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Dematerialisation and sharing of goods: a systematic review of the determinants and magnitude of the indirect impacts on energy consumption

Scoping note and review protocol

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CREDS is a new national hub for research on energy demand. It began on 1 April 2018 and will run for 5 years, with funding from UK Research and Innovation (UKRI). It builds upon the work of the existing six UKRI-funded Research Centres on End Use Energy Demand.

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Digital Society Theme

Since the 1970s, information and communication technologies (ICTs) have driven a new industrial revolution that is transforming industrial structures, business strategies, employment patterns, consumer preferences, and social practices around the world. However, their net impact on energy demand remains unclear.

The Digital Society Theme seeks to answer the following overarching research questions:

1. What are the historical and potential future impacts of ICTs on sectoral and economy-wide energy consumption?
2. What factors and mechanisms explain those impacts?
3. How can the future energy-saving potential of ICT's be maximised?

C R E D S

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1 Importance of the subject and challenges

The potential contribution of information and communication technologies (ICTs) to a low carbon economy is unclear. On the one hand, ICTs offer many benefits for reducing energy demand and emissions. For example, e-commerce can displace personal transport demand and improve logistics efficiency; e-materialisation can substitute for more resource intensive services (e.g., digital news displacing print media); digital monitoring and control can optimise in-use energy consumption (e.g., building energy management systems, smart homes, smart motors, industrial process control); teleworking can displace commuting and business travel; and so on. On the other hand, the digital economy has a large and rapidly growing energy and carbon footprint, with the continuing improvements in the energy and material efficiency of individual devices being more than offset by the continuing increases in the number, power, complexity and range of applications of those devices (Galvin, 2015). Digital technologies can also stimulate demand for existing and new services (e.g., mobile GPS) that require complex, energy-intensive systems to provide (e.g., 4G networks, satellites, data centres).

While it has been argued that the ICT revolution is net energy-saving (Kander et al., 2013) and can form the basis of a new surge of green growth (Perez, 2013), this hypothesis has also been contested (Galvin, 2015; Williams, 2011). The complexity of impact pathways (e.g., the emergence of entirely new services) makes the quantification of historical impacts challenging, as well as creating uncertainty over future impacts. To understand and address this challenge, a first step is to review the existing evidence on the impact of ICTs on energy consumption.[1]

The diversity of the literature on ICTs and energy consumption, encompassing a range of applications, empirical methods, impact mechanisms and system boundaries, generate patchy and contradictory results that makes it difficult to draw any firm conclusions. To organise this literature, Section 2 proposes a classification of ICT end-uses according to their application domain and relationship to economic sectors. It also identifies the mechanisms through which ICT's influence energy consumption, and summarises the key literature reviews to date on this topic. Informed by this classification, Section 3 defines the scope of our study and our proposed research questions, while Sections 4 and 5 summarise our methodology.

[1] Two other projects will follow in the Digital Society theme. They will respectively focus on the econometric estimation of the historical impacts of ICTs on energy consumption, and the modelling of the future impacts of ICTs on energy consumption.

2 ICT services, energy impacts, and existing literature reviews

2.1 Classifying ICT end-uses

ICTs provide a multitude of end-uses, but these may be grouped into two broad categories, namely virtualisation and optimisation:

- **Virtualisation**: is where ICTs provide a complete or partial substitute for previously existing goods (e.g., books, music, videos) or services (e.g. healthcare), or provide entirely new goods or services (e.g. online games).[2]
- **Optimisation**: where ICTs monitor, control and/or improve the operation of established technologies, systems and processes (e.g. buildings, logistics, industrial processes).

These two categories may be broken down into several application domains. Here, we subdivide virtualisation into three application domains, namely: **e-services**, **e-materialisation**, and **e-mobility**.[3] Similarly, we subdivide optimisation into two application domains, namely **e-design**, and **e-monitoring and control**.

Each application domain encompasses a variety of different services. For example, e-materialisation includes electronic versus print newspapers (e-news), electronic versus traditional books (e-books) and DVDs versus streaming video (e-video) amongst others. Simply, 'e-monitoring and control' includes electronic control of industrial processes, and electronic control of heating, ventilation and air-conditioning in buildings amongst others. There are also overlaps and interdependencies between different services and domains: for example, e-books are dependent upon e-payment mechanisms, such as electronic bank transfers.

Each of these different services may in turn have indirect impact on energy consumption several different **economic sectors** – such as transport, buildings and agriculture.

Figure 1 summarises this proposed classification scheme and provides some illustrative examples.

2.2 Taxonomy of the energy impacts of ICTs

There are different taxonomies of the energy impacts of ICTs (e.g., Börjesson Rivera et al., 2014; Hilty and Aebischer, 2015; Horner et al., 2016), but all share the idea that ICTs have both **direct** and **indirect impacts** on energy consumption. ICTs have direct impacts through the energy used in their manufacture, operation and disposal, along with the energy used for the associated data transmission networks. They also have indirect impacts through their influence on energy consumption in other systems. For example, digital systems may improve the efficiency of energy use in appliances, networks,

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[2] ICTs frequently complement material goods rather than substitute for them. Subscription to both paper and digitalised versions of a journal is an example.

[3] All material goods provide services, and all services require material goods. Our subdivision simply reflects whether the material good or 'immaterial' service is dominant. We classify mobility separately owing to its importance for energy consumption.

buildings, industrial processes and transport systems; and may substitute for more energy-intensive services–such as working from home rather than commuting. But there is no guarantee that the substituted ICT service will be less energy intensive than the conventional service it replaces, and evaluating even simple cases can be challenging.

The net impact on energy consumption will depend upon the balance between these direct and indirect impacts. On the one hand, authors such as Laitner and Ehrhardt-Martinez (2008) claim that ICTs are key to a low carbon economy, with the indirect energy savings being up to ten times larger than the direct energy consumption. On the other hand, authors such as Galvin (2015) highlight the potential for significant rebound effects from ICTs, with increases in the number, power, complexity and range of applications of those technologies more than offsetting the associated energy savings. Table 1 illustrates the complexity of these effects for a particular ICT application (logistics). In practice, we may expect the magnitude and sign of these different mechanisms to vary widely from one ICT application to another.

Table 1 Classifying the mechanisms influencing the impact of ICTs on energy consumption. Source: based on Horner et al. (2016).

Hilty et al. (2015) aggregate category	Horner et al. (2016) aggregate category	Specific mechanism	Logistics industry example
1st order	Direct	Embodied energy	Energy used to manufacture a smart logistics system.
		Operational energy	Energy used to operate a smart logistics system.
		Disposal energy	Energy used to dispose of a smart logistics system.
2nd order	Indirect: single-service	Efficiency/optimisation	Energy saved by more efficient logistics (e.g. efficient routing; minimising empty running).
		Substitution	Energy saved by customer-deliveries substituting for 'last mile' travel by consumers.

3rd order		Direct rebound	Energy consumed in additional freight transport, stimulated by falling freight costs and saved time
	Indirect: complementary services	Indirect rebound	Energy used in manufacturing and consuming goods, whose demand has increased because of falling freight costs.
	Indirect: economy-wide	Economy-wide rebound (including time rebound)	Energy used and saved in multiple markets because of economy-wide adjustments in prices, quantities, and time allocation (e.g., more efficient freight transport reduces demand for diesel, which lowers the price of diesel which stimulates the partially offsetting increase in diesel consumption).
	Indirect: society-wide	Transformational change	Energy used and saved because of far-reaching changes in the structure and organisation of manufacturing supply chains.

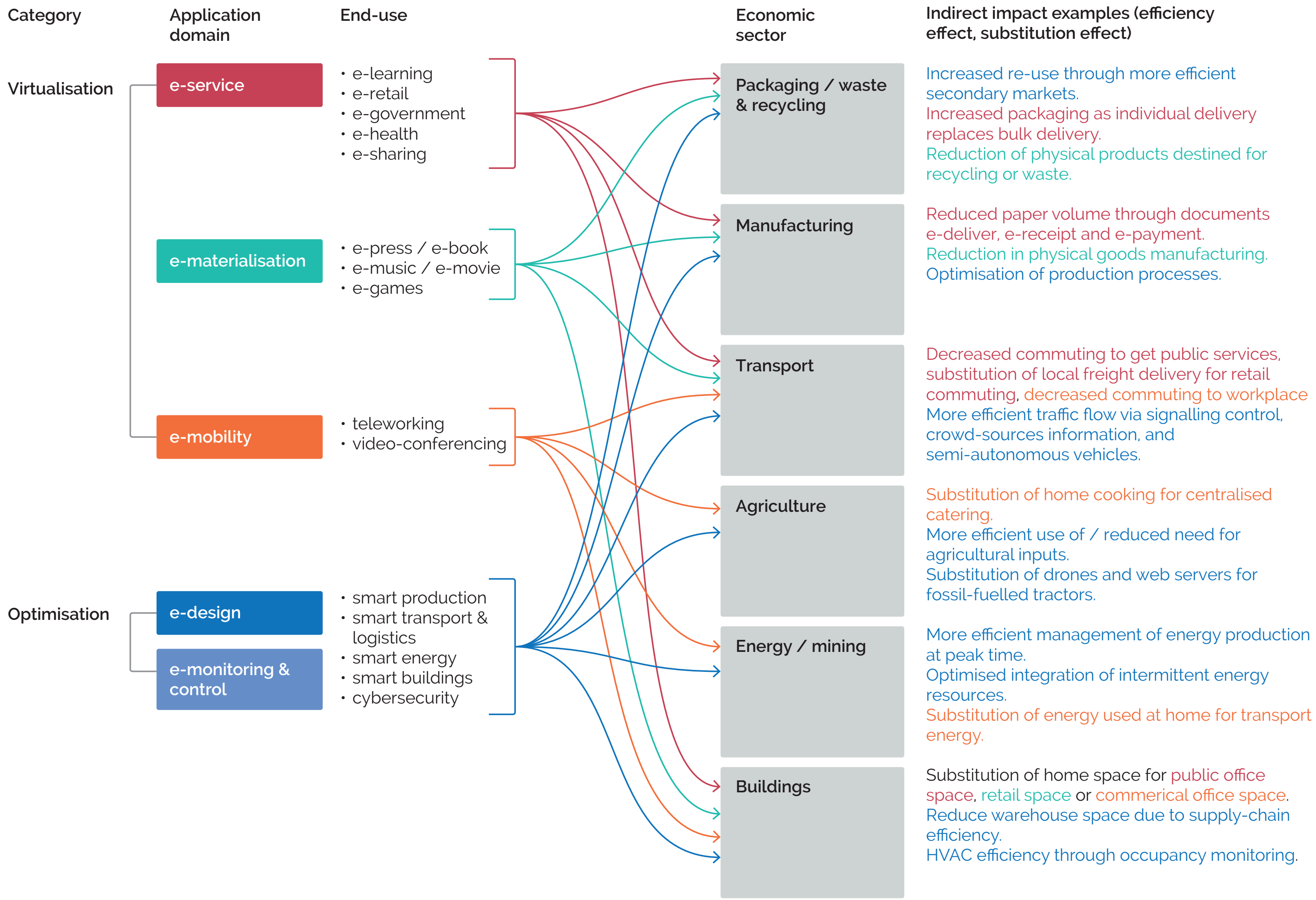

Figure 1 Classifying ICT end-uses based upon their application domain and relationship with economic sectors. Source: based on Horner et al. (2016).

2.3 Existing literature reviews

There are several literature reviews of the environmental impacts of ICTs, and four of these are worth mentioning. Arushanyan *et al.* (2014) review life cycle assessments (LCAs) of ICT products and services and find that: first, relatively few compare digital and non-digital products and services; and second, those that do typically neglect rebound effects. Horner *et al.* (2016) provide an insightful review of the energy impacts of selected ICT applications, focusing in particular upon comparing quantitative estimates. However, they do not employ a systematic review methodology and they do not systematically examine the factors determining those impacts in different contexts. Bieser and Hilty (2018) conduct a systematic review of studies assessing the indirect environmental effects of ICTs, but (unlike Horner *et al.*) their aim is solely to identify the research methods employed. Hankel *et al.* (2018) perform a systematic literature review of the factors influencing the environmental impact of ICTs, but do not assess the impacts of these factors on the environmental outcomes.

All of these reviews emphasise the need to assess the specific factors that determine the environmental impacts of ICTs in particular applications. But none of them systematically link those factors to the magnitude of the indirect impacts on energy consumption. Our study aims to fill this evidence gap.

3 Initial scope and research questions

3.1 Initial scope

The evidence on the impact of ICTs on energy consumption is very large and is likely to prove unmanageable in a single study. Our criteria for narrowing our scope is that: a) the topic of interest should be economically significant and/or expected to become significant in the future; b) there is evidence available on the indirect energy impacts of these ICTs; c) there is reason to believe that these impacts are significant; and d) there is controversy over the magnitude and sign of these impacts. This leads us to propose to confine our review to:

- **e-materialisation**: defined as the partial or complete substitution of material products with electronic equivalents. Examples include e-news, e-books, e-music and e-movies.
- **e-sharing**: defined as the sharing of physical goods, enabled through ICTs. Examples include tool sharing, accommodation sharing, and car sharing.

Although, according to Figure 1, e-materialisation is an application domain whereas e-sharing is an end-use of the application domain of e-services, both topics are related to material goods.

Hence, the aim of this study is to systematically examine the current state of knowledge of the indirect impacts of these two ICT applications on economy-wide energy consumption. Direct impacts will be excluded, as a number of reviews of this topic have already been published (Arushanyan *et al.*, 2014; Coroama and Hilty, 2014; Schien and Preist, 2014). Depending upon both available resources and the size of the evidence base for the two topics we chose, we may extend the review to include other ICT end-uses of the e-service application domain.

3.2 Initial research questions

In addition to comparing quantitative estimates of energy impacts, we aim to clarify the drivers, mechanisms and determinants of those impacts, and the conditions under which they are likely to be positive or negative, or larger or smaller. Our proposed research questions (RQ) for the two sub-projects are as follows

RQ1. What are the determinants and magnitude of the indirect impacts of e-materialisation on economy-wide energy consumption?

RQ2. What are the determinants and magnitude of the indirect impacts of e-sharing on economy-wide energy consumption?

Proposed research sub-questions (RSQ) common to both sub-projects are the following

RSQ1. What are the full range of impacts identified in the literature?

RSQ2. What are the key socio-technical determinants of those impacts?

RSQ3. How sensitive are the estimated impacts to the identified determinants?

RSQ4. What is the level and quality of evidence on the mechanisms contributing to those impacts?

RSQ5. To what extent is there a consensus on the sign and magnitude of impacts?

RSQ6. What potential does different ICT end-uses offer for energy savings?

The proposed scope and phrasing of these research questions is subject to change following initial investigation of the size and nature of the evidence-based.

4 Methodology

4.1 Systematic literature review approach

To answer the research questions, we plan to perform a systematic literature review. There are many forms of literature review ranging from expert elicitation techniques taking a few hours to exhaustive literature analyses taking many months. The important point is to ensure that the review protocol is appropriate to the research question. Combining a systematic search for evidence with a narrative synthesis of the results has the benefit of providing a clear audit trail from research evidence to policy-relevant insights. This can be particularly valuable where the evidence base is scant, or context-dependent (Dicks *et al.*, 2014; Snilstveit *et al.*, 2012).

The evidence that underpins a systematic review can take many forms including experiments and quasi-experiments, surveys, econometric analysis of secondary data, economic models and qualitative evidence (Sorrell, 2007). Under some circumstances, quantitative evidence can be combined and synthesised using meta-analysis techniques. However, if the evidence is largely qualitative and/or context-dependent, a narrative analysis may be more appropriate.

A systematic literature review offers a number of advantages compared to a traditional, or "narrative" literature review (Haddaway *et al.*, 2015; Petticrew and McCartney, 2011). In particular:

- a focused research question avoids excessively wide-ranging discussion and inconclusive results;
- selective and opportunistic selection of evidence is avoided;
- replicability is increased by documenting the criteria for including or excluding studies;
- assessment of methodological quality assists discrimination between sound and unsound studies; and
- increased transparency reduces subjectivity and bias in the reporting of results.

An important caveat is that a systematic review may not be appropriate where the evidence base is heterogeneous, highly context-specific, or draws heavily on knowledge falling outside the academic mainstream (e.g., indigenous and local knowledge).

4.2 Assessment sequence

Figure 2 summarises the proposed stages of our systematic literature review. The approach will be consistent with the available timescale of 12 months. The research outputs will take the form of two academic articles (one for each ICT application), to be submitted to a special edition of *Environmental Research Letters*. These will be accompanied by a single policy brief to promote the results to a wider audience.

4.3 Expert advisory group

The project team will engage with a small team of expert advisors who can bring their experience and perspectives to bear on the subject. The expert advisors will be asked to comment on the scope of the project and the proposed approach; advise and assist the project team in the selection of relevant evidence sources; and review draft results. The expert advisors will be announced in due course and will be listed in the resulting academic article(s) and policy brief.

	Scoping prospective issues	Develop search & screening protocol	Perform search & screening protocol	Data extraction, critical appraisal	Data synthesis / interpretation	Write report / academic article	Consult, peer review & refine	Publish & promote results
Issues	• Need to define and scope an answerable research question	• Ensure transparent, rigorous and replicable process	• Need to review literature thoroughly	• Need to apply rigorous criteria to evaluation of relevant studies	• Need to link various results in order to generate convincing and robust synthesis	• Need to identify key issues and discuss initial findings with expert advisers and stakeholders	• Need to seek peer review and gain wide-ranging criticism of initial work	• Need to ensure the final report / article / policy brief reaches key audience
Actions	• Write scoping note • Seek feedback from advisory group	• Define search terms, literature database, cut-off year, explicit criteria for Inclusion / exclusion of studies, and transparent criteria for quality assessment	• Apply search protocol to literature • Perform detailed and transparent screening protocol • Identify relevant sources	• Apply quality assessment protocol to evaluation of selected studies	• Perform detailed and transparent analysis of evidence • If possible generate quantitative synthesis • If not, perform only narrative synthesis	• Write preliminary draft report / academic article	• Possibly host stakeholder workshop to discuss draft report • Send draft report / article to peer review • Make appropriate revisions to draft report / article	• Publication of final report / article / policy brief • Launch events • Communication via social media and press
Outputs	• Scoping note with focused and well-specified research question	• Assessment (i.e. search + screening + quality appraisal) protocol	• Selection of relevant references	• Knowledge on intrinsic quality of each selected study	• Results answering the research question	• Draft report / academic article	• Final report / academic article	• Published report / academic article / policy brief

Figure 2 Typical steps with specific issues, actions, and outputs of a systematic literature review. Source: based on Heptonstall and Gross (2017).

5 Sources, search terms, and relevance ratings

The initial choice of databases, search terms, inclusion/exclusion criteria, and methods of categorising evidence are summarised below. These will be revised following experimentation and discussion with expert advisors.

5.1 Sources/databases

The evidence will be drawn from peer-review academic journals, conference proceedings, working papers, books, and techno-economic reports. We will give priority to studies that provide quantitative estimates, but broader qualitative evidence will also be examined to obtain a deeper understanding of relevant mechanisms and determinants.

We will apply our search protocol to the most widely used scientific literature databases and platforms, namely *Scopus*, *Web of Science*, and *Google Scholar*. Given the pace of technical change in this area, older studies are unlikely to be of much value. Hence, we propose to confine the review to studies published after 2000. Also, we exclude all studies for which our research team does not have language competencies, namely English and French.

5.2 Search terms and their combination

For each of our sub-projects, we propose to combine four types of keywords in our search query, namely a first synonym for 'ICT' or equivalent; a second for 'energy' or equivalent; a third for 'consumption' or equivalent; and a fourth for the specific ICT application. Considering variations around these terms with Boolean operator OR and AND, we propose the two following search queries.[4]

- **For the e-materialisation sub-project**: ("Information and communication technolog*" OR ICT OR "information technolog*" OR "digital technolog*" OR informatic*) AND (energ* OR electricit* OR environment* OR carbon OR "greenhouse gas*" OR GHG) AND (consumption OR efficienc* OR utilisation OR use OR expenditure OR demand OR saving* OR emission* OR impact*) AND ("virtual* good*" OR "digital* good*" OR "demateriali* good*" OR e-book* OR "digital* journal*" OR newspaper* OR magazine* OR music* OR video* OR television* OR film* OR movie* OR "motion picture*" OR game*).
- **For the e-sharing sub-project**: (energ* OR electricit* OR environment* OR carbon OR "greenhouse gas*" OR sustainab* OR GHG) AND ("sharing economy" OR "e-sharing" OR "collaborative economy" OR "collaborative consumption" OR carsharing OR "sharing platform*" OR "peer-to-peer sharing" OR "car-sharing" OR "car sharing" OR "vehicle sharing" OR "shared mobility" OR "tool sharing" OR "ride-sharing" OR "ride-on-demand" OR "ridesharing" OR "Airbnb" OR "uber" OR carpooling OR "bike sharing")

[4] Depending on the search platform, the entire search string must be put into brackets with a specific prefix. In *Scopus*, to avoid thousands of results, the search is made through the title, abstract, and key words only with "TITLE-ABS-KEY (…)". In *Web of Science*, the search terms relate to topics (and not author for instance), with "TS=(…)".

The reason for proposing *environment**, *carbon*, "*greenhouse gas**" and *emission** as variants for energy is because the determinants that affect impacts on these measures are likely to be similar to those affecting impacts on energy consumption. Hence, both the quantitative and qualitative insights of a study assessing the impact of an ICT (that is relevant for our sub-projects' scopes) on any one of these measures is worthwhile investigating.

We anticipate that initial trial searches will lead us to modify or add terms to the search query. As already noted, depending upon the results obtained, we may choose to expand the scope of our review to other ICT applications. In particular, we will check if our search queries are able to identify the papers included in previous reviews on the environmental impacts of ICTs (i.e., Arushanyan *et al.*, 2014; Horner *et al.*, 2016; Bieser and Hilty, 2018; and Hankel *et al.*, 2018).

5.3 Inclusion/exclusion criteria

Once the search protocol is realised, we will first remove duplicates before applying inclusion/exclusion criteria to screen the studies found in the libraries and select only those publications that appear relevant to our research questions. The inclusion criteria should apply to all remaining studies, while none of the exclusion criteria should apply. Table 2 lists the criteria that we plan to use.

Table 2 Proposed inclusion and exclusion criteria. Source: based on Hankel et al. (2018).

	Description	Rationale
		Inclusion criteria (IC)
IR1	The study relates to, or incorporates, one or more ICT end-uses that are within the scope of the study	This is to exclude studies that focus on ICTs related to other topics than e-materialisation or e-sharing.
IR2	The study contains primary research results	This is to exclude studies that only report quantitative estimates and qualitative effects of determinants from other primary sources.
IR3	The study measures or models one or more indirect impacts of this ICT-end-uses on energy use or greenhouse gas emissions	This is to include only those studies that provide estimates or qualitative appraisals of one or more indirect impact, rather than solely direct impacts. Whether the environmental impact considered is energy-related or not (e.g., GHG emissions), both quantitative and qualitative data on the importance of socio-technical determinants and magnitude of impacts should be extracted.

		Exclusion criteria (EC)
EC1	The main topic of the study is unrelated to ICT.	This is to exclude studies from other research fields that were caught by the search query but are not relevant to the research question.
EC2	The topic of the study is related to ICT, but no particular ICT service is discussed qualitatively or quantitatively	This is to exclude studies from the ICT research field that were caught by the search query but are not relevant to our research question (e.g., article detailing a research agenda without studying a particular ICT service).
EC3	The study is not accessible.	This is to exclude studies for which the full-text version is not accessible at the time of review (e.g., pre-publication).

5.4 Relevance ratings

We anticipate that the diversity of evidence will preclude a strict ranking of studies on the basis of their methodological rigour. However, we propose to develop some straightforward criteria for weighting the quality of different types of evidence. Hence, when conducting this step, a relevance rating will be assigned to each piece of evidence and additional categorisation of references may take place following the initial search process. The proposed relevance ratings (RR) are:

RR1. The study shows a clear link with the research question and provides quantitative estimates that are well-specified with respect to system boundary and determinants.

RR2. The study shows a clear link with the research question; however, quantitative estimates are not well-specified with respect to system boundary and determinants.

RR3. The study shows a link with the research question; however, quantitative estimates are not provided, so only qualitative insights can be extracted.

References

Arushanyan, Y., Ekener-Petersen, E., Finnveden, G., 2014. Lessons learned – Review of LCAs for ICT products and services. *Computers in Industry*, **65**: 211–234.

Bieser, J., Hilty, L., 2018. Assessing Indirect Environmental Effects of Information and Communication Technology (ICT): A Systematic Literature Review. *Sustainability*, **10**: 2662.

Börjesson Rivera, M., Håkansson, C., Svenfelt, Å., Finnveden, G., 2014. Including second order effects in environmental assessments of ICT. *Environmental Modelling and Software*, **56**: 105–115.

Coroama, V.C., Hilty, L.M., 2014. Assessing Internet energy intensity: A review of methods and results. *Environmental Impact Assessment Review*, **45**: 63–68.

Dicks, L. V., Hodge, I., Randall, N.P., Scharlemann, J.P.W., Siriwardena, G.M., Smith, H.G., Smith, R.K., Sutherland, W.J., 2014. A Transparent Process for "Evidence-Informed" Policy Making: A process for evidence-informed policy making. *Conservation Letters*, **7**: 119–125.

Galvin, R., 2015. The ICT/electronics question: Structural change and the rebound effect. *Ecological Econmics*, **120**: 23–31.

Haddaway, N.R., Woodcock, P., Macura, B., Collins, A., 2015. Making literature reviews more reliable through application of lessons from systematic reviews. *Conservation Biology*, **29**: 1596–1605.

Hankel, A., Heimeriks, G., Lago, P., 2018. A systematic literature review of the factors of influence on the environmental impact of ICT. *Technologies*, **6**: 85.

Heptonstall, P., Gross, R., 2017. Explaining the impact of policy on consumer energy bills: scoping note and review protocol. UK Energy Research Centre (UKERC), Technology and Policy Assessment.

Hilty, L.M., Aebischer, B., 2015. ICT for sustainability: an emerging research field, in: Hilty, L.M., Aebischer, B. (Eds.), ICT Innovations for Sustainability. Advances in Intelligent Systems and Computing. Springer, pp. 3–36.

Horner, N.C., Shehabi, A., Azevedo, I.L., 2016. Known unknowns: indirect energy effects of information and communication technology. *Environmental Research Letters*, **11**: 103001.

Kander, A., Malanima, P., Warde, P., 2013. Power to the People: Energy in Europe Over the Last Five Centuries. Princeton University Press, Princeton, NJ.

Laitner, J.A. "Skip", Ehrhardt‐Martinez, K., 2008. Information and communication technologies: The power of productivity (Part I). *Environmental Quality Management*, **18**: 47–66.

Perez, C., 2013. Unleashing a golden age after the financial collapse: Drawing lessons from history. *Environmental Innovation and Societal Transitions*, **6**: 9–23.

Petticrew, M., McCartney, G., 2011. Using Systematic Reviews to Separate Scientific from Policy Debate Relevant to Climate Change. *American Journal of Preventive Medicine*, **40**: 576–578.

Schien, D., Preist, C., 2014. Approaches to energy intensity of the internet. *IEEE Communications Magazine*, **52**: 130–137.

Snilstveit, B., Oliver, S., Vojtkova, M., 2012. Narrative approaches to systematic review and synthesis of evidence for international development policy and practice. *Journal of Development Effectiveness*, **4**: 409–429.

Sorrell, S., 2007. Improving the evidence base for energy policy: The role of systematic reviews. *Energy Policy*, **35**: 1858–1871.

Williams, E., 2011. Environmental effects of information and communications technologies. *Nature*, **479**: 354–358.