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Lorena Parra Boronat, Universitat Politècnica de València, València & Instituto Madrileño de Investigación y Desarrollo Rural, Agrario y Alimentario, Madrid, Spain

GREEN 2021

Forward

The Sixth International Conference on Green Communications, Computing and Technologies (GREEN 2021), held on November 14-18, 2021, continues the series of events focusing on current solutions, stringent requirements for further development, and evaluations of potential directions. The event targets are bringing together academia, research institutes, and industries working towards green solutions.

Expected economic, environmental and society wellbeing impact of green computing and communications technologies led to important research and solutions achievements in recent years. Environmental sustainability, high-energy efficiency, diversity of energy sources, renewable energy resources contributed to new paradigms and technologies for green computing and communication.

Economic metrics and social acceptability are still under scrutiny, despite the fact that many solutions, technologies and products are available. Deployment at large scale and a long term evaluation of benefits are under way in different areas where dedicated solutions are applied.

We take here the opportunity to warmly thank all the members of the GREEN 2021 technical program committee, as well as all the reviewers. The creation of such a high quality conference program would not have been possible without their involvement. We also kindly thank all the authors who dedicated much of their time and effort to contribute to GREEN 2021. We truly believe that, thanks to all these efforts, the final conference program consisted of top quality contributions.

We also thank the members of the GREEN 2021 organizing committee for their help in handling the logistics and for their work that made this professional meeting a success.

We hope that GREEN 2021 was a successful international forum for the exchange of ideas and results between academia and industry and to promote further progress in the field of green communications, computing and technologies.

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John S. Vardakas, Iquadrat, Barcelona, Spain
Roberto Verdecchia, Vrije Universiteit Amsterdam, Netherlands

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A Target System for the Introduction of IT-based Sustainability Management in Companies

Volker Stich
Managing Director
FIR e. V. an der RWTH Aachen
Aachen, Germany
e-mail: st@fir.rwth-aachen.de

Mathis Niederau
Information Management
FIR e. V. an der RWTH Aachen
Aachen, Germany
e-mail: ni@fir.rwth-aachen.de

Jan Hicking
Information Management
FIR e. V. an der RWTH Aachen
Aachen, Germany
e-mail: hg@fir.rwth-aachen.de

Robert Schröder
Information Management
FIR e. V. an der RWTH Aachen
Aachen, Germany
e-mail: sr9@fir.rwth-aachen.de

***Abstract*— Sustainability is a fundamental issue for companies, especially for Small and Medium-sized Enterprises (SMEs). A key challenge for the realization of sustainability is its complexity and multidimensionality. The content of this paper is a target system in which the field of sustainability is broken down to a level that is manageable for SMEs. By means of a hierarchy of the target system, dependencies between goals are made transparent and prioritization is made possible. The target system consists of eight key objectives and sixteen accompanying targets that concretize the Triple Bottom Line. The approach enables SMEs to take sustainability-relevant aspects into account in a targeted and structured manner.**

Keywords-digital transformation; target system; sustainability management; energy management

I. INTRODUCTION

Rising awareness of sustainable business practices in the corporate world can be observed [1][20]. On the one hand, companies are motivated to establish a strategy for sustainable management due to regulations, e.g., taxation benefits for sustainable companies. On the other hand, customers call for change and reward sustainable products by increased willingness to pay [2].

Often, a company's first approach to sustainability can be found in energy management. Governments are also aware of the significance of energy management. In practice, Energy Information Systems are used for tasks related to energy management. Target systems that support companies selecting a suitable software for their needs are the origin of the target system described in this article. Thus, a significant part of the target system is referring to energy management.

The article is structured as followed: Section 2 describes the state of the art, section 3 the approach, and section 4 the conclusions.

II. STATE OF THE ART

In this section, information regarding sustainability and target systems, in general, is provided. In addition to governments and NGOs, companies also need to play an active role to tackle global problems, such as climate change and social inequality. They are expected to play an active role. According to the triple bottom line approach, sustainability considers economic, ecological, and social aspects [3]. After [3], the founder of this approach, companies that pay attention to both ecological and social aspects can determine a positive effect on economic development, such as better access to new customers due to improved reputation regarding sustainability [4]. The Sustainable Development Goals of the United Nations (UN), which include, e.g., Climate Action or Reduced Inequalities, can serve as a further point of reference for companies, even if the goals are originally intended to address the member states of the UN [5]. The more globally a company operates and the larger its influence, the more goals are relevant. The Global Reporting Initiative is an independent, international organization, which aims to support companies when it comes to the preparation of sustainability reports [6]. Another initiative is the WIN-Charta of the German state of Baden-Württemberg, which can be described as a regional response to the global trend towards sustainability. The provided guiding principles are closely correlated to the SDGs and thus also build on the Triple Bottom Line [7].

Entrepreneurial action is characterized by constant decisions to maintain profitability. Concrete goals and their regular monitoring make it easier to determine the progress of management measures, as well as to derive improved options for action. Often it is necessary to prioritize goals, thus a target system can facilitate this prioritization. One approach of target systems is the Goal-Means-Thinking

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approach of HABERFELLNER, which defines a multi-level effect system [8]. The author distinguishes goals and means, where means serve as a solution for the goal above them on the one side, whereas the means represent a goal for the next subordinate level as well.

Another approach is the Plural target system according to SCHEIBLER [9]. Plural target systems have such key objectives which are free of conflict among each other. A key objective is a top-level goal in the system, for example, profit maximization. There are two levels below filled with subordinate goals that are derived from the guiding goals. Only the integration of the lower levels, i.e., contradiction-free, supply to superordinate goals constitutes a well-structured goal system [9].

III. APPROACH

The procedure for creating the target system is divided into three steps according to [3]. First, a target set is identified through desk research and analysis of relevant literature. The objectives of this set are abstracted based on measures, advice, and best practices cited in the literature, checked for relevance to SMEs, and summarized in case of overlaps. Then, complementary, or conflicting cause-effect relationships between the objectives are derived factually. Subsequently, the conflicting goals are mapped using HABERFELLNER's goal-means thinking in such a way that there are no longer any conflicting relationships between a leading target and the subordinate target. Finally, the hierarchical target system is transformed into a plural target system according to SCHEIBLER [9].

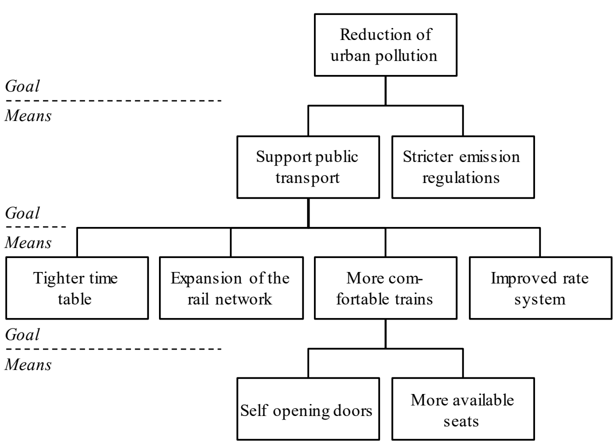

Figure 1. Structure of the target system

An example for a target system is shown in Figure 1. It combines several targets in a hierarchical structure by the goal-means-thinking by HABERFELLNER.

A. Economic dimension

One of the top priorities of entrepreneurial activity is to perpetuate high profitability, which is why it has found its way into a key objective. In addition to pure profitability, customer loyalty is the key to the long-term success of a company.

In economic terms, the main objectives listed are those aimed at reducing costs or ensuring the long-term existence of a company on the market through strong customer loyalty.

Increase profitability: The objective can be divided into two accompanying objectives.

Reduce risks in energy and raw material supply: This accompanying target is associated with the term resilience. Every manufacturing company depends on a reliable supply of energy and raw materials. Bottlenecks in the procurement of raw materials can bring production to a temporary standstill, and interruptions in the energy supply can cause additional damage to machinery and equipment. In either case, negative consequences for profit prospects must be expected.

Reducing energy and resource procurement costs: Expenditures for energy and resources account for almost half of total costs in the manufacturing sector. Other costs such as wages, depreciation, and amortization are less significant. To increase profitability, measures must therefore be taken to achieve cost efficiency in energy and resource procurement.

Expanding customer loyalty: Two accompanying targets are assigned to the key objective "Expand customer loyalty".

Improve image: A positive image has paramount importance for companies. The interaction of the three pillars of sustainability can be seen here. Even small efforts, such as publishing image brochures on the social and ecological commitment performed, can improve the image and contribute to economic success [10].

Increase customer satisfaction: The basis of stable customer loyalty is customer satisfaction [11]. All parameters during the contact between company and customer as well as the product's life cycle contribute to customer satisfaction. Starting with reliable and accurate information, a company's sphere of influence extends from pricing to after-sales service.

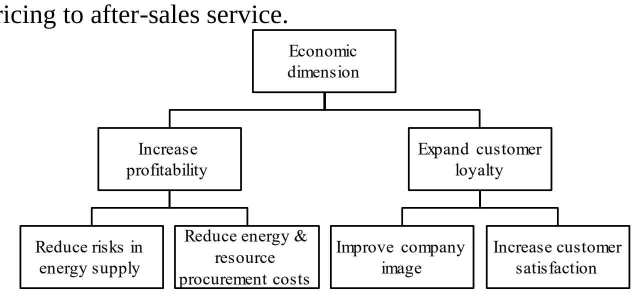

Figure 2. Economic dimension of the target system

B. Ecological dimension

Ecological aspects are prominent in the perception of sustainability. Sustainable ecological action encompasses

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many aspects, such as emissions. The central goal is a general reduction in environmental impact.

Optimize energy use: Making energy use sustainable means energy that is based on sufficient availability of suitable resources, while negative impacts are limited [12].

Minimize energy use: The most effective way to reduce CO2 emissions is to consistently diminish energy use. Less energy use means less environmental impact, and companies also benefit from lower procurement costs. A detailed examination of the energy flows and the associated costs of a business unit is possible.

Ecologize energy use: While it is important to use as little energy as possible, there are also limits to the scope of energy-saving measures. Efforts must therefore also be made to ensure that the energy usage is as environmentally friendly as possible.

Optimize use of resources: Optimizing the use of resources can be realized by the efficient and environmentally compatible use of materials and production goods.

Minimize resource use: Efficient material streams not only protect the environment, but also contribute to lower procurement costs. In addition, further savings are possible due to lower waste and reduced expenditures for further environmental protections, i.e., with innovative environmental technology.

Ecologize resource use: Regarding resources, companies can also strive for more eco-friendly solutions. The use of alternative or recycled raw materials offers numerous possibilities for acting.

Reduce environmental impact: To maintain or improve the current state of the world, a sustainable increase in energy and resource productivity is necessary. Furthermore, there is a need to limit the environmental impact caused by humans.

Minimize negative consequence: Climate and environmentally neutral production are a vision that requires a considerable number of further efforts. A key measure that can be expanded iteratively is to minimize the negative consequences of a company's production activities.

Create positive environmental impact: Another accompanying target of the ecological dimension offers companies numerous opportunities for action to go beyond reducing their ecological footprint and strive for targeted measures for a healthy environment.

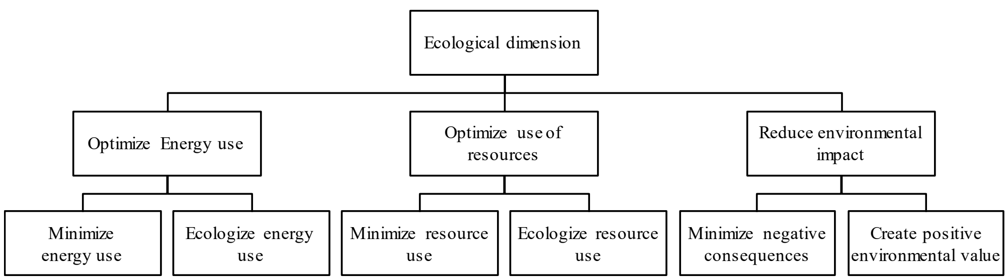

Figure 3. Social dimension of the target system

C. *Social Dimension*

By pursuing social goals many companies can also determine economic benefits. Social commitment improves the brand image and can thus lead to higher sales.

Promote health and safety: Employees of manufacturing companies in particular are exposed to a variety of health risks - for example, through the accumulation of problematic pollutants [12]. Thus, high motivation to perform occupational health management is given. Companies that actively care for the health of their employees are able to retain qualified employees in the company [13].

Ensure good working conditions: Employees in manufacturing SMEs complain about stress, strain due to static posture and noise. Measures are therefore required to ensure health and safety at the workplace, i.e., the establishment of a medical expert [14]. To also ensure the mental health of employees, efforts to ensure a pleasant working atmosphere and regular reviews of employee satisfaction are needed. In the future, concepts for work-life balance will be needed, enabling suitable working time models.

Provide a contractual framework for protection: Companies can protect employees by striving for long-term contracts, as employers feel financially secured and work in a stable environment. Since the search for new employees is a cost driver, it is worthwhile for companies. Extensive transparency regarding the pay structure also avoids potential conflicts. Added benefits for employees that go beyond monetary compensation increase employee satisfaction and strengthen the attractiveness of the employer in terms of employee acquisition. For example, companies can offer leasing models for company bicycles, or subsidize gym fees.

Seek participation and transparency: To ensure long-term identification of the employee with the employer, companies need to encourage employees to participate in sustainability-related topics. The focus of this key objective is the collaboration within the company across different hierarchical levels and includes the involvement of external interest groups.

Increase organizational candor: Clear communication channels and sufficient feedback are elementary factors for employee satisfaction. Feedback should be given in both directions. Candor and extensive conversations result in a high level of job satisfaction; employees are motivated, there is less willingness to change jobs, and employees have a greater interest in the further development of the company [15]. In addition, management must grant all employees the same possibilities and opportunities.

Strengthen employee involvement: Employees who experience a high degree of responsibility, competency, self-determination, and influence are also more satisfied with their work and identify more strongly with the company. Further positive consequences are increased productivity, performance, and innovation [16]. Not only large corporations but also SMEs can share the company's success with their employees. For example, a company will motivate its employees by sharing a percentage of the profit.

Enhance empowerment and cooperation: Not only do in-house training programs contribute to a sustainable employee base, but also external engagement that supports individuals enhances employer reputation.

Support people by corporate activity: Apprenticeships provide companies with qualified specialists who are capable of manufacturing high-quality products and offering sophisticated services. In this way, companies can counter the shortage of skilled workers at an early stage. Regular training also creates greater value for companies. Lifelong learning across all employee groups as well as individual and flexible training measures increase employee productivity and thus contribute to innovative strength and competitiveness [17]. Internal disputes and competing departments cause a shift in the focus on value creation. A harmonious interaction among employees is the basis for a good working atmosphere.

Support people beyond the company: Corporate giving is not yet very common among SMEs. Corporate giving is done above all to improve a company's image. Hence, a positive economic correlation has been proven between the extent of corporate giving and the company's success [18]. For smaller companies, topics with a regional or local connection are particularly suitable [19]. Furthermore, investment to individuals can be made.

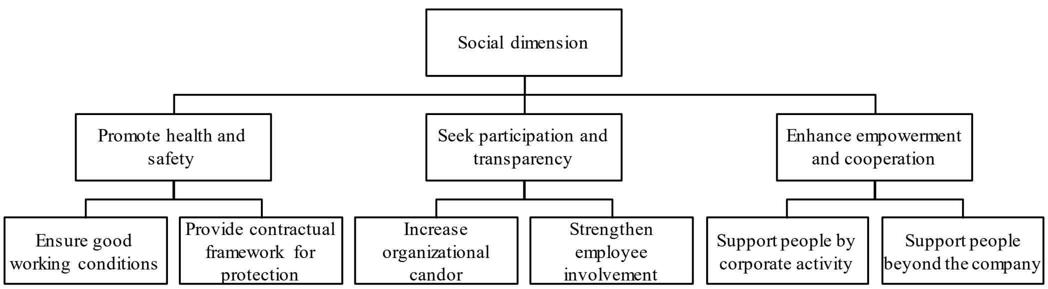

Figure 4. Social dimension of the target system

IV. CONCLUSION

Considering the increasing relevance of sustainability in society and industry, companies see an obligation to act. SMEs are asked by large companies to meet sustainability criteria, in particular, because of their role as a supplier. Hence, the scarce personnel and investment capacities of SMEs must be directed towards this topic to a greater extent in the future. To implement sustainability management on a systemic level in the company, information systems, especially energy information systems (EIS), represent a logical starting point.

EIS provide functionalities that can also be used for other sustainability use cases. This offers enormous opportunities due to data-driven decision-making.

Based on extensive literature research, a target system is presented, that companies can use to prioritize different targets. These targets can be used to define necessary features of EIS and define the necessary scope of IT-based sustainability management.

Further research is needed to examine different software solutions for monitoring success in terms of their functions and relations to the goals specified in the target system. To achieve a level of complexity that is manageable for SMEs, software providers offering modular system worlds are a promising area of investigation for further research work.

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Best Practices Versus Practices That Work

Rethinking Sustainability Strategies in the Mediterranean Region Using Data

Mary Kombolias
Independent Sustainability Consultant
New Orleans, LA, USA & Chania, Crete, Greece
e-mail: mk@marykombolias.com

Abstract—**The Mediterranean region encompasses three continents and a multitude of languages and forms of government. It is also remarkable that this part of the world contributed to the genesis and expansion of three of the world's major organized religions. Despite minimal political integration, there is considerable overlap in terms of lifestyles, diets, climate, history of colonization, and cultural sensibilities between Mediterranean nations. These factors can be leveraged to improve sustainability outcomes, and with contextual data, develop new metrics and targeted and effective solutions for the region. However, before any metrology is created and adopted, there needs to be (1) an assessment of the types of avoided pollution which are a direct result of regional factors and circumstances that may not exist in North America and in Northern Europe where the majority of climate thought leadership is centered and (2) in light of those factors and circumstances, a re-evaluation of the effectiveness of sustainability practices adopted from outside the region.**

Keywords-sustainability; Mediterranean; contextual data analysis; green marketeering.

I. INTRODUCTION

Mitigating environmental damage by human activity during the time when humanity is searching for more efficient and sustainable ways to maintain modern life is something that requires global cooperation. A common issue has been in assessing blame for the current state of affairs which have wrought unacceptably high levels of climate change, biodiversity loss, and human interference in the nitrogen cycle [1][2]. For instance, non-Western nations such as China feel that their economic progress should not be stymied by the West's calls for strict environmental regulation when it was the West which benefited the most from the environmentally unregulated activities of Industrial Revolution and the resultant degradation of the natural environment [3]. Less industrialized nations which are experiencing the deleterious effects of climate change more directly are also demanding immediate assistance [4]. While it is understood that everyone must attempt something in good faith, what that course of action is cannot simply be levied by fiat uniformly across all cultures and climatic zones, as culture and climate dictate the extent of human activity in any given part of the world.

No part of the world is more intersectional than the Mediterranean, the nexus of Africa, Asia, and Europe which is bound together by climate and culture. But because this area is (1) not politically contiguous, (2) contains numerous overlapping transnational political bodies (i.e., the European Union, the Arab League, the African Union, and the Union for the Mediterranean), and (3) also includes non-aligned nations and nations engaged in deep adversarial relationships or active conflicts with neighboring states, it is often difficult to assess the true state of affairs in terms of sustainability and to coordinate efforts. Applying sustainability practices and metrics developed by wealthier nations outside of the region obfuscates reality further.

Incentivizing both individual and collective behavioral changes that have the power to eliminate longstanding impacts toward the environment in the Mediterranean will require confronting the root causes of the worrying current state of affairs in the region. On the other hand, it is also important to expressly acknowledge and promote throughout the region the indigenous cultural practices which are already environmentally beneficial but are not necessarily measured well or measured at all. The purpose of this paper is thus to outline common cultural factors of the Mediterranean which do not necessarily exist in the countries where thought leadership on sustainability resides, to explain the impacts of them be it positive or negative, and to explain the barriers to properly collecting and assessing such contextualized data in the Mediterranean region. Remedies to poor, inefficient, and incomplete data collection and why strategies from outside the region may not be effective also are discussed.

II. CULTURAL FACTORS

The two main categories of cultural factors that have an impact on sustainability but which are not properly quantified and therefore not discussed relate to diet and commercial activity. These cultural factors are discussed in detail in subsections A and B below. Table 1 provides a summary of factors within each category.

A. Food and the Culture and Infrastructure which Surround It

Throughout the Mediterranean, there is an emphasis on eating fresh foods which are locally sourced and unprocessed. Canned and frozen foods are limited in their ability and are generally viewed as unpalatable. There are immediate benefits to the climate because of this cultural preference in terms of forms of avoided pollution such as emissions related to industrialized food processing in factories and transportation to market.

Lack of processing also results in a relative lack of food packaging waste. Together, the food and beverage, pulp and paper, and rubber and plastics industries in Europe comprise over 20% of the customer base of the EU chemical industry [5]. As food packaging itself is produced through industrial processes such as papermaking and plastic manufacturing, the net positive effect, or at least an effect which does not compound an already negative effect of these processes, is compounded. Also, as a result, food packaging (excluding beverage containers) does not dominate the recycling streams.

The famous, heavily plant-centered Mediterranean diet is one that has been developed taking into account various cultural influences, including the indigenous religious faiths of the region. Some faiths, such as Judaism and Islam, prohibit the consumption of certain animal proteins all together. Orthodox Christianity stipulates that believers should consume a vegan diet every Wednesday and Friday and throughout the weeks of Lent and Advent; a strict adherent would then consume a vegan diet for over one-third of the year.

Matters of personal conscience are by their very nature difficult, if not impossible, to quantify. Although faith is a cornerstone of culture in the region, economic constraints have a strong influence on daily dietary choices as well. Though meat and fish are widely available from local producers and preferred over those sourced from factory farms, most households are economically constrained to the point that most days are, in fact, meatless for many people consisting of meals prepared from whole foods instead of industrially-produced, soy-derived meat and dairy substitutes. Typically, meat and fish are reserved for small children to sustain their growth and intellectual development. The main daily household animal protein sources are eggs and dairy, typically yogurt and cheese, which are more easily digestible among populations in the region which have varying degrees of severity of lactose intolerance. A gallon of milk as it is sold in the US would be regarded as an obscene volume in Mediterranean countries.

Dietary suggestions touted from outside the Mediterranean as critical to lessening humanity's impact on global warming, such as "Meatless Mondays," which originated in the United States during World War I, are simply ludicrous in this part of the world [6]. It has been proposed that if the whole United States (population: ca. 300 million people) went without meat and cheese one day a week, this would have the same effect as removing 7.6 million cars off the road [6]. If so, a means of calculating the avoided emissions across Mediterranean countries due to the indigenous, plant-centered diets with much smaller portions of meat and animal products due to cultural, religious, and economic factors is in order.

While the overall food culture can be praised for its contribution to environmental sustainability, the consumption of prepackaged beverages, especially water, has created a major issue which is quite nuanced and typically only discussed superficially. Plastic water bottles are by far the most pervasive type of litter and are poorly recycled across the region. Recent estimates of plastic pollution from coastal areas into the Mediterranean Sea are approximately 500,000 tons per year, excluding the contributions from tourism and shipping [7].

The root cause for the consumption of so much bottled water in developed countries is that there is little faith in the ability of the local public authorities in the region to produce clean, good tasting tap water suitable for drinking. Many freshwater sources are badly polluted along both the northern and southern shores of the Mediterranean Sea. The sources of pollution include inappropriate disposal of municipal wastewater, infiltration from onsite sanitation facilities, excessive use of fertilizers and pesticides in agriculture, and industrial run-off containing heavy metals and polycyclic aromatic compounds [8]. Lack of trust in the public authorities is a longstanding legacy of colonialism in the region; it is also the foundation for corruption. Water treatment is one of many public services administered at the municipal level. Throughout the Mediterranean, corruption in the forms of favoritism in public procurements and nepotism is endemic at local levels of government, resulting in overall low confidence in the abilities of the people responsible to properly administer public works like water treatment, as well as waste management, recycling, and sanitation programs [9].

B. Commercial Activity and The 3 R's: Reuse, Repurpose, and Resale

With the exception of the issue related to beverage containers, the sale of food in the region has a lower carbon footprint and negative environmental impact than in other developed nations because of the way it is sold. There is a higher prevalence of open air street markets, mini-markets, and fewer and smaller supermarkets overall. For instance, the EU average share of supermarkets within the retail food market is 62%; for Italy, Cyprus, and Greece the market share of supermarkets within the retail food market for each nation is below 40% [10]. Open air street markets take place in most neighborhoods at least one day per week in which farmers and producers sell directly to the public, without burden of running lights and air conditioning. Food waste is generally low because nutritious, fresh food is available in every neighborhood and accessible by foot; people generally buy only what they know they will need for the next 24-48 hours. This type of commercial environment is the antithesis of what is seen, for example, in the United States, where access to farm-fresh foods and the people who grow it is considered a privilege of the well-to-do classes.

The only downside, of course, to this otherwise highly sustainable means of commerce is the ubiquitous use of plastic bags. For example, in Greece, a plastic bag tax has been implemented, but in reality, only large chain stores impose it, as the penalty to them from the government would be severe and easy to collect. It has been cited that in Greece each individual will use 300 plastic bags per year [11]. While it seems plausible for an individual to conduct sales transactions which would result in the accumulation of almost one plastic shopping bag per day, the reuse of plastic bags in the Mediterranean region is not discussed. It is common for households to maintain a stash of plastic bags separated by size. The most common and ultimate reuse of plastic shopping bags is for trash disposal, and the purchase of rolls of plastic garbage bags by households is limited to businesses. Individuals and households are primarily motivated by financial constraints, especially in light of the financial crisis of the past decade, more than environmental considerations, as reusing a bag results in one less thing to buy. Sturdy and well-constructed plastic and glass containers for the few pre-packaged foods that households consume (namely, ice cream, margarine, yogurt, and pickles) enjoy a long life preserving leftovers in the refrigerators of Mediterranean kitchens. Aluminum foil is washed and reused until it is punctured with cracks and holes. Thus, it is safe to say that waste generation, at least by households, is generally low, and investigations across the Mediterranean support this observation [11]. Fig. 1 also shows that the waste generated in kilograms per capita in northern Mediterranean countries is significantly less than in other EU countries [12].

A phenomenon which also is not adequately discussed is the overall culture of reuse, repurpose, and resale that is pervasive throughout the region. While declaring publicly that one has purchased an item secondhand or has modified and repurposed something for another use carries a big stigma, as that is regarded as an admittance of one's personal poverty, it is something that is done without fanfare and is seen as an intelligent and sensible to do. Like with diet, real economic constraints motivate this behavior more than environmental activism. Because commerce within the greater economy of individual nations in the region, and especially the circular economy, is mainly transacted in cash [13] and executed at the individual level by sole proprietors or small businesses, many people involved in these activities are able to routinely evade paying a considerable portion of the rightful sales and income taxes related to their business activities [14]. This ultimately creates a metrological issue in quantifying the underlying impacts of these commercial activities that support the circular economy on regional environmental sustainability.

Automobiles in the Mediterranean are generally driven until they are no longer serviceable, generally at around 20 years after the date of manufacture, although in some countries, even older vehicles remain serviceable due to economic difficulty of buying a new car. Greece maintains the oldest busses and trucks in all of Europe, whereas Italy and Spain operate the oldest van fleets on the continent [15]. While older cars are less fuel efficient and do not necessarily meet the most stringent fuel emission standards, the repair and resale of older vehicles leads to less waste in the form of automotive junkyards full of components which cannot be adequately reused or recycled, such as the plastic interiors and electronic components. Although the region as a whole is far behind in the adoption of electric and hybrid vehicles, currently there is no adequate, economically viable industrial process available anywhere in the world to recycle the rechargeable batteries of these vehicles. This means that this is a category of waste which is effectively not being produced here at present time, in addition to the avoided emissions related to producing these new vehicles and the deleterious environmental impacts of lithium and cobalt mining to produce the batteries for them [16].

Repair shops for consumer electronics, which are nearly extinct in wealthier Western countries, flourish in this region, as nearly all electronics are imported. Tailors, seamstresses, and cobblers can also be found in every neighborhood. Used clothing stores, predominantly for women's fashion, have sprung up in recent years due to the economic crisis. Children's clothing is not often featured in these shops because it would be embarrassing to be perceived as someone who could not afford the best for their children. However, for other items, two main avenues of resale which provide some level of privacy exist: Facebook Marketplace and the Roma.

Facebook Marketplace is popular for people with only a few items to sell, whereas the Roma deal with bulk goods. The Roma are a minority group throughout the Mediterranean region who live on the fringes of the dominant society. Though subject to racist stereotypes as thieving and lazy, the Roma are whom members of the dominant society rely upon to liquidate all manners of surplus goods off the books. In turn, the Roma resell these goods for cash back to members of the dominant society. One common area of resale is used furniture and household appliances. Roma merchants particularly scour well-to-do neighborhoods with their trucks and via megaphone announce their availability to haul away furniture, mattresses, cabinetry, and any other large, unwanted household items. The discrimination against the Roma, who experience major barriers toward entry into other types of work, ultimately fuels the shadow economy and vicious cycles of money laundering and tax evasion throughout the Mediterranean.

Because no recording keeping and no tax is properly assessed on these activities, it is difficult to estimate the scale of the positive impact on the environment of the Roma's refurbishing and resale of discarded consumer goods across the region. Rather than be maligned and reviled as black marketeers, the Roma should be recognized, respected, and rewarded for the green marketeering that they do perform, a type hyper-efficient, human-driven materials recovery.

III. The Problems with Applying External Practices Based on What Is Quantifiable Elsewhere

In addition to the gaps in metrology due to what is currently not quantified, there is a problem with applying externally-developed best practices based on what is easily quantifiable elsewhere. What is quantifiable elsewhere is based on assumptions and conditions which may not be applicable to the Mediterranean. Namely, these can be reduced to two factors which are not prevalent in the region: (1) high levels of efficient and equitable tax collection and (2) high levels of trust in the public authorities to do the right thing with the public's money. Strategies developed from outside of the region based on these two factors will naturally result in initiatives which will be executed with less efficacy and less efficiency and will produce data from which an accurate assessment of the impact cannot be deduced. It is not that Mediterranean people are less trustworthy and more corrupt than other people in the world, but the legacy of hundreds of years colonialism in the region does not exist in most parts of the world which dominate thought leadership on environmentalism. People who have been colonized by another power, regardless of the identity of the colonizer,

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be it British, French, Ottoman, etc., view tax evasion as the ultimate act of patriotism because taxes collected by the occupier from the occupied population are, of course, used to maintain the occupation. These days, in the minds of many people in the region, the role of the occupier has been replaced by politicians at all levels of government who are assumed to be corrupt by default, regardless of party affiliation or ideology.

Two particularly problematic external strategies are plastic bag taxes and municipal mixed recycling streams.

A. Plastic Bag Taxes

Numerous countries in the region have instituted plastic bag taxes at points of sale. In Greece, for instance, between 2018 and 2019, the use of plastic bags has dropped 85% as a result of levying the tax [17]. While this is statistic is encouraging it does not tell the full story. This data is based upon merchants who properly charge for bags and issue receipts, and as it was mentioned in previous sections, the vast majority of sales transactions in Greece and throughout the Mediterranean are cash only and most merchants, especially within the otherwise eco-friendly open-air markets, are individuals. The true reality cannot be depicted from data collected from the minority who do comply with the law. Using tax receipts to measure the extent of individual behavioral changes can only work well in societies which trust the government to properly use public funds for the public good and where penalties are evenly applied against those who break the law.

A common argument is to then substitute paper bags free of charge in the place of plastic bags for shoppers. The relative scarcity of water and forests in comparison to Northern Europe and North America places physical limits on how much paper manufacturing infrastructure can be established domestically in any given Mediterranean nation. The use of paper bags is not very widespread because many paper products are, in fact, imported and are somewhat expensive. Also, practically speaking from a materials standpoint, paper bags simply do not have the same reuse capacity as plastic bags. Even in areas where a plastic bag tax has been instituted and is reliably collected and paper bags are provided to consumers without charge, problems can still arise. For example, in July 2021, the residents of Linköping, Sweden were requested to stop using these free paper shopping bags to dispose of their trash because of problems that loose, leaking, and broken paper bags create for waste collectors [18].

B. Municipal Mixed Recycling Streams

Nations like Sweden, Germany and Japan are often lauded in the media for their successes in recycling and deservedly so. Countries such as these aggressively sort their recyclables by type and class, preventing contamination, which is the key factor in retaining the value of recyclable waste as commodity [19]. Also, it should be noted that in Germany, for example, the recycling apparatus is financed by industry rather than the state; Germany has also already reached the 2030 EU target for packaging recycling of 70% fourteen years early in 2016 [20]. This is not necessarily the case in Mediterranean countries. Municipal recycling systems in Greece, for instance, mirror those found in some major US cities like Washington, DC, and rely upon mixed recycling or single streams where there is no sorting performed by the consumer–paper, metals, and plastics are all comingled together. These single stream systems are attractive to municipal governments which finance them through taxpayer money due to supposedly lower costs of administration and higher rates of collection of recyclables [19]. However, the true costs of administration are actually much higher due to the lower quality and value of recyclables collected in comingled schemes due to contamination and the resultant lower market demand for them [19]. In a Canadian study it was determined that single stream recycling only increased municipal recycling rates by 4% and on average is actually 28.5% more expensive than multi-stream recycling in which residents and businesses presort their recyclables [19]. Relying upon tax revenues to fund a recycling system which by its very nature is inefficient does not make sense in a wealthy country like Canada or the US much less in Mediterranean nations like Greece in which tax money is itself also collected inefficiently and significantly less of it is available to fund government projects.

IV. SYNTHESIZING PRACTICES THAT WORK

The key to synthesizing practices that work is to adapt the best practices from elsewhere with practices that are already successful locally which take into consideration cultural nuances and constraints. Publicly available data can assist with targeting hybrid initiatives. Key pieces of data are unemployment figures, levels of tax collection (or lack thereof), and utilities usage.

The areas in which unemployment is most severe are naturally going to have less taxes collected. In cash-poor areas with high numbers of unemployed people, free market solutions, like reverse vending machines returning beverage bottle deposits make more sense that using limited public funds to empty mixed recycling receptacles, the contamination of which has rendered them into ersatz trash cans (Fig. 2). Reverse vending machines are ubiquitous in within grocery stores in places like Sweden and Germany for the mechanized collection PET beverage bottles and aluminum cans and are capable of distributing payment to consumers in real time. Paying people for recyclables can go even further – for instance, the recycling of paper is extremely high in India, a nation with low and unbalanced levels of tax collection. No clean, dry paper is thrown out as door-to-door merchants will pay households by weight for their waste paper separated by grade (newsprint, writing, magazine, kraft, corrugated, etc.) Post-consumer paper collection accounts for 95% of total recyclable waste in India [21]. This strategy makes more sense than dumping unsorted paper into a bin contaminated with all manners of items.

Data on electrical and water usage should also be utilized. These will to demonstrate which areas suffer the greatest fluctuation in demand in public resources due to the tourism industry and can be used as a basis to rebalance public services for optimizing sustainability. It is unfair to full-year residents of touristic areas to assume the full tax burden of funding municipal waste management systems, water treatment, and sanitation when the population throughout the region swells by one-third and the marine litter can increase as much as 40% [11]. Tourists should bear responsibility for the stresses their presence creates on the public infrastructure and the natural environment, and they are a population from which it is far easier and more reliable to collect taxes. These taxes, so long as oversight systems are put in place to ensure their conscientious administration by local governments, could be applied toward efforts that make sense, such as national and transnational capital improvements on infrastructure related to water treatment, sanitation, and waste management. Private enterprises should be incentivized to install water purification systems for drinking water, solar panels, and energy efficient appliances, and free market solutions should be encouraged to commoditize uncontaminated recyclable waste like corrugated board and beverage containers generated in large volumes by the hospitality industry rather than businesses paying employees and taxes in order to dispose of these items unsorted where they ultimately lose value due to contamination. One such organization which has had success is Enaleia, a Greek startup that pays fishermen for marine plastics, which are then recycled into durable consumer goods. Since 2016 Enaleia has recruited ca. 1,300 fishermen who have collectively removed over 180,000 kg of plastic and over 20,000 kg of used fishing nets from the Mediterranean Sea as part of their day-to-day work [22].

Above all, Mediterranean nations should actively seek out the best practices amongst themselves before applying a solution from elsewhere. To that point, the lidded blue mixed recycling bins work well in cold climates with lots of snow and rain in order to keep recyclables dry, but in hot climates, they are breeding grounds for pests and vermin and smell badly in the summer months. Israel has a source-separated recycling system that utilizes simple and inexpensive metal cages with orifices sized to capture plastic bottles [23]. Contamination with other materials is prevented, maintaining the value of the materials, and air is allowed to circulate, eliminating odors and discouraging the nesting of pests.

While measuring the positive impact of the Roma people's business activity on the environment may seem nearly impossible, an indirect measure could be through measuring the sales and installation of new household goods and building materials, like doors and windows. A steady or lowered demand for new items correlated with an increase in building permits from local authorities may suggest the availability of acceptable used goods in the marketplace. Governments should also seek solutions to reward this commercial activity and drive it out of the shadows so it can be adequately quantified.

V. CONCLUSION AND FUTURE WORK

What ultimately should be landfilled is the notion that something from a "wealthy" or "Western" nation is automatically superior to a homegrown system or methodology. As the Roman philosopher Seneca, a native of what is now Spain, once said, "The law is general but each case is specific." Each nation and each culture is doing something positive, and the focus should be on learning from each other, leveraging data contextually through an understanding of culture, and innovating to enhance sustainability and the metrology of sustainability in region-specific ways that can identify inefficiencies and shortcomings, as well as provide markers of progress. The next steps are to begin designing a model to estimate the positive contributions of the unmeasured aspects highlighted in this paper, particularly the green marketeering of the Roma merchants.

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The title of this paper was inspired by the following statement made by the former Mayor of Barcelona, Dr. Octavi Quintana Trias while he served as an instructor at the 2021 Science and Technology Diplomacy Summer School of the Institut Barcelona Estudis Internacionals: "There are best practices, and then there are practices that work."

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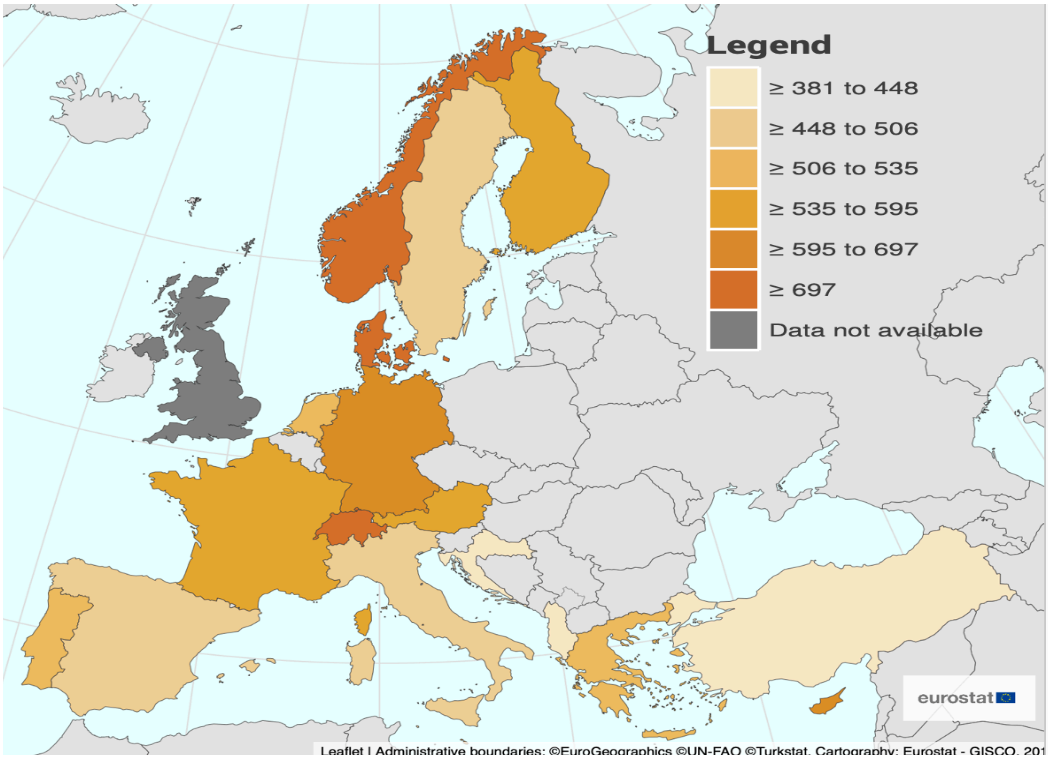

Figure 1. Waste generated in units of kilogram per capita for selected European nations in 2019. Figure has been generated from dataset in reference [12].

Figure 2. Photo montage illustrating state of municipal recylcing in Chania, Crete, Greece. Photo A (above) is of a waste management truck clearly depicting the types of items which are acceptable for municipal collection. Photos B and C (below) depict blue recycling receptacles on the street in the "Kentro" ("Center") neighborhood of Chania contaminated with trash and improperly disposed recyclables. Photo credit: M. Kombolias

TABLE I. SUMMARY CULTURAL, ECONOMIC, AND LIFESTYLE FACTORS WHICH AVOID OR MINIMIZE EMISSIONS, POLLUTION, OR WASTE

Category	**Summary of Factors which Avoid/Minimize Emissions/Pollution/Waste**			
	Factor	***Description***	***Areas of Avoided or Minimized Emissions/Pollution/Waste***	***Challenges to Quantification***
Food and Diet	Meat Consumption	Generally low with cultural preference for meat of smaller animals over beef. High availability of locally raised meat and minimal packaging (wrapped in paper). Cultural preference for fresh meat versus frozen or processed meat products (cold cuts, canned meat).	Packaging waste Methane Emission Transport to market	Some black market activity; sales receipts may not produced by small-scale producers or may not accurately reflect a sale to avoid taxation.
	Dairy Consumption	Preference for and higher availability of cheese and yogurt over fresh milk. Dairy products are more often sourced from smaller animals (sheep and goats) than cows.	Food waste due to spoilage of milk	Some black market activity; sales receipts may not produced by small-scale producers or may not accurately reflect a sale to avoid taxation.
	Produce Consumption	High with preference for locally sourced fruits and vegetables.	Packaging waste Transportation to market	Some black market activity; sales receipts may not produced by small-scale producers or may not accurately reflect a sale to avoid taxation.
	Religious Dietary Restrictions	Some restrictions are cyclical/temporal (Orthodoxy, Islam, Judaism). Others are mandatory (Islam, Judaism).	*See meat and dairy consumption factors*	Levels of religious observance are deeply personal and vary; some nations do not collect population statistics on religious identity.
	Limited Consumption of Factory-Produced Foods (i.e., canned and frozen products with the exception of ice cream)	Low – culturally unpalatable	Packaging waste Industrial food manufacturing processes Transportation to market Refrigerants (frozen food only) Electricity (frozen food only)	Needs to be reported in comparison to another population.
Commerce	Open air street markets	Located within walking distance of residential neighborhoods and present 1-2 times weekly. In addition to fresh produce, clothing, shoes, and miscellaneous household items are also available for sale.	Refrigerants Packaging waste (except for plastic bags) Electricity consumption Transportation by consumer to reach market	Some black market activity; sales receipts may not produced by small-scale producers or may not accurately reflect a sale to avoid taxation. Plastic bags are main form of packaging. Plastic bag taxes often not levied against consumers.
	Mini Markets	Located within walking distance in every neighborhood. Smaller stores catered specifically to the items most popular among local residents. High turnover of fresh products.	Transportation by consumer to reach market Food waste Electricity consumption (compared to large supermarkets)	Some black market activity; sales receipts may not produced by small-scale producers or may not accurately reflect a sale to avoid taxation. Plastic bags are main form of packaging. Plastic bag taxes often not levied against consumers.
	Repair over Replacement	Mainly driven by economic necessity and high price of imported goods, especially electronics and automobiles.	Packaging waste Transportation to market Industrial processes required to manufacture a new item (mining, petroleum drilling/refining, etc.)	Some black market activity; sales receipts often not produced.
	Local Salvaging and Resale of Large Household Goods (furniture, appliances, etc.)	Mainly driven by economic necessity and high price of imported goods	Packaging waste Transportation to market of new goods Industrial processes to manufacture a new item	Nearly exclusive black market activity.

Deployment of a Campaign to Measure the ICT Carbon Footprint

Experimentation in French-Speaking Europe

Guillaume Bourgeois
IT, Image, Interaction Laboratory (L3I),
University of la Rochelle
La Rochelle, France
Email : guillaume.bourgeois@univ-lr.fr

Vincent Courboulay
IT, Image, Interaction Laboratory (L3I),
University of la Rochelle
La Rochelle, France
Email : vcourbou@univ-lr.fr

Benjamin Duthil
EIGSI
La Rochelle, France
Email : duthil@eigsi.fr

***Abstract* — ICT Maturity Models are essential for any organization to improve the environmental footprint of its Information Technology (IT) operations and determine how its IT infrastructure, products, services, operations, applications and practices can be environmentally friendly. To combat global warming induced by greenhouse gas emissions, the IT industry is responsible for three to four percent of global carbon dioxide emissions. While organizations aiming for a green IT strategy should not only improve their environmental impact, but also their financial situation. IT hardware will never be absolutely sustainable, as its manufacturing process uses many non-renewable resources. However, its environmental impact can be reduced. There is only one way to do this: measure. This study explains how organizations can measure the impact of their IT systems and thus make decisions to reduce them using WeNR2021.**

Keywords-IT; Sustainable Information Systems; Literature Review; Environmental Awareness; Green Computing; eco-responsible; ecological impact; sustainable development; energy consumption; WEEE.Introduction.

I. INTRODUCTION

It is within a global framework that the Paris Agreement limits the global temperature increase to "well below 2°C" by 2100 and calls on states to continue working towards +1.5°C. To achieve this ambitious goal, the agreement calls for "a balance between human-induced emissions and the Earth's natural absorption capacity to play a role in carbon sequestration such as forests" [1].

While the text does not mention any quantitative reduction in greenhouse gas emissions, the Intergovernmental Panel on Climate Change (IPCC) states states in its latest report that in order to keep global warming below 1.5 degrees, greenhouse gas emissions must be reduced by 70% to 80% over half a century. Zero emissions will be achieved by 2100 at the latest [2].

At the same time, most households and businesses use Information and Communication Technologies (ICT) on a daily basis. These technologies integrate information technology, telecommunications and electronic products. Furthermore, attention to the environment is inevitable. These technologies are generally considered as "intangible", and their impact on the planetary ecology seems to be neglected [3][4].

Moreover, we have also discussed ecological responsibility at length. Green IT is one aspect of the relationship between ICT and sustainability. Understanding and measuring the environmental impact of these technologies allows us to take better measures to reduce them. Raising awareness of environmental issues and integrating information systems into an organization's environmental policy should encourage the development of environmentally friendly information and communication technologies [5].

Finally, although the number of studies is small [6][7], more and more companies around the world are integrating global corporate social responsibility projects into their green IT strategies, which include information to measure the environmental impact of their enterprise systems. In this article, we will describe the first major French study on the environmental impact of information systems. Then, we will present the rest of the research and extend it to French-speaking Europe, and present the different perspectives and expected benefits that it allows.

II. CONTEXT

First, the data center is big polluter. The electricity consumption of new technologies represents 8.5% of the world consumption, and one third of it comes entirely from data centers. In contrast, an "average" Facebook center consumes as much energy as the city of Strasbourg. There are 45 million data centers in the world [8].

Moreover, digital devices (cell phones, tablets, computers, etc.) [9] are also a huge source of pollution. Indeed, the production of these devices requires the exploitation of rare and non-renewable mineral resources. According to the French Agency for Ecological Transformation (ADEME), the greenhouse gases generated during the extraction, manufacturing and transportation stages of the final product represent 90% of the emissions linked to the life of electronic equipment. The remaining 10% is released during use, for example when the device is charging. In addition, the update

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rate of electronic devices is quite high (cell phones can be used for 2 years on average) [10].

Since the Kyoto Protocol of 1998, tools are needed to accurately measure environmental impact. A software-based carbon calculator can be used to "predict and monitor the carbon emissions of everything we do" [11].

To this end, Life cycle assessment or LCA is one of the most accurate methods for estimating carbon footprint [15]. Since LCA takes more time than simply estimating the energy footprint, as part of the procurement process, the organization needs to obtain information on the emissions included in the potential procurement and the emissions associated with its disposal. This information can be added to the product's activity footprint estimate, and if possible, its recycling footprint can be added to estimate the product's life cycle footprint via LCA [12].

Although, on June 10, 2021, the French National Assembly passed the first reading of a bill to reconcile digital and environmental issues. Its objective is to "guide the behavior of all digital actors, whether they are consumers, industry professionals, or public actors, to ensure sober and responsible digital technology and sound ecological development in France." Among the users targeted by the law, organizations obviously have a role to play [13].

Secondly, we need to gain unprecedented knowledge through an activity to measure the level of knowledge and commitment of the community to digital sobriety. The response will provide the initial foundation for the digital footprint repository that will enable digital and ecological transformations to be operationalized [14].

III. STATE OF THE ART

In order to address this issue, a first study has been set up called WeGreenIT2018. The WeGreenIT study, published on 11 October 2018, assesses the environmental footprint of digital technology. It is co-produced by WWF France and the Green IT Club, created in 2014 to lead green IT projects and at the origin of responsible digital methods [15].

First, the study came to a conclusion: even today, digital and sustainable development are still two areas where there is little overlap. Besides, as the first consumers of digital technologies, with the strengthening of national and international regulations, the company can play a central role in actively repositioning the digital revolution. Thus, in March 2018, 24 companies from all walks of life responded to the questions of this research, including: Caisse des Dépôts, Engie, La Poste, Pôle Emploi, Schneider Electric, or SNCF.

The results show that the main sources of environmental impact are the manufacture of IT equipment (accounting for 54% of greenhouse gas emissions), the user's work environment (computers, screens, etc.) and even the IT department. The study also highlighted that there are large differences in the maturity of companies in terms of responsible digital technologies, depending on their sector of activity. However, whatever the sector, WeGreenIt underlines that good digital management represents a kind of lever, both social, job-creating and environmental for the company [16].

In addition to the results of the survey, this document aims to promote the development of a corporate culture and common strategies more widely in order to better integrate digital with sustainable development. In particular, it makes recommendations and provides methods and tools adapted to their departments so that they can better identify the main sources of digital environmental impacts and solutions to reduce these impacts [17].

Finally, while there is still considerable room for improvement, WeGreenIt's research highlights the company's progress in certain areas. Especially with the new channels created within the framework of the Social and Solidarity Economy (SSE), the life span of equipment is now longer and should be reused more frequently, which is the case.

However, the study has many limitations:

- It takes place in 1 country.
- The study did not take into account the different entities that make up an organization.
- The sample studied is not large enough to create a reliable model.
- The level of granularity of the research is low.
- The local community is underrepresented.
- The Cloud part is not detailed.

Based on this observation, a new, more ambitious tool designed to reach the largest number of people was officially launched on March 31, 2021, namely WeNR.

IV. SPECIFICATION

This section focuses on the specification, design and implementation of tools designed to support the analysis process for quantifying the carbon footprint of an organization's ICT [18].

The objective of this study is to assess the carbon footprint of the target organization's IT equipment and to help the company understand the environmental impact.

The following research objectives achieve this goal :

- Define the scope and objectives of the survey.
- Conduct a literature review on current climate change and green IT issues.
- Conduct a survey of current IT audit methodologies to determine the most appropriate method.
- Conduct a survey to collect quantitative and qualitative data.
- Provide recommendations, with supporting evidence, on how the organization can reduce its overall carbon footprint and compare this footprint with that of other organizations.
- And finally, compare them with the company's current strategy to determine if they complement or reinforce the company's green IT strategy.

In order to achieve this different objective, the technical specifications must be clarified.

The tool must specifically :

- Use eco-friendly design and development practices (restricted exchanges, lean web pages, optimized transmission, etc.)
- Be attractive to influence the perceived ease of use and usefulness of the tool.
- With contextual help, e.g. a user guide accessible to all.
- Ability to compare searches against previous benc hmark.
- Flexible, with basic, simple and detailed views.
- Use filters to display only partial results, e.g. filtering by equipment type (Desktop).
- Sort by role category, customized results for each decision maker. Example: System and network administrator or accountant.
- Possibility to quantify carbon emissions by integrating behavioral aspects of energy consumption (time use).

V. STUDY

To begin, WeNR [23] is an Institute for Sustainable IT (ISIT) project based on work conducted during the 2014-2018 period: the ISIT (then called Club Green IT) conducted three consecutive benchmarks in 2016, 2017 and 2018 to calculate the environmental footprint of large French companies. In 2018, this benchmark facilitated the dissemination of research on responsible digital.

In addition, WeNR is more ambitious than WeGreenIT and contains more indicators. The questionnaire (see figure 1) is accessible online, then the data will remain confidential. The tool should therefore allow any organization to understand the impact of the "People-Planet-Prosperity" triptych and to measure its level of responsible digital maturity.

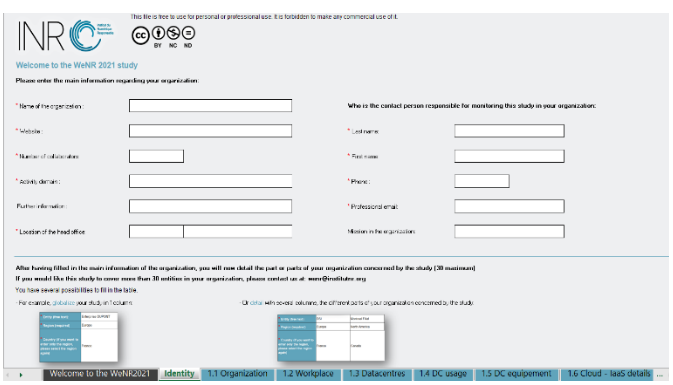

Figure 1 : Homepage of the questionnaire.

Consequently to the previous WeGreenIT study, the objective of the WeNR2021 study is to cover most of the French speaking European countries, including France, Belgium and Switzerland. There is also Luxembourg, but there is currently no responsible sustainable it institute attached to this country.

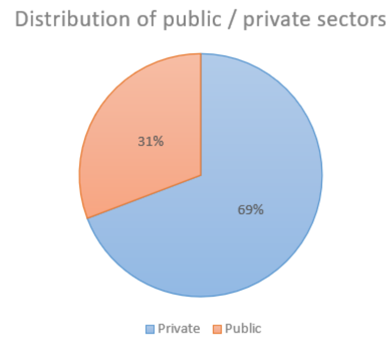

Figure 2: Distribution by sector.

On the other hand, as shown Figure 2, the distribution of public organization types is 31%. For private organizations, this proportion is about 69%. This means that most of the organizations participating in WeNR are private, although there are large cities, public corporations, etc. WeNR has collaborated with the University of La Rochelle and EIGSI, based on thesis work funded by La Rochelle and scientific collaboration between ISIT France, ISIT Switzerland, ISIT Belgium and the University of Leuven (UCLouvain).

Also, WeNR takes the form of an online questionnaire that all organizations (large and small) can use and access free of charge, so that as many people as possible can assess the footprint of their information system.

To this end, ISIT is providing an open access tool based on open and public data, and we hope to publish its method in a peer-reviewed journal to ensure that the method is fully transparent. Thus, this questionnaire allows you to evaluate your equipment, your data center and its uses, your use of the cloud, and to assess the maturity of your organization in responsible digital.

To date, more than 75 organizations have responded to WeNR, covering more than one million employees, including MICHELIN, ENGIE, CGI, EDENRED and many more. The responses provided free of charge to participants will allow them to quantitatively and qualitatively assess IS greenhouse gas emissions and maturity in many areas of digital business [21].

Finally, what characterizes the WeNR2021 study is that the scale of the participating organizations varies greatly . To illustrate this point, we can see the number of employees in about 60 companies in the image above. We have a small organization with 15 employees to a large organization with 120,000 employees. Figure 3 shows the great homogeneity of WeNR2021.

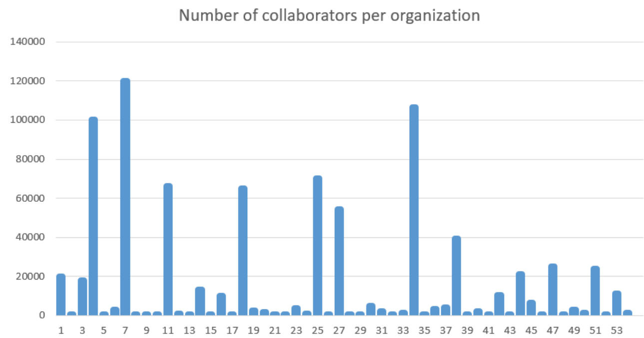

Figure 3 : Number of employees per organization.

Table 1 illustrates the differences that may exist between the old and new studies.

TABLE I. COMPARISON OF THE TWO STUDIES.

Comparison of the two studies: :

	WeNR2021	WeGreenIT2018
Country concerned :	*France, Belgium, Switzerland*	*France*
Language of Rendering :	*English, French*	*French*
Participating Organization :	*75*	*24*
Collaborator involved :	*1 200 000*	*775 000*
Transparent methodology :	*Yes*	*No*
Individual Report Rendering :	*Yes*	*No*
Global Report Rendering :	*Yes*	*Yes*
Predictive System (AI) :	*Yes*	*No*
Creation of a web-based tool :	*Yes*	*No*

VI. PERSPECTIVE

WeNR tools can be developed in a variety of ways. The need to expand and improve the data sources used is critical.

In the future, the WeNR tools will be developed in different ways. The data sources used will be expanded and optimized. But this is just the first step. In the future, WeNR will incorporate continuous monitoring over time. Monitoring is needed to highlight changes that can be made to reduce the carbon footprint. To that end, two future projects, WeNR Light and WeNR Plus, are planned. Users of the WeNR Light solution will be able to quickly and fairly accurately understand the environmental impact of their IT assets and their NR maturity directly online.

WeNR Plus will use WeNR models and calculation methods to provide more comprehensive and detailed reports in terms of quantity, quality and comparison with the same industry organization, but most importantly to analyze the impact of strategic decisions.

Also, the analysis tools provided will help determine the action plan for the formulation of a responsible digital strategy.

Finally, with the liberalization of the carbon impact of different cloud providers, the next version of WeNR will include the implementation of APIs to quantify the greenhouse gas emissions of cloud systems.

VII. CONCLUSIONS

A number of conclusions can be drawn from the WeNR.

First, it can be seen that there are few solutions for estimating an organization's ICT carbon footprint, and the solutions that have been implemented are primarily focused on households and transportation, and rarely provide accurate information. The transparency issues discussed are partially addressed by WeNR, through a broad exchange of sources and factors used [23].

Second, our research related to green computing recognizes that ICT needs to pay more attention to its energy consumption. While most large data center manufacturers and vendors are aware of this need and are adopting varying degrees of emissions reduction, the study also found that there are few solutions available for smaller organizations. However, the results of this study confirm that there is still much work to be done in this area and that services are needed to help companies reduce their expenses and emissions [22].

In carbon reduction efforts, communication is as important as the policies and actions themselves. In order to reach as many of the organization's stakeholders as possible, publicity activities should be conducted. Such activities should help increase the number of people affected by the activities, and help trigger self-reflection, which can reduce carbon emissions.

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Dynamic Business Modeling for Sustainability: Exploring a System Dynamics Perspective to Integrate Social Lifecycle Sustainability Assessment

Jing Lin
Global Integration Services Practice
Siemens Digital Industries Software
Munich, Germany
jinglin.nuernberg@yahoo.de

Selmin Nurcan
Centre De Recherchae En Informatique

Sorbonne Business School (EMS)
University Paris 1 Pantheon-Sorbonne
Paris, France
selmin.nurcan@univ-paris1.fr

Clotilde Rohleder
Market Oriented Management
University of Applied Sciences Constance
Constance, Germany
clotilde.rohleder@htwg-konstanz.de

Stephane Copin
Sorbonne Business School (EMS)
University Paris 1 Pantheon-Sorbonne
Paris, France
stephane.copin@univ-paris1.fr

***Abstract*—In the last decade, both sustainability (Green & Blue Economies) and business models for sustainability (BMfS) have increased in importance. Social life cycle sustainability assessment has not fully achieved goal, mainly because sustainability-oriented business is very complex and dynamic. System Dynamics (SD) is a powerful methodology and computer simulation modeling technique for framing, understanding and discussing complex issues and problems. This paper responds to the urgent need for a new business model by presenting a concept for dynamic business modeling for sustainability using system dynamics. The paper illustrates the key operating principles through an application from the smartphone industry with help from STELLA® software for simulation. Simulations suggest that dynamic business modeling for sustainability may contribute to sustainable business model research and practice by introducing a systemic design tool that frames environmental, social, and economic drivers of value generation into a dynamic business model causal feedback structure, therefore overcoming shortcomings of current business models when applied to complex systems.**

Keywords— business models design; business models for sustainability; system dynamics modeling; sustainability; social lifecycle sustainability assessment .

I. INTRODUCTION

In the last decade, both sustainability (Green & Blue Economies) and business models for sustainability (BMfS) have gained increasing attraction worldwide. Research streams are multiplying (e.g., Business Model (BM) ontology, Business model design (BMD), BM innovation, circular BMs, etc.) as testified by the growing number of contributions appearing in scientific journal special issues, dedicated conferences, workshops, as well as international academic networks [1]. Researchers addressed topics such as how to make a supply chain sustainable and how to use system dynamics methods to analyze sustainability issues in the smartphone lifecycle.

A. Sustainability issues in the smartphone lifecycle

Figure 1 shows issues in the smartphone lifecycle, which are provided by J. Zufall et al. [2].

Life cycle	Resource extraction and manufacturing	Distribution and network operations	Usage	End-of-life
Sustainability issues	Hazardous or conflict minerals extracted for smartphones (Fitzpatrick et al., 2015; Wu, Chan, Middendorf, Gu, & Zhong, 2008); poor working conditions: harmful practices of mining, extraction and processing (Wilhelm, Hutchins, Mars, & Benoit-Norris, 2015); low living wages, long working hours (Wernink & Strahl, 2015); energy and resource intensive manufacturing processes (Li, Ortiz, Kuczenski, Franklin, & Chong, 2012)	Freight and transport emissions (Moberg et al., 2014); locked-in business models at the point of sales (Boons & Lüdeke-Freund, 2013)	Short use phase varies between 12 month to 3 years on average (Suckling & Lee, 2015); behavior acts as barrier for return, reuse and recycling (Welfens, Nordmann, & Seibt, 2016)	Informal recycling sector for valuable materials, environmental pollution and health problems caused by toxic materials in e-waste (Bridgens et al., 2017; Panambunan-Ferse & Breiter, 2013)

Figure 1. Sustainability issues in the smartphone lifecycle.

They also identified seven sustainable business model patterns to cover different life cycle phases [3]. This paper focuses on the first pattern, "Sustainable Resource Company," during the "Resource Extraction" and "End-of-Life" phases (see the red labeling in Figure 2. High resolution figure can be viewed in Appendix I). Social sustainability issues like child labor, poor working conditions, low living wages, pollution, and health problems caused by toxic materials in e-waste occur mainly in these two phases. Our study applied system dynamics methods with simulation software to determine how a solution applied to a complex system would impact environmental, social and economic aspects.

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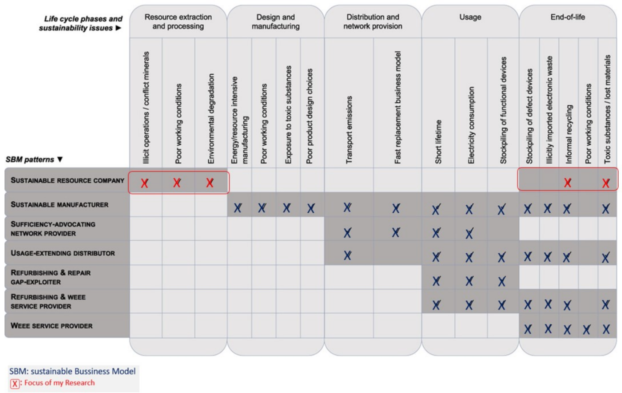


Figure 2. Lifecycle sustainable issues along smartphone lifecycle and the research focus

B. System Boundaries

Life cycle sustainability assessment refers to the evaluation of all environmental, social, and economic impacts in a decision-making process according to the sustainability of products throughout their life cycles [4]. Although it involves several aspects including environmental and economic, our study focuses on social impacts. The system boundaries we used are presented in Figure 3. This research focuses on three categories: sustainability, environment and social. The environmental part is divided into two subcategories - upcycling and recycling. Upcycling focuses on the evaluation of smartphone function prolongation, and recycling focuses on reducing the environmental impact of smartphone disposal by recycling its parts. The social category focuses on social issues created by resource extraction and the manufacturing process [5].

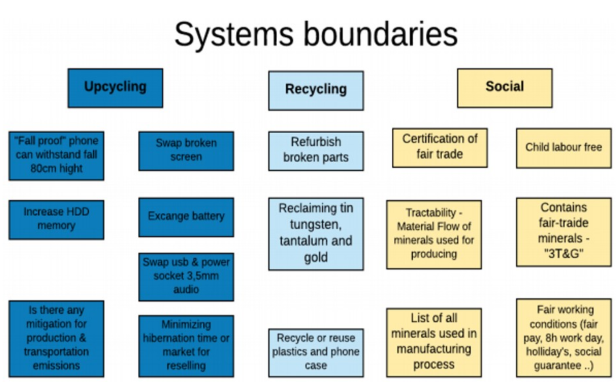


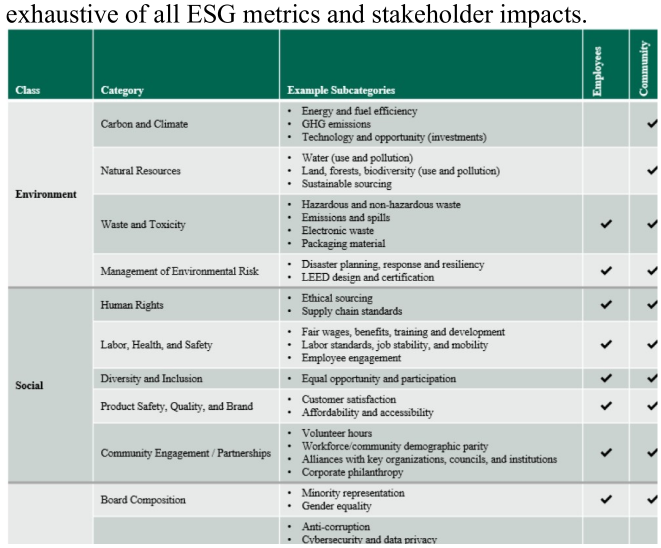
Figure 3. System boundaries of this research

C. Stakeholder -influence matrix

In August 2019, the Business Roundtable released its new stakeholder model of the revised purpose of the corporation, stating explicitly that businesses exist to serve multiple stakeholders—including shareholders, customers, employees, communities, the environment, and suppliers.

The stakeholder model represents an emerging model for the *strategic* vision of a company. Environmental, Social, and Governance (ESG) metrics can be used to measure company performance and its relative positioning on a range of topics relevant to the broader set of company stakeholders in the same way that financial metrics assess company performance for shareholders. This paper addresses at a "conceptual" level the key questions and guidelines for assessing a company's *readiness* for - and potential approach to - implementing ESG metrics and goals in executive incentive programs [6].

Figure 4 provides Pay Governance's generalized perspective on the alignment between ESG initiatives and stakeholders. The matrix below is illustrative and is not exhaustive of all ESG metrics and stakeholder impacts.



Class	Category	Example Subcategories	Employees	Community
Environment	Carbon and Climate	• Energy and fuel efficiency • GHG emissions • Technology and opportunity (investments)		✔
	Natural Resources	• Water (use and pollution) • Land, forests, biodiversity (use and pollution) • Sustainable sourcing		✔
	Waste and Toxicity	• Hazardous and non-hazardous waste • Emissions and spills • Electronic waste • Packaging material	✔	✔
	Management of Environmental Risk	• Disaster planning, response and resiliency • LEED design and certification	✔	✔
Social	Human Rights	• Ethical sourcing • Supply chain standards	✔	✔
	Labor, Health, and Safety	• Fair wages, benefits, training and development • Labor standards, job stability, and mobility • Employee engagement	✔	✔
	Diversity and Inclusion	• Equal opportunity and participation	✔	✔
	Product Safety, Quality, and Brand	• Customer satisfaction • Affordability and accessibility	✔	✔
	Community Engagement / Partnerships	• Volunteer hours • Workforce/community demographic parity • Alliances with key organizations, councils, and institutions • Corporate philanthropy	✔	✔
	Board Composition	• Minority representation • Gender equality	✔	✔
		• Anti-corruption • Cybersecurity and data privacy		

Figure 4. ESG metrics and stakeholder impacts

Figure 5 shows the Stakeholder Influence Matrix derived from a survey in 2021 and interviews with stakeholders from electronic companies including Siemens, Huawei, and Samsung.

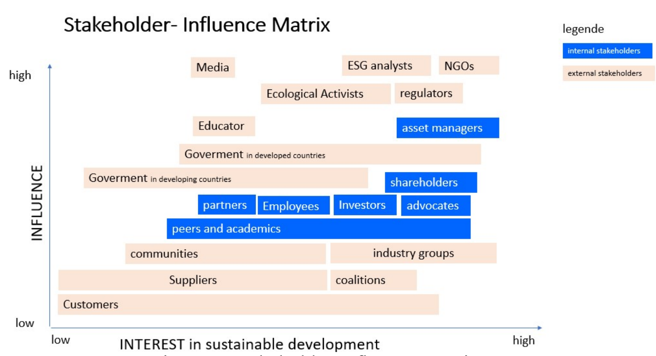


Figure 5. Stakeholder Influence Matrix

The remainder of this paper is organized as follows. Next, we describe the system dynamics method and software. Section III presents the dynamic business modeling framework. Section IV discusses the case study with the smartphone life cycle. The last section on modeling STELLA® simulation software concludes with

- Modeling with simulation software STELLA®

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- Dynamic business modeling framework
- Case study with smartphone

II. System Dynamics Method and Software

System Dynamics (SD) is a methodology for analyzing complex systems and problems over time with the aid of computer simulation software [7]. It handles complex systems in different domains. SD steps include making a loop diagram, connecting the variables, and documenting the relationships among them (direct or inverse). SD can improve communication and identify interactions among different related components in a system that enhances decision making policies in different scenarios. The modelled systems could be socio-economic, financial, climatic, or physical. System Dynamics models consist of only a few basic types of variables which are used to construct stock and flow diagrams with feedback loops and delays [8].

Table I lists software tools for simulation [9]. Dynamo was a breakthrough and foreshadowed several numerical modeling approaches and non-procedural programming languages [10]. It was a text-based system for representing model equations and continued to be used for multiple decades. Current software for System dynamics is diagram-based, but equations are still part of the model and retain forms quite similar to those of Dynamo.

Other modeling products include Anylogic, Goldsim, Berkely Madonna, Sysdea, and SimGua. Vensim, Insight Maker, and StatSim are free for education and personal use.

TABLE I. System Dynamics modeling Software

DYNAMO	No longer distributed commercially.
iThink ® and STELLA®	Two names for one model development platform published by **iSEE™** systems. STELLA® (Systems Thinking, Experimental Learning Laboratory with Animation) is available in different configurations under commercial and academic licenses for Windows and Macintosh.
Powersim Studio	Available in a number of different configurations from Powersim Software. This Windows software is available under commercial and educational licenses and comes in a free version. It allows publishing standalone models.
VenSim®	Available in a number of different configurations from Ventana Systems, Inc. Licenses are available for commercial use, funded research, and academic use. It runs on Windows and the Macintosh.

Both STELLA® and Powersim Studio support system dynamics; build graphical diagrams using stocks and flow, including delays and feedback for non-linear models; support units, multi-dimensions running scenario simulations and Monte Carlo simulations. STELLA® also supports JavaScript and has discrete event modeling with some agent-based capabilities. The drag-and-drop user interface builder in the Architect version allows simulations to be published online. It handles multilevel hierarchical models, reusable modules, multidimensional arrays, optimization, and Monte Carlo analysis [11].

STELLA®, also marketed as iThink®, is a visual programming language for system dynamics modeling introduced by Barry Richmond in 1985. The program distributed by **iSEE™** systems allows users to run models created as graphical representations of a system using four fundamental building blocks. STELLA® has been used in academia as a teaching tool and has been utilized in a variety of research and business applications. The program has received positive reviews, particularly for its ease of use and low cost.

Our research used STELLA® Architect (Version 2.1.x).

III. Dynamic Business modeling Framework

Cosenz et al. proposed a dynamic business modeling for sustainability approach that combines an adapted sustainable business model canvas and system dynamics modeling. They also reviewed the state of the art in Design Business Modeling for Sustainability (DBMfS) design tools [1].

Building on this comprehensive literature review, the paper proposes and illustrates the DBMfS approach as a lean systemic method to model and explore sustainable value creation processes. Then, following a qualitative perspective, the approach is tested empirically. Figure 6 shows the research approach.

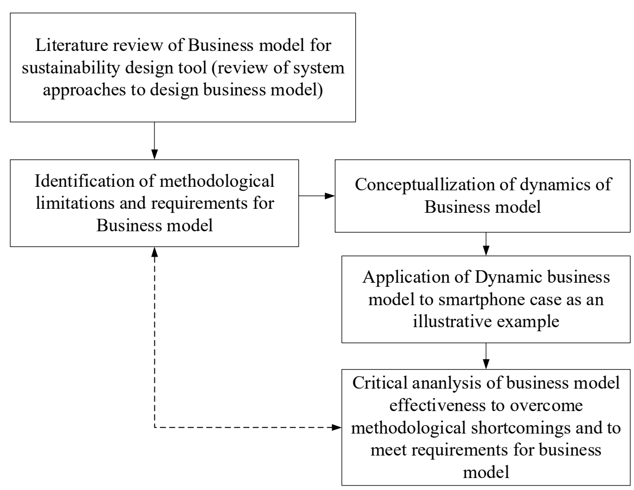

Figure 6. Research Approach Using Design Business Modeling for Sustainability

A case study may help evaluate a modeling approach. In our research, it could help determine how to frame BMfS elements within a systemic structure [1]. Figure 7 (high resolution figure can be viewed in Appendix II) displays an application of DBMfS to cobalt usage in a smartphone lifecycle.

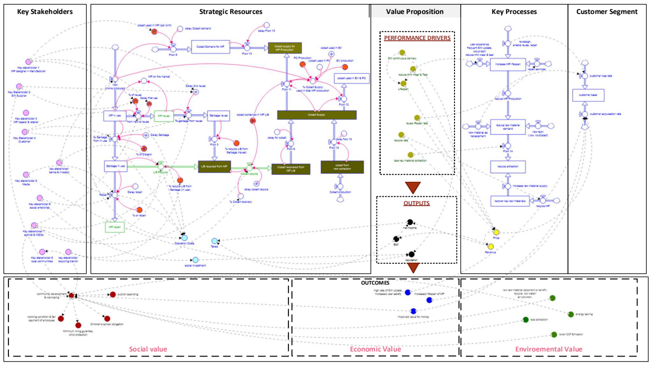

Figure 7. Dynamic business modeling for sustainability applied to Cobalt usage in a Smartphone lifecycle
EBIT, earning before interest and taxes; NGO, nongovernmental organization.

DBMfS elements outline how an organization operates in achieving both sustainability and viability goals. They are (a) Key Stakeholders, (b) strategic resources, (c) value proposition, (d) key processes, (e) customer segments, (e) cost structure, and (f) revenue streams [1].

IV. Case Study with Smartphone

A. *Selecting a case study*

Smartphone has been chosen as case study for this research because of its ubiquity and the global cooperation involved in many types of products.

A huge part of the world population uses smartphones.

- 7.9 billion people by 2020
- 6 billion smartphones end of 2020
- In average 1.5 billion new smartphones produced per year
- 36 smartphones are produced per second, which exceeds the human birth rate

A typical smartphone lifecycle includes the following:

- Mine/Mine Traders#, Smelters/Refinery in DRC#
- Design, development, marketing, and creation of software in USA.
- Mixed-signal chips (such as NFC): NXP from Netherlands; accelerometer from Bosch in Germany, Gyroscope from Italy/France
- Smelters/Refinery in China and
- Batteries** & Flash memory from Korea
- Display/Camera and eCompass from Japan
- Touch ID Sensor and DRAM mostly from Taiwan
- Plastic Construction in Singapore
- Assembly in China#
- Disposal/Dismantle/*Recycle*## done mostly in Africa and China

Figure 8 presents the globalization of a typical smartphone (high resolution figure can be viewed in Appendix III).

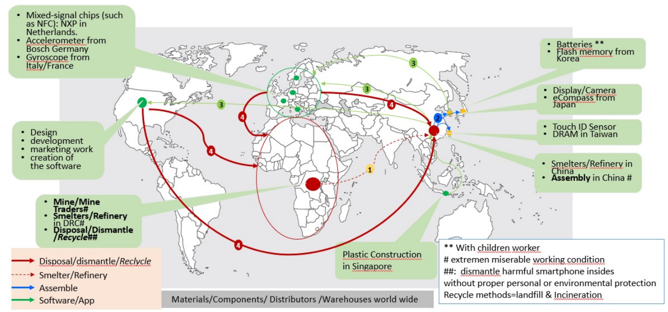

Figure 8. Material Life Cycle of smart Phone

Child labor might be hidden in the smartphone's supply chain [12], e.g., in Resource extraction and process, or End-of-Life phase.

Recently, many have expressed concerns about smartphone issues such as adverse impact on the environment from pollution in manufacturing and failure to recycle. The industry pays workers poorly, provides unhealthy working conditions, and employs children.

Figure 9 shows that smartphone manufacturers use deadly chemicals and up to 46 precious materials, like tin, tantalum, tungsten, Gold (3TG) and cobalt [13].

Figure 9. Application of Tantalum, Molybdenum and other metals in Mobile Phones

In 2020, smartphones averaged 8 grams of cobalt vs. 28 grams in a laptop, and 6803 grams in an Electric Vehicle (EV). **Statista**, the global Business Data Platform, reported 1.38 smartphones sold to end users worldwide in 2020 and projected 1.53 billion by 2021. 222.5 million laptops were shipped in 2020, and 276.8 million are expected in 2021. EVs numbered 6.0 million at the end of 2020. The total amount of cobalt used in smartphone is about 11250 tons vs. 62967 tons in laptops and 40800 tons in EVs. Table II summaries the total cobalt usage by the end of 2020 in different electric devices.

TABLE II. COBALT USAGE IN ELECTRONICS BY END OF 2020

Smartphone	Laptop	electric vehicle
7.5 gramms of cobalt per unit	1 ounce (28.3 grams) of cobalt per unit	15 lbs (6.8 kg) of cobalt per unit
1.5 billion sold	222.5 million sold	6.0 million sold
11250 tonnes total cobalt used	6296.8 tonnes total cobalt used	40800 tonnes total cobalt used

Cobalt is a metal that occurs naturally in rocks, water, plants, and animals. Cobalt is less toxic than many other metals. At low levels, it is beneficial to human health and is a component of vitamin B12. But it is dangerous in high doses. Health risks depend on the amount and duration of exposure. The Centers for Disease Control and Prevention in the US warns that chronic exposure can cause "hard metal disease" and even skin contact with cobalt salts or hard metals can result in rashes. They say the safe workweek limit is 0.1 milligrams per cubic meters.

Cobalt is used in alloys, semiconductors, fertilizer, as a drying agent for varnish and enamel coating for steel. In the form of cobalt sulphate, it is particularly important in lithium batteries, where it acts as a cathode stabilizer. Lithium-ion batteries are increasingly in demand for electric cars, laptops and mobile phones, which means cobalt – once deemed a worthless chemical – is now the object of rivalry between the world's biggest economies. A study from Kosiorek and Wyszkowski [14], shows that global production had increased more than sevenfold between 2008 and 2015 with an increasingly evident impact. "The appearance of cobalt levels exceeding environmental threshold levels has led to disturbances in the proper functioning of living organisms," the paper concluded.

Amnesty International says human rights abuses, including the use of child labor, in the extraction of minerals, like cobalt, used to make the batteries that power electric vehicles, are undermining ethical claims about the cars.

The environmental impact extends through the lifecycle of the product from refineries, battery plants, consumers goods manufacturers, electronic recycling facilities and waste dumps. Among the most affected are workers at poorly regulated mines [15]. This has allegedly reached alarming levels in the Congo, As it is the largest cobalt mining country globally, this country is also by far the largest producer of cobalt intermediates. They produced 87.7kt Cobalt contained in intermediates in 2020, accounting for 68% of the global supply [1].

V. MODELING WITH SIMULATION SOFTWARE STELLA®

A. *Identify paramters*

Cobalt issues are paramount. e.g., reduce cobalt extraction while satisfying the increasing demand for cobalt in Lithium-ion batteries.

1) Reduce cobalt extraction from mines

2) Increase cobalt recovery from spent cemented carbide

3) Increase cobalt recovery from spent Lithium-Ion smartphone batteries using liquid–liquid extraction

a) Increasing recovery of cobalt from smartphone Lithium-Ion Batteries is one way to reduce cobalt extraction from mines.

4) Extend cobalt usage cycle by extending smartphone lifespan

b) Increasing the 25% smartphone recycle rate or extending the 2.5-year smartphone lifespan can also reduce the demand on new cobalt, especially cobalt extracted from mines.

c) The lifespan may be extended by (i) repairing smartphones instead of discarding them (e.g., change the battery or screen) (ii) increasing usage of second-hand phones. (iii) more frequently updating software to improve smartphone performance, thereby reducing demand for new phones.

5) Low-cobalt or cobalt-free battery design

Figure 10 shows a simplified STELLA® model with the above parameters that simulates cobalt usage in a smartphone (high resolution figure can be viewed in Appendix IV).

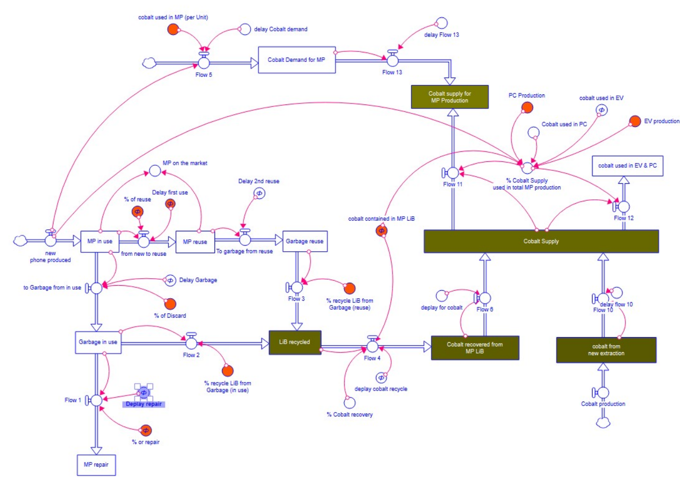

Figure 10. STELLA® Model for simulation of cobalt usage in smartphone.

EV: electric Vehicle
MP: Mobile Phone
Li.B.: Lithium Battery
PC: Personal Computer

B. *Calibration of model*

The model was calibrated step by step, parameter by parameter using real data.

Parameter 1: Reuse (smartphone)
Parameter 2: Delay of Reuse (smartphone)
Parameter 3: Discard (smartphone)
Parameter 4: Recovery Li.B. from discarded phone

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Parameter 5: Recovery cobalt from Li.B.
Parameter 6: Cobalt-free battery
Parameter 7: Production of e-Vehicles
Parameter 8: Production of PC (including Desktop, Notebook, Ultra-Portable personal computers)
…

Since it is almost impossible to get real data without company support, we used statistical data.

The goal of this model is to show the possible measures, which can be taken to reduce the raw material extraction in certain period, then indirectly solve the related social issues like child labor, unfair Payment, worse working condition, etc.

- Cobalt it taken as one example of relevant raw material because it comes from mines in areas with severe social problems.
- The typical and reasonable time span for long-term projects is 10 ~20 years.
- The measurements are those parameters for the model defined above.

The lowest target is to keep the current cobalt extraction amount (considering of the increasing demand on e-Vehicles and smartphones).

Figures 11-13 show the calibration result of the model. For example, Figure 11 illustrates graphically the Model calibration concerning mobile phone reuse/repair & discard. By calibrating Parameter 1 (Reuse), Parameter 2 (Delay of Reuse.) and Parameter 3 (Discard), increasing the rate of Reuse/Repair for Mobile Phone, extending the lifespan of Mobile Phone (increase the delay of reuse), reducing the rate of discard (see the line for “MP in use”) will reduce first then stay steady. More mobile phones are reused phone (see the line for “MP Reuse”). The total number of phones on the market stays steady too, assuming the population is unchanged. The more phones are reused, the part of garbage caused by reused phone increase too.

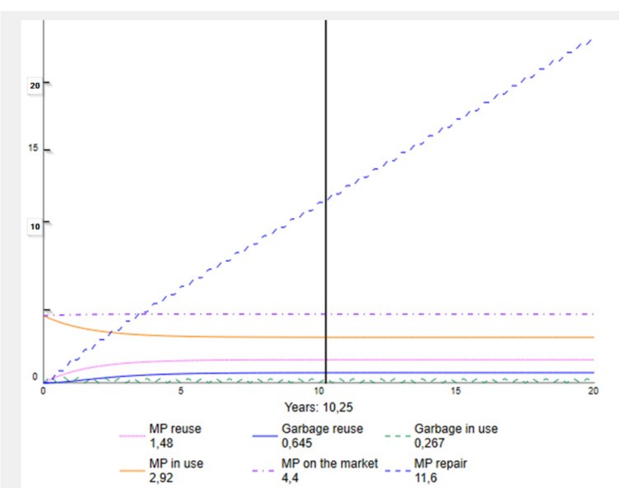

Figure 11. Model Calibration for Mobile Phone Reuse, Repair, Discard

Figure 12 illustrates the Model Calibration concerning Cobalt Supply and Demand. The X (horizontal) axis is the time axis, the Y (the vertical) axis is the unit axis, with measurement unit in Tons. By calibrating Parameter 4 (Recovery Li.B. from discarded phone) & Parameter 5 (Recovery cobalt from Li.B.), increasing the rate of recovery Lithium battery from Mobile Phone, and rate of cobalt recovery from lithium battery, the cobalt supply for Mobile Phone production increases too. Assume the demand on Cobalt keeps steady, then less cobalt would be extracted from mines. (see the vertical black line, shown in Figure 12, to the year of 8).

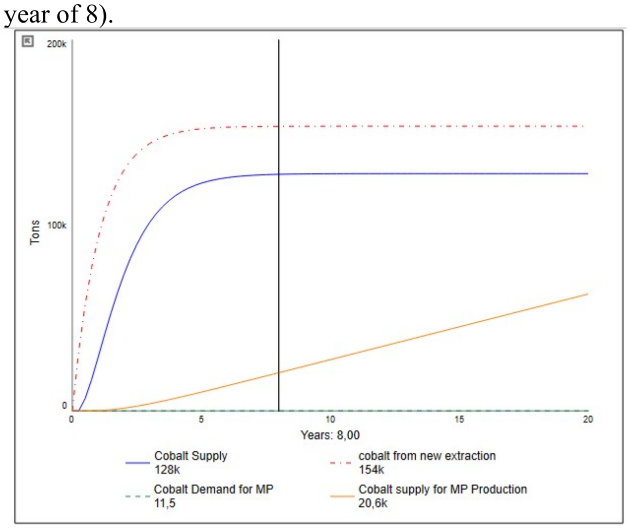

Figure 12. Graphic illustration of Model Calibration concerning Cobalt supply and demand

Figure 13 shows the same change trend and synchronously change of lithium battery recycled from Mobile phone; cobalt recovered from Mobile Phone Li.B.

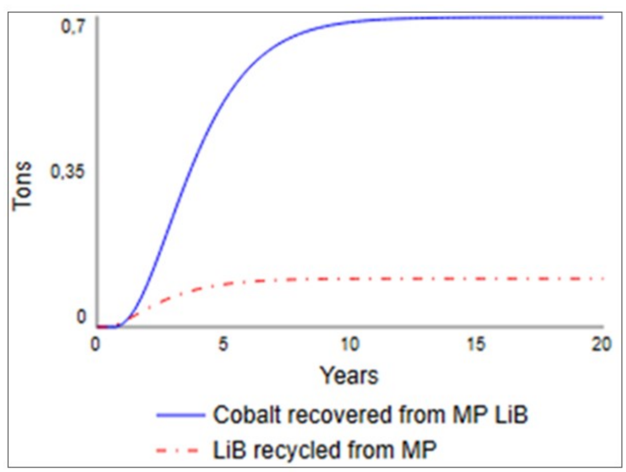

Figure 13. Timing of Model Calibration of Li.B. Recycling and Cobalt Recycling for a Mobile Phone (MP)

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C. Visualization and Simulation of Model

With the help of STELLA®, a user can explore different assumptions and see the outcomes over time; add objects for interacting with the model such as action run buttons for simulating, and for viewing results such as graphs, tables, and gauges.

Figure 14 is one example, shows the immediately visualization how variables affect each other during a simulation. Here "Garbage Reuse" is taken as output, the relevant variables are "% of reuse rate", "delay of 1st. Reuse", "delay of 2nd. Reuse", "the rate of discard", "the amount of cobalt usage in each Mobile Phone unit".

Table III list the value setting for each variable in each run. Table IV is the simulation result of "Garbage Reuse" for each run over time frame of 20 years.

TABLE III. VALUE SETTING FOR EACH VARIABLE

variable / run	% of reuse	Delay first use	Delay 2nd reuse	% of Discard	Cobalt contained in MP LiB
Run 1	0	2	0,5	100	10
Run 2	25	2,5	0,5	75	7,6
Run 3	50	5	2	50	5
Run 4	75	5	2	25	3
Run 5	90	10	5	10	0

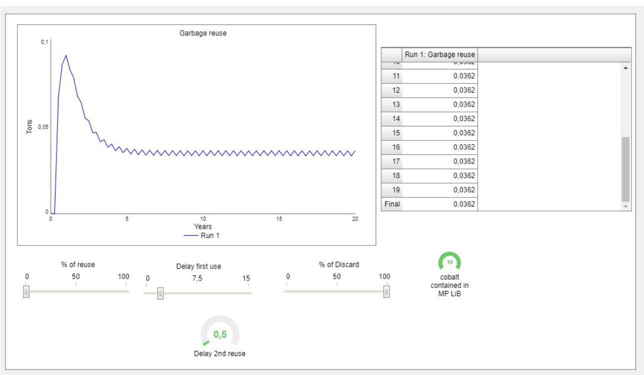

Figure 14 (A). Simulation result after 1. Run

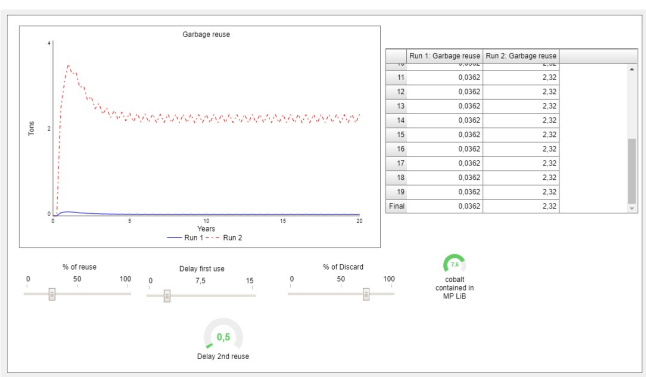

Figure 14 (B). Simulation result after 2. Run

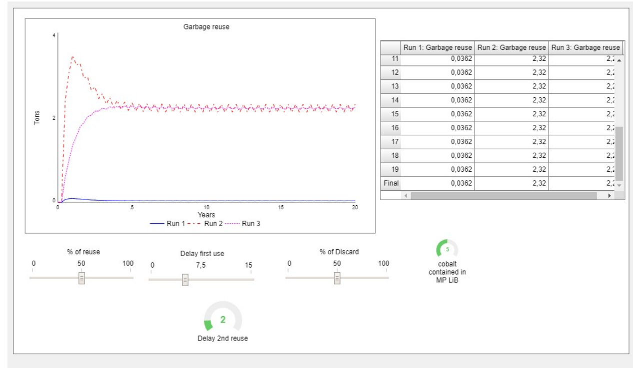

Figure 14 (C). Simulation result after 3. run

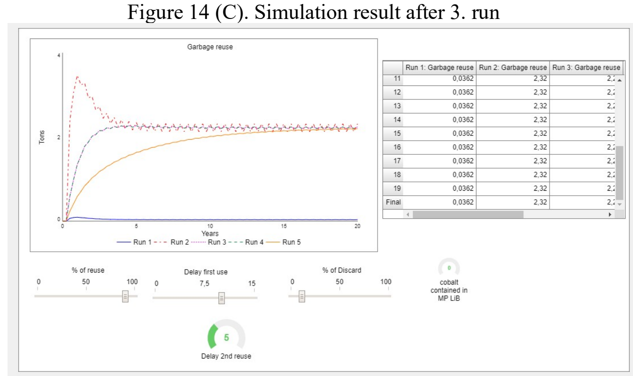

Figure 14 (D). Simulation result after 5. run

TABLE IV. SIMULATED "GARBAGE REUSE" UNDER DIFFERENT CONDITIONS

Year / Run	Run 1	Run 2	Run 3	Run 4	Run 5
0	0	0	0	0	0
1	0,091	3,47	1,35	1,35	0,587
2	0,0637	2,97	2,02	2,02	1,03
3	0,0466	2,57	2,22	2,22	1,3
4	0,04	2,41	2,27	2,27	1,49
5	0,0376	2,35	2,27	2,27	1,64
6	0,0367	2,33	2,26	2,26	1,75
7	0,0364	2,32	2,26	2,26	1,84
8	0,0363	2,32	2,25	2,25	1,91
9	0,0362	2,32	2,25	2,25	1,97
10	0,0362	2,32	2,24	2,24	2,02
11	0,0362	2,32	2,24	2,24	2,06
12	0,0362	2,32	2,24	2,24	2,09
13	0,0362	2,32	2,24	2,24	2,12
14	0,0362	2,32	2,24	2,24	2,14
15	0,0362	2,32	2,24	2,24	2,15
16	0,0362	2,32	2,24	2,24	2,17
17	0,0362	2,32	2,24	2,24	2,18
18	0,0362	2,32	2,24	2,24	2,19

19	0,0362	2,32	2,24	2,24	2,2
Final	0,0362	2,32	2,24	2,24	2,2

Figure 15 shows an extension of the model in Figure 10 that covers financial aspects. Take repair as example. Assume the repair cost per year per unit of a phone is about 30 Euro annually and a new phone costs about 200 Euro per year for a 2-year life span. Figures 16(A) & 16(B) show the simulation results of the total costs over time. To this time point, this simulation is simplified by assuming the repair also happens in the first two years of usage. Repairing a phone is worthwhile after about 3 years of usage if the average repair cost is about 30€.

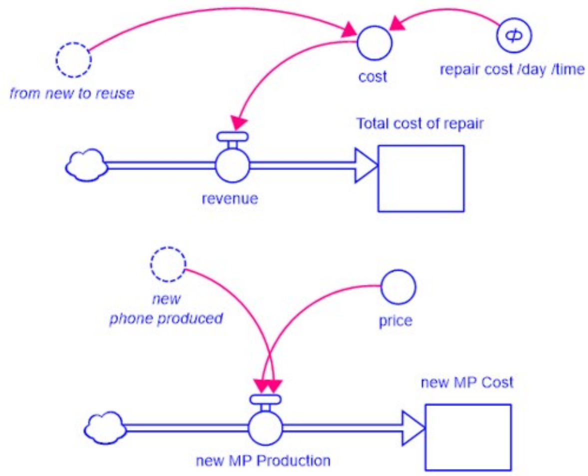

Figure 15. Financial sector of the model

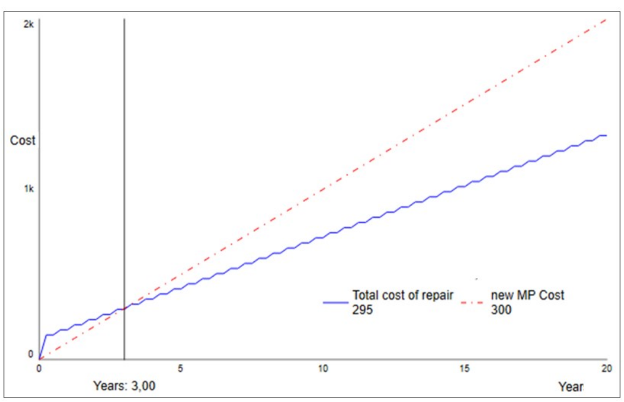

Figure 16(A). Comparison of new mobile phone cost and repair cost by reusing phone over time (Repair cost =30€ /a, new cost=400€)

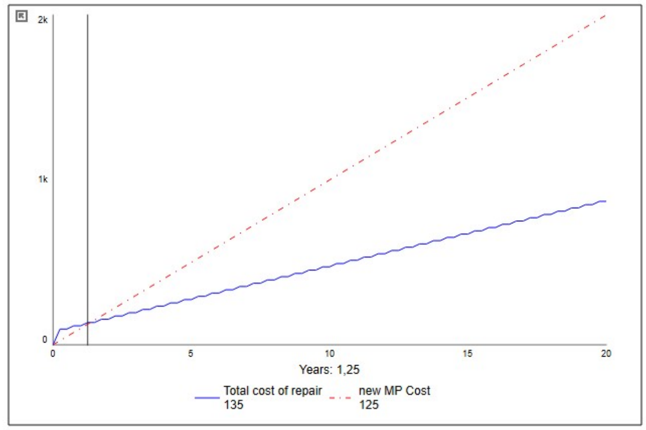

Figure16(B). Comparison of new mobile phone cost and repair cost by reusing phone over time (Repair cost =20€ /a, new cost=400€)

VI. CONCLUSION AND FUTURE WORK

Model-building and calibration will continue, until a satisfactory number of parameters are accounted for. Parameters from economic and financial aspects will be added to the model. However, the more parameters added, the more complex the system will be. Statistical analysis of empirical data can help estimate some structural parameters of the model. This study contributed to the state of the art by applying system dynamic modeling and simulation to sustainability.

We provided researchers a new perspective for investigations into employing novel design tools and simulation to analyze complex systems. Practitioners could benefit from a better understanding of issues of a product or industry branch. The proposed DBMfS approach might aid policymakers in the development of sustainability-related regulations.

Applicability of our findings is limited by our use of statistics rather than real data from a company. Gathering both structural and non-structural data would strengthen findings in this research area. In the future, real data from a smart phone company will be very valuable to validate the model built and the solutions or parameters applied to the model.

ACKNOWLEDGMENT

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Appendix I: Lifecycle sustainable issues along smartphone lifecycle and the research focus

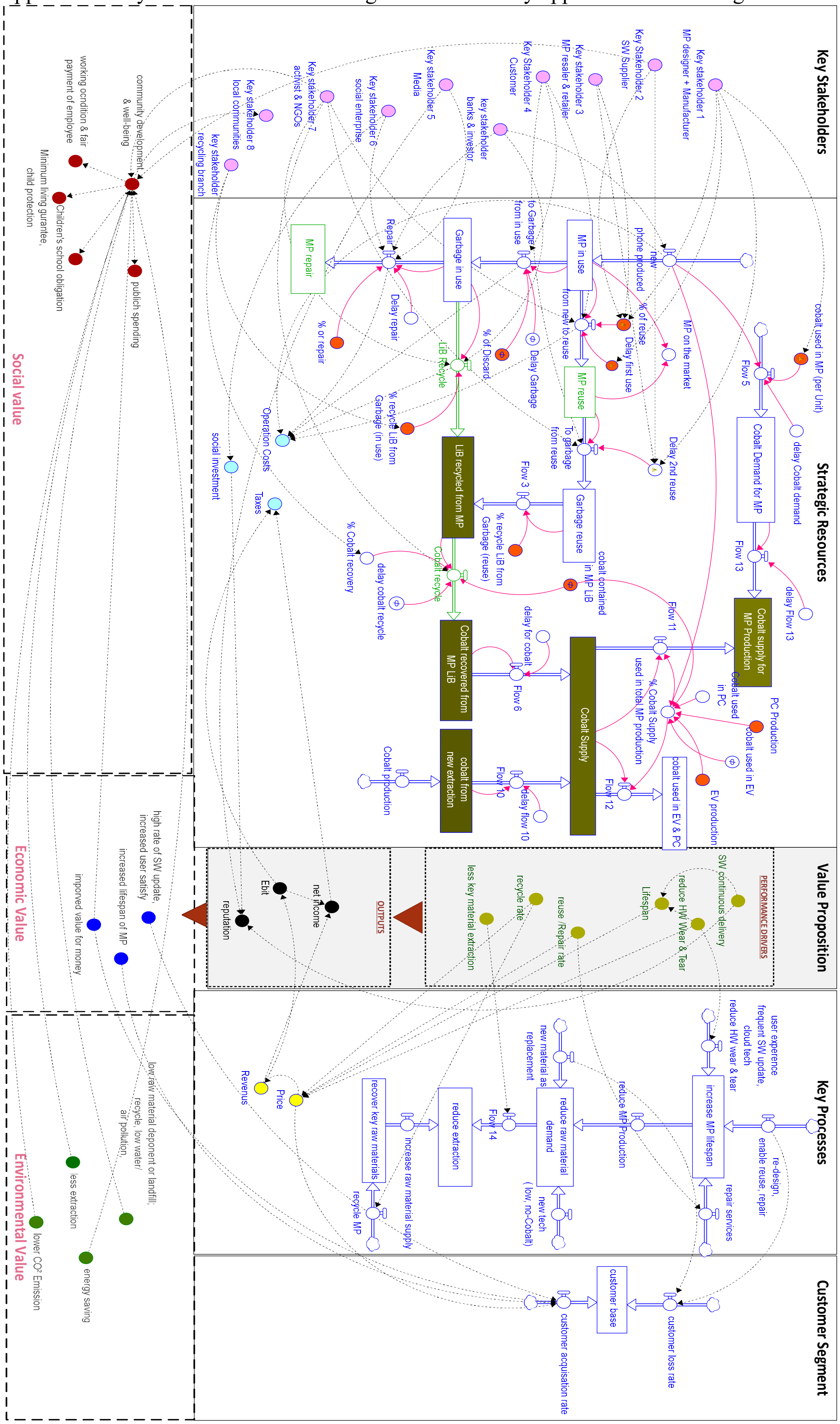
LifeCycle Sustainable Issues along Smartphone Lifecycle

SBM: Sustainable Bussiness Model

X: Focus of my Research

Life cycle phases and sustainability issues ►	Resource extraction and processing			Design and manufacturing				Distribution and network provision		Usage			End-of-life				
SBM patterns ▼	Illicit operations / conflict minerals	Poor working conditions	Environmental degradation	Energy/resource intensive manufacturing	Poor working conditions	Exposure to toxic substances	Poor product design choices	Transport emissions	Fast replacement business model	Short lifetime	Electricity consumption	Stockpiling of functional devices	Stockpiling of defect devices	Illicitly imported electronic waste	Informal recycling	Poor working conditions	Toxic substances / lost materials
SUSTAINABLE RESOURCE COMPANY	X	X	X												X	X	
SUSTAINABLE MANUFACTURER				X	X	X	X	X	X	X	X	X	X	X	X		X
SUFFICIENCY-ADVOCATING NETWORK PROVIDER								X	X	X	X						
USAGE-EXTENDING DISTRIBUTOR								X		X	X	X	X	X	X		X
REFURBISHING & REPAIR GAP-EXPLOITER										X	X	X					
REFURBISHING & WEEE SERVICE PROVIDER										X	X	X	X	X	X		X
WEEE SERVICE PROVIDER													X	X	X	X	X

Appendix II: Dynamic business modeling for sustainability applied to Cobalt usage in a Smartphone lifecycle



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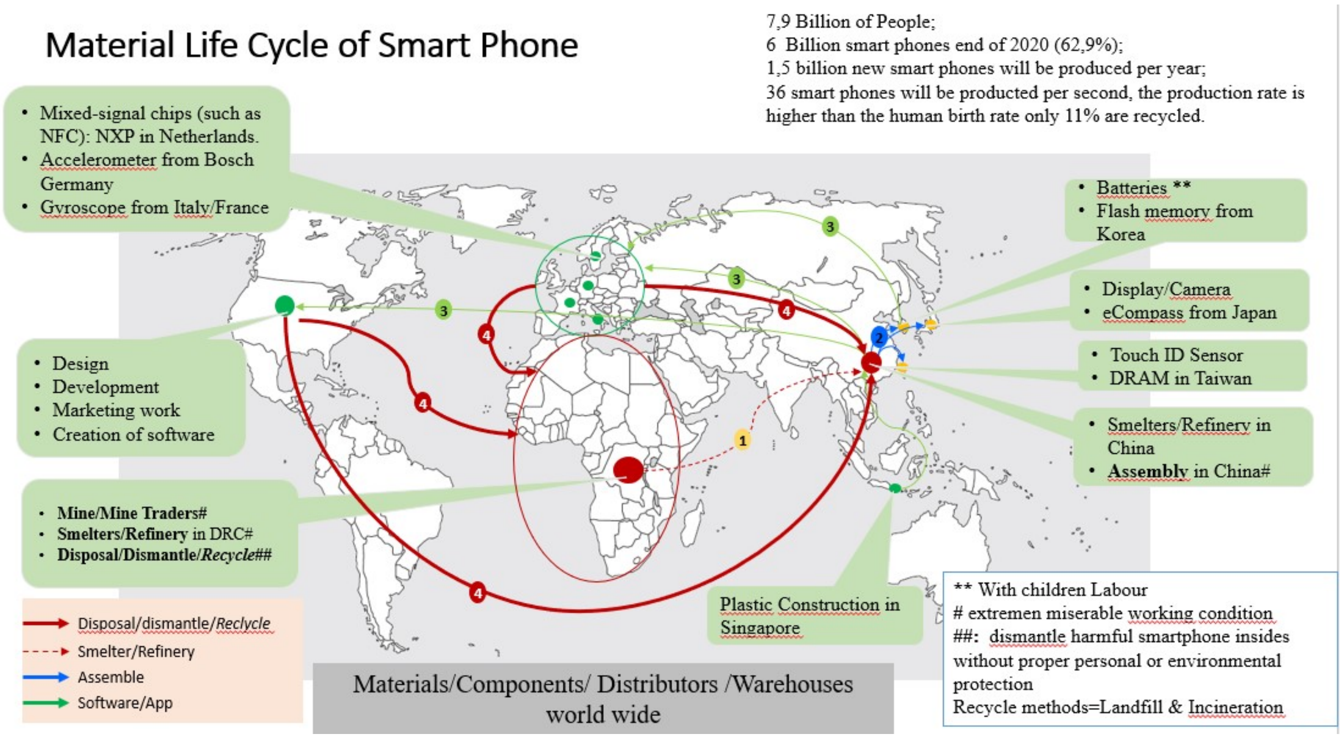
Appendix III: Material Life Cycle of Smart Phone



Appendix IV: STELLA® Model for simulation of cobalt usage in smartphone