A framework for sustainability assessment of ICT futures

Scenarios and sustainability impacts of future ICT- societies

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Abstract— **The rapid development of information and communication technology (ICT) has an influence on all societal sectors and can have both positive and negative consequences. To support ICT for sustainability (ICT4S), we need to learn when and how ICT can enable sustainable development. It is important to take into account all types of potential impacts – environmental and social, direct and indirect. Looking at future ICT societies and their potential environmental and social implications is of special interest, as this can provide valuable knowledge for planning and policy-making today to enable ICT4S.**

A methodological framework for environmental and social assessment of future ICT societies with a consumption perspective was developed as a part of a joint project with researchers at KTH, ICT industry, municipality and county. The overall goal of the project was to develop five different future scenarios for Swedish ICT societies and to assess the risks and opportunities for environmental and social consequences in those scenarios.

This paper presents the framework for environmental and social assessment of future scenarios and discusses the challenges experienced and lessons learned in the process of the framework development.

The framework is aimed to deal with a broad and complex object and scope of assessment, the inherent uncertainty and data restrictions of future scenarios, and is applying qualitative analysis.

Keywords—**sustainability assessment, environmental, social, ICT societies, framework, future scenarios**

I. INTRODUCTION

The development of the information and communication technology (ICT) is rapid and affects all sectors of society. This can be regarded as an opportunity, a risk, or a challenge. From a sustainability perspective, ICT is not automatically leading to sustainable development. In combination with selected incentives and other actions, however, there seem to be ways to facilitate ICT for sustainability (ICT4S).We need to learn when and how ICT can enable sustainable development. A number of environmental assessments of ICT-solutions have been performed, mainly focusing on direct, negative environmental impacts, arising from manufacturing, use and disposal of hardware [1]. There is also potential for overall positive impacts, for example when ICT-solutions can replace other products and activities (e.g. [2]). However, benefits provided by dematerialization may be counteracted by an induction of more or other activities [2, 3]. Some social assessments with a life cycle perspective have also been done, considering the social consequences throughout the supply chain of e.g. computers [4], or social consequences of introducing ICT, mainly considering the users [5].

When aiming for ICT4S, all types of potential impacts need to be taken into account. Perhaps the most difficult impacts to assess are implications in the future. How might future ICT societies look like from a sustainability perspective? How positive impacts can be supported and negative counteracted?

Futures studies is a research area used to learn about alternative futures, act on them and prepare for them [6, 7], and could be used to address these questions. To capture sustainability in its true sense, broad environmental and social consequences need to be addressed. With a structured and transparent assessment process of future ICT societies, valuable new insights can be gained and improved decision-support for planning and policy-making can be given.

As industry and policy-makers increasingly adopt life cycle thinking in strategic processes, an evaluation of long-term consequences of future ICT societies would also benefit from incorporating a life cycle perspective when assessing consequences.

To learn more about future ICT societies and their respective environmental and social consequences, researchers at KTH in collaboration with ICT industry and the Stockholm municipality and county engaged in a joint project aiming at developing future scenarios of Swedish ICT societies,

This paper is a part of the project Scenarios and sustainability impacts of ICT-societies. Funding for this project was supported mainly by VINNOVA-the Swedish Innovation Agency. We are thankful for ideas and comments from partners in the Centre for Sustainable Communications, CESC, and other experts, provided during workshops.

assessing them from a sustainability point of view, and giving policy recommendations based on the project outcomes. The overview of the ongoing project is presented in Fig.1. Each of the three main work packages (WP) has its own task(s) and outcome(s), however, the work is performed in close collaboration with other WPs. The purpose of the project is to provide basis for discussions about future planning on different levels that would consider ICT for enabling and facilitating sustainable development of the Swedish society.

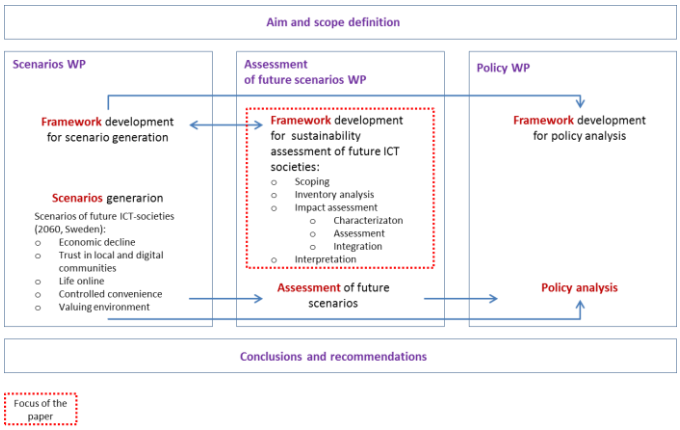

Fig. 1. Project overview

In order to assess the environmental and social consequences in the scenarios, an assessment framework has been developed within the project. This paper aims to present the developed framework (as an intermediate outcome of the project) and to discuss challenges related to the process of its development.

II. Method and Process

The process of developing the framework consisted of iterative steps including a literature overview, discussions within the interdisciplinary project group, and workshops with experts and stakeholders from academia, industry, city and regional planning administrations and authorities.

A. *Looking for existing frameworks*

Prerequisites for the framework were that environmental and social consequences should be assessed using a life cycle perspective. In line with the Swedish government's ambitions to consider the impacts occurring in other countries due to Swedish consumption when setting and reaching the environmental objectives [8, 9], a consumption perspective was to be used. This means that impacts of all goods and services consumed in Sweden are to be considered in the assessment, regardless of where the products are produced.

A literature overview aimed at identifying previous work in the field was made. However, no ready-to-use methodologies for the sustainability assessment of future societies with the desired scope were found. It was thus decided to develop a sustainability assessment framework. Since life cycle thinking was considered to be crucial, the standardized methodology for life cycle assessment (LCA) was used as a basis [10]. To support the framework development, the literature on the state of the art for sustainability assessment was studied (e.g. [11-14]). A few case studies were found (e.g. [15-17]) that provided ideas for the framework design regarding e.g. how large scale assessments can be handled, how future scenario assessment can be approached, and how life cycle perspective can be applied in this kind of studies.

B. *Creating the framework*

As the assessment was expected to deal with high uncertainty it was decided to assess risks and opportunities for environmental and social consequences rather than impacts.

According to [14] the choice of approach for an impact assessment framework is guided by several factors, such as the context, assessment level (local, regional, national, global), available resources and the preference of stakeholders. In this project the context was to consider environmental and social risks and opportunities related to ICT in future societies and the views from partners in the project, as well as some other stakeholders. The assessment level was set to be Sweden, but in a consumption, thus global, perspective.

When constructing the sustainability framework, some guiding principles from [11] were utilized: 1) both environmental and social issues were addressed, and the trade-offs and interdependencies were considered; 2) the future was considered (being the primary aim of the work) acknowledging the uncertainties in the use of qualitative data; 3) different stakeholders were involved in the process, even though the broader public was not engaged; 4) equity was considered in the social assessment part.

The project group was truly interdisciplinary and one of its main undertakings was to combine skills and knowledge from the fields of futures studies (scenario group) and of life cycle assessment, both social and environmental (assessment group), as well as a planning perspective (scenario and assessment group).

Workshops with experts and stakeholders were used as a method in the process of framework development. Workshops were chosen as a way of gaining new perspectives on complex issues. The experts and stakeholders involved were from academia, ICT industry, and Stockholm municipality and county. They were invited based on one (or a combination of few) of the following criteria: interest in the area; expertise in environmental and/or social issues; expertise in planning; knowledge of ICT industry. No broader public was involved; however, in future applications of this framework the variety of the stakeholders can be improved.

The workshops were held separately to define the environmental (WS1-2 e) and social (WS1-2s) aspects to be assessed. A first draft of the suggested framework was then discussed at a joint workshop (WS3) with experts. Here a draft of the framework was presented focusing on its main elements – the environmental and social aspects (hereafter – aspects), the contextual factors (presented below) and their interrelationship. Establishing these interrelationships was

deemed critical for the functioning of the framework. The discussion on WS3 was focused on the question whether it is feasible to do an assessment within the proposed framework and which additional and/or amended features would be needed to improve the functioning of the framework.

III. Result: The Assessment Framework

This section presents the assessment framework as a result of this work and reflects on the process of its development.

A. Framework overview

As mentioned above, the standardized LCA methodology [10] was used as a basis, and thus it is suggested the framework encompasses the following steps (Fig.1):

- Scoping – defining the goal and scope of a study and the procedure for the assessment;
- Inventory analysis – systems description and data collection;
- Impact assessment – assessment of the potential risks and opportunities related to environmental and social consequences;
- Interpretation – the outcomes from the above steps are interpreted.

The detailed description of each step of the framework, including the guidelines for application, is presented in subsections B-E.

B. Scoping

At this stage the goal and scope of the study are to be defined. While defining the scope, aspects and indicators to be assessed and contextual factors to be used need to be defined. Both steps are described further in this section.

1) Aspects and indicators

In the process of the framework development a set of environmental and social aspects and indicators were identified and defined. Aspects here mean environmental or social issues that were considered to affect the sustainability performance in the scenarios. In case an aspect needed to be specified further, sub-aspects were used, i.e. an issue was split into smaller issues. Indicators here mean a specific way of measuring an aspect. The set of aspects and indicators is a part of the framework, although, it could be modified when applied on other case studies.

As outlined by [18], one of the ways of choosing aspects is using subjectivity-based methods, which include own opinion, external recommendation or panel of experts. In this study, a combination of the three subjectivity-based methods was utilized: the selection was based on literature and own opinions, and then discussed within expert groups. Discussing a shortlist of aspects with the experts was seen as time efficient and reliable approach.

According to [14] the aspects and indicators should adhere to some basic principles by being relevant to the assessment scope, understandable to all participants, and not redundant with other indicators. These issues were addressed during the internal discussions and workshops (WS1-3) where the aspects were scrutinized and accepted, rejected or altered.

Aspects were defined aiming for an assessment that i) is as comprehensive as possible, ii) uses a consumption perspective, and iii) recognizes that the results would be largely qualitative due to inherent uncertainties and limited availability of data. The set of aspects and indicators took a slightly different form for the environmental and social assessments. Social aspects proved to be more complex and thus sub-aspects were introduced in order to better define and understand the aspects and assist the assessment. For each sub-aspect indicators were chosen. However, these are to be used more as discussion points rather than indicators in traditional understanding. Defining the environmental aspects was more straightforward in this sense - no sub-aspects were needed and indicators were defined directly for each aspect.

Environmental aspects and indicators

Based on literature, discussions and workshops (WS1-2e), it was decided to focus on resource input rather than emissions-related aspects. The purpose was mainly to simplify the assessment and make it more transparent. The aspects decided upon are Water, Land, Minerals, Chemicals, and Energy. Climate change was added as the only emissions-related aspect having such high importance and interest as well as rather good data availability. The aspects were all considered in a Swedish consumption perspective.

The descriptions of aspects and indicators below are based mainly on [8, 19-25].

The ***Water*** aspect considers water use, i.e. the amount of direct and indirect (used for goods production) water use over a year.

The indicators to be used for assessment are: i) Water footprint (WF) – the total amount of water used during one year (direct and indirect, in Sweden and outside); ii)Water scarcity – the share of the overall WF originating from regions with water scarcity problems.

The ***Land*** aspect covers land use, i.e. considering the land used for different purposes both inside and outside Sweden. Key to this aspect is the limited availability of land, the competition for which is becoming increasingly fierce in the context of demographic expansion and global per capita economic growth.

The indicator to be used for assessment is: i) Land cover pattern - the change of land cover pattern in the scenarios compared to today, reasoning about which type of land use is required, and if possible where this land use occurs.

Minerals are non–renewable natural resources, which are crucial for ICT, but also for other societal sectors. Minerals extraction and disposal may be related to considerable environmental impact. Here, the mineral use is assessed.

The indicators to be used for assessment are: i) DMC (domestic material consumption) of minerals per year, i.e. the amount of metallic and non-metallic minerals (including

production in Sweden and import but excluding export). ii) Consumption of critical minerals. No specific minerals are in focus here, but rather the group of critical minerals will be qualitatively addressed. The criticality of a mineral is typically given by a set of factors including its scarcity, importance to the GDP, and the set of countries it originates.

Chemicals (chemical products) are substances and mixtures of substances produced for specific purposes. The amount of hazardous chemicals used over a year is assessed.

The indicators to be used for assessment are: i) Consumption of "products mainly from petroleum products" per year. These products (i.e. heating oils, diesel, petrol, and aviation fuels) have been shown to contain numerous hazardous chemicals. ii) Consumption of CSMR-risk chemicals - the total amount of cancer, sensitizing, mutagenic, reprotoxic chemicals, excluding fossil fuels.

Energy used is considered by the following indicator: i) Total energy consumption - the total energy use by Swedish households, excluding energy embodied in goods, i.e. energy for heating, electricity and transport. It may be of interest to present the energy use in separate sub-indicators, e.g. for heating, electricity, and transport.

Climate change potential caused by Swedish consumption is considered using the following indicator: i) ton CO_2eq emissions per year.

Social aspects and indicators

Social aspects were first defined based on a literature review [26] and then further developed to increase the comprehensiveness and to align with the preconditions of the project using input from the 11 health objectives of the Public Health Agency of Sweden [27].

The proposal was discussed internally and at expert workshops (WS1-2s). The resulting aspects are Participation and Influence in society, Health conditions, Equity and Justice, Social cohesion, and Learning and Education. The sub-aspects and indicators for each aspect are described below.

Participation and Influence in society is defined by everybody being allowed and willing to take part in societal processes and influence them. It consists of two sub-aspects: Democracy, legitimacy and trust in government; and Equal participation.

Democracy, legitimacy and trust in government can be assessed using the following indicators: i) Participation in elections, for all as well as divided by different groups in society; ii) Mistrust among citizens in politics and for politicians.

Equal participation, defined as participation free of discrimination, based on e.g. health, geographical location, or cultural identification, can be assessed using the following indicators: i) Accessibility to important societal functions for all; ii) Presence of structures and systems for taking the views of the citizens into consideration in planning and decision making on local issues.

Health conditions consider a broad sense of health that includes physical, psychological and social well-being. The following sub-aspects are used: Equity from the start; Healthy places and social protection; Fair employment and decent work; and Universal health care.

Equity from the start, seen as equal access to healthcare in young age, can be assessed using the following indicators: i) Health care system generally available to all children; ii) Health care actively supplied to all children.

Healthy places and social protection, providing for safe and secure life conditions, can be assessed using the following indicators: i) General social security system; ii) Commitment by society to provide for everyone to have a home in a safe environment.

Fair employment and decent work can be assessed using the following indicators: i) Work environment; ii) Labor rights; iii) The work-life balance.

Universal health care can be assessed using the following indicators: i) Provision of health care of reasonable quality accessible to all citizens; ii) Disease-preventive activities.

Equity and Justice, defined as fair and just life conditions, consist of three different sub-aspects: Redistribution and access to resources; Recognition; and Absence of segregation.

Redistribution and access to resources, seen as a just distribution of resources and goods, can be assessed using the following indicators: i) Redistribution of income; ii) Access to services and infrastructure, and to education, including knowledge and skills development, access to bases of social power and to informal networks.

Recognition, seen here as the condition in a society, when equal rights and opportunities for everyone are recognized, when the society is 'difference-friendly', recognizing the distinctive perspectives of ethnic, 'racial', and sexual minorities, as well as gender difference. Recognition can be assessed using the following indicator: i) Societal consideration of the needs and rights of all groups.

Segregation describes the geographical separation of different social groups. It can be assessed using the following indicators: i) The mix or no mix of inhabitants in an area, based on socio-economic status; ii) Process of gentrification, the reshaping of an urban community by shifts in lifestyle and an increasing share of wealthier residents and/or businesses and increasing property values.

Social cohesion, viewed here as the way societies manage collective action and problems-solving, consists of three sub-aspects: Civil society; Social capital - bonding and bridging; and Sense of belonging.

Civil society can be assessed using the following indicators: i) The presence of Civil society organizations (CSOs), playing a key role in society by representing groups

of citizens, providing them with a collective identity, making their 'voice' heard and influence societal norms.

Social capital - bonding and bridging describes the integration of individuals into groups, communities or even general society, which can improve the efficiency of society by facilitating coordinated actions. This sub-aspect can be assessed using the following indicators: i) Integration within groups (bonding); ii) Integration between groups (bridging); iii) Level of trust in society.

Sense of belonging, defined as the identification of oneself as belonging to the society or a group, can be assessed using the following indicators: i) Willingness to participate and engage in society.

Learning and Education is defined here by the issue of *Supportive setting for learning for different groups* and can be assessed by the following indicators: i) Access to qualitative education for all for a sufficient number of years, irrespectively of income level; ii) School dropout rate; iii) Ongoing learning throughout the life span, including work-life.

2) Contextual factors

In order to be able to assess future scenarios in a consistent way, a set of so-called contextual factors needs to be defined. The contextual factors define information that is requested from the scenario descriptions for the purpose of assessing environmental and social risks and opportunities. Here it was done in an iterative process involving both scenario and assessment groups. The contextual factors are part of the framework, although, may be modified when applied to another case study depending on the goal and scope of a study.

Six contextual factors with a number of sub-factors were defined:

i. "Demographic conditions/population" describes the demographic situation in each scenario indicating the population growth or decline, cultural and ethnical diversity and the distribution of population between urban and rural areas.

ii. "Governance/state system" denotes political system and societal structure in each scenario, indicates economic growth or decline, relations of Sweden with the rest of the world, identifies policies (e.g. environmental policies) and social system (distribution and social security).

iii. "Value system (social and cultural)" defines the norms and values of the society in each scenario, describes relationship and people's behavior.

iv. "Life style" describes how people live in each scenario – what and in which amounts they consume (goods, services and food), how they work, live (housing size) and travel (how much and by which means), and what they do in their spare time (social life and societal engagement).

v. "ICT maturity" – describes the technological development of ICT infrastructure, the affordability and availability of ICT to population, the level of ICT use by the society as well as privacy issues if any.

vi. "Industry and technology" describes the production and trade pattern in each scenario and the level and development of general technology (in e.g. production and energy generation).

C. Inventory analysis

In the inventory analysis the information needed for the assessment is to be gathered.

First, the contextual factors and sub-factors, relevant for the specific assessment need to be identified. For example, "travel" (amount and means) is highly relevant for environmental assessment, but less relevant for the social one, while "social life" is relevant for the social assessment, but less so for the environmental one. Then, the information on all relevant contextual factors needs to be derived from the scenarios and summarized. When testing this element of the framework on our case study, the discussions with the scenario group were used to clarify and complete the descriptions.

Data on the performance of each aspect in the current state needs to be collected as part of the inventory analysis, as later in the assessment the performance of the aspects in each scenario is to be compared to the current state.

Additional information needed for the assessment is also to be gathered in this step.

The suggested sources of information for the inventory are the scenario descriptions (and background information used for scenario development), relevant additional literature and communication with experts, in workshops and individually.

D. Impact assessment

The impact assessment step of the framework consists of three sub-steps – *characterization*, *assessment* and *integration*. During *characterization* the contextual factors are to be analyzed in relation to the aspects and indicators, using the potential interrelationship between them. If an interrelationship is found, i.e. when a contextual factor is considered to have a substantial impact on an environmental or social aspect, it is to be described.

With the plethora of contextual factors and aspects identified, it is considered an insurmountable task to find support in literature for each and every interrelationship. Thus, it is suggested to use support from expert groups to discuss and define these interrelationships. When testing the framework on this case study this was done during the workshops (WS4e and WS4s) with expert groups. The usefulness and possible application of the results were also discussed.

During the next sub-step - *assessment* - the results of characterization are to be translated into indicator/aspect results for each scenario, resulting in a description of each aspect/indicator for each scenario compared to the current

state, i.e. stating whether there is a risk for performance to decline or not change, or an opportunity to improve. When testing this on our case study the input from WS4e and WS4s was taken into account and complemented by further internal discussions.

In *integration* the results for social and environmental consequences are to be integrated. The integration can be done in several ways and a combined workshop with both environmental and social experts (WS5) was used to discuss the alternatives. It is concluded that integration is to be done in a form of a feedback loop – considering the social implications of the environmental risks identified in the environmental assessment in a second round of social assessment.

The expected outcome of the impact assessment would mainly be a qualitative description of the integrated environmental and social risks and opportunities in the different scenarios. However, it is recommended to present the results in different ways in order to target a number of potentially interested stakeholders and to provide grounds for various types of discussions. The results for environmental and social aspects in each scenario presented separately can be used to provide information about the reasons for various consequences, and to facilitate the discussion on the importance of various factors for environmental and social consequences. The aggregated environmental and social results for each scenario can be presented to give an overview of the environmental and social risks and opportunities in each scenario. The integrated results for social and environmental assessment can further highlight the interrelation between the two and the importance of considering both types of consequences when making assessments of future scenarios.

E. Interpretation

In this step of the framework the results are to be summarized and discussed in relation to data gaps, uncertainties and assumptions made. The impact assessment results are to be put into this context.

Since the framework is mainly developed with the purpose of assessing the consequences of ICT societies, the main aim of the assessment is to consider the consequences that are in some way related to ICT. This is to be handled in the interpretation stage where the level of influence of ICT on results for each aspect is to be considered.

IV. Discussion

A number of challenges were faced when developing the framework. Some challenges for the further application were also identified during the development process and testing the elements of the framework. In order to further develop frameworks of this kind and improve further possibilities of evaluating the future consequences of ICT, we present, discuss and reflect on these challenges below.

A. Aspects and indicators

Defining the aspects and indicators was a challenging process in itself. While aiming to cover all the important environmental and social impacts, it was crucial to keep in mind the data restrictions present when dealing with future scenarios.

For the environmental aspects, it was decided to include all aspects that were considered important, even though some were difficult to assess. This was done in order to show the difficulties and highlight the need in further research. Chemicals, Minerals, and Land use were considered the most difficult.

One way of decreasing the uncertainty for environmental assessment was to define the environmental aspects as input indicators instead of emission-related indicators. This was seen as a possibility for avoiding problems with lack of data and additional uncertainties that occur when considering emissions-related indicators. A related challenge was to find the balance between usefulness and relevance and the way to use a qualitative approach in the situation of high uncertainty and data restrictions.

Due to the emphasis on resource use rather than emissions in the environmental assessment, the chosen aspects are not always clearly indicating if this is a positive or negative effect. For example, it is not evident what is a preferred change in the land use activities, thus the chosen indicator of land use pattern does not strive to show whether the land use gets better or worse, but rather provide grounds for the discussion on what kind of changes might occur and what would that mean.

Another indicator – critical minerals use – might not be considered an environmental indicator in a traditional meaning. It is, however, meaningful from an environmental perspective to assess the consumption of critical minerals in a study with ICT focus.

For the social aspects, there is no predefined set of aspects and indicators, and the range of social issues is very wide and context-dependent. One issue complicating the choice of aspects further is the mixed and interrelated perspectives inherent in social sustainability, considering impacts on societal as well as on individual level. Thus, the input from the stakeholder workshops was vital for the process of establishing the set of social aspects and indicators applied in the project.

B. Consumption perspective

The framework uses a consumption perspective, where social and environmental consequences related to the consumption of Swedes are to be covered. To be able to consider the implications Swedish consumption has on social conditions and the environment elsewhere, the impacts from products imported to Sweden need to be taken into consideration. This means that the activities, inputs and outputs related to the supply chain of all products consumed within Sweden are to be considered.

The consumption perspective is one of the crucial features of this framework. It is of great importance when assessing a society in a globalized world, with traded products from all over the world, and especially important when looking at environmental and social consequences related to ICT. Most negative impacts of ICT manufacturing (both environmental and social) are currently happening outside Sweden, mainly in the developing countries, while the positive impacts from the ICT use (e.g. efficiency gains, dematerialization, access to education, etc.) occur in Sweden.

Developing the framework it was important to see if it is feasible to make an assessment in a suggested way. Thus as a test, an inventory analysis for the current state of the environmental aspects including consumption perspective was made for our case study. This proved to be a challenge. Addressing a consumption perspective relies on knowing a country's trade flows and the related activities occurring at the places of production for imported goods and services. In practice, however, numerous challenges may arise (see also [8, 22]).

Trade statistics typically only encompass the monetary volume of international trade, and sometimes the sector, but not the exact products traded. For the same monetary value, however, different goods may have very different environmental impacts. Assumptions are needed for the distribution of goods among sectors and within a sector. Also, the economic sectors might be grouped and monitored in different ways in different countries, making comparisons more difficult.

Usually trade statistics only present the final exporting country. This, however, is often not the same place as where a product was manufactured. Thus, there is no information on the geographical spread of the full supply chain. This is a problem, since for many aspects, e.g. land use or water use, the magnitude of the impacts depends to a large extent on where they occur.

Climate impact has previously been assessed with a consumption perspective in Swedish context [8], but for other environmental aspects this type of information regarding current state was not available. The production perspective has so far been the main approach used for assessments on national or regional levels, and national statistics are to date concerned with occurrences within the borders of a nation.

When it comes to social aspects, the situation is a little bit different. The social impacts do not necessarily differ very much with the type of production process, thus the need for data on processes are not as important. However, the conduct of the production company and more so the production location is of importance, and thus the same challenges as for environmental aspects arise.

C. Quantitative - qualitative

Due to the broad scope and long term futures focus it was decided to develop an assessment framework that would lead to mainly qualitative results.

Avoiding quantitative results in this kind of assessment is deliberate, not to give an unsubstantiated sense of certainty and exactness. Still, to some extent at least the environmental indicators selected are in a sense quantifiable.

The starting point for developing the assessment framework was to be able to answer the questions *"What are the social and environmental consequences of ICT scenarios?", "How different is an aspect/indicator in each of the scenarios from the current state?"*. This can be answered both by a quantitative and a qualitative assessment, and the former would perhaps give more substantial information and also make it easier to draw overall conclusions when comparing the different scenarios. However, it is good to remember that maybe even more important questions to be answered are *"What are the reasons for these consequences and differences?", "What are the factors and combinations of factors that may lead to these changes?"*, etc. These questions may very well be answered using a qualitative approach.

D. Process – knowledge input and learning

It was considered of outmost importance that the framework was developed with participation and input from the interested stakeholders (e.g. industry and municipality). When further developing the framework and applying it, new and possibly enlarged stakeholder participation is encouraged, as this influences prioritization of the different aspects to assess and contextual factors needed. Participation is crucial for the important mutual learning outcome.

Working on the framework development in an interdisciplinary way has proved to be both beneficial and challenging. In a study like this, looking at the whole society and considering a wider range of environmental and social aspects, the value of an interdisciplinary approach to the framework development is extensive. The expertise in different fields and experience in different areas for the various stakeholders provided valuable input to the work, facilitated discussions approaching the issues from different angles and allowed for getting varied critical feedback. Environmental and social assessments are usually not done using one common framework. In this case, developing the framework together helped the integration to take off already from the start and gave a unique opportunity to consider the interrelation between various social and environmental issues already in the framework and not only later in the assessment.

However, an interdisciplinary approach means more challenges to find acceptable compromise on the way forward for a group of researches with different backgrounds and experiences. The main drawback has thus been that the process has probably been more time-consuming than it would have been without such a commitment.

The methodology development was partly done in joint discussions with the scenario group. The obvious benefit for the assessment group was the possibility to request information in a step-wise process in order to be able to adjust the framework for the needs of the future assessment of the scenarios. In this process it became clear that there was no sharp line between the scenarios and the assessments. The results of assessment using the suggested framework, i.e. risks and opportunities for social and environmental consequences, could be brought back to the scenarios in a feedback loop to inform revised scenarios. The assessment would then be a way of improving the scenarios. However, by presenting the assessment results separately this part can get more attention and the questions *"What are the reasons for these consequences and differences?"* and *"What are the factors and combinations of factors that may lead to these changes?"* are easier to address.

Futures studies researchers are used to dealing with uncertainties and do not strive for making scenario descriptions precise, while from the assessment point of view the more precise information can be provided, the better. As striving for quantitative assessments was impeded by the lack of data, discussions with the futures studies researchers have led to an insight that the detail and the precise results may not be of importance in this type of assessment. The key reason of performing this kind of study may be to raise discussions and to identify major reasons for different possible future consequences. For this, detailed quantitative results are not necessary.

Further, as guided by [12], the process of assessment using this framework can be deemed effective in the way that it can provide the partners (e.g. the municipality) with useful tools for their long-term planning, and can result in a lot of learning for all actors involved on how policies today may materialize in the future, along with the consequences they may have on future sustainability.

Finally, the way in which the assessment can be done using this framework can provide an opportunity for additional learning and discussion on how the various contextual factors and combinations of them may affect the environmental and social performance. This can be very useful in policymaking and planning for the future.

V. Concluding remarks

The outcome of this work is a framework for assessment of risks and opportunities for environmental and social consequences of future ICT societies. The framework is using consumption perspective and mainly leads to qualitative assessment results. With the ambition to deal with broad and complex objects and scope, and the inherent uncertainty and data restrictions related to future scenarios, there are many challenges that arise. Unlike a more quantitative assessment, with a more narrow scope, this framework does not suggest using precise data and modeling all related processes. Instead, more qualitative analysis is done, facilitating discussions about the different future scenarios and their consequences, the path towards these futures, how different consequences can be supported or avoided.

Evaluating future environmental and social risks and opportunities of ICT societies is challenging. The major reason for still taking on the task is to enable discussions related to policy and policy-making. One of the contributions of this work is providing a basis for and input to more substantial ICT environmental politics and social actions.

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