as 90-98% in one study depending on types of feedstock, form of feedstock

(e.g. chip, pellet,) and boiler efficiency and loading. Highest GHG savings come from using waste wood or forest residues (**HIGH AGREEMENT, ROBUST EVIDENCE**)

- For other environmental impact indicators including acidification, eutrophication, terrestrial toxicity, air, water and soil quality the issue is less clear. Biomass DH is typically worse for air quality than DH burning natural gas due to particulates and NOx but there are differences dependent on feedstock types; a number of studies highlight that this is likely to be an issue in urban rather than rural areas (**HIGH AGREEMENT, ROBUST EVIDENCE**). These impacts differed significantly between feedstocks. For example, straw had the highest impacts for acidification and eutrophication due to compensatory fertiliser application to balance straw removal from land. Long rotation forestry had low impacts due to minimal management e.g. low fertiliser applications and low diesel use in machinery. (Generally **MEDIUM AGREEMENT, ROBUST EVIDENCE**)
- Different parts of the lifecycle are responsible for specific impacts. Feedstock production has greatest impact on GHG savings due to changes in biomass and soil carbon (C) stocks or through the use of waste wood or straw. Combustion is the greatest contributor to air quality impacts and human toxicity. (Generally **MEDIUM AGREEMENT, ROBUST EVIDENCE**)
- The main impacts arising from boiler manufacture are from steel production.
- A long-term temporal scale should be used to account for carbon impacts of growth of energy crops and forestry.

Socio-economic

- The labour requirements of constructing and operating a biomass district heating plant, and of supplying it with feedstock biomass, are reasonably likely to result in a net employment benefit within the region concerned (**MEDIUM AGREEMENT, MEDIUM EVIDENCE**)
- Most averaged plant-lifetime and lifecycle estimates of net employment impact are in the range of 2-4 FTEs / MW installed plant capacity, or 0.001 – 0.002 FTEs / MWh input biomass (**MEDIUM AGREEMENT, MEDIUM EVIDENCE**).
- Over the lifetime of the plant, the extent of the impact on employment, and whether it is net positive or net negative, is significantly affected by the type of feedstock which is used (**HIGH AGREEMENT, MEDIUM EVIDENCE**).
- Forestry based feedstocks may have stronger net positive employment impacts than agricultural energy crops. If agricultural energy crops directly compete for land use with, and ultimately displace non-energy crops such as wheat which are more labour intensive, there could be a net negative impact on employment within the region as a whole, as a result of growing biomass for energy (**MEDIUM AGREEMENT, MEDIUM EVIDENCE**).
- Other important counterfactuals are which source of energy for heat the biomass is assumed to be replacing – whether it is competing with fossil fuels or other types of renewables. Biomass has been suggested to have positive employment impacts in comparison to both types of competition, however the evidence is limited (**LOW AGREEMENT, LIMITED EVIDENCE**).

Caveats arising from the REA process

- **This study should not be viewed as a comprehensive review** of small/medium scale district heating powered by biomass. The study was performed to test the guidance and instructions developed in SPLiCE and the reviews (sources and interpretation) were very selective. Outputs were produced as demonstrations and exemplars to feed into the specification of SPLiCE's Knowledge Gateway (work stream 3).
- **District heating is not currently common in the UK**, so many of the relevant studies describe other nations, especially those in northern Europe and the USA. The REA has made specific assumptions about the relevance of these studies to UK, but the assumption must be born in mind whilst viewing the output.
- **Counterfactual analysis** – much of the literature claims that biomass based energy generates more employment than other energy options, both fossil and low carbon. However the literature is limited in the extent to which such counterfactuals are systematically analysed, which weakens the claims that can be made for the net employment benefits of bioenergy compared to other options. Further research should more systematically explore competition effects both in the energy and the agricultural sectors, and how these impact upon net employment creation of bioenergy

- **Imported bioenergy** – most supply analyses assume that the biomass is grown and sourced within the same region that uses it for energy. However, imported woody biomass from large scale producers for example in the USA or Canada, might become cost competitive with locally grown supplies especially if activities by large electrical companies create economies of scale for imports. Further research should analyse how net employment is affected by a supply chain with imported biomass compared to one with domestically sourced biomass.

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Appendices

1 Protocol [Output 1]

Authors

Report authors: The Review Team is led by Paolo Agnolucci (UCL) and David Howard (CEH), with work being carried out by Jeanette Whitaker (CEH) and Nick Hughes (UCL) other input was provided by Richard Smithers, Pat Howes (AEA Ricardo) and Josie Coburn (Sussex). Jeanette led the establishment of the environmental approach and initial searches and extraction; Nick assisted in designing the search strategy with a focus on the socio-economic searches and data extraction. Paolo and David then contributed to the critical appraisal and synthesis with assistance from Pat and Josie. Richard's expertise on the REA methodology was drawn on throughout the study. Although individuals had specific roles and responsibilities the team did work collaboratively, not only using e-mail and teleconference links, but also by working on shared documents through Dropbox. There are no known conflicts of interest.

Steering Group

The Steering Group have a crucial role to play in an REA as they propose the focus of the initial question. The role should normally be filled by a small group who have an appreciation of the reason the evidence is needed and the constraints on its use; typically this will be a group from Government departments. For the case study, Paul Nunn (Defra) agreed to act as the Steering Group. Over a longer period, available for a comprehensive REA, the Steering Group should be involved formally (meetings and video conferences) and informally. Interaction with Paul Nunn was largely through e-mail and information passed through the project fortnightly reviews.

Aim

The question finally agreed with the Steering Group was "***What are the life-cycle impacts of a small-scale district heating facility using biomass feedstocks?***" The proposal had initially been to describe "*the impacts (environmental, social and economic) of a single energy supply option: electricity generation from dedicated bioenergy feedstocks*". The size, complexity (especially of supply chains), dynamics and transitional status in relation to demand were recognised as problems and following discussions with the Steering Group it was decided that the question would be refined. The review focused on work relevant to UK.

Rationale

In order to use evidence to make better decisions a comprehensive assessment of the impacts of differences in energy pathways and their components must be made. These impacts have to be attributed to their source and confidence in the quality of the information determined. All impacts through the life-cycle (from cradle to grave) must be considered and evaluated against alternative (counterfactual) options.

As the goals of the study were to demonstrate the process using a realistic example in a very short period, terms were considered and applied to deliver the most efficient returns for the effort. For environmental issues only whole system studies were included (i.e. where a life cycle had been reported). To be thorough, details of all the components in the conceptual model need to be examined individually (for example the supply chain and impacts of the production of biomass crops for any purpose) and the synthesis draw them together and comment on their suitability; in this study we were more selective. For socio-economic data there are far fewer whole system approaches, so a more compartmentalised approach was adopted.

Objective

Small scale district heating is not widely used in UK, but the system is recognised as offering advantages in terms of efficiency of use of heat and can maximise the value of waste (both heat from processes and material). In this study we focussed on the use of biomass to feed small scale district heating systems. We did not extend our search to cover all forms of biomass production for energy, irrespective of its use, but focussed narrowly on where it is used for small scale DH.

Our goal was to identify all relevant information from academic, grey and Government literature that describes the overall impacts and costs of employment of small scale DH. If the deployment was

reported to have led to the displacement of other activities they were included, but this is an under-researched topic and little information was found.

Primary question

The primary question is defined in terms of the Population, Intervention/Exposure, Comparator and Outcome (PICO) elements in Table 1.

Table 1: The PICO elements of the preferred primary question

Question	*What are the life-cycle impacts of a small-scale district heating facility using biomass feedstocks*
Population The subject or unit of study	*UK: environment, economy and society*
Intervention/exposure The proposed energy supply or demand option(s) (and their component drivers of impact and pressures)	*Small district heating unit (50-300 kW) consuming biomass feedstocks, typical of developments currently used in Britain. Life-cycle includes construction, commissioning, operation, decommissioning & interactions with other sectors.*
Comparator	*No installation of district heating*
Outcome The type(s) of impacts resultant from the drivers of impact and pressures	*Direct, indirect and cumulative impacts on the environment, society and the economy (positive, negative and neutral)*

Supplementary questions

The information obtained from addressing the primary question can be examined in order to answer specific questions related to knowledge gaps and research outputs. Initially three supplementary questions were drafted:

- What is the distribution of existing evidence between environmental, social and economic impacts?
- How can we combine existing evidence between environmental, social and economic impacts?
- What do the results suggest about research needs for individual energy options or environmental, social or economic criteria?

However, due to the time constraints these were not formally addressed and the principle question was tuned to make the process achievable within the timeframe. The primary question was narrowed in terms of:

- Intervention/exposure, i.e. narrow the system boundaries of the life cycle
  - specify the size of DH unit within certain range (e.g. 50-300 kW)
  - exclude heat pipe network,
- Outcome, i.e. the range of impacts considered – due to time constraints the range of categories were restricted for analysis and synthesis whilst ensuring that economic, social and environmental impacts were considered; following the search and extraction environmental topics were restricted to climate change/GHG emissions, combustion emissions and complete LCA.

Scope

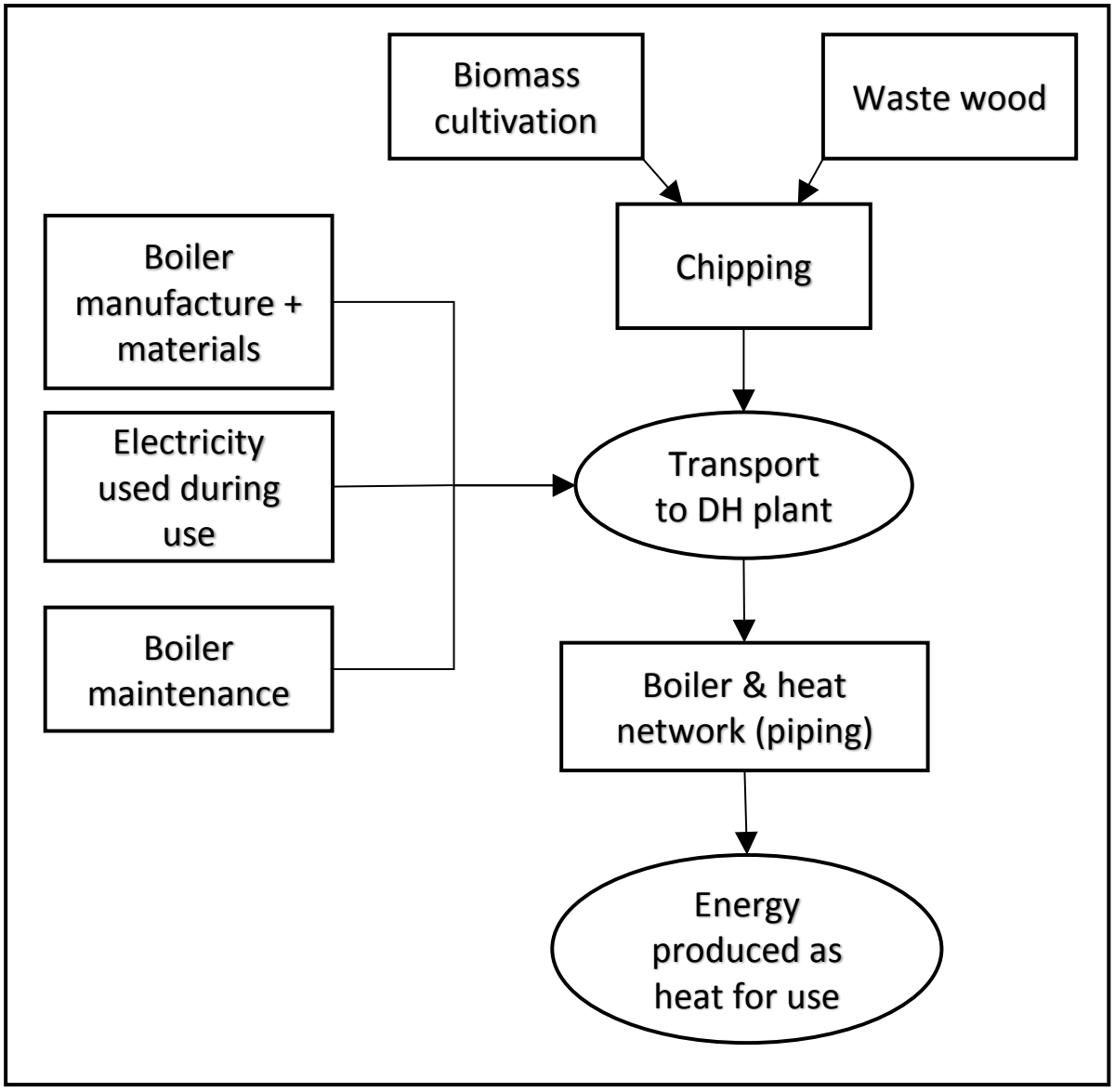
- *Geographic range*: The study focussed on small scale DH using biomass in UK. Literature from outside UK was initially included, but then filtered to leave in UK and European material.
- *Topic*: A number of overlapping or similar technologies were excluded, these included combined heat and power (CHP), anaerobic digestion, gasification and trigeneration. Biomass is a large and complex source; the following areas were initially excluded: food

waste, 1st generation crops and municipal solid waste. The use of liquid and gaseous biofuels were also rejected (namely biodiesel, bioethanol, biofuel, oil, biogas and biomethane)

- *Language*: Only texts in English were reviewed
- *Time period:* Assessment of environmental, social and economic impacts will be restricted to documents published in the period from 2000.

Conceptual model

Figure 1. The conceptual model used to frame the approach



2 Methods

Keywords

Initially, a series of scoping searches were made to test for specificity and sensitivity using Web of Knowledge and GovUK. From these a set of search terms were developed as shown in Table 2.

Keywords and combinations were defined and wildcards (*) used to pick up multiple word endings. Each bibliographic database had its own set of wild cards (?*$ etc.) and implementation of Boolean logic. The terms equate to different topics; Primary covers the technology, Secondary covers the biomass and the Tertiary are environmental and socio-economic impacts (note the italicised Secondary terms are headings for sets of Tertiary terms).

Table 2. Principle keywords considered for the targeted literature search

Primary	*Secondary*	*Tertiary*
District heat*		
Heat network*		
Biomass	wood*, straw, crop*, forest*, waste wood, import*, residue*	
Bioenergy		
Life-cycle	*Land*	Land-availab*, land-use change, DLUC, ILUC
	Soil	erosion, compaction
	Climate change	mitigation, abatement, emission*, greenhouse gas*, GHG, carbon dioxide, CO_2 equivalent*
	Biodiversity	species, habitat, disturbance, invasion, connectivity
	Air quality	particulate*, pollut*, volatile, organic compound*, emissions, combustion, ozone
	Water	eutrophication, pollut*, flood*, water resource*, hydrology, flow*
	Noise	ambient, impulsive
	Governance,	planning, "property right", contracts, "land use"
	Cultural,	"traditional lifestyle", spiritual, values, "visual impact", landscape
	Heritage,	"historic building", "Historic structure", "Historic site", "Historic environment"
	Health,	stress, wellbeing, "air quality", mental, "local air pollut*", noise
	Cost,	"input costs", "energy cost", "R&D", "cost reduction", competition, market
	Revenues,	GVA, turnover, profit, income, operation, construction, growth, development
	Social Justice	allocation, "fuel poverty", unskilled, deprivation
	Employment	job, unemployment, "job prospects",
	Transport	traffic, HGV, freight, infrastructure

Search strategy

A search strategy was developed to consider three main types of evidence (peer-reviewed journal articles, grey literature and Government documents), to reduce publication bias and to address current issues where limited academic research has been undertaken. Unpublished information was not considered, as the process to discover, obtain and value this is very time consuming.

- **Peer-reviewed journal articles**: Web of Science (http://apps.webofknowledge.com/) was used to search for relevant peer-reviewed articles (from the UK, Europe and internationally) and produce repeatable results
- **Grey literature:** the 'Open Grey' search engine (www.opengrey.eu) was used for grey publications along with industry sites such as the District Heating Association (www.ukdea.org.uk) but these had a very limited searching capacity
- **Government publications:** initially the whole Government site (www.gov.uk) was searched, but there are very few search tools to allow finer filtering, so the publications section of the web-site was searched which resulted in a far greater number of records (https://www.gov.uk/government/publications).

Other databases were considered and some tried including:

Scopus, Wiley Online Library , EThOS – e-theses online service , CAB Abstracts , Google Scholar, Cambridge Scientific Abstracts, Elsevier "Science Direct", Worldcat (Online Computer Library Centre, OCLC), SIGLE (System for Information on Grey Literature in Europe) and GreyNet International.

Refinement of search strings

An initial dataset of documents was identified through an iterative process balancing keyword strings (linked by the terms AND, OR and NOT) with a goal of including all relevant documents whilst excluding irrelevant to produce a workable the number of results. The final search strings, including the use of wildcard characters are shown in Table 3. As a check, expertise within the review team was used to ensure that known key publications were included. Further details of the iterative process used in its development are given in **[Output 2]**, for both environmental and socio-economic searches.

Table 3. The search strings used to discover appropriate evidence for the case study

	Keyword strings
Primary keywords Technology string	(District OR network*) AND (heat*) later amended for environmental searches to (District OR network* OR system*) AND (heat*)
	AND
Secondary keywords Biomass string	((biomass OR bioenerg*) AND (wood* OR straw OR crop* OR forest* OR "waste wood" OR import* OR residue* OR chip* OR pellet* OR willow OR miscanthus)) NOT (biofuel* OR bioethanol OR biodiesel OR oil)
	AND
Tertiary keywords Environmental impacts	AND (life cycle OR "LCA" OR indirect OR cumulative OR embedded OR environment* OR emission* OR impact*) AND (Land OR soil OR "climate change" OR biodiversity OR "air quality" OR noise OR (Water AND (use OR quality))) AND ("Land availab*" OR "land-use change" OR "DLUC" OR "ILUC" OR indirect) AND (Soil AND (erosion OR compaction)) AND (Climat* AND (change OR mitigation OR abatement)) AND (Emission* AND ("greenhouse gas*" OR GHG OR "carbon dioxide" OR "CO2 equivalent*")) AND (Biodiversity AND (species OR habitat OR disturbance OR invasion OR connectivity)) AND ("Air quality" AND (particulate* OR pollut* OR "volatile organic compound*" OR emission* OR combust* OR ozone)) AND (Water AND (flood* OR resource* OR hydrology OR flow* OR eutrophication OR pollut*)) AND (Noise AND (ambient OR impulsive))

Tertiary keywords Social and/or economic impacts	AND (employment OR job* OR "macroeconomic" OR "GVA" OR "economic impact*") AND ("visual impact*" OR "landscape impact*" OR "amenity value*" OR "aesthetic impact*" OR "cultural value*" OR "public perception" OR "public opposition" OR "public objection" OR "public accept*") AND (wellbeing OR "mental health" OR noise OR "human stress") AND (impact OR effect) AND (local OR population OR communit*) AND (traffic OR HGV* OR "heavy goods vehicle*" OR freight OR infrastructure) AND (impact* OR effect*)

Outline inclusion and exclusion criteria

Once the initial selection was made then a filtering process reduced the number of documents by progressively removing records. The basic exclusion criteria were as defined within the scope above (P4) covering the geographic range, topic, language and timeframe. The second phase involves an assessment of the document title and finally review of the contents (starting with the abstract or summary). The reasons for rejection are recorded throughout the process **[Output 2]**.

3 Results

Evidence extracted

Details of the publications from which data were extracted are shown in **[Output 3]**. Although 66 documents were identified through this process, only selected impact categories were fully analysed leaving 34 documents from which information was extracted (18 documents for environmental impacts and 16 for socio-economic). The occurrence of the different search terms (Table 2) in each paper was recorded and presented. Most papers were primary data sources, but some reviews were also included and highlighted as such; they were ranked using slightly different metrics during the critical appraisal as in the REA methodology.

Critical appraisal of the evidence

Having identified the papers through the filtering process they were then reviewed, scored and ranked for their pedigree and for the strength of information presented. The ranking was derived by counting the number of studies as a proportion of all studies which were relevant to the keyword. Agreement was ranked from low to high. The information was then combined with the mid-point of the pedigree scores; quality of evidence was scored on the amount and strength of evidence, papers were labelled from poor to very good. The scoring system is relatively subjective and influenced by the number of papers identified during the previous phases.

The pedigree scores showed a relatively normal distribution, with about 15% scoring poor and only slightly more very good. The socio-economic assessment had generally lower values than the environmental. The number of papers clearly influences the overall confidence, with poorly represented topics (e.g. biodiversity that only had 2 papers) having a low score.

Details of the confidence rankings are provided in **[Output 4]**, summarised in Table 4. It should be noted that the secondary terms qualifying the feedstock were not assessed for their degree of agreement or overall confidence as they were descriptive terms for the DH system and not describing relationships or specific impacts.

Table 4. Degree of confidence in the evidence

	Key words used in extracting evidence	Number of studies	Pedigree scores	Score No of studies	Strength of evidence	Evidence rank	Degree of agreement	Overall confidence
Secondary terms (feedstock)	wood	11	1P, 4M, 5G, 1VG	M	M	M		
	waste wood	2	1G, 1VG	L	R	M		
	straw	6	1P, 2M, 2G, 1VG	M	M	M		
	energy crops	6	2M, 4G	M	M/R	M		
	forest residues	5	3M, 2G	L	M	L/M		
	imported feedstock	4	2M, 1G, 1VG	L	R	M		
Secondary terms (Environmental Impact)	Land use & availability	6	1 M, 3G, 2VG	M	R	M	Med	High
	Soil impacts (erosion/compaction/toxicity)	4	1 M, 2G, 1VG	L	R	M	Med	Med
	Climate impacts & GHG emissions	18	1P, 4M, 10G, 3VG	R	R	R	High	High
	Biodiversity	2	1M, 1G	L	M	L	Low	Low
	Air quality	4	1M, 2G, 1VG	L	R	M	High	High
	Water use & quality	4	1M, 2G, 1VG	L	R	M	Low	Low
	Noise	0	-	-	-	-	-	-
Secondary terms (Socio-economic Impact)	Employment creation	23	10P, 1M, 2G, 4VG	M	M	M	Med	Med

Synthesis of the evidence

[Output 5] contains statistics describing the quantity and types of evidence and their location, scale and pedigree. These are summarised in the Tables 5–7.

Table 5. The number of studies identified and retained at each stage of the screening process

	Environmental	Socio-economic	Total
Initially identified	2,227	1,900	4,127
After first phase of screening	308	176	484
After second phase of screening	93	117	210

Table 6. The number of studies related to each primary keyword retained after the second phase of screening, and the type of literature

Relevant to each primary and/or secondary keyword	Environmental	Socio-economic	Total
*District heat**	18	11	29
Heat Network	2	0	2
Biomass/ Bioenergy	18	18	36
manufacture	6	5	11
construction	7	6	13
operation	15	9	24
de-commissioning	4	0	4
feedstock (cultivation/ processing/ transport)	15	18	33
Life-cycle	15	0	15
Relevant to each tertiary keyword			
Environment			
wood	11	15	26
waste wood	2	9	11
straw	6	3	9
energy crops	6	9	15
forest residues	5	8	13
imported feedstock	4	0	4
Land use & availability	6	0	6
Soil	4	0	4
Climate & GHGs	17	0	17
Biodiversity	2	0	2
Air quality	4	0	4
Water use & quality	4	0	4
Noise	0	0	0
Socio-economic			
Employment creation	0	17	17
Macro-economic impact	0	3	3
Micro-economic analysis	0	0	0

Public acceptance	0	0	0
Amenity value	0	0	0
Health and wellbeing	0	0	0
Traffic and infrastructure	0	0	0

Table 7. The location, scale and pedigree ranking for the 66 studies taken to the data extraction stage

In each of the following categories:	Environmental	Socio-economic	Total
Type:			
Peer-reviewed	39	16	55
Grey literature	5	6	11
Unpublished	0	0	0
Location:			
UK	5	3	8
EU	12	12	24
International	4	6	10
Scale of study:			
Site level	6	0	6
Local	5	0	5
Country	6	13	19
Region	4	2	6
International	0	4	4
Relating to each pedigree ranking for individual studies			
poor	1	7	8
moderate	3	1	4
good	10	2	12
very good	3	1	4
Relating to each pedigree ranking for reviews.			
poor	0	3	3
moderate	1	0	1
good	0	0	0
very good	0	3	3

Evidence summary

A summary of the evidence obtained is discussed below **[Output 6]**.

There is considerable literature on the use of district heating (DH) including references to the use of a range of forms of biomass as feedstocks. However, much of the material is not relevant to issues surrounding the potential development of small scale DH using biomass in the UK. Several levels of filter were applied before eventually identifying 34 publications from which detailed information was drawn. The evidence can be divided into material derived from two distinct disciplines environmental science and socio-economics.

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- There is broad agreement from the studies that DH fuelled by biomass has a significantly lower impact on the climate and lower greenhouse gas (GHG) emissions than DH using fossil fuel (with natural gas, heating oil and coal as comparators). For example, GHG reduction potentials quoted as 90-98% in one study depending on types of feedstock, form of feedstock (e.g. chip, pellet,) and boiler efficiency and loading. Highest GHG savings come from using waste wood or forest residues (**HIGH AGREEMENT, ROBUST EVIDENCE**)
- For other environmental impact indicators including acidification, eutrophication, terrestrial toxicity, air, water and soil quality the issue is less clear. Biomass DH is typically worse for air quality than DH burning natural gas due to particulates and NOx but there are differences dependent on feedstock types; a number of studies highlight that this is likely to be an issue in urban rather than rural areas (**HIGH AGREEMENT, ROBUST EVIDENCE**). These impacts differed significantly between feedstocks. For example, straw had the highest impacts for acidification and eutrophication due to compensatory fertiliser application to balance straw removal from land. Long rotation forestry had low impacts due to minimal management e.g. low fertiliser applications and low diesel use in machinery. (Generally **MEDIUM AGREEMENT, ROBUST EVIDENCE**)
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- The main impacts arising from boiler manufacture are from steel production.
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Socio-economic

- The labour requirements of constructing and operating a biomass district heating plant, and of supplying it with feedstock biomass, are reasonably likely to result in a net employment benefit within the region concerned (**MEDIUM AGREEMENT, MEDIUM EVIDENCE**)
- Most averaged plant-lifetime and lifecycle estimates of net employment impact are in the range of 2-4 FTEs / MW installed plant capacity, or 0.001 – 0.002 FTEs / MWh input biomass (**MEDIUM AGREEMENT, MEDIUM EVIDENCE**).
- Over the lifetime of the plant, the extent of the impact on employment, and whether it is net positive or net negative, is significantly affected by the type of feedstock which is used (**HIGH AGREEMENT, MEDIUM EVIDENCE**).
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- Other important counterfactuals are which source of energy for heat the biomass is assumed to be replacing – whether it is competing with fossil fuels or other types of renewables. Biomass has been suggested to have positive employment impacts in comparison to both types of competition, however the evidence is limited (**LOW AGREEMENT, LIMITED EVIDENCE**).

A synthesis of the evidence is provided in Table 8 **[Output 7]**.

Table 8. Synthesis of the evidence of impacts of biomass fed district heating on different ecosystem services

Energy supply/demand option driver of impact: ***District heating***	**Impact**				
Pressure: ***Biomass/bioenergy***	***GHG emissions***	***Air Quality***	***Biodiversity***	***Net employment creation***	**Cumulative impacts**
Positive or negative (+/-)	+	-	+/-	+	+++/--
Extent (site level, local, national, regional, or international)	international	local	international	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	L	L	mixed
Confidence (high, medium, low)	H	H	L	M	mixed
Significance: magnitude x confidence (see key)					
Significance with climate change					

Key to colour scheme

		Magnitude		
		L	M	H
Confidence	H			
	M			
	L			

Implications for policy and / or practice

The possibilities for mitigating impacts or enhancing the additional benefits of energy options were occasionally discussed in the papers reviewed. Where examples were found, these are identified in Table 9 **[Output 8]**.

Table 9. Practices for the mitigation of negative impacts and enhancement of benefits

Energy supply/demand option	Impact					
	Conservation (Biodiversity)	*Climate Change*	*Sustainable production*	*Net job creation*	*Net job loss*	Cumulative impacts
Mitigation: practice		7, 8			1, 2	7
Mitigation: policy		7, 9			1, 2	7
Enhancement: practice	7	9	6	2,3,4,5		
Enhancement: policy			6	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

Knowledge gaps and research needs

Despite the restricted nature of this scoping exercise areas where improvements in knowledge and understanding have been identified. The major themes in these gaps are highlighted below and reported in **[Output 9]**:

- **Focus on the UK.** For DH and its supporting supply chain information has been drawn from Europe and USA (where the systems are more common). Research is needed to highlight any differences that will be encountered in UK due to different environment, demand or socio-economic interaction
- **Scale and location**. Work is needed to inform policy on how to determine impacts at specific locations (both social and environmental) and with operations at different scales and magnitudes. Although our assessment was of small-scale DH, supply chains for multiple

installed systems can be large. Specific focus needs to be made on manufacture of devices, construction on site and de-commissioning.

- **Feedstocks**. Further investigation into the impacts of biomass and bioenergy, particularly in the UK is clearly needed (our study did not fully address these issues, simply in relation to DH). Some specific feedstocks (e.g. waste wood and straw) require a stronger evidence base covering a wider range of impacts.
- **Impacts**. Noise and biodiversity were only briefly covered in the literature reviewed. Research is needed even if it is just to confirm the lack of impacts.

Caveats arising from the REA process

The following caveats should be attached to this report **[Output 10]**:

- **This study should not be viewed as a comprehensive review** of small/medium scale district heating powered by biomass. The study was performed to test the guidance and instructions developed in SPLiCE and the reviews (sources and interpretation) were very selective. Outputs were produced as demonstrations and exemplars to feed into the specification of SPLiCE's Knowledge Gateway (work stream 3).
- **District heating is not currently common in the UK**, so many of the relevant studies describe other nations, especially those in northern Europe and the USA. The REA has made specific assumptions about the relevance of these studies to UK, but the assumption must be born in mind whilst viewing the output.
- **Counterfactual analysis** – much of the literature claims that biomass based energy generates more employment than other energy options, both fossil and low carbon. However the literature is limited in the extent to which such counterfactuals are systematically analysed, which weakens the claims that can be made for the net employment benefits of bioenergy compared to other options. Further research should more systematically explore competition effects both in the energy and the agricultural sectors, and how these impact upon net employment creation of bioenergy
- **Imported bioenergy** – most supply analyses assume that the biomass is grown and sourced within the same region that uses it for energy. However, imported woody biomass from large scale producers for example in the USA or Canada, might become cost competitive with locally grown supplies especially if activities by large electrical companies create economies of scale for imports. Further research should analyse how net employment is affected by a supply chain with imported biomass compared to one with domestically sourced biomass.

4 Resources

A summary of the time required for this scoping exercise is provided in Table 10. The estimates are only approximate as the tasks often merged and there were feedback loops.

Table 10. Time required for the different steps in the REA process

Task	Days	Notes
Identifying the research question	2	Involved the Steering Group
Developing a protocol	3	Completing individual tasks within the protocol is covered by the tasks below.
Iterative development of keywords	5	Databases selected and search strings/keywords trialled across multiple databases.
Search for evidence	5	Extracting a large number of references from search engines/databases.
Screening the search results	9	Time taken to exclude references; depends on the number of references returned and the level of automation that can be used (later phases take longer).
Extracting evidence	6	Although a limited number was selected for the current review this stage requires attention to detail and increased time expenditure.
Evaluating strength of the evidence	4	Time needed again dependent upon the number of references/evidence pieces.
Ranking confidence across multiple papers	2	Time taken included time to develop the methodology from the basic protocol
Evidence synthesis and reporting	9	Summarising, formatting, integrating and checking for inconstancies
TOTAL	**45**	

5 References and sources of information

Smithers, R. 2015. SPLiCE Phase 1: A methodology for Rapid Evidence Assessments. Report prepared for DEFRA. Draft version dated 13 January 2015.

Appendices

Appendix 1 Filenames for rapid evidence assessment outputs

Appendix 2 Comments on draft REA method arising from this case study

Appendix 1 - Filenames for rapid evidence assessment outputs

This rapid evidence assessment has been conducted following a draft method and guidance prepared as part of SPLiCE Phase 1 (Smithers, R. 2015). The draft guidance specifies ten outputs. Each has been prepared as a separate file. Some are included in this report in full and others are summarised or referred to. The table below lists the outputs specified in the guidance, the filename for each output and the degree to which it is included in this report.

Table A1.1. Outputs from the SPLiCE Phase 1 Rapid Evidence Assessment case study on small-scale district heating using biomass feedstocks

Output	Output title – from guidance	Filename (All are xls files)	Extent of inclusion in this report
1	The REA protocol	WS2 Biomass CS - OUTPUT 1 - Protocol 29Mar15	In full – see section 1 – protocol. Primary question included in the Executive Summary
2	Results of screening all individual papers	WS2 Biomass CS - OUTPUT 2 - Combined 29Mar15 WS2 Biomass CS - OUTPUT 2 - Environmental screening 29Mar15 WS2 Biomass CS - OUTPUT 2 - Socioeconomic screening 29Mar15	Referred to
3	Data extraction form	WS2 Biomass CS - OUTPUT 3 - Combined data extraction 29Mar15 WS2 Biomass CS - OUTPUT 3 - Environmental data extraction 29Mar15 WS2 Biomass CS - OUTPUT 3 - Socioeconomic data extraction 29Mar15	Referred to
4	Confidence in evidence across multiple papers	WS2 Biomass CS - OUTPUT 4 - Ranking 29Mar15	Referred to Summary provided in Table 4
5	Volume and characteristics of the overall evidence base	WS2 Biomass CS - OUTPUT 5 - Evidence base 29Mar15	Referred to Summary provided in Tables 5-7
6	A concise summary of the evidence	WS2 Biomass CS - OUTPUT 6 - Impacts Summary Text 29Mar15	In full – See section 3 Results – evidence summary Also in full in the Executive Summary

7	Significance of impacts of energy supply/demand option	WS2 Biomass CS - OUTPUT 7 - Summary of impacts table 29Mar15	In full – see Table 8
8	Implications for policy and/or practice	WS2 Biomass CS - OUTPUT 8 - Implications 29Mar15	In full – see section 3 – Results - Implications for policy and / or practice
9	A list of knowledge gaps and research needs	WS2 Biomass CS - OUTPUT 9 - Knowledge gaps and research needs 29Mar15	In full - see section 3 – Results - Knowledge gaps and research needs
10	Caveats arising from the REA process	WS2 Biomass CS - OUTPUT 10 - Caveats 29Mar15	In full - see section 3 – Results - Caveats arising from the REA process Also in full in the Executive Summary

Appendix 2 - Comments on draft REA method arising from this case study

As in the Executive Summary, the aim of this case study was to test a draft method for a Rapid Evidence Assessment (draft 3 issued on 13th January 2015). A number of comments were made by the authors of the case study on the REA method and these are summarised below.

Table A2.1. Summary of comments on draft REA method from experience with biomass case study

REA section	Comment	How addressed in updated REA draft
Protocol	Might it be worth having a brief section (i.e. a paragraph) describing the form of the outputs and their purpose. The audience for the results should influence both format and content.	The outputs have been added to Figure 1
Review team	Size of review team? Need experience of handling information from different disciplines (ecology, environmental science, sociology, economics, geography, etc.). Smaller teams may work better together (i.e. 2-3 people).	Rather than specifying a team size, a Section 5.1 has been added "Membership of Review Team". This includes a table for identifying the team member responsible at each stage of implementing the protocol, together with their role and responsibilities
Background	Any guidance as to the form of background? How much information, is it best presented as bullet points. Should it define the domain of the study (i.e. say what is not covered)?	A suggested word limit has been added – to indicate the amount of information
Example REA question - Population	I think it should always give the geographic and temporal dimensions, that will usually be UK and covering last 5 to next 5 years. However, information may be differentially available for UK, GB, nation states and must be set in European and global context. As this is policy driven, these can all have a bearing.	Guidance on the "Population" has been updated by adding "However, if desired, the subject or unit of study may be a specific region, location or energy facility"
Example REA question - Comparator	Single counterfactual? Other alternatives may also need to be considered.	Considered. No change
Objectives – Comment on sentence "By agreement with the Steering Group, key stakeholders should be given opportunity to comment on the scope of the review …."	Stakeholder (or external expert) input is extremely valuable. Rather than By agreement with…, I would say With the assistance of… as it sounds less like they will resist the involvement. I would like it to sound more like stakeholders would be involved through the different phases providing early and ongoing feedback.	Considered. No change
Implementing the protocol – searching	Just so long as the utility can be accessed for any necessary audit, it doesn't matter if it is not freely	Noted

for evidence. Comment on phrase "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 …"	available. The results should not be communicated using it, and the approach should be capable of being performed without it (i.e. with commonly available utilities such as Excel). The methodology should be noted and reported.	
Implementing the protocol – searching for evidence. Comment on sentence "It is not appropriate to try to manipulate the number of papers identified by using a narrower set of keywords that do not fully address the scope of the REA.	Another working test is to identify a small number of papers/ documents that you (or stakeholders) tell you are central to the question and then make sure that they appear in your search results.	Noted – No change
Implementing the protocol – screening the search results Comment on sentence "Screening of all the evidence should be undertaken by one person in order to ensure that the criteria are applied consistently"	Even one person may end up returning to some of the original papers/documents once the criteria are properly embedded. Is there any benefit in numbering the documents and recording the order in which they are processed?	Noted – No change

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