MASTER

Practical application of the Social-LCA methodology in the energy field

Kuzeva, Denitsa Dobrinova

Award date:
2018

Graduation Project

Practical application of the Social-LCA methodology in the energy field

Master:	Sustainable Energy Technology
Department:	Industrial Engineering and Innovation Sciences
Research Group:	Technology, Innovation and Society
Student:	Denitsa Dobrinova Kuzeva
Identity Number:	1282212
Thesis Supervisor:	Dr.ir. A.F. (Arjan) Kirkels
Date:	31 – 08 – 2018

Technische Universiteit Eindhoven University of Technology

Declaration concerning the TU/e Code of Scientific Conduct for the Master's Thesis

I have read the TU/e Code of Scientific Conduct[1].

I hereby declare that my master's thesis has been carried out in accordance with the rules of the TU/e Code of Scientific Conduct.

Date 22.08.2018

Name Denitsa Kuzeva

ID-number 1282212

Signature

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Executive summary

The current research, as part of the second-year of the SELECT Master program by EIT InnoEnergy graduation project in Eindhoven University of Technology (TU/e), was carried out to analyse how the Social Life Cycle Assessment (SLCA) method can be applied to evaluate the local and global impacts by energy systems. The goal of the project was to answer what is SLCA, how social impacts are assessed in the energy field and how to capture both the local and global social impacts in the energy field using the SLCA methodology.

This work was formed by two key elements: literature review and case study analysis. The review defines the concept of SLCA and existing methodologies, tools and datasets for its assessment and how social criteria are evaluated in the energy field. Then, an SLCA case study was conducted for a smart grid implementation project in the resort city of Albena, Bulgaria. All the data for the case study analysis was collected on-site form available documentation, interviews and observations. A recently completed smart grid project was used as a background of the research. As a detailed SLCA assessment of the whole smart grid would require more time, the focus was narrowed down to the most common components of a smart grid namely solar PV and battery and the overall impact on the national electricity system.

The pathway to answer the research question was to first examine what SLCA is for the energy domain. The work presents methodologies and tools used in the SLCA science. The findings indicate that UNEP/SETAC Guidelines and Methodological sheets are most commonly used when conducting an SLCA case study. The Social Hotspot Database (SHDB) is found to be a very commonly used tool, unpacking the global social risks by certain sectors. The ways of social impact assessment in energy systems was overviewed including different sustainability assessment methods. This included a summary of existing SLCA studies in the energy field, where the indicators and methods of assessment are detailed.

Then, the case study is presented, following the UNEP Guidelines. The analysis is mostly qualitative. The inventory stage was divided in two parts: generic and site-specific analysis. For the generic assessment SimaPro software and the SHDB were used to generate results on the potential impacts of the smart grid implementation on global scale. Those were evaluated by country and sector. The most impacted sectors detected by SimaPro were analyzed. The site-specific assessment included stakeholder analysis where interviews and grey literature was used to position the identified stakeholders and rank them using impact/influence and rainbow diagrams. In the life-cycle impact assessment – categories, subcategories and indicators were selected and presented. Then scoring system was used to evaluate the results. The social impact risks were classified and weighed.

The results from the case study showed that most social impact risks are on local perspective – 97%. The analysis shows that the highest risk is by the Bulgarian national energy market players. On the global perspective the highest risk is related to the solar PV panels from China that could be minimized by choice of different panels with less social risks. The overall impact of the full smart grid integration in Albena to the national grid would be minor. Nevertheless, if such projects scale up those effects would be more significant.

The SLCA methodology and its assessment tools have drawbacks that could be improved and further developed. This current work unpacks the application of SLCA in the energy field. The chosen case study showed that a researcher using the SLCA methodology is facing a lot of challenges. The assessment is based on many decisions. However, the findings show that the SLCA methodology can play a significant role in the sustainability assessment that can be applied to assess the local and global impacts of energy projects and help the energy transition towards people and communities with higher quality of life and lower consumption.

Acknowledgements

This work is successful, with the help, trust and support of Dr. ir. Arjan Kirkels, part of the Technology, Innovation and Society research group of the TU/e, thanks to his supervision, feedback and advises throughout the graduation project.

Many thanks, to Assoc. Prof. Lluis Batet and Assoc. Prof. Cesar Valderrama, who gave the opportunity for the current research and helped with discussions and feedback. The author would like to express her appreciation to Dr. Catherine Benoit for sharing her experiences in the SLCA field and providing access to SHDB and SimaPro software for the outcomes of this project.

The author would also like to thank Prof.dr.ir. G.P.J. Verbong for accepting the invitation to be the Chairman and part of the Examination Committee along with Dr. ir. Arjan Kirkels, Prof. Han van Kasteren and Assoc. Prof. Lluis Batet.

For carrying out the case study, gratitude to Albena JSCo and especially Dimitar Stanev, for providing insights, documents and sharing data for the case study assessment. The high value of the work is due to the SEASON-ALL project and its team members. Finally, the success of this work is highly dedicated to the gathered data during the study visit. For this reason, the author would like to express high appreciation to EIT InnoEnergy, for the financial help and support within the master program.

Abbreviations

ARV	Average Risk Value
BG	Bulgaria
CBA	Cost Benefit Analysis
CEWR	Commission for Energy and Water Regulation
CH	China
CSR	Corporate Social Responsibility
DE	Germany
DSM	Demand Side Management
DSO	Distribution System Operator
ELCA	Environmental Life Cycle Assessment
ESIA	Environmental Social Impact Assessment
ESO	Energy System Operator
GTAP	Global Trade Analysis Project
IEA	International Energy Agency
INVADE	Integrated electric vehicles and batteries to empower distributed and centralised storage in distribution grids
IO	Input-Output
JRC	Joint Research Centre
JSCo	Joint Share Company
LCA	Life Cycle Assessment
LCC	Life Cycle Costing
LCSA	Life-Cycle Sustainability Assessment
LTD	Limited
MCA	Multi-criteria Assessment
MCDM	Multi-criteria….
MD	Manufacture and Distribution
NGO	Non-Governmental Organization
NPP	Nuclear Power Plant
PLC	Private Limited Company
PSILCA	A Product Social Impact Life Cycle Assessment
PV	Photovoltaic
R&D	Research and Development
RMT	Risk Mapping Tool
SCADA	Supervisory Control and Data Acquisition
SEASON-ALL	Strategies for energy autonomy and sustained operations of Albena, BG
SELCA	Social and Environmental Life Cycle Assessment
SETAC	Society of Environmental Toxicology and Chemistry
SHDB	Social Hotspot Database
SHI	Social Hotspot Index
SIA	Social Impact Assessment
SLCA	Social Life Cycle Assessment
TPP	Thermal Power Plant
TSO	Transmission System Operator
UA	Ukraine
UNEP	United Nations Environment Program
USD	United States Dollar
UZ	Uzbekistan

Contents

1. Introduction

We live in interesting times, facing challenges and opportunities as never before. Agenda 2030 and its 17 goals show commitment to sustainable development and ensure sustained and inclusive economic growth, social inclusion and environmental protection [1]. The Sustainable development methodology uses a holistic approach to solving problems by addressing problems at their roots to create positive change with less negative impact on society and the environment. Of this, specifically, the Sustainable Development Goal 7 is to ensure access to affordable, reliable and sustainable energy for everyone.

With technological progress and human development, the increase of the demand for energy has been one of the most significant factors in the acceleration of climate and environmental changes observed and described by the scientific community. Indeed, the increasing demand for energy has required strategies to be developed on the local and global level to enhance energy security and sustainability through innovative energy policies and measures [2]. Thus, the energy transition towards sustainable energy to decentralized, renewable and more efficient solutions, in every level of the energy supply and demand chain, can be seen to be happening [3]. However, there is a need for building further effective ways to navigate the future - bringing practical and sustainable solutions. Technology and science should take into account the cultural and social behaviour and create innovative solutions to problems. To improve well-being and economic development, humanity is using fossil fuels. In this regard, innovation should be done not only with concern for sustainable global development, but also human health and well-being, related to those issues and the amount of energy used per unit of human well-being [4]. The combination of these factors should lead us to communities that live happily and consume less.

All this cannot be achieved without the proper tools and methods. The need of measuring impact of products and services has initiated the developments of sustainability measurement tools such as Cost Benefit Analysis (CBA), Multi-Criteria Analysis (MCA), Life-Cycle Analysis (LCA), Life-Cycle Costing (LCC), Social Impact Assessment (SIA), Corporate Social Responsibility (CSR) etc. [5]. The reasons for performing such analyses can differ: decision making, influencing policy or as a marketing strategy. The role of LCA is to assess the environmental impact of products associated with all stages of its life-cycle – from raw material extraction to disposal. It is used for decision making, learning and market claims among other [6]. Furthermore, Environmental LCA (ELCA) has been developed, to deepen the knowledge of the impact on the environment. Then, the social criteria are included and Social Life-Cycle Assessment (SLCA) originated. Its main aim is to analyze the social impact of products or services throughout their life-cycle.

Recently, considerable research has been performed in the field of SLCA. It is an important tool in the sustainability science that adds in critical indicators of human well-being, influenced by processes or companies in supply-chains, such as worker's rights, community development, consumer protections, and social benefits. Depending on the set system boundaries, the analysis starts from raw material extraction, trough production and transportation, until use phase and final disposal, through a range of impact categories. Methodologies and applications of SLCA are still under development although there are many existing examples [7]. Some SLCA studies have focused on specific energy technologies and products, such as biomass [8] or PV [9]. However, most of them have not followed specific methodology only focused on energy systems.

For sustainable energy transition – the social impact of the energy systems has to be evaluated, because the sustainability relates not only to environmental impact but also social, such as human health issues caused by fossil fuels [10]. The debates, around how to tackle climate change, manage resources and lower emissions; transform the technical, engineering issues to complex socio-technical problems that need more attention. Decreasing social impact and maximizing value will result in a faster uptake of energy transition technologies.

The social criteria are currently being considered for energy projects, along with the technical, economic and environmental aspects of the same. However, the overall social impact on local and global scale is hardly addressed by most currently used method for social evaluation in the energy field. SLCA could solve this and bring considerable value to the energy transition. For this reason, the current study is focusing on the potential use of SLCA methodology for assessment of the local and global social risks related to the energy field.

2. Goal and Research question

Recently, there is increased interest in the social and ethical dimensions of technology and engineering sciences. Based on the fact that energy has a big impact in the modern society there is the need to apply new tools to assess them besides traditional tools like techno-economic assessments. For these reasons, this work will investigate the application of SLCA in the energy field. The primary objective of this study is to evaluate how Social life cycle assessment (SLCA) methodology can bring value in energy projects to uncover their social impacts. Therefore, the following research question is the major guideline for this report:

How can SLCA be applied to evaluate the local and global impacts by energy systems?

This question is answered and serves as the basis for further development of a SLCA methodology in this current study. For simplification, to unpack this question, the research is divided into three sub-questions that are used as a backbone to answer the main one. The sub-questions are the following:

1. ***What is SLCA?***
2. ***How social impacts are assessed in the energy field?***
3. ***How to capture both the local and global social impacts in the energy field using the SLCA methodology?***

The first objective: *What is SLCA?* is the literature review that makes an overview of SLCA to identify: methodologies, applied tools and data. The research also aims to examine quantitative and qualitative social indicators, on the local and global scale, in general, and in the field of energy. In-depth research of performed case studies of energy projects and use of different analytical tools in energy and sustainability science is intended to answer the second objective: *How social impacts are assessed in the energy field?,* to understand what has been done in the past and what is needed for the future. This includes also the methods used to measure impact, weighing and classification of indicators. After that, a case study analysis is chosen to unpack the process of SLCA application in energy and the corresponding issues. The analysis would be performed using identified analytical methods and tools. The final outcomes would answer the third objective: *How to capture both the local and global social impacts in the energy field using the SLCA methodology?,* and the research question, including drawbacks, method limitations and proposal for further work of development. The following methodology chapter presents the analytical methods and tools used to answer the research question and sub-questions.

3. Methodology

In this chapter, the methodological steps taken in the study are presented in order to highlight the key elements in the current research. The tools and approaches are described for each part of the analysis with the corresponding intends and expected results. First, a literature study is performed on SLCA, assessment of social impacts of energy systems, in order to identify the methods and tools that are usually used. This is based on indepth research in order to show the relevant steps and analytical tools in research studies. Then, SLCA application in the energy field is explored reviewing performed case studies. Finally, a case study approach is chosen to show the local and global impacts using the SLCA method. A case study is analyzed on the social impact of smart grid in Albena, Bulgaria.

The literature review, as a fundamental part of the current work, aims to uncover the concept of SLCA method and its use in the energy field. The research answers the questions what is SLCA, what methodologies and tools exist and are often used and their contributions, e.g. how the different SLCA frameworks measure impact and which indicators are used in the different methodologies. Scientific papers were identified by a Google Scholar search [11], using keywords "Social Life Cycle Assessment", "Social-LCA" and "SLCA". This provided over 10 000 hits of which the most relevant articles that have the key word in the title were sieved, taking into consideration journals with higher ranking. Especially, the International Journal of Life Cycle Assessment [12] showed to be of great relevance, covering a lot of the debate on SLCA. Besides the journal articles, the literature search also extended to grey literature (relevant websites, books, and reports). Of special interest were the Life Cycle Initiative website [13] for providing relevant information regarding databases; the Social Life-Cycle Assessment handbook [7] that is used as a resource for existing methodologies and tools in the SLCA; and the UNEP/SETAC guidelines [14] and Methodological sheets [15], that are found to be key feature in the SLCA science. The findings include the position of SLCA in the sustainability science, the methodologies developed for SLCA by different researchers, the identification methods of stakeholders. Within the research, a description of how the frameworks measure impact and the different types of indicators that are used is elaborated. To answer fully the first sub-question - *What is SLCA?*, a study of different tools applied in the SLCA science is performed. The literature search not only focuses on the concept of SLCA, but also covers available software tools and datasets. Reflecting on the recent development, it is relevant due to the data-intensive nature of impact assessment in SLCA and provides relevant information, as the target is to apply these tools on the research. Within the LCI website [13] - the OpenLCA Nexus tool for datasets [16] is used to find that the two most widely applied instruments for SLCA are PSILCA [17] and the Social Hotspot Database (SHDB) [18], later applied in the analysis.

To answer the second sub-question - *How are social impacts assessed in energy?*, first, an overview of the available analytical methods within the sustainability assessment is done for indicators and indices; product-related assessment and integrated assessment [5]. Then, the Social Impact Assessment (SIA) case studies in energy are reviewed to identify how social impacts are measured in energy. The multi-criteria decision-making strategies used within energy projects are also examined [10]. The SLCA case studies in the energy field are analyzed in depth to identify how indicators and system boundaries are chosen and what kind of tools are applied. This second part of the literature review aims to create a selection of quantitative and qualitative social indicators, representing human well-being in the field of energy. The case studies are found via Google Scholar [11], by using key words such as "social impact on energy systems/projects", "social LCA on energy systems/projects", "SLCA in the energy field" to find articles in the International Journal of Life Cycle Assessment [12] as well as in different energy journals, such as Energy Research & Social Science Journal [19]. A paper summarizing case studies in SLCA is also found [20] and the energy related reports are analyzed in detail. To summarize the social indicators – the Methodological sheets [15] and the found case studies are used. The applied tools and methods for measuring, weighing and scoring the indicators used in the different studies are also explored. The multi-criteria decision making tool is further analyzed, exploring articles in energy journals such as Renewable & sustainable energy reviews [21], Renewable energy journal [22] and Energy Sources [23] by searching for “multi-criteria/multiple criteria assessment/analysis for energy/power systems/project” or “MCA in the energy field”. This analysis is used to answer the second sub-question - *What is SLCA in the energy field?* and how social impact is measured in the energy field.

The literature review gives a generic overview of the tools, impact methods and indicators used in SLCA and particularly energy. In order to answer the third sub-question - *How to capture the local and global social impacts in the energy field using the SLCA methodology?*, a case study approach is chosen to test the method within the energy context [24]. This approach brings value by building knowledge from observation within a context environment, for supporting information or exposition of the main thesis of the work. Methodological choices are taken for the selection of the case study through relevance, rationality, depth of research, how data will be collected and measured etc. The topic of the case study aims to be rational, exploring social phenomena related to the energy field, appearing in different projects or systems. Within times of energy transitions in a different level, smart grids are identified as a practical topic with high relevance. This topic is also interesting due to novelty [25], social involvement [26] and in relation to European energy transition plan [27]. The criteria for the case study are to be effective, realistic and with access to data. A potential smart grid project is identified in a resort city in Bulgaria, with data availability as a major asset. The balance between the social and technical aspects of the study aims to be maintained [28] in the description, the case is defined with the corresponding technical details. The studied product is a Smart Grid with main components PV and Battery and main functions Peak Shaving, Demand Side Management and Flexible Energy Operations. First, the case study is described in detail starting with the location, the energy consumption and identified the potential of smart grid implementation with its added values. A previously conducted study of the smart grid implementation in Albena is used intending to evaluate the social impacts that the implementation would bring. The sizing and the percentage of autonomy that the resort will achieve by the smart grid implementation, in the long run, are employed by the other study to evaluate the annual savings to the Bulgarian electricity mix and the amount of saved electricity by conventional power generation, taking into account the power generation strategy of the country. The main components of the grid are described using reference installation offers.

The goal of the case study is to identify the social impact of a smart grid implementation in Albena, Bulgaria using the SLCA method. After the definition of the case study, the SLCA methodology, as presented in the UNEP/SETAC guidelines [14], identified as the most used in SLCA studies and as a backbone for the different methodologies, is applied as follows: 1. Definition of Goal and Scope; 2. Inventory analysis; 3. Impact Assessment; 4. Life Cycle Interpretation. The boundaries in terms of timeline, location and the detail of analysis are set. First, the ideal system is described. Then, the necessary assumptions and simplifications are made in order to be able to perform the analysis, taking into account the life-cycle perspective and the different risks. The model system is described with the corresponding system boundaries, impact stakeholders and locations. Data concerning the National Grid and the energy mix in Bulgaria is gathered from the national TSO - Energy System Operation (ESO) [29].

For the inventory analysis, identification of the global and local social impacts within the smart grid implementation is done. SimaPro and the SHDB software and datasets are strategically chosen for the generic analysis. SimaPro software is used to identify the hotspots in the Bulgarian electricity sector. The findings show and classify the most impacted global sectors by the Bulgarian electricity. Then, by using the Risk Mapping Tool (RMT) from Social hotspot database (SHDB) [18], the risk categories related to the social issues of the highest impact sectors, in international level are uncovered. The Social Hotspot Index is used to visualize and measure the average risk value of the categories with the highest risk on the five sectors, namely Bulgarian Electricity, Uzbekistani Gas manufacture and distribution, Ukrainian Coal, Ukrainian Electricity and Bulgarian Coal. Multiple issue data tables are created on the same sectors of the identified risk categories to define the indicators scoring high and very high risks. The same analysis is performed for the smart grid components - PV and Battery, namely the Chinese Electronic equipment sector for PV and German Machinery and equipment sector for the Battery.

For the identification and evaluation of the local impacts, as part of the research question - qualitative stakeholder analysis is performed. The initial SHDB risk assessment helps the identification of relevant global stakeholders in the study, as well as for the indicators selection on a later stage in the analysis. A stakeholder analysis is conducted to define and categorize the interested parties by the SG implementation, using stakeholder identification and categorization strategies [30]. Identification of the stakeholders is done using data collected by on-site visit, documentation, observations, interviews with employees and visitors, journal articles and the media. As per the smart grid definition by the EU Commission "A smart grid is an electricity network that can cost-efficiently integrate the behaviour and actions of all users connected to it — generators, consumers and those that do both — to ensure an economically efficient, sustainable power system with low losses and high levels of quality and security of supply and safety", so the local actors in the supply chain of the components, the users and operators of the smarts grid, the actors in the energy market, the local community and the local employees are considered as relevant stakeholders. They are identified and presented with labels with different colours per country.

The most fundamental part of the case study analysis – application of the methodological framework of SLCA, as stated in the UNEP guidelines, follows. It aims to integrate both a quantitative and qualitative analysis. However, due to time limitations and lack of socio-economic data, only a qualitative analysis is performed. The analysis integrates the social impact on the local and global perspectives. Respectively, the data collected is both generic and site-specific. The calculation of the indicator results involves the conversion of the results into common units, within the same impact category, using a scoring system. The expected outcome is a numerical indicator result. The analysis is divided into generic and site-specific and then the results are compared using weighing criteria. For the generic analysis, the Average Risk Values AHV for the identified hotspots and themes, based on the RMT findings in order to choose the relevant indicators are used, adopting the categories, themes and risks from SHDB into the SLCA categories, sub-categories and indicators. The values are then averaged and a result for each sector is conducted.

For the site-specific analysis, tools, such as analytical categorization of interest and influence - identification of key stakeholders [30], that allow the visualization of relationships, interests and level of affection are used to present the distinctions between the stakeholders, using the same colour code. Visualization is performed using Microsoft Visio [31]. The rainbow diagram - classification of stakeholders according to the degree that they affect or are being affected by a problem [32][30] is also carried out. The results are later used to help with the scoring during the assessment of the impacts of the different stakeholders, considering the chosen qualitative indicators. Then the identified stakeholders are placed in the stakeholder categories proposed by the guidelines, namely Workers, Local community, Society, Consumers and Value chain actors. The relevant sub-categories and indicators are chosen from the Methodological sheets. The scoring is done according to the Generic analysis so that the results could be comparable. It is based mostly on the observations and conversations during the site-visit. The scoring system is from 0 to 10, where 2 is used for low risk, 4-medium, 6-high and 8 for very high risk. The results are averaged per stakeholder, as in the generic analysis.

Based on the literature review, the weighing criterion chosen to measure the indicators is a normalized value of the measure of impact after aggregation of the qualitative inventory information with the quantitative social data. The chosen weighing to perform the final results of the impact assessment are scores between 0 and 1, depending on if the stakeholders are global or local, measured within the functional unit. The results provide an estimation of a measure of impact for each category. Charts and tables are created after measuring the impact of each of the chosen indicators to visualize the results. The results are compared and the significant issues, within the social findings, are identified. The main concerns include the hotspots within the generic assessment and the site-specific issues. The involved stakeholders in the key issues are discussed. The chosen methodological steps are based on the performed overview and aim to answer the research question. The goal is to solve the problem of how to take decisions within a research and how to tackle issues that arise within the analysis.

Evaluation process follows including critical review, actions taken to ensure transparency, reliability of the findings, relevant critical issues, the value choices, level of details, data quality, followed by a discussion on uncertainty, recommendations and conclusions. The assumptions taken under the analysis are summarized. Consideration of the applications and limitations within the research is presented, including business and innovation potential. A business, entrepreneurial and innovation potential (business case opportunity) that can be deducted from the results of the thesis work is also discussed.

4. Literature review

This review aims to uncover the concept of SLCA and the methodologies used for analysis. It answers the questions what is SLCA, what methodologies are there, how the different SLCA frameworks measure impact and which indicators are used. Overview of the available analytical methods within the sustainability assessment has been done. The multi-criteria decision making strategies used within energy projects as well as SLCA and SIA case studies in the energy field were analyzed to identify how indicators and system boundaries are chosen and what kind of tools are applied.

4.1. Social-LCA

The discussion about the Social Impact Assessment (SIA) has inititated in the 1970s. Kurt Finsterbusch performed a review of the state of the art of SIA in 1985 [33], also outlining the general methodology at that time to review the same. That included standard social science research procedures of surveys, interviews, field observations, use of records and documents and study of published articles. It is said that there are five types of policy research that answer a different question: (1) Problem identification – What is the problem?; (2) Policy development – What should be done?; (3) Impact assessment – Which alternative is the best?; (4) Program evaluation – Is the program worthwhile?; (5) Program improvement – How can it be improved?. The identified categories for SIA in that article are new technologies, constructed facilities, environment use plans, environmental designs and development projects in the third world. The general methodology was developed by Wolf (1983) for standardization of several other methodologies that were already developed. It consists of ten assessment steps with the corresponding questions: Scoping, Problem identification, Formulation of alternatives, Profiling, Projection, Assessment, Evaluation, Mitigation, Monitoring and Management. In the section on SIA methodology for facility construction, several socioeconomic conditions (impact categories) were considered. A general SIA and Management model was presented. New directions for SIA methodology were suggested as well. This is the foundation for measuring the social impact.

Since then, a lot of research and studies have been preformed. In 2016, PRé Sustainability, together with AkzoNobel, BASF, BMW Group, DSM, Goodyear, L'Oréal, Mahindra Sanyo, Philips, Steelcase and Vattenfall founded the Roundtable for Product Social Metrics Members. They have published a Handbook for Product Social Impact Assessment [34]. The main focus is a practical method for organisations to assess the social impacts of products. Three stakeholder groups are being considered. The UNEP Guidelines for SLCA (2009) [14] and different corporate standards are used as references. 10 different pilot case studies are presented. This report proves that in practical level SIA is still used for the use phase of goods and services but for real assessment of the Social impact – the whole life cycle has to be considered.

There are many different studies and innovations in the recent years for SLCA, including frameworks, methodologies, business guides [35] etc. A very important document issued in the field is The Guidelines for SLCA, produced by the UNEP/SETAC Life Cycle Initiative at UNEP, CIRAIG, FAQDD and the Belgium Federal Public Planning Service Sustainable Development [14]. It states that: SLCA is Impact assessment technique that aims to assess the social and socio-economic aspects of products and their potential positive and negative impacts along their life cycle. It is used as a framework in most SLCA case studies [20]. The Guidelines give tools for social impacts assessment in relation to an area of protection, such as human well-being. They suggest five stakeholder categories: worker, local community, society, consumer and value chain actor. Every stakeholder is associated with a number of impact subcategories, such as child labour, fair salary, health and safety, local employment, cultural heritage and corruption, human rights, working conditions, governance and socioeconomic repercussions. The Methodological Sheets for Subcategories In Social Life Cycle Assessment (SLCA) [15], also by UNEP/SETAC (2014) provide a framework for every different stakeholder including subcategories, definition, policy relevance, directions how to assess data and examples of indicators.

Conduction SLCA has been shown to trigger improvement social performance of products at different stages in the lifecycle, by providing information towards decision makers from companies, governments and NGOs, through choice of performance indicators and marketing. In Figure 1 the Scope of CSR and impact assessment techniques of enterprises and their products, as presented in the Guidelines, are shown. It can be seen that SLCA is considering most factors when applied [14].

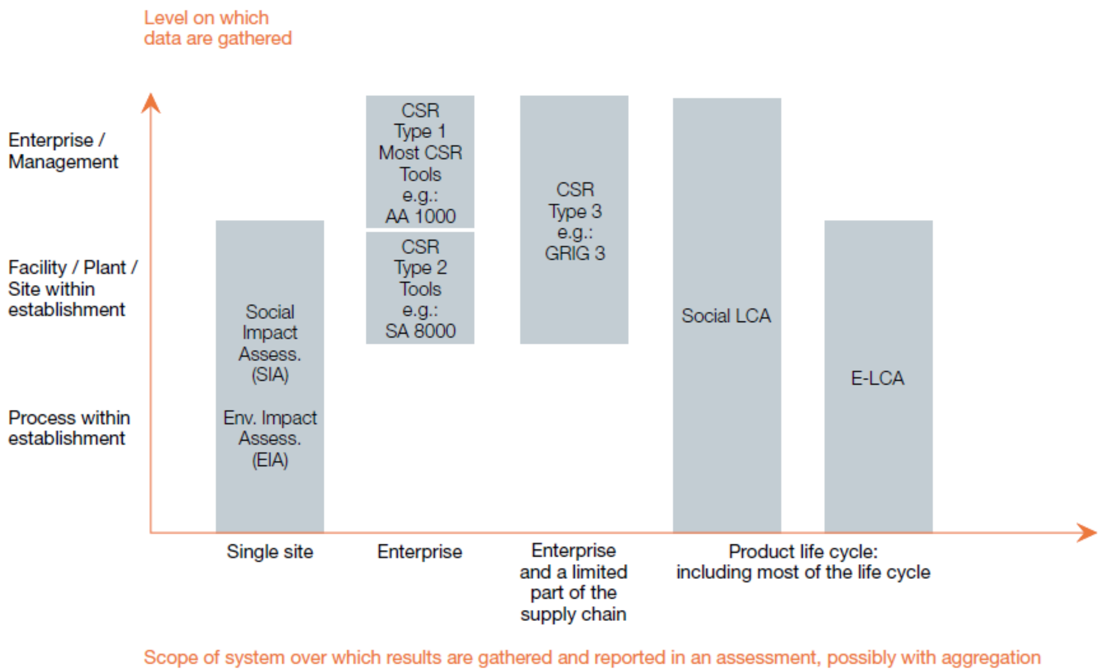

Figure 1. Scope of CSR and impact assessment techniques of enterprises and their product [14].

4.1.1. Existing methodologies for SLCA

The Social and Socio-economic criteria in LCA prospective was officially discussed for the first time in a workshop report from 1993 [7]. In JRC Technical Report on Social Life Cycle Assessment: State of the art and challenges for supporting product policies from 2015, the state of development of SLCA has been described in detail, giving overview of the main theoretical and methodological elements under discussion [36], which will be summarized below. Also, the Business, Policy and NGO perspectives on SLCA are discussed. It overviews methods in SLCA and process identifications and quantifications, studying the four methods of Dreyer, Norris, Hunkeler, and Weidema, identifying human well-being as the basis for SLCA [7], each of which will be discussed below in more detail. According to the document – Environmental LCA (ELCA), sometimes includes social aspects and in general - is more developed and mature than SLCA. In the same article - the following problems of SLCA were identified: (1) the definition of human well-being; (2) the selection of social indicators for SLCA; (3) the preference of site-specific data or generic data; and (4) the method for quantifying the social impacts.

The first presented framework for SLCA was developed by Dreyer, issued in 2006, in accordance with the ISO 14040 and 14044 standards for ELCA, with some adaptations. It is defining two basic categories – from a social perspective and from a company perspective. That predefines how important SLCA is in a business perspective. Later in 2010, he further developed a quantifiable impact assessment method according to the ISO for LCA (1997, revised 2006 [37]). A multi-criteria indicator assessment was proposed. It consisted of three steps - identification of the impact category; scoring the managerial effort on the protection of human dignity and well-being, and conversion from the managerial effort score to the company risk score. The key concept that used by the methodology proposed by is Corporate Social Responsibility (CSR) (Figure 1) with the ultimate goal to improve "human dignity and well-being". As an example, a Multi-Criteria Indicator-Assessing Model Case Study is given, by Dreyer.

The methodology by Norris was developed to measure the health impact of a product`s life cycle. It was used as an example endpoint indicator the health impact, measured by life expectancy, based on the World Health Organization, stating that poverty is the most important single determinant of ill health in Europe. It assesses how human health is influenced by industrial pollution but also economic growth. In conclusion – he suggested including more endpoint indicators in SLCA rather than using the health impact as the only indicator for SLCA. Example of Endpoint SLCA Case Study is shown.

In Hunkeler`s method – directly existing ELCA data is used to calculate the amount of basic human needs, measured in labour hours, using the unit process. He has found that using generic data is more practical than using site-specific data. This methodology is similar to Norris's approach – both use generic data to determine the social impacts, but Hunkeler gives value to social benefits, while Norris - health impacts. The case study for Hunkeler's methodology is Geographically Specific Method in five steps.

Weidema introduced a SLCA quantification methodology for social impact by a human life-year as a result (2008), later improved using the UNEP/SETAC framework (2009). It focused on human health, identifying damage categories and quantifying human life-years lost. The Indicator used is measured by human longevity. Impact pathway was used to define the links between inventory indicators and damage categories through social impact categories. Generic data is applied in this methodology. Details are given with Weidema's Damage-Oriented Case Study.

Jorgensen proposed a more general framework, drawing on the insights of the previous discussed studies (2008) [38], including a set of indicators proposed by the already mentioned methods. He has pointed out data accessibility as the most critical points in SLCA.

The SLCA methodology by UNEP/SETAC (2009) follows ISO 14040 framework with some adaptations: (1) Goal and Scope, (2) Life Cycle Inventory Analysis, (3) Life Cycle Impact Assessment and (4) Life Cycle Interpretation[14], where system boundary, stakeholders, subcategories, and limitations are stated. In the inventory analysis, data is collected based on stakeholders and subcategories identified, from reports, interviews, documentation and literature. In the Life cycle impact assessment phase, it is not specified what should be done by the guidelines so it is quite flexible – the impact assessment can be specific or general, depending on data availability. However, before application of the framework general important considerations should be analyzed: definition of the social impact in the study; description of the problem and type of system; stakeholder categories and different impact categories. Figure 2 shows the stakeholder categories as presented in the Guidelines and the relations between them. After research, it was found that most SLCA studies performed are following the considered steps defined in the Guidelines (UNEP/SETAC) [20]. In fact, the authors of the guidelines are some of the authors of the methodologies already mentioned – Weidema and Norris.

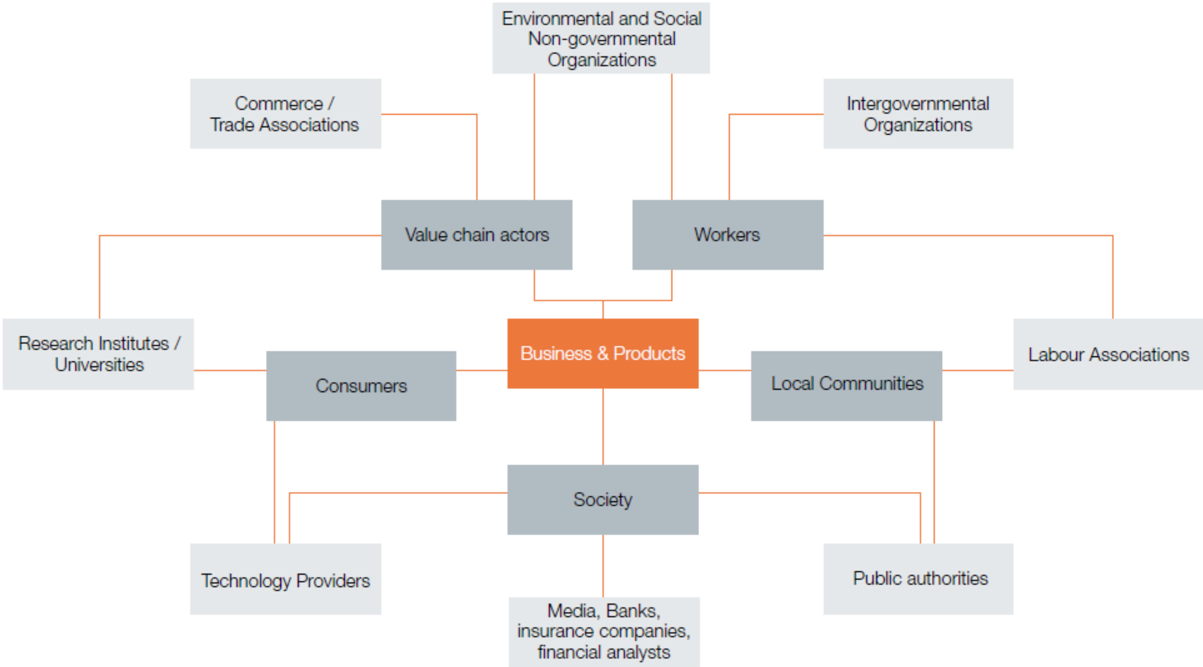

Figure 2. Stakeholder categories as presented in UNEP/SETAC Guidelines for SLCA[14]

Catherine Benoît, also one of the authors of the Guidelines, explains the key parameters required in SLCA study design, dividing them into the identification of different considerations - goals, social issues, the context of the application and life-cycle stages [39] (2013). She clarifies the two types of data required in SLCA - modelling data and social impact data. The modelling data is related to the quantitative metrics of the study and ensures that the life-cycle perspective is captured. The system boundaries, the scope of the study and the functional unit are also part of this type of data. The social impact data, on the other hand, elaborate on the social impact category or a stakeholder group affected by the production activity. It includes the causal-chain impact, social performance and contextual data.

Hybrid methodologies for SLCA such as Social-Organizational LCA (SOLCA) [40], Life-Cycle Sustainability Assessment (LCSA) and Social and Environmental Life Cycle Assessment (SELCA)[41] also exist.

4.1.2. Indicators for SLCA

The definition of stakeholder impact categories, subcategories and indicators have to be defined for the inventory analysis. The inventory indicators have different characteristics and they can be quantitative as well as qualitative. Methodological sheets defining the subcategory of an impact as well as suggesting inventory indicators, such as child labour, corruption and gender equity, are the basis for the development of the inventory. The methodological sheets by UNEP/SETAC provide a definition of subcategory of impact with examples of inventory indicators for each subcategory with the unit of measure and the source of data [15]. In Table 1 - examples of different inventory indicators for each subcategory of every stakeholder group are shown[1]. There are two types of indicators described: generic – the hotspots and specific to the case.

Table 1. Examples of inventory indicators in the different sub-categories (UNEP/SETAC)[15]

[1] The full tables with inventory indicators can be found in the methodological sheets [15].

Stakeholder	Subcategory	Inventory indicator (generic and specific)
Local community	Delocalization and Migration	Forced Evictions stemming from Economic Development
		Strength of organizational policies related to resettlement
		International Migrants as a Percentage of Population
	Community Engagement	Transparency of Government Policymaking
		Public Trust of Politicians
		Diversity of community stakeholder groups that engage with the organization
	Cultural Heritage	Presence/Strength of Organizational Program to include Cultural Heritage Expression in Product Design/Production
	Respect of Indigenous Rights	Indigenous Land Rights Conflicts/Land Claims
		Prevalence of Racial Discrimination
	Local Employment	Unemployment Statistics by Country
		Poverty and Working Poverty by Country
		Percentage of workforce hired locally
	Access to Immaterial Resources	Patent Filings
		Do policies related to intellectual property respect moral and economic rights of the community?
	Access to Material Resources	Changes in Land Ownership
		Levels of Industrial Water Use
		Has the organization developed project related infrastructure with mutual community access and benefit
	Safe and Healthy Living Conditions	Pollution Levels by Country
		Management effort to minimize use of hazardous substances
	Secure Living Conditions	Strength of Public Security in Country of Operation
		Number of casualties and injuries per year ascribed to the organization
Value Chain Actors	Fair Competition	National/sectorial law and regulation
		Sectorial agreement
		Membership in alliances that behave in an anti-competitive way
	Respect of Intellectual Property Rights	General Intellectual Property Rights and related issues associated with the economic sector
		Organization's policy and practice
	Supplier Relationships	Payments on time to suppliers
		Sufficient lead time
	Promoting Social Responsibility	Industry code of conduct in the sector
		Integration of ethical, social, environmental and regarding gender equality criterions in purchasing policy, distribution policy and contract signatures
Consumer	Health and Safety	Quality of or number of information/signs on product health and safety
		Presence of Management measures to assess consumer health and safety
	Feedback Mechanism	Number of consumer complaints at the sector level
		Presence of a mechanism for customers to provide feedback
	Privacy	Country ranking related to strength of laws protecting privacy against organizations and government
		Strength of internal management system to protect consumer privacy, in general
	Transparency	Sector transparency rating; number of organizations by sector which published a sustainability report
		Consumer complaints regarding transparency
Stakeholder	**Sub-category**	**Inventory indicator (generic and specific)**

Consumer	End-of-Life Responsibility	Strength of national legislation covering product disposal and recycling
		Do internal management systems ensure that clear information is provided to consumers on end-of-life options (if applicable)?
Worker	Freedom of Association and Collective Bargaining	Evidence of restriction to Freedom of association and Collective bargaining
		Workers are free to join unions of their choosing
	Child Labour	Percentage of children working by country and sector
		Absence of working children under the legal age or 15 years old (14 years old for developing economies)
	Fair Salary	Minimum wage by country
		Lowest paid worker, compared to the minimum wage
	Hours of Work	Excessive Hours of work
		Clear communication of working hours and overtime arrangements
	Forced Labour	Risk of forced labour used for production of commodity
		Workers are free to terminate their employment within the prevailing limits
	Equal Opportunities/Discrimination	Women in the Labour force participation rate by country
		Ratio of basic salary of men to women by employee category
		Presence of formal policies on equal opportunities
	Health and safety	Occupational accident rate by country
		Number/ percentage of injuries or fatal accidents in the organization by job qualification inside the company
	Social Benefit/Social Security	Social security expenditure by country and branches of social security (eg. Healthcare, sickness, maternity)
		Percentage of permanent workers receiving paid time-off
Society	Public Commitment to Sustainability Issues	Engagement of the sector regarding sustainability
		Presence of mechanisms to follow-up the realisation of promises
	Prevention and Mitigation of Conflicts	Is the organization doing business in a region with ongoing conflicts?
		Organization's role in the development of conflicts
	Contribution to Economic Development	Economic situation of the country/region (GDP, economic growth, unemployment, wage level, etc.)
		Contribution of the product/service/organization to economic progress (revenue, gain, paid wages, R+D costs in relation to revenue, etc.)
	Corruption	Risk of corruption in the country and/or sub-region/sector
		Formalised commitment of the organization to prevent corruption, referring to recognised standards
	Technology Development	Sector efforts in technology development
		Involvement in technology transfer program or projects
		Investments in technology development/ technology transfer

4.1.3. Tools and databases in SLCA

The following subchapter aims to make a review of the existing tools and databases that are being used in SLCA. The Life-Cycle Initiative website [13] presents the OpenLCA Nexus [16] tool that incorporates different datasets for various types of LCA. The datasets include (1) LCI databases: ecoinvent, idea, GaBi, Agri-footprint, ARVI, Agribalyse, soca, EuGeos' 15804-IA, NEEDS, ESU World Food, ELCD, LC-Inventories.ch, ProBas, bioenergiedat, USDA, Ökobaudat, openLCA LCIA methods; and (2) Input/Output (IO) databases: exiobase, PSILCA and Social Hotspot Database. The databases that include social indicators are found to be exiobase, PSILCA and Social Hotspot Database. However, the SHDB has the largest amount of social datasets 6441, followed by PSILCA 246 and only 144 for exiobase. The JRC Technical Report on Social Life Cycle Assessment is describing in details the state of development of SLCA, giving an overview of the main theoretical and methodological elements under discussion [36]. Databases and indicators for SLCA are described with the main focus on (1) Social Hotspots Database Method and (2) PSILCA: Product Social Impact Life Cycle Assessment database. For these reasons, only PSILCA and SHDB are discussed in detail.

PSILCA is a software developed by Greendelta [17], that is providing a database for SLCA. The latest version has been developed at the end of 2017. Product Social Inventory Life Cycle Assessment – database for SLCA for products and can also detect Social hotspots during the products lifecycle [42]. PSILCA is using Eora as a backbone – multiregional input-output database. It covers 189 individual countries with 14 838 sectors. It also gives a high resolution sector classification which gives more detailed information. The social indicators are inspired by UNEP Guidelines they look into different stakeholders with different subcategories measured by quantitative or qualitative indicators assessed by different risk and opportunity levels, taking into account data quality and availability.

The UNEP/SETAC guidelines give a definition of "social hotspots", which are unit processes located in a region where a situation occurs that may be considered a problem, a risk or an opportunity, in relation to a social theme of specific interest [14]. This concept is used as a foundation for the construction of SHDB [18], which is the most concrete example on how to assess potential social issues with a life cycle orientation. Social Hotspot Database (SHDB) has been created to foster greater collaboration in improving social conditions worldwide by providing transparent data and tools necessary for greater visibility of social hotspots and product supply chain. The SHDB is made up of the country and sector-specific indicator tables to help to identify hotspots, the countries and sectors of concern, in supply-chains based on potential social impacts. Therefore, by using SHDB as the background dataset for a foreground life cycle model of the production system, the analyst can generate geographically specific supply chains models. Within five Social categories, there are many different Social themes [18], within those themes, there are different indicators that are characterized by a level of risk or opportunity. This may allow estimating the labour intensity by economic sector of activity, to make transparent compilation and interpretation of a large number of publicly available data, and to perform diverse applications not necessarily specific to S-LCA, relying on systematic and consistent methodology. SHDB enables the modelling of product systems and the initial assessment of potential social impacts. It is based on the Global Trade Analysis Project (GTAP), using the Input/output (IO) model to provide values about country and sector-specific activities in product supply chains [39]. The SHDB is analogous to other IO models used for hybrid LCA, providing very comprehensive top-down results, at the cost of reduced granularity relative to process-level data [43]. The SHDB is built upon the GTAP multi-regional IO framework [18], with a global resolution of 113 countries and 57 sectors. The database has been included in the LCA software OpenLCA and SimaPro. There are other tools that are used in SLCA (Life Cycle Working Environment (LCWE); Potential Hotspot Analysis (PHA)[20]), however, they have not be analyzed in detail.

SHDB gives the opportunity to visualize, analyze and compare data. It provides tools and services at a country or sector level also within, such as Risk mapping tool (RMT). RMT is an analysis tool that aids in researching potential social impacts on country and sector lever. It can be also integrated as a database in LCA software. Global input-output model can be created that will provide data on for example labour intensity on a country-specific sector. The web portal has different visualization capabilities such as single issue risk map, multiple issue bar chart, multiple issue data, risk tree-maps and social hotspot index. The Risk Mapping Tool of SHDB has been chosen for the current case study analysis.

To summarize this chapter, the first research sub-question of the current analysis is answered: *What is SLCA?* - a methodology that is used to evaluate the social impact of products/systems/services on local and global dimension. The literature review shows that different methodologies exist, however the most common practice, when performing an SLCA analysis, is to follow the UNEP Guidelines and Methodological sheets. This is based on choices that the author has to make e.g. categories, subcategories and indicators and ways to measure them. There is a variety of tools and datasets available to help those choices. The most commonly used of which is found to be SHDB.

4.2. Social Impact in the energy field

As explained in the chapter above, the most common practice when conducting SLCA study is application of UNEP guidelines methodology. The role of this section would be to answer the second sub-question: *How social impacts are assessed in the energy field?* For this reason, review of decision-making tools in the sustainable energy field is performed. Then, the focus is specifically on SLCA in the energy field and analysis of performed case studies.

4.2.1. Methods for sustainability assessment of energy projects

To achieve the sustainability goal when evaluating energy systems, the socio-economic and biophysical systems need to be considered [10]. The consideration of different criteria is discussed, wherein the social criteria is included together with the technical, economic and environmental considerations. There are many different tools used for sustainability assessment. They can be categorized into three groups: Indicators/indices, Product related assessment and Integrated assessment [5]. The areas to be sustained are identified as nature, life-support systems and community, taking into account the environmental, social and economic issues. The evaluation of global and local systems in the short and long term is necessary to determine which actions to be taken to make a society sustainable. The sustainability assessment indicators are simple quantitative measures that represent environmental, economic and social development [5]. The indicators are characterized by simplicity, scope, quantifiability, and time and trend identifiability.

The social criteria are included in many tools used in the sustainability assessment: as indicators and indices, such as the Wellbeing index and the Human development index, or as separate tools - CSR, Risk Analysis, SIA, MCA and SLCA [5]. For sustainable energy assessment, the multi-dimensionality of the impacts of the system should be considered depending on the goal of the study [10]. Multi-criteria decision analysis (MCDA) is mostly applied considering the technical, economic, environmental and social criteria. There are multiple methods for criteria selection, weighing, analysis and aggregation. Usually, the analysis is an integrated combination of numerous techniques, due to the complexity that energy management brings.

The environmental criteria can also be related to social issues when it comes to health impact by emissions or land and water use. Technical issues that affect social problems are safety, noise and reliability. The social acceptance is a qualitative figure measured with surveys and interviews. Job creation and social benefits are also related to the social criteria. Moreover, the quality of life and health impact should be considered. For example, energy used per household, the share of household income spent on fuel/electricity, number of injuries per energy output or number of working hours per energy produced, may be used to express social impact. Different principles and methods may be used for criteria selection: Systematic, Consistency, Independency, Measurability or Comparability principles; Delphi, Least mean square (LMS), Minmax deviation and Correlation methods [10]. There is a wide variety of weighing methods used in MCDM described in details in "Review on multi-criteria decision analysis aid in sustainable energy decision-making" (et. al. J. J. Wang) [10]. Wang also describes MCDA methods using different categories along with the most common aggregation methods.

4.2.2. SLCA in the energy field

For the purpose of this current work, the social impact of energy project on a life-cycle perspective have been measured and considered. For this reason, SLCA studies on energy systems are being assessed to identify the used indicators. This section also aims to create a selection of quantitative and qualitative social indicators, representing human well-being in the field of energy.

A research on case studies in the energy field that used SLCA for assessment of the social impact of a product or a system was performed. Several articles were found: two for PV technology - Solar

Photovoltaic Development in Australia - A Life Cycle Sustainability Assessment Study [9] and Towards life cycle sustainability assessment: an implementation to photovoltaic modules [44]; four about coal and biomass-based fuels - Social dimensions of energy supply alternatives in steelmaking: comparison of biomass and coal production scenarios in Australia [45], Social life cycle assessment of palm oil biodiesel: a case study in Jambi Province of Indonesia [46], Prioritization of bio ethanol production pathways in China based on life cycle sustainability assessment and multi-criteria decision-making [47] and Screening potential social impacts of fossil fuels and bio fuels for vehicles [48]; and one for a country`s energy system - Towards prospective life cycle sustainability analysis: exploring complementarities between social and environmental life cycle assessments for the case of Luxembourg's energy system [49]. The life-cycle analysis method, social stakeholder group or category and the indicators used in each of them are summarized in Table 2.

Table 2. Summary of stakeholder groups/categories and the applied indicators of SLCA case studies about energy systems.

N	Title	Group / category	Indicators	Method
1	Solar Photovoltaic Development in Australia - A Life Cycle Sustainability Assessment Study	Trina Solar	Business ethics, Supplier relationships, Care for employees, Health and safety, Contribution to society, End of life management	LCSA = ELCA + LCC + SLCA
		UQ R&D	Contribution to technology development, Contribution to research collaboration	
		Local government	Consistency with Federal government, Commitment to carbon emission reduction, Social influences	
		Electricity distrib. network	Compatibility and stability, Profitability	
		Local community	Health and safety, Feedback mechanism, Transparency, Awareness and training, Community engagement, Local employment	
2	Towards life cycle sustainability assessment: an implementation to photovoltaic modules	Workers	discrimination, child labour, wages, working hours, social benefits and health conditions	LCSA= ELCA +LCC +SLCA
3	Social dimensions of energy supply alternatives in steelmaking: comparison of biomass and coal production scenarios in Australia	Land-use, Employment, Health & safety	Forest utilisation values, Amenity and traffic, Water management, Community health & safety from charcoal plant, Land values, Community identity, Investment and profitability uncertainty, Soil erosion and compacting, Food security, Subsidence (& associated ground and surface water impacts), Amenity and community health (dust)	SLCA
4	Social life cycle assessment of palm oil biodiesel: a case study in Jambi Province of Indonesia	Workers	**Human right:** Free from the employment of child labour, Free from the employment of forced labour, Equal opportunities, free from discrimination; **Working condition:** Freedom of association and collective bargaining, Fair salary, Decent working hours, Occupational health and safety, Social benefit	SLCA
		Local community	**Cultural heritage:** Land acquisition, delocalization, migration; Respect on cultural heritage and local wisdom; Respect on customary right of indigenous people; Community engagement; Safe and healthy living condition; Access to material resources; Access to non-material resources; Transparency on social/env. issues	

N	Title	Group / category	Indicators	Method
4	Social life cycle assessment of palm oil biodiesel: a case study in Jambi Province of Indonesia	Society	**Socio-economic repercussion:** Contribution to local employment; Contribution to economic development; Food security; Horizontal conflict; Transfer of technology and knowledge	SLCA
		Value chain actors	**Governance:** Public commitments to sustainability; Fair competition; Free from corruption	
5	Towards prospective life cycle sustainability analysis: exploring complementarities between social and environmental life cycle assessments for the case of Luxembourg's energy system	Labour rights and decent work, Health and safety, Human rights, Governance, Community infrastructure	Child Labour, Collective bargaining, Corruption, Drinking water, Excessive working, Forced Labour, Gender, High Conflict High, Hospital Beds, Improved Sanitation, Indigenous Rights, Injuries and Fatalities, Legal System, Migrant Labour, Poverty Wage1, 2, 3, Toxic and Hazards	LCSA, ELCA, SLCA, SHDB
6	Prioritization of bioethanol production pathways in China based on life cycle sustainability assessment and multicriteria decision-making	Workers	**Human right:** Free from the employment of child labour, Free from the employment of forced labour, Equal opportunities, free from discrimination; **Working condition:** Freedom of association and collective bargaining, Fair salary, Decent working hours, Occupational health and safety, Social benefit	LCSA, MCDM, LCA, LCC, SLCA
		Local community	**Cultural heritage:** Land acquisition, delocalization, migration; Respect on cultural heritage and local wisdom; Respect on customary right of indigenous people; Community engagement; Safe and healthy living condition; Access to material resources; Access to non-material resources; Transparency on social/environmental issues	
6	Prioritization of bioethanol production pathways in China based on life cycle sustainability assessment and multicriteria decision-making	Society	**Socio-economic repercussion:** Contribution to local employment; Contribution to economic development; Food security; Horizontal conflict; Transfer of technology and knowledge	LCSA, MCDM, LCA, LCC, SLCA
		Value chain actors	**Governance:** Public commitments to sustainability; Fair competition; Free from corruption	
7	Screening potential social impacts of fossil fuels and bio fuels for vehicles	Labour rights and decent work	Child labour, Forced labour, Excessive working time, Wage assessment, Poverty, Migrant labour, Freedom of association etc., Unemployment, Labour laws	SLCA, SHDB
		Health and safety	Injuries and fatalities, Toxics and hazards	
		Human rights	Indigenous rights, High conflicts, Gender equity, Human health issues	
		Governance	Legal systems, Corruption	
		Community infrastructure	Hospital beds, Drinking water, Sanitation, Children out of school, Small holder or conventional farms	

The article about Solar Photovoltaic Development in Australia - A Life Cycle Sustainability Assessment Study [9] is analyzing a 1.2 MW flat-roof mounted PV solar array called UQ Solar and its impacts using LCSA as a combination with three different methods: Environmental Life Cycle Assessment, Life Cycle Costing and Social Life Cycle Assessment. For ELCA, all data collected in the inventory analysis was placed in SimaPro, the primary energy consumption was calculated and mid-point environmental impacts were assessed. Then, the energy payback time (EPBT) was calculated. In the LCC, weather, technical performance and financial performance data were collected and modelled into System Advisor Model. A nine-colour qualitative assessment was adopted in SLCA to assess the social impacts of UQ Solar. Interpretation was given based on inventory results and impact assessment.

Towards life cycle sustainability assessment: an implementation to photovoltaic modules [44] also incorporates with three different methods within LCSA – Environmental Life Cycle Assessment, Life Cycle Costing and Social Life Cycle Assessment to carry out the implementation of sustainability assessment of the assembly step of photovoltaic (PV) modules production comparing three different types of modules. The tools used are SimaPro, Gabi, UNEP/SETAC Guidelines for LCSA[50], UNEP/SETAC Guidelines for SLCA and the Life Cycle Sustainability Dashboard (LCSD).

Social dimensions of energy supply alternatives in steelmaking: comparison of biomass and coal production scenarios in Australia [45] – the paper adapts SLCA to analyse the social dimensions of energy supply alternatives in steelmaking in Australia. Three regionalised production scenarios are investigated – two charcoal alternatives and metallurgical coal. The study does not follow any specific methodology and the indicators are chosen based on a literature review, identified issues by stakeholders at a local and regional scale.

The Social life cycle assessment of palm oil biodiesel: a case study in Jambi Province of Indonesia [46] aims to investigate the social implications of palm oil biodiesel via case study using SLCA methodology by UNEP/SETAC. First, the authors decide to develop the social impact weighing criteria by adopting the criteria provided by UNEP/SETAC, supplemented by a survey that involved a panel of experts and decision-makers in the palm oil industry in Indonesia. The stakeholders' perspectives are evaluated by determining the gaps between expected and perceived quality of each social criterion, which are gauged using seven-point Likert scale.

Prioritization of bio ethanol production pathways in China based on life cycle sustainability assessment and multi-criteria decision-making [47] aims to combine the LCSA framework and the multi-criteria decision-making (MCDM) methodology and determine the most sustainable scenario for bio ethanol production in China. LCA, LCC and SLCA are combined to collect the corresponding criteria data on environmental, economic, and social aspects. The LCA methodologies include the CML 2 baseline 2000 V2.04 characterization and the ReCiPe 2008. The LCC consists of the costs in the entire product life cycle- design, construction, production, distribution, operation, maintenance and support, retirement and material disposal. SLCA was assessing multiple impacts -from direct impacts on workers to broader societal consequences using UNEP/SETAC Guidelines.

The generic social and socioeconomic impacts of various bio fuels and fossil fuels are assessed in Screening potential social impacts of fossil fuels and bio fuels for vehicles [48] using SLCA methodology and SHDB. Only high and very high risk indicators are considered for each combination in order to limit the amount of data. Each fuel type assessed is then aggregated by counting the number of high and very high risk indicators for that fuel.

The article Towards prospective life cycle sustainability analysis: exploring complementarities between social and environmental life cycle assessments for the case of Luxembourg's energy system [49] discusses the complementarily between SLCA and ELCA towards the definition of prospective LCSA approaches. A case study is presented comparing ELCA results of business as usual scenarios of energy supply and demand technology changes in Luxembourg, up to 2025, based on economic equilibrium modelling and hybrid life cycle inventories, with a monetary based input-output estimation of the related changes in the social area, using SHDB and the categories introduced there.

In addition, social indicators in the power generation are also suggested by Barclays in Environmental and Social Risk Briefing Power Generation [51]. It covers the power generation industry and includes power stations and the use of fossil fuels, nuclear power and renewable energy sources. A standard life cycle for each power generation sector is proposed: project feasibility and planning, construction, operations, power supply and facility (plant) decommissioning. For each stage and type of power generation – risk indicators are highlighted in tables. The report is also stating that for almost all large-scale new build, expansion and development projects – ESIA will be required especially when external financing is provided.

The Literature review answers the first two sub-questions of the research: *What is SLCA?* and *How social impacts are assessed in the energy field?* The most of the found existing SLCA methodologies and case studies are based on the UNEP/SETAC Guidelines [14] and use Methodological sheets and the proposed indicators there [15]. The social criteria are considered in sustainability assessment of energy systems, mainly considering local perspectives. SLCA is considering both local and global perspectives. The evaluated SLCA case studies found in the energy field are all different but most use a combination of multiple methodologies (LCA, ELCA, MCA, LCSA), including SLCA. Many of them apply SHDB to analyze the global social hotspots for particular sector and region, as explained above. They use different indicators to assess social impact, some from the Methodological sheets and some from the SHDB. The socio-economic criterion is also included in most of them as a quantitative measure, while the qualitative indicators are based on interviews and local perspectives. There are some indicators used more than once in the case studies but due to the limitation of a number of studies, it cannot be stated that those are always applicable for the different energy systems. The indicators would be unique for every individual case due to the difference in specificities. However, it must be noted that there is a big amount of literature, articles and papers for the explored topics, as explained in the Methodology section.

5. SLCA Case Study analysis

The Literature review, showed the relevance of SLCA methodology in the energy field and the assessment methods used. In order to fully unpack the potential of the SLCA application for energy systems and to answer the third research sub-question: *How to capture both the local and global social impacts in the energy field using the SLCA methodology?*, the chosen research strategy*,* is a case study. The expected outcomes would provide interesting data and results. Within the case study research - a phenomena is studied within its concept. The results would strongly depend on the methodological choices. A qualitative research, due to data limitations, is conducted.

When selecting the case, several aspects should be considered such as completeness, sufficient evidence and significance. A case study should have engaging manner and reflect on alternative perspectives, revealing local and global issues, leading to deeper understanding how SLCA is applied in the researcher point of view. The results can provide sufficient ground to be extended to other industries and applications with suitable modifications and possibly provide more detailed insights in how to assess these technologies. It should also describe the motivation for the research and define the social phenomena (industrial life cycle, group behaviour, organization process, international relations, maturation of industry), as well as clarify the primary research question. Referring to the depth of research it should be stated if it is holistic (generic) or embedded (just some aspects are considered). After the definition of rationale, background, problem statement, the purpose of research and limitations, the methods for data collection should be defined - interviews, document review, focus groups, observations etc [24].

A suitable topic for a case study analysis that would unpack the process of SLCA application in energy and the corresponding issues are identified. Within times of energy transitions in different levels, smart grids are identified as a practical topic with high relevance. This topic is also interesting due to novelty [25], social inclusion [26] and in relation to the European energy transition plan [27]. The criteria for the case study are to be pragmatic, realistic and with access to data. A potential smart grid project has been identified in a resort city in Bulgaria. The problem is identified as follows:

Evaluation of the social impacts of a Smart Grid implementation in the resort city of Albena, Bulgaria using the SLCA methodology

As explained above, SLCA has the advantage of dealing with both global and local impacts of the examined system. Therefore, the goal is to apply the SLCA methodology, unpacking the generic and site-specific social impacts of the potential Smart grid implementation with the exploratory purpose of research. The case study criteria, such as data availability and relation to the energy field, are met, as explained in the case study description below. Moreover, a prior knowledge and data on the studied systems were available by the Strategies for Energy Autonomy and Sustained Operations of Albena, Bulgaria (SEASON-ALL) project[2] [52]. The potential smart grid is first described with its technological details, size and system integration. The methodological framework of SLCA, as stated in the UNEP guidelines, is then applied. The methodological choices and tools are based on the literature review. The Social impacts of the smart grid implementation are measured, compared and discussed.

The SLCA methodology is applied to measure the social impact after smart grid implementation in Albena on different stakeholders. The social impacts are understood as stated in the UNEP Guidelines: consequences of positive or negative pressures on social endpoints (well-being of stakeholders), weaved in the context of an activity in three dimensions – behaviours, socio-economic processes and capitals [14]. Based on the literature review the global risk analysis is performed using SHDB and SimaPro software and the local impact - by stakeholder analysis.

[2] The SEASON-ALL project report is provided as a separate attachment and can be found with the author or the supervisor of this graduation project.

5.1. Case Study Description

The resort city Albena is located 30 km north of Varna – the Sea capital of Bulgaria , by the Balata National Reserve and the slopes of Dobrudzha plateau far away from heavy industry activities, with coordinates [4]: 43°22'05.6"N 28°04'49.7"E; (43.368 N, 28.08 E). Albena JSCo is the largest hotel company in Bulgaria [53]. It is an integrated brand, incorporating hotel facilities, agriculture, medical centre, sport and cultural event organization, auxiliary services with a focus on sustainable growth [53]. The resort Albena, owned by Albena JSCo covers an area 140 ha with 3.5 km long and 150m wide beach. It is divided into lower and upper part. Within the boundaries of Albena, there are 34 hotels [54] built in different years with a different star ranking, including 6,800 rooms (2017) [53] and 18 congress halls with a capacity of over 4,400 seats. It is a predominantly summer resort, with one hotel operating during winter since 2017, with a total peak potential to accommodate around 20,000 people (including personnel). It is also one of the biggest sports complexes in South-East Europe offering over 42 sports. There are 7 football stadiums, 19 outdoor and 3 indoor tennis courts, over 25 pools, horse riding centre and more. Most facilities in the resort are owned by Albena Holding JSCo, including the middle voltage electric grid of 20KV, infrastructure, transport systems within the resort [52].

The Albena group consists of several companies operating in diverse industries under the same management. Albena resort is the main asset of the company and the uniting link in the group. There are 9 companies in Tourism and General aviation industry – Albena tour JSCo, Flamingo tours - Germany, Medical centre Medica Albena JSCo, Albena Avtotrans PLC, Intersky PLC and others. Besides, EcoAgro PLC is a company in the agriculture sector; Perpetum Mobile BG PLC is in the bio-energy industry with 1MW Biogas power plant, located 10 km from the resort [55].

Every year, Albena invests in new projects such as the renovation of old hotels, building new facilities, expanding attractions and improving infrastructures. Albena, in accordance with its commitment to sustainable development and climate conservation, is a participant in the INVADE project [56][56], under the Horizon2020 program. The resort has been rewarded with the blue flag for being an ecologically clean area. As an organization, they have expressed the willingness to become energy independent for its operations, as well as increasing its revenue stream through implementing year-long operations and marketing the green image of the resort.

The energy consumption of Albena is complex. Primarily the resort is consuming electricity; naphtha and diesel are also used for heating and in standby electricity generators. Propane-Butane mixture is usually used for cooking. Figure 3 shows monthly electricity consumption variation in the resort for the year 2017.

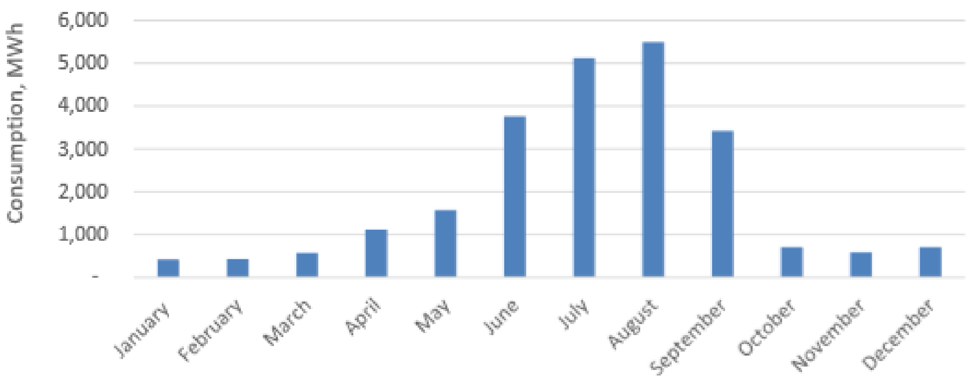

Figure 3. Monthly Electricity Consumption in 2017

Electricity usage in the resort has grown at an annual rate of 11.6% in 2016 to the value of 22,664 MWh compared to the corresponding value of 20,302 MWh in 2015. In 2017 the consumption got even higher due to initiation of winter operation of one hotel amounting to about

23,800 MWh. Clearly, as can be seen from Figure 3, July and August are the two peak months. The summer operation usually lasts from May to October following the tourist season. This results in a steep electricity rise, with regards to the Energy consumption of the preceding and following months. Indeed, energy consumption during the peak tourist season shows the peak of the electricity consumption is 5 500 MWh, which is much greater compared to the usage in the rest of the year.

Due to a smaller number of tourists in the winter season, the percentage share of consumption in restaurants is significantly lower in winter compared to summer months. Infrastructural operations in Albena are proportional to the number of hotels in operations and hence, to the number of tourists. Correspondingly, the distribution of electricity consumption percentage of hotels, relative to the overall electricity consumption remains constant throughout the year. Even though hotels and restaurants are the main consumers, street and park lights play a crucial role in winter consumption, consuming over 22% of Albena's energy. The energy losses through transmission remain constant, is based on the net energy consumed.

Albena JSCo currently pays for its electricity to two actors: the local DSO "Energo-Pro" and the energy retailer - "Energy Market". The tariff is usually negotiated once a year at a flat price per kWh, based on off-peak, peak and base load periods. The higher the consumption during peak hours - the higher the price of electricity is.

Table 3. Energy Market average prices for Albena

	Supply	**Excise**	**Social Obligation**	**Total**
Price [€/MWh]	41.4	1	18.8	61.2

Table 4. Energo-Pro average prices for Albena

	Transmission HV	**Access HV**	**Transmission MV**	**Access MV**	**Reactive Power Component**	**Power Factor <0,9**
Price [€/MWh]	3.9	0.6	5.8	4.1	55.0	5.5

Table 3 and Table 4 underline the importance of regulating the quality of the power demand. In fact, the penalties for reactive power are very high. Thus, it presents an interesting investigation of the impact of the addition of a capacitor bank to increase the power factor thereby decreasing the reactive power consumption. The constant increase in the electricity price for Albena, from 85.0 €/MWh in October 2016 to 99.4 €/MWh in October 2017, makes an investment in energy projects increasingly interesting.

For this reason, a Smart Grid implementation has been considered. A Smart Grid in Albena is possible due to the ownership of the grid, the favourable conditions of the local policies and regulations as well as the benefits that it would bring to the company. What is meant by an SG, in this case, is optimization of the current grid, using the same infrastructure but installing additional components such as Smart meters, SCADA monitoring system, Rooftop PV, Li-ion battery storage and EV charging station that would serve in favour of lowering the net electricity consumption as well as the peak hours of consumption. Those measures would significantly cut the electricity consumed by the grid replacing it with self-generated power. Moreover, Albena could decide to become an independent operator in the electricity grid and avoid the intermediate energy retailers (i.e. Energo-Pro and Energy Market).

From a technical point of view, a complete installation of SCADA system and battery storage are essential components necessary for this process, due to the need to forecast and control the load with an acceptable degree of freedom. Albena would, therefore, need to be able to forecast its energy demand for the day-ahead-market and control the load in case of anomalies. This process is currently done by the energy retailers in the balancing group that charge their customers for this service. Therefore, by 2035, as assessed in the SEASON-ALL project, with the installation of battery storage and other building management systems including SCADA, together with considerable on-site renewable energy generation, both in the form of heat and electricity and with additional measures such as energy efficiency reduction, also part of the smart grid strategy, Albena can indeed become an Independent Market Operator. This would further avoid intermediary costs and provide more advantages to Albena in a future, where, according to the "Clean Energy for All Europeans" package from EU, prosumers and flexibility actors would play an important role [57]. Finally, by 2035, with considerable battery storage and a good share of both predictable and fluctuating renewables in the form of Solar, Biogas and also use of heat energy generation, could lead to 84.6% reduction of electrical power consumption by the grid [52] and would provide Albena the opportunity to opt for flexible operations and completely take advantage of all the future improvements of the Bulgarian Energy Market.

However, when considering a simplified version, the two components considered for the smart grid implementation in Albena, for the short and medium term, are rooftop PV and Li-ion Battery storage[3]:

Rooftop Solar PV

Solar PV, by far, is the most suitable electricity generation technology at present, from solar energy[3]. The available rooftop area in Albena has been evaluated to be 8000 m^2. This would allow installation of around 4000 PV modules. Based on the detailed system design performed and the offer for polycrystalline solar PV panels received by the company, Table 5 represents the summary of the net Rooftop Solar PV generation potential in Albena [58].

Table 5. System Description of Rooftop Solar PV System in Albena

System capacity	2.4 MW
Initial yearly generation	2.85 GWh
PV panel size	320 W
Inverter Size	Above 80% of system size

Battery Storage

The battery storage for peak shaving alone provides an interesting business case for Albena even when additional services that battery storage could provide are excluded. The Li-ion battery storage with potential installed capacity of 600 kWh could allow performing peak shaving during the day, and thus during the whole year with greater impact. The technical details for the storage system are given in Table 6 with expected lifetime [59][52].

[3] The values for PV and Battery differ from the ones in the SESON-ALL. In SEASON-ALL project the results are based on reference values found in literature, while here real offers for Albena are used.

Table 6. Technical parameters for the battery storage system

Lifetime	15 years
System capacity	600 kWh

After the necessary assumptions and simplifications are made, it is possible to analyze the case study and evaluate the size of the system compared to the local perspective [52]. As the goal of the case study is to identify the social impact of a smart grid implementation in Albena, Bulgaria - it is important to know how much electricity will be saved from the National Grid.

In the national TSO - Energy System Operation (ESO) [29] website, it is shown that the Bulgarian electricity mix is 40% from Nuclear Power Plants (NPPs), 40% from Thermal Power Plans (TPPs mainly Coal and Gas) and 20% from Renewables (percentages vary throughout the day) [29]. The total energy autonomy that can be achieved with the total Smart grid implementation[4] is 84.6% [52]. With annual electricity consumption of Albena 24 GWh this would mean that the annual savings would amount to 20.3 GWh/year (Table 7).

Table 7. Comparison of the electricity bill in Albena with and without the Smart Grid [52]

	Without Smart Grid	With Smart Grid
mln EUR/year	2.5	0.4
GWh/year	24	3.7

If the savings are distributed equally to the sources of energy generation by the electricity mix, annually TPPs would generate 8.22 GWh less. However, for the purpose of this analysis, the assumption that only TPPs are affected by compensation of this load is used, also due to trends in the national regulations [60]. This means 20.3 GWh less electricity produced by TPPs annually. According to the International energy agency (IEA) Bulgaria is producing 49 228 GWh/year electricity. Assuming, 40% of that is from TPPs [29], this would mean 19 691 GWh/year from Coal and Gas power plants. Cutting 20.3 GWh/year would bring change in the total final electricity production of TPPs of about 0.1% (Table 8).

Table 8. Parameters of the full Smart Grid integration

CAPEX	17	mln EUR
Payback period	9	years
Savings	84.60 20.3 2.1	% GWh/year mln EUR/year
Total electricity consumption Bulgaria	49228	GWh/year
Electricty consumption from TPPs (40%)	19691	GWh/year
Electricity savings from TPPs	0.1	%

[4] The complete Smart grid in Albena is a complex multi-component system. However, this study has focused on battery and solar PV as the two most significant components for smart grid projects in general

5.2. Goal and Scope

The goal of the case study is to evaluate the social impacts of a Smart Grid implementation in the resort city of Albena, Bulgaria. The results could also be further integrated as a study material. The goal is to assess the positive and negative impacts of the Smart Grid and its components identifying the local and global social impacts.

The timeline for the project implementation is full implementation until 2035. The product to be studied is a Smart Grid with the main components – PV and Battery; and functions - Peak Shaving, Demand Side Management and Flexible Energy Operations, connected to the national grid. The implementation of such a system would lead to significant savings on the energy bill for the company, but also annually cut the big amount of energy produced by conventional generation techniques. The potential implementation of the technology would lead to job creation in the local level. The global data is collected using the generic social risks are assesses using the Social Hotspot Database (SHDB) and the Risk Mapping Tool integrated with the SimaPro software.

The steps that need to be taken when defining the functional unit include: description of the product, the relevant market segment, alternatives to the product, definition and quantification of the functional unit related to the properties of the product in the relevant market segment and determination of the reference flow for each system of the product. The properties of the product could be related to the product functions, technical quality, the image of the company, the costs or specific environmental or social properties [14].

As per the smart grid, it is part of the energy market segment. Its functions would be Peak Shaving, Demand Side Management and Flexible Energy Operations, as stated above and it would give better image and cost savings to the company. These functions would influence the stakeholders of the implementation project and would bring social impact on the local level. However, the research would give only qualitative results and a functional unit is not necessary for qualitative analysis. Therefore, no functional unit is proposed in the current research.

The studied system is a potential smart grid in a summer resort in Bulgaria as described above. The ideal system includes the smart grid with its entire components from cradle-to-grave. However, the modelled system focuses only on the main components, PV and Battery with the impacts on the electricity system. For this reason, the considered system boundaries are from component manufacture, installation and operation to impact on the electricity system considering electricity generation from raw material extraction and distribution to production and distribution. The considered components of the Smart grid are the Battery Storage and the PV panels as well as the installation and operation and the impact from electricity savings. As per the SLCA analysis, the modelled system aims to be kept as simple as possible, as shown in Figure 4.

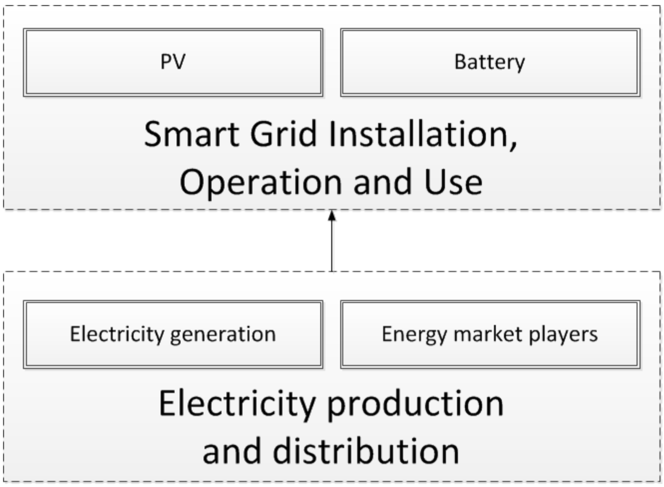

Figure 4. Modelled system

5.3. Inventory analysis

In this section, the data collection for prioritization, hotspot assessment, site-specific evaluation and impact assessment is performed. The actions undertaken are data collection on unit process activity variable, hotspots assessment, primary data, and data for characterization and refinement of system boundary. The main steps, detailed below, are generic analysis and site-specific analysis. After that, in Life Cycle Impact Assessment, the categories and indicators are chosen, weighed and scored.

The approach for data collection includes hotspot assessment, desktop screening and a limited number of on-site visits that include observations and interviews that lead to convenient prioritization in the social analysis. For the generic analysis first SimaPro software is used for hotspot identification, then, the Risk Mapping Tool from SHDB is used to uncover the sector-specific risks. For the site-specific data, an on-site study visit was performed where observations and interviews were conducted in order to identify the stakeholders and their involvement in the project. The wage rates in the country sector are overviewed by desktop research.

5.3.1. Generic analysis

Hotspots identification using SimaPro software

As per the Literature review, SimaPro software, where not only the social but also the economic results can be visualised, is chosen to define the most impacted sectors by the smart grid implementation project. The SimaPro software gives an overview of where the hotspots are and then the defined sectors are detailed with SHDB and the Risk Mapping Tool. The results from SimaPro as percentages are used also when weighing the numerical results.

The impacts on the Bulgarian electricity system are investigated in the software. The social issues of the energy sector in the country, found by SimaPro software, are uncovered in Figure 5, as well as the source of the materials used in the Bulgarian Electricity mix. It can be seen that the top 5 social risk in the energy sector in Bulgaria is by the Bulgarian Electricity sector (20%). After that, Gas manufacture and distribution in Uzbekistan and Ukrainian Coal sectors are most impacted by equal percentage (10%) followed by the Bulgarian Coal and Ukrainian Electricity sectors (5%). This figure represents the total global picture that the Bulgarian energy sector has in terms of social impacts.

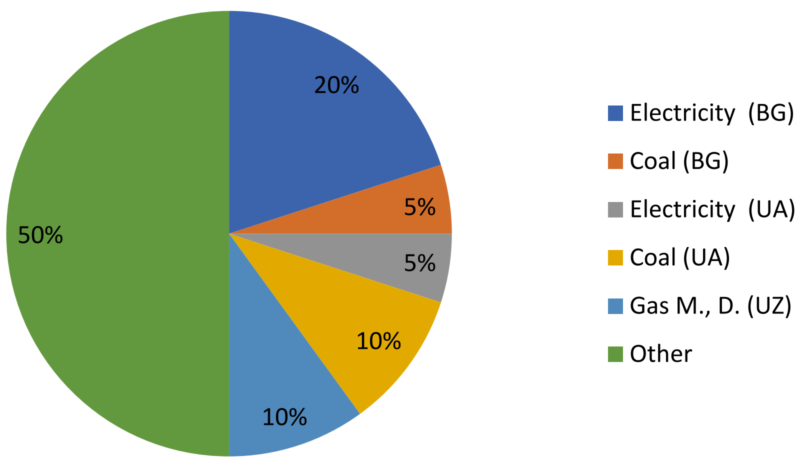

Figure 5. Bulgarian Energy Sector risk mapping pie chart (visualization from SimaPro software)

The reason behind the global affected sectors, is that Bulgaria imports electricity from Ukraine (about 4-5 billion kWh annually). Coal mining in Bulgaria is insufficient for the needs of the country, which makes about 3.5 million tons of coal imported annually mainly from Ukraine / 1.9 million tons of anthracite and 1.5 million tons of black [61].

The Sima Pro simulation result also showed that the key impact categories are Labour rights and decent work, Health and safety and Governance. Those are further assessed by the online SHDB and the RMT, in detail.

Risk Assessment using Social Hotspot Database

After the identification of the five impacted sectors by the Bulgarian Electricity - the same involved in the Smart grid are considered – in this case, for simplification, the PV from China and Battery from Germany. The corresponding sectors are China: Electronic equipment and Germany: Machinery and equipment. The impacted sectors are examined using the Risk Mapping Tool (RMT) by SHDB [18]. Hence, the hotspots within countries and sectors can be identified within social categories and related themes. The Social Hotspot Index (SHI), as part of the RMT, is then used to visualize the impact by category in the risk sectors. Table 9 shows the result of the Combined Social hotspot index (SHI) for the chosen categories. The Index of Uzbekistani Gas manufacture and distribution is the highest – 242.5, followed by Ukrainian Coal and Electricity sectors that have 190 and 185.5 indexes respectively. The combined SHI of Bulgarian Coal and Electricity sectors are the same – 129.

Table 9. Results of Social Hotspot Index for the impacted sectors by the Bulgarian power generation [18]

	Labour rights & Decent work	Human Rights	Health & Safety	Governance	Community Infrastructure	Total
Electricity BG	27	6	65	30	1	129
Gas M&D UZ	63.5	44	15	100	20	242.5
Coal UA	51	20.5	37.5	75	6	190
Electricity UA	46.5	20.5	37.5	75	6	185.5
Coal BG	27	6	65	30	1	129

A similar methodology was used to assess the global impact of the smart grid and more precisely by the PV and Battery as its main components for the present case study. The SHI is used to compare the German Machinery and equipment and the Chinese Electronic equipment sectors with Bulgarian Electricity, Ukrainian coal and Uzbekistani Gas and Manufacture sectors[5]. Since the SHI allows only 5 sectors at time, in order to draw a comparison, the ones that score the same are merged. The results, as presented in Table 10, show that the Social hotspot index of the corresponding sector in Germany is only 22 while for Bulgaria it is 129, Ukraine – 190, China – 227 and Uzbekistan – 242.5. Those results are used for weighing and scoring of the global risks.

[5] The SHI platform allows comparing only five sectors at a time, so since the Bulgarian Electricity and Coal sectors score the same - only Bulgarian Electricity is taken in the second comparison, same for the Ukrainian Coal and Electricity.

Table 10. Social Hotspot Index for 5 sectors impacted by the smart grid implementation.

	Labour rights & Decent work	Human Rights	Health & Safety	Governance	Community Infrastructure	Total
Machinery & equip. DE	7	0.5	12.5	1	1	**22**
Electricity BG	27	6	65	30	1	**129**
Coal UA	51	20.5	37.5	75	6	**190**
Electronic equip. CH	79	44	42.5	30	31.5	**227**
Gas Manuf. & Distrib. UZ	63.5	44	15	100	20	**242.5**

The Risk Mapping Tool also allows the evaluation of Average Risk Value (ARV) for every theme in the different categories; this is used in the scoring process below. The result for each country follows.

Table 11. Average risk values per category for Bulgarian Electricity and Coal Sectors.

Labour rights & decent work		**Health & safety**		**Human rights**		**Governance**	
AHV	Themes	AHV	Themes	AHV	Themes	AHV	Themes
1	Child labour	1.6	Occupational Toxics & Hazards	0.4	Gender equity	3.6	Corruption
0.3	Forced labour	5.25	Occupational Injuries & Deaths	0.7	High Conflict Zones	2.5	Legal system
1	Freedom of Association, Collective Bargaining, Right to Strike			1.65	Human Health - Communicable Diseases		
0.4	Labour Laws			1.5	Human Health - Non-Communicable Diseases		
3.4	Migrant workers			0	Indigenous Rights		
1	Poverty						
3	Unemployment						
10	Wage assessment						
0	Working time						

For the Bulgarian Electricity and Coal sectors, the impact is predominantly in the Health and safety category, where the theme Occupational Injuries & Deaths takes has the most impact with Average Risk Value (ARV) of 5.25 (Table 11). Then, the Governance sector, dominated by the corruption theme shows a score of 3.6. For Labour rights & decent work, Wage assessment is with ARV of 10 followed by Migrant Workers and Unemployment with AHV of 3.4 and 3 respectively. In the Human rights the hotspot is on the Health topics with AHV 1.5. The impact of Community infrastructure is minor so this category is neglected.

Ukraine Governance is the most impacted category in the Ukrainian Coal and Electricity sectors. It has ARV of 7 for Corruption and 7.5 for Legal system. For Labour rights & decent work Wage assessment is the hot topic with ARV of 10, Freedom of association, collective barging & right to strike - 8.3, Migrant Workers – 7.5, Forced labour – 5.3 and Child Labour – 2.8. Health and safety category has 100% impact of the Occupational Injuries & Deaths takes theme with ARV of 5. In the Human rights category - the hotspots in Ukrainian Electricity and Coal sectors are Human health with AHV - 3.5 and 2, Gender equity – 3.3, High conflict zones – 2 and Indigenous rights 2. The impacts in the Community infrastructure category are on Children out of school topic with AHV 1 (Table 12).

Table 12. Average risk values per category for Ukrainian Electricity and Coal Sectors

Labour rights & decent work		**Health & safety**		**Human rights**		**Governance**		**Community Infrastructure**	
AHV	Themes	AHV	Themes	AHV	Themes	AHV	Themes	AHV	Themes
2.8	Child labour	5.2	Occupational Toxics & Hazards	3.3	Gender equity	7	Corruption	0	Access to hospital beds
5.2	Forced labour			2	High Conflict Zones	7.5	Legal system	1	Children out of school
8.3	Freedom of Association, Collective Bargaining, Right to Strike			3.5	Human Health-Communicable Diseases			0.7	Access to improved sanitation
0.2	Labour Laws			2.1	Human Health-Non-Communicable Diseases				
7.5	Migrant workers			2	Indigenous Right				
1	Unemployment								
10	Wage								
1	Working time								

In the Uzbekistani Gas manufacture and distribution sector - governance is found to be the most impacted category by the combined SHI (100), with ARV of 7.75 for Corruption and 10 for the Legal system. The Labour rights & decent work category has AHV for Wage assessment of 10, Freedom of association, collective barging & right to strike - 10, Migrant Workers – 2.8, Forced labour – 7.5, Poverty - 10 and Labour laws – 4. In the Human rights category - the hotspots are Gender equity – 5.75, High conflict zones – 2.86 and Human health with AHV - 2. The impacts in the Community infrastructure category are on Children out of school topic with AHV 1. Health and safety category has 100% impact of the Occupational Injuries & Deathstakes theme with ARV of 1.6 (Table 13).

Table 13. Average risk values per category for Uzbekistani Gas Manufacture and distribution sector

Labour rights & decent work		**Health & safety**		**Human rights**		**Governance**		**Community Infrastructure**	
AHV	Themes	AHV	Themes	AHV	Themes	AHV	Themes	AHV	Themes
0	Child labour	1.6	Occupational Toxics & Hazards	5.9	Gender equity	7.75	Corruption	1	Access to hospital beds
7.5	Forced labour		Occupational Injuries & Deaths	2.9	High Conflict Zones	10	Legal system	0	Access to Improved Sanitation
10	Freedom of Association, Collective Bargaining, Right to Strike			1.9	Human Health-Communicable Diseases			1	Children out of school
4.2	Labour Laws			2.2	Human Health - Non-Communicable Diseases			2	Access to improved drinking water
2.8	Migrant workers			0	Indigenous Rights				
10	Poverty								
0	Unemployment								
10	Wage assessment								
1	Working time								

Table 14. Average risk values per category for Chinese Electronic equipment sector

Labour rights & decent work		**Health & safety**		**Human rights**		**Governance**		**Community Infrastructure**	
10.0	Child labour	8.4	Occupational Toxics & Hazards	6.6	Gender equity	1.4	Corruption	5	Access to hospital beds
5.2	Forced labour	1	Occupational Injuries & Deaths	8	High Conflict Zones	6	Legal system	3.7	Access to Improved Sanitation
8.3	Freedom of Association, Collective Bargaining, Right to Strike			4.8	Human Health-Communicable Diseases			0	Children out of school
2.4	Labour Laws			2.6	Human Health-Non-Communicable Diseases			0.7	Access to improved drinking water
3.0	Migrant workers			3	Indigenous Rights				
5.0	Poverty								
1.0	Unemployment								
7.5	Wage assessment								
10.0	Working time								
1	Working time								

The Chinese Electronic equipment sector has the most impact on the Labour rights & decent work with Working time and Child labour as major issues with AHV=10 (Table 14). In the Health and safety category, the Occupational Toxics & Hazards takes has the most impact with Average ARV of 8.6. Then, the Governance sector, dominated by the Legal system theme has AHV of 6. In the Human rights, the hotspot is on the High conflict zones with AHV 8. The impact of Community infrastructure is Access to hospital beds AHV 5 followed by Access to improved sanitation AHV 3.7.

For German Machinery and equipment sector – the SHI is very low (22). Only three categories are impacted by this sector. Unemployment seems to be the highest social risk for this sector with AHV 7.5. Migrant workers theme, from Labour rights and decent work, has AHV - 3.5 (Table 15).

Table 15. Average risk values per category for German Machinery and equipment sector

Labour rights & decent work		**Health & safety**		**Human rights**	
0	Child labour	2.4	Occupational Toxics & Hazards	0.15	Gender equity
0.2	Forced labour			0	High Conflict Zones
1	Freedom of Association, Collective Bargaining, Right to Strike			0.7	Human Health - Communicable Diseases
0.5	Labour Laws			0.8	Human Health - Non-Communicable Diseases
3.5	Migrant workers			0	Indigenous Rights
0	Poverty				
7.5	Unemployment				
0	Wage assessment				
1	Working time				
1	Working time				

After evaluation of the Social Hotspot Index and the Average Risk Values for the most impacted categories by the smart grid implementation project, Multiple Issue Data Tables for the categories have been created in the Risk Mapping Tool to find the risks indicators affected by the same sectors (Bulgarian Electricity, Bulgarian Coal, Uzbekistani Gas manufacture and distribution, Ukrainian Coal, Ukrainian Electricity, German Machinery and equipment and Chinese Electronic equipment). The risks represented the hotspot themes found by the SHI, mentioned above. The results are detailed in Annex A.

5.3.2. Site-specific analysis

The site-specific analysis includes a stakeholder analysis of the future smart grid implementation project. It aims to evaluate the social impacts of such system on local level, involving participants in the national electricity network and other impact categories.

Stakeholder Analysis

In order to answer the research question to evaluate the social impact of smart grid implementation project – the local affected groups need to be identified and categorized. For this reason, a stakeholder analysis is preformed. This is a tool to identify, prioritize and define the influence of different people or organizations that are impacted or have an impact on a project or system. The process includes the identification and impact assessment. Tools, such as the rainbow diagram - classification of stakeholders according to the degree that they affect or are being affected by a problem [32][30], and analytical categorization of interest and influence - identification of key stakeholders [30], that allow the visualization of relationships, interests and level of affection are then used to present the relations between stakeholders.

Identification

Stakeholders are the people/organizations that are actively involved or are positive/negative affected by the project`s execution, they can be internal or external [62]. A stakeholder analysis has been conducted using stakeholder identification and categorization strategies [30]. The applied tool is stakeholder analysis, using methods such as scoping interviews and focus groups [30].

As defined above, smart grid by the EU Commission is: "A smart grid is an electricity network that can cost efficiently integrate the behaviour and actions of all users connected to it — generators, consumers and those that do both — to ensure an economically efficient, sustainable power system with low losses and high levels of quality and security of supply and safety" [63]. Potential stakeholders could include the following: Competitors; National communities Employees; Professional associations; Government Prospective customers; Government regulatory agencies; Prospective employees; Industry trade groups; Public at large (Global community); Investors; Shareholders; Labour unions; Suppliers and Local communities [62]. For the current analysis, the results from SimaPro and the Risk Mapping tool have been used for the initial identification as well.

The actors in the supply chain of the components, the users and operators of the smarts grid, the actors in the energy market, the local community and the employees at different affected sectors have been considered. Face-to-face interviews with target groups, such as visitors (20 interviews) and employees (15 interviews with employees from different departments) of Albena resort have been performed. The form of the interview is open conversation, aiming to gain understanding of the interviewed individual position in regard to the implementation project after short explanation of the expected changes. Other interviews include Dimitar Stanev - Deputy Director "Business Development" in Albena and the Head of the division at Electricity System Operator in Bulgaria – Stefan Sulakov. In addition, follow-up phone calls were done whenever necessary. The organisations and affected groups by the Smart grid implementation in Albena have been classified into three stakeholder groups: Individuals and Community groups, Companies and Organizations and National Government Institutions are summarized in Figure 6. Each stakeholder is described below based on the interviews and the site visit.

Local community

The local community is identified as potentially affected by the project. The Smart Grid implementation would influence the local people as more job opportunities for local engineers and workers, as for now, most employees of Albena are from the local villages and cities. Moreover, as the stability in the local grid will increase that would lead to fewer blackouts. The possible negative impacts are that higher automation may actually lead to fewer jobs and the need for high qualified personnel may cause the need to hire from elsewhere or provide trainings.

Employees of Albena

According to the feasibility study, the employees of Albena will have to take care of operation and maintenance of the SG. The engineers would prepare schedules for electricity consumption as well that all other employees would have to consider and change their behaviour to achieve peak shaving and demand-side management.

Visitors of Albena

The visitors could also be involved and get befits from the peak shaving, as part of the demand side management strategy, if they would like to. As per the preformed interview with them - they are willing to pay more for more sustainable vacation so they will have an added value for their holiday. However, not all would be involved in the peak shaving strategy.

Albena JSCo

The biggest impact of the implementation of the smart grid is to Albena. They will have a lower price of electricity and less consumption so their electricity bill will be significantly lower. Moreover, their image of being a sustainable resort will bring them more visitors and they can promote themselves as a company that is concerned about the environment and sustainability. In addition, they will less become less dependent on the DSO and the energy retailers [55]. The SG will help Albena to balance their electrical load, minimize losses and go in the energy market as an independent player in order to avoid fees and taxes, minimize their electricity bill, gain savings, monitor and control the electrical load and be less dependent on other market players such as DSO/Retailers and be more autonomous.

DSO Energo-pro

The DSO and Albena have an argument regarding the ownership of the grid. The electric company complained that they had not been allowed to remove a fault on an underground cable line between the Fish-Fish and Zvezda power transformers, owned by ENERGO-PRO Grids, supplying part of the complex. From the holiday village, they claim that the company prevented them from entering the free energy market [64][65]. Albena would be getting more autonomous with the SG implementation so the DSO would have less influence and loose revenue from the big consumer that the resort is [66].

Transmission system operator (ESO)

In order to go as market player Albena needs permits and contracts with the Energy System Operator [29]. They will be responsible to set the scheduling and forecasting, requirements and feed-in tariff, as stated in an interview performed with Stefan Sulakov - Head of the division at Electricity System Operator in Bulgaria. Moreover, the lower electricity consumption (0.5 - 1%) could affect the scheduling of the generators and import-export of electricity.

Energy retailers

After Albena goes as an Independent energy market player - they will no longer need energy retailers, so the retailer would lose a client and they can even become a competitor. The current energy retailer for Albena is Energy Market [67], based on the current electricity bill.

Government/Municipality

New policies in regard to flexibility operation are needed by the Government. So the full integration of the strategy would rely on the new policies and regulation in this regard. Albena is located in the Municipality of Dobrich and so far they have good communication. For the SG implementation permissions from the municipality could be needed. So the municipal stakeholder may play a crucial role in the implementation. The Commission of energy and water regulation (CEWR) would have influenced by the new policies for flexible operation and smart grid [60].

Supplier PV and Battery

As per the offer provided, the supplier of PV, Batteries and other components would be "3K" , based on offer to Albena by the company [68]. They would provide and install the systems in Albena and get profit.

PV producer China

The solar polycrystalline photovoltaic modules are produced by Jinko Solar [69], in China. They would deliver 4000 PV modules to the supplier, based on the offers by 3K and the feasibility study.

Battery producer Germany

The manufacturer of the Battery Storage system is TESVOLT [70]. Their manufacturing facility is based in Germany. The company would sell a storage system with 600 kWh capacity, as per the offer by 3K.

Bulgarian Electricity and Coal sectors

According to the hotspot analysis, the Bulgarian electricity and coal sectors are identified to be influencing the smart grid implementation project. There is no evidence that due to Smart Grid there will be fewer jobs in the sector. However, this might be considered as potential negative social impact. Some power plants may need changes to their schedule and lower their generation hours due to the lower electricity consumption of the resort. Mostly affected would be the TPPs running on Coal and Gas.

Ukrainian Electricity and Coal sectors

The SHDB results also show that Ukrainian Electricity and Coal sectors are affected by the Bulgarian Electricity. Reduction of the energy consumption could affect the global coal and electricity suppliers/importers/workers in the sector in Ukraine.

Uzbekistani Gas manufacture and distribution sectors

Another impacted sector would be the Uzbekistani Gas manufacture and distribution sector, SHDB shows. The reduction of the energy consumption could affect the global gas suppliers/importers/workers in the sector in Uzbekistan.

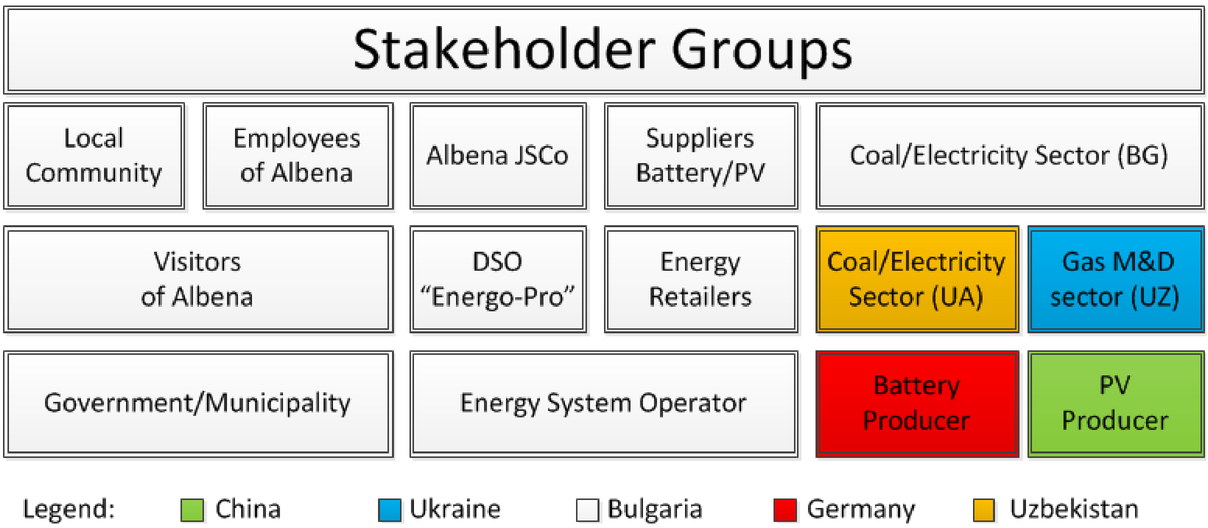

Figure 6. Stakeholders for Smart Grid implementation in Albena

5.4. Life Cycle Impact Assessment

The goal of this section is to select the impact categories, subcategories and characterization methods, relate the inventory data to them (classification) and determine/calculate the results for the subcategory indicators (characterization).

5.4.1. Selection of impact categories, subcategories and characterization models

The impact categories are divided into local impact and global impact. To analyze the local impacts for the stakeholder analysis – a rainbow diagram and influence/impact diagram are used to visualize the impact of different stakeholders. The global impact is measured by the SHDB and integrated into the stakeholder analysis. Then subcategories and indicators are chosen and presented as part of the classification step.

A rainbow diagram has been created to classify the stakeholders according to the degree they can affect or be affected by the Smart grid in Albena (Figure 7). The most affected and affecting stakeholder is Albena JSCo followed by the ESO, DSO and the municipality. The most affecting is the regulatory commission. Suppliers of the equipment are moderately affected and a little affecting in terms of cost. The most affected Stakeholders are the energy retailers. After them are the local people, employees and visitors of the resort. The least affected are the global stakeholders.

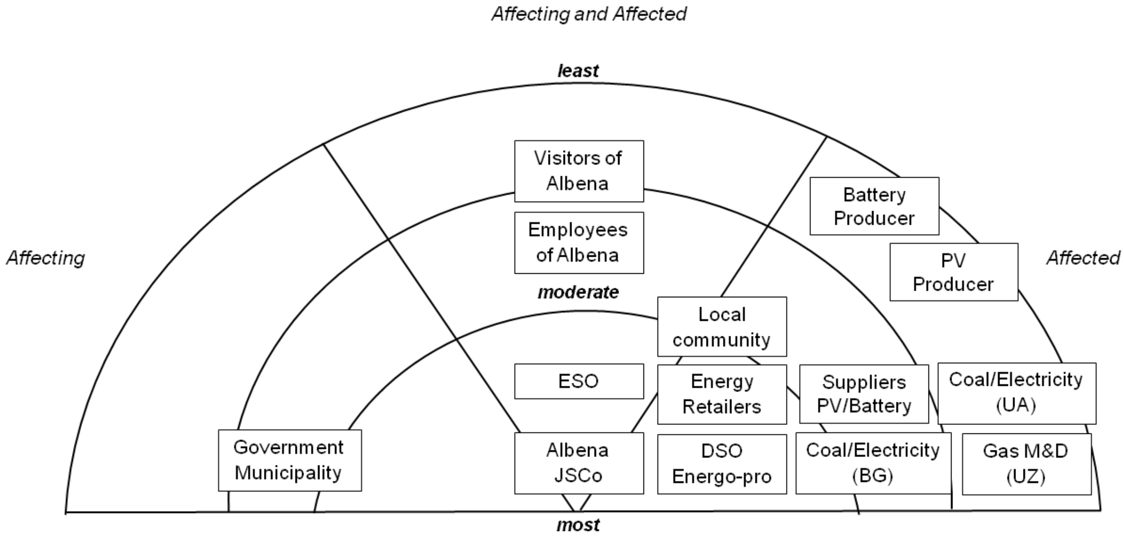

Figure 7. Rainbow diagram – affected and affecting stakeholders by the Smart Grid project

After identifying the stakeholders in the SG implementation project and classification by affection degree using the rainbow diagram, analytical categorization by influence and interest is performed to identify the key stakeholders in the project. Figure 8 shows the results of the analysis. The key stakeholders are in the top right corner, namely Albena, the DSO Energo-pro, the Energy system operator ESO and the Energy retailers – EnergyMarket [30], who have high interest and high influence. The other important stakeholders are the ones with either high influence or interest in the top left and the bottom right corners. Those include the municipality, the energy regulator, local community, component suppliers and employees of Albena. The stakeholders in the down left corner are also affected by the project but don't have much interest or influence.

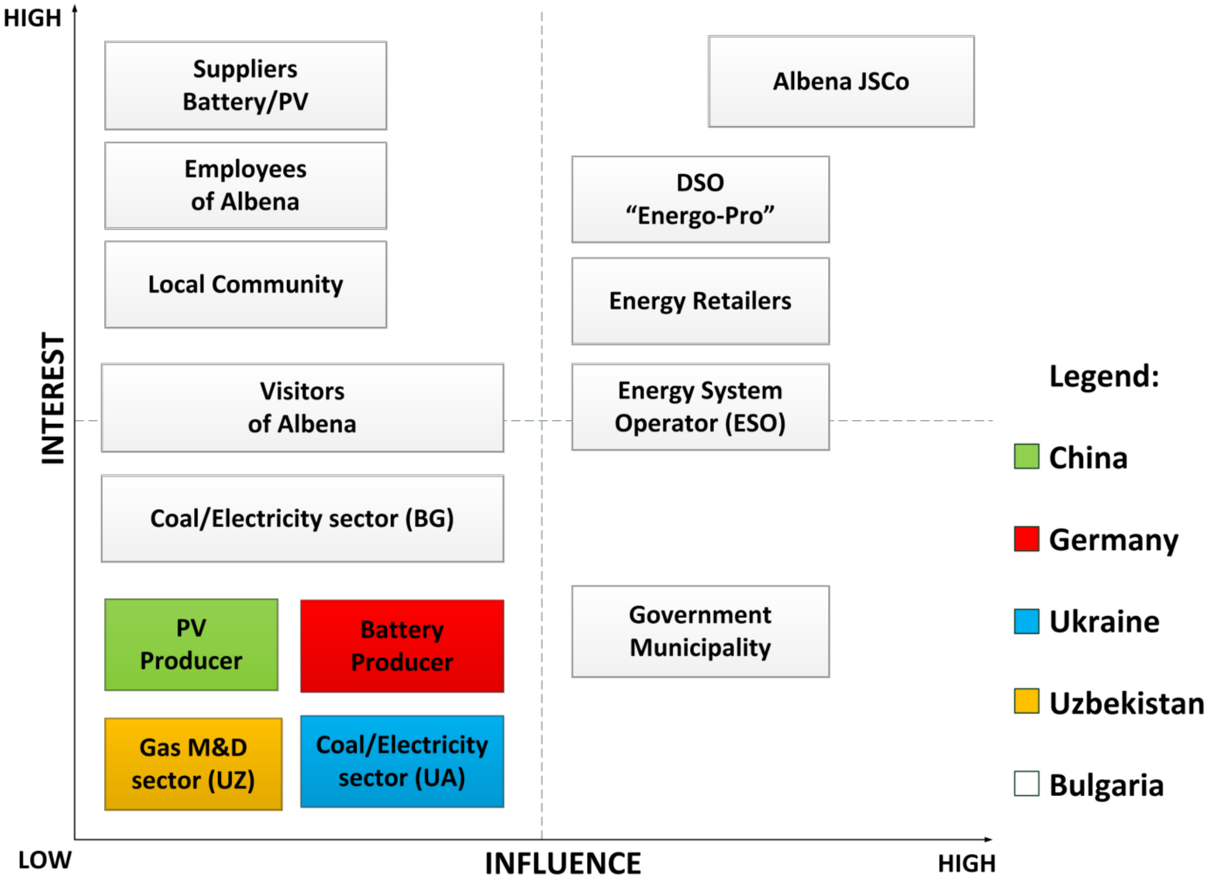

Figure 8. Interest-influence diagram

5.4.2. Classification and characterization

The data type to be collected is generic for global social impact; and site-specific for the local social impacts. The identified stakeholders in the preformed stakeholder analysis are used and integrated into the SLCA methodology and the stakeholder categories considered by UNEP Guidelines [14] as well as the impact categories. For the generic analysis, the global impact stakeholders are classified using the Average Risk Value results from the SHDB results. The site-specific assessment is fully conducted based on grey literature, interviews and on-site observations, considering the conducted rainbow and influence/impact diagrams. This analysis is fully qualitative. The local impact categories are assessed using adopted SLCA categories, sub-categories and indicators by the Methodological sheets. The evaluation is performed using a weighing criterion, as explained above. For the generic analysis, the SHI, ARV and SimaPro results (Generic analysis) are used for scoring and for the site-specific – the performed graphs (Site-specific analysis). Then the results are combined and compared.

Generic analysis

The generic analysis is performed using the ARV results from SHDB using only the themes with high and very high-risk scores as indicators as shown in Table 16. The indicators are numbered for simplification.

Table 16. Categories and indicators for the generic analysis.

Category	Indicator	Ind. Abr.
Health & safety	Occupational Toxics & Hazards	HS1
	Occupational Injuries & Deaths	HS2
Human rights	Gender equity	HR1
	Human Health - Non-Communicable Diseases	HR2
	Indigenous Rights	HR3
	High Conflict Zones	HR4
	Human Health - Communicable Diseases	HR5
Labour rights & decent work	Migrant workers	LR1
	Unemployment	LR2
	Wage assessment	LR3
	Working time	LR4
	Child labour	LR5
	Forced labour	LR6
	Freedom of Association, Collective Bargaining, Right to Strike	LR7
	Labour Laws	LR8
	Poverty	LR9
Governance	Corruption	G1
	Legal system	G2
Community	Access to improved drinking water	C1
	Access to hospital beds	C2
	Access to Improved Sanitation	C3

The indicators are automatically scored in the SHDB with average risk values that are between 10 and 0. The results are presented in Table 17 with the averages per sector and per category.

Table 17: Results of ARV from SHDB for the Indicators in the different sectors

Category	Ind. Abr.	Electricity (BG)	Coal (BG)	Coal (UA)	Electricity (UA)	Gas M&D (UZ)	PV (CH)	Battery (DE)
Health & safety	HS1	1.6	1.6	5.2	5.2	1.6	8.4	2.4
	HS2	5.3	5.3	0.0	0.0	0.0	1.0	0.0
Human rights	HR1	0.4	0.4	3.3	3.3	5.9	6.6	0.2
	HR2	1.5	1.5	2.1	2.1	2.2	2.6	0.8
	HR3	0.0	0.0	2.0	2.0	0.0	3.0	0.0
	HR4	0.7	0.7	2.0	2.0	2.9	8.0	0.0
	HR5	1.7	1.7	3.5	3.5	1.9	4.8	0.7
Labour rights & decent work	LR1	3.4	3.4	7.5	7.5	2.8	3.0	3.5
	LR2	3.0	3.0	1.0	1.0	0.0	1.0	7.5
	LR3	10.0	10.0	10.0	10.0	10.0	7.5	0.0
	LR4	0.0	0.0	1.0	1.0	1.0	10.0	1.0
	LR5	1.0	1.0	2.8	2.8	0.0	10.0	0.0
	LR6	0.3	0.3	5.2	5.2	7.5	5.2	0.2
	LR7	1.0	1.0	8.3	8.3	10.0	8.3	1.0
	LR8	0.4	0.4	0.2	0.2	4.2	2.4	0.5
	LR9	1.0	1.0	0.0	0.0	10.0	5.0	0.0
Governance	G1	3.6	3.6	7.0	7.0	7.8	1.4	0.0
	G2	2.5	2.5	7.5	7.5	10.0	6.0	0.0
Community	C1	0.0	0.0	1.0	1.0	2.0	0.1	0.0
	C2	0.0	0.0	0.0	0.0	1.0	5.0	0.0
	C3	0.0	0.0	0.7	0.7	1.0	3.7	0.0
Average		**1.78**	**1.78**	**3.35**	**3.35**	**3.89**	**4.90**	**0.85**

Site-specific analysis

For the Site-specific analysis, a weighing criterion is chosen based on the generic analysis. The indicators are scored in the range between 0 and 10 as the average risk values from SHDB and due to the qualitative nature of the analysis approximate values are given with the low to very high-risk meaning, as also in SHDB, see Table 18. The scoring system is chosen for comparison reasons based on the generic results. The used indicators are adopted from the methodological sheets when applicable to the given stakeholder categories, where only the relevant indicators are selected. Abbreviations for the same are used for simplification reasons, see Table 19 for Stakeholder categories, sub-categories and indicators.

Table 18. Scoring system for the site-specific analysis

Risk	Score
very high	8
high	6
medium	4
low	2

Table 19. Stakeholder categories, sub-categories and indicators for the site-specific analysis.

Stakeholder Category	Sub-categories	Indicators	Ind. Abr.
Worker	Freedom of Association and Collective Bargaining;	Workers are free to join unions of their choosing	W1
	Health and Safety	Health conditions	W2
		Safety level	W3
	Working Hours	Decent working hours	W4
	Child labour	Absence of working children under the legal age	W5
	Fair Salary	Satisfaction of workers by their salary	W6
Consumer	Feedback Mechanism	Level of consumer satisfaction	C1
	Transparency	Level of sustainability practices/reports	C2
		Willingness to pay for sustainability	C3
Local community	Delocalization and Migration	Level of organizational policies/procedures for integrating migrant workers	LC1
	Community engagement	Level of engagement	LC2
	Respect of indigenous rights	Issues related to human rights	LC3
	Local employment	Workforce hired locally	LC4
		Level of local supply	LC5
	Access to immaterial resources	Presence of community education initiatives	LC6
	Access to material resources	Development of project-related infrastructure with mutual community access and benefit	LC7
		Presence of environmental management system/program	LC8
	Secure living conditions	Security issues	LC9
Society	Public commitments to sustainability issues	Engagement regarding sustainability	S1
	Contribution to economic development	Contribution to economic growth	S2
	Corruption	Level of corruption	S3
	Technology development	Level of technology development	S4
		Involvement in technology development program/projects	S5
Value chain actors	Fair competition	Anti-competitive behaviour and violations of anti-trust and monopoly	VC1
	Supplier relationships	Level of acceptance regarding the implementation project	VC2
	Promoting social responsibility	Presence of initiative that promotes social responsibility along the supply chain	VC3
		Integration of ethical, social and environmental policy	VC4

The scoring is performed based mainly on site-visit observations and interviews. The results are shown in Table 20. For every stakeholder, only the relevant indicators and those with sufficient evidence are considered. Most of the conclusions are made based on conversations with the employees and visitors of the resort. They could be highly influenced by the local specific situation and there is uncertainty in the accuracy of the perception. The performed diagrams in Site-specific analysis section are used for the exact scoring (detailed in Annex B).

Table 20. Site-specific scoring and average risk results

Ind. Abr.	Employees Albena	Visitors Albena	Albena JSCo	Local community	Government/ Municipality	Supplier	TSO	DSO	Retailer
W1	2	-	2	4	-	-	-	-	-
W2	2	2	2	4	-	-	-	-	-
W3	2	2	2	4	-	-	-	-	-
W4	2	-	2	4	-	-	-	-	-
W5	2	-	2	4	-	-	-	-	-
W6	2	-	2	6	-	-	-	-	-
C1	-	4	2	6	-	-	-	-	-
C2	2	-	2	4	4	-	-	-	-
C3	4	6	4	8	6	-	-	-	-
LC1	2	-	2	6	4	-	-	-	-
LC2	4	4	2	4	4	-	-	-	-
LC3	4	2	4	6	6	-	-	-	-
LC4	2	-	2	4	2	-	-	-	-
LC5	2	-	2	4	-	-	-	-	-
LC6	-	-	2	6	6	-	-	-	-
LC7	-	-	2	4	6	-	-	-	-
LC8	-	4	2	6	4	-	-	-	-
LC9	4	2	2	6	4	-	-	-	-
S1	2	6	2	8	4	4	4	6	6
S2	4	4	2	4	4	4	4	4	4
S3	4	2	2	6	6	4	6	6	4
S4	-	-	2	4	4	2	6	8	4
S5	-	-	2	4	4	4	4	4	4
VC1	-	-	4	2	4	2	6	8	6
VC2	2	2	2	4	4	2	6	8	6
VC3	-	-	2	6	6	4	4	4	4
VC4	-	-	2	6	6	4	4	4	4
AV.	**2.67**	**3.33**	**2.22**	**4.96**	**4.63**	**3.33**	**4.89**	**5.78**	**4.67**

5.4.3. Social impact LCA

The scores per category are presented in Figure 9. They show that the highest social risk in the implementation project is with the local DSO, followed by the Local community, national TSO, the PV sector in China, the Energy retailer and the Local Government (Municipality). However, these results, as presented, are directly compared without weighing, which would further change the scores of local versus global impact, as explained in the Methodology chapter.

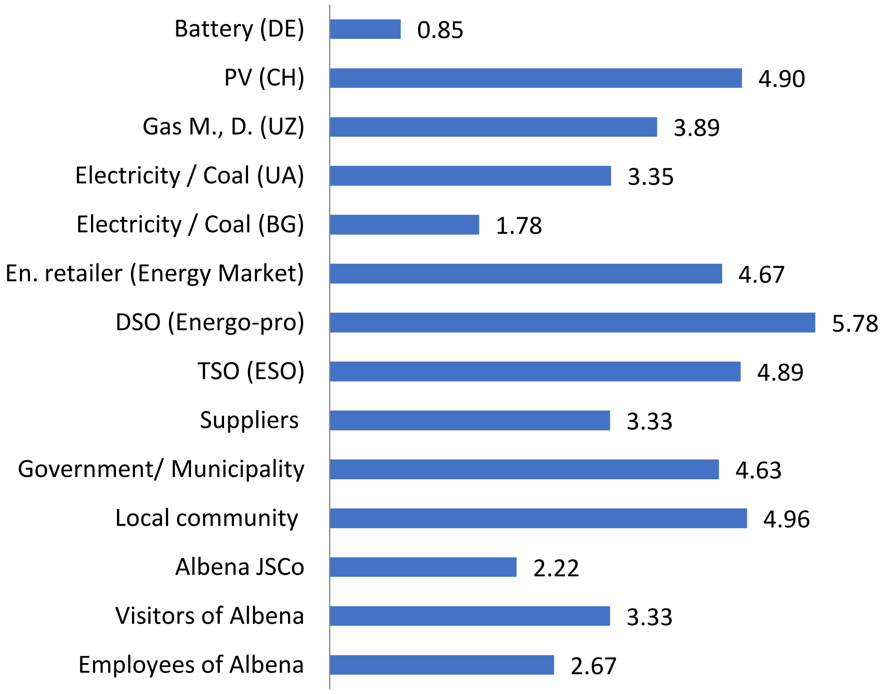

Figure 9. Overall scores per stakeholder category.

Weighing

The impact of/to the different stakeholders needs to be weighed for the smart grid. For this reason – the performed stakeholder analysis, the nature of the stakeholder (local or global) and the time-frame are considered. A coefficient in percentage for each stakeholder is given from 0 to 100, as shown in Table 21 (detailed in Annex B).

Table 21. Weighing coefficients for project stakeholders

Employees of Albena	Visitors of Albena	Albena JSCo	Local community	Government Municipality	Supplier	TSO	DSO	Energy retailer
0.5	0.3	1	0.5	0.3	0.5	0.8	0.8	0.7

	Electricity (BG)	Coal (BG)	Electricity (UA)	Coal (UA)	Gas M., D. (UZ)	PV (CH)	Battery (DE)
SimaPro	0.2	0.05	0.05	0.1	0.1	1	1
Stakeholder analysis	0.2	0.2	0.1	0.1	0.1	0.1	0.1
Comb.	0.04	0.01	0.005	0.01	0.01	0.1	0.1

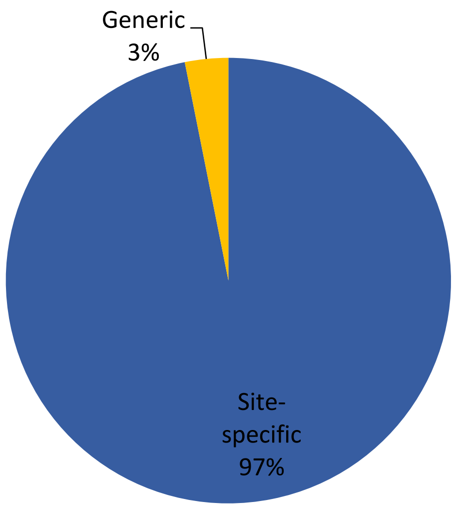

Figure 10. Generic vs. Site-specific social impact risk analysis result

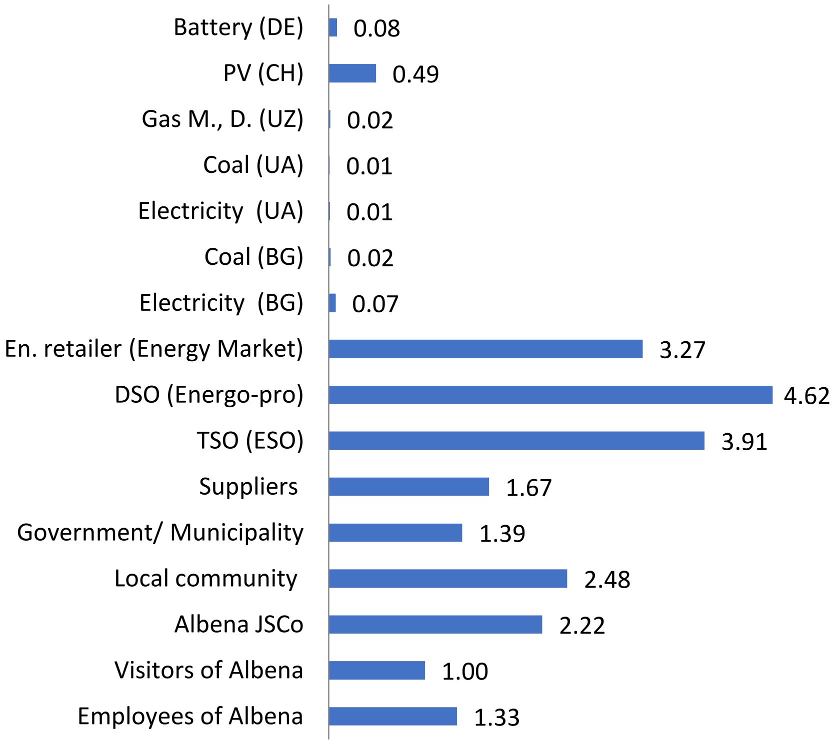

Figure 11. Visualisation of social risks related to the different stakeholders analysis results

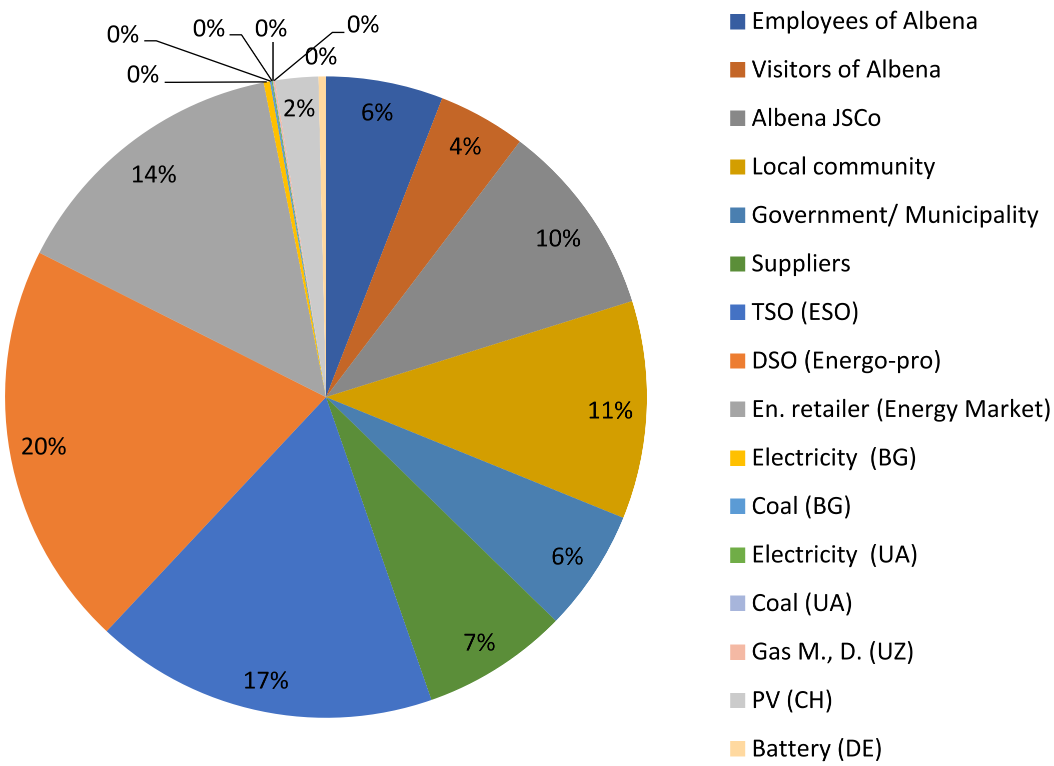

Figure 12. Combined result of social risk related to the smart grid implementation project

5.4.4. Case study Interpretation

Based on the results of the case study analysis, presented in Social impact LCA, the following statements are conducted:

1. The social risks related to the project implementation are 97% site-specific and 3% generic (*Figure 10*).
2. The highest social risks are on local level, namely the DSO Energo-pro, followed by the TSO ESO and the Energy retailer Energy Market, which together are over 50% of the overall social risk related to the implementation project (*Figure 13*).
3. The highest global risk is related to the PV panels from China (*Figure 11*).

Following the scoring system used throughout the local and combined analysis, Energo-pro, ESO and Energy market are scoring approximately 4, meaning medium risk (Table 18). All other stakeholders score with low to zero risk. This means that the smart grid implementation project in Albena, Bulgaria is not related to any high or very high social risks. However, based on the research the project may face problems with the energy market players on national level mainly. This would mean that such smart grid projects in the country may have the same risks for the market implementation.

Regarding the global stakeholders, it can be noted that the global social impact risk of the components from China is much higher than the one in Germany. This means that when there is possibility to choose the components – it would be better to choose such components that are related to lower social risks. In the studied example, this would mean that the PV panels could be supplied from another country with lower social risks in that sector, e.g. Germany. This would also help to improve the CSR of the company. However, the socio-economic criteria, as well as the transportation social risks, have not been included in the analysis, so the results may vary.

The risks related to the Bulgarian Electricity sector include five sectors that are affected – including the Electricity and Coal sectors in Bulgaria, Ukraine and Gas Manufacture, Distribution in Uzbekistan. Due to the fact that the annual electricity savings would be minor (less than 1%), the effect on the sectors, especially Coal in Ukraine and Gas Manufacture, Distribution in Uzbekistan would also be minor, if any. Nevertheless, if more such smart grid projects would be implemented in the country the total electricity savings would be also bigger and so the impact of the social risk would also grow, especially for the national sectors. The question: *What will happen to the coal/gas sectors in Uzbekistan and Ukraine?* , arises. In short term, there is a low probability that those sectors would be affected by such projects in Bulgaria. However, in the long run, following the European trends in the energy transition plan, more such projects would appear not only on Bulgarian national level but also on European level. Based on the discussions in the Clean Energy for All Europeans package and the EIA energy forecast, gas would still be a part of the primary energy supply for Europe, while coal would be banned, according to the roadmap for decarbonisation of the electricity market. This means that more interest and investments in such smart grid projects will arise in the near future and that makes the field attractive for new businesses.

This current case study could be extended considering the socio-economic criteria, full system with all integrated components and life-cycle stages, deeper local analysis with more quantitative data, for more accurate results.

6. Conclusions

Throughout the project the following assumptions and limitations have been considered:

- For the case study analysis, the results of the SEASON-ALL project for smart grid implementation have been considered;
- The annual electricity savings are assumed to be compensated only by conventional TPPs (coal, gas and oil);
- Transportation was not included in the analysis;
- Final disposal has not been considered in the analysis, due to system complexity;
- Not all identified stakeholders and components are included, for simplification reasons;
- Due to the big amount of literature, only the found to be most relevant articled are studied in-depth;
- The SEASON-ALL project proposes many different technologies, however, only battery and PV are assessed in this current work due to relevance for smart grid projects and simplification reasons.
- The performed analysis is fully qualitative. Due to time and resource limitations, the quantitative socio-economic analysis was not conducted.

The current works focuses on the following research question:

How can SLCA be applied to evaluate the local and global impacts by energy systems?

To answer that question, the research was divided into three sub-questions:

1. ***What is SLCA?***
2. ***How social impacts are assessed in the energy field?***
3. ***How to capture both the local and global social impacts in the energy field using the SLCA methodology?***

The work ingrates a literature review and a case study as strategy to answer the questions. The major findings from the literature review show that more case studies would be needed to create a methodology that evaluates the social risk impacts using the SLCA methodology in the energy field. Further development of the SLCA guidelines is also necessary with more concrete steps to follow, to be able to conduct more identical and comparable studies. Better classification on qualitative and quantitative data and indicators must be stated with access to concrete datasets. This would bring high value in the SLCA research field. The local and global perspectives in the different case studies would differ; however, better guidelines are necessary on the local level assessment. It is not clearly stated how the stakeholders should be analyzed and which methods shall be applied to classify and categorize them. Especially, the weighing should be specified in this aspect.

The tools for risk assessment should also be further improved, for example to compare different sectors in the SHDB Risk Mapping Tool only 5 sectors can be compared at a time. Also, the data from SHDB cannot be extracted in table format, which limits the analysis options to the ones available in the tool itself. Moreover, the indicator results have different values that sometimes are incomparable; this creates difficulties in the evaluation process. Furthermore, other tools, such as PSILCA, were not applied so it cannot be stated that such issues are not solved in different databases. Further on, other tools could be applied to compare results of the same case study.

The SLCA methodology has been previously applied in the energy field, as the literature review shows. The value that it brings is assessment of not only the local environmental and social impacts but can also give an idea of the social risks that projects or systems bring on global scale with a life cycle perspective. However, its application is quite complex and further cases should be performed in order to identify clear steps to achieve that goal.

The SLCA is analytical tool that evaluates the social impacts or risks in a life-cycle perspective on local and global scale. It needs further development for easier assessment. Its application in the energy field so far is quite limited. It could be used for decision making in the energy sector for future projects, as the examined case study. This current work had a goal to unpack the application of SLCA in the energy with a case study analysis. The choice of a research case study showed that a researcher using the SLCA methodology is facing a lot of challenges. The assessment is based on many decisions. That can be positive, due to freedom while performing the analysis, but also negative because creates uncertainty for the use of the method and the final results, that could significantly vary, based on the author choices.

The SLCA methodology can play a significant role in the sustainability assessment of energy projects. It is a tool that can be applied to assess the local and global impacts of energy projects. That could lead to more sustainable energy transition that allow for future that people and communities live happier and consume less.

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Annex A

Annex A presents the multiple issue data tables by the SHDB analysis. Due to the same risks are integrated in different sectors of the same country, two sectors in the same country are presented in one table. Only High (in orange) and Very high (in red) risk indicators by category are considered in this section. In Table 22, the results of the Bulgarian Electricity and Coal sectors show that the impacts are related with risks of injuries and noise, corruption, low wages, unemployment, unfair conditions for migrants and inadequate labour laws. Community category is excluded due to low-risk impacts.

Table 22. Indicators with high and very high risk in four categories for the Bulgarian Electricity and Coal sectors

No	Category			
	Labour rights & decent work	**Health & safety**	**Human rights**	**Governance**
1	Risk of Sector Average Wage being lower than Country's Non-poverty Guideline	Risk of fatal injury by sector	Risk of Measles	Risk that corruption is increasing in a country over the last 3 years
2	Risk that migrant workers are treated unfairly (qualitative)	Risk of non-fatal injuries by sector	Risk of Death from Cardiovascular diseases	Characterization of Cingranelli-Richards Human Rights Dataset - Independent Judiciary
3	Risk of Sector Average Wage being lower than Country's Minimum Wage	Risk of workplace noise exposure to females-indicator1	Risk of Rubella	Overall Risk of Corruption
4	Risk that a country does not pay immigrants enough for remittances	Risk of workplace noise exposure to females-indicator2	Risk of Mumps	
5	Risk that a country has not ratified international conventions or set up policies for immigrants	Overall Risk of workplace noise exposure, both genders	Risk of Death from Cerebrovascular disease	
6	Risk that a country's remittances from its emigrants is low		Risk of Death from Malignant neoplasms	
7	Risk of Unemployment in Country			
8	Risk that Country does not provide adequate labour laws by Sector			

Table 23 shows the results of the Ukrainian Electricity and Coal sectors. The major impacts are related to risks of different diseases, different government issues, low wages, forced and child labour, lack of freedom and many health and safety issues. Community category is excluded due to low risk impacts.

Table 23. Indicators with high and very high risk in four categories for the Ukrainian Electricity and Coal sectors

No	Category			
	Labour rights & decent work	**Health & safety**	**Human rights**	**Governance**
1	Risk of Sector Average Wage being lower than Country's Non-poverty Guideline	Overall Risk of workplace noise exposure, both genders	Risk of Death from Cardiovascular diseases	Characterization of Global Integrity Index
2	Risk that a country has not ratified international conventions or set up policies for immigrants	Overall Risk of death by exposure to carcinogens in occupation	Risk of Rubella	Characterization of Cingranelli-Richards Human Rights Dataset - Independent Judiciary
3	Risk that a country lacks or does not enforce Collective Bargaining rights	Overall Risk of loss of life years by exposure to carcinogens in occupation	Risk of Pertussis	Characterization of Bertelsmann Transformation Index - Rule of Law
4	Risk of Sector Average Wage being lower than Country's Minimum Wage	Risk of death by lung cancer due to occupation	Risk of HIV	Overall Risk of Corruption
5	Risk that migrant workers are treated unfairly (qualitative)	Risk of death by mesothelioma due to occupation	Risk of Death from Cerebrovascular disease	Risk that a country ranks poorly on the World Bank Worldwide Governance Indicator's Corruption Index
6	Risk that a country lacks or does not enforce the Right to Strike	Risk of loss of life years by airborne particulates in occupation	Risk of Death from Malignant neoplasms	Characterization of World Bank Worldwide Governance Indicator - Rule of Law
7	Risk that a country lacks or does not enforce Freedom of Association rights	Risk of loss of life years by asbestosis due to airborne particulates in occupation	Risk that a country does not provide laws to protect indigenous	Characterization of World Justice Project – Rule of Law Index
8	Risk of Forced Labour by Sector	Risk of loss of life years by chronic obstructive pulmonary disease due to airborne particulates in occupation	Risk of Tuberculosis	Overall Risk of fragility in the legal system
9	Risk of Child Labour in sector, Total (qualitative)	Risk of loss of life years by lung cancer due to occupation	Risk of Mumps	Risk that a country ranks poorly for corruption perception
10		Risk of loss of life years by mesothelioma due to occupation	Risk of Mortality from Injury	Risk that corruption is increasing in a country over the last 3 years
11		Risk of loss of life years by silicosis due to airborne particulates in occupation	Risk of Mortality from Non-communicable Diseases	Risk that corruption is a hinder to doing business in a country
12			Risk of Diphtheria	
13			Risk of Tetanus	

Table 24 presents the results of the Uzbekistani Gas manufacture and distribution sector. The results show that the main risks in that sector are related to poor governance, corruption, low wages, poverty, health and safety risks and gender inequality.

Table 24. Indicators with high and very high risk in five categories for the Uzbekistani Gas manufacture and distribution sector

No	Category				
	Labour rights & decent work	**Health & safety**	**Human rights**	**Governance**	**Community Infrastructure**
1	Risk of Sector Average Wage being lower than Country's Non-poverty Guideline	Overall Risk of workplace noise exposure, both genders	Risk of Death from Cerebrovascular disease	Risk that a country ranks poorly on the World Bank Worldwide Governance Indicator's Corruption Index	Risk that corruption is a hinder to doing business in a country
2	Risk of Forced Labour by Sector		Risk of Mumps	Overall Risk of fragility in the legal system	
3	Risk that a country lacks or does not enforce Collective Bargaining rights		Risk of Death from Cardiovascular diseases	Characterization of Cingranelli-Richards Human Rights Dataset - Independent Judiciary	
4	Risk of Sector Average Wage being lower than Country's Minimum Wage		Risk of Measles	Characterization of Bertelsmann Transformation Index - Rule of Law	
5	Risk that a country lacks or does not enforce Freedom of Association rights		Risk of Mortality from Communicable Diseases	Characterization of World Bank Worldwide Governance Indicator - Rule of Law	
6	Risk that a country lacks or does not enforce the Right to Strike		Risk of Mortality from Non-communicable Diseases	Risk that a country ranks poorly for corruption perception	
7	Risk of Wages being under $2 per day		Risk of Tuberculosis	Overall Risk of Corruption	
8	Risk that Country does not provide adequate labour laws by Sector		Risk of Death from Digestive diseases		
			Overall Risk of Gender Inequality in country		
			Overall Risk for High Conflict		

The results for the Chinese Electronic equipment sector are presented in Table 25.

Table 25. Indicators with high and very high risk in five categories for the Chinese Electronic equipment sector

No	Category				
	Labour rights & decent work	**Health & safety**	**Human rights**	**Governance**	**Community Infrastructure**
1	Risk that a country has not ratified international conventions or set up policies for immigrants-indicator1, 2, 3 and 4	Overall Risk of workplace noise exposure, both genders	Characterization of Cingranelli-Richards Human Rights Dataset-indicator1-3	Characterization of Bertelsmann Transformation Index - Rule of Law	Risk that there are too few hospital beds to support population
2	Risk of Forced Labour by Sector	Overall Risk of death by exposure to carcinogens in occupation	Characterization of Social Institutions and Gender Index	Risk that a country ranks poorly on the World Bank Worldwide Governance Indicator's Corruption Index	Risk of no access to an Improved source of Sanitation-total
3	Risk that a country lacks or does not enforce Collective Bargaining rights	Overall Risk of loss of life years by exposure to carcinogens in occupation	Characterization of World Economic Forum's Global Gender Gap Index	Characterization of Cingranelli-Richards Human Rights Dataset - Independent Judiciary	Risk of no access to an Improved source of Sanitation-urban
4	Risk that migrant workers are treated unfairly (qualitative)	Risk of death by lung cancer due to occupation	Overall Risk of Gender Inequality in country	Characterization of Global Integrity Index	
5	Risk that a country lacks or does not enforce Freedom of Association rights	Risk of death by mesothelioma due to occupation	Characterization of Heidelberg Barometer-indicator1-3	Characterization of World Bank Worldwide Governance Indicator - Rule of Law	
6	Risk of Wages being under $2 per day	Risk of loss of life years by airborne particulates in occupation	Characterization of People Under Threat Score	Overall Risk of fragility in the legal system	
7	Risk that a country lacks or does not enforce the Right to Strike	Risk of loss of life years by asbestosis due to airborne particulates in occupation	Characterization of Refugees		
8	Risk of Sector Average Wage being lower than Country's Minimum Wage	Risk of loss of life years by leukemia due to occupation	Overall Risk for High Conflict		
9	Risk of Child Labor in sector Male, Female Total (qualitative)	Risk of loss of life years by lung cancer due to occupation	Risk that a country does not provide laws to protect indigenous		

No	Labour rights & decent work	Health & safety	Human rights	Governance	Community Infrastructure
10	Characterization of U.S. Department of Labour's Trafficking in Person's Forced Labour Tiers	Risk of loss of life years by mesothelioma due to occupation	Risk of Japanese encephalitis		
11	Risk of Forced Labour in Country (qualitative)	Risk of loss of life years by silicosis due to airborne particulates in occupation	Risk of Death from Cerebrovascular disease		
12	Risk that Country has not ratified ILO conventions	Risk of death by leukemia due to occupation	Risk of Measles		
13	Characterization of the number of emigrants	Risk of loss of life years by asthma due to airborne particulates in occupation	Risk that Population may be affected by natural disasters		
14	Risk of Sector Average Wage being lower than Country's Non-poverty Guideline	Risk of loss of life years by chronic obstructive pulmonary disease due to airborne particulates in occupation	Risk of Pertussis		
15	Risk of excessive working time by sector	Risk of workplace noise exposure to males/females-indicator1&2	Risk of Rubella		
16			Risk of Leprosy		
17			Risk of Cholera		
18			Risk of Respiratory diseases		
19			Risk of Tuberculosis		
20			Risk of Mumps		
21			Risk of Poliomyelitis		
22			Characterization of Indigenous Population		
23			Risk of Death from Malignant neoplasms		

The evaluated results for the German Machinery and electronic equipment are shown in Table 26

Table 26: Indicators with high and very high risk in five categories for the German Machinery and Electronic equipment sector

No	Category		
	Labour rights & decent work	**Health & safety**	**Human rights**
1	Characterization of the number of immigrants	Risk of loss of life years by asthma due to airborne particulates in occupation	Risk of Diphtheria
2	Risk that a country has not ratified international conventions or set up policies for immigrants-indicator1, 2, 3 and 4	Overall Risk of death by exposure to carcinogens in occupation	Risk of Measles
3	Risk of unemployment by sector	Overall Risk of loss of life years by exposure to carcinogens in occupation	Risk of Death from Malignant neoplasms
4	Risk of unemployment in country	Risk of death by lung cancer due to occupation	Risk of Obesity (BMI = 30 kg/m²), Aged 15+,Females
5	Characterization of population that are immigrants	Risk of loss of life years by chronic obstructive pulmonary disease due to airborne particulates in occupation	
6	Characterization of the number of emigrants	Risk of loss of life years by lung cancer due to occupation	
7		Risk of loss of life years by mesothelioma due to occupation	
8		Risk of death by leukaemia due to occupation	
		Risk of loss of life years by leukaemia due to occupation	

Annex B

The scoring system for the site-specific analysis is based on the results of the Inventory analysis. Figure 13 and Figure 14 express the findings of the Site-specific analysis in percentages. The combination of both give a numerical result used for scoring in the Case study Interpretation section.

Albena JSCo is considered as 100% due to the direct impact to and by the company to the project. This is used as a reference point. The local stakeholders are weighed based on the interest/impact diagram (Figure 13), where the top right corner is 100% and the bottom left – 0% and the rainbow diagram (Figure 14) where most affected gets 100% and least 0%.

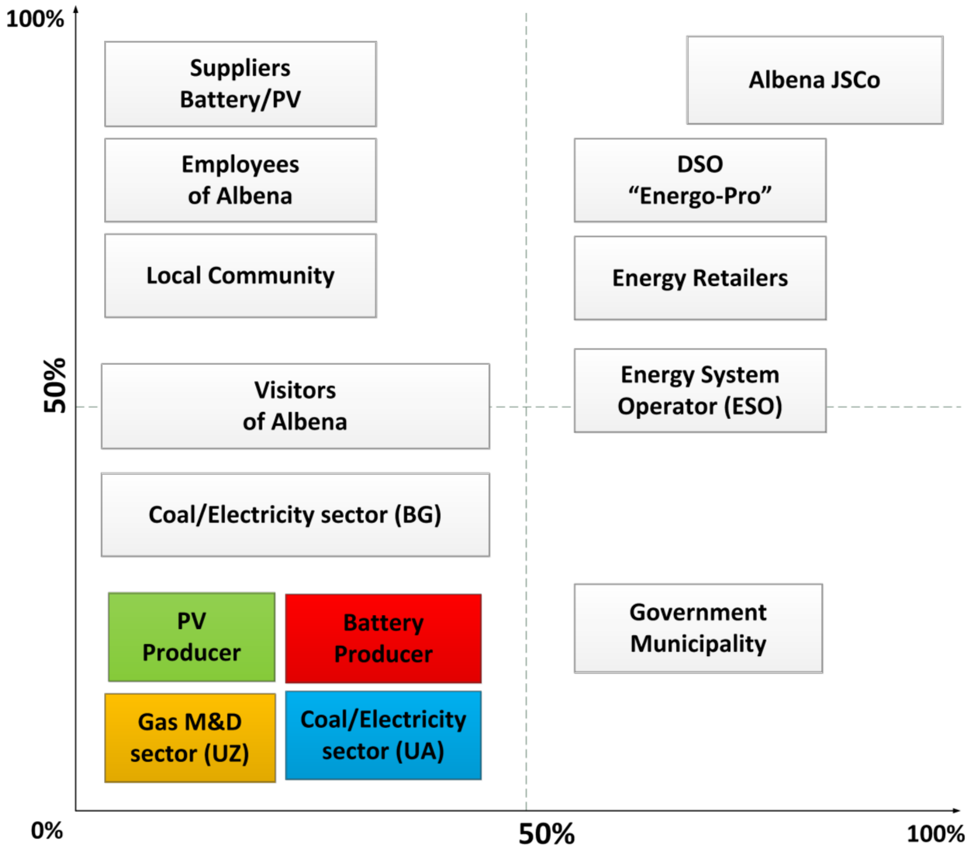

Figure 13.Impact influence diagram for the stakeholders expressed in percentages

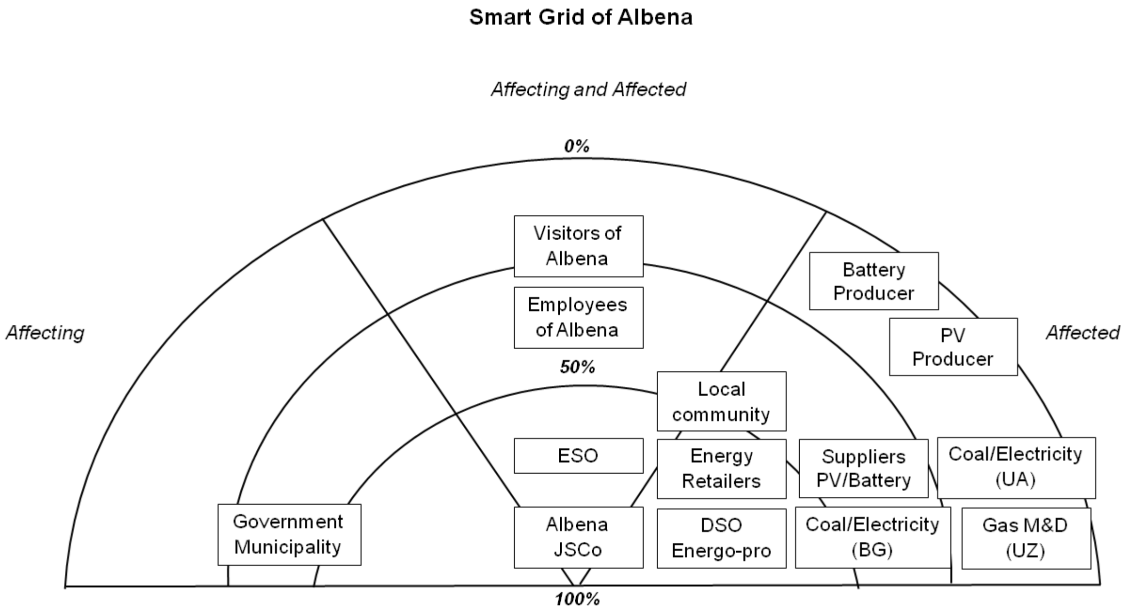

Figure 14. Rainbow diagram for the stakeholders expressed in percentages