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# BUSITEMA UNIVERSITY

# FACULTY OF ENGINEERING

## DEPARTMENT OF POLYMER, TEXTILE AND INDUSTRIAL ENGINEERING

## FINAL YEAR PROJECT REPORT

## LIFE CYCLE ASSESSMENT (LCA) OF SOLAR PHOTOVOLTAIC (PV) PANELS FROM GATE TO GRAVE IN UGANDA

**By**

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***A final year project report submitted to the Department of Textile and Ginning Engineering in partial fulfillment for the award of a bachelor of science in polymer, textile and industrial engineering***

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## ABSTRACT

Uganda is richly endowed with abundant energy resources, which are fairly distributed throughout the country. These include **hydropower, biomass, solar, geothermal, peat and fossil fuels**

The need to exploit energy sources that are alternative to fossil fuels, whose use is the major cause of air pollution and climatic change, is becoming important. These alternative energy sources are renewable energy sources such as solar energy, hydro energy, wind energy and geothermal. Though solar panels produce clean energy, they seem to have potential environmental impacts while in the production process(Dr. Norasikin Ahmad Ludin, 2019). Also, in most situations, the expected life for PV panels appears to be 25 years, and afterward their end-of-life management is not guaranteed with current practices. (Dumping PV waste in landfills, water and exposure to air would cause severe health and environmental problems)(Stolz et al., 2016).

This study investigated environmental impacts of solar panels in photovoltaic plants from use to disposal (case study Tororo solar North Limited) in Tororo district Uganda on resources and the environment.

The study evaluated the environmental impacts and therefore the actual sustainability of solar photovoltaic system. A gate to grave Life Cycle Assessment (LCA) of polycrystalline and monocrystalline panels was conducted over their useful life using **OpenLCA** software and the NEEDS database, Ecoivent impact assessment methods and following LCA standards created by the International Organization for Standardization (ISO 14040 and ISO 14044).

## DECLARATION

I **OLOWO PHILIMON REG NO: BU/UG/2017/133** hereby declare that this project research is my original work and that the information contained in this project is out of my hard work and research, except where explicit citation has been made. This work has not been presented to any institution of higher learning for any academic award.

Signature ……

Date…….....

## APPROVAL

This project report has been submitted for examination with approval from the following supervisors:

SUPERVISORs

1. Dr. NIBIKORA ILDEPHONSE

Signature: ……

Date: ……

2. Mr. KASEDDE ALLAN

Signature: ……

Date: …….

## DEDICATION

I would like to dedicate this report to my beloved family at large especially father Mr. OKETCHO JASPA, MY MOTHER Mrs. FLORESCNCE OKETCHO, all my brothers and sisters, my dear wife Ms. JOAN ABOTH and all my friends for their support in my journey of academics.

Truly I appreciate any kind of support rendered, encouragements together with a positive attitude and determination towards achieving my dreams, I salute you all and may the almighty reward you abundantly.

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## Table of Contents

## LIST OF FIGURES



## ABBREVIATIONS/ACRONYMS

LCA……Life cycle assessment

PV……. Photovoltaic

LCI……. Life cycle inventory

LCIA……. Life cycle impact assessment

AC……... Alternating current

DC……. Direct current

EU……. European union

BOS……. Balance of system

ISO……International organization for standardization

GHG……Greenhouse gasses

# CHAPTER ONE INTRODUCTION

## Background of the study

Energy is an essential part of the world today because it is difficult to imagine a world without it. Modern day households rely on it for daily activities and preservation of food. Industries rely on it for manufacturing and processing. The business world relies on it for ease of transactions and transfers. Media depends on it for the gathering and distribution of information. Night life will be much more difficult without advantage of lights(Winterbach, 2011). Energy sources are classified into nonrenewable and renewable, nonrenewable sources include, coal fire, fossil fuel (thermal energy), natural gas, and nuclear energy. Renewable sources of energy are wind energy, hydro energy, solar energy and geothermal energy(Mahmud et al., 2018).

The major concern is that, the means by which most of the energy is produced causes harm to humans and the environment, including the fauna and flora. Coal fire is the most prominent way of producing energy, but since it creates the most harm to the environment, alternatives ways of energy production must be looked at. All of these have the potential to be very harmful to the environment. That is why renewable sources of energy should be considered. Such sources include wind energy, hydro-energy, solar energy and geothermal energy.

In the new energy sector, solar photovoltaic (PV)-based electricity generation is increasing, due to which the PV industry has also seen tremendous growth over the years.

Solar photovoltaic (PV) systems are semiconductor devices that convert sunlight into DC electricity through the transfer of electrons. The process of energy conversion mainly occurs in two stages; generation of electron-hole pair through the absorption of light in semiconductor material and afterwards, separation of electron to the negative terminal and hole to the positive terminal by the structure of the device to supply electricity (Pandey et al., 2017). It uses solar radiation as fuel for the energy generation process. The core components of a solar-PV system are PV panel, charge controller, battery pack, DC/AC inverter, DC/DC converter, and DC shunt. The balance of system (BOS) encompasses all components of a photovoltaic system other than the photovoltaic panels. In order to increase this energy, tracking flat PV system can be employed and thus there is an increase in capturing solar energy due to tracking the path of sun's movement (Abu-Khader et al., 2008). A photovoltaic

system employs solar modules, each comprising a number of solar cells, which generate electrical power. PV installations may be ground-mounted, rooftop mounted, wall mounted or floating. The mount may be fixed or use a solar tracker to follow the sun across the sky. Photovoltaic systems have long been used in specialized applications as stand-alone installations and grid-connected PV systems have been in use since the 1990s. After hydro and wind powers, PV is the third renewable energy source in terms of global capacity. The International Energy Agency expects a growth by 700 - 880 GW from 2019 to 2024. Photovoltaic technology enables to transform solar energy directly into electricity using photovoltaic effect with pollutant emissions during the operation phase.

This study investigated and assessed the overall environmental impact of active solar photovoltaic panels (Monocrystalline and polycrystalline panels) of a power plant on resources and the environment, by implementing a gate to grave LCA using OpenLCA software. This included all processes from manufacture of solar panels to their disposal.

## Problem Statement

The European Union (EU) assumed the use of solar photovoltaic system as the leading role in achieving the final goal of the substitution of fossil fuels with renewable energies, which leads reduction of greenhouse gasses (GHG) and other environmental impacts (Muteri et al., 2020).

But recently, there have been many concerns raised over the environmental impacts associated with solar PV systems. Though solar panels do not produce any harmful chemicals or noise in the operational stage and the energy produced from solar PV plants seems to be clean and comparatively free from carbon emissions, they seem to have potential environmental impacts while in the production process(Dr. Norasikin Ahmad Ludin, 2019). Also, in most situations, the expected life for PV panels appears to be 25 years, and afterward their end-of-life management is not guaranteed with current practices. (Dumping PV waste in landfills, water and exposure to air would cause severe health and environmental problems)(Stolz et al., 2016). This also raises concerns over the environmental impacts due to improper management of solar power plant waste. This has resulted in many potential environmental, health, and safety hazards. One of the best ways to understand these environmental impacts is by diving deep into the solar PV system life cycle by LCA(Muteri et al., 2020). This allows us to understand the exact environment impacts possible with solar PV technologies.

Therefore, life cycle assessment of solar photovoltaic panels was conducted from gate to grave to identify and compare the environmental impacts of the two types of most used types of solar panels in Uganda (monocrystalline and polycrystalline panels). This study helped to identify the environmentally least impactful type of solar panel, a metric which can be used for decision making during establishment of solar power plants, panel purchase and many more.

## Purpose of the study

This study (LCA) will be used by a variety of users for a range of purposes.

- Decision making in solar making industry, governmental or non-governmental organizations (e.g.) strategic planning, priority setting, product and process design or redesign) of least impactful energy generation method.

- ❖ Selection of relevant indicators of environmental performance (e.g.) waste management bills, energy bills, purchasing bills travel receipts), including measurement techniques
- ❖ Identifying opportunities to improve the environmental aspects of solar photovoltaic system at various points in their life cycle.
- ❖ Marketing for example an environmental claim.

## Justification/Rationale of the Study

According to the ISO standards on LCA, when the study is fully executed well and valid results are found then;

- ❖ Environmental impacts caused by use of solar photovoltaic system will be determined
- ❖ Comparison of environmental impacts of photovoltaic panels (monocrystalline and polycrystalline solar panels) will be conducted.
- ❖ The most sustainable and least environmentally impactful energy source will be determined.

The above will lead to the following applications;

- ✓ Strategic planning
- ✓ Product improvement
- ✓ Public policy making

## Significance of the study

The study can be used by following groups;

**Industry;** as a way of identifying environmental hot spots and to develop and advertise their environmental management strategies.

**Government;** Governments use LCA for data collection and developing more effective environmental policies related to materials and products.

**Universities;** There are many universities researching and developing LCA methodology and data.

## Objectives of the study

***Main objective/goal of the Study***

To assess the life cycle of a solar photovoltaic plant with the focus on the panels from gate to grave

***Specific objectives***

These objectives of the study need to be completed to achieve the final goal and they are as follows;

- To perform life cycle inventory analysis of solar photovoltaic system.
- To carry out environmental impact assessment of life cycle inventory indicators.
- To perform life cycle inventory interpretation, compare the impacts of solar PV panels and evaluate the sustainability

## Scope of the study

***Content scope***

This study only focused on PV panels (monocrystalline and polycrystalline) of the solar photovoltaic plant. Other components of the solar power plant like charge controller, battery pack, DC/AC inverter, DC/DC converter, and DC shunt were not considered. The study was taken from gate to grave life cycle assessment.

***Geographical scope***

The study was limited to Tororo solar power station, a solar photovoltaic plant located in Tororo district along Jinja Malaba main road.

***Time frame***

The research was conducted according to Busitema university timeline

## References


Dr. Norasikin Ahmad Ludin. (2019). *Life Cycle Assessment of Photovoltaic Systems in the APEC Region APEC Energy Working Group* (Issue April).

Jungbluth, N., & Stucki, M. (2012). Life cycle inventories of photovoltaics. *ESU-Services Ltd., …*, *17*, 250.

Mahmud, M. A. P., Huda, N., Farjana, S. H., & Lang, C. (2018). Environmental impacts of solar-photovoltaic and solar-thermal systems with life-cycle assessment. *Energies*, *11*(9). https://doi.org/10.3390/en11092346

Muteri, V., Cellura, M., Curto, D., Franzitta, V., Longo, S., Mistretta, M., & Parisi, M. L. (2020). Review on life cycle assessment of solar photovoltaic panels. *Energies*, *13*(1). https://doi.org/10.3390/en13010252

Samarghandian, S., Ohata, H., Yamauchi, N., & Shibasaki, T. (2016). Guidance on Data Quality Assessment for Life Cycle Inventory Data. *Neuroscience*, *116*(2), 519–524.

Stolz, P., Frischknecht, R., Stolz, P., & Frischknecht, R. (2016). *Life Cycle Assessment of Photo- voltaic Module Recycling Authors*. *October*.

Stoppato, A. (2008). Life cycle assessment of photovoltaic electricity generation. *Energy*, *33*(2), 224–232. https://doi.org/10.1016/j.energy.2007.11.012

Winterbach, F. (2011). *Life Cycle Assessment ( LCA ) of various solar heat technologies Focus on Heliostat construction and maintenance*. *December*.



Dr. Norasikin Ahmad Ludin. (2019). *Life Cycle Assessment of Photovoltaic Systems in the APEC Region APEC Energy Working Group* (Issue April).

Jungbluth, N., & Stucki, M. (2012). Life cycle inventories of photovoltaics. *ESU-Services Ltd., …*, *17*, 250.

Mahmud, M. A. P., Huda, N., Farjana, S. H., & Lang, C. (2018). Environmental impacts of solar-photovoltaic and solar-thermal systems with life-cycle assessment. *Energies*, *11*(9). https://doi.org/10.3390/en11092346

Muteri, V., Cellura, M., Curto, D., Franzitta, V., Longo, S., Mistretta, M., & Parisi, M. L. (2020). Review on life cycle assessment of solar photovoltaic panels. *Energies*, *13*(1). https://doi.org/10.3390/en13010252

Samarghandian, S., Ohata, H., Yamauchi, N., & Shibasaki, T. (2016). Guidance on Data Quality Assessment for Life Cycle Inventory Data. *Neuroscience*, *116*(2), 519–524.

Stolz, P., Frischknecht, R., Stolz, P., & Frischknecht, R. (2016). *Life Cycle Assessment of Photo- voltaic Module Recycling Authors*. *October*.

Stoppato, A. (2008). Life cycle assessment of photovoltaic electricity generation. *Energy*, *33*(2), 224–232. https://doi.org/10.1016/j.energy.2007.11.012

Winterbach, F. (2011). *Life Cycle Assessment ( LCA ) of various solar heat technologies Focus on Heliostat construction and maintenance*. *December*.