

**GREENING UGANDA'S URBANIZATION AND INDUSTRIALIZATION REPORT
PAKWACH INDUSTRIAL PARK.**

**Developing Material and Energy flow plan and Industrial Symbiosis layout
plan for Dero Pakwach Eco-Industrial Zone (DPEIZ)**

Submitted to



By

Twinomujuni Edson

CONSULTANT

JUNE-DECEMBER 2023.

Acronyms

BOD	Biochemical Oxygen Demand
CE	Circular Economy
CO ₂ eq	Carbon dioxide equivalent
IS	Industrial Symbiosis
COD	Chemical Oxygen Demand
EU	European Union
GHG	Greenhouse Gases
J	Joules
kV	Kilo Volts
kVA	Kilo-Volt-Amperes
kVAr	KiloVolt-Ampere Reactive
kWh	Kilo Watt-hour
MFA	Material Flow Analysis
MJ	Mega Joules
MW	Mega Watts
MWE	Ministry of Water and Environment
MTIC	Ministry of Trade Industry and Cooperatives
NPA	National Planning Authority
NEMA	National Environment Management Authority
NIP	National Industrial Policy
NDP	National Development Plan
RECP	Resource Efficiency and Cleaner Production
SMEs	Small Medium scale Enterprises
UGGDS	Uganda Green Growth Development Strategy
UIA	Uganda Investment Authority
UNEP	United Nations Environment Programme
UNIDO	United Nations Industrial Development Organization

Abstract

Global Green Growth Institute (GGGI) has partnered with the European Union (EU) as part of the EU-inclusive green economy uptake program (Green UP). At present, GGGI delivers a project entitled “Greening Uganda’s Urbanization and Industrialization” (2020-2023). The program is aligned with the government of Uganda’s Vision 2040, the third National Development Plan (NDP III), and the Uganda Green Growth Development Strategy (UGGDS). The project promotes sustainable development and inclusive green growth in Uganda. It focuses on green city development, green industrialization, efficient waste management, and green growth integration into planning and budgeting. The main objective is to develop green masterplans including symbiotic infrastructure plans and project concept notes for the Entebbe International Airport Freezone (EIAFZ), Soroti Business and Industrial, and Dero Pakwach Eco-Industrial Zone

This report presents a Resource Efficient and Cleaner Production (RECP) assessment carried out at Dero Pakwach Eco-Industrial Zone (DPEIZ). The RECP assessment entailed carrying out material flow and energy flow analysis to establish waste generation trends of potential sectors and selected feasible sectors/processes based on the environment-bearing capacity of the zone, identifying potential areas for substitutions of materials, detect opportunities for new technologies that help reduce inefficiencies in energy and materials use, increase domestic reuse or recycling, and the use of alternative materials. Material and energy flow analysis was carried out following the guidance of the UNIDO RECP toolkit. The RECP assessment also included mapping industrial symbiosis synergies using the UNIDO industrial symbiosis identification tool. The proposed RECP improvement measures were informed by baseline operating practices and the best available techniques/technologies in manufacturing enterprises.

The assessment carried out shows that Pakwach Industrial Park has the potential to anchor manufacturing enterprises processing cassava, coffee, fish, fruits and vegetables, seed oil, tourism, and logistics entities. At maximum production capacity, the projected business-as-usual energy and water energy demand (of starter sectors) is estimated to be 247,144.04 GJ and 648.43 m³ per day respectively. Through the adoption of Resource Efficient and Cleaner Production (RECP) measures and industrial Symbiosis synergies, Pakwach Industrial Park has the potential to reduce energy and water demand to 120,907.872 GJ and 468.38 m³ per day respectively. The proposed RECP measures to enable Pakwach Industrial Park to improve water and energy productivity include; (i) the Use of low-pressure foam and/or gel instead of water cleaning, (ii) Fitting of cleaning hoses with hand-operated triggers, (iii) High-pressure cleaning ranging from 15 bars to 150 bars, (iv) Use of various automated flow regulators to optimize process water, (v) Use of correct number and position of nozzles; (vi) Segregation of water streams; (vii) Optimization of chemical dosing and water use in cleaning-in-place (CIP), (viii) Maximisation of condensate return, (ix) Recirculation of water from the cooling tower, (x) use of closed-circuit cooling, (xi) Frequency converters (or variable speed drivers), (xii) Energy-efficient lighting and light controls, (xiii) Use of high-efficiency motors especially IE4, (xiv) Generate renewable energy using solar PV and (xv) Recover energy from waste through production of biomass briquette.

Furthermore, material flow analysis indicated that manufacturing enterprises in Pakwach Industrial Park will be generating about 78.5 tons of organic waste per day. This provides an opportunity for industrial symbiosis to valorise the organic waste and bi-products to produce useful products including animal feeds, omega-3 oil, and biomass briquettes. Implementation of RECP and industrial symbiosis has the potential to reduce GHG emissions of Soroti Industrial Park by 40,125.61 tCO₂eq per year.

Contents

Acronyms	2
Abstract	3
1. Background	5
1.1. Introduction	5
1.2. Objectives	5
2. Methodology	5
2.1. Stakeholder Identification and Consultations	5
2.2. Material and Energy Flow Analysis	5
2.3. Identification of Resource Efficient and Cleaner Production Options	7
2.4. Identifying Industrial Symbiosis Synergies and Infrastructure Layout Plan	7
3. Findings From the RECP Assessment	7
3.1. Status of Dero Pakwach Eco Industrial Zone	7
3.2. Material and energy Flow analysis for DPEIZ	8
3.2.1 Cassava Processing	8
3.2.2 Ethanol Production	10
3.2.3 Fish Processing	11
3.3.4 Seed oil Processing	11
3.2.5 Coffee Processing	13
3.3. Selection of Priority Sectors for Pakwach Industrial Park	14
3.4. Resource Efficient and Cleaner Production options for DPEIZ	18
3.5. Proposed Water Efficient and Conservation Measures	20
3.6. Proposed Energy Efficient and Conservation Measures	24
3.7. Best available technology for Fish Smoking.	27
3.8. Industrial symbiosis and RECP infrastructure.	28
3.9. GHG emissions reduction potential of Pakwach Industrial Park.	31
4. Conclusion	31
5. ANNEX	32
5.1. Annex1: Concept for a Solar PV Power facility	32
5.2. Annex 2: Concept note for Industrial Scale Biomass Briquette Facility	38

1. Background

1.1. Introduction

Based in Seoul, the Global Green Growth Institute (GGGI) is an intergovernmental organization founded to support and promote green growth. It targets key aspects of economic performance such as poverty reduction, job creation, social inclusion, and environmental sustainability. GGGI works with countries around the world, building their capacity and working collaboratively on green growth policies that can impact the lives of millions. The organization partners with countries, multilateral institutions, government bodies and the private sector. This is to help build economies that grow more economically and efficiently. Ultimately, they become more effective and sustainable in the use of natural resources, less carbon intensive, and more resilient to climate change.

GGGI is partnering with the European Union (EU) as part of the EU inclusive green economy uptake programme (GreenUP). At present, it is delivering a project entitled “Greening Uganda’s Urbanization and Industrialization” (2020-2023). The programme is aligned with the government of Uganda’s Vision 2040, the third National Development Plan (NDP III), and the Uganda Green Growth Development Strategy (UGGDS). The project promotes sustainable development and inclusive green growth in Uganda. It focuses on green city development, green industrialization, efficient waste management and green growth integration into planning and budgeting.

1.2. Objectives

To support Uganda in becoming mid-income status via industrialization, the project hopes to support the development of 3 industrial parks in Entebbe, Soroti and Pakwach. The overall goal is to design the infrastructure to allow the industrial park and its contextual city to thrive, as an economic system. Develop green masterplans including symbiotic infrastructure plans and infrastructure project concept notes for the 3 locations.

The scope of work is predicated by the ambition to achieve industrial-urban symbiosis. Thus, future strategic infrastructure is to be planned and designed to serve both the industrial park and the wider city in a green way. This extends to planning and engagement with not only those responsible for the development of the industrial park but also, the city council and local businesses. The consultant will be the primary expert for resource efficiency and cleaner production deliverables with supervision from the team leader.

2. Methodology

2.1. Stakeholder Identification and Consultations

The consultant carried out a stakeholder analysis to identify the key stakeholders that may influence or be impacted by the sustainable industrialization in the target areas (See Annex 1). The target stakeholders were engaged through bilateral and multilateral meetings. Stakeholder consultations aimed at ensuring that the proposed sustainability options are in the interest of stakeholders and beneficiaries. The consultant engaged with the above stakeholders to integrate their opinions in designing RECP improvement measures, carrying out material and energy flow analysis, and identifying industrial symbiosis synergies. Stakeholder consultation was conducted by holding online and physical meetings.

Discussions with stakeholders were guided by questionnaires and toolkits (indicated in Annex 4). The Data collected from target stakeholders was analyzed to inform green projects for DPEIZ.

2.2. Material and Energy Flow Analysis

Material Flow Analysis (MFA) is the study of the physical flows of natural resources and materials into, through and out of a given system. Material flow analysis helps to identify waste of natural resources and other materials in a defined system that would otherwise go unnoticed in conventional economic monitoring systems. Material flow analysis enables manufacturing entities to trace the flow of raw materials through the company; retrace waste to the point where it is generated; identify weaknesses in the production

process; and set priorities for appropriate measures aimed at minimizing waste and emissions.¹ Material flow and energy flow analysis was carried out for DPEIZ (starter sectors including cassava, seed oil, fish, ethanol, coffee, fruits and vegetables and tourism) to:

- i. Establish waste generation trends of the potential sector, and select feasible sectors (process and activities) based on the environmental bearing capacity of the site,
- ii. Identify potential areas for substitutions of materials.
- iii. Detect opportunities for new technologies that help reduce inefficiencies in energy and materials use, increase domestic reuse or recycling, and the use of alternative materials.

Material and energy flow analysis was carried out using a methodology adopted from the UNIDO RECP toolkit see [PR-4-Worksheets-4_0.doc \(live.com\)](#). Material flow was calculated based on the law of mass balance with the formula in Equation 1.

$$\sum_{i=1}^n M_i = \sum_{o=1}^n P_o$$

Equation 1

Since DPEIZ is under the pre-start phase, data used in the toolkit was obtained from operational enterprises in Uganda with similar process operations as the feasible sectors. Additional data was obtained from published resource use and environmental performance indicators of the target sectors.

Data and information obtained from material and flow analysis were used to establish energy, water, and emission (effluent) intensities of potential sectors. The established intensities were used to calculate projected energy and water demand, GHG emission, and wastewater pollution load using the formulas below.

$\text{Pollution load} = K \sum_1^n C_i Q_i \Delta t$ <p>Equation 2</p>	$\text{GHG reduction} = \sum_j^n F_j E_j$ <p>Equation 3</p>	$\text{Water Demand} = \sum_p^n W_p O_p$ <p>Equation 4</p>
$\text{Energy Demand} = \sum_p^n E_{in_p} O_p$ <p>Equation 5</p>		
<p>Where</p> <p>k-Conversion constant</p> <p>C-Concentration of a Pollutant</p> <p>Q-wastewater flow rate</p> <p>Δt-Period of Production</p>	<p>F-GHG emission factor</p> <p>E-energy saving potential.</p> <p>j-Energy Efficient Option</p> <p>i-Pollution parameter</p>	<p>p- type product processed.</p> <p>W-Water Intensity</p> <p>O-Production Output</p> <p>E_{in}-Energy intensity</p>

¹ [PR-3-Textbook-heft3_14072003neu \(unido.org\)](#)

2.3. Identification of Resource Efficient and Cleaner Production Options

In practical terms, RECP entails the continuous application of preventive environmental strategies to processes, products and services to increase efficiency and reduce risks to humans and the environment. RECP addresses the three sustainability dimensions individually and synergistically: a) heightened economic performance through improved productive use of resources, b) environmental protection by conserving resources and minimizing industry's impact on the natural environment, and c) social enhancement by providing jobs and protecting the wellbeing of workers and local communities.

To identify RECP options for the feasible sectors. The consultant engaged the technical team of operational manufacturing enterprises in Uganda with similar process operations as feasible sectors for DPEIZ in order to establish business-as-usual operating practices. The proposed RECP measures were informed by successfully implemented RECP options in manufacturing enterprises in Uganda as well as published best available practices and technologies.²

2.4. Identifying Industrial Symbiosis Synergies and Infrastructure Layout Plan

Industrial parks use large quantities of resources, resulting in considerable waste. This accelerates the rate of raw materials' depletion and waste accumulation creating a need for stakeholders to shift from linear to circular business models by adopting novel strategies. Industrial Symbiosis (IS) employs a cross-organizational perspective to seek synergistic pairings of one company's waste output to another company's input, enabled by inter-firm cooperation through resource and information sharing.³ IS encompasses all types of interfirm cooperation to achieve a green, waste-free supply chain and at the same time to attain profits.

In order to develop an industrial symbiosis layout plan, the consultant undertook mapping of industrial symbiosis synergies using UNIDO industrial symbiosis identification tool accessible from [Eco-Industrial Parks - Tools | UNIDO Knowledge Hub](#). The identified Industrial symbiosis synergies were screened, and evaluated, to select priorities industrial symbiosis synergies (project).

3. Findings From the RECP Assessment

3.1. Status of Dero Pakwach Eco Industrial Zone

Pakwach Industrial Park is in Pakwach district, in the West Nile region of Uganda. It borders with Nebbi district to the West, Nwoya and Amuru districts to the East, the Democratic Republic of Congo (DRC) to the South-West, Arua to the Northwest, and Buliisa district to the South. The park is located close to the Albert Nile and Kabalega National Park. Atara village, Alwi sub-county approximately 9.1 km west of Pakwach Central Business District along Pakwach -Nebbi road. It covers approximately 500 acres of land and is intended to be a regional Science and Technology Park (STIP) and agricultural value addition industry and logistics industrial park as per the UIA's July 2021 industrial parks development status report by Uganda Investment Authority (UIA).

Pakwach Industrial Park is in the pre-planning phases. At the period of the field visit, the park didn't have support infrastructure including park service roads, water, and energy supply infrastructure. The potential sector for Pakwach Industrial Park includes cassava processing (flour and starch), fruits and Vegetables, Fish, Seed oil, ethanol, cold chain service, briquettes and Tourism.

² [BAT reference documents | Eippcb \(europa.eu\)](#)

³ Zhiquan Yeoa,b, Donato Masic , Jonathan Sze Choong Lowb , Yen Ting Ngb Puay Siew Tanb , Stuart Barnes Tools for promoting industrial symbiosis: A systematic review, WMG, International Manufacturing Centre, University of Warwick, Coventry, CV4 7AL [Tools for promoting industrial symbiosis: A systematic review \(warwick.ac.uk\)](#)

3.2. Material and energy Flow analysis for DPEIZ

Material and energy flow analysis (MEFA) was carried out for DPEIZ to identify and quantify the flow of materials and energy in the system. This aimed at identifying feasible sectors for DPEIZ, Resource Efficient and Cleaner Production (RECP) options for improving resource productivity, mitigating waste, and managing material resources as strategies to facilitate the creation of eco-industrial parks. This will contribute to energy savings, reduction in GHG emissions as well as the sustainable use of non-renewable natural resources.

3.2.1 Cassava Processing

According to the Uganda Investment Authority, cassava plants are widely grown in the West Nile, with yields of up to 14,000 kgs per acre. In Pakwach district, cassava processing is majorly done by small and medium-scale enterprises that apply batch and traditional processes which involve the use of sun/solar drying and artisanal fabricated driers. Discussions with SMEs in Pakwach reveal that the Cassava flour business is profitable and promising in Uganda. There is a growing demand in the market for high-quality cassava flour by breweries and bakeries, similarly on the international market there is a growing demand for cassava starch for pharmaceutical applications. To produce such quality cassava products requires scaling up production operations and investment in modern processing facilities.

Cassava flour production involves;

- **Cleaning:** The cassava roots are washed and peeled to remove dirt and impurities
- **Pulping:** The cassava roots are cut into small pieces
- **Drying:** The cassava pieces/flakes are dried using a dryer or a sun dryer to reduce the moisture content
- **Crushing:** The cassava pieces/flakes are broken and milled to produce fine flour
- **Screening:** The cassava flour is sieved to remove any lumps or impurities and obtain a uniform product

While production of cassava starch includes

- **Cassava root receiving and washing:** Cassava roots are delivered to the factory, weighed, and stored on a concrete floor. They are then cleaned to remove soil, sand, peels, and impurities.
- **Cassava crushing and extraction:** Cassava roots are chopped and ground by a rasper to release the starch granules from the cells. The starch slurry is then passed through a series of extractors, from coarse to fine, to separate the starch from the pulp and fiber.
- **Cassava starch refining and concentration:** The starch slurry is further purified by washing, sieving, and filtering to remove impurities and residual fiber. The starch slurry is then concentrated by a hydrocyclone or a centrifuge to increase the starch content and reduce the water content.
- **Cassava starch dewatering and drying:** The concentrated starch slurry is dewatered by a centrifuge or a vacuum filter to reduce the moisture content to 35-40%. The wet starch cake is then dried by a flash dryer or a rotary dryer to obtain the final product with a 12% moisture content.
- **Cassava starch screening and packaging:** The dried starch is screened by a sieve or a sifter to ensure uniform particle size and quality. The starch is then packed in bags or stored in silos for sale or further processing.

Discussion with cassava flour producing SMEs reveals that the Production of 1 ton of cassava flour requires about 5 m³ of water. Water is mainly required for washing and cleaning purposes and immediately turns into wastewater. The major waste associated with cassava flour production is peelings estimated at about 100 kg per ton of cassava. Cassava peeling waste doesn't pose challenges because it can be used as input in briquet production. The wastewater pollution load is relatively low and largely organic because it is majorly a physical process without use of chemicals. On average the energy demand in the production of cassava flour is 814 kWh_{eq}/ton where thermal energy accounts for about 60%.

The production of 1 ton of starch requires about 4 to 6 tons of cassava, 10 to 25 m³ of water, 190 to 260 kWh of electricity, and 1000 to 2000 MJ of heat (steam). The waste streams from the production of 1 ton of starch include low grad starch 4 kg, sand 170 kg, cassava peels 100kg, rhizomes 170kg, wet pulp 2500kg, and wastewater 8.4 to 20 m³. Wastewater from the cassava starch process is generally organic matter and has a high level of chemical oxygen demand or COD (4800–70,000 g m⁻³), high total volatile solids (1200–39,000 g m⁻³), and low pH (4.3–5.6). The figure below shows the material flow analysis of cassava flour and starch production.

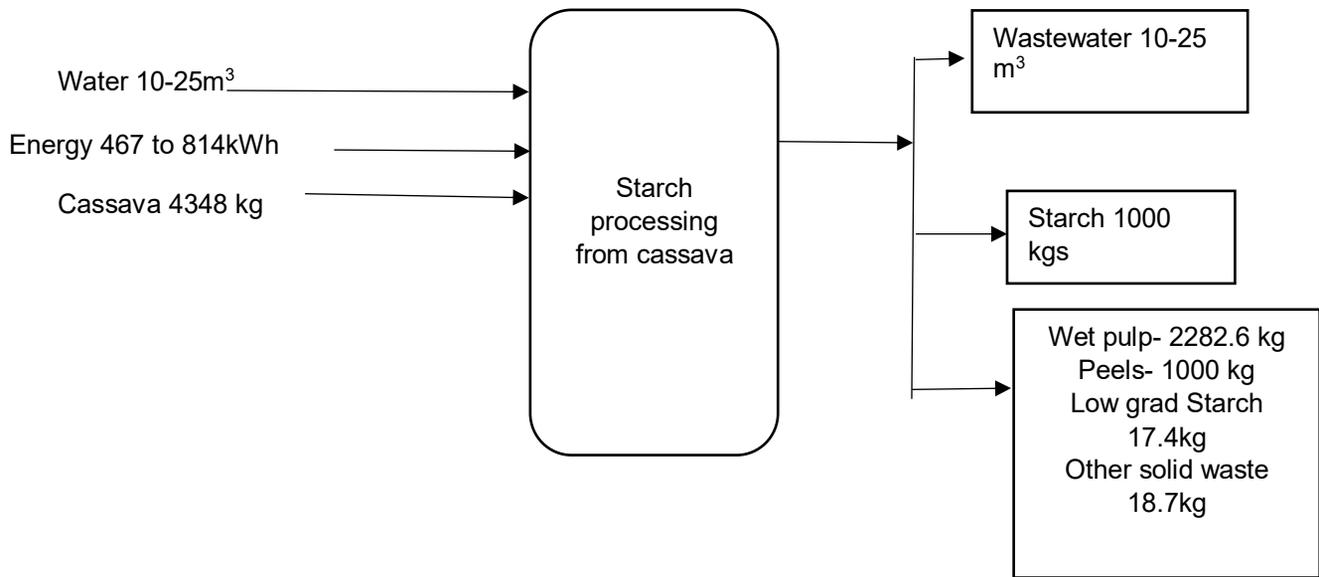


Table 1 Material and energy flow starch production from cassava

company	Determined product output per day	Energy demand in kWh eq	water m3	wastewater m3	cassava peels tons	Wet pulp kg	low grade starch kg	other solid waste kg
Cassava flour	128	104,192	512	512	12.8	nil	nil	nil
Cassava starch	128	104,192	3200	3200	12.8	21.78	0.512	2.4

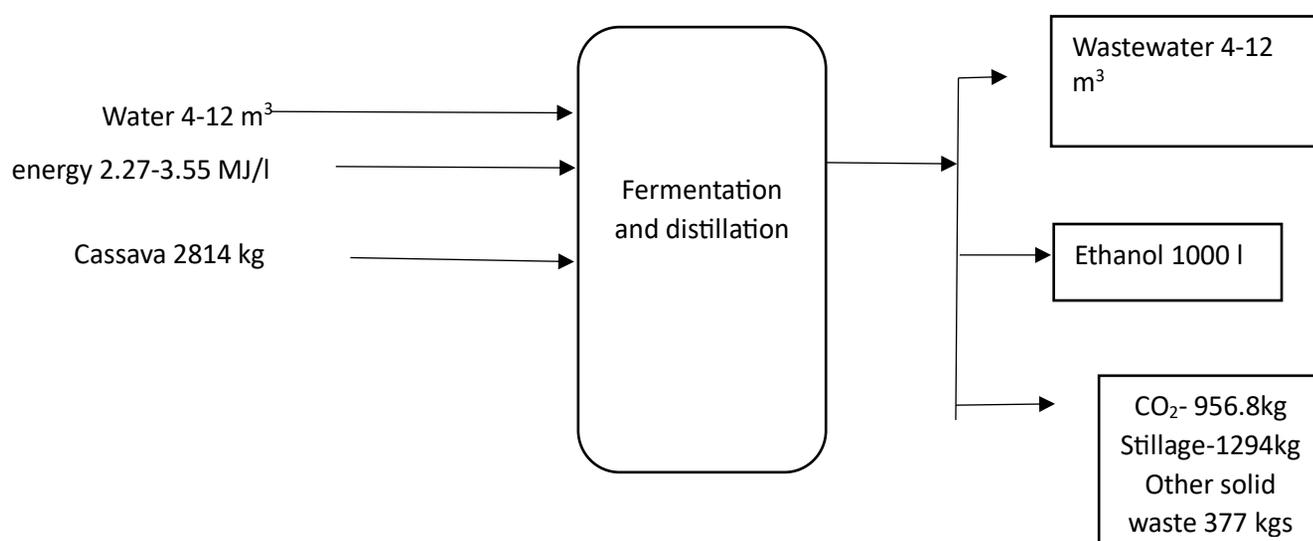
From the RECP perspective cassava starch process has a higher water, and waste footprint compared to processing cassava flour. Mass balance shows that processing 1 ton of starch requires 5 times more water compared to producing a similar quantity of cassava flour. Furthermore, from the value chain analysis, SMEs were more interested and experienced in processing cassava flour due to the readily available market. Therefore, for DPEIZ priority should be given to cassava flour process. Cassava flower can be only

anchored at DPEIZ when water supply challenges are addressed, and best available cassava starch processing techniques and practices are adopted.

3.2.2 Ethanol Production

Due to high cassava production in the West Nile region, the production of ethanol is potentially feasible for DPEIZ. However, ethanol production is water and energy-intensive and is associated with the generation of wastewater with a high pollution load. Information from distilleries (ethanol-producing companies) in Uganda shows that water demand in ethanol production ranges from 0.4-1.2 m³ per hectoliter of ethanol produced. The ethanol yield rate of ethanol is reported to range from 26-37% of cassava flour used.

Material and energy flow of (cassava brew) ethanol production facility



Risk associated with ethanol production.

The industrial production of ethanol by fermentation results in the discharge of large quantities of high-strength liquid wastes. Distillery wastewater is one of the most polluted waste products to dispose of because of the low pH, high temperature, dark brown color, high ash content, and high percentage of dissolved organic and inorganic matter with high biochemical oxygen demand (BOD) and chemical oxygen demand (COD) values. Due to the large volumes of effluent and the presence of certain recalcitrant compounds, the treatment of this stream is rather challenging by conventional methods. Distillery wastewater, without any treatment, can result in the depletion of dissolved oxygen in the receiving water streams and poses a serious threat to the aquatic flora and fauna. Because of the high starch and moisture content, the cassava pulp decays quickly causing environmental problems such as the formation of foul smell due to the starch fermentation. Furthermore, the production of ethanol from cassava may compete with food security.

Therefore, ethanol production can only be produced when strategic interventions are put in place not to compromise food security and state-of-the-art wastewater water technologies are adopted including recovery of biogas from wastewater and bio filters installed in fermentation rooms to control smell.

Table 2 Characteristics of the ethanol wastewater used in this study.

Parameters	Values
------------	--------

Total chemical oxygen demand (COD)	80,000 mg/l
Total volatile fatty acids (VFA)	12,600 mg/l
Total suspended solids (TSS)	31,700 mg/l
Total phosphorous (P)	1070 mg/l
Total nitrogen (N)	825 mg/l

3.2.3 Fish Processing

According to the value chain analysis, the annual fish catch in Pakwach district is about 58,204 tons. The small fish types (Pelagics) account for 20% of total fish catch. The availability of reasonable quantities of fish, makes fish a potential sector of DPEIZ. However, fish processing is an energy and water intensive process as shown in the table below.

Currently, the Cwaranguta group (in Pakwach) uses a solar drier, locally designed, and fabricated by NARO to dry pelagic fish. The technology relies on availability of sunlight and this can compromise quality, especially in the rainy season. To the meet growing demand for dried fish and improve quality, the group needs to upgrade to a solar-biomass hybrid drier. The solar-biomass hybrid drier improves quality control and reliability. Furthermore, at least 1-2 tons of fish (the bigger type) can be harvested per day in Pakwach. This fish can be directly transported in refrigerated trucks to the Industrial Park and fish can either be processed into fish fillets or smoked using the purified-smoke technology.

Table 3 Water and energy demand and pollution associated fish processing in Uganda.

No	Major fish products	Energy demand kWheq/ton	Water demand in m ³ /ton	Pollution load kgCOD/ton
1	Fish fillet	425	15	90
2	Dried fish	-	0.75	<1
3	Smoked fish	294	3	<2

Due to high water demand and pollution load associated with fish fillet processing it is recommended not to prioritize fish fillet production for DPEIZ. This is because the high pollution load poses environmental challenges to the River Nile and Kabalega National Park that boards DPEIZ. Pakwach catches a high volume of pelagic fish that are usually processed by smoking and sun drying. This makes fish smoking and drying potential feasible process operations. The pollution loading associated with fish drying and smoking is relatively low compared to the processing of fish fillets. This makes fish drying and smoking the most technically feasible sectors for DPEIZ.

3.3.4 Seed oil Processing

The production of seed oil (Peanuts, soybean, sesame, and sunflower seeds) including shelling and cleaning of seeds. In the subsequent phase, a roller mill cracks the kernels into smaller pieces. Then, the

cracked seeds are conveyed to the cooker dryer where they cook for about 20 to 30 minutes at 190 degrees Fahrenheit with moisture levels controlled at 9-11%. The cooking temperature is crucial for increasing the yield of oil during extraction. After cooking, the material is dried to 2-3% moisture. The dried mash seeds are then sent to the pressing machine where about 80-90% of oil is extracted. After the first pressing, the meal might still contain 14-20% residual oils (RO), while the second pressing can reduce RO to about 6%. The unique dual-press design efficiently crushes the seed material twice in a single pass. Using mechanical force to double-squeeze oil from the peanuts, the Super Duo discharges a press cake containing about 5-7% RO.

Table 4 Oil yield for different seeds⁴

Seed	Yield
Peanuts	38-45%
Sunflower seed	32-40%
Sesame	50-56%
Soya beans	18-20%

Material flow and energy flow of seed oil processing

The oil content in peanuts is reported to range from 35% to 50%. The cold pressing can achieve up to 85% extrusion of oil from peanuts. The residue is a cake meal containing a maximum of 15% oil that be extracted using solved extraction or double pressing. Water audits in Oil mills in Uganda show that water demand varies between 2 to 5 m³ per ton of filtered oil. However, soya oil mill is reported to consume up to 6 m³ per ton of filtered oil. Discussions with the health and safety manager of AK Oils indicate that the electrical energy demand for cold-hot press oil mills ranged from 80-130kWh per ton. For the integrated oil mills and refinery, the energy demand and water demand are shown in Table 4.

Table 5 specific energy and water consumption of integrated seed oil mill

	electricity	Steam	water	wastewater
Integrated oil mill and refinery	120-420 kwh/ton	480-1120kWh	4-12 m ³	4.5 to 13

In refined edible seed oil production, several chemicals are used including phosphoric acid, Sodium Hydroxide Sulphuric acid. For Phosphoric acid, an acid strength in the range of 20 to 60 wt % is preferred. In the neutralization of crude oil, a total of 1–6 kg NaOH /t oil is used depending on the function of the type of oil. Sulphuric acid used in soap-stock splitting amounts to 100–250 kg H₂SO₄/t soap. The intensive use of chemicals in the refining process results in wastewater with a high pollution load. This makes integrated seed oil mills more polluting compared to cold-hot press oil mills.

According to the value chain analysis, the determined maximum production capacity of seed oil production for DPEIZ is about 4 tons per day. The material and energy flow of a facility with a production capacity of 4 tons of oil per day is shown in Table 6 below.

⁴ See [8 Steps To Start a Small Edible Oil Manufacturing Business \(oilxpeller.com\)](http://oilxpeller.com)

Table 6: Material and energy balance for seed oil processing companies in DPEIZ

	Calculated production capacity per day	Energy Demand	Water m ³ /ton	Wastewater m ³	cake in tons/ton
Sesame (integrated mill and refinery)	4	2587	48	48	3.36
Sesam oil (cold-hot press)	4	2400	16	16	4.2

Environment impact of seed oil Processing

Key environmental aspects of oilseed crushing, and vegetable oil refining are the consumption of water, steam, electricity, hexane, bleaching earth, acids, caustic soda, emissions to air (VOCs, H₂S, CO₂) and wastewater. Pre-treatment of edible seeds is energy-demanding but has no direct water requirements. Extraction and refining consume large volumes of water and generate effluent that is difficult to remediate. Seed oil mill extraction generates wastewater with high organic loads. The soya bean oil mills are reported to demand more water on average of 6 m³ per ton of filtered oil BODs and COD loads of effluents from oil mills range from 600 to 900 mg/L and 800 to 1400 mg/L. Wastewater from integrated oil mills has a high pollution load as indicated in Table 6. The pH of the wastewater from integrated oil mills varies because both acids (e.g. H₃PO₄ for degumming, H₂SO₄ from soap splitting and alkalis (NaOH for neutralization during chemical refining) are typically added. The wastewater also contains high concentrations of organics, with chemical oxygen demand (COD) concentrations of up to 8.3 g/L being reported. High total phosphate (TP) concentrations are found in effluent from residual oil phosphatides from H₃PO₄ (if used for degumming).

Table 7: Characteristics of wastewater from seed oil processing factories

Seeds	COD mg/l	TP mg/l	SO ₄ ²⁻ mg/l	TSS g/l
Sunflower	8300-9700	52-420	10800-11700	1500-2000
Peanuts	1500-8400	10-152		

Integrated seed oil mills are water and chemical intensive. The water demand of an integrated seed oil mill is almost 3 times that required in cold-hot press oil mills. Due use of chemicals in oil refining the wastewater from integrated mills is usually acidic with a high COD load (above 116.4 kgCOD/ton). This makes cold-hot press oil mills a more technically feasible process operation for DPEIZ.

3.2.5 Coffee Processing

In Uganda, green (clean) coffee beans are obtained by either wet processing or dry technique. Wet processing is processed in three major stages:

- i. Removal of pulp and mucilage followed by washing to obtain clean wet parchment.
- ii. Drying of the parchment coffee
- iii. Removal of the parchment and film through hulling followed by grading to obtain the desired grades (sizes) of the clean coffee.

Wet processing requires a significant amount of water, with estimates ranging from 5 to 50 liters of water per kilogram of processed coffee.

Dry processing involves two stages: Drying of the cherries (usually under the sun) and removal of the dried coverings (husks) in a mechanical operation (hulling). The dry coffee process requires little water usually less than 1 liter per kilogram. This method requires much less water than wet processing, making it a more water-efficient option for coffee processing.

Material and energy flow of coffee processing

The value chain analysis established the feasible production of coffee processing to be 5 tons per day. Coffee processing factories (wet and dry process) each with a production capacity of 5 tons per day were assumed to establish energy and water demand as well as waste generation as shown in table 8.

Table 8 material and energy flow for coffee processing techniques

Processing techniques	Production capacity ton per day (green beans)	Energy demand	Water demand	Wastewater	Coffee husks
Wet coffee processing	5	-	125	127	2.3
Dry Coffee processing	5	250	5	5	5

Environment risks and opportunities

The analysis of liquid pollutants from wet coffee processing shows that the waste (pulp juice and mucilage) has high organic components, 66.5% and 90.2%, respectively. This wastewater (pulp juice and mucilage) is acidic with pH ranging from 4.75- 3.67. The pollution parameter values of wastewater from the wet coffee process are BOD of up to 25,600 mg/L and COD as high as 45,000 mg/L.⁵ Liquid Pollutants from wet processing are known for, causing eutrophication, and acidification. In sustainable coffee processing systems, the liquid pollutants are subject to anaerobic treatment to recover energy (biogas) and fertilizer (bio-slurry).

Dry coffee processing produces large quantities of coffee husks and generally, doesn't generate wastewater. Coffee husks pose major challenges because they are usually used as mulches to conserve moisture and can be compressed into biomass briquette.

To minimize water demand and environmental risks associated with wet coffee processing. It's recommended that coffee processing enterprises be anchored at DPEIZ invest in dry coffee processing. This will contribute to reducing the overall water demand and pollution load of the industrial park.

3.3. Selection of Priority Sectors for Pakwach Industrial Park

The potential sectors for Pakwach industrial park are predominantly agro-food processing enterprises. The agro-food processing enterprises are water intensive and generate huge volumes of wastewater. Wastewater generated from food production and agricultural activities is a major source of environmental pollution. It is also among the most difficult and costly waste to manage because food processing wastewater contains large quantities of nutrients, organic carbon, nitrogenous organics, inorganics, suspended and dissolved solids, and it has high biochemical and chemical oxygen demands. Wastewater generation in food processing is directly proportional to water demand. Given that Pakwach industrial park is located close to the Nile and kabalega National Park, priority is given to less water-intensive industries/processes. Water-intensive processes/industries such as fish filet production (15 m³/ton), wet

⁵ [A0240105.pdf \(ijres.org\)](#)

coffee processing (50 m³/ton), cassava starch (25 m³/ton), and ethanol production (12 m³) were not considered to be in Pakwach Industrial Park (see Figure 3).

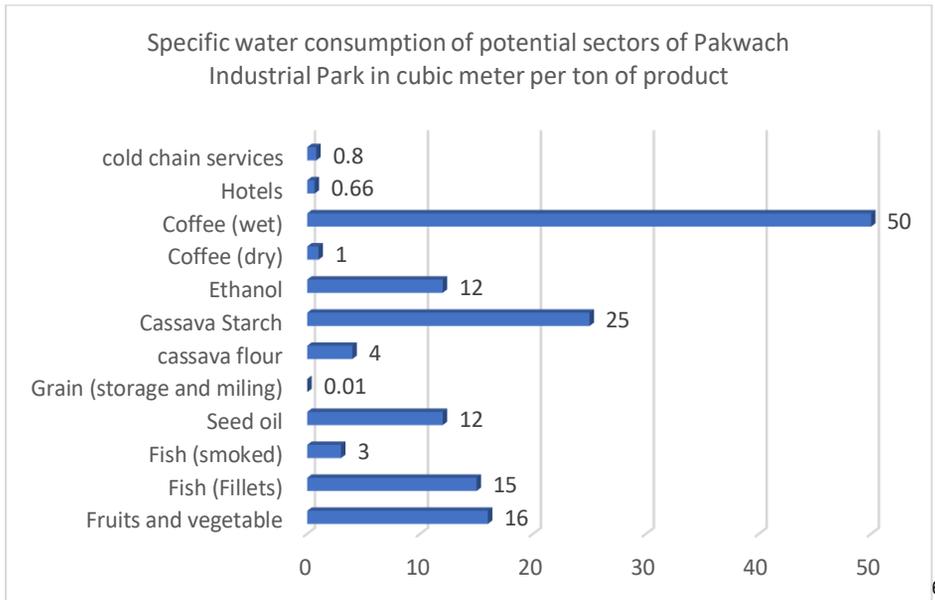


Figure 1: Specific water consumption of potential sectors for Pakwach Industrial Park

Cassava processing: From the RECP perspective cassava starch process has a higher water, and waste footprint compared to processing cassava flour. Mass balance shows that processing 1 ton of starch requires 5 times more water compared to producing a similar quantity of cassava flour. Therefore, the cassava flour process is more technically feasible for DPEIZ than starch processing.

Ethanol production: Ethanol production generates large volumes of effluent and contains certain recalcitrant compounds; the treatment of this stream is rather challenging by conventional methods. Additional production of ethanol from cassava can comprise food security for Pakwach. Therefore, ethanol production can only be produced when strategic interventions are put in place not to compromise food security and state-of-the-art wastewater water technologies are adopted including recovery of biogas from wastewater and bio-filters installed in fermentation rooms to control smell.

Fish processing: Due to high water demand and pollution load associated with fish fillet processing. It's recommended not to prioritize fish fillet production for DPEIZ. This is because the high pollution load poses environmental challenges to the River Nile and Kabalega National Park that boards DPEIZ. Pakwach catches a high volume of pelagic fish that are usually processed by smoking and sun drying. The pollution loading associated with fish drying and smoking is relatively low compared to the processing of fish fillets. This makes fish drying and smoking the most technically feasible sectors for DPEIZ.

Seed oil production: Integrated seed oil mills are water and chemical intensive. The water demand of an integrated seed oil mill is almost 3 times that required in cold-hot press oil mills. Due use of chemicals in oil refining the wastewater from integrated mills is usually acidic with high COD load (above 116.4 kgCOD/ton). This makes cold-hot press oil mills more feasible process operation for DPEIZ.

Coffee processing: To minimize water demand and environmental risks associated with wet coffee processing. It's recommended that coffee processing enterprises to be anchored at DPEIZ invest in dry coffee processing. This will contribute to reducing the overall water demand and pollution load of the industrial park.

⁶ Water use in the hotel is measured in m³ per guest per day.

Table 9 Calculated pollution load of potential sectors for DPEIZ

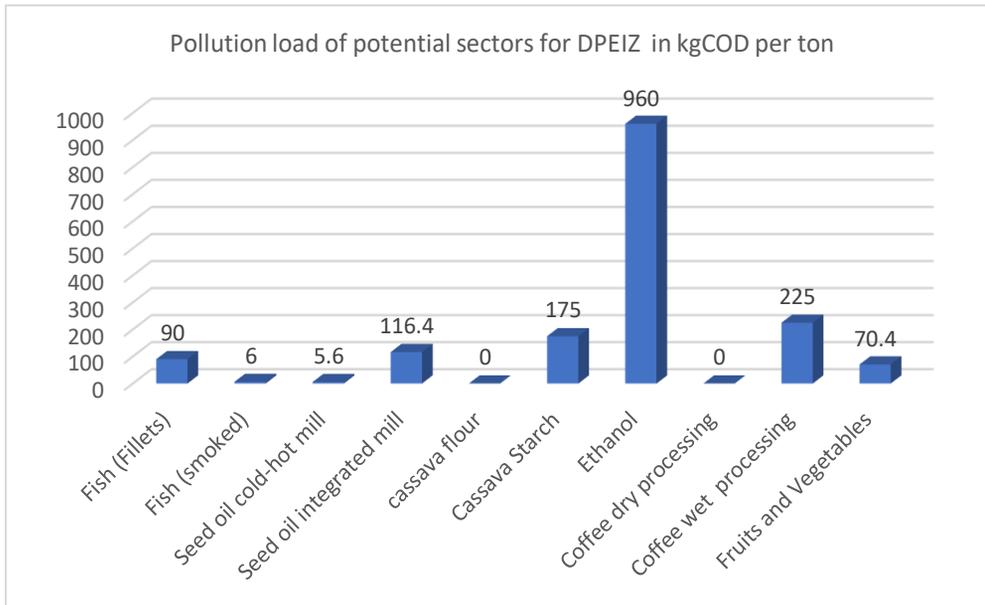


Table 10: Projected Material and energy flow of the agro-processing enterprises in Pakwach Industrial Park business as usual scenario

No	Agro-processing sector	Calculated Production capacity per day(tons/day)	Energy demand(kWh)	Water demand(m ³)	Wastewater generation(m ³)	Solid waste generation (organic)/tons	GHG emissions(tons)
1	Fish (smoked)[1]	5.12	1505.894	15.36	15.36	0.256	0.93365453
2	Fruits and vegetables	7.7	848.003	23.1	23.1	1.001	0.52576186
3	Cassava Processing [2]	128.2	44870	512.8	512.8	67.305	27.8194
4	Seed oil	4	6160	48	48	4.2	3.8192
5	Coffee Processing (dry process)	5	1750	5	5	5	1.085
6	Hotel (50 rooms)	50	575	16.675	16.675	0.0125	0.3565
7	Tourism camp site	32	1500	12.5	12.5	0.025	0.93

8	Briquettes	15	11250	15	15	0.75	6.975
Total		247.02	68458.9	648.435	648.435	78.5495	42.444516

To improve resource productivity and establish an eco-industrial Park it is recommended that the enterprises in Pakwach Industrial Park adopt Resource Efficient and Cleaner Production. To significantly improve energy productivity and minimize the associated emissions specific focus should be given to cassava flour and seed oil processing because they account for 66% and 16% of total energy demand respectively (see Figure 1). Similarly, to minimize wastewater pollution load special focus should be given to cassava flour production and seed oil processing because they account for 79% and 7% percent of water demand respectively (see Figure 2).

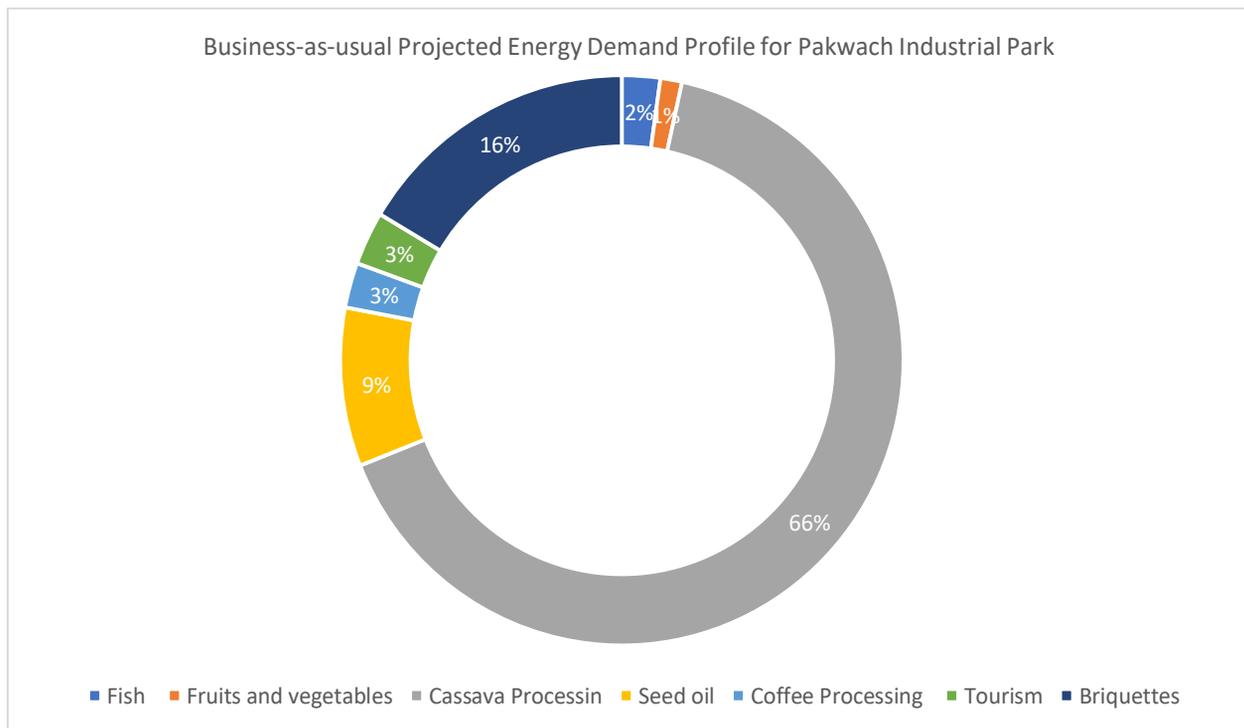


Figure 2: Projected energy demand profile of Pakwach Industrial Park

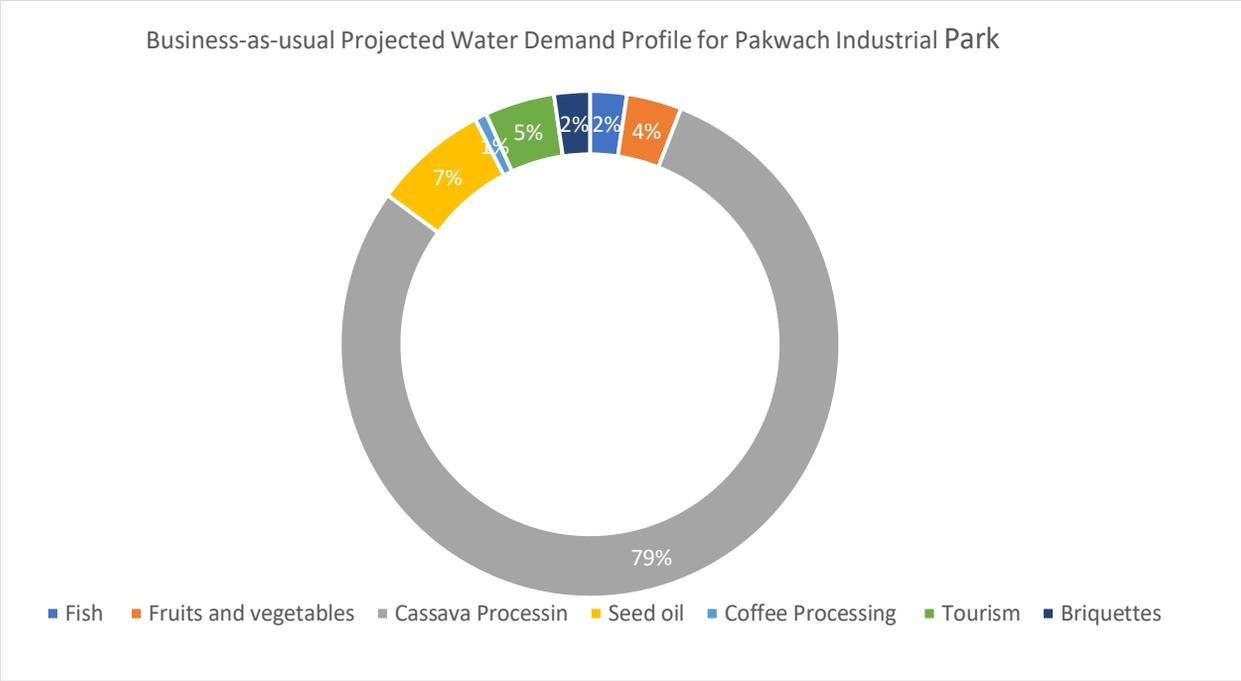


Figure 3: Projected water demand for Pakwach Industrial Park

3.4. Resource Efficient and Cleaner Production options for DPEIZ

Resource Efficient and Cleaner Production (RECP) is a preventive, enterprise-level approach to improve resource use, reduce environmental pollution, and contribute to sustainable industrial development. RECP applies an integrated environmental strategy to processes, products, and services to increase efficiency and reduce risks to humans and the environment. RECP addresses the three sustainability dimensions individually and synergistically: heightened economic performance through improved productive use of resources, environmental protection by conserving resources and minimizing industry’s impact on the natural environment, and social enhancement by providing jobs and protecting the well-being of workers and local communities. It’s been projected that through the adoption of RECP, the material and energy flows of the Industrial Park will be as shown in Table 2.

Table 3-11: Projected Material and energy flow of the agro-processing enterprises in Pakwach Industrial Park Green Manufacturing scenario

No	Agro-processing sector	Calculated Production capacity per day(tons/day)	Energy demand(kWh)	Water demand(m ³)	Wastewater generation(m ³)	Solid waste generation (Organic)/tons	GHG emissions(tons)
1	Fish (smoked)]1]	5.12	1107.968	15.36	15.36	0.256	0.6869402
2	Fruits and vegetables	7.7	550.056	15.4	15.4	1.001	0.3410347

4	Cassava Processing [2]	128.2	19230	384.6	384.6	67.305	11.9226
6	Seed oil	4	2400	16	16	4.2	1.488
7	Coffee Processing (dry process)	5	250	5	5	5	0.155
8	Hotel rooms	50	147.5	5.675	5.675	0.0125	0.09145
9	Tourism camp site	32	600	11.35	11.35	0.025	0.372
10	Briquettes	15	9300	15	15	0.75	5.766
Total		247.02	33585.52	468.385	468.385	78.5495	20.82302

Comparing business-as-usual and green manufacturing material flow projections it's estimated that implementation of RECP among enterprises within Pakwach Industrial Park can reduce energy consumption by 34873.37 kWh, water demand by 180.05 m³ and GHG emissions by 21.62 tCO₂eq per day. This translates to annual energy savings of 10880 MWh, water savings of 56175.6 m³ and GHG emissions reduction of 6745.44 tCO₂eq. Such improvement in water and energy productivity as well as reduction in GHG emissions can be achieved by implementing RECP measures (water and energy efficient options) shown in Tables 3 and 4.

3.5. Proposed Water Efficient and Conservation Measures

Table 3-12: Proposed cleaner Production Technologies to improve water use efficiency.

No	Resource Efficient and Cleaner Production option	Technical description	Benefits (environmental, economic and social)
1	Use of low-pressure foam and/or gel instead of water to clean walls, floors, and/or equipment surfaces.	Low-pressure foam cleaning can be used instead of traditional manual cleaning with water hoses, brushes and manually dosed detergents. It can be used to clean walls, floors, and equipment surfaces. A foam cleaner, such as an alkaline solution, is sprayed on the surface to be cleaned. The foam adheres to the surface. It is left for about 10–20 minutes and is then rinsed away with water. Centralized systems supply pre-mixed cleaning solutions and pressurized water from a central unit and during cleaning they automatically change between foam spreading and rinsing.	The use of low-pressure foam and/or gel can reduce water, chemical and energy consumption compared to the use of traditional water hoses, brushes and manually dosed detergents. Implementation of low-pressure foam in a cheese factory with a production capacity of 25,000 tons per year resulted in savings of 19,800 m ³ water/year and 1160 MWh/year.
3	Fitting of cleaning hoses with hand-operated triggers.	Trigger control shut-offs can be fitted to cleaning hoses with no other modification if a water heater is used to provide hot water. Automatic shut-off valves are often sold with nozzles attached. Nozzles increase the water impact and decrease the water flow rate.	For example, a hose was running for 8 h/day before installation of a trigger control and 4 h/day afterward. Therefore, use of water trigger guns achieved an annual water saving of about 237 m ³ in one of the dairy factories in western Uganda.
4	High-pressure cleaning: This involves Spraying of water onto the surface to be cleaned at pressures ranging from 15 bars to 150 bars.	In high-pressure cleaning, water is sprayed onto the surface to be cleaned at pressures ranging from 15 bars, which is considered to be low pressure, up to 150 bars, which is considered to be high pressure. Pressure of about 40–65 bars has also been described as high.	Pressure cleaning reduces water and chemical consumption compared with main hoses. The cost savings, in steam, water and wastewater, of high-pressure low-volume systems compared with low-pressure high-volume systems are reported to be around 85 %. There are

			also reduced costs associated with reduced consumption of chemicals.
5	Use of various automated control devices (flow regulators), e.g. photocells, flow valves, and thermostatic valves, to adjust the water flow. Flow regulators are used to provide a constant flow at a predetermined rate. The flow regulators can be fitted on steam lines, cleaning systems and material transfer lines.	Flow measurement and control techniques can reduce material waste and wastewater generation in food processing. Applying flow measurement and control in transfer lines allows the accurate addition of materials to storage and processing vessels and filling packaging, thereby minimizing the excessive use of materials and the formation of out-of-specification products. Sensors such as photocells can be fitted to detect the presence of materials and to supply water only when it is required. Water supplies can be turned off automatically between products and during all production stoppages.	At a chicken processing installation, the introduction of flow regulators cost less than GBP 1 000 and resulted in water savings worth over GBP 10 000/year. At a fish processing installation, the 40 % reduction in water use saved GBP 2 500/year and gave a payback period of 5 weeks.
6	Use of correct number and position of nozzles; adjustment of water pressure.	Water nozzles are widely used in the food processing sector, e.g. for washing and sometimes for thawing the product, and cleaning the equipment during processing. Water consumption and waste water pollution minimisation can be carried out by correctly positioning and directing the nozzles. In addition, water consumption can be optimised by monitoring and maintaining the water pressure of the water nozzles.	In the fish sector, a reduction in water consumption of about 0.13–0.2 m ³ /t of raw material has been reported due to use of correct number and positioning of nozzles. In white fish filleting, water consumption can be reduced by up to 90 % by installing nozzles and sprinkling the water for one or two seconds out of every three.
7	Segregation of water streams; Water streams that do not need treatment (e.g. uncontaminated cooling water or uncontaminated run-off water) can be segregated from wastewater that has to undergo treatment, thus enabling uncontaminated water recycling.	Contaminated wastewater may be segregated to receive appropriate treatment according to its characteristics. It may then be possible for the high-volume, low-polluted streams to be either recycled following suitable treatment or discharged directly to the Wastewater Treatment Plant (WWTP) without treatment. In some cases, materials can be recovered from process water for use in the process or for other uses such as animal feed. Uncontaminated water for which	Segregation of wastewater can involve a high capital cost at existing installations. However, this may be offset by the reduced operating costs due to the lower requirements for wastewater treatment (e.g. water-holding capacity, energy consumption), whether on site, at a MWWTP or a combination of both. Wastewater separation/segregation

		there is no reuse opportunity available should be discharged without treatment provided that the requirement on the recipient quality can be met. If that is not possible, it should be considered whether treatment of the specific water stream is an option, thus preventing an unnecessary load on the WWTP	systems can be installed efficiently at new installations
8	Optimization of chemical dosing and water use in cleaning-in-place (CIP). Optimizing the design of CIP and measuring turbidity, conductivity, temperature, and/or pH to dose hot water and chemicals in optimized quantities.	Design and operational features that increase the efficiency of the CIP system include: (i) using a turbidity or conductivity detector to optimize both the recovery of materials/products from water and the reuse of cleaning water during pre-rinsing and (ii) measuring pH to optimize chemical consumption.	By implementation CIP optimization (collection and reuse of detergents) in a dairy facility for at-least 6years, consumption of water decreased by 55 % and consumption of detergents decreased by 34 %. In a brewery installation, the application of one phase of CIP resulted in a 30 % reduction of water consumption for cleaning
9	Maximisation of condensate return; Recovered condensate can be reused as feed water to the boiler, heated water, for other equipment or cleaning other installations.	In this technique, water and heat which is contained in discharge condensate is taken advantage of. This recovered condensate can be reused as feed water to the boiler, heated water, for other equipment or cleaning other installations. A condensate recovery unit is a vessel which receives condensate from all practical points where condensate is produced. The vessel stores the condensate and mixes it with fresh make-up water prior to it being used as boiler feed water. If hot condensate is not returned to the boiler it has to be replaced by treated cold make-up water. The additional make-up water also adds to water treatment costs. Instead of routinely discharging condensate to the WWTP because of the risk of contamination,	If hot condensate is not returned to the boiler, it must be replaced by treated cold make-up water leading to at-least 20 % loss from the energy absorbed in the generation of the steam from which the condensate is derived. This may be the greatest single energy loss in steam use.
10	Recirculation of water from the cooling tower pond through a vessel containing electrodes	The technique involves the recirculation of water from the cooling tower pond through a	For example, in a brewery started using this method and reduced the

	made from a combination of metal oxides which act as anode where oxidising ions are generated from water.	vessel containing electrodes made from a combination of metal oxides which act as anode where oxidising ions are generated from water. Furthermore, the vessel wall acts as the cathode, reaching a pH of 13 which causes the precipitation of calcium salts on the vessel wall, preventing the concentration of salts in the tower pond and, therefore, preventing the need to purge water from the pond. Periodically, in a programmed way, the salty precipitate on the vessel wall is washed off and drained. By applying direct current voltage to electrodes in the chambers, OH ions are produced by partial electrolysis of the water	cooling towers' water consumption by 80% and the chemical consumption by 100% by avoiding continuous chemical treatment.
11	Green Cooling. Use of refrigerants without ozone depletion potential and with low global warming potential	Prevention of emissions of substances that deplete the ozone layer or have a high global warming potential by using alternative refrigerants, such as water, carbon dioxide	Substitution of refrigerants is energy-efficient for industrial cooling systems. The installation cost for use of refrigerants without ozone depletion potential and with low global warming requires an additional investment which is about 20% to 30% high compared to conventional Hydrochlorofluorocarbons (HCFCs). However green cooling can save up to 27% in electricity consumption
12	Closed-circuit cooling	The water is recirculated via a cooling tower, or a cooler connected to a central refrigeration plant, i.e. it is rechilled and returned to the equipment being cooled. If there is a need to prevent algae or bacterial growth, chemicals may be added to the recirculated water. Otherwise, the cooling water can be reused for cleaning purposes.	It is reported that closed-circuit cooling can save at-least 80 % of water consumption, compared to an open system. For example, in a brewery with a capacity of 500000 hl/year, a closed-circuit cooling system was introduced in a tunnel pasteurization unit to replace an open system that cooled using fresh water. This led to an estimated reduction in water consumption of at-least 50000 m ³ /year

3.6. Proposed Energy Efficient and Conservation Measures

Table 13: Proposed techniques to improve energy use efficiency.

No	Proposed Cleaner Production option	Technical description	Benefits
1	Frequency converters (or variable speed drivers) regulate the speed of the impeller to the required output of the motor.	Controlling the speed of the pump motor by frequency converters ensures that the speed of the impeller is exactly adapted to the required output of the pump.	The reduction of the power consumption depends on the capacity and number of pumps and motors. Generally, a 10 % reduction in the output of a pump corresponds to a 28 % reduction in the power consumption of the pump. In a Danish dairy, 203 motors were equipped with frequency converters. The total power of the motors was 1216 kW. The estimated cost of the investment was EUR 311 000. The estimated annual saving was EUR 90 000 (1 325 000 kWh).
2	Energy-efficient lighting; Measures such as energy-efficient lamps, use of natural light, or automatic light control.	More energy-efficient lighting can be attained by replacing conventional tungsten light bulbs or other low-efficiency light bulbs with more energy-efficient lights such as LED lights; ii. using devices such as sensors or room-entry switches to control the lighting; iii. allowing more natural light to enter, e.g. by using vents or roof windows;	In a Tea factory, 74 fluorescent tubes of 36W each were replaced with LED tubes of 12W each. This investment cost Ugx 18,250,000/= and resulted in energy savings of over 10,000 kWh/year. The payback period was about 3.5 years.
3	Use of high-efficiency motors to minimise motor losses.	Over 60% of all electrical energy consumed in industries is used by electric motors. Improving the efficiency of electric motors reduces operating costs and improves enterprise productivity. Motor losses can be minimized by specifying higher-efficiency motors where feasible. This can be done at procurement by giving preference to motor international Efficiency (IE) rating of IE 2, IE 3 and IE 5	Procuring and installation of Efficient motors can achieve up to 30% reduction in energy consumption compared to conventional of standard efficiency.
4	Thermal vapour recompression (TVR). This technique is applicable in sugar starch processing; tomato, apple and citrus juice	Water vapor from an evaporator is entrained and compressed with high pressure steam in a thermos-compressor so it can be condensed in the evaporator heat exchanger. TVR makes use	Significant energy and cost savings and its ideal for low boiling-point rise liquids.

	<p>concentration; brewing; and in the evaporation of milk and whey.</p>	<p>of steam injection compressors to compress the vapour. Steam injection compressors may have fixed or variable injection nozzles. The thermal energy needed for compression is live steam from a boiler. The live steam passes through the injection nozzle and is throttled to the pressure level of the receiving vapour. Vapour is entrained as a result of the difference in speed. Vapour and live steam are mixed in the mixing chamber. Changing the flow aperture in the diffuser determines the pressure at which the mixed steam leaves the steam injection compressor.</p>	
<p>6</p>	<p>Reduction of air leaks and optimization of pressure settings of the compressed air system. Ensure that leak prevention measures and periodic leak tests are carried out. Set the pressure at the compressor to the maximum required and then regulate it at each individual application.</p>	<p>Consumption losses during production downtime can be avoided by sectorization of pressure (multiple changes to the pressure distribution). Several additional techniques can be implemented to optimize compressed air generation and use.</p> <ul style="list-style-type: none"> i. replace pneumatic installations with electric ones. ii. use a variable speed compressor. iii. adjust the pressure level (more pressure is provided with a separate compressor); iv. adapt the compressor to the need (flow/pressure). <p>The pressure at the compressor can be set at the maximum required and then regulated at each individual application to minimize the energy required to produce compressed air and reduce leakage. For applications which require higher pressures or have longer operating hours than the majority of the applications that use compressed air, it may be more energy- and cost-effective to install a dedicated compressor</p>	<p>In a grain milling installation with a production capacity of around 500 tonnes/day the energy losses were reduced by 10%. The cost of implementation was EUR 7000, and the technique also led to achievement of annual savings of EUR 7000</p>

7	Energy efficiency plan	<p>An energy efficiency plan entails defining and calculating the specific energy consumption of the activity (or activities), setting key performance indicators on an annual basis (for example for the specific energy consumption), and planning periodic improvement targets and related actions. The plan is adapted to the specificities of the installation. There are different ways to develop to energy efficient plans, but most widely accepted management systems are based on the plan-do-check-act approach (which is widely used in other company management contexts). ISO 50001 is one of the more globally widespread standards for energy efficiency management systems.</p>	<p>This improves energy management thereby reducing energy consumption, environmental impact and increasing profitability.</p>
---	------------------------	---	--

3.7. Best available technology for Fish Smoking.

Fish smoking is associated with the emission of volatile Organic Compounds, Dust, carbon monoxide, polycyclic aromatic hydrocarbons, organic acids, acrolein, acetaldehyde, formaldehyde, and nitrogen oxides. To manage this environmental risk Entebbe Freezone should adopt a Purified Smoke method. In the Purified Smoke method, the smoke is treated in a liquid phase for cleaning purposes (e.g. to remove undesired and harmful substances such as tar and ashes). Using compressed air, the purified smoke is afterward regenerated as smoke in a closed circuit and applied through the air to the goods to be smoked.

Table 14 recommended RECP techniques for fish smoking.

No	Proposed technique	Benefits
1	Use of purified smoke- Smoke generated from purified primary smoke condensates is used to smoke the product in a kiln. In this step, the smoke is treated in a liquid phase for cleaning purposes (e.g. to remove undesired and harmful substances such as tar and ashes). Using compressed air, the purified smoke is afterward regenerated as smoke in a closed circuit and applied through the air to the goods to be smoked.	<p>Purified smoke is carried out in enclosed smoking chambers, thus no emissions to air are generated.</p> <p>Purified smoke has the potential to reduce water consumption by 92 %; CO2 emissions by 83 %; wastewater by 83 %; cleaning detergents consumption by 68</p>
2	Use of Bio-filter. The waste gas stream is passed through a bed of organic material (such as peat, heather, compost, root, tree bark, compost, softwood and different kinds of combinations) or some inert material (such as clay, activated carbon, and polyurethane), where organic (and some inorganic) components are transformed by naturally occurring microorganisms into carbon dioxide, water, other metabolites and biomass.	<p>In a Norwegian salmon installation, a biofilter dimensioned for 3000 m³ air/h is installed on fish smoking machines and after the biofilter application, no bad smell was detectable in the local environment. A correctly operating biofilter will exhibit an outlet odor concentration of typically 150– 200 OUE/m³. Odor removal efficiencies of up to 99.5 % can be achieved, although the removal percentage is very dependent upon the inlet concentration</p>

3.8. Industrial symbiosis and RECP infrastructure.

Much as Resource Efficiency and Cleaner Production can minimize waste generation, other industrial processes are associated with inevitable waste that can't be eliminated by RECP. Inevitable waste in industrial parks can be addressed through the implementation of industrial symbiosis. Industrial symbiosis is a circular business model that promotes collaboration across sectors and industries and redirects wastes and raw materials from a certain process to be used in another process. Industrial symbiosis will facilitate collaboration across sectors and industries within Pakwach Industrial Park and redirect wastes and raw materials from a certain process to be used in another process. This will consequently reduce raw material and waste disposal costs, thus generating new revenue from residues and by-products, diverting waste from landfills, saving energy, reducing water and material consumption, minimizing waste disposal, reducing greenhouse gas emissions, averting the use of virgin materials, and reducing pollution to land, water, and air. It will also create new business opportunities, strengthen environmental profiles, increase business revenue, and contribute to greener cities and regions. To facilitate swift collaboration across sectors and the flow of resources shared industrial infrastructure is required. Shared industrial infrastructure refers to the sharing of facilities, services, and resources among companies in an industrial park or region. The shared infrastructure reduces capital and operating costs, improving resource efficiency while at the same reducing environmental impacts. From the industrial symbiosis assessment, the following industrial symbiosis synergies and shared infrastructure were identified for Pakwach Industrial Park.

Table 15 Proposed Industrial symbiosis and RECP infrastructure for DPEIZ

No	Recommended RECP infrastructures	Description and benefits
1	Grid-tied Solar PV Plant	<p>Although Pakwach district has access to the national grid, the quality of power is often low and unreliable. Discussions with SMEs in Pakwach revealed that enterprises suffer unplanned, unpredictable power outages, as well as scheduled and controlled electricity shutdowns (load shedding), where power is deliberately rationed to relieve pressure on the system and prevent complete collapse. These problems can last for hours, sometimes days, and can be frequent. For example, cassava flour processors claim to experience about 4 to 10 hours of power outages or poor power quality per week. Frequent or long-lasting power outages and voltage fluctuations forced some businesses to spend money on backup diesel generators, an expensive alternative to grid electricity that also increases CO₂ emissions.</p> <p>In a business-as-usual scenario, the projected annual electrical energy demand for Pakwach Industrial Park is about 16,824 MWh. Without access to the national grid, enterprises usually operate diesel generators, and this can result in direct GHG emissions estimated at 9,942 tons CO₂eq per year. Generating electricity using diesel generators is costly. At the current average price of diesel (USD 1.34) the cost of generating 1 kwh of power is about USD 0.302 which is relatively high compared to the power from the national grid. To address the problem of power in Pakwach, a solar PV system is proposed to generate electrical power for Pakwach Industrial Park. Investing in a solar PV power system will save about 22,403.7 tCO₂eq per year which translates to 560,092.5 tCO₂eq saved over the lifetime of the power plant. The project has the potential to create over 700 jobs during the construction and installation phase.</p> <p>The solar radiation of Pakwach ranges from 4.6 to 4.8 kWh/kWp. Given the availability of land, the park can accommodate at least a</p>

		22MWp solar PV plant, thus improving energy mix and security. (see the attached concept note for detailed description)
2	Biomass Briquette making facility	<p>Agro-processes generate large volumes of agro-residues which can be densified into briquettes to meet the thermal energy demand of anchor industries.</p> <p>The team investigated several options to improve the scale and impact of the facility for example exploring ways to resell briquettes to the general population thus contributing to the fight against deforestation. However, the supply of agro-residue options is not fully known, especially as the commercial competitiveness of the briquettes is highly dependent on the possibility of obtaining cheap resource, including reduced transport costs. The possibility to grow energy crops has been discarded on two main grounds. First of all, it may compete with food security in a region where it is more appropriate to promote food crops to ensure both revenue and household consumption. Secondly, cash crops promoted by the Government of Uganda such as Elephant grass are discarded due to their often-invasive nature and the risk they pose to the national park.</p>
3	Shared Fruits and Vegetable cold storage	Shared cold storage improves energy productivity and reduces operational costs. Given the important development to be expected in the logistics sector for the park once the transportation infrastructures are completed, including the Internal Container Depot (ICD), this proposal merely serves as a booster for the agro sector and can be easily replicable for increased volumes.
4	Green Hydrogen Production	<p>Given the availability of land and renewable energy. It is possible to explore opportunities for storing excess renewable energy into green hydrogen for improved energy security. However, that shouldn't be detrimental to water availability for both the park and the community. Theoretically, 9 tons of water is required to generate 1 ton of hydrogen through electrolysis. In practice, the water demand for producing one ton of green hydrogen is about 20 tons of water. This includes the water needed for the electrolysis process, as well as the water required for cooling and purifying hydrogen. For this reason, it is not recommended to market this opportunity before water supply recommendations are put in place, a thorough environmental assessment is performed and prior to developing the park other sectors to better capture the overall park water demand including in the tourism sector.</p> <p>Economically studies done in African countries show that the Levelized Cost of Energy (LCOE) from green hydrogen production ranges from 1.79 to 4.8 Euros/kg for 2020.⁷ However, according to a report by the International Energy Agency, LCOE will range from \$1.8 to \$2.6 per kilogram (kg) in 2030, and it's expected to further decrease to about US\$1.2 to 1.6 per kg by 2050 as hydrogen production technology matures and renewable energy costs continue</p>

⁷ See [H2 Atlas Africa](#)

		<p>to decline.⁸ The energy equivalent of 1 kilogram of hydrogen is about 33.3 to 39.4 kilowatt-hours (kWh). The energy density of hydrogen is between 120 and 142 mega joules per kilogram (MJ/kg), which means that for every 1 kg of mass of hydrogen, it has an energy value of 120-142 MJ⁹.</p> <p>Provides water supply and security concerns are addressed green hydrogen production provides a clean and low carbon alternative for storage of excess (solar) energy, improving energy mix and security.</p>
5	Automated external solar lightning.	<p>Installation of External lightning that can be activated by movement detectors and powered by solar cells to improve security and night and minimize on electrical power demand load of anchor industries.</p> <p>Solar-powered security lights have several benefits over traditional lighting systems. The benefits include.</p> <ul style="list-style-type: none"> i. Solar power security lights require minimal maintenance and are highly reliable. ii. They offer significant cost savings by eliminating energy costs and reducing the need for expensive wiring and fixtures. iii. The advancement of LED technology has significantly elevated the performance of solar-powered security lights, providing brighter and more effective lighting for enhanced security. iv. They offer flexibility and adaptability as they can be strategically placed to maximize sunlight exposure, ensuring optimal charging and illumination. <p>In summary, solar-powered security lights offer a sustainable and cost-effective solution for lighting up areas without access to the grid.</p> <p>Considering a security light with 4000 lumens and a coverage area of 205 square meters, an acre of land would require about 108.9 security lights. Therefore, DPEIZ would require about 2467.6 pieces of solar security with a rating of 600 watts and 4000 lumens. This would reduce electrical load demand of DPEIZ by 1480.6 kW.</p>
6	Fire security and disaster risk management	<p>Fire detectors and fire rescue equipment need to be available in strategic locations. A fire brigade equipped with at least one truck should be on site and available for intervention in the national park. Contingency plans (multi-risk) need to be developed, including simulations and training.</p>

⁸ [Africa Likely to Capture 10% of Global Green Hydrogen Market by 2050 - Hydrogen Central \(hydrogen-central.com\)](https://hydrogen-central.com)

⁹ [Energy Content of Hydrogen: A Comparison | Sustainability Info](#)

3.9. GHG emissions reduction potential of Pakwach Industrial Park.

Through implementation of RECP measures, adoption of renewable energy technologies and harnessing industrial symbiosis synergies, Pakwach Industrial Park has the potential to reduce GHG emissions by 40,125.61 tCO₂eq per year as shown in table below.

Table 3-16 GHG emission reduction potential of Pakwach Industrial Park

No	Improvement option	Estimated GHG emissions reduction potential in tCO ₂ eq
GHG emissions reduction potential for RECP measures		
1	Water efficient and conservation measures	6745.91
2	Energy Efficient and conservation measures	
GHG emissions reduction potential for Industrial symbiosis and shared infrastructure		
	Solar PV power plant	22,403.70
3	Biomass briquette Production	10,976.00
Total		40,125.61

4. Conclusion

Uganda is on track to developing a green economy though it is struggling to keep pace with industrial growth and ever-accelerating urbanization. The goal of sustainable industrialization will not be met unless progress is greatly accelerated, to facilitate the development of eco-industrial parks. On the development of eco-industrial parks, Dero Pakwach Eco-Industrial Zone (DPEIZ) is lagging far behind the progress needed to attain sustainable industrialization. If no interventions are made to facilitate such, the energy and water and GHG emissions are projected to exceed 247,144.04 GJ and 648.43 m³ and 15,490.6 tCO₂eq annually. The relatively slow progress in the development of eco-industrial when compared with the goals of sustainable industrialization an urgent need to pick up the pace. There is widespread acceptance that RECP and Industrial symbiosis can facilitate the creation of eco-industrial parks. The RECP assessment conducted at Dero Pakwach Eco-Industrial Zone (DPEIZ) Park shows that the adoption of industrial symbiosis and RECP measures can improve resource productivity, create green jobs, and reduce GHG emissions contributing to the creation of the eco-industrial park. Several lessons have been learned within the sector.

- i. Sustainable RECP delivery depends on how the decentralized authority (UIA) and private sector are empowered to make well-informed choices about technical RECP options. It is recommended that UIA develop a partnership with UCPC to pre-screen all industrial park projects applying RECP tools (in particular the material and energy flow analysis) and this logical tree. This should be complemented by a program to train companies in RECP measures implementation and park management in monitoring those.
- ii. Industrial symbiosis interventions have more impact if approaches are intersectoral. It is therefore important to develop an engagement strategy for the identification of new tenants in the FZ/IP that can optimize symbiosis by characterizing waste and resource consumption as well as adherence to green standards.

5. ANNEX

5.1. Annex1: Concept for a Solar PV Power facility

Table 17 Development of 22 MWp Solar PV facility to improve energy access and security for Pakwach Industrial Park

Project Summary	
Sector	Energy
Project Title	Development of 22 MWp Solar PV facility to improve energy access and security for Pakwach Industrial Park
Project Duration (Financial Years)	3 years
Estimated Project Cost	USD 16,259,833
Officer Responsible	Industrial Officer Global Green Growth Institute Uganda Office
Date of Submission	15 th November 2023
Section 1: Project Background	
<p>Situation analysis Provide a background to the project idea or the problem your project will focus on by: (i) describing current situation including past and on-going interventions; ii) recent developments in interest, achievements and challenges if any, iii) Explain projected trends using published forecasts. Quote official statistics to support your narrative.</p> <p>Pakwach Industrial Park is likely to be dominated by agro-processing enterprises. The agro-processing enterprises are energy intensive yet Pakwach Industrial lacks access to modern energy services. The nearest electricity grid is in Pakwach Town about 25 km from the Industrial Park.</p> <p>Although Pakwach district has access to the national grid, the quality of power is often low and unreliable. Discussions with SMEs in Pakwach reveal that enterprises suffer unplanned, unpredictable power outages, as well as scheduled and controlled electricity shutdowns (load shedding), where power is deliberately rationed to relieve pressure on the system and prevent complete collapse. These problems can last for hours, sometimes days, and can be frequent. For example, cassava flour processors claim to experience about 4 to 10 hours of power outages or poor power quality per week. Frequent or long-lasting power outages and voltage fluctuations forced some businesses to spend money on backup diesel generators, an expensive alternative to grid electricity increasing Co2 emissions.</p> <p>In a business-as-usual scenario, the projected annual electrical energy demand for Pakwach Industrial Park is about 16,824 MWh. Without access to national grid enterprise usually use diesel generators this can result in direct GHG emissions estimated at 9,942 tons CO₂eq per year. Generating electricity using diesel generators is costly. At the current average price of diesel (USD 1.34) the cost of generating 1 kwh of power is about USD 0.302 which is relatively high compared to the power from the national grid. In order to address the problem of power in Pakwach, a solar PV system is proposed to generate electrical power for Pakwach Industrial Park. Pakwach Industrial Park is endowed with solar energy with solar generation potential of pakwach estimated to range from 4.6 to 4.8 kWh/KWp and a solar irradiation ranging from 5.0 -5.6 kWh/m²/day.</p>	
1.1	Problem Statement

Provide an explicit definition of the problem to be addressed in terms of challenges, constraints or gaps that the market or private sector cannot resolve and:

- (i) Mention the likely causes of the problem both direct and indirect,**
- (ii) Give a brief insight of the likely consequences if no government intervention is made.**

The cost of electrical energy for Pakwach is projected to be over USD 0.302 per kWh which is double the cost of electricity from the national grid. This is because of a lack of access to the national grid. Usually, in the absence of the national grid enterprises use diesel generators to generate electrical power. This increases the cost of power and GHG emissions. The GHG emissions generated while using diesel generators is about 0.74 kgCO₂ per kWh. Addressing this will require extending the national grid to the industrial park as well as investing in a micro power generation system to complement grid power and increase its reliability. This kind of investment requires huge capital which SMEs and park management can hardly afford/access. If there are no interventions made to enhance energy access of Pakwach Industrial Park, the manufacturing enterprises are anticipated to incur an extra cost of about USD 3 million compared to when power is obtained from a renewable energy alternative. The GHG emissions associated with power generation are projected to be above 9,942 tons CO₂eq per year.

1.2 Relevance of the Project Idea

Justify the need for the proposed project by: (i) linking the project to the National Development Plan (NDP) strategic interventions by identifying the objective (s) that the proposed project is expected to contribute to; (ii) Linking the proposed project to Sector Investment Plan (SIP) objectives by describing the sector outcomes that the project is expected to impact.

Reliable, affordable, and clean energy is crucial for economic growth and societal transformation. Improving energy access and reliability facilitates sustainable industrialization by, reducing the cost of doing business, enabling production, and ultimately contributing to increased competitiveness and sustainable economic growth.

Enhancing access to modern forms of energy is a prioritized intervention under the sustainable energy programme of the National Development Plan 2021/22-2025/26. (NDP III). SDGs 7 aims at ensuring access to affordable, reliable, sustainable and modern energy for all by 2030¹⁰. Furthermore, the National Development Plan (NDP III) plans to increase access and utilization of electricity by developing renewable off-grid energy solutions and increasing electricity generation capacity. Develop medium and small power plants.

Therefore, developing and installation of solar PV plant in Pakwach district will contribute to government plans of increasing access and utilization of electricity, increasing electricity generation capacity, creating eco-friendly fully serviced agro-industrial parks/export processing zones as well as pursuing sustainable industrialization.

The project will also contribute to the government's commitment to reducing the emission of 0.0003MtCO₂eq through increasing renewable energy generation by 2030¹⁰

Section 2: Technical Approach

2.1 Stakeholders

Identify the key stakeholders that are likely to be affected by the interventions including (i) Direct Beneficiaries (ii) Indirect Beneficiaries (iii) Project Affected Persons. Give a brief description of the likely impact of the project on the stakeholders.

No	Project Beneficially	Project impact
1	Pakwach Industrial Park	They will benefit by getting access to clean and affordable energy enhancing their productivity and competitiveness.

¹⁰ See [Updated NDC Uganda.pdf \(mwe.go.ug\)](#)

2	Pakwach local communities	Access to energy will facilitate the establishment of manufacturing enterprises that will create jobs for the people of Pakwach district.
3	Pakwach Municipality	Establishment of manufacturing enterprises will create local revenues in form of taxes and licenses fees.
4	Famers	Farmers will be able to sell their produce especially to agro-processing enterprises established with Pakwach industrial park.

2.2 Project Outcomes

Define the project objectives in terms of the positive impact that the project is expected to have on the economy and key stakeholders.

The objective of the proposed Solar Photovoltaic (PV) system is to enhance access to modern and affordable clean energy services for Pakwach Industrial Park contributing to improved energy mix and security of the national grid.

- i. The projected is estimated to generate about 36.135 GWh per year.
- ii. Use of solar-generated electricity will save about 22,403.7 tCO₂eq per year this translates to 560,092.5 tCO₂eq saved over the lifetime of the power plant.
- iii. The project has the potential to create over 700 people during the construction and installation phase
- iv. The project will also create permanent jobs have also been created to assist with the operation and maintenance of the facility.

2.3 Proposed Project Interventions

Describe the interventions, project outputs/components that need to be undertaken by the government through the proposed project to address the problem. For each output briefly highlight the major activities that you propose to implement to achieve the objectives mentioned in Section 2.2 above. Describe the strategy you will adopt to implement the proposed activities.

The proposed Project will support the construction of solar photovoltaic (PV) power plants in Pakwach. This will address the country's need to expand low-cost power generation, diversify the power generation mix and increase the percentage of clean energy in its generation mix reducing heavy reliance on hydro-electrical power. The project will have two outputs: solar PV park and transmission facilities. constructed. These outputs will result in increased solar power generation in Pakwach consequently enhancing energy access and security. The project will support the Pakwacki Industrial Pack in constructing solar power and a transmission interconnection system to a nearby grid substation to supply power to Pakwach Industrial Park. Based on solar irradiation for Pakwach (5-5.6 kWh/m²/day), the solar PV facility will be on about 65 to 85 acres with fencing, drainage, roads, and plant buildings. The power plant will accommodate at least 22 MWp of solar PV system including mounting structures, power conversion units (inverters and associated transformers), direct current and alternating current plant cabling, power controls, and Supervisory Control and Data Acquisition system (SCADA). The transmission interconnection system will include a solar park substation with transformers, switchgear, and a Supervisory Control and Data Acquisition system with the national grid requirements.

2.4 Coordination with other Government Agencies

Identify specific activities and issues for which you will need to coordinate implementation of activities with other government agencies. List the relevant Government partner agencies and briefly describe their roles.

- i. Ministry of Energy and Mineral Development will provide overall project oversight and monitor the progress of project implementation.
- ii. Electricity Regulatory Authority will issue the necessary permits and licenses for carrying detailed renewable energy feasibility study, generation, transmission, distribution or sales of electricity, and ownership or operation of transmission systems.

- iii. Uganda Electricity Generation Company will ensure that the design, planning, development and operation of the proposed Solar PV power generation project is in accordance with prudent utility practice and international best practice.
- iv. Uganda Electricity Transimmission Company will negotiate all agreements for the purchase of power generated by the proposed solar PV plant.
- v. Uganda Electricity Distribution Company will take the lead in extension of electricity distribution grid within the Proposed Pakwach Industrial Park.
- vi. National Environment Management Authority will ensure that environment and social impact assessment is carried, and the project meets the minimum requirement according the environment impact assessment regulation and ensure that during operation environment audits are carried in accordance with the Environment act.
- vii. Uganda Investment Authority will issue investor license for developing and operating of a solar PV power
- viii. Ministry of Gender, Labor and Social Development will monitor project development to ensure that Construction, Electrical, Mechanical, and Installations meet the Safety requirements as provided for by the law
- ix. Ministry of Water and Environment will issue water abstraction and wastewater discharge permits

Section 3: Estimated Project Cost and funding sources

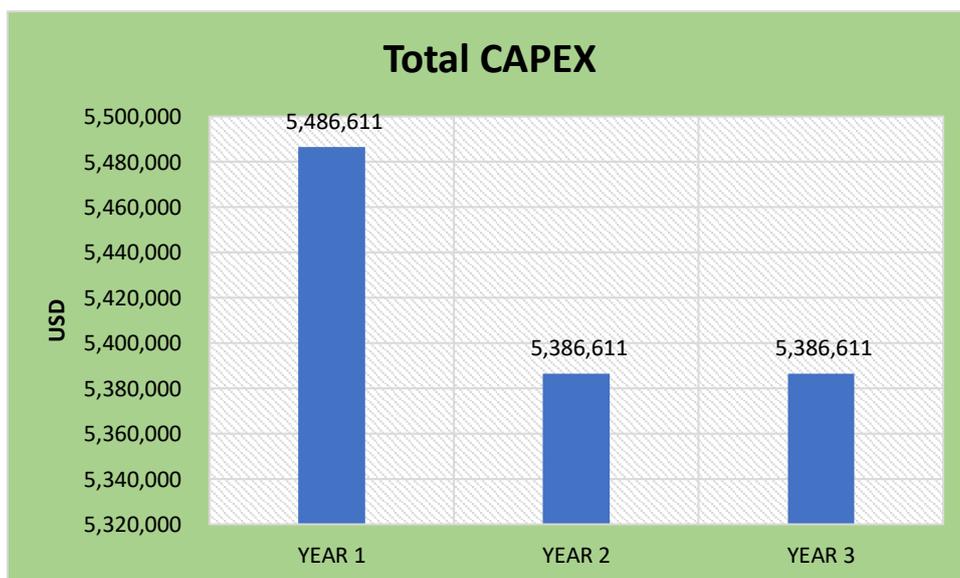
3.1 Project Cost (Annualised Costed work plan)

Give an estimate of the total project cost and disaggregate by year for each output/component or intervention described in 2.3 above. The project period should correspond to the period it takes to have the physical infrastructure in place and ready to be operated.

3.1 Project Cost (Annualised Costed work plan)

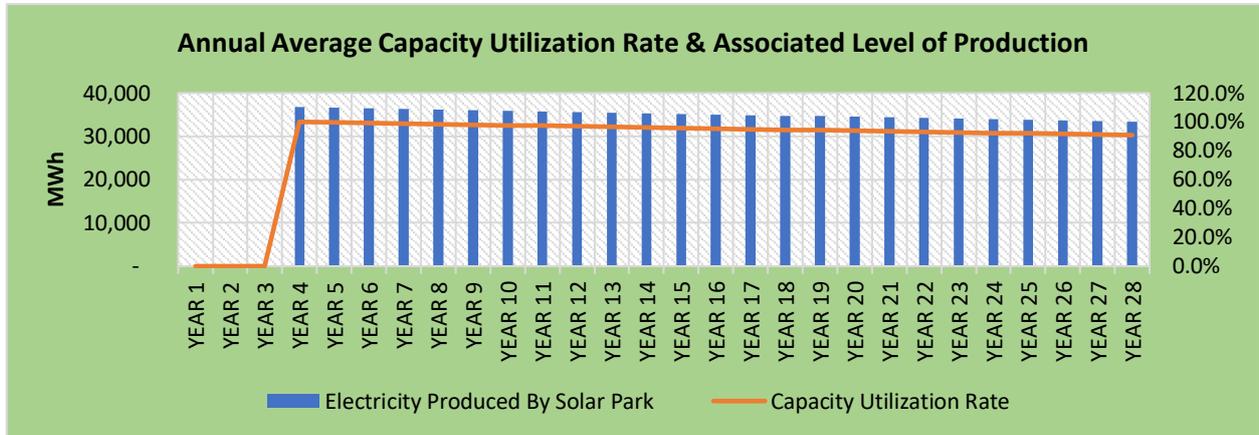
Give an estimate of the total project cost and disaggregate by year for each output/component or intervention described in 2.3 above. The project period should correspond to the period it takes to have the physical infrastructure in place and ready to be operated.

Based on 3 Scenarios, the expected average total CAPEX is USD 16,259,833. This outlay is expected over a 3-tear period as shown below:



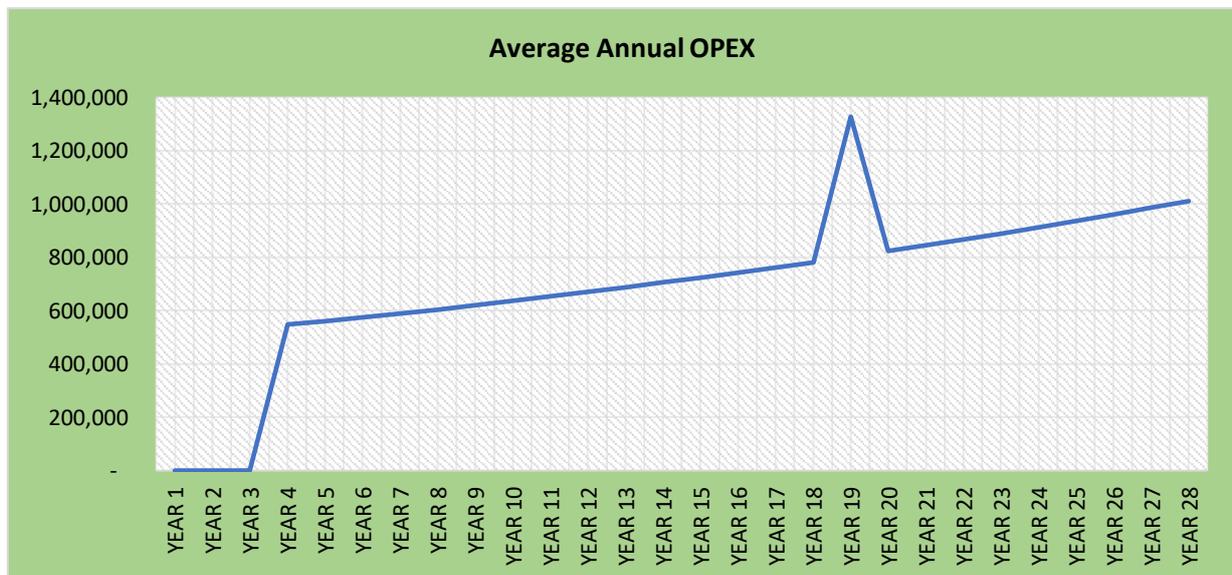
3.2 Projected Annual Electricity Generation

Projected initial average electricity generation is expected to be 36.8 MWh. This is expected to reduce by 0.4% per year as shown below.



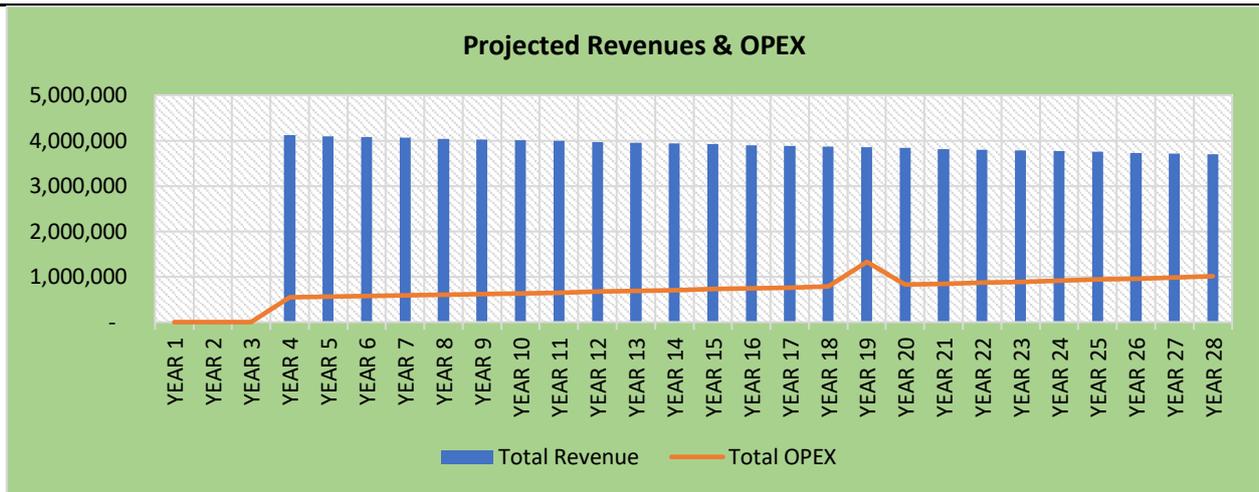
3.2 Projected Operating Expenses

Lifetime average annual OPEX are expected to be USD 719,495, rising from USD 547,268 to USD 1,010,861. The progression of these expenses is shown below.



3.2 Projected Revenues

Projected average annual revenue for the solar park at Pakwach EIP over a 20-year period is USD 3,484,880, growing from USD 4,117,637 to USD 3,699,749. The schedule of projected revenues is shown below.



3.3 Project Performance Metrics

Pre-Tax Unlevered Net Present Value	USD	6,204,578
Pre-Tax Unlevered IRR	%	4.6%
Pre-Tax Unlevered ROI	%	253.0%
Pre-Tax Unlevered Breakeven Period	Years	8
Lifetime Reduced Green House Gas Emissions	USD	19,018,542
Number of People Gaining Access to Clean Energy	People	218,547

5.2. Annex 2: Concept note for Industrial Scale Biomass Briquette Facility

Table 18 Establishment of Industrial Scale Biomass Briquette Production Facilities for Pakwach Industrial Park

Project Summary	
Sector	Energy
Project Title	Establishment of Industrial Scale Biomass Briquette Production Facilities for Pakwach Industrial Park
Project Duration (Financial Years)	3 years
Estimated Project Cost	USD 1,008,937
Officer Responsible	Industrial Officer GGGI
Date of Submission	15 th November 2023
Section 1: Project Background	
1.3	<p>Situation analysis Provide a background to the project idea or the problem your project will focus on by: (i) describing current situation including past and on-going interventions; ii) recent developments in interest, achievements and challenges if any, iii) Explain projected trends using published forecasts. Quote official statistics to support your narrative</p> <p>Manufacturing enterprises in Uganda use woody biomass or fossil fuel to generate steam to meet their thermal energy demand.¹¹ The cost of woody biomass and fossil fuels has been steadily growing in the last decades. This increases the cost of production and reduces the profitability of manufacturing enterprises. Findings from assessments conducted with SMEs in Pakwach Municipality show that the cost of woody biomass has increased from USD 4/m³ in 2010 to about USD 24/m³ in 2023 while the cost of diesel increased from USD 0.7/liter in 2010 to 1.34/liter. The increase in the cost of woody biomass is attributed to the increasing scarcity of firewood accruing with unsustainable utilization of forests in search of energy. The deforestation rate is estimated at 13%.</p> <p>Studies show that fossil fuel-based steam generation methods release large amounts of carbon dioxide and other pollutants (short-lived climate pollutants) into the atmosphere, which contributes to global warming and climate change. In the business-as-usual scenario the thermal energy demand of Pakwach Industrial Park is projected to be 134,952 GJ per year equivalent to 411 acres of a 15 years-old forest cut or 4.22 million liters of diesel, emitting about 10,976 tons CO₂eq. The woody biomass scarcity and increased costs of fossil fuels have triggered SMEs and start-ups to develop innovative solutions to utilise agro-residues as alternative sources of energy. For example, Jenon Waste Recycling Studio an SME in Pakwach Municipality is producing biomass briquette from Agro-residues. Furthermore, utilization of Agro-residues as an affordable and clean source of energy has been successfully applied in agro-processing in Uganda, especially in the sugar, paper and pulp, textile, and dairy sectors. The waste Nile, Albertian, and Lango regions are reported to be major producers of rice, cassava, sunflower, and coffee which are potential sources of agro residues. The regions of Lango, West Nile and Albertian have an estimated potential of 368,560.3 tons per year of agro-residue</p>

¹¹ See ubos.org/wp-content/uploads/publications/09_2021Uganda-National-Survey-Report-2019-2020.pdf

(biomass). To efficiently utilize agro-residues as a clean low-cost source of energy requires adoption of modern biomass energy technologies like high-pressure biomass briquette technologies. This is because utilization of agro-residues through direct burning of loose biomass is associated with very low thermal efficiency and widespread air pollution. The conversion efficiencies are as low as 40% with particulate emissions in the flue gases more than 3000 mg/Nm³. Short and long-term exposures (hours and days) to particulate matter and other pollutants from inefficient combustions can aggravate lung disease, causing asthma attacks and acute bronchitis, and may also increase susceptibility to respiratory infections. Briquetting of the agro-residues can mitigate these inefficiency and pollution problems while at the same time making use of this important energy resource. Although the importance of biomass briquettes as a substitute fuel for wood, and fossil fuel is well recognized, the uptake of the technology in Uganda is on a micro-scale. This is because of the technical constraints limited access to finance and lack of knowledge to adapt the technology to suit local conditions.

1.4 Problem Statement

Provide an explicit definition of the problem to be addressed in terms of challenges, constraints or gaps that the market or private sector cannot resolve and:

- (iii) Mention the likely causes of the problem both direct and indirect,**
- (iv) Give a brief insight of the likely consequences if no government intervention is made.**

The increasing cost of woody biomass and fossil fuel is continuously increasing the cost of energy and consequently cost of production. This affects the profitability and competitiveness of manufacturing enterprises. The unsustainable/inefficient utilization of woody and increasing dependence on fossil fuel as a source of energy for steam generation in industries is worsening the situation and increasing industrial GHG emissions. The energy demand of Pakwach Industrial Park is projected to be 134,952 GJ per at full operation scale.

To simultaneously deal with the growth in energy demand and mitigate problems, such as the high cost of energy, GHG emissions, and polluting gases, a new energy system is needed. High-efficiency energy transformation technologies such as industrial-scale briquette production technology need to be adopted. Production of briquettes agro-residues will facilitate switching from fossil fuels and provide a low-cost alternative to firewood and diesel.

Failure to adopt such technology is likely to increase deforestation by 411 acres of a 15 years-old per year or demand for about of 4.22 million of litres diesel per year. This is equivalent to USD 5.7 million of foreign exchange loss and 10,976 tons CO₂eq emitted.

1.5 Relevance of the Project Idea

Justify the need for the proposed project by: (i) linking the project to the National Development Plan (NDP) strategic interventions by identifying the objective (s) that the proposed project is expected to contribute to; (ii) Linking the proposed project to Sector Investment Plan (SIP) objectives by describing the sector outcomes that the project is expected to impact.

The Uganda Vision 2040 aspires to pursue economic development and socioeconomic transformation premised on the principles of a green economy such as equity, environment sustainability, resource efficiency, climate change adaptation and mitigation, and inclusiveness.¹² The Agro-Industrialization programme of the NDP (III) also aims at establishing eco-friendly fully serviced agro-industrial parks/export processing zones.

Briquetting will provide a sustainable way of converting loose biomass residues such as sawdust, coffee husk, and forestry waste into high-density solid blocks that can be used as fuels. Biomass briquettes are an environment-friendly, efficient solution to recycling, organic solid (municipal and industrial) agriculture and forest waste while simultaneously creating clean fuel for burning purposes.

Investing in an industrial-scale biomass briquette production facility will allow utilization of agro-residues (including industrial and municipal biomass waste) contributing to sustainable utilization of biomass. This will create industrial-urban symbiosis facilitating the transition to an eco-industrial park and circular economy in general.

Section 2: Technical Approach

¹² See [Uganda Green Growth Development Strategy – National Planning Authority \(npa.go.ug\)](http://npa.go.ug)

2.1 Stakeholders

Identify the key stakeholders that are likely to be affected by the interventions including (i) Direct Beneficiaries (ii) Indirect Beneficiaries (iii) Project Affected Persons. Give a brief description of the likely impact of the project on the stakeholders.

- i. Local communities: installation and operation of industrial scale biomass briquette production facilities will create employment opportunities (green jobs) for the locals
- ii. Pakwach Industrial Park: SMEs in park will get access to affordable clean energy for steam generation
- iii. Farmers: the farmers will generate an addition revenue stream from sell of agro-residues.

2.2 Project Outcomes

Define the project objectives in terms of the positive impact that the project is expected to have on the economy and key stakeholders.

The objective of the project is to generate energy from renewable sources by utilizing low-cost, locally available agricultural residues to meet the thermal energy demand of enterprises in Pakwach Industrial Park and reduce dependence on fossil fuels.

The technology will also facilitate the transition from fossil fuel use to biomass reducing dependence on fossils and the associated GHG emissions. The construction and operation phase of the project will create green jobs, especially for people in the West Nile region. This will not only contribute the Uganda Vision 2040 and NDC but also to Sustainable Development Goals (SDGs), especially SDG 7 on affordable and clean energy and SDG 12 on responsible consumption and production

2.3 Proposed Project Interventions

Describe the interventions, project outputs/components that need to be undertaken by the government through the proposed project to address the problem. For each output briefly highlight the major activities that you propose to implement to achieve the objectives mentioned in Section 2.2 above. Describe the strategy you will adopt to implement the

The proposed project is a biomass briquette production facility with a production capacity of 14 tons per hour. The production facility will include a production hall and a perimeter wall, a biomass drier, conveyors, grinders, a biomass densification machine, and a packaging machine. The biomass drier consists of the feed hopper mounted on a screw conveyor, air blower, burner, and rotary drum cyclone for dust collection before being discharged through the exhaust stack. The biomass drier is required to ensure that briquette feedstock is fed in the densification process with desired moisture content. A grinder/crusher is required to crush the biomass in fine particles to allow binding under high pressure. The facility will adopt a high-pressured briquette production technique to eliminate the need for using binders in creating bonds between biomass. The briquette production facility will include high-pressure screw extrusion machines. The screw press briquettes have a concentric hole which gives better combustion efficiency due to a larger surface area. The screw press briquettes are also homogeneous and do not disintegrate easily. Having a high combustion rate, these can substitute fossil fuels in most applications and boilers. Briquettes will be produced with a density of 1.2 g/cm³ from loose biomass with a bulk density of 0.1 to 0.2 g/cm³.

The biomass briquette production facility will result in one major outcome which is affordable clean energy for the heating process. This will consequently lower the cost of steam generation, create additional revenue stream for farmers, and reduce GHG emissions.

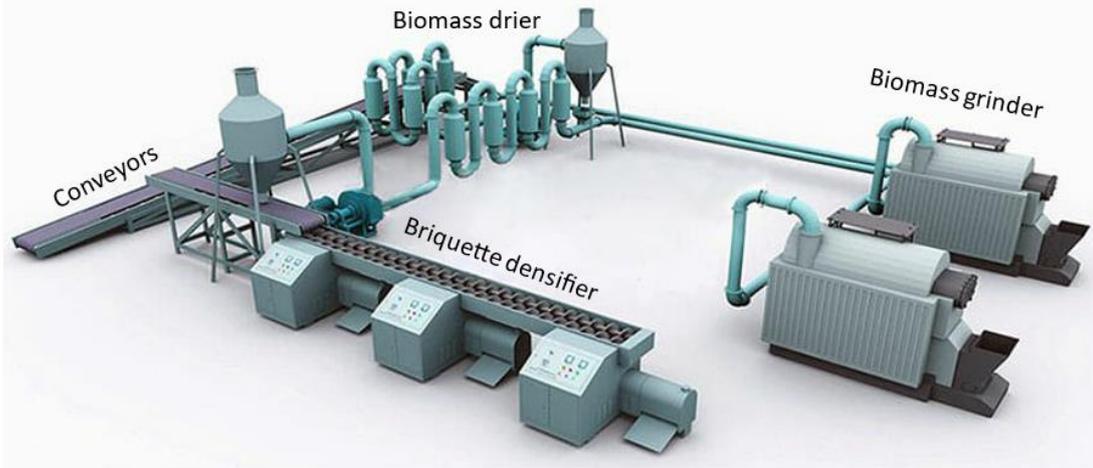


Figure 4 Proposed industrial scale Biomass Briquette Production facility.

2.4 Coordination with other Government Agencies

Identify specific activities and issues for which you will need to coordinate implementation of activities with other government agencies. List the relevant Government partner agencies and briefly describe their roles.

- x. National Environment Management Authority will ensure that environment and social impact assessment is carried out and that the project meets the minimum requirements according to the environment impact assessment regulation and ensure that during operation environment audits are carried following the Environment Act provisions.
- xi. Uganda Investment Authority will issue an investor license for developing and operating an industrial Scale Biomass briquette production facility
- xii. The Ministry of Gender, Labor, and Social Development will monitor project development to ensure that Construction, Electrical, Mechanical, and Installations meet the Safety requirements as provided for by the law
- xiii. Ministry of Water and Environment will issue water abstraction and wastewater discharge permits

Section 3: Estimated Project Cost and funding sources

3.1 Project Cost (Annualized Costed work plan)

Give an estimate of the total project cost and disaggregate by year for each output/component or intervention described in 2.3 above. The project period should correspond to the period it takes to have the physical infrastructure in place and ready to be operated.

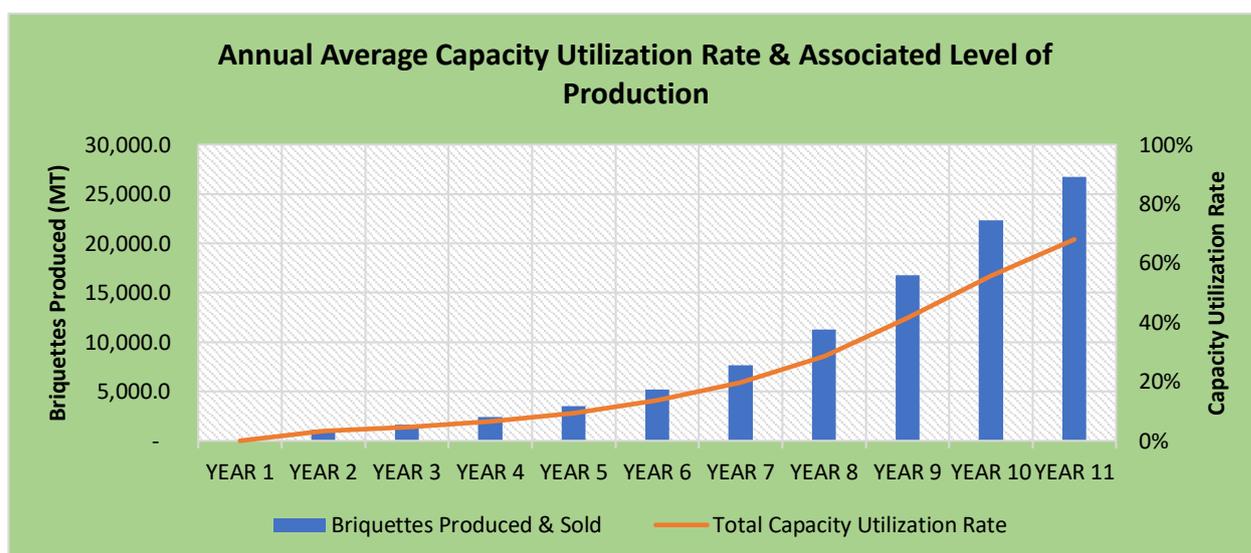
The figures shown below relate only to capital expenditures required to set up the production process.

	Year 1	Total cost
Screw Press Briquette Machine	USD 328,281	USD 328,281

Biomass Waste Collection Truck	USD 45,000	USD 45,000
Auxiliary Equipment	USD 32,828	USD 32,828
Office Equipment	USD 32,828	USD 32,828
Civil Works	USD 570,000	USD 570,000
Total	USD 1,008,937	USD 1,008,937

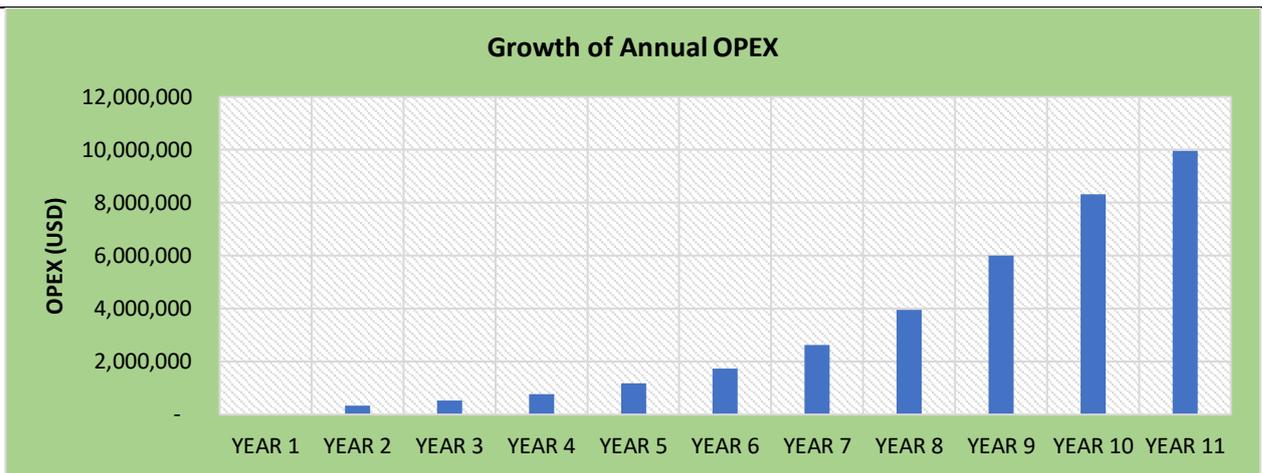
3.2 Projected Annual Briquette Production

Over a 10-year operational period, annual production of briquettes is expected to grow from 1,118 MT to 26,725 MT. This translates to a growth in the average annual capacity utilization rate from 3.2% to 68% over the same period. Both metrics are shown in the figure below.



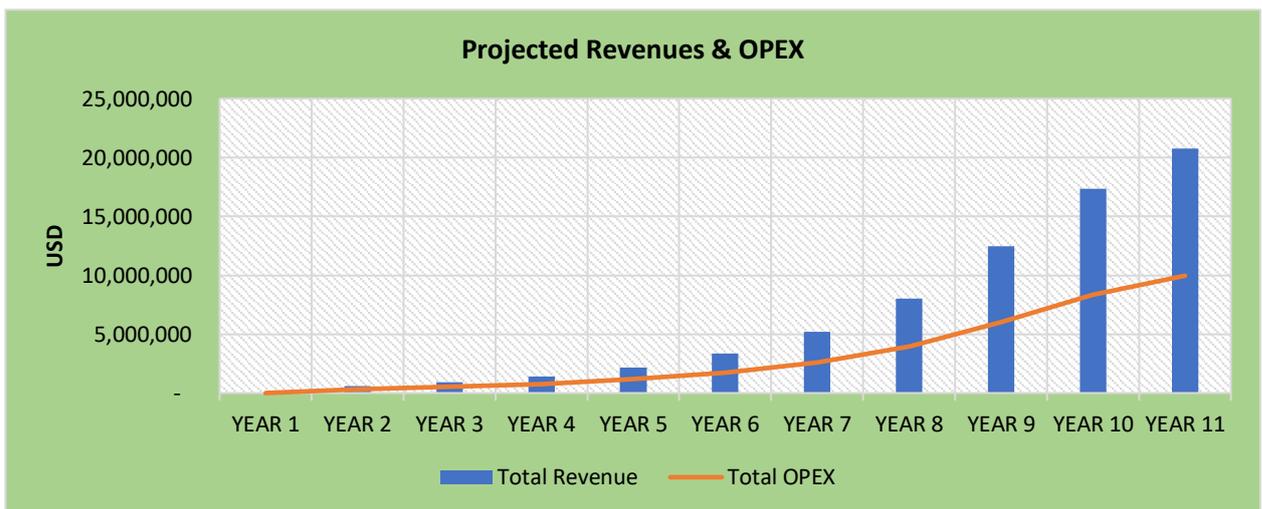
3.2 Projected Operating Expenses (OPEX)

Annual total OPEX is expected to grow from USD 347,047 to USD 9,965,302 over a 10-year operational period, as shown in the figure below (excludes depreciation).



3.2 Projected Revenues

Annual revenues from the sale of briquettes is expected to grow from USD 610,432 to USD 20,761,353 as shown in the figure below.



3.3 Project Performance Metrics

Unlevered NPV	US \$	9,795,303
Unlevered IRR	%	54.4%
Breakeven Period	Years	6
Breakeven Point	Metric Tonnes	4,093.4
Return On Investment (ROI)	%	1278.0%
Reduction in GHG Emissions	Metric Tonnes	-
Number of People Gaining Access to Clean Energy	People	40,942