Delivering Tangible Carbon Emission and Cost Reduction through the ICT Supply Chain

Anders S.G. Andrae1,*, Ling Hu2, Long Liu3, John Spear4 and Keagan Rubel5

1Huawei Technologies Sweden AB, Skalholtsgatan 9, 16494 Kista, Sweden; 2Huawei Technologies CO. Ltd., Industrial Base, Bantian Longgang, Shenzhen 518129, China; 3Huawei Technologies CO. Ltd., 158 Shichuang Technology Park, Beijing Road, Zhongguancun, Haidian District, Beijing, China; 4epi Consulting, 4th Floor, Rex House, 4-12 Regent Street, London, United Kingdom and 5epi Consulting, A207, Yuexing 3rd Rd No. 8, Nanshan district, Shenzhen, China

Abstract: Actual commitments by suppliers—in the Information and Communication Technology (ICT) supply chain—to reduce their energy use are rare. The upstream supply chain is also very complex for electronic/ICT products and therefore challenging to control and measure for use by Life Cycle Assessments (LCAs) of products and upstream Scope 3 footprints of companies. In LCAs primary measured data over time are rarely used. The purpose of this research is to propose a method for identification, measurement and analysis of specific energy (electric power) and CO₂-eq. savings in the supply chain of an ICT Original Equipment Manufacturer (OEM). The aim is also to find the share of the supply chain savings—of energy use and CO₂-eq. emissions—compared with a telecom carriers' total supply chain spend for an identified contract. It is described how three suppliers of a large ICT OEM are engaged—via a contractual requirement—to identify and commit to substantial energy, cost and CO₂-eq. savings. First streamlined LCAs are performed—of four specific products—identifying the most impacting parts from a CO₂-eq. perspective. Second specific suppliers and factories are identified. Third visits are done in which energy assessments are made, savings identified, implementation costs quantified, and net cost saving opportunities are calculated. The suppliers are also trained in the International Performance Measurement and Verification Protocol (IPMVP). All in all these efforts are estimated to help save around 27,000 MWh energy and around 25,700 tonnes CO₂-eq. annually. For a five-year rollout contract around 1.5 times more CO₂-eq. can be saved than emitted. More than 1% of the telecom carrier’s annual energy consumption and CO₂-eq. savings followed by actual implementation and monitoring with IPMVP. All in all these efforts are estimated to help save around 27,000 MWh energy and around 25,700 tonnes CO₂-eq. annually. For a five-year rollout contract around 1.5 times more CO₂-eq. can be saved than emitted. More than 1% of the telecom carrier’s annual energy consumption and Scope 3 ‘Purchased goods and services’ emissions can be saved. This shows a clear indication of the possibilities of the proposed approach. Broadly speaking, the methodology presented is a potentially replicable model that can be used by ICT OEMs to make significant cuts within their supply chain, while lowering their suppliers’ operational cost base. By using the proposed methodology it is possible to address specific suppliers and engage them via a contractual requirement to identify and commit to specific savings to the benefit of ICT OEMs and telecom carriers both. In order to improve the current practice, the next step is to integrate the savings framework into an end-to-end dynamic framework based on LCA.

Keywords: Carbon footprint, Electric power, Energy, ICT, Scope 3, Supply chain, Supplier, Upstream.

1. INTRODUCTION

Presently the Information and Communication Technology (ICT) sector currently represents around 8% of the global electricity consumption and about 2% of the global carbon emissions [1]. The production of ICT devices is expected to escalate in the next decade [1]. This may lead to additional energy consumption and carbon emissions, especially in areas with high carbon intensity electricity grids [1]. Worldwide, research is being carried out to reduce CO₂ emissions—and other greenhouse gases—and increase CO₂ sequestration [2].

Manufacturing organizations’ environmental impacts are often attributable to processes in the firm’s upstream supply chain [3]. Environmentally preferable procurement (EPP) and the establishment of environmental purchasing criteria can potentially reduce these indirect impacts. Telecom carriers buy products and services from ICT Original Equipment Manufacturers (OEMs) and therefore improvements of ICT OEM product’s life cycle ‘sustainability’ performance will in turn improve telecom carriers ‘sustainability’ performance. As an example, British Telecom (BT) Group’s Scope 3 emissions from ‘purchased goods and services’ constitute ≈40% of their end-to-end net carbon footprint [4]. Pelton et al. argued that Life Cycle Assessments (LCAs) can help identify the purchasing criteria that are most effective in reducing environmental impacts [5]. However, as modeling each single unit process and its associated flows each time an LCA is performed will be time and data consuming, Lesange and Muller [6] identified that the LCA community has developed life cycle inventory (LCI) databases and LCA tools. Large Electrical and Electronics Engineering (EEE) companies such as General Electric (GE) have ongoing efforts—which involve LCA—to evolve sustainability concepts that improve the environmental performance of its
products and technologies while adding value to its customers and to society [7]. Inakollu et al. mentioned that the GreenHouseGas (GHG) Protocol lists analytical solutions to calculate the amount of carbon emissions in three sections: Scope 1, Scope 2 and Scope 3 [8]. Scope 3 refers e.g. to emissions caused by ‘purchased goods and services’ [6]. However, the upstream supply chain is very complex for EEE and ICT products—and therefore challenging to control and measure in LCAs of products and upstream Scope 3 footprints of companies. In addition it is often challenging to engage and motivate reductions in a suppliers carbon footprint based on LCA alone, especially in smaller and lower tier suppliers in the supply chain.

1.1. Review of Prior Knowledge Observations

Actual commitments and quantifications—by suppliers in the ICT supply chains—to reduce energy use and CO₂-eq. emissions are rare. Moreover, in LCA primary measured data collected over time are rarely used for ICT products. Additionally, methods for practical LCI data collection—such as CO₂-eq. emission data—are rarely explained. Huang et al. instead proposed streamlined approaches for enterprise carbon footprinting based on Environmental Economic Input–Output LCA (EIO-LCA) methodology [9]. EIO-LCA methods can be used for roughly estimating—and prioritizing—indirect emissions upstream and downstream of the supply chain.

Blanco et al. argued that little is known about how comprehensively firms are currently measuring their supply chain carbon emissions—or upstream Scope 3 [10]. Innakollu et al. concluded that one of the uncertainties in Scope 3 calculations arise from the amount of CO₂-eq. emissions generated by purchased goods [8]. Lee and Ma attempted to improve the problem of cutoff uncertainty in hybrids approaches—mixing process LCA and EIO-LCA—and proposed a method to minimize the cutoff uncertainty [11]. They concluded that when higher precision is required, process LCI will need to play an important role [11]. However, for less complex products than ICT—such as breakfast cereal manufacturing firm procuring grain, containerboard boxes, plastic packaging, electricity, and industrial cleaning solutions—Pelton et al. found that methods are common to estimate product impact-reduction opportunities [5].

GE developed an Excel-based LCA screening tool—using secondary data—by which questions such as “how significant are my materials and supply chain impacts relative to my use phase?” can be answered by nonexperts [7]. Moreover, based on EIO-LCA methodology, GE developed a tool to perform priority screening on their supply chain [7]. BT Group also used EIO-LCA for estimating their emissions from ‘purchased goods and services’ [4].

However, ICT OEMs are not yet covered by the academic literature as far as methodologies for defining and measuring supplier commitments to reduce CO₂-eq. emissions. To the authors’ knowledge, no successful approaches for practical collection of process LCI data—including International Performance Measurement and Verification Protocol (IPMVP) procedures—have yet been published by the ICT industry. Nor has the CO₂-eq. savings potential in the upstream for a telecom carrier been quantified.

1.1.1. The role of and need for LCA

Without LCA modeling there will be no starting values for ‘environmental impact’ per product, no parts of environmental importance can be identified on product level, and moreover no end-to-end product CO₂-eq. emission reduction assessment can be performed. Standardized LCA is also expected to be mandatory for all products sold in the European Union in the future [12,13]. It is likely that those LCAs—which use a higher share of primary data—will obtain a higher quality ranking than others. Nevertheless, this paper will focus on supplier engagement, primary data collection and saving commitments and less on full LCA results.

A short review of prior knowledge of supply chain carbon footprinting techniques is found in Section 1.1. Partial disclosure of methods, data and other relevant information is given in Section 2. The main results are found in Section 3 and then discussed in Section 4. The conclusions provided in Section 5 are consistent with the evidence.

1.2. Objectives

The main aim of the present research is to briefly, for the first time, describe a method for how three part suppliers of a large ICT OEM—and the ICT OEM itself—are engaged, via a contractual requirement from a telecom carrier. The goal is specifically to make the suppliers identify and commit to specific energy (electric power), cost and CO₂-eq. savings—as well as quantify and analyze these savings at the request of the ICT OEM and the telecom carrier. The specific contract refers to a rollout of four different ICT products—
produced in China—during five years in the United Kingdom. Other midpoint indicators than global warming potential—such as eutrophication potential—might be affected by highly variable local conditions.

The ‘environmental impact’ reduction is reported as CO₂-eq. emissions savings committed for one year and five years. However, the present research does not attempt to introduce any new methodological advances in LCA of organizations and products. Instead, streamlined attributional process LCAs are performed for four products—a modem and three access modules—in order to identify the most impacting part suppliers as far as use of energy and CO₂-eq. emissions. The choice of attributional LCA modeling instead of consequential modeling is motivated by the limited objective of this research. That is the goal is not the long-term environmental consequences of reducing energy consumption and related CO₂-eq. emissions in certain unit processes.

1.3. Hypotheses

**Hypothesis 1 (H1):** The specific contract will be net positive in CO₂-eq. emission terms over five years. Net positive means that the savings of three part suppliers and the ICT OEM will be larger than the upstream baseline CO₂-eq. emissions from the four products—each containing some of the three parts and others. The baseline is defined as the rollout amount of each of the four products multiplied by the CO₂-eq. emissions from upstream production—defined by Andrae as the pre-final assembly and final assembly [14]—for each product as identified with LCA described in sections 2.1.1-2.

**Hypothesis 2 (H2):** >1% of the total annual energy consumption and CO₂-eq.—of the telecom carriers Scope 3 ‘purchased goods and services’—can be avoided by three suppliers and the ICT OEM by using the proposed method valid for a particular contract.

The intention is not to allocate the overall energy and CO₂-eq. savings—done by the three suppliers and the ICT OEM—to the four products. Neither is an attempt done to quantify the savings achieved by a specific rollout of different amounts of modems and access modules.

2. METHODS

In this section it is explained which methods are used to obtain the results shown in section 3. The present communication article is restricted regarding the availability of materials or information due to confidentiality reasons. However, the description is aimed at being as transparent as possible regarding main assumptions.

2.1. The method and the Process

The scope of the project is four different devices—a modem and three access modules—used in optical networks. By focusing on upstream LCAs of these products, clear results can be achieved. Figure 1 shows the overall approach.

![Conceptual flow diagram for the method used to identify and achieve the CO2-eq. reduction results.](image-url)
2.1.1. Perform Streamlined Process-Based Life Cycle Assessments (LCAs) of Products

Streamlined LCAs of four optical devices are done to identify parts and unit processes of interest for energy and carbon footprint reduction. An LCA is usually performed on a single product to identify drivers of environmental impacts. LCAs can also show which technology scenarios exhibit the highest overall environmental and lowest economic impacts. According to Laurent et al., the more primary data are used in LCAs, the more environmental impact categories can be used for decision-making [15]. Here only the Global Warming Potential Indicator (GWPI) is used as only a few—but important—primary data are available and here the telecom carrier only requests CO₂-eq. results.

The present research makes use of LCA in one way: perform streamlined LCAs of a modem and three access modules to identify parts of importance for CO₂-eq. saving in the upstream supply. LCAs can in this context be used in more ways, which is discussed briefly in section 6.

2.1.2. Identify Most Significant Parts

The streamlined LCAs use secondary data from the Ecoinvent database for CO₂-eq. emissions and the LCA tool Simapro 8.2.3.0 for the modeling of the four products. The purpose of the screening LCAs—for the current phase of the project—is to identify the parts shown in Figures 2a-b. The functional unit is one piece of equipment.

This approach is enough for identifying the most important parts; Printed Circuit Boards (PCBs), Power Supply Units (PSUs) and Mechanical Enclosures (MEs). Gomez et al. [16] and Gomez et al. [17] found that such approaches are not enough for precise eco-design in which more specific LCAs—e.g. using primary material content data—are necessary.

Certain CO₂-eq. intensities—wherever applicable to final assembly of PCBs, PSUs, MEs, modem and access modules—within the LCA tool are however replaced with local ones based on Chinese statistics [18]. This replacement is done for electric power production—0.949 kg CO₂-eq./kWh—natural gas combustion—0.0022 kg CO₂-eq./dm³, diesel fuel combustion—3.65 kg CO₂-eq./kg—and petrol fuel combustion—3.94 kg CO₂-eq./kg. In this manner the sources of electric power, natural gas, petrol and diesel given in the original Ecoinvent LCI models—for PCBs, PSUs and MEs—are changed to the new intensities. As an example, within “Printed wiring board, for surface mounting, Pb free surface [GLO]” production | Alloc Def, U—in the Ecoinvent database—the process “Electricity, medium voltage [GLO]” market group for | Alloc Def, U” is changed to the local “Electricity mix used by local suppliers and ICT OEM” emitting 0.949 kg CO₂-eq./kWh. In this manner the drivers for CO₂-eq.—in the chosen modem and access modules—can be clarified. Figure 2a shows the upstream drivers for the modem: PCBs, PSUs and Integrated Circuits (ICs).

Upstream CO₂-eq. repartition for the modem

Figure 2a: Significant parts in the upstream supply chain for the GWPI of the modem.

Figure 2b shows the upstream drivers for one of the access modules: PCBs, MEs and ICs.

Upstream CO₂-eq. repartition for one of the access modules

Figure 2b: Significant parts in the upstream supply chain for the GWPI of one of the access modules.

It is beyond the purpose of this research to show the exact details of the upstream LCAs of the modem and the access modules. Moreover, the results for the distribution, use and end-of-life stages of these products are not relevant for the purpose of this research. The annual total CO₂-eq. upstream emissions from Raw Material Acquisition, Part Production and Final Assembly of the contract rollout of thousands of modems and access modules equal some 17,200 tonnes, i.e. 86,000 tonnes in five years. Sections 2.1.3-9 describe how the annual savings of the PCB, PSU, ME suppliers and the ICT OEM are estimated. These
savings will then be related to the upstream emissions to test the hypotheses H1 and H2 listed in section 1.2.

2.1.3. Identify Suppliers and Specific Factories

Specific suppliers—for some significant parts—are selected based on a checklist, which identifies suppliers with the greatest potential to meet the project goals. So even if integrated circuits (ICs) is one of the most important parts (Figures 2a-b), the IC suppliers and factories are excluded in this project due to higher chance of success with other parts types—as far as commitment to CO2-eq. reductions are concerned.

Suppliers submit energy and cost data prior to factory visits to allow careening to validate their selection (they are likely to meet the project goals).

2.1.4. Engage, Visit the Factories and Perform Energy Assessment

This section refers to descriptions of the actual visits to the factories where the project is introduced to the suppliers. PCB, PSU and ME factories are visited and energy assessments are conducted by consulting energy experts, shadowed by ICT OEM energy efficiency staff during two weeks. These energy assessments validate the submitted data, baseline current energy consumption levels, identify savings and identify improvement opportunities. The assessments also quantify the estimated implementation costs and net cost savings opportunities. The energy experts train the ICT OEM staff in the International Performance Measurement and Verification Protocol (IPMVP) energy savings protocol. Then the ICT OEM use the protocol to create accurate baseline scenarios and savings calculations that can be validated throughout the lifecycle of the improvement initiatives.

2.1.4.1. International Performance Measurement and Verification Protocol

IPMVP provides best-practice methods for measuring and verifying the results of Energy Conservation Measures (ECM). IPMVP is a best practice methodology commonly used in industrial and commercial performance-based contracts. IPMVP is here used to identify energy saving opportunities.

2.1.5. Quantification and Analysis of Energy Conservation Measures

This section refers to the identification of the suppliers’ main energy flow diagrams and the energy saving opportunities on-site. The opportunities are mainly based on cost saving. This section also refers to the type of actions identified by each supplier and factory.

2.1.5.1. PCB Opportunities

The PCB supplier had previously undergone energy audits by government and client entities. Still they find five ECMs—for delivering further improvement—totaling some 10,000 tonnes of CO2-eq. Compressor and chilling solutions, respectively, are the biggest areas for improvements. All in all the ECMs equal to around 5% of their total annual release. The ECMs represent around 6% of their total annual costs, which are paid back on average in 2.7 years.

2.1.5.2. PSU opportunities

The PSU supplier has relatively more room for improvement than the PCB and ME suppliers. The PSU supplier owns the factory site, implying greater opportunity for longer-term investments than leased properties. The PSU supplier found six ECMs totaling some 4,000 tonnes of CO2-eq. Optimization of chilling and air compressors are the biggest areas for improvements, equal to around 15% of their annual total release. The ECMs represent around 16% of their total annual costs, which are paid back on average in 2.3 years.

2.1.5.3. ME Opportunities

The ME supplier is already operating at a high level of energy efficiency. Nevertheless, the supplier identified six energy saving initiatives totaling some 120 tonnes of CO2-eq. Powder coat washing optimization—and turning off the entrance and exit area fans—are the biggest areas for improvements equal to around 3% of their annual total release. The ECMs represent around 4% of their total annual costs, which are paid back on average in 2.5 years.

2.1.5.4. ICT OEM Opportunities

The ICT OEM finds 20 energy saving initiatives totaling some 3,700 tonnes of CO2-eq. Introduction of Light Emitting Diode (LED) lamps and air conditioning optimization are the biggest areas for saving electric power. Use of more solar power is the biggest area for CO2-eq. reduction. These ECMs equal to around 0.3% of their total annual release. The cost of the ECMs is paid back on average in 0.5 years.

2.1.6. Discussion with Suppliers on the Findings

This section refers to the final alignment and agreement with the four program participants on which ECMs they will commit to complete, in consideration of their feasibility analysis of all potential ECMs proposed as part of the program.
Following the identification of the above savings, discussions are held with suppliers who are asked to review the proposed plans and undergo a feasibility study of each ECM proposed from the assessment to determine its practicality and desirability in the context of existing operational considerations and capital requirements. The outcome of their respective studies is an improvement plan that each supplier commits to in terms of targets for CO2-eq. and cost reduction. Each factory has the opportunity to additionally add ECMs that they identify outside of the programme, providing they are consistent with the IPMVP methodology the factory personnel are trained in.

2.1.7. Suppliers Agree to Implementation Plan, Net CO2-eq. and Cost Savings

This section refers to final agreements on realistic energy savings targets for the identified opportunities, as well as the implementation plan, implementation costs, net CO2-eq. and cost savings targets. The agreements refer to newly identified and existing plans.

2.1.7.1. PCB Further Opportunities

The PCB supplier is able to find additional measures for improvements totaling some 4,000 tonnes of additional CO2-eq. These are e.g. switching to LED lamps and optimization of humidification and infrared ovens. All in all—by agreeing to ten different measures—more than 14,000 tonnes of CO2-eq. is committed annually. This is equal to ≈6.7% of their annual total GHG emissions. The measures represent around 7% of their total annual costs, which are paid back on average in ≈1 year.

There is seemingly a strong correlation between cost savings and GHG emissions savings. This will be discussed further in section 4.

2.1.7.2. PSU Further Opportunities

The PSU supplier agrees to the initial savings and finds no more ECMs. The ECMs represent around 16% of their total annual costs, which are paid back on average in 2.3 years.

2.1.7.3. ME Further Opportunities

The ME supplier removes its biggest saving opportunity—due to capital investment and site leasing considerations—and the final agreed saving—by agreeing to three different ECMs—is ≈30 tonnes of CO2-eq. annually, equal to 0.8% of their annual total GHG emissions. The ECMs represent around 0.8% of their total annual costs, which are paid back on average in 0.1 years.

2.1.7.4. ICT OEM Further Opportunities

The ICT OEM finds another saving of 3,400 tonnes in air conditioning optimization. This makes their final agreed saving—by agreeing to 21 different measures—6,900 tonnes CO2-eq. annually, which is around 0.6% of their total annual. The cost of the measures is paid back on average in about 0.23 years.

2.1.8. Savings Projections Made with IPMVP and Calculated According to the Exact Commissioning Times

This section refers to the planning of the actual implementation of the measures which could save energy and thereby CO2-eq. A time-plan is set up for the start and the end date of each ECM. The savings do not start until the ECMs are fully operational.

2.1.9. Actual Implementation and Monitoring with IPMVP

This section refers to monitoring and measuring of actual energy saving and emission reduction. The monitoring will be done quarterly for the duration of the supply contract with the telecom carrier. Whenever any measurement and reporting of the ECMs will be done, the IPMVP protocol will be applied. During the coming years the Accumulated Net Cost Savings ANCS in year \( y \) are calculated according to Eq. 1:

\[
ANCS_{i,j,y} = l_c - \sum_{y} y FPBT
\]

Where

\( ANCS_{i,j,y} = \) Accumulated Net Cost Savings of ECMs \( j \) for supplier \( i \) and the ICT OEM at year \( y \)

\( i = \) supplier type, e.g. PCB

\( j = \) ECM type, e.g. humidification optimization

\( l_c = \) Implementation Cost, e.g. £

\( y = 1,2,\ldots,Y \) number of years for the contract

\( FPBT = \) Average Pay Pack Time of a number of ECMs \( j \) at a supplier \( i \) or the ICT OEM

\( FPBT \) is calculated according to Eq. 2:

\[
FPBT = \left( \frac{\sum_{a=1}^{n} FPBT_{1,j}}{\sum_{a=1}^{n} a} \right)
\]
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where

\[ FPBT_{ij} = \text{Pack Back Time for } j \text{ at supplier } i \text{ or the ICT OEM}, \text{ years} \]

\[ n=1,2,...,20 \]

\[ a=\text{number of ECMs } j \text{ implemented at supplier } i \text{ or the ICT OEM} \]

3. RESULTS

Here follows a concise and precise description of the results. Table 1 shows a summary of the project results for annual CO\textsubscript{2}-eq. and energy savings compared to the corresponding annual data.

Table 1 shows that the total annual GHG emissions from the suppliers and the ICT OEM are \(\approx 1,518,000\) tonnes.

Figure 3—derived from Eq. 1—shows that the quotient between ANCS and \(I_c\) is much higher for the ME supplier (green line) than e.g. the PSU supplier (black line). The blue line in Figure 3 is represented by the ICT OEM and the red line by the PCB supplier.

![Figure 3: The share of Accumulated Net Cost Savings of Implementation Cost as a function of year after full implementation of Energy Conservation Measures.](image)

4. DISCUSSION

Here follows an interpretation of the results.

A potential weakness of the present approach is that attributional corporate inventories may not capture

Table 1: Total Project Savings Committed by Suppliers and ICT OEM

| Supplier | Accumulated Net Cost Savings (ANCS) after 5 years as share of Implementation cost \((I_c)\) (see Figure 3) | Annual CO\textsubscript{2}-eq. emissions before savings project [tonnes] | Annual Electric power consumption before savings project [MWh] | Annual CO\textsubeq. saving in 2018 [tonnes] after full implementation in 2017 of all measures | Share of annual CO\textsubeq. savings of annual total CO\textsubeq. emissions [%] |
|----------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|
| Printed Circuit Board (PCB) manufacturer | \(\approx 300\)% | \(\approx 216,000\) | \(\approx 227,900\) | \(\approx 14,700\) | \(\approx 6.7\) |
| Mechanics Enclosure (ME) manufacturer | \(\approx 4700\)% | \(\approx 3,700\) | \(\approx 4,000\) | \(\approx 30\) | \(\approx 0.8\) |
| Power Supply Unit (PSU) manufacturer | \(\approx 29\)% | \(\approx 27,000\) | \(\approx 28,000\) | \(\approx 4,000\) | \(\approx 15\) |
| Information and Communication Technology (ICT) Original Equipment Manufacturer (OEM) | \(\approx 2000\)% | \(\approx 1,272,000\) for Scope 1 and 2 [19] | \(\approx 1,340,000\) [19] | \(\approx 6,900\) | \(\approx 0.5\) |
| Annual upstream for modem, access modules and ICT OEM | | | | | |
| TOTAL | | | | \(\approx 25,700\) | |
| Telecom carrier | | | | \(\approx 2,266,000\) [20] | |
| Contract total after 5 years | | | | | \(\approx 128,500\) |
the full consequences of the decision in question, even with full scope 3 reporting—and are therefore not—according to Brander [21]—sufficient for mitigation planning.

Martinez-Blanco et al. [22] found that LCA of organizations may represent a key element in the internal decision-making system of an organization, as it can provide insight on the organization and value chain and identify hotspots where action is more needed. This study aims to improve the decision-making system in the ICT supply chain.

In a wider sense—as part of the next step of this research—a reporting framework should be developed which would help the ICT OEM and the telecom carrier to know which supplier and part type savings lead to the most CO2-eq. savings.

Moreover, the payback periods of CO2-eq. are not estimated for each ECM in the same manner as the financial pay back times. For example the CO2-eq. payback periods are not calculated according to Eq. 3:

\[
CO2PBT = \frac{ECM_{LCA,CO2}}{ECM_{CO2avoid,year}} 
\]

where

\[ CO2PBT = \text{Pay Back Time for CO2-eq., years} \]

\[ ECM_{LCA,CO2} = \text{life cycle CO2-eq. emitted in Raw Material Acquisition, Production, Distribution, Use and End-of-Life Treatment by the ECM}_{i,j}, \text{e.g. life cycle emissions from LED lightning or solar cells.} \]

\[ ECM_{CO2avoid,year} = \text{avoided CO2-eq. per year from ECM} \quad \text{(see Table 1 for each program participant)} \]

Still, there seems to be a strong correlation between cost savings and CO2-eq. savings—e.g. for the PCB supplier (see section 2.1.7.1). This is not surprising as most CO2-eq.—for the suppliers at hand—can be avoided by reducing electric power costs. The four programme participants are located in China, where coal typically accounts for \(\approx 3/4\) of thermal and electric energy production, and therefore carbon savings are significant when energy savings are reduced.

Table 1 shows that—for the present contract—the telecom carrier can save around 1% of its baseline electric power consumption and 1% of its Scope 3 “Purchased goods and services” emissions. However, the share of savings will likely be less than 1% after allocation—with LCA—of savings between suppliers, ICT OEM and telecom carriers. These allocations have to be done as the ICT OEM is not the sole customer of the three suppliers and the four products are not the sole output of the ICT OEM. Still the order of magnitude of the savings and per cent potential has been quantified.

Figure 3 shows that the share of ANCS of \(\ell_c\) is much smaller for the PSU supplier than for the other three manufacturers. The explanation is the relatively higher \(\ell_c\) and \(FPBT\) for the PSU supplier.

Anyway, around 1.5 times of the total annual GHG emissions from the suppliers and the ICT OEM can be avoided by the present contract. The accumulated savings over five years—taking place year on after full implementation, 42,000 tonnes—could be equivalent to around 5,400 new average cars emitting 120.1 gram CO2-eq./km and driving 12,900 km per year.

The suppliers use the CO2-eq. intensities mentioned in section 2.1.2. However other unit processes upstream are not investigated. This suggests that the 17,200 tonnes per year could be underestimated if those pre-final assembly processes would use high carbon power—and if they use relatively high amounts of electricity. The primary data collection presented in this paper “puts the spotlight” on such analyses.

5. CONCLUSIONS

The conclusion is that it is possible to address specific suppliers and make them identify and commit to specific savings to the benefit of ICT OEM and telecom carriers both. Around 27,000 MWh electric power and 25,700 tonnes of CO2-eq. can be saved annually by three suppliers and the ICT OEM for the specific contract. The contract is net positive in CO2-eq. emission terms over five years as around 1.5 times of the total annual GHG emissions from the suppliers and the ICT OEM can be avoided.

The annual data represent around 1% of the telecom carrier’s total electric power and 1% of its CO2-eq. emissions from “Purchased goods and services”. Broadly speaking, the methodology presented is a potentially replicable model that can be used by ICT OEMs to make significant cuts within their supply chain, while lowering their suppliers’ operational cost base. In this respect the approach was found to be readily accepted by suppliers as it directly improves a supplier’s cost base.
6. NEXT STEPS

ICT OEM suppliers’ CO₂-eq. emissions—and saving opportunities—are located in a longer chain of unit processes in the life cycle of individual products than is represented by the three suppliers of PCBs, PSUs and MEs. Andrae et al. argued that the intermediate unit processes are non-negligible for upstream LCAs of electronic devices [23]. This research will be able to shed more light on the importance of these processes as the present data collection approach likely can be applied widely in the supply chain. Actually only a certain share of the 25,700 tonnes ICT OEM supplier CO₂-eq. savings is attributable to individual telecom carrier carbon footprints. Not all of the present PCB manufacturer’s emissions are attributable to one ICT OEM, and not all ICT OEM emissions are attributable to one telecom carrier. Developing a method for achieving this allocation will be the next step of this research. The vision is that ICT OEM product LCAs can be combined with telecom carriers Scope 3 calculations in an overall framework by which strategic questions can be answered at any time—such as:

-Which part types are most sensitive to optimizing the telecom carrier Upstream Scope 3 emissions?

-What is the reduction potential of a certain product rollout from the ICT OEM to the telecom carrier?

-What is the efficiency of individual suppliers’ parts—e.g. PCBs—factory level savings to individual products’ energy and carbon footprint reduction over their whole life cycle?

-How do use stage electric power improvements for the products compare with suppliers and ICT OEM savings in manufacturing?

In this regard a method for ICT products must be developed by which the savings are allocated to individual products overall life cycle.

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AUTHOR CONTRIBUTIONS

Anders S. G. Andrae wrote the main parts of the paper except as follows. Keagan Rubel wrote several parts of sections 2.1.3-9, 4 and 5. Ling Hu wrote parts of Figure 1, Long Liu wrote parts of sections 2.1.5.4 and 2.1.7.4. John Spear wrote the title, parts of the abstract, section 1 including the hypotheses, and sections 2.1 and 5.

CONFLICTS OF INTEREST

The authors declare no conflict of interest. The views of this paper are the authors own and not those of the companies.

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