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Published in:
International Journal of Sustainable Development and Planning

DOI:
10.2495/SDP-V11-N6-1064-1076

Published: 01/01/2016

Document Version
Publisher's PDF, also known as Version of record

MEASURING THE ENVIRONMENTAL IMPACT OF ICT HARDWARE

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ABSTRACT

Society needs information and communication technology (ICT) hardware to produce, process and store highly valuable information. This hardware, of course, affects the environment throughout its whole life cycle, starting with manufacturing, where the necessary scarce and precious resources (e.g. rare earth metals) are often mined under miserable environmental conditions. This leads to pollution of soil, water and air in the present as well as for the future. During the use phase of ICT hardware, energy consumption impacts the environment. At the end of life of ICT hardware, recycling, disposing as e-waste in landfills or disassembling are additional impacts that affect the environment. More and more producers and users, especially companies, want to measure these impacts, which is a complex task. However, approaches to measure the impacts are at hand, either as single indicators, measuring one specific impact, or as composed indicators, combining different single indicators into one 'summarizing' indicator. However, collection of data, measurement, assessment and interpretation are challenging. Unfortunately, guidelines for those who want to measure the impact of ICT hardware are rare. With our research, we aim to shed light on the various approaches to measure impacts of ICT hardware as well as their application in practice. Based on a literature review, we identified different indicators and them to the attention of experts from companies to assess these approaches in terms of practicability, significance and value for practice. The results show that research investigates and proposes a variety of different more or less complex indicators. However, business prefers single indicators, which are easy to measure and understand.
Keywords: impact of ICT hardware, measurement, performance indicators.

1 INTRODUCTION

Information and communication technology (ICT) hardware has found its way in our everyday private and business life. However, its extensive use has immense impacts on the environment. Throughout the whole lifecycle, ICT hardware affects the environment. Indicators for measuring those impacts are at hand. However, due to the complexity of ICT hardware, and also because companies prefer to measure by financial and non-financial indicators, which are easier to assess, a clear picture on ICT hardware impact measurement indicators does not exist. In this research, we focus on indicators applied by companies to measure the environmental impacts of ICT hardware. We identified different indicators from literature and brought the resulting approaches to the attention of experts from companies to assess these approaches in terms of practicability, significance and value for practice.

The remainder of the paper is structured as follows: first, we give a short overview on the current state of the field in performance and impact measurement, with special emphasis on ICT hardware. Second, we explain our methodological approach, in particular sampling of the literature and assessment of the indicators found. Third, we present the results, discuss

WIT CONFERENCES
This paper is part of the Proceedings of the 3rd International Conference on Environmental and Economic Impact on Sustainable Development (Environmental Impact 2016)
www.witconferences.com

ISSN: 1743-7601 (paper format), ISSN: 1743-761X (online), http://www.witpress.com/journals
DOI: 10.2495/SDP-V11-N6-1064-1076

them and provide propositions for further research. Finally, we provide a conclusion, limitations and further research.

2 STATE OF THE FIELD

Companies adopt different ways to measure their performance and impacts [1]. Results are used as a basis for decision making and changes in the company [2]. On one hand, financial performance is measured to document the success and wealth of a company [2]. Financial performance indicators [3] are the basis for financial reports, which are disclosed to the wider public in accordance with different laws [4]. Special emphasis to assess the success of companies has been put on key performance indicators (KPIs), which measure the critical aspects of companies' performance [5]. Non-financial performance indicators, like customer satisfaction or loyalty, employee training or product quality, have been evidenced to influence companies' success, as well [6]. Furthermore, it has been evidenced that non-financial indicators provide important information for a company in their original, non-peculiar form (e.g. CO2 emissions in tons per year). However, approaches to monetize such indicators can be observed [5] (e.g. costs evolving from CO2 emissions in tons per year). Clearly, companies measure their non-financial performance in terms of their impacts on society and environment. This has not always been the case but due to pressure from society in the context of environmentalism [6] and the advent of business ethics and corporate social responsibility (CSR) [7], companies adopt and integrate them in their measurement systems. In many countries, measurement and disclosure of non-financial reports is regulated by laws [8]. However, companies started to voluntarily disclose information beyond the obligatory financial reports [9] in the form of CSR or sustainability reports [7]. Sustainability reports integrate indicators, measuring environmental and societal impacts like greenhouse gas (GHG) emissions or employee satisfaction to state companies' activities in this area [10]. Different indicator schemes, measuring environmental performance such as Environmental Performance Indicators (EPI) [11], Key Ecological Indicators (KEI) or Green Performance Indicators (GPIs) [12], to name just some, are at hand for governments and organizations alike. But still, 'what' and 'how' to measure are open questions requiring further investigation [1]. Although the number of environmental and social indicators seem to be exploding, in the context of green ICT indicators measuring impacts are rare. Green ICT comprises greening by ICT (e.g. environmental information systems) or greening of ICT (reducing environmental impacts of ICT products) [13].

Particularly, the possibilities to reduce environmental impacts of ICT hardware require sound measurement. ICT hardware affects the environment throughout the whole lifecycle. When manufacturing ICT hardware, scarce and precious resources (e.g. rare earth metals) are mined under miserable environmental conditions [14, 15], leading to pollution of soil, water and air [16] in the long term. with usage of computers, power consumption further impacts the environment [17]. At the end of life, the impacts are even more severe, as ICT hardware can be recycled, disposed as e-waste in landfills or disassembled requiring energy and when operated in an inappropriate way, pollutes the environment [18, 19]. Especially at the end of life, the variety of products (e.g. mobile phones, servers, printers, computers integrated into other products) and different materials integrated (e.g. plastic, metals, liquids) makes measurement of impacts a hard task [20]. Besides the complexity of the product, the lack of green ICT indicators may be other reasons. On one hand, Green ICT is a rather new field [13]; on the other, sustainability frameworks like ISO 14001, the Greenhouse Gas Protocol (GHGP) or the Global Reporting Initiative (GRI) barely address Green ICT [21].

All indicators, financial or non-financial, require sound data collection. While accounting systems and enterprise resource planning systems automatically generate data for financial indicators, data for environmental indicators requires additional sources. For both – financial and non-financial indicators – different indicator types are at hand. Single (or pure) indicators measure one specific impact (e.g. CPU power consumption). They can be pure numbers of units (e.g. number of hardware), express relations to other numbers (e.g. number of hardware per user) or time (e.g. number of hardware per year). The number of single indicators used in a company may be enormous, making them hard to understand and maintain. Thus, indicator systems (e.g. DuPont system), composed of compound indicators (e.g. ecological footprint [22]) have been created to assess more complex relationships in a summarizing number. On a more abstract level, symbolic representation of compound indicators, such as the footprint of a human being in terms of resources used, has found attention. Besides those, holistic approaches, integrating financial and non-financial indicators have the potential to overcome disadvantages of pure financial measurement in balancing the different aspects [23]. Especially in the context of ICT hardware, research and business discuss compound and holistic approaches. For example, the Lifecycle Assessment (LCA) tries to integrate all environmental impacts throughout the whole lifecycle [24]. Clearly, producers of different parts that are integrated, have to cooperate and provide according data [25]. Fairphone, (https://www.fairphone.com/projects/life-cycle-assessment/) is an example, produced based on fair, responsible and environmental considerations. In general, indicators for measuring financial performance have been criticized to reduce complex situations to simple numbers [23]. While single financial and non-financial indicators are narrow in their exploratory power, compound indicators are hard to interpret. When the results vary from measurement to measurement it remains unclear which underlying indicator has changed [2].

3 METHODOLOGICAL APPROACH

We applied a systematic literature review for identifying indicators for measuring environmental impacts of ICT hardware. First, we identified appropriate search terms based on a short pre-study. Queries included different combinations of Green ICT/IT/IS, ICT/IT hardware, (performance) indicator (performance) measurement, metrics, performance management, environment, energy, pollution as well as scorecard. We applied Boolean operators (AND, OR, NOT) to combine the search terms, on two scientific databases (EBSCO and ABInform/TI ProQuest) in December 2015. The search resulted in 350 academic papers (7 excluded due to language issues). We further selected the papers based on reading the abstract and further reduced the sample to 118 papers. By investigating their content, we excluded all papers that reported performance measurements of governments or pure environmental indicators, not targeting towards ICT hardware. Finally, we identified 59 papers for analyses. Further screening to identify indicators was performed by the co-authors using a software program for content analysis (Atlas.ti).

The results of the literature review were brought to the attention of three experts for assessing their opinion on practicability, significance and value for practice. First, experts were asked to mark the indicators in terms of ‘known’, ‘used by us’ (in the company) and ‘used by others’ (other companies). Second, in a short interview based on rough guidelines, we wanted to identify practicability (efforts for measuring the indicators), significance and value for practice. Interviewees were asked to describe how they think the indicators are or can be used in practice. Finally, to gain a broader understanding on the research–practice gap, we asked them to name other indicators they use and explain the advantages or disadvantages of these indicators in brief. All interviews were conducted in the native language of the interviewees, and were audiotaped. Quotations from the interviews have been translated.

4 RESULTS

We found 77 different indicators (listed in Appendix A), measuring the impact of ICT hardware in the literature. Hereinafter we refer to them as ICTIMIs (ICT impact measurement indicators). We investigated the literature from different perspectives: resource (energy, water, emissions, waste, other), type of indicator (single, compound, holistic, symbolic measurement), to which ICT hardware they were applied (Specific hardware, Network, Data centers, System/service or general) as well as ICT facilities (e.g. cooling). In addition, we identified whether the ICTIMIs target towards efficiency, consumption or other parameters (e.g. utilization).

Most of the ICTIMIs target towards energy (47) and only a few assess emissions (5), waste (4), water (1) or combinations of them (20). The majority of the ICTIMIs discussed in literature are single indicators (54), have a symbolic representation such as footprint (11), are compound indicators (6) or holistic (6). Concerning hardware, most of the ICTIMIs are general (41) without further specifying on which hardware they are applied, 11 are hardware specific, 9 measure the impacts of networks, systems or services (6), or data centers (5). Some ICTIMIs measure facilities like air-conditioning, space (7), however, 5 of them are only targeting towards facilities, 2 in addition towards data centers. Out of the ICTIMIs identified, 27 measure the consumption, 25 efficiency and 25 target towards other aspects like productivity or utilization to name just some. Figure 1 summarizes the numbers, and a full representation can be found in Appendix A.

The results were brought to the attention of three experts. Expert 1 (E1) has been Chief Security Officer (CSecO) in a transportation company since 2011. The company has about 6 000 employees worldwide, using a variety of ICT hardware. Expert 2 (E2) is a consultant for different small- and medium-sized companies. He has been self-employed since 1995. His expertise is especially on network, network equipment and data centers. Most of his

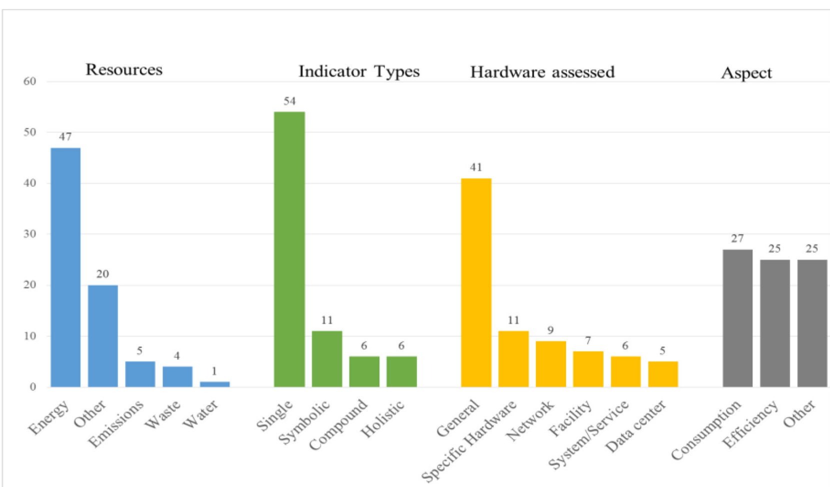

Figure 1: ICTIMIs by resources, type of indicator, hardware assessed, aspect.

customers are telecommunication companies or internet service providers. Numbers in the table summarize all his current customers. Expert 3 (E3) is Chief Technology Officer (CTO) of a medium-sized company in the retail sector. She has been working in the company since 2000 and in this position since 2013. The company sells hardware and software (see Table 1).

The three experts assessed the list of ICTIMIs quite differently. Concerning marking the indicators in terms of 'known', 'used by us', 'used by others', all experts know about half of the ICTIMIs found (E1: 37; E2: 42; E3: 32). However, Expert 1 mainly knows indicators for measuring energy efficiency in general. Expert 2, by contrast, knows many of the indicators, but in the companies he is working with, he uses only 13, mainly addressing networks and data center efficiency. Expert 3, is aware of many footprint indicators, but has neither used them nor have seen them used. Most well-known and applied indicators are CPU usage efficiency, energy efficiency, energy efficiency of data centers, paper used for printing, PC power management, PUE, ScE. Although they know some indicators (e.g. Green IT BSC), they do not apply them. The ratio between indicators known and indicators used varies from 0.65 (E1), 0.47 (E3) to 0.41 (E2), whereas the ratio between knowing and used by other companies is slightly higher (E1: 0.78; E2: 0.62; 0.88). Table 2 summarizes the results; Appendix A represents all results.

Table 1: Characteristics of experts.

	E1	E2	E3
Position	CSecO	Consultant	CTO
In the company since	1990	1995	2000
In this position since	2011	1995	2013
Industry	Transportation	ICT	Retail
Employees (approx.)	6 000	-	320
IT hardware	300 servers, 7 networks, 30 000 devices 2 data centers	450 servers 12 networks 4 500 devices 5 data centers	5 servers 1 network 500 devices 2 data centers

Table 2: Summary of Experts' Assessment of ICTIMIs.

	E1	E2	E3
Known (K)	37	42	32
Used by us (U_U)	20	13	15
Used by others (U_O)	29	26	28
Ratio U_U/K	0.65	0.41	0.47
Ratio U_O/K	0.78	0.62	0.88

Indicators unknown	24
Known by one expert	20
Known by two experts	8
Known by all experts	25

In the interviews, the experts expressed their points of view on practicability, significance and value for practice. All three explained that compound indicators such as footprints are not useful for them because they are ‘hard to assess and even harder to understand’ (E2). The same applies to holistic approaches like LCA or the Green IT BSC. Expert 1 mentioned that they started a project to set up the lifecycle assessment for one specific hardware they bought, but ‘due to the massive amount of data needed, we stopped it’. Furthermore, Expert 1 specifically expressed that the Green IT BSC ‘is too complicated and requires a lot of resources to collect the necessary data’. Expert 3 mentioned that they do not use the balanced scorecard approach in their company, so there is no basis for the Green IT BSC. All experts expressed their preference for single performance indicators, especially energy measures. Furthermore, they found it important that collection data, calculation and monitoring operate automatically. Expert 2 mentioned that ‘the data to measure CPU usage efficiency, for example, can be collected automatically via integrated protocols making monitoring easy – that is why we use it’. All three agreed upon energy being the most significant resource measured, since ‘energy means money’ (E3). However, Expert 2 reported that one of his customers stopped measuring the energy efficiency of servers since it influenced the general performance. Expert 1 made a similar statement by explaining ‘that we only measure where it has not influence on the performance’. All three experts expressed that some results from measuring impacts of ICT hardware are published in internal or external sustainability reports (e.g. PUE), but only because they were existing. When buying new hardware, labels like the energy star are ‘somehow relevant, but price and functionality are more important’ (E3). Expert 3 mentioned, that ‘especially the PUE and similar indicators were helpful when we set up our new data center’. When asking them to name indicators not listed in our results, Expert 1 named very generally ‘indicators from ITIL, COBIT or ISO 14001’, whereas Expert 3 came up with a list of six indicators, she could name by heart, because they are ‘extensively used in the company’ (see Table 3). Only Expert 2 did not name any indicators, but explained that

Table 3: List of Indicators (Expert 3).

	Energy	Other	Single	Compound	General	Spec. Hardware	Facility	Consumption	Efficiency	Other
Paper pages per employee		x	X							
Percentage of energy used from renewable sources	x		X							
Percentage of recycled printer paper		x	X							
Renewable energy use										
Software sustainability index		x		x						
Watts per Active Port	x		X							

'indicators have to fit to the company and depend on the requirements and specifications'. Interestingly, Expert 1 explained that there is no plan or strategic decision on indicators used to measure impacts of ICT hardware. Some are measured 'because we know how to measure them' (E1), 'we can visualize them in the dash board' (E2) or 'they have always been measured' (E3). Out of the list of ICTIMIs from literature, none seemed to be interesting at the current state. Experts 1 and 3 expressed that they would use repositories of ICTIMIs, but they were not aware of an existing one.

5 DISCUSSION AND PROPOSITIONS

With our research, we aim to shed light on the approaches to measure impacts of ICT hardware as well as their application in practice. Our research revealed that academic literature discusses a respectable number of different indicators. However, the experts in our study were not aware of many of the indicators developed from literature. Although well known, complex compound indicators such as the LCA and the Green IT BSC are rarely applied in practice. Practice by contrast applies indicators, which are easy to measure and understand. In research and practice, measuring efficiency and consumption of energy dominates by far measurement of other resources. This may be because energy measurement is directly connected to cost considerations. In general, we see that companies have adopted some ICTIMIs, but reasons for their implementation remain unclear. Hence, we contribute to research and practice alike. For research, the propositions may foster as a starting point whereas practical implications arise from the knowledge gained concerning factors influencing ICTIMIs application.

Experts know more than the half of the indicators collected from literature, but apply only a few of them. Based on the interviews, we conclude that several factors influence the application of ICTIMIs. First, it is their practicability. When the data for the ICTIMIs can be easily collected, best case automatically, they have a good chance to be applied. This is clearly connected to what has been said before about financial indicators, where the data is collected or created almost automatically by accounting systems [2]. Second, the experts in this study expressed that the priority is on the performance of hardware, not on measuring impacts. Companies that need to have clear and understandable indicators also explain the reluctance of the experts to implement compound indicators, indicator systems and holistic approaches. Other research already revealed that compound indicators such as the ecological footprint are often used on the governmental level, but not on the company level. Hence, we postulate:

Proposition 1: Easy collection of data, no or low influence on the performance of the hardware measured as well as easy to understand results are factors influencing the application of ICTIMIs in companies.

As we have seen in the literature review and learned from the experts, energy efficiency and consumption are in focus. First, energy consumption is easy to measure, but second and even more important, decrease of energy consumption immediately reduces costs. This is somehow in line with research, where monetarization of non-monetary indicators has been discussed lengthily [5]. Reasons for these efforts may lie in the long tradition of financial indicators, the current economic system or the need to be comparable with other competitors. However, we propose:

Proposition 2: Adoption of ICTIMIs with a clear and direct connection to monetary consequences (costs, savings) will be more likely compared to non-pecuniary ICTIMIs.

Interestingly, the experts in this study did not express any strategic considerations for implementing ICTIMIs. This is somewhat contradictory to results from research, since the responsibility for the selection of performance indicators is often seen as a strategic task [2]. In the rather new area of 'greening ICT', other factors influence the selection of ICTIMIs. First, pragmatic considerations like employee knowledge on the measurement are more important. Second, the fit to operational requirements for monitoring (like visualization) plays an important role. Third, a kind of convenience also influences the selection (e.g. 'have always been measured', 'is implemented into the hardware'). It is important to make clear that ICTIMIs are not randomly selected, because – as already described in proposition 1 and 2 – several factors influence the implementation and application. Consequently, we state:

Proposition 3: Pragmatic considerations, fit of ICTIMIs to companies' operational requirements as well as convenience influence the implementation of ICTIMIs more than strategic considerations.

6 CONCLUSION, LIMITATIONS AND FUTURE RESEARCH

Measuring the impacts of ICT hardware is a complex task. As we have shown, different approaches are at hand, but application in practice is rare. Main factors for adoption in practice are measurability and fit to task. Of course, this research has some limitations. First, due to the mere exploratory nature of our research, we did not test our assumptions and proposition. Second, the number of experts is rather low. A quantitative evaluation could be helpful to gain broader understanding. Our literature review serves as a solid basis for further research on privacy and security performance indicators. Future research should focus on the applicability of ICTIMIs as well as on testing the propositions mentioned above.

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Appendix A: List of Indicators

	Resources	Indicator Types	Hardware assessed	Aspects*	Known	Used by us*	Used by others*
APC - Area Power consumption	En	Si	Ge	Cs	0	0	0
Availability of formal environmental technology procedures	O_R	Si	Ge	O_A	0	0	0
CADE - Corporate Average Data Efficiency	O_R	Co	DC	Ef	3	0	2
Carbon footprint / CO2 footprint	Em	Sy	Ge	Cs	2	0	0
Carbon footprint of digital information services / storage	Em	Sy	Se	Cs	0	0	0
Cloud computing energy efficiency	En	Si	Se	Ef	2	1	1
Cooling System Efficiency	En	Si	Fa	Ef	3	1	2
CPE - Compute Power Efficiency	En	Si	Ge	Ef	1	0	1
CPU usage efficiency	En	Si	SH	Ef	3	3	3
CUE – Carbon Usage Effectiveness	Em	Si	Ge	Ef	1	0	0
Data centre physical footprint	O_R	Sy	DC	Cs	1	0	0
DCiE - Data Centre infrastructure Efficiency	En	Si	Fa	Ef	3	2	3
DCP – Data Centre Productivity	En	Si	DC*	O_A	1	0	0
DPPE - Data Centre Performance Per Energy	En	Si	DC*	O_A	0	0	0

	Resources	Indicator Types	Hardware assessed	Aspects*	Known	Used by us*	Used by others*
ECG - Energy Consumption Gain	En	Si	Ge	Cs	1	0	0
Ecological footprint	O_R	Sy	Ge	Cs	3	0	0
ECR - Energy Consumption Rating	En	Si	Ne	Cs	0	0	0
ECRW - ECR-Weighted	En	Si	Ne	Cs	1	0	0
EE - Energy efficiency	En	Si	Ge	Ef	3	3	3
EE in data centres	En	Si	Se	Ef	3	3	3
EE of (mobile sensor) networks	En	Si	Ne	Ef	2	0	2
EE of ICT operation	En	Si	SE	Ef	3	2	3
EE of ICT products	En	Si	Ge	Ef	0	0	0
EE of infrastructure	En	Si	SH	Ef	3	2	3
EE of Location Based Services	En	Si	Se	Ef	0	0	0
EE of systems	En	Si	Se	Ef	3	2	3
EE of terminals	En	Si	SH	Ef	0	0	0
Energy footprint	En	Sy	Ge	Cs	0	0	0
Energy star	En	Co	Ge	O_A	3	0	3
EnergyBench – Throughput of Joule for computing	En	Si	Ge	Cs	0	0	0
Environmental footprint	O_R	Sy	Ge	Cs	1	0	1
Environmental impact assessment	O_R	Ho	Ge	O_A	3	0	0
EPI - Energy Proportionality Index	En	Si	Ge	O_A	0	0	0
ERF – Energy Reuse Factor: Amount of reusable energy	En	Si	Ge	O_A	2	0	0
ESI - Energy scaling index	En	Si	SH	Ef	1	0	0
E-Waste per unit	Wa	Si	Ge	O_A	3	1	2
GHG footprint	Em	Sy	Ge	Cs	3	0	3
Global footprint	Em	Sy	Ge	Cs	3	0	3

	Resources	Indicator Types	Hardware assessed	Aspects*	Known	Used by us*	Used by others*
Green IT BSC (Green IT Balanced Scorecard)	O_R	Ho	Ge	O_A	3	0	2
Hazardous waste ratings	Wa	Si	Ge	O_A	0	0	0
HVAC – Heating Ventilation Air-conditioning Effectiveness	En	Si	Fa	Ef	2	2	2
ICT sector footprint / ICT's environmental footprint	O_R	Sy	Ge	Cs	1	0	0
ISO 14001 certification	O_R	Co	Ge	O_A	3	2	3
ITEE – IT Equipment Energy Efficiency	En	Si	Ge	Ef	1	1	0
ITEU – IT Equipment Utilization		Si	Ge	O_A	1	1	0
Joulesort – Amount of energy required to sort different size of records in data centre	En	Si	Ge	Cs	0	0	0
LCA – Lifecycle Assessment	O_R	Ho	Ge	O_A	3	0	3
LCA of supply chains	O_R	Ho	Ge	O_A	3	0	3
Material Flow Analysis	O_R	Ho	Ge	Cs	3	0	3
Memory footprint	O_R	Sy	Ge	Cs	0	0	0
Mobile Energy Efficiency network Benchmarking	En	Co	Ne	Ef	0	0	0
NPC - Normalized Power Consumption	En	Si	Ge	Cs	0	0	0
Number of IT environmental award	O_R	Si	Ge	O_A	0	0	0
Number of IT environmental certificates	O_R	Si	Ge	O_A	0	0	0
Number of trainings related to green technology usage	O_R	Si	Ge	O_A	0	0	0
Obsolescence Indication	Wt	Si	Ge	O_A	1	1	1
Paper used for printing	Wa	Si	SH	Cs	3	3	3
PBBline - Power consumption per line of Broadband	En	Si	Ne	Cs	0	0	0
PC Power Management	En	Co	SH	O_A	3	3	3
Power footprint of picocell	En	Sy	Ne	Cs	0	0	0
Power per User Ratio of total power consumed w.r.t number of subscribers	En	Si	Ge	Cs	0	0	0

	Resources	Indicator Types	Hardware assessed	Aspects*	Known	Used by us*	Used by others*
PUE Power Usage Effectiveness	En	Si	DC	Ef	3	3	2
Recycling Rate	Wa	Si	Ge	O_A	2	2	2
Risk technology assessment	O_R	Ho	Ge	O_A	2	0	0
ScE – Server Compute Efficiency	En	Si	SH	Ef	3	3	3
SPECPower – Power consumption per server on a given workload to complete	En	Si	SH	Cs	1	0	1
Sustainability performance record	O_R	Co	Ge	O_A	0	0	0
SWaP – Space Wattage and Performance	En	Si	Fa	Cs	1	0	0
TDP – Thermal Design Power: maximum amount of heat generated for which the cooling system is required	En	Si	Fa	O_A	0	0	0
TEEER - Telecommunications Equipment Energy Efficiency Ratio	En	Si	SH	Ef	1	1	1
TEER - Telecommunications Energy Efficiency Ratio	En	Si	SH	Ef	1	1	1
TPC - Total Power Consumption	En	Si	Ge	Cs	1	1	1
UPS System Efficiency	En	Si	SH	Ef	2	1	1
Utilization of ICT	O_R	Si	Ge	O_A	1	1	1
Wake on LAN	En	Si	Ne	O_A	3	0	2
WattsPerMAC Watts Per MAC port	En	Si	Ne	Cs	1	1	1
WattsPerVLL (Virtual Leased Line)	En	Si	Ne	Cs	1	1	1

Legend:

- Resources: En – Energy (47); O_R – Other resources (20); Em – Emissions (5)Wa – Waste (4); Wt – Water (1)
- Indicator Types: Si – single (54); Sy – symbolic (11); Co – compound (6); Ho – Holistic (6);
- Hardware assessed: Ge – General (41); SH – Specific Hardware (11); Ne – Network (9); Fa – Facility (7); Se – Systems and Services (6); DC – Data Center (5);
- Aspects: Cs – Consumption (27); Ef – Efficiency (25); O_A – other aspects (25)

* number of experts