An environmental assessment of energy sector: a critical review

Ndala Yves Mulongo and Pule Aaron Kholopane
Faculty of Engineering and the Built Environment
University of Johannesburg, PO BOX, 524,
Auckland Park, 2006,
South Africa
nmulongo@uj.ac.za

Abstract

Over the past decades, the primary goal of business corporations has customarily concentrated on the economic growth, and meanwhile keeping consumers happy by meeting their needs. Nevertheless, due to ever-increasing pressure regarding ecological and social concerns from governments, non-governmental organizations, and consumers have forced various organizations, mainly electricity utilities and manufacturing companies, to reconsider their goals by taking the environmental and social aspects into account. However, a global challenge has emerged concerning the development of such concept. Because, there is a lack of a rational and trustworthy approach designed for measuring environmental burdens, which remain a complex task for various business corporations. Especially for the energy sector that is considered as the driving-factor of ecological deterioration all over the world. Considering this, this paper reviews a set of previous environmental frameworks applied to energy sector. The results indicate that there is a lack of a holistic framework in the current literature, since many studies focused on evaluating the environmental impacts generated during the extraction of raw material and production of energy stages, thus, ignoring other life cycle stages such as processing of raw material, transportation of raw material, and transmission and distribution of end-product to end-users. Therefore, this paper seeks to bridge this gap by assisting decision policy makers to have a comprehensive understanding regarding the connections between all the life cycle stages and thus identifying ways to analyse them.

Keywords.
Environmental assessment, life cycle approach, energy sector.

I. Introduction

The ecological burdens related to contemporary electrical energy production have not happened within a vacuum. They are considered as part of a larger relapse of the planet 's environment triggered through mankind activities. This relapse is exclusively huge since the environment offers the society various vital products and life-support services [30]. These comprise sanitisation of atmosphere and water, management of climate, and the generation and maintenance of biodiversity. Environment resources are viewed undeniably indispensable to industrial sector and overall welfare. Previously, demand concerning those resources was trivial that stern environmental impacts triggered by means of activities associated with human being were curbed in scope and duration. Nevertheless, as worldwide inhabitants and demand concerning those resources has been growing at

a fast pace, strain on the environment has amplified considerably. Human being change of the globe has generated immense soil alteration, biodiversity damage, and a substantial upsurge regarding atmospheric carbon dioxide levels [25, 26, 29]. These ecological burdens are generating growing strain over mankind society. As they are worsening on a daily basis, the alternatives and flexibility offered to mankind are expected to steadily decline, making the transformation to an environmentally thorough framework much more complex. The figure of speech concerning a funnel could be employed to streamline the worldwide situation whilst recognising the links between ecological concerns [28]. Non-sustainable development could be pictured as keying a chimney where the spaces are narrowed and more limited. This reduction of alternatives is generated through the ecological and social issues, which are becoming common incidences, such as global warming, climate change, resource depletion. Undesirable impacts from these consequences could be pictured as striking the walls of the chimney. Alternatively, a sustainable society, cannot only alleviate ecological and social issues, however, will also provide mankind society with various options and flexibility to meet new challenges. The shift in relation to sustainability would necessitate creativity, commitment, and easy access to electricity. Lack of an affordable, reliable, clean, and secure power supply system, the flexibility and alternatives accessible to move toward sustainability narrow substantially. Due to its springiness and related ease of consumption, it is logical to assume that electrical energy is a key player concerning the sustainable society. To this end, the main goal of sustainable development should be based on the development of a power supply system, which can offer energy for a shift into sustainability without causing huge ecological and social issues. Despite the sustainability of energy system has attracted important consideration from scholars and industrial practitioners, various studies failed to develop a holistic environmental framework able to measure to environmental impacts associated with all the stages related to life cycle. In light of this, the overall of this paper is to single out gaps concerning the environmental assessment framework and to propose future use of such framework. The next section will discuss the Life Cycle Environmental Assessment (LCEA) used to evaluate the environmental burdens.

II. Life Cycle Environmental Assessment (LCEA)

LCEA is a crucial tool use to assess the potential effects that a planned project might have on the environment. The goal of the analysis is to make sure that all the stakeholders involved in decision making process take the ecological issues into account while deciding on whether to go ahead with the construction of project. Studies by [27] and [28] describe the LCEA as "the process of determining, foreseeing, assessing and alleviating the biophysical and other pertinent impacts of development proposals prior to important decisions to be made. Thus, a comprehensive environmental sustainability assessment should always include all the stages related to life cycle of a product or process. However, during the past decades a flow has emerged in the current body of knowledge since various studies focused on evaluating the environmental burdens associated to extraction of raw material and generation stages ignoring to incorporate the processing and transmission and distribution stages. To bridge this gap, wee review a sample of previous studies and propose a model concerning future employment of LCEA due to the significance of sustainability issues toward the current and potential energy growth. The system boundary considers in this paper includes Extraction of Raw Material (ERM) and Conversion of Raw Material into Electricity (CRE). The figure 1 below displays the components of a standard LCA. Primarily, a LCA takes into account anything that occurs due to the project, product, or process. In the context of energy sector, a holistic LCEA includes the activities related to Extraction of Raw Material (ERM), Processing of Raw Material (PRM), Conversion of Raw Material into Electricity (CRE), and Transmission and Distribution of Electricity (TDE) to the end-users. This is generally called ‘’cradle to grave’’.

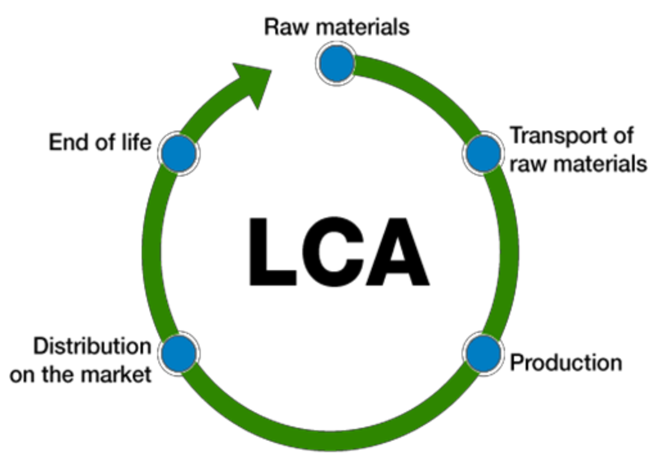

Figure 1. Typical Life Cycle Assessment

The phase of goal and scope definition is concerned with every single debate concerning the decisions for implementing measures that will enable to conduct the environmental evaluation. Often those decisions are made in such a way that they should be coherent with the aimed application and involve the implementation of the temporal, geographical and technological scope of the intended study. Furthermore, an operational unit should be well-defined [30]. It is imperative to point out that LCA is viewed as an iterative process, which enable to redefine the goal and scope regarding the outcomes of analysis, assessment and the interpretation with the objective of meeting the expected results of the planned study. The inventory analysis is the only LCA step that requires a lot time, it encompasses the collection and quantification of inputs and outputs for a specific product system and its components (unit processes and intermediate flows) throughout its life cycle as shown in a generalized example in figure 1.

II.1. Benefits of LCA

The application of LCA is followed with various advantages in helping decision policy makers. Some of the benefits are presented in the lines below:

- Assists in organizing data within a structured way
- Helps in giving clarification regarding different tradeoffs
- Allowing consideration of an inclusive array of effects
- Stimulating novelty
- Allowing a comparative assessment of various assets

II.2. Limitations of Life Cycle Assessment

The main attribute of LCA is its holistic nature that is viewed as its main strength and, meanwhile, its drawback [2, 17, 19, 22]. The large scale of scrutinizing the whole life cycle of goods may only be met at the cost of making simpler other characteristics. Initially, LCA is a sustainability assessment tool that is not designed to address localised bearings. It is, therefore, possible to scale down some of the outcomes and to determine the areas in which some greenhouse gases emissions occur, afterward divergence within the sensitivity of these areas may be considered from LCA perspective. However, the current LCA does not offer the model for a full-sized local risk analysis study, determining which bearings may be foreseeable because of the implementation of a service within a particular zone. The same is true for the time aspect. LCA is naturally a steady-state, rather than a dynamic method [5, 9, 11, 14]. Nevertheless, forthcoming technological inventions are gradually considering additional thorough LCA studies. The current LCA framework emphases mainly on physical aspects of the company's actions and other economic courses; it does not consider market mechanisms or secondary impacts on technological advancement [22]. Generally, LCA considers all courses as linear, both within the economy and the environment. Further, certain development is noticeable concerning the reduction of its limitation, however at heart, LCA is a tool based on linear modeling. Additionally, LCA concentrates more on the ecological aspects of goods, and does not include the other sustainability characteristics such as economic, social. The ecological bearings are often viewed as "possible effects" (see also the ISO definition), since they are not quantified in time and space and are associated with an (regularly) subjectively described operational unit. Despite LCA is designed as science-based, it comprises various technical hypotheses and worth selections [8]. A crucial role is enacted by the ISO standardization process that is assisting to elude uncertainty. The major goal is based on making these hypotheses and selections as understandable as possible; this is also a vital component for implanting LCA within procedures. Another snag lies within the availability of data. Undeniably, catalogues are being invented within many nations across the world, and the format for catalogues is being standardized [11, 14, 18, 25]. However, practically information is often outdated, unrivalled, or of unidentified quality. More specifically, information that in general are available at the level of building blocks. For example, those related to the combinations of processes such as electrical energy generation' or 'metal production', rather than for the entities establishing processes themselves. Lastly, an important aspect issues the nature of LCA as an analytical tool. Considering this, it offers data for decision making support. It should be pointed out that LCA cannot substitute the decision-making process itself.

III. Critical review of previous studies

This section aims at scrutinizing all the studies that used only Life Cycle Assessment (LCA) tool to assess the environmental aspect of electricity generating technologies. It should be noted that the environmental system boundaries considered in these are also scrutinized.

Ning et al [1] carried out a sustainability study regarding the electricity sector in China. The focus was on thermal power, hydropower, solar PV, nuclear power, and wind power. The system boundaries considered here for the sustainability assessment comprised Extraction of Raw Material (ERM), Conversion of Raw Material into Electricity (CRE), and Transport and Distribution of Electricity (TDE). To this end, the sustainability of this study is not complete because the authors focused only on the environmental aspect ignoring two crucial sustainability pillars which are economic and social aspects. Additionally, the environmental assessment of power plants is naïve since the TRM was left out. Therefore, one should not fully rely on the results of this study. In light with this, the findings gathered by the authors show that there are discrepancies regarding Global Warming Potential (GWP) of those power plants. Particularly, thermal power release 19, 66, 123, and 164 times more emissions comparing to solar PV, hydro, wind, and nuclear power plants, separately. Furthermore, there are inconsistencies in the GWP about 1 kWh of thermal power regarding different regions and national average. Lastly, the outcomes show that there are incongruities in the GWP of hybrid power concerning various regions. For example, the results show that Inner Mongolia and Qinghai have the largest and the smallest GWP for 1 kWh of hybrid electricity supply, respectively.

Tonini and Thomas [4] conducted an environmental analysis of power sector in Denmark. The authors focused on fossil fuels, wind and biomass energy considering 2008 as the reference year, and energy scenarios for 2030 and 2050 were evaluated. To this end, the sustainability of this study is not complete because the authors focused only on the environmental aspect ignoring two crucial sustainability pillars which are economic and social aspects. Additionally, the environmental assessment of power plants is naïve since the ERM and TDE were left out. The findings of this study demonstrate that the life cycle GHG per PJ energy generated may be importantly lessen (from 68 to 17 Gg CO2-eq/PJ) by increasing the deployment of wind and residual biomass power plants. Energy crops for producing biofuels and the deployment of these biofuels for heavy terrestrial transport contribute significantly to the pollution of the environment in the 2050 scenarios, specially emissions generated from upstream due to land occupation, fertilizer use and nitrogen oxides emissions emitting during the TRM. Land used by energy crop production augmented to an array of 600–2100 106 m2 /PJ depending on the quantity and kinds of energy crops introduced.

Turconi et al [32] conducted a critical assessment of 167 case studies. These studies focused on the LCA of power generating sources (coal, natural gas, oil, nuclear, biomass, hydroelectric, solar PV and wind. The authors aimed at determining extent of emission regarding GHG, nitrogen oxide, and sulphur dioxide associated with different technologies. However, the study conducted by these authors based on the critical appraisal of those 167 case studies does not add significant value to the field of sustainability. Because the sustainability frameworks of those studies are not comprehensive since they focused only on the environmental aspect leaving out two critical sustainability pillars which are economic and social aspects. In addition, the environmental analysis of those study including for Turconi et al [32] is biased since the TRM and TDE are ignored. The findings demonstrate that most of emissions are emitted during the operation of the plant and are generated by fossil fuel technologies. In contrast, fuel provision was the major contributor concerning biomass technologies (71% for GHG, 54% for NOx and 61% for SO2) and nuclear power (60% for GHG, 82% for NOx and 92% for SO2). The construction of infrastructures offered the contribute significantly for renewable energy sources. Therefore, this critical review shows that the inconsistency of current LCA outcomes for power production plants can give rise to contradictory decisions concerning the environmental impacts of implementing new technologies.

in their works Rita et al [2] and Hans & Anders [3] performed an environmental assessment of different electricity generating sources. The authors focused only on one aspect of sustainable development. Due to this blow, the results of this work should not have been fully relied on. As the authors missed to include other two critical aspects of sustainability, which are financial and social aspects of a power production plant. Fatemeh et al [25] conducted a critical literature review of previous LCA studies. However, as mentioned in the lines above that an -in-depth sustainable development evaluation takes into account three main components, thus, the results of this work should not be fully relied on. As the authors missed to include other two critical aspects of sustainability, which are financial and social aspects of a power production plant.

In light with the above studies, there are also studies such as Peng et al [5]; Ming et al [6]; Pehnt [7]; Pehnt et al [8] ; Pehnt and Henkel [9]; and Onat and Bayar [10] conducted an environmental performance of nuclear power plants in China. However, their work did not meet the requirement for a complete sustainable development evaluation, which relies on three main components, thus, the results of this work should not been fully rely on. As the authors missed to include other two critical aspects of sustainability, which are financial and social aspects of a power production plant.

Valentina et al [11] conducted a LCA study to assess the environmental sustainability of power generation from an Anaerobic Digestion (AD) unit employing a combination of dedicated energy crops, agrarian waste and livestock wastes as raw materials. The authors used 1MJ of electrical energy as the operational unit. System boundaries were from cradle to grave considering all the stages from agricultural of energy crops to biogas generation and its employment within a CHP to generate electricity. Though, the environmental analysis of this study is based on cradle to grave. Due to non-inclusion of economic and social aspects in the framework, therefore, one should not fully rely on the findings presented in this study in terms of sustainable development. Another bias is based on TDE, which is not included in the environmental assessment. The findings illustrate that the major hotspots are energy crops cultivation and the management of digestate, largely owing to both NOx and CH4 emissions, affecting Global Warming, Acidification, Marine and Freshwater Eutrophication.

Yemane et al [12] carried out an environmental analysis concerning three biomass-based options cases that characterised energy transition and transformation of power sector in Canada, with the dominant case of coal electrical energy generating source. This study treats the sustainability matter naively because it does not cover social aspect and also the environmental assessment include only the PRM phase ignoring three main phases ERM, TRM, and TDE. To this end, the findings collected concerning the biomass environmental life cycle demonstrated a significant improvement from 47 to 92% for global warming, 46 to 90% for mankind health, and 47 to 91% for environmental issues comparing to coal-fired power plant case. In contrast, the coal power production plant showed roughly 63-83% less life cycle cost impact than other options.

Sastre et al [15] conducted a sustainability assessment study of electricity in Spain. The aim of their study was to offer more accurate findings regarding LCA of electrical energy production from wheat straw grown by including certain factor ambiguity and erraticism in the inventories. Their findings demonstrate that most of the simulations electrical energy generated through the combustion of wheat straw biomass release very few GHG emissions and used up not as much of fossil energy than electrical energy produced by gas technology. But, their findings also revealed that only 58% of the simulations met the sustainability target of 60% GHG savings as recommended by the European Union (EU). Although, the results of this study shows a significant saving of GHG emissions of around 58%, the sustainability analysis is still incomplete since economic and social aspects, which two fundamental sustainability aspects were ignored. Furthermore, the environmental assessment only considered the ERM and CRE stages ignoring other crucial life cycle stages. To this end, one should not fully rely on the results of this study because it does not meet the requirement of a holistic sustainability framework.

Santoyo-Castelazo et al [13] used LCA approach to assess the environmental sustainability of electricity generating sources in Mexico, where 79% of electricity is generated from fossil fuels, hydropower 13.5%, geothermal 3% and wind 0.02% and 4.8% is produced by nuclear technology. The findings of this study show that 225 TWh of electrical energy produced emit at least 129 million tonnes of CO2 eq. per annum, most of which (87%) is because of the burning of fossil fuels. Whereas, hydropower, geothermal, wind and nuclear contribute only 1.1% to the overall CO2 eq. Despite this, the sustainability framework developed by Santoyo- Castelazo et al [13] is biased because it only focused on environmental aspect, thus, leaving out economic and social impacts of the power plants. Additionally, some important environmental indictors, such as ERM, TRM, and TDE.

Santoyo-Castelazo et al [14] develop a sustainability analysis model in order to decarbonise the power sector in Mexico. To this end, they focused on environmental impact of different power production plants up to 2050. In light with this, the covered 10 environmental issues, including global warming, resource and ozone layer shrinking, acidification, eutrophication, summer smog, human and ecotoxicity. According to Santoyo-Castelazo et al [14] based on the findings that they collected carrying on using fossil fuels to generate electricity can double the life cycle GHG emissions, albeit yearly electrical energy demand growth was lowered to 2.25% from the 2014 percentage of 2.8%. Thus, they argued that changing from the employment of fossil fuel mix to a higher contribution of renewables (55–86%) and nuclear power (up to 30%) can cause an important diminution of all ten life cycle issues comparing to the 2014 circumstances and up to an 80% decrease. However, this study does not also add substantial value to the field of sustainability. Because the sustainability framework developed concentrated only on the environmental aspect ignoring two critical sustainability pillars which are economic and social aspects. Additionally, the environmental analysis is not complete since the ERM, TRM, and TDE stages were not included in the framework.

Paul et al [16] assessed the impact of life cycle GHG emissions per MWh of electrical energy generated, this is based on a range of various power production plant for Australian electricity sector. They findings show that Liquefied natural gas does not emit a lot of GHG emission as black coal, however, the difference is minor for OCGT plant and for CSG. In accordance with their results traditional natural gas consumed within a traditional OCGT plant is roughly

38% less GHG intensive throughout its life cycle than black coal consumed in a sub-critical plant, per MWh of electrical energy generated. Paul et al (2012) point out that, if OCGT combustion is compared to the most efficient new ultra-supercritical coal-fired power, the difference narrows significantly. Coal seam gas LNG is roughly 13–20% more GHG intensive during its life cycle, on a like-for-like basis, than conventional LNG, and thus compares less favourably to coal than conventional LNG under all technology combinations. But, this study does not also add significant value to the field of sustainability. Since the sustainability framework developed is incomplete due to the fact that they authors considered only the environmental aspect disregarding two critical sustainability pillars which are economic and social aspects. Additionally, the environmental analysis is not complete since the ERM, TRM, and TDE stages were not included in the framework.

Andrew et al [18] applied LCA to a 3 kW hydro-power located in Thailand. The authors considered the cradle to grave assessment framework for the hydropower during a period of two decades, as well as all appropriate equipment, materials and transportation. Their findings demonstrate that when comparing small-scale hydropower plant with largescale hydropower plant. The former one has a greater environmentally impact per kWh of electricity generated and perform less well environmentally than latter one. However, the results show that hydropower unit used in this study produce better ecological and financial results than diesel generator and grid connection options. However, the framework developed in this study is biased and does not also add substantial value to the field of sustainability. since the authors considered only the environmental impact, thus, disregarding two critical sustainability pillars which are economic and social aspects. Additionally, the environmental analysis itself is not complete due to lack of the ERM, TRM, and TDE stages in the framework.

Oliveira et al [17] developed a LCA model to assess the impacts of the climate change, mankind toxicity, particulate matter formation, and fossil resource diminution. Various power plants mix were deployed to demonstrate cases where the designated technologies meet particular applications. Their findings show that the impacts renewable energy sources during the employment phase of the storage technologies is insignificant. Belgium electricity mix of 2011 was used as benchmark, the sodium sulphur battery is revealed to be the best performer for all the impacts assessed. With pumped hydro storage ranks at the second position. Considering infrastructure and end of life, the findings illustrate that battery systems have higher impacts due to lower number of cycles and life time energy. However, the framework developed in this study is biased and does not also add substantial value to the field of sustainability. Because the authors took only the environmental aspect into account, therefore, ignoring two significant sustainability aspects, which are financial and social aspects. In addition, the environmental analysis itself is not complete because it did not cover the ERM, TRM, and TDE stages in the framework.

Messagie et al [21] used LCA approach to assess the GWP per kWh of electricity generated for each hour on the year basis for power sector in Belgium. The authors believed that the environmental analysis would have enabled them to assess the impact of the electrical energy demand on the GHG emissions. the authors state that due to the LCA tool, the carbon dioxide equivalent content does not only reflect activities associated with the electricity generation in a power plant, however, including GHG emissions associated with the construction of the plant and the fuel supply chain. In their work Messagie et al [21] focused on nuclear, oil, coal, natural gas, bio-waste, blast furnace gas, wood, solar PV, hydro-power installations and wind power plants. However, the downside with this study is that it cannot fully be relied on since is messing critical information regarding some aspects of sustainability such as economic and social impacts. In addition, the environmental appraisal of those power production plant is not comprehensive because of lack of the TRM, and TDE stages in the analysis. The results of this work indicate that electricity produced through the wind and solar power plants is more carbon intensive than the electrical energy generated by thermal power plants, one possible explanation is because of the lower electricity output. The total average GWP per kWh was 0.184 kg CO2eq/kW h. over the 2011, the authors argued that this figure varies from a minimum of 0.102 kg CO2eq/kW h to a maximum of 0.262 kg CO2eq/kW h depending on the timing.

Meier et al [20] investigated the sustainability of natural gas power plant for the electricity sector in United States. In their work Meier et al [20] viewed natural gas as a sustainable carbon-lowering measure. Their results indicate that important GHG emissions are emitted into the environment during the gas power plant’s upstream, mostly over fuel-cycle operations. The authors tested two carbon- lowering measures making use of life-cycle emission rates developed for the United States power sector. Depending fully on new natural gas units for CSA compliance can necessitate a 600% growth in natural gas produced electrical energy and practically full shift of coal from the fuel mix. On the other hand, a 240% growth in nuclear or renewable energy sources achieve the same target with minimal coal usage. The authors concluded their work by arguing that their study illustrate that how disregarding life-cycle GHG, particularly those being generated in upstream of the gas power plant, can lead to flawed appraisal of supply side compliance options. However, there is an important gap in this study due to sustainability framework developed, which treats the sustainability issues naively. Because, the model is pure environmental, thus, it does not consider the impacts associated with economic and social aspects. Another prejudice to this study is that the environmental evaluation of the power plants leaves out some crucial stages of life cycle such as ERM, TRM, and TDE.

Changqing et al [19] used LCA approach to compare the environmental sustainability of biomass and coal-fired plant. The focus of the environmental analysis was on TRM, PRM, and TDE. His findings demonstrate that for each biomass based scenario, the driving elements polluting the environment comprise GHG emissions such as nitrogen oxides, phosphorus, mercury, and particulate matter. Additionally, CO2 produced from CH4 burning, road transport, and electrical energy use contribute significantly to the pollution of the environment. But, when comparing with coal-fired power plant, it generates important ecological benefits in most key categories with the exception of climate change and human toxicity. Hence, in accordance with the results biomass is not totally cleaner than fossil fuel. however, this study does not add much on sustainability field. Because of lack of economic and social impacts in the assessment and in the context of environmental analysis there ERM stage was not considered. Thus, this gag needs to be filled in order to have a comprehensive assessment.

Yuan et al [23] used LCA models to measure the extraction- to-wire GHG emissions and water usage per kWh generated through coal-fired plant and shale gas power plant in China. The outcomes illustrate that shifting from coal to shale gas and upgrading coal-based poer plants can create routes for a smaller amount of GHG and water consumption for power sector in China. Additionally, the GHG emissions generated from gas-fired plant turned around 530 gCO2e/kWh that is 38-45% less than the current China's coal-based power plant. Moreover, the results show that Gas-fired CT plant has the least ETW water use estimated at 960 g/kWh, which is 34-60% lesser than China's current coal power plant. However, this study does not also add substantial value to the field of sustainability. Because the sustainability framework developed concentrated only on the environmental aspect ignoring two critical sustainability pillars which are economic and social aspects. Additionally, the environmental analysis is not complete since the TRM, and TDE stages were not included in the framework.

Yaw et al [24] conducted a critical review of 79 studies based on LCA of onshore and offshore winds, hydropower, wave and tidal energy, geothermal, solar PV, solar thermal, biomass, waste, and heat pumps. The results show that offshore wind had the least GHG emissions since its life cycle GHG emissions was estimated at 5.3–13 gCO2 eq/kWh. The findings also revealed that GHG generated by fossil fuel heat and electricity are relatively higher compared to renewable energy sources without considering nuclear technology. In their work Yaw et al (2014) considered renewable energy sources, waste treatment and dedicated biomass technologies (DBTs) were found to potentially have high GHG emissions based on the feedstock, selected boundary and the inputs required for their production. Though, the authors have given insight regarding environmental assessment of different power plants, the sustainability appraisal itself is not complete since it is missing some crucial information regarding economic and social impacts. Furthermore, the environmental assessment did not consider some important life cycle stage, such as TRM, and TDE.

Manfred [22] reviewed a set of studies regarding environmental impact of nuclear technology. The results show that the GHG emissions emitted by nuclear power plants using the reactor of types LWR and HWR range from 0.1 and 0.3 kWh, and on average about 0.2 kWh for every kWh of electrical energy produced. These energy intensities translate into GHG emissions for LWR and HWR ranging from 10 and 130g CO2- e/kWh, with an average of 65 g CO2-e/kWh. Despite the fact these GHG emissions are expectedly lower than those of fossil technologies (typically 600–1200 g CO2-e/kWh), they are higher than reported figures for wind turbines and hydroelectricity (around 15–25 g CO2-e/kWh) and in the order of, or slightly lower than, solar PV or solar thermal power (around 90 g CO2-e/kWh). However, the downside with this study is that it cannot fully be relied on since is messing critical information regarding some aspects of sustainability such as economic and social impacts. In addition, the environmental appraisal of those power production plant is not comprehensive because of lack of the ERM, TRM, and TDE stages in the analysis.

IV. Future use

Due to the criticality of environmental issues to current and future energy development, transmission and distribution, and consumption, it appears reasonable to see growing employment of this approach. Actually, with regard to the development of reliable strategies and plans, LCEA is very crucial. Linking LCEA with scenario planning can help to guarantee acceptable results over an array of settings. Best outcomes could be met through direct and permanent involvement of decision makers concerning the collection of data, debates, judgments, and constant monitoring for success. In case the defined tool is applied to various strategies concerning a matter, then different power production alternatives can equally and fairly be assessed and compared on a basis of full life cycle. We have presented a set of works to show the extent of LCEA applications in power sector. We have observed that each work focused on ERM or CRE stages. Thus, there still work that should be conducted to guarantee a most effective and efficient use of LCEA.

CONCLUSION

Life Cycle Environmental Assessment is an environmental assessment tool that its use is increasing considerably. It acknowledges shifting circumstances over time, and also different portions of the life cycle. As more employments and assessments are being reported, it is expected that in coming decades many will acknowledge the significance as a method for both sustainable development and policy improvement. In order to guarantee best deployment of such tool, future studies need to carry on advancing consideration of all the stages pertaining to development a product or process. Since in the existing literature there is a lack of a holistic environmental assessment framework that incorporate all the life cycle stages from extraction of raw material to the distribution of product to end-users.

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Biography

Ndala Yves Mulongo is currently conducting a PhD degree in the Faculty of Engineering and the built environment, University of Johannesburg. He holds bachelor of engineering in extraction metallurgy and master of engineering in engineering management from University of Johannesburg, South Africa. His research interests involve life cycle approach, cost of electricity production, energy efficiency measures, green supply chain management, impact of mining operations on environment, mineral processing, manufacturing processes.

Dr Pule Kholopane is currently a Senior Lecturer and Head of Department in the Department of Quality and Operations Management, Faculty of Engineering and the Built Environment, University of Johannesburg, South Africa. He has both industrial and academic experience for more than twenty years. He has got a Doctor of Engineering Management degree from the University of Johannesburg where he has been supervising masters and PhD students during the current decade. He has published several journal and conference research papers. His research areas include project management, process optimizations, manufacturing processes, supply chain management, sustainability, production planning, energy efficiency, waste reduction, product development and marketing, product quality related issues, cost analysis, etc.

Prof Clinton Aigbavboa is currently a Senior Lecturer and vice-dean of research and innovation in the Faculty of Engineering and the Built Environment, University of Johannesburg, South Africa. He has got a Doctor of Engineering Management degree from the University of Johannesburg where he has been supervising masters and PhD students during the current decade. He has published several journal articles and conference research papers. His research areas include construction management, project management, process optimizations, manufacturing processes, supply chain management, sustainability, production planning, energy efficiency, waste reduction, product development and marketing, product quality related issues, cost analysis, etc.