Evaluating the carbon-reducing impacts of ICT

An assessment methodology

GeSI
GLOBAL e-SUSTAINABILITY INITIATIVE

BCG
THE BOSTON CONSULTING GROUP

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Forewords

About GeSI
GeSI (www.gesi.org) is an international strategic partnership of ICT companies and industry associations committed to creating and promoting technologies and practices that foster economic, environmental and social sustainability and drive economic growth and productivity. Formed in 2001, GeSI fosters global and open cooperation, informs the public of its members' voluntary actions to improve their sustainability performance and promotes technologies that foster sustainable development. It partners with two UN organizations: United Nations Environment Programme (UNEP) which hosts GeSI's Secretariat and the International Telecommunications Union (ITU). These partners help shape our global vision regarding the evolution of the telecommunications sector and how we can best meet the challenges of sustainable development.

Over the past couple of years, the Global e-Sustainability Initiative (GeSI) has been participating in the global dialogue on climate change. Evidence shows that the Information and Communication Technology (ICT) industry has tremendous potential to increase energy efficiency and curb carbon emissions. However, in order to realize this promise, merely implementing ICT solutions will not be sufficient—being able to assess their impact more precisely is also critical.

One of the GeSI missions in this respect is to develop methodology and standards to measure and cut the carbon footprint of the ICT sector and other industries through innovative technology. This report fulfils this mission by proposing a methodology for identifying and quantifying the impacts of ICT adoption.

Aware of the need to move from discussion to action, GeSI continues to develop and implement solutions that will drive the world toward a low-carbon society—something that is essential if we are to make the world more environmentally sustainable.

GeSI's message has not yet been heard or fully understood by the decision makers who can make a difference. Yet the risks of not taking action are too serious to be ignored. However, given the growing recognition of GeSI's work—including its influential SMART 2020 report and subsequent regional reports—policy makers and indeed, the ICT industry, are taking note. It is now time to build and generate further momentum - GeSI members have well understood "the size of the opportunity" and together, we will speed up the process of driving the low carbon economy agenda.

Now, with the launch of this report—Evaluating the carbon-reducing impacts of ICT: An assessment methodology—GeSI has produced a powerful tool with which to mitigate the risks that lie ahead.

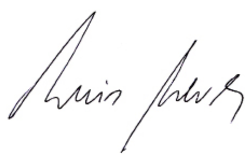
In addition to the direct carbon emissions associated with the development and use of ICT solutions, this methodology assesses what are known as the "enabling effects" of ICT—the extent to which ICT technologies and systems can reduce or avoid the carbon emissions associated with traditional manual, mechanical, or physical activities. The report supplements the evidence documented in the SMART 2020 report of the important role that ICT, through its enabling effect, can play in reducing global carbon emissions.

The report recognizes the response of GeSI's members to calls for action. Now is the time to build on this support and generate further momentum. GeSI members have understood the magnitude of both the challenges and the opportunities and, together, they will help speed up the process of moving to a low-carbon economy.

By establishing a consistent methodology and roadmap for measuring ICT's low-carbon enablement capacity, this report represents an important step toward realizing our sector's potential contribution in the fight against climate change.

It is therefore our responsibility to promote the methodology, to engage others, and to ensure that the ICT industry as a whole adopts it and implements it fully. At the same time, we must cooperate with appropriate stakeholders worldwide to guarantee that the methodology is recognized and widely embraced so that the industry can move toward alignment in its assessment and communication of the positive benefits of ICT.

I believe that GeSI's ICT Enablement Methodology will be recognized as a landmark initiative and that GeSI, its member organizations, and other ICT industry companies and stakeholders will bring us closer to actualizing the low carbon promise of ICT through its implementation.



Luis Neves
GeSI Chairman

This report marks another milestone reached by the Global e-Sustainability Initiative (GeSI) and ICT industry toward building a global low carbon economy. The SMART 2020 series of studies initially identified the key role that ICT can play in abating climate change. Cited at length by governments, policy makers and academia, these studies concluded that ICT can deliver critical energy savings and support the sustainable development of buildings, infrastructure and operations in developed and developing countries.

This report contributes to realizing ICT's promise through the establishment of a consistent methodology and roadmap for assessing ICT's low carbon enablement capacity. The ICT Enablement Methodology proposed in this report provides immediate guidance on the process of identifying and quantifying the effects of implementing an ICT solution. With its focus on simplifying assessment via a generally-applicable approach, diverse members of the ICT industry, businesses and policy makers should find this methodology a practical guide for tackling the assessment process. Moreover, through the widespread adoption of the proposed approach to assessment, the industry will move toward greater alignment in its evaluations and communications of the positive benefits of ICT.

In establishing SMART buildings, grids, logistics and transportation (as described by the SMART 2020 series) what are the next steps for industry and government to enable the intelligent integration of ICT? We propose that the next phase is to apply the recommended methodology to establish a body of relevant knowledge and further refine actual ICT applications and net beneficial impacts through case studies. With this additional input, we can create tools for use by enterprises, government officials, planners and policy makers to enable more informed decision making.

A low carbon economy encourages innovation and efficiency, and preserves our environment. GeSI and its member companies are committed to the thoughtful and sustainable realization of this vision.

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ICT Enablement Study Team, Chair

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Report summary

As reported in SMART 2020: Enabling the low carbon economy in the information age, information and communication technologies (ICT) could cut global "business as usual" greenhouse gas emissions by 15%[1] and save up to €600 billion by 2020.[2] The continued development of smart motors, smart logistics, smart buildings, smart grids and dematerialization would drive this reduction by decreasing the emissions generated by sectors such as transport, buildings, power and industry.

A greater understanding of the carbon-reducing potential of these ICT products and services will greatly accelerate their adoption. To this end, a common means of assessing the low-carbon enabling effects of ICT solutions is required. Without a standard methodology for assessment, the rate of investment in ICT to combat climate change may slow and lose focus, despite scientific consensus that immediate, direct action is needed to halt climate change.

In recognition of this urgent need, the Global e-Sustainability Initiative (GeSI) has taken the bold action of establishing a methodological framework for assessing the enabling effects of ICT—the ICT Enablement Methodology. Building on existing assessment standards and proposed methodological approaches, as well as the commitment of industry leaders and researchers, GeSI has developed a methodology tailored to the needs of the ICT industry and its customers, with a focus on ease of assessment where possible.

Developed in compliance with broadly-accepted guidelines for life cycle assessment (LCA) put forth by the International Organization for Standardization (ISO), the methodology proposes a three-step process to evaluate the carbon impact of ICT solutions. It emphasizes streamlining the evaluation process by identifying and assessing the ICT-related impacts that are most relevant to the goal and scope of each study.

By addressing the ICT industry's assessment needs, GeSI's proposed methodology represents an important step toward quantifying the gains realized across all business and public sectors through the application of ICT solutions. The methodology is intended for immediate use as a guide for assessing the net enabling effect of an ICT product or service.

The ICT Enablement Methodology also paves the way for further development, including the standardization of criteria for assessing specific types of ICT solutions. This will increase the ease and consistency of applying the ICT Enablement Methodology. In addition, development of compatible software tools will reduce resource and cost requirements.

To demonstrate the immediate relevance of the ICT Enablement Methodology, six case studies applying the methodology are included in this report. These studies were developed retrospectively, based on existing research.

GeSI believes the ICT Enablement Methodology and corresponding case studies represent a critical step toward common approaches to assessing ICT impact. However, only real-world adoption, use and refinement of the methodology will drive true acceptance. Therefore, the establishment of an ongoing dialogue and the development of additional case studies using this methodology are essential next steps.

GeSI looks forward to engaging the broader stakeholder community in the further development of the ICT Enablement Methodology. The introduction of this common approach for assessing the enabling effects of ICT will undoubtedly bring nearer the realization of a 15% reduction in global emissions from the use of ICT.

[1] The total footprint of the ICT sector in 2007 was estimated as 2% of total emissions. On the other hand, development and use of ICT solutions has the potential to reduce global business as usual emissions by 15% by 2020. This figure comes from SMART 2020: Enabling the low carbon economy in the information age published by GeSI and The Climate Group in 2008. This study can be downloaded in full at http://www.smart2020.org/_assets/files/02_Smart2020Report.pdf.

[2] Exact figures: €553 billion in energy and fuel saved an additional €91 billion in carbon saved, assuming a cost of €20/tonne, for a total of €644 billion savings.

01: Introduction

The need for a methodology to assess the ICT enabling effect

ICT has tremendous potential to improve energy efficiency, cut carbon emissions and mitigate climate change. However, to understand and promote these benefits, merely implementing ICT solutions will not be sufficient—quantification of their impact is also critical. This report proposes a methodology for identifying and quantifying the impacts of ICT adoption, including the "enabling effects" of ICT by which carbon emissions associated with traditional manual, mechanical or physical activities are reduced or avoided.

SMART 2020 identifies the following areas as fertile grounds for emissions savings:

- Smart motors – technologies that reduce the energy consumed by industrial motors, or support industrial process automation. These motors can, for example, run at variable speeds, using only the energy required for the task in hand, rather than operating at full capacity regardless of load

- Smart logistics – technologies that enable fuel reductions and energy efficiency through better route and load planning. For example, operations management software can reduce inventory storage, fuel consumption, kilometers driven and number of vehicles traveling empty or partially loaded

- Smart buildings – solutions that maximize energy efficiency in buildings, such as building management systems that run heating and cooling systems according to occupants' needs

- Smart grids – digital technology that allows greater visibility of energy use and power flows. For example smart meters give consumers real-time information on the energy they use, while demand management systems automate the reduction of appliances' energy load at peak times

- Dematerialization – the substitution of high-carbon products and activities with low-carbon alternatives, such as replacing paper bills with e-billing

Appendix 1 details the estimated potential for ICT solutions to reduce emissions in each of these opportunity areas.

Despite this potential for reduction, the lack of a standard methodology for assessment of net enabling effects constrains investment in ICT as a tool for combating climate change. In March 2009, the European Commission stated that:

> "In order to promote legitimacy, transparency and real progress in the application of ICTs to improving energy efficiency, there is a clear need to create a level playing field based on common ways of assessing energy performance—especially in more complex systems—and on a common understanding of commitments, targets and methodology."[3]

Accordingly, in an October 2009 Recommendation, the European Commission challenged the ICT industry to use collective consensus and rigorous research to develop and adopt common methodologies to assess its own role in enabling a low-carbon age.[4]

The present lack of common

[3] Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions on mobilising Information and Communication Technologies to facilitate the transition to an energy-efficient, low carbon economy, March 2009, http://ec.europa.eu/information_society/activities/sustainable_growth/docs/com_2009_111/com2009-111-en.pdf.

[4] Commission Recommendation on mobilising Information and Communications Technologies to facilitate the transition to an energy-efficient, low carbon economy, October 2009, http://ec.europa.eu/information_society/activities/sustainable_growth/docs/recommendation_d_vista.pdf.

methodologies and tools creates obstacles in the move toward a low carbon economy. For example, lack of accepted data on the potential CO_2e enabling effects of ICT makes it difficult for governments to provide employers incentives to embrace teleworking or videoconferencing. It also inhibits governments from introducing the incentives needed to encourage owners of commercial and residential buildings to, for example, invest in technologies to manage and reduce building energy use.

The establishment of a widely adopted methodology to assess the net enabling impacts of ICT will benefit businesses, consumers and policy makers. A consistent approach to quantifying both the carbon-generating and carbon-saving impacts of ICT solutions will inform customer purchase and procurement decisions and provide the evidence base for government efforts to introduce supportive policies. Establishing a methodology will also speed up the development of assessment standards and tools needed by the ICT industry.

In response to this opportunity, the Global e-Sustainability Initiative (GeSI) has launched a major piece of work to establish a methodological framework for assessing the enabling effects of ICT. GeSI recognizes the need to establish an approach tailored to the requirements of the ICT industry—one that builds on the work of existing assessment standards and guidelines while introducing a more streamlined approach to the process of quantifying the impacts of ICT.

Overview of existing efforts to develop ICT assessment methodologies

Recent efforts to develop assessment methodologies have focused on two areas—first, approaches for assessing direct ICT emissions (the emissions generated by the ICT solutions themselves, in their manufacture and operation) and, second, approaches for identifying and quantifying ICT enabling effects (emissions reduced in other sectors by implementing ICT solutions).[5] Both areas need to be addressed to assess the net benefit of an ICT solution.

Organizations currently developing methodologies include standards bodies and industry consortia. Many are developing methodologies to assess both direct ICT emissions and ICT enabling effects. These include recognized standards bodies such as the International Telecommunication Union (ITU), the European Telecommunications Standards Institute (ETSI), and the Japan Environmental Management Association for Industry (JEMAI). In addition to GeSI, industry consortia active in this area include the ICT for Energy Efficiency Forum (ICT4EE) and the Roadmap Enabling Vision and Strategy for ICT-enabled Energy Efficiency (ReViSITE) consortium. Meanwhile, another industry consortium, the International Electronics Manufacturing Initiative (iNEMI), is focusing on the development of a methodology to assess the carbon footprint of ICT products, with a tool and database to streamline this process.

As part of GeSI's efforts to develop a methodology for assessing ICT enabling effects, it conducted a review of these efforts. From this review, a number of conclusions were drawn:

- The industry consortia ICT4EE Forum, ReViSITE and iNEMI are in the early stages of developing a methodology. Meanwhile, the standard-setting bodies ITU[6] and ETSI[7] are engaged in ongoing efforts to develop detailed methodologies that will propose standards for assessing impact from ICT solutions.[8] Many of the findings and recommendations of these efforts are not yet finalized or published. GeSI expects its contribution to the development of an enablement methodology to pave the way for other organizations to further develop

5 Note that rebound effects may also be present; defined as increases in demand that offset some of the positive impact of ICT implementation, rebound effects act as counter-acting agents to enabling effects.

6 In late-2009, ITU's Focus Group on ICT and Climate Change published a report discussing an energy efficiency methodology relevant for the assessment of both direct ICT emissions and ICT enabling impacts. ITU's current Study Group 5 on "Environment and Climate Change" is building upon this work by developing more detailed ICT methodologies. A methodology specific to the assessment of direct ICT emissions is planned for late-2010, while a next-generation methodology for assessing ICT enabling impacts is expected in 2011.

7 ETSI's working group addressing the topic of ICT enablement is DTR/EE-00008: Environmental Impact Assessment of ICT including the Positive Impact by using ICT Services, which is a technical report, that is, an assessment rather than an actual standard to be used by stakeholders. An additional work item, DTS/EE-00014 LCA assessment of telecommunications equipment and service part 1 is a standard meant to provide general definition and common requirements, aiming to cover the product, network and service level. This is expected in the second half of 2010.

8 The standards under development will apply broadly to ICT equipment, network and services, and will not be specific to individual forms of ICT equipment. For example, a standard may be put forth that requires assessment of ICT emissions including the manufacturing stage for integrated circuits and batteries.

and integrate standards ensuring worldwide integration of ICT sector efforts.[9]

- Based on currently available information it is clear that all ICT-specific assessment methodologies are using a life cycle assessment (LCA) approach for estimating both direct ICT emissions and ICT enabling effects. Further, the existing LCA standard, ISO 14040-series, serves as the foundation for the ICT-specific methodologies proposed. According to ISO, LCA is "the compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle."[10] Appendix 2 provides a detailed review of LCA and the ISO 14040-series standard.

- Most industry consortia and standard-setting bodies recommend using a process-sum LCA approach to assess ICT impacts. Process-sum is a bottom-up approach that assesses the environmental impacts of individual products/processes. ITU and ReViSITE also recommend use of a hybrid LCA where appropriate. A hybrid LCA approach marries a process-sum LCA with economic input-output LCA (EIO-LCA), a top-down approach that uses economic input-output tables to estimate sector-level impacts. ITU and ReViSITE suggest that economic input-output data be selectively integrated into the assessment when expanding the scope of assessment from a product-level to sector-level. An overview of the three forms of LCA is included in Appendix 2. GeSI recognizes that a process-sum LCA approach presents broad applicability and is usually sufficient for assessing direct ICT emissions and enabling effects. However, certain studies quantifying the large-scale impact of implementing an ICT solution may require use of a hybrid LCA approach.

The role of GeSI in establishing an enabling effect methodology

Efforts to develop a methodology for assessing direct ICT emissions and ICT enabling effects are helping to define broadly acceptable approaches. However, agreement on a single methodology has yet to emerge. This lack of consensus exists partly because of the need for further work on the various methodologies involved. For example, while ITU's previous work detailing existing LCA approaches and proposing a preliminary energy efficiency assessment methodology represent a significant first step toward achieving industry-wide alignment, ITU itself has acknowledged the need for additional work and collaboration—hence the formation of its ITU Joint Coordination Activity Group (JCA) and Study Group 5 on "Environment and Climate Change."

GeSI believes that its proposed enablement methodology makes significant improvements over existing approaches, facilitating simplified assessments with strong potential for increased ease and automation via future enhancements. Moreover, it believes the methodology will complement and support other future efforts, including those of ITU.

Promoting a single methodological framework will also require endorsement from leading organizations within the ICT sector. GeSI believes its ICT Enablement Methodology has strong industry backing and that its adoption, by both GeSI members and non-members, will demonstrate its value and establish a base from which the method will continue to evolve.

However, to gain general acceptance, the methodology must reflect the specific needs of the ICT industry and other private and public sectors for both accuracy and ease of application. GeSI has identified a number of key criteria in this regard. In particular, the assessment process should consider all impacts on carbon-emissions, but limit rigorous assessment to those effects and life cycle processes with significant emission impact. Considering the complexities of the ICT sector, reducing the time and resources the assessment process requires will drive broader adoption of a single methodology.

[9] For example, the ICT Enablement Methodology may feed into the efforts of ITU and ETSI to detail life cycle inventory, data and reporting requirements for conducting assessments of ICT solutions.

[10] ISO 14044, Environmental management – Life cycle assessment – Requirements and guidelines, 8.

With these considerations in mind, GeSI has sought to develop an approach that:

- Is able to capture all significant effects of ICT implementation, both positive and negative
- Minimizes the time and resources needed for assessment by facilitating exclusion of negligible components of net effect (through impact estimates of life cycle processes in the screening assessment of relevant effects)
- Supports clear, transparent communication of methodological approach and findings to a broad stakeholder audience, including consumers, ICT and non-ICT industry sectors and policy makers
- Is widely applicable across ICT products, services and category levels
- Is effective when applied in both the developed and the developing world
- Is general and flexible enough for large-scale adoption and will meet current and future stakeholder assessment needs as sector innovation occurs
- Can adapt as more detailed guidance, industry-wide standards and software assessment tools are developed

GeSI's proposed enablement methodology serves as an immediate guide for assessing ICT enabling effects and paves the way for the systemic evaluation of ICT solutions. Development of additional guidelines will enhance and may further simplify application of the methodological framework described in this report. However, the development of such standards will require time and effort beyond the publication of this report, and thus comparison between different studies cannot occur immediately. The ITU, ETSI or other entities may propose potential add-ons or enhancements to the methodology, including:

- Guidance on functional units appropriate for use in evaluating each category of ICT
- Identification of likely effects that should be addressed in evaluations of specific types of ICT solutions
- Quantitative values with which to determine whether or not identified effects should be included in more rigorous assessments

GeSI believes integration of these critical inputs into its proposed methodology will establish a more consistent, effective approach to assessment. Further consideration of these and other potential next steps will be discussed later in the report.

02: ICT Enablement Methodology

Summary of approach

When it comes to assessing the net enabling effects of ICT, we propose adoption of an ICT Enablement Methodology. This methodology uses an LCA approach to guide the assessment of changes to the BAU system resulting from adoption of an ICT solution (the BAU, or business-as-usual, system refers to the components in the existing manual, mechanical or physical processes that are impacted by the implementation of the ICT solution).

As this methodology was developed to assess the capacity of ICT implementation to reduce the carbon footprint of other sectors, it focuses on quantifying CO_2e (carbon dioxide equivalent) emissions. It does not assess other important environmental impact categories such as acidification, eutrophication, or land use, although the methodology could potentially be adapted in the future to consider these impacts.

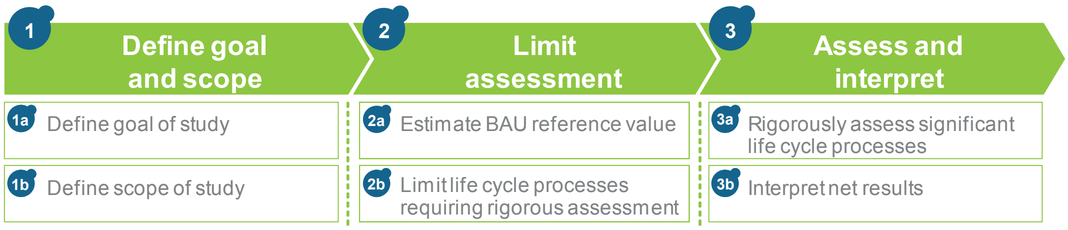
The ICT Enablement Methodology goes further than a typical product or service LCA, which considers life cycle stages and processes of a single system. In addition to the direct life cycle emissions of an ICT system, the methodology considers the emissions saved or generated by various enabling and rebound effects resulting from changes to the BAU system. Enabling effects are those that reduce emissions in non-ICT sectors; rebound effects are those that increase emissions, thus offsetting the emission reductions.[11] Rebound effects are typically changes within the BAU system, though may also result from increased use of the ICT system above its intended use to mitigate non-ICT sector emissions.

Assessing the emissions generated by both the ICT and BAU systems is far more complex than conducting a single-system LCA. However, the ICT Enablement Methodology simplifies the process of quantifying the net enabling effects of ICT wherever possible without sacrificing comprehensiveness or accuracy. For the purposes of this report, assessment is inclusive of both measurement (the collection and observation of quantifiable data) and estimation (the establishment of data via assumption-based modeling). Note that quantification of enabling effects may involve either or both forms of assessment.

The ICT Enablement Methodology consists of three major steps: (1) defining the goal and scope of the study, (2) limiting the life cycle processes of relevant components identified in Step 1, and (3) assessing and interpreting the net enabling effect. These steps are introduced briefly below, with greater explanation and context provided in subsequent sections of the report.

[11] Note that introducing more energy efficient processors or virtualization of software will reduce net emission volumes, but might not be considered an enabling effect since these innovations reduce emissions from the ICT sector itself.

Figure 1: Steps of ICT Enablement Methodology



Step 1: Define goal and scope

The methodology requires consideration of all potential CO_2e effects of ICT implementation, regardless of the goal of the study. However, not all effects are ultimately assessed and included in the quantification of net enabling effects. Select effects may be excluded if they are unlikely to significantly impact CO_2e levels, given the expected scale of adoption. For example, quantification of impacts from long-term reductions in infrastructure use may be excluded in cases where the ICT solution's scale of adoption is very low. A single business implementing telecommuting will not reduce future demand for road construction in light of wider vehicle usage patterns and trends.

Step 2: Limit assessment

A screening assessment of the relevant effects is conducted to obtain a rough estimate of the changes in emissions for each life cycle process. The methodology allows the exclusion of life cycle processes across both the ICT system and the BAU system that are insignificant and do not materially affect the study's conclusions.[12] Rigorous calculations are not necessary in Step 2 of the ICT Enablement Methodology.

The life cycle processes chosen for inclusion will depend on their significance relative to a BAU reference value (the change in emissions level of the life cycle process that is deemed the major driver of reduced emissions). While the BAU reference value focuses on reduced emissions in only one life cycle process for the BAU system, it does not ignore the possibility that other life cycle processes might have an equally large impact. Its purpose is to exclude from rigorous assessment those life cycle processes (and in many cases, entire stages) whose impact is significantly smaller than the BAU reference value.

Step 3: Assess and interpret

Once the relevant effects and the corresponding significant life cycle processes have been identified, the net reduction in CO_2e is determined by rigorously assessing those life cycle processes. A process-sum (bottom-up) LCA approach may be sufficient for evaluating products whose impacts are readily-defined. In cases where assessment includes interdependent, economy-wide impacts or where data availability is scarce, a flexible hybrid LCA incorporating economic input-output data may be necessary.

Finally, the net enabling impact is interpreted using discussion of assumptions, limitations, uncertainty, data quality and conclusions.

[12] This approach is compliant with the ISO 14040 standard, which permits simplification of LCA with justification. In general an LCA study considers the full life cycle. However, if there are processes or stages that are magnitudes smaller than the dominating processes or stages it is reasonable to exclude those in a study.

[13] E.g., ISO 14040 Standard, PAS 2050 Standard, GHG Product Protocol, International Reference Life Cycle Data System (ILCD handbook from the European Commission).

Intended use and limitations of the ICT Enablement Methodology

As noted in the previous section, the ICT Enablement Methodology is intended to serve as a framework for evaluation. It provides guidance on the process of identifying and evaluating the net enabling effect of an ICT solution. It does not, however, contain detailed ICT industry standards on which impacts and life cycle processes to include when assessing individual ICT solutions.

This report outlines the basic steps of the methodology with illustrative case studies and explains the general principles governing what is included and excluded from assessment. Further, Appendix 4 contains worksheets and illustrative output for each sub-step as added guidance for applying the methodology to conduct a new study. The report and methodology do not, however, explicitly define the full set of potential positive and negative impacts from introducing ICT solutions, nor do they offer guidance on how to conduct research or gather data on these impacts.

Differing geographical, behavioral and temporal conditions in the scope of a study can lead to varied effects, even where the ICT solution is the same. Availability of existing data or requirements for conducting research to generate data will also vary. Therefore, assessment of life cycle processes requires careful planning and execution that is tailored to the goal and scope of each study undertaken. The reader is encouraged to explore other resources for further guidance on assessment.

Comparative assessments across studies can only be made using this methodology if care has been taken to set similar system boundaries and other parameters. In the absence of formal assessment standards, established knowledge and/or existing data may help to define the set of potential enabling and rebound effects. Where necessary, a new study may need to be conducted that encompasses both products/services that are being compared.

Further steps, not specifically outlined in this report, are necessary to comply fully with LCA standards such as ISO standards. Appendix 2 provides an overview of LCA and suggests resources for LCA guidelines and standards.[13]

Step 1: Define goal and scope

The first step of the ICT Enablement Methodology is to define the goal and scope of the study. This includes considering the entire set of potential enabling and rebound effects resulting from implementation of the ICT system. The ICT system includes all components necessary to make the ICT solution operational. For instance, an ICT system designed to optimize digital delivery would include these individual components: a data center, PCs, servers and the software itself.

Step 1a: Define goal of study

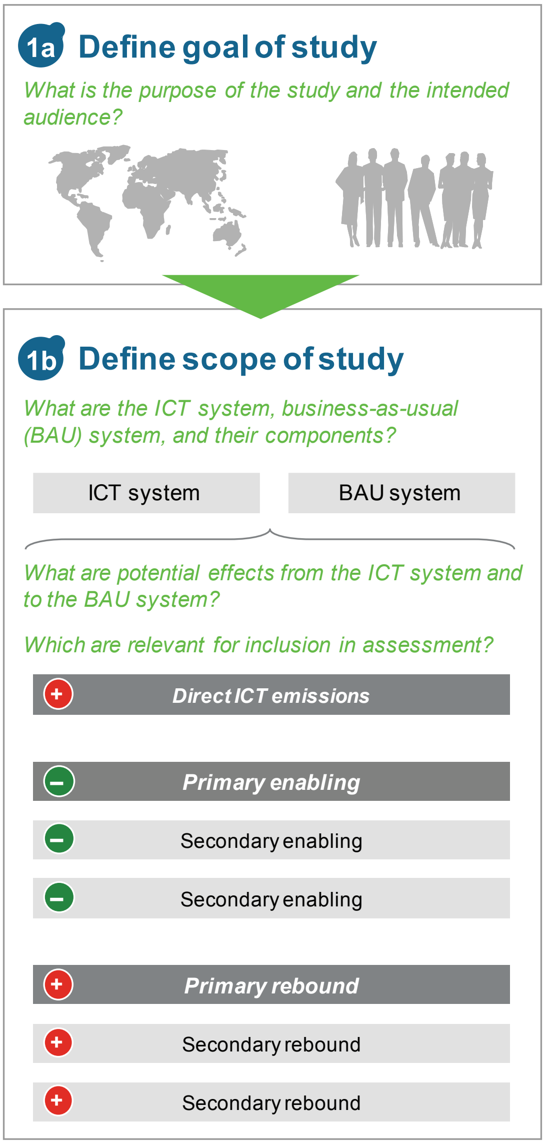
Defining the goal of the study requires documentation of:

- Purpose of the study
- Intended audience[14]

Documenting the purpose of the study includes providing a detailed explanation of the intended use of the results of assessing the net enabling effects. For instance, the purpose of the study may be to establish the environmental benefits of a specific product, or to forecast the potential for an ICT solution to lower CO_2e emissions country-wide.

The intended audience of the study is particularly important. Typically, a strong correlation exists between audience and the scale of adoption, which directly influences the effects deemed relevant in Step 1b. An individual customer will not measurably affect the development or use of infrastructure. Thus, an application of the ICT Enablement Methodology intended to assess adoption of an ICT solution by individual customers would implicitly assume a low scale of adoption. On the other hand, a wider corporate or public sector implementation could lead to broader adoption and a more measurable effect. Figure 3 illustrates how the intended audience can imply different scales of adoption (note that the figure includes only three of many types of intended audiences, and variations may emerge among members of each of these three audiences).

Figure 2: Step 1



[14] ISO defines the relevant aspects of the goal of study as: the intended application, the reasons for carrying out the study, the intended audience (to whom the results of the study are to be communicated) and whether the results are intended to be used in comparative assertions intended to be disclosed to the public. Further, ISO notes that defining the goal and scope of a study is an iterative process with refinements made as-needed throughout the course of a study. As such, an iterative process may occur when defining the goal and study for an application of the ICT Enablement Methodology.

Figure 3: Illustrative scale considerations by audience

Step 1b: Define scope

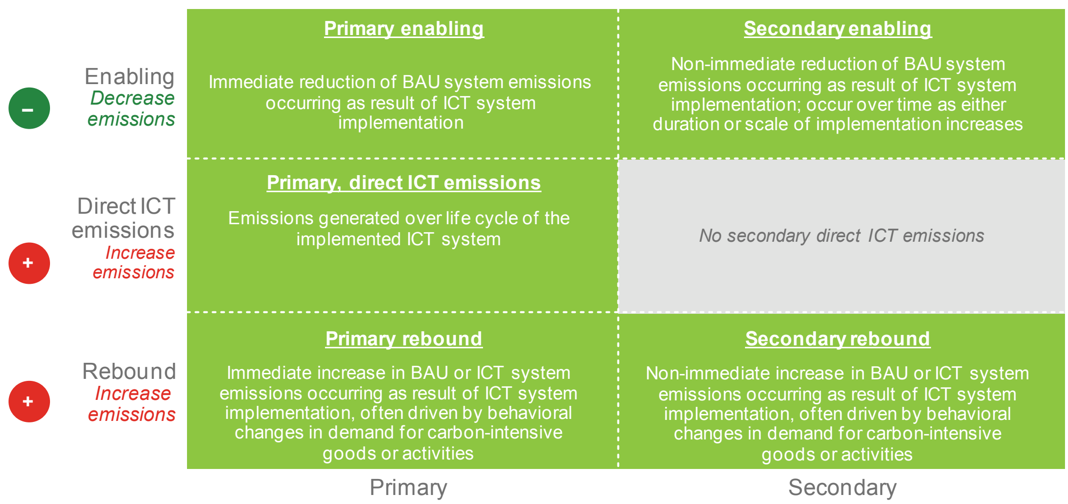
Defining the scope of the ICT Enablement Methodology includes identification of:

- The ICT system
- The BAU system
- All potential enabling and rebound effects, from which relevant effects are determined
- The relevant components of each effect

Key effects that may be evaluated and quantified include direct ICT emissions, primary enabling effects, secondary enabling effects, primary rebound effects and secondary rebound effects. Figure 4 provides definitions of the terms above. Illustrative examples of these effects will be provided in greater detail below.

Any BAU or ICT system consists of one or more "components" that are necessary to make the system operational. Each identified effect (including direct ICT emissions) will correspond with components of the BAU or ICT system for which an LCA is possible.

Figure 4: Types of potential effects of ICT introduction



Following ISO's lead, the ICT Enablement Methodology allows for exclusion of potential effects. The ISO principle of limiting inclusion based on the goal of study states, "the scope, including system boundary and level of detail, of an LCA depends on the subject and the intended use of the study. The depth and breadth of LCA can differ considerably depending on the goal of a particular LCA".[15] In other words, certain secondary enabling and rebound effects can be excluded from rigorous assessment based on the goal and scope of the study. However, the primary enabling effects and direct ICT emissions should always be considered relevant.

[15] ISO 14040:2006, Environmental management – Life cycle assessment – Principles and framework, v.

Primary enabling effects

Following introduction of an ICT solution, there are three possible primary enabling effects on the BAU system:

- Reduced energy consumption, via enhanced efficiency or reduced operations
- Reduced or eliminated travel/shipment as vehicles are used less frequently to move people or distribute goods
- Reduced or eliminated materials

Examples of primary enabling effects include decreased electricity use due to new "smart" lighting systems, fewer miles traveled from telecommuting and eliminated production and distribution of CDs and DVDs from online media.

Figure 5 suggests the primary enabling effect associated with a number of technologies, as discussed in SMART 2020.[16]

[16] In SMART 2020: Enabling the low carbon economy in the information age, these technologies are referred to as "ICT opportunity levers."

Figure 5: Expected primary enabling effects of ICT opportunity levers

SMART opportunity	*Sub-opportunity*	1 Reduced energy consumption	2 Reduced or eliminated travel/shipment	3 Reduced or eliminated materials
SMART Motors	Smart Motor	• Optimization of variable speed motor systems • ICT driven automation in key industrial processes		
SMART logistics	Air transportation	• Reduction in ground fuel consumption • In-flight fuel efficiency	• Reduction in unnecessary flight time	
	Road transportation	• Eco-driving	• Optimization of logistics network • Intermodal shift (to other transports) • Optimization of truck itinerary planning • Optimization of truck route planning • Flexible home delivery methods • Intelligent traffic management	• Minimization of packaging
	Ship / Rail / Other	• Optimization of ship operations	• Optimization of train operations • Maximization of ship load factor	
	Warehouse	• Centralized distribution centres • Reduction in inventory		• Reduction of damaged goods • Recycling and remanufacturing
SMART buildings	Building design	• Improved building design for energy efficiency • Reduced building space through design		
	Building technology	• Building management systems • HVAC automation • Lighting automation • Ventilation on demand • Intelligent commissioning • Benchmarking and building recommissioning • Voltage optimization		
SMART grids	Consumption efficiency	• Reduce consumption through user information • Demand management • Intelligent load dispatch		
	Renewable Energy	• Integration of renewables		
	T&D Loss	• Reduce transmission and distribution losses		
Dematerial-ization	Physical material			• Online media • E-commerce • E-paper
	Travel substitution		• Video-conferencing • Telecommuting	

Secondary enabling effects

Secondary enabling effects are those expected to reduce emissions relative to the BAU system, but which occur over a longer timeframe or as a result of increased scale of adoption. Forms of secondary enabling effects include:

- Reduced use of goods or vehicles
- Eliminated production of goods or vehicles (this could also include a reduction in the number of manufacturing facilities)
- Reduced use of infrastructure (such as buildings and roads)
- Eliminated development of infrastructure

Figure 6 suggests a number of potential secondary enabling effects associated with each of the three forms of primary enabling effects.

Figure 6: Illustrative secondary enabling effects

		Primary enabling effects		
		Reduced energy consumption	Reduced travel/shipment	Reduced materials
Associated secondary enabling effects	Reduced use of goods/vehicles	• Monitoring of home energy use leads individual to avoid consumption more generally (e.g., via vehicle/office)	• Individuals telecommuting may use public transportation in lieu of cars on more regular basis	
	Eliminated production of goods/vehicles		• Fewer cars manufactured	• Individuals using online media may not purchase new CD or DVD player in future
	Reduced use of infrastructure		• Fewer individuals using office space leads to reduced use of buildings	• Less storage of materials lead to reduced use of buildings
	Eliminated development of infrastructure	• Lower energy need results in construction of fewer power plants	• Lower energy need results in construction of fewer power plants • Over long-term, smaller or fewer buildings and roads may be built	

Secondary enabling effects vary widely, and decisions on whether or not to include them in assessment depend largely on the scale of adoption. The ICT Enablement Methodology does not attempt to define a full set of potential secondary enabling effects nor prescribe which to include or exclude. Note that assessing secondary enabling effects that are harder to predict—in either likelihood of occurrence or potential impact—may rely partly on assumption-driven modeling, with results presented as ranges.

Rebound effects

Rebound effects are increases in emissions that offset some portion of the enabling effects of the ICT system, and may be driven by behavioral changes.[17] Primary rebound effects occur immediately after and as a direct result of implementation of the ICT system. They can take one of three forms:

- Increased energy consumption
- Increased travel or shipment
- Increased materials

Secondary rebound effects are those occurring later in time, often as a result of the cumulative impacts of larger-scale adoption. These can take one of four forms:

- Increased use of goods/vehicles
- Increased production of goods/vehicles
- Increased use of infrastructure
- Increased development of infrastructure

As with secondary enabling effects, the scale of adoption often drives the decision on whether to include or exclude individual rebound effects. Figure 7 provides illustrative rebound impacts.

[17] In SMART 2020, rebound effects are defined as "increases in demand caused by the introduction of more energy efficient technologies. This increase in demand reduces the energy conservation effect of the improved technology on total resource use."

Figure 7: Illustrative rebound effects

		Primary enabling effects		
		Reduced energy consumption	**Reduced travel/shipment**	**Reduced materials**
Associated rebound effects	**Primary rebound**	• **Home energy monitoring**: Increased energy use during non-peak periods in-lieu of use during peak periods	• **Telecommuting**: Increased home energy use *(e.g., heating and lighting on at home)*	• **Online media**: Increased computer use to browse and sample music
	Secondary rebound	• **Home energy monitoring**: Increased consumption of goods using savings from lower energy bill	• **Telecommuting**: Increased urban sprawl (and associated inefficiencies) from employees' ability to live further from office	• **Online media**: Increased computer and server manufacturing

In general, to avoid overstating the positive impacts of ICT implementation, greater levels of proof are needed for the exclusion of any rebound effect than for the exclusion of secondary enabling effects. Unfortunately, the uncertainty of rebound effects, especially secondary rebound effects, makes them difficult to quantify. However, performing sensitivity analysis during assessment and presenting a range of potential net enabling effects can mitigate this uncertainty. This conservative approach to assessment will enhance the credibility of the reported net enabling effect.

Illustrative example: Assessment of delivery optimization software – Step 1

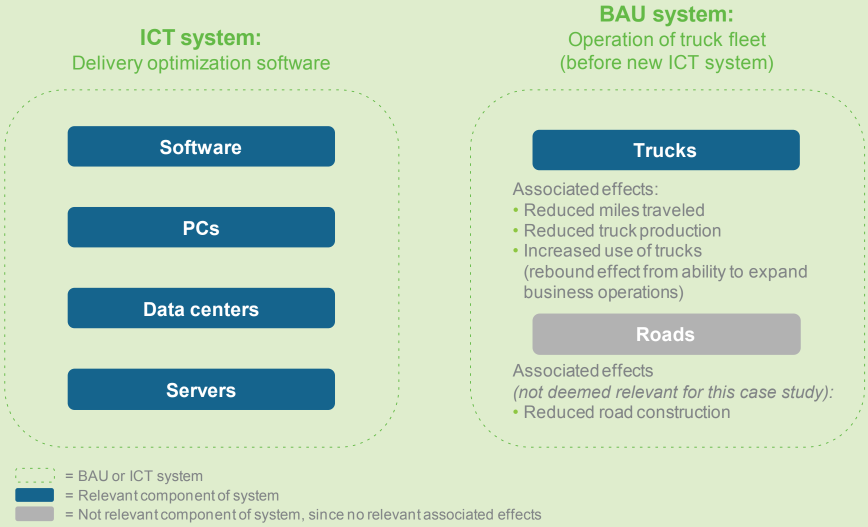
A hypothetical case study will illustrate use of the ICT Enablement Methodology. Assume a company has developed a software solution that optimizes delivery schedule and load times thus reducing unnecessary truck travel. This ICT solution falls within the SMART category of SMART logistics. In 2008, the SMART 2020 Report estimated that logistics network optimization could lead to a 0.34 $GtCO_2e$/yr reduction in emissions by the year 2020 relative to a business-as-usual scenario. Our hypothetical company would like to use the ICT Enablement Methodology to quantify the extent to which its own ICT solution can reduce CO_2e emissions.

For the hypothetical company, the goal of the delivery optimization software study is to produce an accurate range for the total emissions reduction potential from a customer implementing its software. The BAU system was defined as the client's trucking operations—or its pickup, transport and delivery of goods. The ICT system was defined as the network of software, PCs, servers and data centers required to implement the solution across the organization. The ICT solution improves the BAU trucking operations, via its network logistics optimization intelligence. Thus the primary enabling effect is reduced travel/shipment.

For secondary enabling effects, the company considered all the potential implications of reduced vehicle use over time. It identified the following potential effects: reduced future vehicle production (as existing vehicles would be able to make more deliveries and be kept in service longer) and reduced road construction and upkeep (as reduced vehicle use lowered the burden on road infrastructure). Given that the scale of adoption would be a full roll-out across the company's 500-truck fleet, avoided road construction and upkeep was deemed irrelevant. It would take a significantly larger scale of adoption before infrastructure impacts became relevant.

Finally, the company needed to document potential rebound effects. It did not identify any primary rebound effects (those occurring within a short-time frame as a result of implementation). However, over time, it expected some increase in business operations resulting from the time and money saved by reducing vehicle routes. In other words, as improved logistics fed into the company's bottom line, the operational impact would be greater shipments of goods and increased truck loads or routes. This rebound effect was considered relevant to include.

Figure 8: Illustrative ICT and BAU system components



In this example, the ICT system was defined as the network of software, PCs, servers and data centers required to implement the delivery optimization software. The software, PCs, data centers and servers are each "components" of the ICT system. The BAU system is defined as the trucking operations, made up of the many components needed for the fleet to operate. For the ICT Enablement Methodology, it is not necessary to define all possible components of the BAU system, but rather to focus on the relevant components of the system for assessment. Relevant components for the system are those that are impacted (through increased or decreased emissions) by the ICT solution. In this example, the enabling and rebound effects considered relevant by the end of Step 1 are reduced miles traveled, reduced truck production and increased use of trucks. The associated component for these effects is the truck fleet.

Step 2: Limit assessment

In Step 1, the relevant set of primary and secondary enabling and rebound effects are identified. Step 2 is focused on limiting the breadth of assessment of these relevant effects. For the components of the BAU and ICT system associated with these effects, only those processes[18] within the product life cycle that significantly impact carbon emissions are included for rigorous assessment in Step 3a. In many cases, entire life cycle stages may be excluded from additional assessment. To help identify potential life cycle processes or full stages to exclude, the concept of a BAU reference value is introduced below.

ISO 14044:2006 states: "The deletion of life cycle stages, processes, inputs or outputs is only permitted if it does not significantly change the overall conclusions of the study. Any decisions to omit life cycle stages, processes, inputs or output shall be clearly stated, and the reasons and implications for their omission shall be explained."[19] A screening assessment of all life cycle processes is required before a process or full stage can be excluded.

Step 2 provides opportunities to simplify assessment by excluding life cycle processes that will not significantly change the overall conclusions of the study. However, should the intended audience desire consideration of all life cycle processes for relevant components of the BAU and ICT system, it is reasonable to bypass Step 2 and move directly to assessment in Step 3.[20]

[18] ISO defines a process as a "set of interrelated or interacting activities that transforms inputs into outputs" (ISO 14044, 9). Note that for the purposes of the ICT Enablement Methodology, the term "processes" is used in a broad sense to cover all carbon-generating activities associated with a product or service over its entire life cycle, e.g., extraction of raw materials, materials processing and manufacturing, product use and disposal.

[19] ISO 14044:2006, Environmental management – Life cycle assessment – Principles and framework, in 4.2.3.3.1 setting of the system boundary, 8.

[20] Life cycle processes or stages may be recommended for inclusion even when the associated emission volumes are determined not significantly to impact the overall net assessment. This may occur if the intended audience identified in Step 1a demands a high degree of rigor in assessment. Furthermore, defining "significance" is as much art as it is science, requiring careful consideration of the goal and scope of the study as well as thorough documentation of choices on whether to include or exclude certain impacts or life cycle stages.

Step 2a: Estimate BAU reference value

The implementation of an ICT solution reduces emissions of the BAU system. In many cases, the reduction in emissions of a single process or stage of a single BAU component will contribute a disproportionate amount to the overall net reduction. For example, a logistics optimization solution will disproportionately reduce emissions generated during use of vehicles. [21] Identifying this life cycle process or stage and obtaining a preliminary quantification for the scale of its contribution is a useful tool in the "limiting" step of the ICT Enablement Methodology.

The "BAU reference value" is the change in emission volume of the BAU life cycle process presumed to be the major driver of reduced emissions.

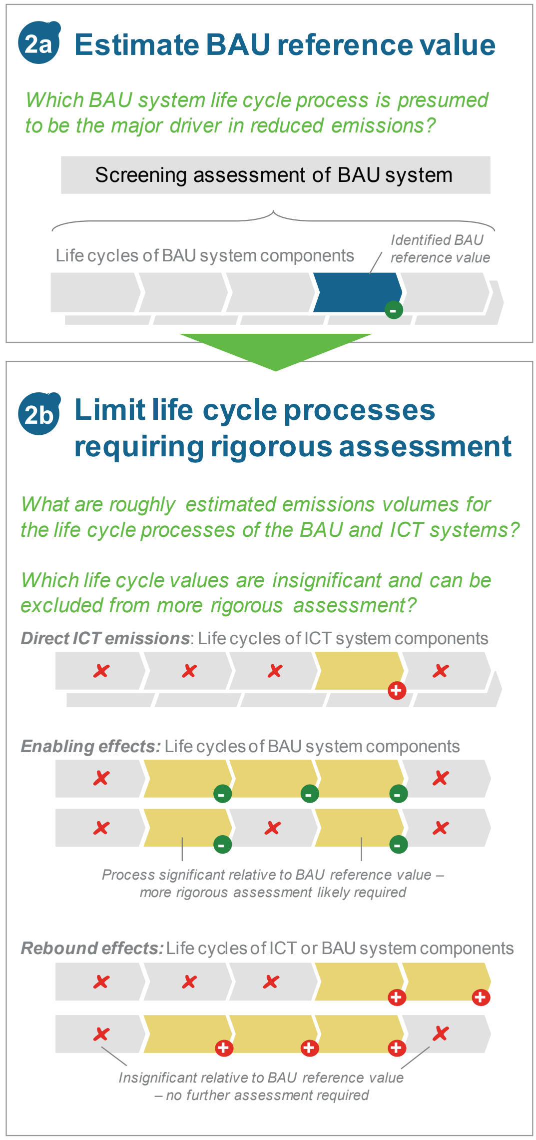
The purpose of the BAU reference value is to establish a point of comparison by which other "insignificant" life cycle processes or stages can be excluded from more rigorous assessment. In some situations, multiple life cycle processes or stages (perhaps even spanning multiple systems) drive substantial reductions in emission. Because the BAU reference value is intended as a means of excluding only the processes or stages that are magnitudes smaller, these and all other significant emission-reducing processes or stages will be included in further assessment.

The BAU reference value may take the form of a numerical value, a numerical range, or an order of magnitude. As for the other measured or estimated components of an LCA, is typically established using one or more types of data:

1. Modeled data: Assumption-driven estimates that are forward looking or scaled up from smaller pilot studies

2. Secondary data[22]: Data that has been collected for another purpose, but can be analyzed again in a subsequent study; for example, LCA estimates by academia, government, or industry organizations for components of the ICT and BAU systems[23]

Figure 9: Step 2



3. Primary data: Data collected by a researcher, specifically for the research project; for example, pilot studies or customer or manufacturer surveys

Clearly, far more time and effort are required to establish a BAU reference value when shifting from use of readily available secondary data to modeled or primary data. Reliable secondary data should be used wherever possible in order to minimize time and effort necessary to quantify the BAU reference value. [24]

[21] In applying the methodology, a practitioner may believe impact occurs via processes of other life cycle stages, such as manufacturing of vehicles, and may even choose to use an estimate of reduced emissions from manufacturing as the BAU reference value. The choice of which life cycle process to use as the BAU reference value is driven by the practitioner's assumptions about which life cycle stage drives the greatest reduction in emissions. Regardless of the choice, the BAU reference value will allow exclusion of insignificant life cycle processes and stages.

[22] Definition of primary and secondary data from EPA Program Evaluation Glossary http://www.epa.gov/evaluate/glossary/all-esd.htm.

[23] Caution should be exercised in using dated secondary data. For instance, as technological innovation drives increased energy efficiency, the manufacturing stage processes may become a more significant driver of emissions relative to the use stage processes; this may not be reflected when outdated secondary data is used. As a corollary, as secondary or modeled data improve over time, assessments may need to be updated with the most up-to-date figures.

[24] Allocation of environmental impacts may be required when the ICT system is only responsible for a fraction of the environmental impacts from any given data source (for example, if the ICT product is manufactured in a factory where other products not considered in assessment are also manufactured or if a service such as connectivity is allocated based on time of use or data traffic). ISO provides guidance on allocation procedures, which may be used as needed (such as for quantifying BAU reference/reference value or emission volumes for other life cycle processes).

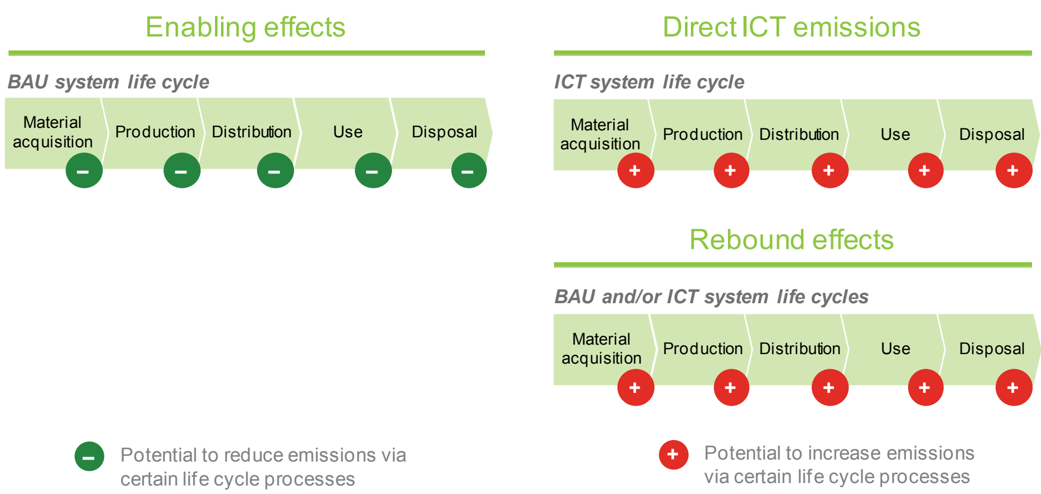
Step 2b: Limit life cycle processes requiring rigorous assessment

For each effect identified as relevant and within the scope of the study in Step 1b, the change in emissions for each life cycle process should be estimated via a screening assessment. Modeled, secondary or primary data can be used, with preference given to readily accessible secondary data (as is the case when establishing BAU reference value). The BAU reference value is meant to be a tool to help determine which life cycle processes or stages are insignificant. For instance, the practitioner could determine that any life cycle process representing less than 1% (or 5% or 10%) of the reference value should be insignificant. Insignificant processes or full stages can then be excluded from more rigorous assessment in Step 3. Note that where several insignificant processes are excluded, consideration of their aggregate contribution to emissions is required because, when taken together across multiple enabling and rebound effects, insignificant processes could have a substantial impact.

For many—but certainly not all—ICT solutions, the use stage and its associated processes will generate the greatest added emissions relative to the BAU reference value. For example, the energy consumed by a videoconferencing system over its lifetime may far exceed its "sunk" embodied carbon volume or the carbon emitted during its disposal. Thus, only the operation of the system (i.e., its use stage) may be significant relative to the BAU reference value.

In the absence of established assessment standards for a given type of ICT solution, it is necessary to estimate independently the impact for each life cycle process (with estimates taking the form of numerical values, ranges or an order of magnitude).

Figure 10: BAU and ICT life cycle processes evaluated via screening assessment



Illustrative example: Assessment of delivery optimization software – Step 2

For the primary enabling effect, the use of the truck fleet of our hypothetical logistics software company is the only life cycle process to consider as the BAU reference value, as the trucks have already been produced and cannot be "un-made" as a result of the new system.

The company establishes a BAU reference value for its study using secondary and modeled data. A model-based estimate is made of the number of miles that an average truck "wastes" annually, either due to poor route planning or because it is running empty. Next, secondary data from customers is used to estimate that the ICT solution cuts wasted mileage by 50%. The 50% estimate is multiplied by the average "wasted" miles. This figure is applied across the 500 trucks in its customer's fleet to calculate a total "miles saved" figure. Finally, this is converted from miles to CO_2e (using an established conversion factor) to arrive at an estimate of the annual carbon savings.

For the direct ICT emissions, the company considers all the necessary components to implement the solution—the software, PCs, servers and data centers required to run it—and uses secondary and modeled data to perform rough estimates on the life cycle processes of each. The ICT company finds that all life cycle processes of the software, servers and data centers are negligible and not necessary for inclusion in more rigorous assessment. The processes associated with the use stage of the PCs are significant and therefore deemed necessary to assess further in Step 3. All other PC life cycle processes and stages are found to be negligible.

The company estimates that, as a result of the ICT solution, it will not have to buy as many vehicles each year. The reduced emissions associated with this secondary enabling effect are deemed significant relative to the BAU reference value. The ICT company also determines that the secondary rebound effect from increased net incomes will be worth considering in Step 3. It bases this decision on a 2007 report by the UK Energy Research Centre that highlights the likelihood of economy-wide rebound effects arising from energy efficiency improvements. Observing the conservatism principle, the ICT company decides to estimate a range of potential secondary rebound effects in Step 3.

Step 3: Assess and interpret

The final step in the ICT Enablement Methodology is to assess more rigorously and aggregate the relevant effects and life cycle processes identified in Steps 1 and 2, and interpret these results in the context of all assumptions made and of any potential uncertainty.

Step 3a: Rigorously assess significant life cycle processes

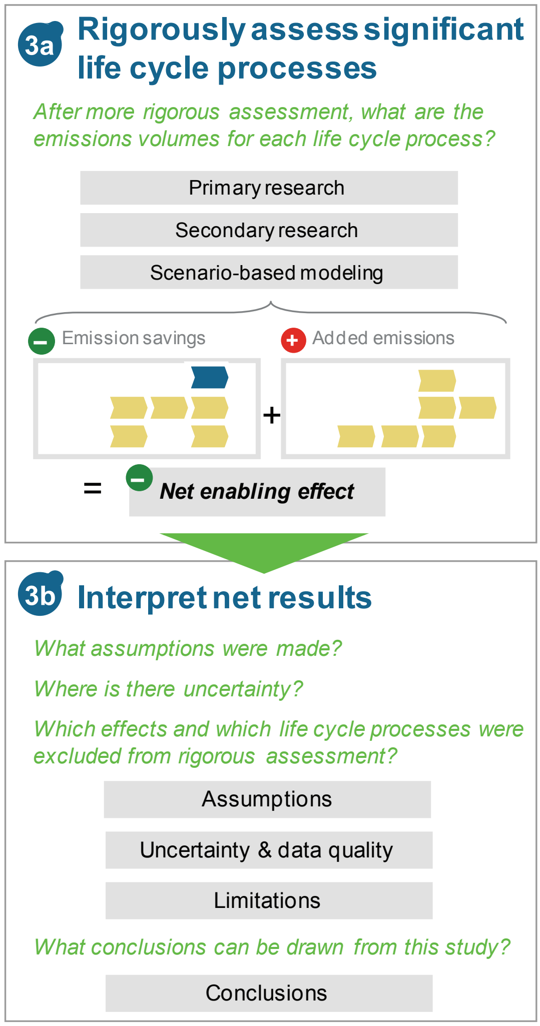
Only relevant effects and life cycle processes, as established in Steps 1 and 2, are necessary to quantify net enabling effects for the purposes of the ICT Enablement Methodology.[25] However, it is up to the practitioner's discretion to determine whether or not to include insignificant life cycle processes or stages in Step 3a, as the change in emissions has already been estimated in Step 2. Including these impacts can further bolster the comprehensiveness of the study and underscore the more complete LCA scope of inclusion. Whether or not these are included should be clearly documented and justified in Step 3b during interpretation.

Figure 12 illustrates the concept of net enabling effect based on decreased emissions from the BAU system, and increased emissions from the ICT system and related rebound effects.

In most cases, the assessment performed in Step 3a will be more rigorous than any preliminary estimate used to establish life cycle limits in Step 2. While secondary data is appropriate and even recommended for establishing the significance of life cycle processes in Step 2, it may not satisfy demands for a robust final assessment. In Step 3, primary data is considered the "gold-standard", as it best captures real-world adoption and behavioral changes.

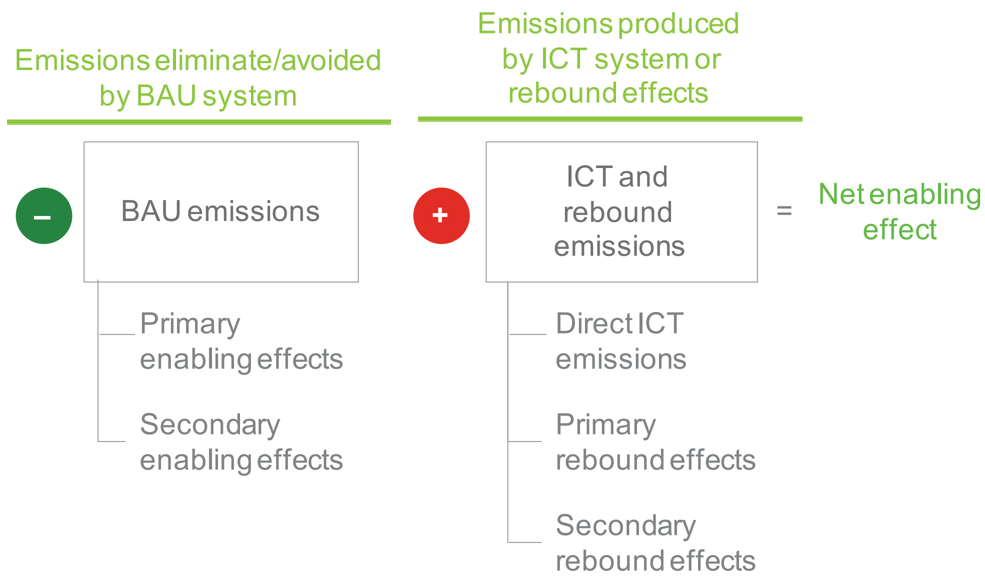
However, where the scale of adoption is particularly large or where the assessment is forward-looking, assumption-based modeling may be necessary. This may also be required when collecting primary or secondary data for a life cycle process proves too difficult. Whenever assumption-based modeling is used, different scenarios should be assessed to establish a range of potential outcomes and limit uncertainty. For instance, it is critical to estimate the level of adoption of the ICT solution, considering both conservative and optimistic scenarios for these factors. Appendix 3 more fully describes situations in which different sources of data would be appropriate for use.

Figure 11: Step 3



[25] ISO provides additional guidance on process of life cycle impact assessment (LCIA), though for purposes of ICT Enablement Methodology this process should be straight-forward as assessment is limited to global warming (versus other impact categories such as acidification, land use) and category indicator is limited to CO_2e emissions; thus, LCIA may be considered as implicit component of assessment and interpretation step of ICT Enablement Methodology.

Figure 12: Calculation of net enabling effect



Step 3b: Interpret net results

Interpretation of results includes documentation of how the methodology was applied and should address the following subjects:

- Assumptions
- Limitations
- Uncertainty and data quality
- Conclusions

All underlying assumptions and exclusions of enabling and rebound effects in Step 1 should be documented and justified, as should those life cycle processes or full stages considered insignificant and excluded from further assessment in Step 2. Assumptions related to allocation of impacts should also be well documented. For example, documentation should include whether the allocation of collected data is based on physical quantity or economic-level data and across which life cycle processes of an ICT product it has been applied.

Uncertainty of results must also be addressed. Often this will be most relevant for modeled data. In line with ISO, uncertainty analysis is recommended "to quantify the uncertainty introduced in the results … due to the cumulative effects of model imprecision, input uncertainty and data variability."[26]

Data quality should be considered when assessing uncertainty. Weaknesses of primary data could include any potential biases (such as a pilot study across potentially non-representative populations). Weaknesses of secondary data may arise from use of a dated study.

The ICT Enablement Methodology does not propose any standardized approach to Step 3b, as the output will vary in each case.[27] The practitioner should provide transparent assessment of how the methodology was applied, to provide a source for future studies and knowledge creation.

[26] ISO 14044:2006, Environmental management – Life cycle assessment – Principles and framework, 5.

[27] Further guidelines are provided in the ISO standard, including specific topics to address for third party/external reports.

Illustrative example: Assessment of delivery optimization software – Step 3

The ICT company's ultimate goal in its study was to reach an estimated net enabling effect for a company with a 500-vehicle fleet. This was obtained by performing sensitivity analyses on the values determined relevant in Step 2: reduction in travel (BAU reference value), avoided purchases of new trucks, use of PCs and secondary rebound effects due to expanded business operations. The average outcome from these various scenarios was reported as the expected net enabling effect.

In Step 3b, the company explained that precise calculation of the net enabling effect was difficult because of its heavy reliance on modeled data and assumptions. As such, it presented the entire range of estimated outcomes to disclose all potential results. It pointed out the inherent uncertainty in estimating the secondary rebound effects and highlighted a need for future study in this area. However, it concluded that, despite the obstacles, the ICT Enablement Methodology provided the most reliable and robust assessment of the net enabling effect.

03: Application of Methodology

Introduction to case studies

The following case studies have been developed to illustrate application of the ICT Enablement Methodology in real-world settings. These case studies were also used to test and refine the methodology during its development.[28] They focus on application of the methodology, and therefore do not capture additional benefits arising from implementing ICT solutions, such as improved work-life balance for employees from telecommuting or the financial gains a company realizes by adopting an ICT solution such as a telepresence system.[29]

The case studies highlight application of the methodology in a variety of scenarios. For example, the form of direct enabling impact, the intended audience and the significance of ICT and BAU life cycle processes vary extensively across the case studies. The case studies also illustrate a number of key terms and concepts in the methodology such as the identification of a BAU reference value and limiting of life cycle processes or stages from more rigorous assessment. Finally, the case studies highlight the simplicity of the methodology. Whereas the conceptual description of the methodology is intended to address all possible scenarios—that is, any form ICT solution with varying types of impact and assessment intended for multiple audiences—the actual application of the methodology usually leads to a far more streamlined assessment process. Figure 13 summarizes the different case studies.

[28] The intent of the case studies is to demonstrate the application of the ICT Enablement Methodology; they are not intended to endorse any particular ICT solution. The case studies were developed with input from the respective organizations conducting the original research upon which each case study is based. These organizations have confirmed that the data and information provided is, to their knowledge, the most accurate and representative available at the time of the report creation. Neither BCG nor GeSI have independently verified the data and assumptions used in these case studies.

[29] Carbon Disclosure Project Study 2010, The Telepresence Revolution (produced by Verdantix, and supported by AT&T), found that through global deployment of telepresence, US and UK businesses with annual revenues of more than $1 billion could achieve economy-wide financial benefits of almost $19 billion by 2020.

Figure 13: Overview of case studies

	SMART area	Location	Description
1 Home energy monitoring kit	SMART grids	United Kingdom	Energy savings in household before and after installation of AlertMe home energy monitoring kit
2 HVAC automation system	SMART buildings	United States	Energy savings in building complex after installation of HVAC automation system
3 Eco-driving software solution	SMART logistics	United Kingdom	Fuel efficiency gains across 350+ vehicle fleet after software implementation
4 Telecommuting	Dematerialization	United Kingdom	Assessment of whether telecommuting has positive net enabling effect despite rebound effect of increased home energy use
5 E-health delivery system	Dematerialization	Croatia	Emission-reducing impact of e-referral and e-prescription services in Croatia
6 Telepresence system	Dematerialization	Multinational company	Assessment of net enabling effect from company-wide adoption of telepresence

Case study 1: Home energy monitoring kit

[30] High-level description of this case study can be found at http://www.smart2020.org/case-studies/alertme/. Further work was done with AlertMe to understand the data used in this case study.

AlertMe provides residential clients with home energy monitoring kits to increase user information about energy consumption. By observing their consumption patterns, homeowners are able to modify their behaviors to optimize energy use. The solution includes a meter reader that clips to the home's electric meter, a wireless hub that compiles usage data to be viewed online and smart plugs that allow remote control of individual appliances.[30]

Figure 14: Home energy monitoring kit case study

Summary

Assessor and location of ICT solution

ALERT ME Cambridgeshire, UK

Smart opportunity area

Smart grids: user information
- Estimated 2020 abatement potential: 0.28 $GtCO_2e$†

Description of assessment

Energy savings in household before and after installation of AlertMe home energy monitoring kit

Net enabling effect

Reduced emissions by 4.33tCO_2e/household/yr (pilot study result)

Sources of data

Pilot primary data only; larger study in progress

Goal of study

Purpose of study

Produce a consumer-ready claim of potential CO_2e reduction from ICT implementation

Intended audience

Individual homeowners

Scope of study

Direct ICT emissions

Increased emissions from home energy monitoring kit

Enabling effects

Primary: reduced energy consumption
Secondary: none assessed

Rebound effects

Primary: increased non-peak consumption
Secondary: none assessed

†Source: *SMART 2020: Enabling the low carbon economy in the information age*

Step 1: Define goal and scope

Step 1a: Define goal of study

Because the AlertMe home energy monitoring kit is a product marketed to consumers, the purpose of this study is to produce a figure for the potential CO_2e reduction from implementation that can be marketed to the intended audience—individual homeowners looking to lower their carbon footprint. No assumptions are made about units sold across broad swathes of the population, so the scale of adoption is low.

Step 1b: Define scope of study

The ICT system for the AlertMe kit consists of all its necessary components—the meter reader, wireless hub, smart plugs and batteries. The BAU system can be defined as the home prior to implementation of the kit.

Figure 15: ICT system, BAU system, and their components

System	Description	Components of system	
ICT	*Home energy monitoring kit*	1 *Wireless hub* 2 *Meter clip*	3 *Smart plugs* 4 *Batteries*
BAU	*Home prior to installation of ICT solution*	1 *Home*	

Two effects occur shortly after implementation that are relevant to individual homeowners—reduced energy consumption in the home, as customers have new information on energy use (primary enabling) and increased non-peak energy consumption as they switch to less expensive non-peak hours (primary rebound). Both of these effects are driven by homeowner behavior readily verified via utility bills and thus are relevant to the intended audience.

Figure 16: Potential effects of home energy monitoring kit implementation

Category	Identified effects	Exclude?	Rationale for exclusion	System components assessed
+ Direct ICT emissions	*ICT emissions*			*Wireless hub, meter clip, smart plugs, batteries*
− Primary enabling	*Reduced energy consumption*			*Home*
− Secondary enabling	*Increased energy efficient purchases*	*Yes*	*Difficult to assess; likely small impact*	*Not applicable*
	Reduced power plant construction	*Yes*	*Relevant for large scale of adoption only*	*Not applicable*
+ Primary rebound	*Increased non-peak energy consumption*			*Home*
+ Secondary rebound	*Increased consumption of carbon intensive goods*	*Yes*	*Difficult to assess; occurs over long duration*	*Not applicable*

Reduced power plant construction (secondary enabling), increased purchases of energy efficient appliances (secondary enabling) and increased consumption of carbon intensive goods (secondary rebound) are effects that would take either significant time or scale of adoption to occur. These are beyond the goal and scope of assessment in the case of an individual homeowner.

Additional considerations: Intended audience

Assume that AlertMe was interested in communicating the benefits of installing an emission-reducing monitoring kit not only to individual homeowners, but to policy makers as well. In this case, AlertMe may endeavor to assess impact at a much larger scale—for example installation across a million homes. The intended audience, policy makers, would be interested in a much broader set of impact considerations, which would require different choices when applying the methodology.

For example, it might be relevant to consider the avoided need for increased power generation capacity in Step 1b as a secondary enabling effect. A policy maker may also want to understand secondary rebound effects more thoroughly. Estimates of the economy-wide impact of indirect rebound effects from energy savings are upwards of 50% in the UK (source: UK Energy Research Centre, "The Rebound Effect", 2007). In other words, more than half of the carbon emissions reduction from decreased home energy use could be offset by increases in other forms of consumption. This is clearly a relevant consideration when broad-based implementation is being explored.

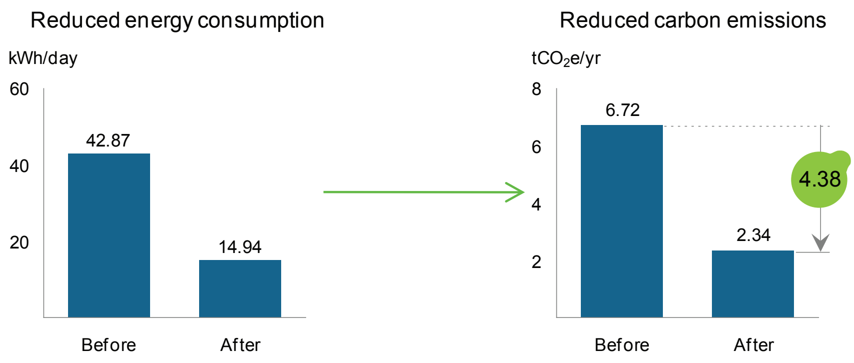
Step 2: Limit assessment

Step 2a: Estimate BAU reference value

The primary enabling effect for the AlertMe kit was defined in Step 1a as reduced energy consumption. The ICT solution is added to the existing BAU system, so there is no avoidance of the creation of the BAU system (because the home already exists). No disposal of the existing BAU system is necessary. As such, we can limit our BAU reference value search to the use stage process of home electricity consumption.

To quantify the BAU reference value, AlertMe conducted a small-scale pilot study to assess the impact of its kit on home energy use. It observed electricity consumption for a single home over the course of 15 months.[31] The result showed an annualized CO_2e reduction of 4.38 tons.[32] While the usage patterns of this individual household are insufficient to justify any positive claims about the AlertMe kit's ability to reduce carbon emissions, it does give a rough idea of the emissions reduction potential of the kit. The BAU reference value will help determine which life cycle processes from relevant effects are significant and worth considering in Step 3.

Figure 17: Estimate of BAU reference value for home energy monitoring kit assessment



[31] While this does not control for seasonality or the individual characteristics of this homeowner, the purpose of this step is to estimate a magnitude for the BAU reference value, not to quantify it precisely. Those issues should, however, be considered in the Step 3 assessment and interpretation.

[32] The household studied was a six-bedroom home with a high level of energy consumption, creating greater potential for reduction than in the average UK home. However, the average AlertMe customer tends to have much higher than average consumption. Conversion factor used was 0.43 $kgCO_2e/kWh$; description and rationale for this conversion factor can be found at: http://www.defra.gov.uk/environment/business/reporting/pdf/ghg-cf-guidelines2008.pdf.

[33] This rough LCA did not include an emissions estimate for distribution or disposal stage processes. AlertMe ships its kits from China to the UK, so in an actual application of the methodology, it would be necessary to provide an estimate for the emissions associated with transportation. Similar estimates would be required for the disposal stage processes of the home energy monitoring kit (for example, shipment, recycling, incineration or other final disposal).

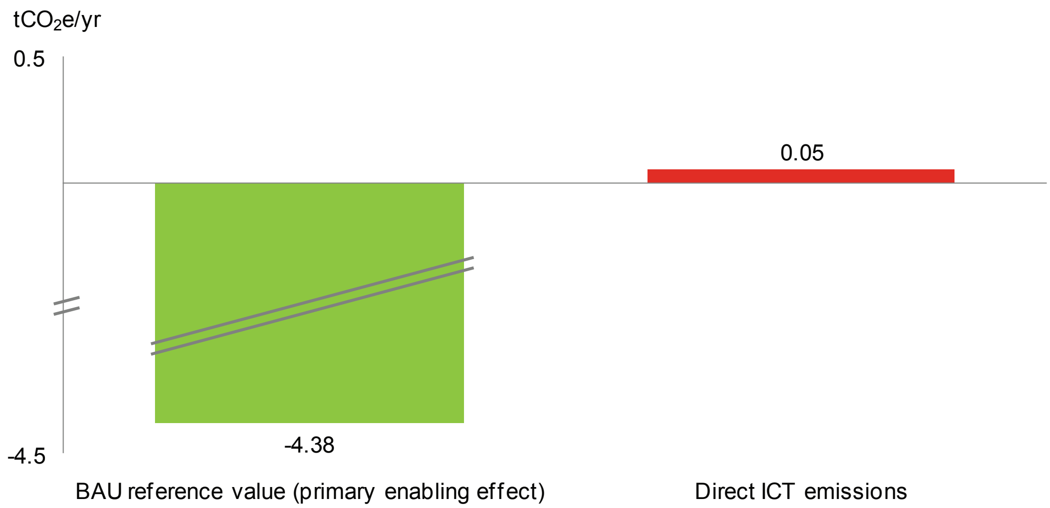
Step 2b: Limit life cycle processes requiring rigorous assessment

In Step 1, the relevant effects were determined to be the direct ICT emissions, reduced energy consumption (primary enabling) and increased non-peak hour consumption (primary rebound). We will address each in turn.

Direct ICT emissions

The AlertMe kit consists of a wireless hub, meter clip and smart plugs. A back-of-the-envelope LCA on a home energy monitoring kit from secondary sources was used to estimate the relative magnitude of direct ICT emissions compared to the BAU reference value. After amortizing the emissions from manufacturing over the expected life of the system, the emissions were estimated to be 0.05 tCO_2e/yr. The relative magnitude compared to the BAU reference value is miniscule, with the resulting conclusion that a full-scale LCA on the ICT system is unnecessary in Step 3.[33]

Figure 18: Estimate of direct ICT emissions relative to BAU reference value



Primary enabling effect

For the primary enabling effect, we already determined in Step 2a that the processes of the use stage were the only life cycle processes worth considering.

Primary rebound effect

The primary rebound effect of increased non-peak energy consumption can be limited to the processes of the use stage for the same reason as the primary enabling effect. To determine the magnitude of this impact, AlertMe observed electricity use during peak and non-peak hours for its pilot household. The data showed that consumption actually decreased during both peak and non-peak hours. The implication is that this direct rebound effect is negligible.

Step 3: Assess and interpret

Step 3a: Rigorously assess significant life cycle processes

AlertMe is currently conducting a Step 3 evaluation in which it is evaluating the energy savings across 50 homes over several years. Based on the limiting of life cycle processes completed in Step 2b, and assuming its intended audience remains individual homeowners, AlertMe can focus solely on the processes of the use stage of the BAU system when assessing the expected carbon-mitigating impact of the company's technology. The end result will be a marketable figure for the net enabling effect arising from the implementation of its system in an individual household.

Step 3b: Interpret net results

After AlertMe obtains the net enabling effect, it should document clearly any remaining issues. Topic areas worth covering might include:

- Reasons for excluding certain effects and life cycle processes or stages
- The increasing relevance of secondary enabling and rebound effects as rates of adoption increase
- Uncertainty around the net enabling effect, since it is driven by changes in end-users' behavior

Interpreting the net enabling effect in the context of these issues is important for the credibility of the study.

[34] Description of this case study can be found at http://www.cypressenvirosystems.com/files/pdf/CountyofSantaClara_EnergySavings_Final.pdf Further work was done with Cypress Envirosystems to understand the data used in this case study.

Case study 2: HVAC automation system

Cypress Envirosystems' HVAC automation system is a retrofit solution for existing buildings that allows greater control of heating and cooling functions through the use of wireless pneumatic thermostats (WPTs) and wireless receiver hubs. The simple installation process does not incur disruption to existing occupants and involves only the disposal of the existing analog pneumatic thermostat.[34]

Figure 19: HVAC automation system case study

Summary

Assessor and location of ICT solution

CYPRESS ENVIROSYSTEMS™ Santa Clara County, CA

Smart opportunity area

Smart buildings: HVAC automation
- Estimated 2020 abatement potential: 0.13 $GtCO_2e^{\dagger}$

Description of assessment

Energy savings in building complex after installation of HVAC automation system

Net enabling effect

Reduced emissions by 345 $tCO_2e/300K\ ft^2$ building/yr (pilot study result)

Sources of data

Pilot primary data only; larger study in progress

Goal of study

Purpose of study

Reliably estimate the emission savings from implementing solution to encourage larger adoption

Intended audience

Building owner/operators

Scope of study

Direct ICT emissions

Increased emissions from wireless thermostats and receiver hubs

Enabling effects

Primary: reduced energy consumption
Secondary: fewer maintenance trips

Rebound effects

Primary: none assessed
Secondary: none assessed

†Source: *SMART 2020: Enabling the low carbon economy in the information age*

Step 1: Define goal and scope

Step 1a: Define goal of study

The purpose of the study is to produce a reliable estimate of the CO_2e emissions reduction potential from implementing the HVAC automation system. The intended audience is any building owner/operator looking to reduce CO_2e emissions related to electricity consumption.

Step 1b: Define scope of study

The ICT system consists of the WPTs, batteries and receiver hubs necessary to implement the solution throughout a building. For this study, the building itself is the BAU system.

Figure 20: ICT system, BAU system, and their components

System	Description	Components of system
ICT	*HVAC automation system*	1 *Wireless thermostats* 2 *Receiver hubs* 3 *Batteries*
BAU	*Building, incl. HVAC system, prior to installation of ICT solution*	1 *Building* 2 *Vehicles*

For the building owner/operator, the relevant effects tend to be directly associated with management of the property. For example, the electricity saved by implementation (direct enabling) and the decreased need for maintenance of the building's HVAC system (secondary enabling) are relevant effects.

Figure 21: Potential effects of HVAC automation system implementation

Category	Identified effects	Exclude?	Rationale for exclusion	System components assessed
+ Direct ICT emissions	*Increased energy consumption from ICT system*			*WPTs, batteries, receiver hubs*
– Primary enabling	*Reduced energy consumption*			*Office building*
– Secondary enabling	*Reduced number of maintenance trips*			*Vehicles*
	Reduced power plant construction	*Yes*	*Requires much larger scale of adoption*	*Not applicable*
+ Primary rebound	*None identified*			*Not applicable*
+ Secondary rebound	*Increased building operations due to energy savings*	*Yes*	*Difficult to quantify and longer term effect*	*Not applicable*

Effects that occur further in the future or only after very large-scale adoption are irrelevant. The impact that a single building owner/operator will have on reduced power plant construction is minimal (secondary enabling).[35] Over time, energy savings could lead to building operations expansion (secondary rebound). However, it would be almost impossible to determine whether expanded operations were driven by natural growth in earnings or as a direct result of energy savings from the improved HVAC system. Thus, this effect should also be considered irrelevant.

[35] One caveat to this: if the customer was, for example, the federal government in the United States, and it decided to implement the HVAC automation system across all its properties, then the magnitude of impact might be large enough to consider avoided need for future power generation.

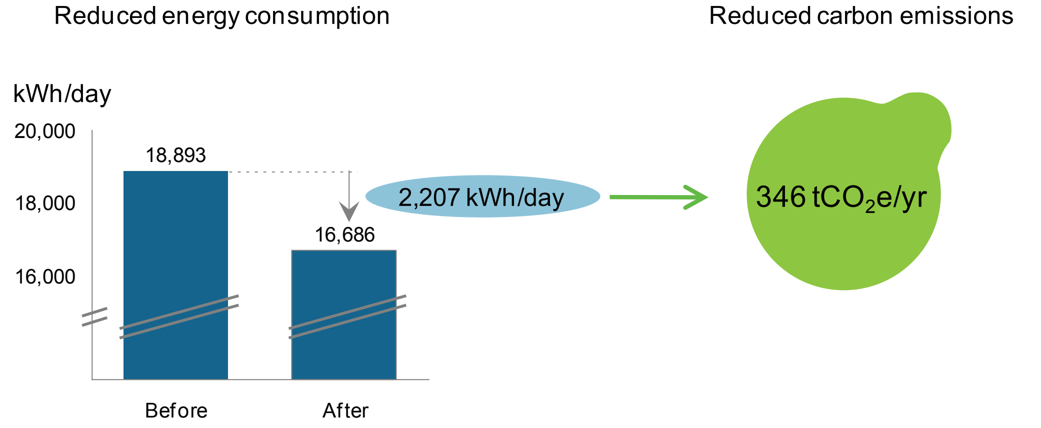
Step 2: Limit assessment

Step 2a: Estimate BAU reference value

The primary enabling effect of Cypress' HVAC automation system is reduced energy consumption. The ICT solution is added to the existing BAU (building) system. This means that all processes of the three pre-use stages are "sunk" embodied carbon that would never be considered as a BAU reference value. While some disposal is necessary (the original analog pneumatic thermometer is discarded), its impact is negligible since the primary materials are simple and recyclable metals and plastics. As such, we can limit our BAU reference value search to the use stage only.

To establish the BAU reference value, Cypress conducted a pilot study that observed electricity consumption for a 300,000-square-foot building complex. The results showed consumption for the months of September and October for the years before and after installation was completed (this was intended to limit seasonality). The observations showed a reduction in emissions of 346 tCO_2e a year/yr, or slightly more than 1.15 tCO_2e per 1,000 square feet annually. The BAU reference value will help determine which additional impacts and effects should be assessed in Step 3.

Figure 22: BAU reference value for HVAC automation system



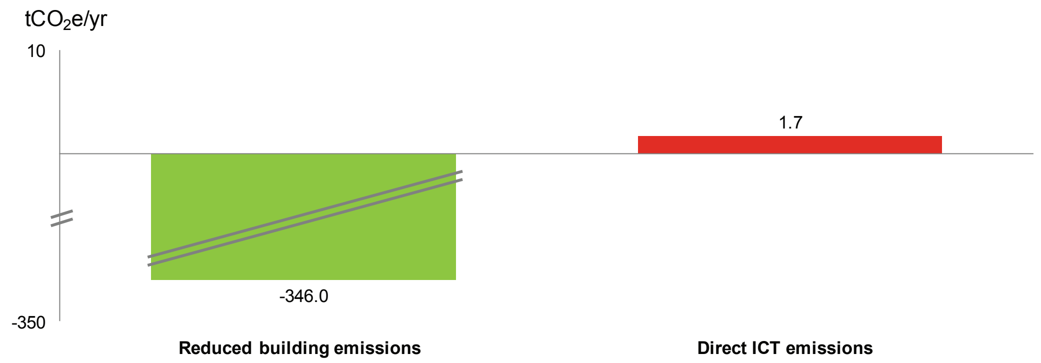
Step 2b: Limit life cycle processes requiring rigorous assessment

For Cypress' HVAC automation system, the relevant effects to consider include the direct ICT emissions, reduced energy consumption (primary enabling) and fewer trips to the building by maintenance staff (secondary enabling).

Direct ICT emissions

For the same pilot study used to obtain the BAU reference value, the following materials were used: 350 WPTs, each with two 3-volt batteries and 4 receiver hubs. Each hub uses approximately 1,000 kWh/yr while each WPT uses only 0.006 kWh/yr. The total carbon impact is less than 2 tCO_2e/yr.[36] Thus, the relative magnitude compared to the BAU reference value is minimal, with the resulting conclusion that a full-scale LCA on the ICT system is unnecessary in Step 3.[37]

Figure 23: Estimate of direct ICT emissions relative to BAU reference value



[36] Calculated using U.K. conversion factor of 0.43 $kgCO_2e/kWh$. Description and rationale for this conversion factor can be found at: http://www.defra.gov.uk/environment/business/reporting/pdf/ghg-cf-guidelines2008.pdf.

[37] This calculation considered only the processes of the use stage for the ICT system. However, following the spirit of the methodology, Cypress would conduct some rough measure of emissions associated with the non-use lifecycle stages so as to exclude more confidently direct ICT emissions from the impacts assessed in Step 3.

Primary enabling effect

For the primary enabling effect, we determined in Step 2a that the processes of the use stage were the only ones worth considering.

Secondary enabling effect

The reduced emissions associated with fewer maintenance trips were estimated using information on the annualized number of maintenance hours before and after installation, and the approximate distance traveled per visit. Using optimistic assumptions, the size of this secondary enabling impact was also minimal relative to the BAU reference value (approximately 0.3 tCO_2e/yr). The implication is that it is insignificant, and so unnecessary to consider in greater depth in Step 3.

Step 3: Assess and interpret

Step 3a: Assess significant life cycle processes

Cypress is currently engaged in a Step 3 study that will assess more thoroughly the reduced power consumption associated with its technology. Its analysis will cover 20 to 30 buildings over the course of several years. The end result should allow the company to produce a marketable claim stating the expected annual emissions reduction of switching from an analog, pneumatic thermometer-based HVAC system to a WPT-based HVAC system. By reporting this on a per-square–foot-basis, it will be applicable to a variety of building sizes.

Step 3b: Interpret net results

In the spirit of the methodology, the interpretation of the results in Step 3a should recap the decisions made in Steps 1 and 2 to exclude certain effects. Regarding potential uncertainty in the net enabling effect, the company may want to explore how emissions reductions from ICT implementation would vary in buildings of different ages, or in different geographies or climates. Cypress may also consider assessing proposed rebound effects, since none were identified during the course of the assessment of the HVAC automation system.

Case study 3: Eco-driving software solution

Microlise provides software solutions that allow companies to track the performance of their customers' drivers. It installs a small GPS- and GPRS-enabled electronics module, which is connected to existing on-board computers via the vehicle's network interface, to capture and relay back relevant driving and vehicle performance information. The web-based smart logistics software identifies good and bad driving skills in areas such as over-revving, accelerator position, speeding, harsh braking and idling. Drivers are given reports on their performance, from which they are able to adjust their behavior, reducing their fuel consumption and the associated emissions.

Figure 24: Eco-driving software solution case study

Summary

Assessor and location of ICT solution

microlise UK

Smart opportunity area

Smart logistics: eco-driving
- Estimated 2020 abatement potential: 0.25 $GtCO_2e$†

Description of assessment

Fuel efficiency gains across 350+ vehicle fleet after software implementation

Net enabling effect

Reduced emissions by 661 tCO_2e/350 vehicle fleet/yr

Sources of data

Secondary and modeled data for limiting step; primary data for assessment step

Goal of study

Purpose of study

Assess the carbon-mitigating potential of eco-driving software solution and use it to market to potential clients

Intended audience

Large fleet operators

Scope of study

Direct ICT emissions

Increased emissions from data centers, PCs and servers

Enabling effects

Primary: reduced fuel consumption
Secondary: none assessed

Rebound effects

Primary: increased fuel use during training
Secondary: decreased driver performance

†Source: *SMART 2020: Enabling the low carbon economy in the information age*

Step 1: Define goal and scope

Step 1a: Define goal of study

Microlise's eco-driving software solution is intended to improve fuel efficiency in large vehicle fleets. The purpose of the study is to quantify the impact of ICT implementation in the operations of a representative client, producing data that can be used in subsequent sales and marketing efforts. The intended audience is business clients who manage and operate large vehicle fleets. Implementation by a single client would be unlikely to have major impacts on infrastructure use and development. This will inform which effects are considered relevant in Step 1b.

Step 1b: Define scope of study

The ICT system includes GPS- and GPRS-enabled electronics module and the data centers and servers devoted to processing all the data collected by the on-board computer.[38] The BAU system for the eco-driving software solution is the truck fleet prior to any ICT implementation.

[38] This case study assumes that all trucks had on-board computers already installed. In reality, some older models require installation of the on-board computer as well, not just the software. This would be a consideration worth documenting in Step 3b.

Figure 25: ICT system, BAU system, and their components

System	Description	Components of system	
ICT	*Eco-driving software solution*	1 *Data centers* 2 *Servers*	3 *GPS-enabled module*
BAU	*Existing fleet of trucks*	1 *Vehicles*	

Based on the goal of the study, the only relevant effects are those that relate to the client's fleet operation. These include the reduced fuel consumption from ICT implementation (primary enabling), as well as the increased fuel consumption related to training (primary rebound). Also, after some initial improvements in driving behavior, drivers may revert back to old habits over time (secondary rebound).

Figure 26: Potential effects of eco-driving software solution implementation

Category	Identified effects	Exclude?	Rationale for exclusion	System components assessed
+ Direct ICT emissions	*Increased energy consumption from ICT system*			*Data center, servers*
− Primary enabling	*Reduced fuel consumption*			*Trucks*
− Secondary enabling	*Reduced refinery use*	*Yes*	*Requires much larger scale of adoption and longer time frame*	*Not applicable*
+ Primary rebound	*Increased fuel consumption from training*			*Trucks*
+ Secondary rebound	*Increased fuel consumption from poorer driver behavior*			*Trucks*
	Increased company operations due to fuel savings	*Yes*	*Difficult to assess and occurs over long duration*	*Not applicable*

For the intended audience, effects that occur well into the future or that require large-scale adoption are deemed irrelevant, including reduced refinery operations as less gasoline is consumed (secondary enabling) and expanded company operations as fuel savings flow into the bottom line (secondary rebound).

Step 2: Limit assessment

Step 2a: Estimate BAU reference value

Since the vehicles have already been built, the pre-use stages are "sunk" embodied carbon. And since no disposal of the vehicles occurs as a result of the eco-driving software, the BAU reference value must come from the use stage.

With this established, the value was estimated by referring to secondary data from the Environmental Protection Agency (EPA) and existing case studies on eco-driving. The average fuel efficiency improvement from eco-driving ranges from 5-20%.[39] Taking the most conservative figure of 5% fuel efficiency improvement, a BAU reference value of 1 tCO_2e/yr per vehicle was established.[40]

Step 2b: Limit life cycle processes requiring rigorous assessment

The relevant effects from Step 1b were used to select for inclusion in assessment the direct ICT emissions, reduced fuel consumption from the software solution (primary enabling), increased fuel consumption from training (primary rebound) and increased fuel consumption due to a deterioration in driver behavior (secondary rebound).

Direct ICT emissions

The ICT-based emissions are concentrated in the data centers and servers devoted to processing all data collected by the on-board computer and eco-driving software. Microlise estimated the use stage emissions per vehicle by taking the total energy consumption of one of its data centers, in kilowatt hours per year, and dividing by the approximate number of vehicles whose data was collected and processed at those centers. This resulted in an estimate for use-stage emissions of 0.0015 tCO_2e/yr for the direct ICT emissions.[41]

Note that this is very small relative to the BAU reference value, but only considers the use stage. In applying the methodology, one should also estimate the non-use processes of the direct ICT emissions including the manufacturing, distribution and disposal of the necessary servers. For the purposes of this illustrative case study, however, we will assume that Microlise did in fact conduct rough estimates for those figures, and that the direct ICT emissions remained insignificant relative to the BAU reference value.

Primary enabling effect

For the primary enabling effect, we determined in Step 2a that the use stage was the only life cycle process worth considering.

Primary and secondary rebound effects

The direct rebound effect of increased emissions due to training was found to be non-existent because all training is conducted in the normal course of business. With regards to the secondary rebound effect, Microlise observed from other clients that driver performance, on average, tended to level off over time but not deteriorate. Furthermore, where driver behavior deteriorates, the individuals responsible are more likely to be given remedial training or be released from their duties. If this remedial training does not result in improved driver behavior the employee will be dismissed. This should prevent a secondary rebound effect. Thus, neither rebound effect is significant relative to the BAU reference value.

Step 3: Assess and interpret

Step 3a: Rigorously assess significant life cycle processes

With the limitations in place from Step 2b, Microlise proceeded to quantify emission reductions across a 350+ vehicle fleet in the UK. The geographic diversity of the fleet across multiple depots and the significant variety in vehicle makes and models made this study a good representative sample for the impact of the eco-driving software solution on the

[39] http://www.drivingsustainability.com/files/EcoDrivingImpact.pdf.

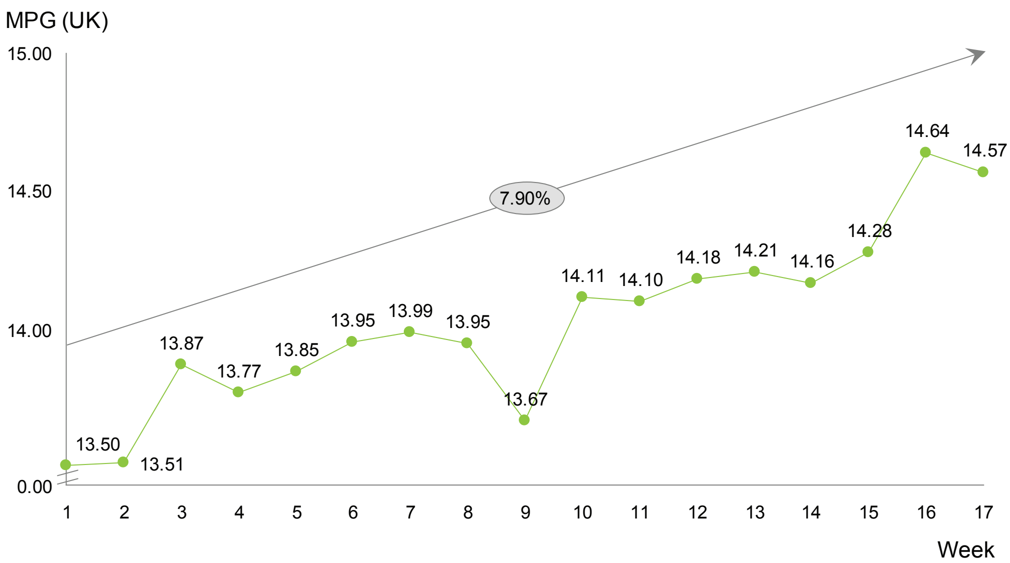
[40] For this estimate of BAU reference value, we assumed the vehicle traveled 90 miles/day at 15 miles/gallon. The 5% improvement in fuel efficiency means that gallons consumed fell from 6/day to 5.7/day. This was then converted to tCO_2e using the EPA's conversion factor of 0.0088 tCO_2e/gal and annualized.

[41] Total energy consumption was 42,120 kWh/yr, which was then amortized across the approximately 12,000 vehicles managed from that site and converted to CO_2e using the DEFRA conversion factor of 0.43 $kgCO_2e$/kWh.

average truck and driver in the UK.

The results of the study, taken over the course of 17 weeks, showed a 7.9% improvement in fuel efficiency, which was equivalent to an annualized emission reduction of 661 tCO_2e.

Figure 27: Assessment of eco-driving software solution



Step 3b: Interpret net results

The results from the previous step achieve the original purpose of the study. Microlise will be able to highlight those results in future discussions with clients. However, in applying the methodology, the results should be accompanied by a discussion of the lingering uncertainties. For example, although direct ICT emissions (data centers and PCs) and long-term driver behavior were deemed insignificant in Step 2, it may be worthwhile considering these factors as potential areas for additional research. Also, the company may clarify that it did not take into account any installation of on-board computers on older vehicles, as this was not relevant to the client in the case study. Finally, Microlise might note that a control group could be a useful addition to this or future studies; for this initial study, the week 1 fuel efficiency performance served a useful proxy for base case MPG.

While these considerations would be unlikely to affect materially the outcome determined in Step 3a, their documentation at this stage would add to the evaluative strength of Microlise's study.

[42] Description of this case study can be found at: http://www.smart2020.org/case-studies/bt-agile-worker-energy-and-carbon-study/. Further work was done with BT to understand the data and develop this case study.

Case Study 4: Telecommuting

Telecommuting refers to work that occurs outside the traditional office, using ICT to avoid the need to be physically located in the office.[42]

Figure 28: Telecommuting case study

Summary

Assessor and location of ICT solution

BT — Suffolk, UK (scaled to national level)

Smart opportunity area

Dematerialization: telecommuting
- Estimated 2020 abatement potential: 0.26 $GtCO_2e$†

Description of assessment

Assessment of whether telecommuting has positive net effect despite rebound effect of increased home energy use

Net enabling effect

Reduced emissions by 14.3 $ktCO_2e$/yr, equivalent to 1.4 tCO_2e/employee/yr

Sources of data

A mix of pilot primary, secondary and modeled data was used

Goal of study

Purpose of study

The purpose was to understand whether telecommuting has a net enabling effect, in spite of increased home energy use

Intended audience

Internal stakeholders and industry bodies

Scope of study

Direct ICT emissions

None assessed

Enabling effects

Primary: reduced private vehicle travel
Secondary: reduced public vehicle travel, reduced building use

Rebound effects

Primary: increased home energy use
Secondary: none assessed

†Source: *SMART 2020: Enabling the low carbon economy in the information age*

Step 1: Define goal and scope

Step 1a: Define goal of study

The purpose of this case study was for BT to understand whether telecommuting has a net enabling effect of reducing emissions, in spite of increased home energy use.

The intended audiences, to whom the results were communicated, were the company's internal stakeholders as well as broader members of industry and policy sectors. The intended scale of adoption was at a company-wide level. The results would allow BT to decide whether policies should incentivize or discourage employee telecommuting, and whether to roll out telecommuting more broadly.

Step 1b: Define scope of study

The ICT system included all components required for telecommuting, including PC, printer and underlying infrastructure such as data centers, servers and networking connections. The BAU system for this case study was the commute from home to office for BT employees.

Figure 29: ICT system, BAU system, and their components

System	Description	Components of system	
ICT	*Telecommuting system*	1 *PCs* 2 *Printers* 3 *Data centers*	4 *Servers* 5 *Network connections*
BAU	*Home-to-office commute*	1 *Private vehicles* 2 *Public vehicles*	3 *Home* 4 *Office building*

All potential rebound and enabling effects from telecommuting would be identified, a decision on their relevance for further assessment would be made, and associated system components would be identified for relevant effects. Figure 30 summarizes these decisions below. Given the goal of the study—to determine the benefits of telecommuting and convey these benefits to internal stakeholders and industry bodies—only effects occurring in immediate short timeframe and with a relatively low scale of adoption (company-wide for BT) require further assessment.

Figure 30: Potential effects of telecommuting implementation

Category	Identified effects	Exclude?	Rationale for exclusion	System components assessed
+ Direct ICT emissions	*Emissions from ICT equipment required for telecommuting*	*Yes*	*No change between BAU scenario and telecommuting*	*Not applicable*
– Primary enabling	*Reduced private vehicle use*			*Private vehicle*
– Secondary enabling	*Reduced public vehicle use*			*Public vehicle (rail)*
	Reduced building use			*Office energy*
	Reduced building construction	*Yes*	*Longer time-frame, beyond goal of study*	*Not applicable*
	Reduced road congestion and construction	*Yes*	*Greater scale of adoption than BT required*	*Not applicable*
+ Primary rebound	*Increased home energy use*			*Home building*
+ Secondary rebound	*Increased urban sprawl*	*Yes*	*Requires greater scale of adoption and time then defined by goal of study*	*Not applicable*

Reduced private vehicle use (primary enabling), reduced building use (secondary enabling) and increased home energy use (primary rebound) occur either immediately or within a short timeframe after telecommuting adoption, and therefore are considered relevant for further assessment. Reduced building use is a result of reduced demand for desks in the office and reduced need for heating, lighting and other energy-generating equipment in the workplace. Increased home energy use is an immediate effect of employees working from home rather than the office.

Reduced use of trains by a single company would not immediately lead to less frequent train routes, but with sufficient scale, this could become a very real effect. However, in applying the methodology, reduced public vehicle use (secondary enabling) would have been excluded as greater scale of adoption would be required to reduce the frequency of train services. BT was more comprehensive in its assessment and made efforts to understand the impact from reduced vehicle use. Should the number have been significant, then a caveat in reporting of the figures would help to identify those effects requiring greater time (or scale of adoption) to materialize.

Reduced building construction (secondary enabling), reduced road congestion and construction (secondary enabling) and urban sprawl (secondary rebound) are excluded, as it would take greater time and scale of adoption for these effects to materialize, and therefore is beyond the goal and scope of the study.

Step 2: Limit assessment

Step 2a: Estimate BAU reference value

The primary enabling effect defined in Step 1b was reduced travel by private vehicles (car). These private vehicles already exist, so the emissions generated during pre-use stages are "sunk" embodied carbon and not relevant for consideration as a BAU reference value (or for further assessment). Telecommuting does not necessitate disposal of these vehicles, so estimating the BAU reference value will come from estimating changes in emissions levels from the processes of the use stage of private vehicles at the company-wide level.

In applying this methodology, BT would have been able to consult secondary data on reduced vehicle use-stage emissions from telecommuting, and model it to extrapolate the potential impact at a company-wide level.

Step 2b: Limit life cycle processes requiring rigorous assessment

The change in emissions from ICT system components is assumed to be negligible and the entire life cycle not relevant for further assessment. Several components, such as data center and servers, do not change, regardless of where the employee is situated. Although employees may purchase an additional home printer or other equipment, the growing prevalence of ICT in the home and the use of portable laptops suggest that this impact would be negligible. In applying the methodology, validation of this assumption would be recommended.

In estimating the BAU reference value, it would have been determined that only the use stage was relevant for the primary enabling effect of reduced private vehicle travel. Relevant impacts identified in Step 1 were reduced building use and increased home energy use. Both effects are strictly related to processes of the use stage of the building and home, and therefore assessment would be limited to these processes. BT also assessed reduced public vehicle use. For this effect, only use stage was considered.

Step 3: Assess and interpret

Step 3a: Rigorously assess significant life cycle processes

Steps 1 and 2 identified the relevant effects and life cycle processes requiring further assessment: reduced vehicle use, reduced building use and increased home energy use. In Step 3, BT assessed the magnitude of each effect, using a combination of primary and secondary data. Figure 31 summarizes the methodology used to assess each effect and its results.

Figure 31: Results of telecommuting assessment

	− Change in BAU emissions		+ ICT/rebound emissions
	Reduced vehicle use (public & private)	**Reduced building use**	**Increased home energy use**
Methodology	Survey captured Adastral Park employee commute distances, assumed to be representative of other office sites Assume 75% travel by car, 25% travel by rail DEFRA emission factors	Employee office use figures and kWh gas and electricity / m^2 from internal BT source UK national grid emission factors	1. Average UK energy consumption from home occupancy 2. Observed use of 30 employees with home energy monitoring kit UK national grid emission factors
Results	9.97 $ktCO_2e$ reduced	15.6 $ktCO_2e$ reduced	11.3 $ktCO_2e$ increased

Several calculations were made to assess the impact from reduced vehicle use, reduced building use and increased home energy use. Primary pilot data was used to capture data that has greater potential variance based on behavioral change, that is, telecommuting distance and rebound effect of increased home energy use. Secondary data was consulted for figures on employee office use, energy/unit of office space, average UK home energy usage and occupancy patterns. These data points were then extrapolated upward to a company-wide level (for the number of known telecommuters), to calculate a net enabling effect in reducing CO_2e emissions by 14.3 $ktCO_2e$/yr. Note that these calculations used the number of permanent homeworkers, where reduced building use was an unambiguous benefit.

Step 3b: Interpret net results

Several effects were considered irrelevant for this study, given its goal (to understand whether telecommuting has a net enabling effect and communicate that to internal stakeholders and industry bodies). Such effects included reduced building construction, reduced road congestion and construction and urban sprawl.

The assumption was made that the change in emissions from the ICT system was negligible, and so it was excluded from further assessment.

In quantifying the net enabling effect in Step 3, it was assumed that 75% of telecommuters traveled by car and 25% by rail. It was also assumed that the telecommuters in Adastral Park and their telecommuting distances were representative of all telecommuting BT employees in the UK, although the saved distance and carbon could vary for different geographic regions (especially for employees in London, which has an atypical commuter catchment area and a different travel mode profile). The increased home energy use of 30 employees was also assumed to be representative of the behavior of all telecommuting BT employees in the UK. However, this was triangulated with another method, using recent secondary data specific to UK home energy use, providing greater confidence in this figure. The reduced building use provides the greatest area of uncertainty for this study because it was difficult to assess, and therefore depended on BT data and the assumption that fewer employees in the office would lead to a corresponding decrease in office building use.

Despite these uncertainties and assumptions, the study does answer the question as to whether or not telecommuting has a net enabling effect. The quantification of relevant effects and processes indicates a definitive net enabling effect. The actual impact could be lower or higher than the reported 14.3 $ktCO_2e$/yr figure, due to uncertainties and assumptions in the assessment, but it would be similar in magnitude.

Finally, in presenting results, one additional option would be to report the emission reduction on an annual per employee-basis. This would make the study more relevant for other companies of varying sizes who are considering telecommuting programs and want to estimate the reduced emissions associated with implementation.

Additional considerations: Scale of adoption

The appropriate ICT enabling impacts, rebound effects and life cycle processes will vary depending on the scale of adoption considered and identified in Step 1a. This case demonstrates assessment when the audience is focused on a more limited set of impacts over a shorter period of time.

Figure 32 compares the inclusion of different impacts for telecommuting when the scope of assessment is narrow (as in this case study) and when the scope of assessment is broad, such as for policy makers considering the impact of telecommuting when adoption is on a national scale. While the assessment of direct enabling impacts and direct rebound effects does not change between the two case studies, the assessment for policy makers would be more inclusive of the indirect enabling impacts and indirect rebound effects.

Figure 32: Telecommuting effects considered under low and high scale of adoption

	Identified effects	Low scale of adoption	High scale of adoption
Direct ICT emissions	• Emissions from ICT equipment required for telecommuting	✗	✗
Primary enabling	• Reduced private vehicle use	✓	✓
Secondary enabling	• Reduced public vehicle use	✗	✓
	• Reduced building use	✓	✓
	• Reduced building construction	✗	✓
	• Reduced road congestion and construction	✗	✓
Primary rebound	• Increased home energy use	✓	✓
Secondary rebound	• Urban sprawl	✗	✓

Case Study 5: E-health delivery system

Ericsson developed a Healthcare Networking Information System (HNIS) in Croatia with the goal of integrating healthcare processes, information management and business workflows. Among other features, this system offers e-referral and e-prescription services that have the environmental benefits of reducing paperwork and patient travel.[43]

[43] "Assessing Emissions Right: Assessing the Climate-Positive Effects of ICT." Ericsson White Paper.

Figure 33: E-health delivery system case study

Summary

Assessor and location of ICT solution

ERICSSON — Impact on Croatia nationwide

Smart opportunity area

Dematerialization: telecommuting and substance elimination

- Estimated 2020 abatement potential: 0.46 $GtCO_2e^{\dagger}$

Description of assessment

Emission-reducing impact of e-referral and e-prescription services in Croatia

Net enabling effect

Reduced emissions by 15,700 tCO_2e/yr in Croatia

Sources of data

Modeled assumptions on behavioral changes, average trip commute distance. Secondary data for emission factors, etc.

Goal of study

Purpose of study

The purpose was to understand the potential for e-health if widely adopted across Croatia

Intended audience

Policy makers in Croatia

Scope of study

Direct ICT emissions

Emissions from PCs and data centers

Enabling effects

Primary: reduced private vehicle use, reduced paper use
Secondary: reduced public vehicle use, reduced vehicle construction, reduced road construction

Rebound effects

Primary: none assessed
Secondary: none assessed

†Source: *SMART 2020: Enabling the low carbon economy in the information age*

Step 1: Define goal and scope

Step 1a: Define goal of study

The purpose of the study was to understand the potential for e-health if widely adopted across Croatia. The intended audience for Ericsson's e-health delivery system could have been policy makers in Croatia. Since policy makers make long-term planning decisions on infrastructure and consider introducing policies to incentivize adoption, the scale of adoption for this study was quite large.

Step 1b: Define scope of study

In this case study, the ICT system included the software and equipment required for the e-health system. The components of the system were PCs and data centers. The BAU system covered the existing healthcare system, including all associated activities and emissions. Changes to these emissions resulting from enabling and rebound effects identified the relevant BAU components.

Figure 34: ICT system, BAU system, and their components

System	Description	Components of system	
ICT	*E-health delivery system*	1 *PCs* 2 *Data center*	
BAU	*Existing healthcare system*	1 *Private vehicles* 2 *Public vehicles* 3 *Paper*	4 *Health clinics* 5 *Homes* 6 *Roads*

The primary enabling effects of the e-health delivery system were reduced private vehicle use by eliminating unnecessary trips to the doctor and reduced paper use through the ability to prescribe online. Relevant components associated with these effects were private vehicles and paper. The figure below summarizes all potential rebound and enabling effects that were identified.

Figure 35: Potential effects of e-health delivery system implementation

Category	Identified effects	Exclude?	Rationale for exclusion	System components assessed
+ Direct ICT emissions	*Emissions from ICT equipment required to for e-referral and e-prescriptions*			*Computers and data centers*
– Primary enabling	*Reduced private vehicle use*			*Private vehicles*
	Reduced paper use			*Paper*
– Secondary enabling	*Reduced public vehicle use*			*Public vehicles*
	Reduced vehicle production			*Private and public vehicles*
	Reduced road construction			*Roads*
	Reduced clinic energy use		*Not in case study*	*Not applicable*
	Reduced clinic construction		*Not in case study*	*Not applicable*
+ Primary rebound	*Increased home energy use*		*Not in case study*	*Not applicable*
+ Secondary rebound	*Increased consumption of carbon-intensive goods*		*Not in case study†*	*Not applicable*

Adoption of an e-health delivery system could generate several potential secondary enabling and rebound effects. Many of them require greater time and scale of adoption to occur. For instance, if the broader population were to reduce its use of public transportation, bus and train services could be run less frequently. Sufficiently widespread adoption could even cut public and private vehicle construction, as routes were cancelled, or families consolidated vehicle use. With fewer vehicles on the road, the need to construct or re-pave roads might also decrease. These effects would be beyond consideration when assessing an e-health system's impact on a single clinic, but given the national implications, these would be all relevant effects to consider when applying this methodology.

In applying the methodology, the following additional effects could have also been identified and included for assessment: reduced clinic energy use and construction, increased home energy use and increased consumption of carbon-intensive goods. Fewer patient visits could allow clinics to shorten their hours, reducing energy consumption. The e-health system would also help existing infrastructure to support greater numbers of patients per doctor/nurse/pharmacist, so as the Croatian population grew, a proportional expansion in number of clinics could be avoided. However, saved time and money could lead to more time at home using energy and higher disposal income (from savings from reduced travel) could lead to consumption of additional goods and services. This secondary rebound effect could offset part of the gains of the system but the resulting effect is associated with high inaccuracy.

Step 2: Limit assessment

The intent of Step 2 is to simplify assessment by limiting life cycle processes or entire stages from rigorous assessment, as long as excluding these life cycle processes or stages does not significantly change the study's conclusions. If the intended audience preferred consideration of all life cycle processes, or the user of the methodology preferred to be more comprehensive in assessment, then Step 2 would be unnecessary. In this case study, Ericsson chose to consider all life cycle processes (with the exclusion of end-of-life[44]) in order to be more comprehensive.[45]

[44] Studies at Ericsson show that the end-of-life phase of ICT products has a relatively insignificant impact when compared to the other phases.

[45] Disposal was also excluded, although in applying this methodology, all five life cycle stages would be considered if addressing a more demanding audience.

Step 3: Assess and interpret

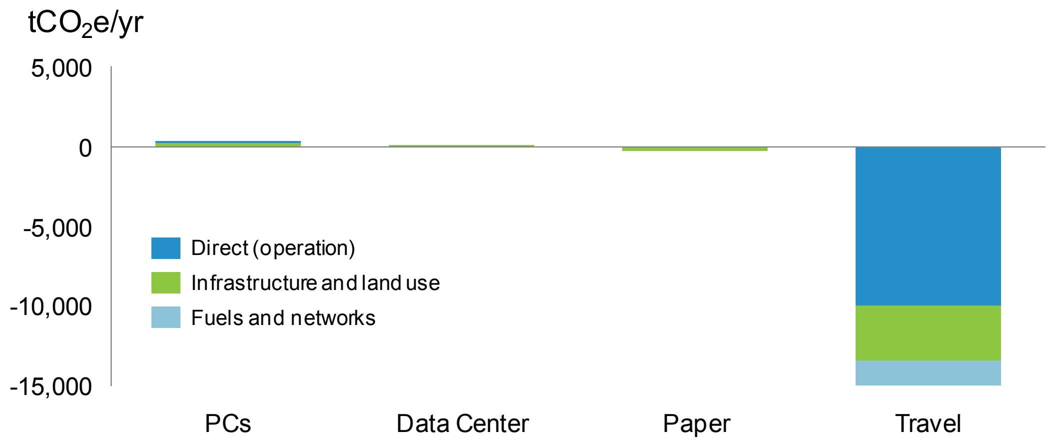
Step 3a: Rigorously assess significant life cycle processes

Ericsson assessed processes for all life cycle stages (with the exception of end-of-life) for those effects deemed to significantly influence the result.

Figure 36: Estimated effects of e-health delivery system

	Identified effects	Quantification of effects
Direct ICT emissions	• Emissions from ICT equipment required to for e-referral and e-prescriptions	• (330) tCO_2e
Primary enabling	• Reduced private vehicle use • Reduced paper use	• 5,760 tCO_2e • 230 tCO_2e
Secondary enabling	• Reduced public vehicle use • Reduced public vehicle production • Reduced private vehicle production • Reduced road construction	• *Included in 7,290 figure* • 7,290 tCO_2e • 2,400 tCO_2e • *Included in production figures*

Figure 37: Quantified enabling effects for e-health system



Calculations to arrive at these figures used a mix of secondary and modeled data. It was assumed a 50% reduction in paper used for prescriptions would occur, as well as a 50% reduction in trips for doctor visits. Secondary and other data was used to determine average paper production and Croatian electricity differences from globally reported figures. Croatian demographic data was used to guide assumptions. As the e-health delivery system runs on PCs rather than a dedicated e-health device, a decision was also made to allocate emissions from the entire HNIS infrastructure to e-health and e-referral.

As mentioned in Step 1, not all secondary and rebound effects were included in Ericsson's study as they come with great uncertainty and are likely to cancel out each other. However, to fully apply the ICT enablement methodology, some assessment of such effects would be recommended in a study intended for a policy maker audience.

Step 3b: Interpret net results

Interpretation of the results would include discussion of key assumptions, limitations, uncertainties and data quality from the study. For instance, the inclusion of nearly all life cycle processes could be mentioned to emphasize the comprehensiveness of the study. Emphasis would also be placed on the uncertainty inherent in forward-looking assessments, and in studies covering a broad scope. Assessing potential emissions reductions across an entire population requires significant assumptions and modeling of data. As a result, any net emissions effects should come with explicit guidance on the assumptions used and with caveats that actual results may differ significantly from those estimated in the study. In this study, it would be important to make policy makers aware of the assumption of a 50% reduction in trips to the doctor and in prescription paper use. Alternatively, the scenario studied in step 3a could be combined with a sensitivity analysis in step 3b, indicating the relative importance of this assumption for the overall result.

Case Study 6: Telepresence system

TelePresence is videoconferencing characterized by high definition video (1080p, 30 fps), life-sized images, spatial audio, imperceptible latency and easy operation. Required ICT equipment includes one or more display screens with microphones, speakers and cameras designed for the telepresence system.

Figure 38: Summary of telepresence case study

Summary

Assessor and location of ICT solution

CISCO — Impact worldwide

Smart opportunity area

Dematerialization: video conferencing
Estimated 2020 abatement potential: 0.08 $GtCO_2e^{\dagger}$

Description of study

Cisco gathered primary data on TelePresence usage and associated reduced travel for 6 years to establish a baseline and understand the impact from installing TelePresence

Net enabling effect

Ratio of reduced emissions to direct ICT emissions as high as 50:1

Sources of data

Primary data to measure direct reduced travel (travel data from FY2007-2009); primary and secondary data to assess direct ICT emissions

Goal of study

Purpose of study

The purpose was to understand the impact from Cisco installing TelePresence to reduce its air travel

Intended audience

Business customers and policymakers interested in understanding impact from a single company adopting TelePresence

Scope of study

Direct ICT emissions

Emissions from TelePresence endpoints and network switch, aggregation and core functions

Enabling effects

Secondary enabling effect: reduced air travel

Rebound effects

Primary: TelePresence use beyond for travel substitution purposes, i.e. to run more effective business meetings; increased rail use

†Source: *SMART 2020: Enabling the low carbon economy in the information age*

Step 1: Define goal and scope

Step 1a: Define goal of study

The purpose of this case study was to understand the net enabling effect of Cisco TelePresence™ use on company operations. The intended audience for this case study was business customers interested in purchasing telepresence systems and policy makers assessing the ability for a single company's adoption of telepresence to reduce their greenhouse gas (GHG) emissions. Scale of adoption occurred at a company-wide level, where Cisco TelePresence systems were available across Cisco's operations.

[46] Long-term impacts from reduced air travel infrastructure would be considered if the purpose was to understand impact of mass-adoption of telepresence to communicate to a policymaker audience. Cisco did in fact consider this but excluded it to be conservative. Quantifying the impact of mass adoption of high-quality videoconferencing on the air travel infrastructure inherently includes uncertainty as business travel is only a portion of overall air travel and it would be difficult to predict change in personal air travel patterns.

Step 1b: Define scope of study

Figure 39: ICT system, BAU system, and their components

System	Description	Components of system	
ICT	TelePresence system	1 TelePresence unit 2 Network services	3 HVAC in room
BAU	Travel for meetings	1 Airplanes 2 Trains	3 Public vehicles 4 Private vehicles

Amongst the set of potential BAU system components potentially impacted by telepresence adoption, this study focused on assessing reduction in air travel. The primary enabling effect of reduced use of private vehicles (i.e., cars) was not assessed. The effects considered were (1) reduced air travel (secondary enabling) and (2) increased use of TelePresence for business meetings not requiring travel (primary rebound) and (3) increased long distance rail travel to replace air travel. Changes in air travel schedules can be reasonably expected with more widespread adoption of telepresence , especially in cases where large employers support regular flights between cities.[46]

Figure 40 summarizes all potential effects identified and deemed relevant for further assessment.

Figure 40: Potential effects of TelePresence implementation

Category	Identified effects	Exclude?	Rationale for exclusion	System components assessed
+ Direct ICT emissions	Emissions from ICT equipment required for TelePresence			TelePresence units; HVAC of room; network components
– Primary enabling	Reduced private vehicle use	Yes	Not part of the purpose of the study	Not applicable
– Secondary enabling	Reduced travel by air			Airplanes
	Reduced travel by rail and public vehicles	Yes	Not part of the purpose of the study	Not applicable
	Reduced construction of airplanes, trains, and vehicles (private and public)	Yes	Not relevant for company scale of adoption	Not applicable
	Reduced travel infrastructure (railways and roads)	Yes	Not relevant for company scale of adoption	Not applicable
+ Primary rebound	Increased telepresence use from additional meetings			See components from Direct ICT emissions
	Increased travel by rail to replace air travel			Train
+ Secondary rebound	None identified			Not applicable

While telepresence could also replace other modes of transportation such as car, bus or rail, these were outside the purpose of the study. Ground transportation to/from the airport was excluded, with the assumption that this was offset by transportation to/from work to use the telepresence unit.

Transportation to/from hotel or travel destination office was assumed to be offset by local transportation to employee's home and primary work location (personal car and commuting). Reduced hotel emissions from less hotel use were conservatively excluded, and assumed to be offset by reduced home emissions. Emissions from reduced hotel and rental car infrastructure were conservatively excluded because, as for air travel infrastructure, quantifying the impact would be highly uncertain. Finally, carbon savings from avoided customer air travel associated with customer briefings at local Cisco TelePresence facilities were outside the boundaries of the study, which was to understand Cisco's ability to lower its own global GHG emissions by reduced air travel. With wider telepresence implementation, the impact of reduced customer air travel would accrue to that customer's emissions reporting from use of its own telepresence facilities.

Step 2: Limit assessment

Step 2a: Estimate BAU reference value

For telepresence , the BAU system is business air travel for meeting participants. The BAU reference value would be assumed to be the process of operating airplanes.

Step 2b: Limit life cycle processes requiring rigorous assessment

The use and non-use processes for telepresence units were determined. Energy consumption by the telepresence units was weighted by the actual meeting count of one-screen and three-screen units. The duty cycle for all telepresence units at Cisco sites is about 50% over a ten-hour, five-day-per-week schedule, and this ratio was also used to allocate idle loads. In addition to end point energy consumption and allocated idle end-point loads, the telepresence room HVAC and switching, aggregation and core network loads were also allocated to the use stage. Using Cisco's actual average emissions factor, emissions from the use stage processes were 4.3 kgCO_2e/hr of telepresence use. The carbon emissions from raw material extraction, production and disposal (recycling)—allocated over a ten-year life time for the installed base of one-screen and three-screen units—were 3.2 kgCO_2e/hr of telepresence use. Embodied emissions were estimated using a process-sum LCA.

LCA software was used to estimate embodied emissions for major subsystems of the telepresence unit. The exception to this was for the screens, where the EcoInvent database of the LCA software did not have relevant data As a result, an EPA study from 2003 was used to understand impact per square inch of similar LCDs and modules, and scaled up to the size of the telepresence screens.

A relevant rebound effect identified in Step 1 was increased telepresence use for more effective business meetings that would not have avoided travel. This effect was quantified through Cisco TelePresence reservation primary data gathered through the Microsoft Outlook scheduling process. The associated use-stage and non-use-stage rebound emissions were calculated to be 6.3 and 4.8 kgCO_2e/hr, respectively.

Longer distance rail travel was reviewed as a possible rebound effect (switch from air travel), where use stage processes would be relevant for assessment. However, no upward trend was observed, with available rail data constituting less than 0.25% of total air travel miles.

Step 3: Assess and interpret

Step 3a: Rigorously assess significant life cycle processes

Cisco conducted full-scale primary data collection to support this case study. Primary data included data for all Cisco flight segments and every scheduled telepresence meeting since Cisco TelePresence product release in October 2006. Three years of air travel data collected from before telepresence inception were used as a baseline. As part of the meeting scheduling process, TelePresence users completed an "entitlement form" on the purpose of each

[47] http://www.cisco.com/web/about/ac227/csr2009/pdfs/CSR_09.pdf.

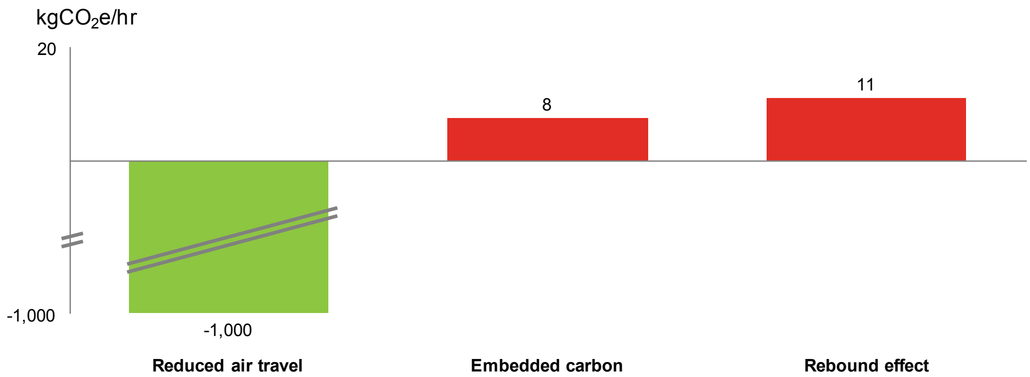
meeting and whether travel was avoided. The scope of this study was global, with Cisco TelePresence units in over 150 cities in more than 40 countries. Details of the TelePresence roll-out are available on p. C36 of Cisco's 2009 CSR report.[47]

Using primary data, Cisco calculated an average trip length of about 4,425 km, which represents an avoided instance of air travel. Average trip length reflects Cisco's travel patterns. Average trip length increased slightly over the three years of this case study, possibly due to the growth in emerging market business and the accompanying increase in longer-haul travel. Average emissions factors from DEFRA were used to calculate an average, Cisco, emissions factor of 0.113 kgCO_2e/km-flown based on actual flight segment primary data.

Using this data, Cisco found that the emissions generated by an average employee air travel trip were 500 kgCO_2e. Correlating only actual air travel trip reductions (and not adding projected avoided trips from headcount and revenue growth) against telepresence use indicates that approximately two trips were avoided per telepresence meeting. Therefore, about 1,000 kgCO_2e were saved per telepresence meeting.

The LCA conducted to understand direct ICT emissions and the primary rebound effect of increased telepresence use in Step 2b was considered sufficient for use in Step 3, and totaled 18.6 kgCO_2e generated. Therefore an average telepresence meeting saved 1,000 kgCO_2e at an approximate "cost" of 18.6 kgCO_2e from use stage processes and embodied emissions – a factor of about 50:1.

Figure 41: Estimated impact of TelePresence usage



Step 3b: Interpret net results

Cisco conducted a robust assessment of the extent to which telepresence deployment reduced air travel within the company, collecting primary data from air travel and surveying users of telepresence units in order to understand when telepresence use was substituted for air travel (enabling effect) as opposed to being used to facilitate a meeting that would not have required travel (rebound effect).

An assumption-driven model was not required to quantify impact in this case study. As a result of the reliance on high-quality and comprehensive primary data and assessment detail, the net enabling effect from Step 3a is deemed reliable. Because the GHG savings are very high compared to costs, the positive assessment of this telepresence ICT technology is relatively insensitive to reasonable uncertainties in carbon "cost". For example, if use stage processes and embodied emissions were twice as high, the reduction ratio would still be an attractive 25:1

Finally, it should be noted that the boundaries of this study correlated telepresence use with reduced air travel. In fact, other ICT remote collaboration tools—such as desktop conferencing and unified communications—are also used to reduce business air travel. However, these same additional remote collaboration tools are used to reduce emissions from commuting. In the future, a more comprehensive case study can be conducted to combine the carbon benefits and costs from the use of all ICT remote collaboration technologies to reduce emissions from more generic work-related employee transport.

Additional consideration: Application of methodology for forward-looking, large-scale assessments

In contrast to Cisco's case study, which assessed impact of telepresence at a company-wide level, analyst firm Verdantix and the Carbon Disclosure Project (CDP), with support from AT&T, quantified the impact of telepresence from a wider-scale, forward-looking perspective. This study forecasted CO_2e emission reductions in 2020 from use of telepresence across 2,653 multinational firms operating in the US.

This study's goal and scope definition would differ significantly from the Cisco case study; namely, the defined scale of adoption would be far greater. As a result, two scale-dependent enabling effects would be relevant for inclusion: reduced vehicle construction and reduced travel infrastructure.

In Step 2, these additional enabling effects would be quantified via a screening assessment of the respective BAU system component life cycle processes. Determination of significance for each life cycle process would dictate where more rigorous assessment would be required.

A key difference in assessment for large-scale or forward-looking assessments occurs in Step 3a, in which additional rigor is employed for evaluating the life cycle processes deemed significant in Step 2. For the Verdantix/CDP study, the relevant effects for which further life cycle assessment was employed included:

- Emission reduction from air travel (secondary enabling effect)
- Emissions generated by use of telepresence to replace air travel (direct ICT emissions)
- Emissions generated by use of telepresence for additional non-necessary meetings using telepresence (primary rebound effect)

Implementing travel surveys at every global firm across the US would be impossible to execute. Moreover, travels surveys alone would only provide historical data. Thus for assessing net enabling impact, Verdantix interviewed 15 global companies that adopted telepresence, spanning different industries, to develop representative travel profiles. For instance, the average "intra-US" trip distance was longer than that of an "intra-Europe" trip (1150km compared to 350km).

Interview findings were also used to assess the utilization rate of telepresence units, as well as the number of additional meetings above and beyond travel substitution. These additional meetings constitute the primary rebound effect of telepresence introduction. The enabling effect of telepresence introduction result was calculated to be a 112K metric ton CO_2e reduction in 2010, rising to 963K metric tons CO_2e in 2020. Cumulatively, across all years between 2010 and 2019, the reduction would be almost 4.6M metric tons CO_2e.

Interpretation of these results would involve discussion of the effects and life cycle processes excluded from assessment (e.g., emissions savings of reduced travel infrastructure were not addressed). In addition, this step would include discussion of sources of data, with the "hierarchy of proof" concept providing guidance for this discussion.

Full-scale primary data (as collected in the Cisco study) would not be feasible for the Verdantix/CDP/AT&T study, given the objective of quantifying impact from a forward-looking vantage point that assumed widespread adoption. Thus, discussion of the study findings would include a review of the assumption-based models developed as well as an acknowledgement of the inherent uncertainty of forward-looking assessments. Finally, results of scenario analysis, which could be used to model varying levels of adoption and/or different travel profiles, might be offered and discussed to provide a range of possible net enabling effects. These results would in turn help bound the uncertainty of the study.

[48] Plans to make this tool publicly available are not yet confirmed.

04: Path Forward in Assessment

The ICT Enablement Methodology provides guidance—but not detailed ICT industry standards—on impacts and life cycle processes to include in assessment. Additional guidance on conducting an LCA to quantify effects of ICT introduction—including research and data collection—may be required by many individuals and organizations. This includes members of the ICT industry itself.

Further development of case studies applying the ICT Enablement Methodology will provide real-world examples of ICT enabling effects and contribute to the body of shared data and information. Expanding publicly available assessment resources—including secondary data sets and published reports and studies—will facilitate use of the methodology without the need to conduct extensive primary research and data collection. New tools and databases will also ease the assessment process and make it accessible to a greater number of stakeholders (for example, ICT customers may be able to assess the extent to which an ICT solution could reduce their carbon footprint). Finally, industry adoption of consistent criteria for determining which effects and life cycle processes to include in the assessment of ICT solutions will significantly enhance the comparability of independent ICT evaluations.

Over time, these efforts will ease application of the methodology, increase consistency of results and lead to growing recognition of its effectiveness by businesses, policy makers and the broader international community.

Development of additional case studies

A set of case studies drawing on existing research and data is included in this report. A larger body of data and conclusions is needed in many areas, such as logistics network optimization (smart logistics) and optimization of industrial motors (smart motors). Application of the ICT Enablement Methodology to these areas would further demonstrate the methodology's ability to enhance the enabling effects of ICT.

The member organizations of GeSI are committed to the continued development of case studies to demonstrate both the power of ICT in cutting carbon emissions and the effectiveness of the ICT Enablement Methodology in quantifying these impacts. Moreover, GeSI calls upon the members of the broader ICT industry to contribute to the body of research and literature demonstrating the effects of ICT adoption via the application of this methodology.

Expansion of shared data

Currently, many assessments of the enabling impact of ICT use modeled data to reflect the behavioral change and adoption arising from the introduction of ICT solutions, particularly for assessments with a broader goal (such as quantifying impact at a regional or country-level). Such assessments should include secondary enabling effects and rebound effects. Yet robust data is often lacking for these effects. As ICT industry adoption of the ICT Enablement Methodology widens, primary data will increase in availability, both for screening estimates of impact, as used in Step 2 (limiting of life cycle stages) of the methodology, and for use as inputs into the final calculations made in Step 3 (assessment of significant processes). Sharing this data through publications, industry organizations and other means will help the ICT sector to improve the accuracy of assessment of actual adoption rates and behavioral changes. This will enhance the reliability of net enabling effect assessments and make conducting assessments quicker and less resource intensive.

Development of assessment tools and databases

Several organizations have developed tools to support the assessment of direct ICT emissions and/or ICT enabling effects. While some have been developed for internal company purposes, a number have a broader audience in mind. For example, the GeSI Climate Change Working Group (CCWG) GHG Emissions Analysis Tool, which GeSI members can use and share with customers[48], has pre-loaded data on the distances between airport hubs and electricity emission factors by country, supporting assessment of BAU emissions for air and ground travel. Other tools include Cisco's Internet Business Solutions Group (IBSG) calculators[49] and internal tools developed by BT and Bell Canada.

In addition, the International Electronics Manufacturing Initiative (iNEMI) is developing a direct ICT emissions assessment tool designed to make use of an extensive database of life cycle emissions data. Continued development of such tools will greatly enhance the ease and effectiveness of employing the ICT Enablement Methodology. As available data is aggregated and becomes more accessible, and as the steps of the methodology are integrated into the form and functionality of assessment tools, the process of identifying, limiting and assessing ICT impacts will become faster and easier.

The ICT community will also benefit greatly from the sharing and integration of its proprietary tools (as well as the underlying data they hold).

Industry standardization of impacts and life cycle processes included in assessment

The ICT Enablement Methodology attempts to simplify assessment by excluding impacts and life cycle processes or stages that are less relevant or significant for a given audience. For many ICT solutions, the set of impacts and life cycle processes to be included may be fairly obvious, given the characteristics of the ICT or BAU system or because of a wealth of existing data. For some ICT solutions, however, selection of relevant impacts and significant life cycle processes may be more difficult.

Here, adoption of consistent approaches for specific ICT product or service categories could help. Assessment rules and norms could dramatically increase ease of applying the methodology and, when sufficiently detailed and prescriptive, could facilitate comparisons of impacts between similar products and services. For business sectors, for example, a consistent set of criteria could define a set of potential secondary enabling effects and rebound effects that would be considered "out of scope" when assessing the impact of a specific ICT solution. Meanwhile, for policy makers, a rule could be established that requires inclusion of certain impacts. A consistent definition could be adopted for the BAU system component and corresponding life cycle process that will serve as the BAU reference value for a specific ICT solution. Even further, benchmark BAU reference values or ranges may be established.

Concluding remarks

GeSI members will adopt the ICT Enablement Methodology for future assessments of the carbon-abating benefits of ICT solutions, testing its applicability and leading to any evolutionary refinements. Moreover, GeSI advocates the broader usage and refinement of this methodology by all those who want to maximize the potential of ICT in battling climate change.

Continued enhancements from a variety of stakeholders will ease the assessment process, increase the accuracy and acceptability of results and drive faster adoption of appropriate ICT abatement choices. Through efforts to use and improve a common assessment methodology, the ICT industry and its partners will move faster toward achieving a global low carbon economy.

[49] Cisco's Green Business Value Calculators help customers quantify both economic benefits and green benefits for Connect Building (smart buildings), Connected Workplace, Remote Collaboration and Telecommuting.

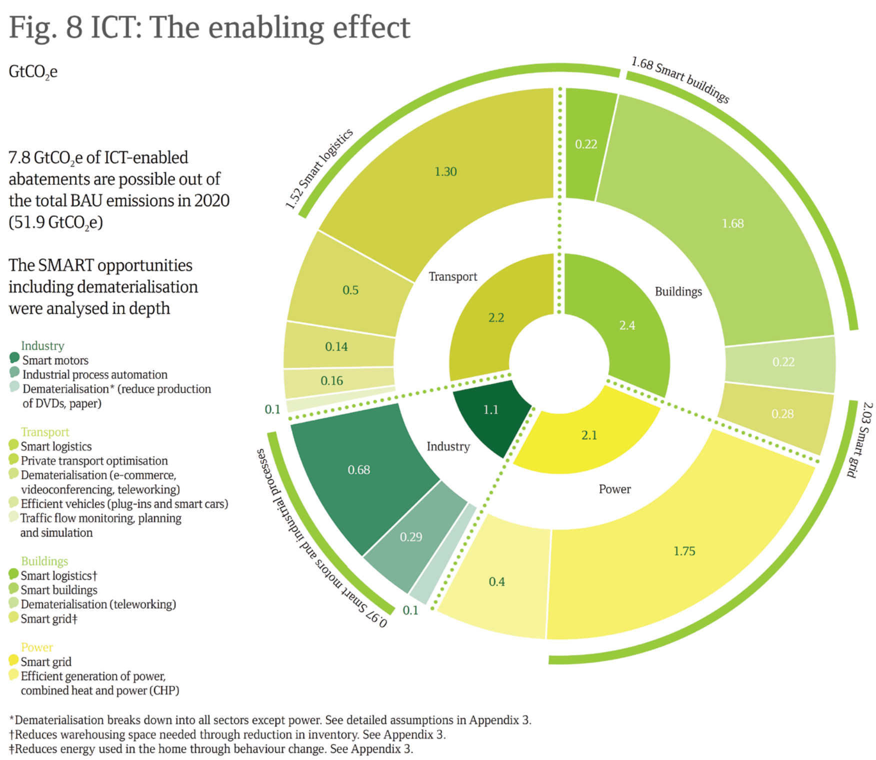
Appendices

Appendix 1: Estimated global enabling effect of ICT

In 2008, GeSI published SMART 2020: Enabling the low carbon economy in the information age. This study concluded that ICTs have the potential to deliver approximately 7.8 $GtCO_2e$ of emissions savings in 2020. The figure below, included in this report, summarizes the industry areas in which these savings could be achieved, and highlights the ICT smart opportunity areas that could be implemented to achieve them.

This study can be downloaded in full at: http://www.smart2020.org/_assets/files/02_Smart2020Report.pdf .

Figure 42: Estimated global enabling effect of ICT



Appendix 2: Overview of Life Cycle Assessment (LCA)

Introduction to LCAs

A life cycle assessment, or LCA, is defined as the "compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle". [50] A product's life cycle includes the following stages: material acquisition (extraction and processing), production (manufacturing and construction), distribution (to end customers), use and disposal.[51]

Figure 43: Product life cycle stages[52]

An LCA captures environmental impact across all life cycle stages, resulting in a comprehensive reporting of a product's environmental impact. In doing so, it facilitates the identification of "hot spots" (relatively high environmental impact) in the life cycle.

Efforts to develop assessment methodologies for ICT-based emissions and enabling effects have identified LCA as the preferred method to use when assessing environmental impacts. An LCA of the business-as-usual (BAU) system assesses the net reduction in emissions volume, while an LCA of the ICT solution assesses the direct emissions associated with the introduction and use of the ICT solution(s).

Differences between process-sum, hybrid and economic input-output LCAs

There are two distinct LCA methodologies: process-sum LCA and economic input-output (EIO) LCA. A third, hybrid LCA methodology combines elements from process-sum and EIO-LCAs.

Process-sum LCA methodology is considered "bottom-up" or "modular". The approach assesses the inputs into a product (primary inputs), the inputs into those inputs (secondary inputs), and so on. For each input considered, the associated outputs of emissions and environmental wastes are considered, as are the emissions and wastes of the final output product. This bottom-up approach allows for more precision than an EIO-LCA; however, it can also be time-consuming and labor-intensive. Tracking inputs backwards to consider second- or third-order effects (and beyond) leads to a "boundary" issue, whereby certain inputs, as well as environmental impacts, have to be excluded from the assessment.

Economic input-output LCA (EIO-LCA) uses economic data from industrial sectors as a proxy to understand environmental impacts.[53] This analysis uses country input-output tables, published by national statistics offices, to understand environmental impact at a higher level. However, these tables are often aggregated (for example, the chemical industry reports as a single sector), and can become dated (many are more than ten years old), making it difficult to conduct precise assessments. Thus, EIO-LCAs are recommended for conducting very rough estimates to understand the orders of magnitude of impact, and for conducting sector-level analysis.

Hybrid LCAs combine the approach of process-sum and economic input-output LCAs. Different models exist, prioritizing data from either process-sum or input-output data.

[50] ISO 14044, Environmental management – Life cycle assessment – Requirements and guidelines.

[51] Cited life cycle stages differ between sources. ISO cites life cycle stages to be: raw material acquisition, production, use, end-of-life treatment, recycling and final disposal. The US EPA defines major life cycle stages as: manufacturing (subdivided into raw materials extraction, intermediate materials manufacturing, finished products manufacturing); finished product transportation; product use; and end-of-life (collection, reuse, remanufacturing, recycling, final disposal). For simplicity, stages discussed in this report are: material acquisition, production, distribution, use and disposal.

[52] Figure represents simple illustrative schematic for product life cycle; alternative renditions may present variations. For example, distribution may be considered a stage spanning the entire life cycle of a product.

[53] Useful documents for further information on EIO-LCA include: Frequently asked questions about input-output analysis, Centre for Sustainability Accounting, March 2010, http://www.censa.org.uk/docs/CENSA_Special_Report_FAQ_IOA.pdf; Hendrickson, C. T., Lave, L. B., and Matthews, H. S., Environmental Life Cycle Assessment of Goods and Services: An Input-Output Approach, Resources for the Future, 2006, http://books.google.com/books?id=-w2KtGXa-OAC; Economic Input-Output Life Cycle Assessment, Carnegie Mellon, http://www.eiolca.net.

[54] Environmental management. Life cycle assessment. Requirements and guidelines , International Organisation for Standardisation (ISO), 2006, http://www.iso.org/iso/catalogue_detail?csnumber=38498.

Existing ICT-industry efforts recommend using process-sum LCA where possible, and supplementing this with input-output data in cases where assessment and other data are unavailable or too time-consuming to gather.

Figure 44: Process-sum, hybrid and EIO LCA

Three LCA "flavors"	1 Process-sum	2 Hybrid	3 Economic Input-Output
Description	Bottom-up; assesses environmental impacts of individual products/processes	Combines process and EIO LCAs	Top-down; uses economic input-output tables to estimate sector impacts
Resources	Substantial depending on scope and boundary	Can help lower overall resource requirement	Initially high to build model, small thereafter
Specificity	Product-specific	Can address all levels	Sector level
Key issues	Boundary issues • Greater detail the wider the boundary		Input-output data becomes dated Industries often aggregated

International Standards Organization (ISO) 14040 – 14044

Several standards exist to provide guidance on conducting LCA methodologies. Candidates applying for eco-label certification are also required to comply with these standards. The most widely accepted standards—ones drawn upon for subsequent LCA standards—are the International Organization for Standardization (ISO) 14040 and 14044 standard. The following section provides an overview of ISO standards for LCAs, highlighting key relationships with the ICT Enablement Methodology.

According to ISO 14044, Environmental management – Life cycle assessment – Requirements and guidelines[54], an LCA study has four phases:

1. Goal and scope definition phase
2. Inventory analysis phase
3. Impact assessment phase
4. Interpretation phase

In the goal and scope definition phase, the goal is defined by stating intended application, reasons for carrying out the study, intended audience and whether results will be used in comparative assertions. The subject and intended use of the study impact the scope, which includes a clear description of the functional unit, system boundary (set of criteria specifying which unit processes are parts of a product system), data quality requirements and other items. In defining the system boundary, ISO provides the following guidance:

> The deletion of life cycle stages, processes, inputs or outputs is only permitted if it does not significantly change the overall conclusions of the study. Any decisions to omit life cycle stages, processes, inputs or outputs shall be clearly stated, and the reasons and implications for their omission shall be explained" (ISO 14044:2006, 4.2.3.3 System Boundary).

For simplifying purposes, the ICT Enablement Methodology rephrases the inclusion of "intended application, the reasons for carrying out the study" to be "purpose of study" and does not require statement of whether the results are intended for use in comparative assertions. Similar to ISO, the ICT Enablement methodology uses the goal of the study to inform the system boundary and which rebound and enabling effects are relevant for further assessment.

In the inventory analysis phase, data required for the study is collected. ISO 14044 provides guidelines on collecting data, calculating data, validating data, relating data to unit process and functional unit, refining the system boundary and allocation procedures. The following guidance is offered:

> Refining system boundary: reflecting the iterative nature of LCA, decisions regarding the data to be included shall be based on a sensitivity analysis to determine their significance, thereby verifying the initial analysis outlined in 4.2.3.3 [system boundary]. The initial system boundary shall be revised, as appropriate, in accordance with the cut-off criteria established in the definition of the scope. The results of this refining process and the sensitivity analysis shall be documented. The sensitivity analysis may result in exclusion of life cycle stages or unit processes when lack of significance can be shown by sensitivity analysis

The ICT Enablement Methodology draws from ISO's inventory analysis phase to define specifically a step to refine the system boundary in order to reduce the burden of rigorous assessment for insignificant processes or stages. A screening assessment, ideally drawing on easily accessed secondary data, is used to understand impact from all life cycle processes. Then, as with ISO's recommendation following sensitivity analysis, life cycle processes or full stages lacking significance can be excluded. The ISO guidelines in the goal and scope definition stage for requiring clear documentation and rationale for omission are also followed, where the screening assessment provides rationale and all limitations of life cycle processes are documented in Step 3 of the ICT Enablement Methodology.

In the impact assessment phase, additional information is provided for better understanding of the environmental significance of results from the inventory analysis phase. The contribution to impact categories such as "climate change" or "acidification" is studied. Mandatory elements of this phase include the selection of impact categories, category indicators and characterization models, assignment of LIC results to selected impact categories (classification) and calculation of category indicatory results (characterization).

For the ICT Enablement Methodology, the only impact category under consideration is "climate change" based on increased or reduced CO_2e emissions. Other impact categories such as "acidification" and "eutrophication" are not considered.

Finally, the interpretation phase involves analysis of the results. This includes reporting on the assumptions made and on any limitations from methodology or data, as well as assessing data quality and disclosing whether or not expert judgment or reasoning was applied. Note that interpretation may also lead to re-examining and iterating on the goal and scope of a study.

The ICT Enablement Methodology draws from ISO's interpretation phase, highlighting the areas believed to be most critical for transparent documentation of how results were obtained: explicit documentation of any assumptions and limitations, a review of uncertainties and data quality and conclusions drawn. Requirements are not as specific or detailed as those listed in ISO, although the user of the methodology is referred to ISO for further guidance on potential additional items to consider and subjects to cover in reporting to a third party.

Appendix 3: Data hierarchy of proof

In limiting life cycle processes or stages in Step 2 and assessing net enabling effects in Step 3, the sources of data used require careful consideration. Clear documentation of data quality and of any supporting rationale for selecting it should also take place when interpreting results in Step 3.

A "hierarchy of proof" can be used to support this process, as illustrated in Figure 45.

Figure 45: Data hierarchy of proof

1. **Primary data – full scale**
   - Observation of impact from implementation of ICT application across entire organization, community, etc.
2. **Primary data – pilot**
   - Observation of impact of limited number of ICT implementations, extrapolated to broader scale
3. **Secondary data**
   - Use of data from outside sources, including leveraging of databases accessed by LCA tools
4. **Modeled data**
   - Modeling impact based on behavior-driven assumptions and secondary effect estimates, e.g. adoption rates

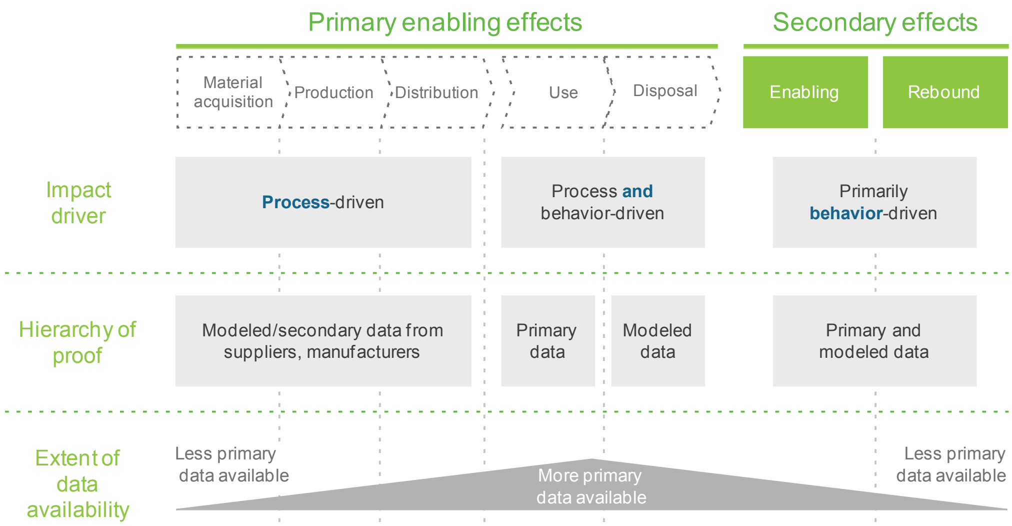
Use of primary data should be considered the "gold standard" for assessing enabling effects and rebound effects. Primary data offers the most compelling and defensible case for all the emission-reducing benefits of an ICT solution. Further, primary data will often best capture ICT adoption rates (where relevant) and the impact of primary rebound effects.

However, the ease and importance of obtaining primary data varies depending on the life cycle stage and whether the effect in question is primary or secondary. For many ICT applications, assessing primary data for use stage processes is most critical and often the most accessible. Pre-use stages are generally driven by standard processes, so secondary and modeled data are recommended, if available. It is reasonable to assume, for instance, that the energy required to manufacture a semi-conductor chip is standard among all chips of that type from the same manufacturer. On the other hand, impact from use stage processes often hinges on behavioral changes, in which case modeling introduces greater uncertainty, while quantification could provide greater certainty or a basis on which to model conservative, expected and optimistic scenarios.

As with the use stage, secondary enabling and rebound effects are often more uncertain and dependent on behavioral changes or on the ICT solution achieving a certain scale of adoption, in which case, assessment of primary data would provide a better basis for the assessment of these effects.

Figure 46 illustrates the relationship between life cycle stages, drivers of impact, commonly-used sources of data and general data availability.

Figure 46: Typical sources of data



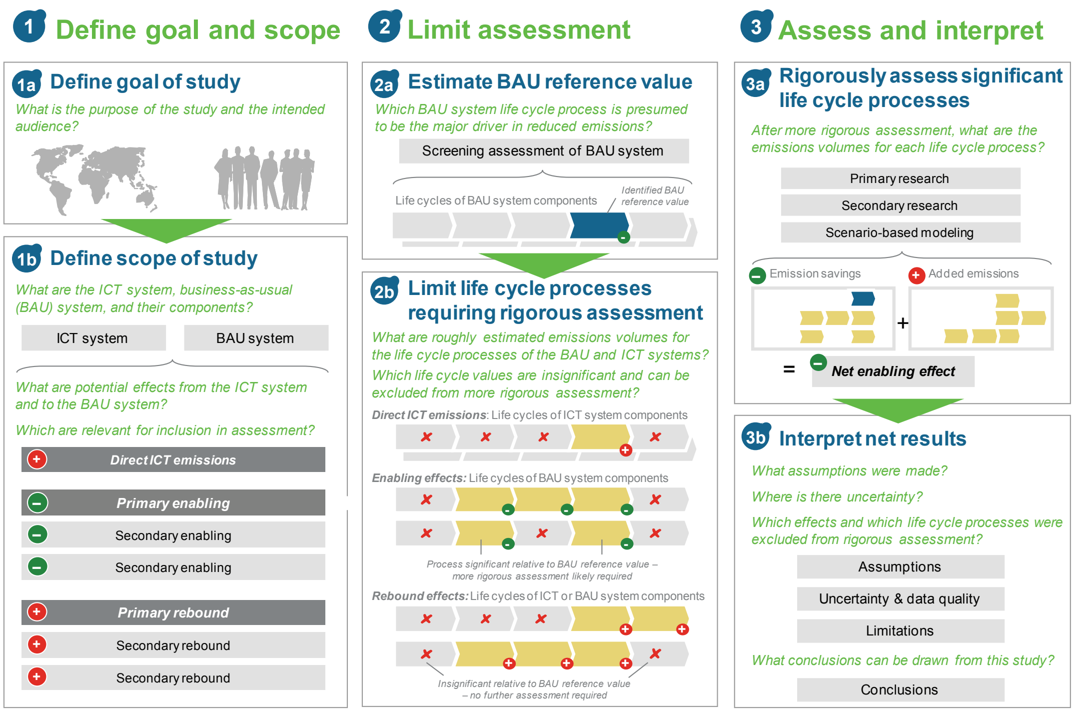
Absence of primary data should not, however, discourage application of the methodology. Often companies will consider the impact of implementing their ICT solution across a broad swathe of the population, in which case it may be impossible to collect primary data. In these cases, it is reasonable to use assumption-driven modeling to derive estimates. This requires a clear explanation of the assumptions underlying the model, as well as an explicit recognition of the high uncertainty inherent in assumption-driven models. Modeling of different use scenarios, such as low, medium, high, will help to limit the degree of uncertainty in the assessment. Further, basing the modeling on pilot-scale, primary data can provide grounds for underlying assumptions.

Appendix 4: Worksheets for application of methodology

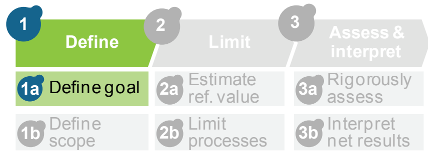
The following worksheet pages are intended to support the application of the ICT Enablement Methodology to a new study.

Figure 47 provides an overall view of the methodology; worksheets and illustrative output for each sub-step (1a – 3b) follow.

Figure 47: Overview of ICT Enablement Methodology



Assessment worksheet



Step 1: Define goal and scope

1a Define goal of study

Define the purpose of the study and the intended audience for the study. These attributes will guide decision-making on the set of effects to include in further assessment.

Q: What is the purpose of the study and the intended audience?

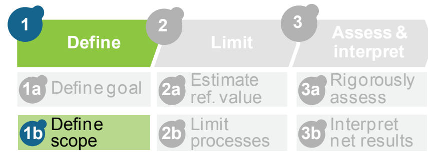
Purpose of study ______________________________

Intended audience ______________________________

Scale of adoption ______________________________

Implications for assessment

Assessment worksheet



1b Define scope of study

Identify (1) ICT system and its components, (2) business-as-usual (BAU) system, and (3) all potential enabling and rebound effects. Irrelevant effects are excluded from assessment given goal of study.

Q: What are the ICT system, BAU system, and their components?

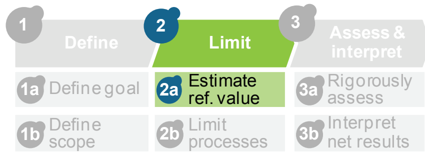
System	Description	Components of system	
ICT		1	4
		2	5
		3	6
BAU		1	4
		2	5

Q: What are potential CO_2e-saving effects to the BAU system and CO_2e-adding effects from the ICT system?

Category		Identified effects	Exclude?	Rationale if excluded	System components assessed
+ Direct ICT emissions	1				
	2				
– Primary enabling	1				
	2				
– Secondary enabling	1				
	2				
	3				
+ Primary rebound	1				
	2				
+ Secondary rebound	1				
	2				
	3				

Effects not excluded are those considered relevant (and thus will be included in further assessment)

Assessment worksheet



Step 2: Limit assessment

2a Estimate BAU reference value

Estimate the life cycle process presumed to be the major driver of reduced emissions, using secondary data where possible (to reduce burden of assessment).

Q: Which BAU system life cycle process is presumed to be the major driver in reduced emissions?

Assumed reference value

Primary enabling effect	System component	Life cycle process	Estimate (unit CO_2e)

Optional – another possibility

Primary enabling effect	System component	Life cycle process	Estimate (unit CO_2e)

BAU reference value intended to serve as a tool for determining significance of all BAU and ICT system life cycle processes by use as a point of comparison

Establish reference value estimate via use of reliable secondary data if possible; if not, primary data collection or assumption-based modeling may be necessary

Assessment worksheet

1 Define	2 Limit	3 Assess & interpret
1a Define goal	2a Estimate ref. value	3a Rigorously assess
1b Define scope	2b Limit processes	3b Interpret net results

2b Limit life cycle processes requiring rigorous assessment

Estimate the change in emissions for the life cycle processes of each relevant effect. The BAU reference value can then provide guidance for cut-off criteria and which processes are insignificant.

Q: What are roughly estimated emissions volumes for the life cycle processes of the BAU and ICT system components?

Category	*Identified in Step 1b*		*Screening assessment only – use secondary data where possible*				
	Relevant **identified effects**	**System components assessed**	**Estimate for processes of each life cycle stage** (unit CO_2e)				
			Material acquisition	Production	Distribution	Use	Disposal
+ Direct ICT emissions	1		☐	☐	☐	☐	☐
	2		☐	☐	☐	☐	☐
– Primary enabling	1		☐	☐	☐	☐	☐
	2		☐	☐	☐	☐	☐
– Secondary enabling	1		☐	☐	☐	☐	☐
	2		☐	☐	☐	☐	☐
	3		☐	☐	☐	☐	☐
+ Primary rebound	1		☐	☐	☐	☐	☐
	2		☐	☐	☐	☐	☐
+ Secondary rebound	1		☐	☐	☐	☐	☐
	2		☐	☐	☐	☐	☐
	3		☐	☐	☐	☐	☐

Q: Which life cycle values are insignificant and can be excluded from more rigorous assessment?

Compare each estimate to BAU reference value established in step 2a: ☐

Identify life cycle processes that are insignificant in comparison, denote with an

- *Note: Cut-off criteria used to define "significance" will vary on case-by-case basis given goal and scope of study*

Assessment worksheet

1 Define	2 Limit	3 Assess & interpret
1a Define goal	2a Estimate ref. value	3a Rigorously assess
1b Define scope	2b Limit processes	3b Interpret net results

Step 3: Assess and interpret

3a Rigorously assess significant life cycle processes

More rigorously assess the effects and life cycle processes identified as relevant in Steps 1 and 2. Where possible, primary data should be utilized.

Q: After more rigorous assessment, what are the emissions volumes for each life cycle process?

		Identified in Step 1b		*Rigorous assessment – use primary data where possible*				
Category		***Relevant*** **identified effects**	**System components assessed**	**Estimate for processes of each life cycle stage** (unit CO_2e)				
				Material acquisition	Production	Distribution	Use	Disposal
+ Direct ICT emissions	1							
	2							
– Primary enabling	1							
	2							
– Secondary enabling	1							
	2							
	3							
+ Primary rebound	1							
	2							
+ Secondary rebound	1							
	2							
	3							

Calculated net enabling effect:

Note: More rigorous assessment not applied to life cycle processes identified as "insignificant" in step 2b. However, screening estimates established for these "insignificant" life cycle processes may still be included in calculation of net enabling effect

- *E.g., decision to include screening estimates may depend on comfort with including figures that were not rigorously, irrespective of significance on net enabling effect calculation*
- *Choice to include or exclude screening estimate values should be documented*

Assessment worksheet

1 Define	2 Limit	3 Assess & interpret
1a Define goal	2a Estimate ref. value	3a Rigorously assess
1b Define scope	2b Limit processes	3b Interpret net results

3b Interpret net results

Document how methodology applied, including discussion of assumptions, limitations, uncertainty/data quality, and conclusions

Q: What assumptions were made? Where is there uncertainty?

Is primary data collected from a representative sample set? Is secondary data outdated?
What assumptions were used in modeling (e.g., behavior change, scale of adoption, etc.)?

Data source	Type of data	Potential assumptions / uncertainty

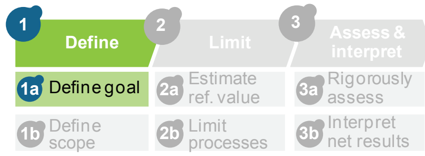
Q: Which effects and which life cycle processes were excluded from rigorous assessment?

		Identified effect	Excluded life cycle processes	Rationale
From Step 1	Entire effect excluded		• *All*	
			• *All*	
			• *All*	
From Step 2	Life cycle processes excluded			

Q: What conclusions can be drawn from this report?

Conclusions

Illustrative output



1a Define goal of study

Illustrative example used throughout worksheets

Purpose of study *Quantify carbon abatements from use of logistics optimization software*

Intended audience *Business customers*

Scale of adoption *Use to manage operations of a single organization's 500-truck fleet*

Implications for assessment

Relevant effects to include in calculation of net impact are limited to near-term effects such as primary enabling and rebound effects, or secondary effects that occur over a shorter period of time

For further reference–additional examples

Purpose of study *Assessment of emission reductions from home energy monitoring system*

Intended audience *Business-to-business customers (marketing communication)*

Scale of adoption *Single-business in United Kingdom*

Implications for assessment

Relevant effects from adopting home energy monitoring system likely to be limited to activities and operations of individual businesses; broader secondary effects such as reduced energy plant construction and operation not relevant

Purpose of study *Communication of macro-scale benefits of telepresence*

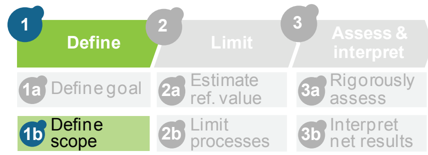
Intended audience *National policy makers*

Scale of adoption *Adoption and use by all businesses in United States*

Implications for assessment

Relevant effects for ICT solution with broad adoption and targeted at policymakers would be more inclusive of enabling and rebound effects which often will only occur with sufficient time or adoption, such as the ability to reduce the need for travel infrastructure

Illustrative output



1b Define scope of study

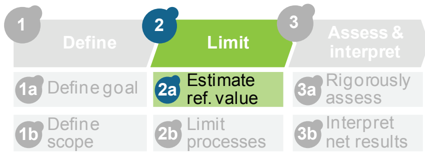
ICT system, BAU system, and their components

System	Description	Components of system	
ICT	*Delivery optimization software, to optimize the distribution of goods*	1 *Software* 2 *PCs* 3 *Servers*	4 *Data centers*
BAU	*Trucking operations prior to introduction of optimization software*	1 *Trucks*	

Potential effects

Category	Identified effects	Exclude?	Rationale if excluded	System components assessed
+ Direct ICT emissions	1 *ICT emissions*			*Software, PCs, servers, data centers*
– Primary enabling	1 *Reduced travel*			*Trucks*
– Secondary enabling	1 *Reduced vehicle production*	*Yes*	*Relevant for large scale of adoption only*	*Not applicable*
	2 *Reduced road construction*	*Yes*	*Relevant for large scale of adoption only*	*Not applicable*
+ Primary rebound	*None identified*			*Not applicable*
+ Secondary rebound	1 *Purchase and use of new trucks with saved costs*			*Trucks*

Illustrative output



2a Estimate BAU reference value

BAU reference value

Assumed reference value

Primary enabling effect	System component	Life cycle process	Estimate (unit CO_2e)
Reduced travel / shipment	Trucks	Truck operation	500 tCO_2e per annum

Illustrative output

1 Define	2 Limit	3 Assess & interpret
1a Define goal	2a Estimate ref. value	3a Rigorously assess
1b Define scope	2b Limit processes	3b Interpret net results

2b Limit life cycle processes requiring rigorous assessment

Roughly estimated emissions volume for each life cycle process

Figures illustrative only

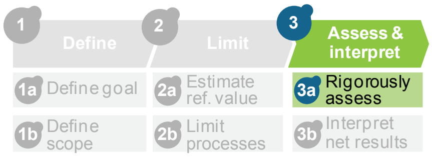
Category	*Relevant* identified effects	System components assessed	Estimate (tCO_2e per annum) Material acquisition	Production	Distribution	Use	Disposal
+ Direct ICT emissions	1 *ICT emissions*	*Software (physical media)*	0.1 ✗	0.1 ✗	0.1 ✗	N/A ✗	>0.1 ✗
		PC	0.4 ✗	0.4 ✗	0.2 ✗	1.0 ✓	0.1 ✗
		Servers	>0.1 ✗	>0.1 ✗	N/A	0.3 ✗	>0.1 ✗
		Data centers	>0.1 ✗	0.1 ✗	N/A	0.3 ✗	>0.1 ✗
– Primary enabling	1 *Reduced travel*	*Trucks*	N/A	N/A	N/A	500 ✓	N//A
+ Secondary rebound	1 *Purchase and use of new trucks*	*Trucks*	5.5 ✓	11.0 ✓	2.2 ✓	50 ✓	4.4 ✓

BAU reference value: *500 tCO_2e per annum*

E.g., cut-off criteria of 0.2% of BAU reference value used in illustrative example above

- *Note that additional life cycle processes of PC might also be included in Step 3 (where more rigorous assessment applied) given that non-use processes exceed cut-off when aggregated*

Illustrative output



3a Rigorously assess significant life cycle processes

Rigorously assessed emissions volume for significant life cycle processes

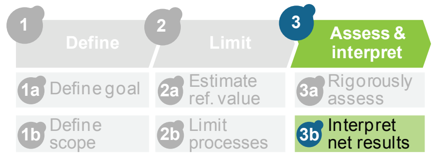
Figures illustrative only

Category	*Relevant* identified effects	System components assessed	Estimate (tCO_2e per annum): Material acquisition	Production	Distribution	Use	Disposal
+ Direct ICT emissions	1 *ICT emissions*	*Software (physical media)*					
		PC				*1.22*	
		Servers					
		Data centers					
– Primary enabling	1 *Reduced travel*	*Trucks*				*542.64*	
+ Secondary rebound	1 *Purchase and use of new trucks*	*Trucks*	*4.92*	*13.72*	*1.83*	*56.21*	*4.43*

Calculated net enabling effect:

460 tCO_2e per annum
+/- 20 tCO_2e based on scenario analysis

Illustrative output



3b Interpret net results

Assumptions and uncertainty

Data source	Type of data	Potential assumptions / uncertainty
• *Published academic study on PC LCA from 2003*	• *Secondary data*	• *LCA from 2003 may be dated if manufacturing processes have changed*
• *Company financial reports*	• *Modeled data*	• *Used to estimate secondary rebound effect. Wide range of potential outcomes presented to emphasize uncertainty*
• *Pilot study on customer implementing ICT solution*	• *Primary data*	• *Pilot study on one company may not be applicable to others (vehicle make and model may be different)*

Excluded effects and life cycle processes

	Identified effect	Excluded life cycle processes	Rationale
Entire effect excluded	*Reduced vehicle production*	• *All for trucks*	*Exclude, large scale of adoption*
	Reduced road construction	• *All for trucks*	*Exclude, large scale of adoption*
Life cycle processes excluded	*ICT emissions*	• *All for software, servers, data centers* • *All non-use for PC*	*Screening assessment used to determine insigificance*
	Reduced travel	• *None*	

Conclusions

The results of the study show that adoption of the delivery optimization software will create a significant net enabling effect. While variation across different makes and models of vehicles may exist, the company has utilized primary data to the extent possible to add legitimacy to its reported results. Remaining uncertainty related to secondary rebound effects suggest this would be an important area for future research.

Appendix 5: Glossary

- Assessment: As defined in this report, a holistic approach to quantifying the impact of ICT implementation that is inclusive of both measurement (the collection and observation of quantifiable data) and estimation (the development of data via assumption-based modeling). See measurement
- Augment/improve/add to BAU system: A situation in which an ICT solution is added to an existing BAU system without having to dispose of any significant portion of the BAU system; for example, a piece of software installed on existing PC hardware that provides information on home energy use
- Avoid/avoidance of BAU system: A situation in which an ICT solution is installed in place of a more carbon-intensive alternative, in which case the entire life cycle of the alternative may be counted as reduced emissions; for example, if a smart lighting system is installed in a new building, then the entire life cycle carbon emissions of the alternative could be counted as avoided emissions
- BAU: Business-as-usual
- Business-as-usual (BAU) system: The components in the existing manual, mechanical or physical processes that are impacted by the implementation of the ICT system; it can range widely in scope, from an inefficient light bulb to a nationwide public transportation system
- BAU reference value: The change in emissions volume of the BAU life cycle process identified to be the major driver of reduced emissions
- CO_2e/carbon dioxide equivalent (ITU): The amount of CO_2 emission that would cause the same radiative forcing as an emitted amount of a well-mixed greenhouse gas, or a mixture of well-mixed greenhouse gases; used as the standard for reporting emission reductions in this report
- Comparative assertion (ISO): Environmental claim regarding the superiority or equivalence of one product versus a competing product that performs the same function
- Component: Parts of the BAU or ICT systems upon which an LCA could be conducted. BAU system components are associated with one or more relevant enabling or rebound effects; for example, if the BAU system was a public transportation system and the ICT implementation led to reduced travel, then BAU components may include buses, depots and bus-only roads
- Conversion factor: Multiplier applied to functional unit in order to convert to CO_2e; conversion factors used from secondary sources such as US EPA and DEFRA
- DEFRA: Department for Environment, Food and Rural Affairs. The UK government body tasked with environmental issues
- Dematerialization (SMART 2020): The substitution of high carbon activities or products with low carbon alternatives
- Direct ICT emissions: CO_2e impact resulting from the ICT solution; defined in SMART 2020 report as "direct footprint"
- Effect: Also impact. Any change in emissions from ICT implementation
- Embodied carbon (SMART 2020): Total CO_2e required to get a product to its position and state. Includes product manufacture, transport and disposal; see "sunk" embodied carbon
- Emissions factor (SMART 2020): Carbon footprint of any energy source, expressed for example as kg CO_2e/kWh
- Enabling effect (SMART 2020): The ability of ICT solutions to facilitate emissions reductions in non-ICT sectors; see primary enabling effect and secondary enabling effect
- Energy efficiency: The effectiveness of energy for a given purpose. Greater energy efficiency refers to the ability to use less energy while providing the same (or better) level of service
- ETSI: European Telecommunications Standards Institute
- Goal of study: Step 1a in the ICT Enablement Methodology in which the purpose of the study and the intended audience are defined

- Hierarchy of proof: Term referring to the fact that different types of data provide varying levels of certainty in their results, or proof: see primary, secondary and modeled data
- HVAC (SMART 2020): Heating, ventilation and air conditioning
- ICT (SMART 2020): Information and communications technology: combination of devices and services that capture, transmit and display data and information electronically
- ICT company (SMART 2020): GeSI constitution definition: "Any company or organization which, as a principal part of its business, provides a service for the point-to-point transmission of voice, data or moving images over a fixed, internet, mobile or personal communication network, or is a supplier of equipment which is an integral component of the communication network infrastructure, or procedures equipment or software associated with the electronic storage processing or transmission of data"
- ICT Enablement Methodology: LCA approach tailored for ease of assessing the net enabling effect of ICT solution. Explicit decision making regarding inclusion of enabling and rebound effects and corresponding life cycle processes. Enabling and rebound effects inclusion determined via consideration of relevance for intended audience. Life cycle processes included determined via consideration of significance relative to BAU reference value
- ICT implementation: the means by which the ICT solution affects the business-as-usual system; see augment, avoid, replace
- ICT solution: Same as ICT product. Defined as any good or service produced or provided by an ICT company
- ICT system: All the components necessary to make the ICT solution operational; for example, if the ICT solution was a piece of software, the ICT system would consist of the software, PC, network connection, etc
- iNEMI: International Electronics Manufacturing Initiative
- Infrastructure: Large-scale projects used by a large number of individuals, such as roads, buildings or power plants; emission reductions associated with lower infrastructure use or avoided infrastructure production is included as secondary enabling effects
- Interpret: As defined in this report, to report the net enabling effect in the context of various assumptions, limitations and uncertainties. This occurs is Step 3b of the ICT Enablement Methodology and allows for qualitative considerations to be aired alongside quantified results
- ISO: International Organization for Standardization
- ISO 14040 (SMART 2020): International 2006 standard, which describes the principles and framework for LCA
- ISO 14044 (SMART 2020): International 2006 standard, which describes the requirements and guidelines for LCA
- ITU (SMART 2020): International Telecommunications Union
- JEMAI: Japan Environmental Management Association for Industry
- LCA (ISO): Life cycle assessment or life cycle analysis. Compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle
- Life cycle (ISO): Consecutive and interlinked stages of a product system, from raw material acquisition or generation from natural resources to final disposal
- Measurement: As defined in this report, the collection and observation of quantifiable data; for example, kWh use for a home can be measured, but an ICT system that reduces home energy consumption is assessed
- Modeled data: Assumption-driven estimates that are forward-looking or scaled up from smaller pilot studies; for example, expected emission reductions from an unproven technology or emissions data from one neighborhood scaled up to an entire nation would count as modeled data
- Net enabling effect: The final output of the methodology, often reported in terms of reduced carbon emissions from ICT implementation
- Primary data (EPA): Data collected by a researcher, specifically for the research project; examples would include pilot studies, customer surveys, or internal research

- Primary enabling effect: Immediate reduction of BAU system emissions occurring as a direct result of ICT system implementation; for example, reduced energy use from a smart lighting system
- Primary rebound effect: Immediate increase in BAU or ICT system emissions occurring as a direct result of ICT system implementation, often driven by behavioral changes in demand for carbon-intensive goods or activities; for example, increased home energy use from telecommuting as workers spend more time at home
- Process (ISO): Set of interrelated or interacting activities that transforms inputs into outputs
- Quantify: As defined in this report, to place a value on an effect of life cycle process or stage, either via measurement or estimation
- Rebound effect (SMART 2020): Increases in demand that reduce the energy conservation effect of the improved technology on total resource use; in other words, effects that offset some of the positive impact of ICT implementation. See primary rebound effect and secondary rebound effect
- Replace/replacement of BAU system: A situation where the installation of an ICT solution also requires disposal of a significant portion of the BAU system; for example, a new HVAC automation system that requires a major retrofit
- ReViSITE: Roadmap Enabling vision and Strategy for ICT-enabled Energy Efficiency
- Scale of adoption: The extent to which the ICT solution is implemented in terms of units, households, businesses or some combination therein. This will inform the extent to which secondary enabling and rebound effects should be taken into consideration
- Scope: Depth and breadth of the assessment or study. Performed in Step 1b in the ICT Enablement Methodology in which the ICT and BAU systems are defined, all potential effects are considered, and relevant effects are chosen for further consideration in Step 2
- Screening assessment: Refers to a preliminary execution of the LCA, to establish rough values of life cycle processes or stages. In the ICT Enablement Methodology, screening assessment refers to Step 2, where change in emissions for life cycle processes or full stages is estimated to determine if further, more rigorous assessment is required in Step 3
- Secondary data: Data that has been collected for another purpose, but can be analyzed again in a subsequent study; this will often come in the form of results of studies from other companies, industry bodies, or government
- Secondary enabling effect: Non-immediate reduction of BAU system emissions occurring as result of ICT system implementation; occur over time as either duration or scale of implementation increases; for example, infrastructure impacts, such as reduced need for future road construction
- Secondary rebound effect: The rebound effect(s) that occur over time as either the duration of implementation increases or wider-scale adoption occurs; for example, expanded operations at a business that saves money by increasing energy efficiency
- Smart building (SMART 2020): Group of embodied ICT systems that maximize energy efficiency in buildings
- Smart grid (SMART 2020): Integration of ICT applications throughout the grid, from generator to user, to enable efficiency and optimization solutions
- Smart logistics (SMART 2020): Variety of ICT applications that enable reductions in fuel and energy use by enabling better journey and load planning
- Smart meters (SMART 2020): Advanced meters that identify consumption in more detail than conventional meters and communicate via a network back to the utility for monitoring and billing purposes
- Smart motors (SMART 2020): ICT technologies that reduce energy consumption at the level of the motor, the factory or across the business
- "Sunk" embodied carbon: Defined as emissions that have already occurred and therefore cannot be abated. This arises whenever the ICT implementation augments or replaces the BAU system, which cannot be un-built
- System boundary: Aspects of ICT system and related environmental considerations deemed

relevant to the study; the system boundary can be based on geography, time, scale of adoption, or any combination therein

- tCO$_2$e: tons of carbon dioxide equivalent
- Telecommuting (SMART 2020): Replacing commuting by rail, car or other transport with working from home
- Teleconferencing (SMART 2020): Service that allows multiple participants in one phone call, replacing or complementing face-to-face meetings
- Teleworking (SMART 2020): Working remotely via the use of ICT solutions. Includes telecommuting and videoconferencing
- Uncertainty: In the context of ICT enabling assessments, refers to ranges of potential results, often related to modeled data used in the application of the methodology
- Videoconferencing (SMART 2020): The audio and video transmission of meeting activities

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