Developing an Eco-Industrial Park; Structures and Policies: A Case study of the KenGen Green Energy Park, Kenya

Irene Jepkorir Ronoh

Thesis of 60 ECTS credits submitted to the School of Science and Engineering
at Reykjavík University in partial fulfillment of
the requirements for the degree of
Master of Science (M.Sc.) in Sustainable Energy Science

June 2020

Supervisor:
Dr. Einar Jón Ásbjörnsson
Associate Professor
Reykjavík University, Iceland

Advisor:
Mr. Sigurður H. Markússon
Project Manager - Geothermal Power Projects
National Power Company-Iceland

Examiner:
Mr. Viðar Helgason
Cluster Manager of Iceland Geothermal

Developing an Eco-Industrial Park; Structures and Policies: A Case study of the KenGen Green Energy Park, Kenya

Irene Jepkorir Ronoh

Thesis of 60 ECTS credits submitted to the School of Science and Engineering at Reykjavík University in partial fulfillment of
the requirements for the degree of
Master of Science (M.Sc.) in Sustainable Energy Science

June 2020

Student:

Irene Jepkorir Ronoh

Supervisors:

Dr. Einar Jón Ásbjörnsson

Examiner:

Mr. Viðar Helgason

Abstract

KenGen Green Energy Park intends to use renewable geothermal resources for the production of steel, glass, textile, leather, organic fertilizer, and food processing. The required thermal energy will be harnessed from 2000 t/hr of geothermal brine in various separator stations and steam from low-enthalpy geothermal wells. The study aims to develop the park as a sustainable and competitive Eco-Industrial Park, through improved efficiency, by embracing a robust circular economy. The objective was to develop industrial clusters, assess material flows within the clusters, and determine industrial symbiotic opportunities between the firms. Using the standard EIP International Framework, the development of a multi-criteria assessment of policy interventions and recommendations to the energy park was done. Tools used in the study were; Stan2Web software for Material Flow Analysis, an EIP policy tool for assessment of policy interventions, a stakeholder matrix for mapping relevant stakeholders and a standard EIP management models as a guide to developing a park management model. From the results, three clusters of companies emerged; steel-glass, textile-leather, and food-organic fertilizer clusters. The clustering of the industries was based on utility requirements; waste generated and emissions potential. The estimated thermal energy available in these clusters is between 2.5 MWt and 69.1 MWt depending on the energy source. The MFA models generated indicate that the flow of raw materials, energy, products, by-products, and wastes generated can be mapped within the production processes. Various synergies emerge between different firms that can potentially share the resources for mutual benefits. This industrial symbiosis links resulted in the creation of opportunities from utility and infrastructure sharing as well as waste and by-product exchanges. From the multi-criteria analysis, the results indicated that the development of a National Action Plan on EIP is essential. This incorporates industrial symbiosis and resource efficiency concepts into the existing industrial policies. Other relevant interventions include inter alia; tax holidays to encourage SMEs, the use of renewable energy for industrial processes, increase foreign direct investment to EIPs and social capital creation. A stakeholder map guided the development of a park management model. The model promotes a collaborative approach that underlines resource use efficiency through cleaner production and industrial symbiosis. It seeks to strengthen partnerships between industry, government, and research institutions to enhance eco-innovation. The findings of this study form the basis for the development of KenGen Energy Park as an Eco-Industrial Park with an integrated and resource-efficient circular economy.

Keywords: *Eco-Industrial Park, Circular Economy, Policy, KGEP*

Nomenclature

BOF-Basic Oxygen Furnace
BOD-Biochemical Oxidation Demand
CE-Circular Economy
COD-Chemical Oxygen Demand
DANIDA-Danish International Development Agency
EIB-European Development Bank
EPZ-Export Production Zones
EIPs- Eco-Industrial Parks
GIZ-German Corporation for International Cooperations
GHG-Greenhouse gases
GOK-Government of Kenya
KAM-Kenya Association of Manufacturers
KenGen-Kenya Electricity Generating Company
KGEP-KenGen Green Energy Park
LCA-Life-Cycle Analysis
MFA-Material Flow Analysis
MWt-Megawatt Thermal
MoU-Memorandum of Understanding
OECD-Organisation for Economic Corporation and Development
OW-Olkaria Well
SME-Small to Medium-scale Enterprises
SEZ-Special Economic Zones
UNCTAD-United Nations Conference on Trade and Development
UNEP-United Nations Environmental Programme
UNIDO-United Nations Industrial Development Organization

Table of Contents

List of Figures

List of Tables

Acknowledgment

My sincerest gratitude goes to my supervisor Dr. Einar Jón Ásbjörnsson of Reykjavik University and my advisor Mr. Sigurður H. Markússon of Landsvirkjun for their resolute support, experience, generous advice, and detailed review during the writing of this thesis. Your insightful guidance on this emerging and promising concept was very valuable. To all those who edited my thesis report, I sincerely thank you.

Special thanks go to the United Nations University Geothermal Training Program (UNU GTP), later GRÓ Geothermal Training Program (GRÓ GTP), and the Government of Iceland for granting me the financial support to pursue my Master of Science degree at the Iceland School of Energy in Reykjavik University. I want to express my gratitude to the former director of UNU GTP, Mr. Lúdvik Georgsson, the current director of GRO GTP, Mr. Gudni Axelsson, Mr. Ingimar G. Haraldsson, Ms. Thórhildur Ísberg, Ms. Vigdís Harðardóttir, Mr. Markús A.G. Wilde and Ms. Málfrídur Ómarsdóttir for their support and ensuring that my entire stay in Iceland was comfortable.

I am indebted to my employer, Kenya Electricity Generating Company (KenGen PLC) for granting me study leave and all the support during my studies. To all those who provided data, I thank you as well.

Finally, I thank my family for their support, empathy, and patience throughout this challenging knowledge-seeking journey. To my three-year-old son Ethan, who could not understand why we were communicating through video calls. Thank you for being a brave boy and enduring my absence, you were the source of my inspiration everyday.

1. Introduction

Development of the Special Economic Zones (SEZs) and industrial parks in many parts of the world, is currently on the rise. These zones are planned and developed for industrial activities and associated commercial, infrastructure, and service provision. They provide useful instruments for attracting investment, fostering technological learning and innovation, and creating jobs. With the potential to generate comparative and competitive advantages, these economic zones attract innovative businesses leading to both more jobs and a larger tax base (UNIDO, 2012). They largely support start-ups, new enterprise incubation, the development of knowledge-based businesses, and offer an environment where local and international firms can interact with a particular center of knowledge creation for mutual benefit. SEZs have a long-established role in international trade. However, it was only in the 1970s and 1980s that these zones became a cornerstone of trade and investment policy in East Asia and Latin America. In 1986, the International Labour Organization (ILO) reported 176 zones in 47 countries. By 2006, this had risen to 3,500 zones in 130 countries (Boyenge, 2007). World Investment Forum (2019) reported that nearly 5,400 SEZs exist today, more than 1,000 of which were established in the last five years. At least 500 more zones (approximately 10 percent of the current total) have been announced and are expected to open in the coming years as shown in Figure 1.

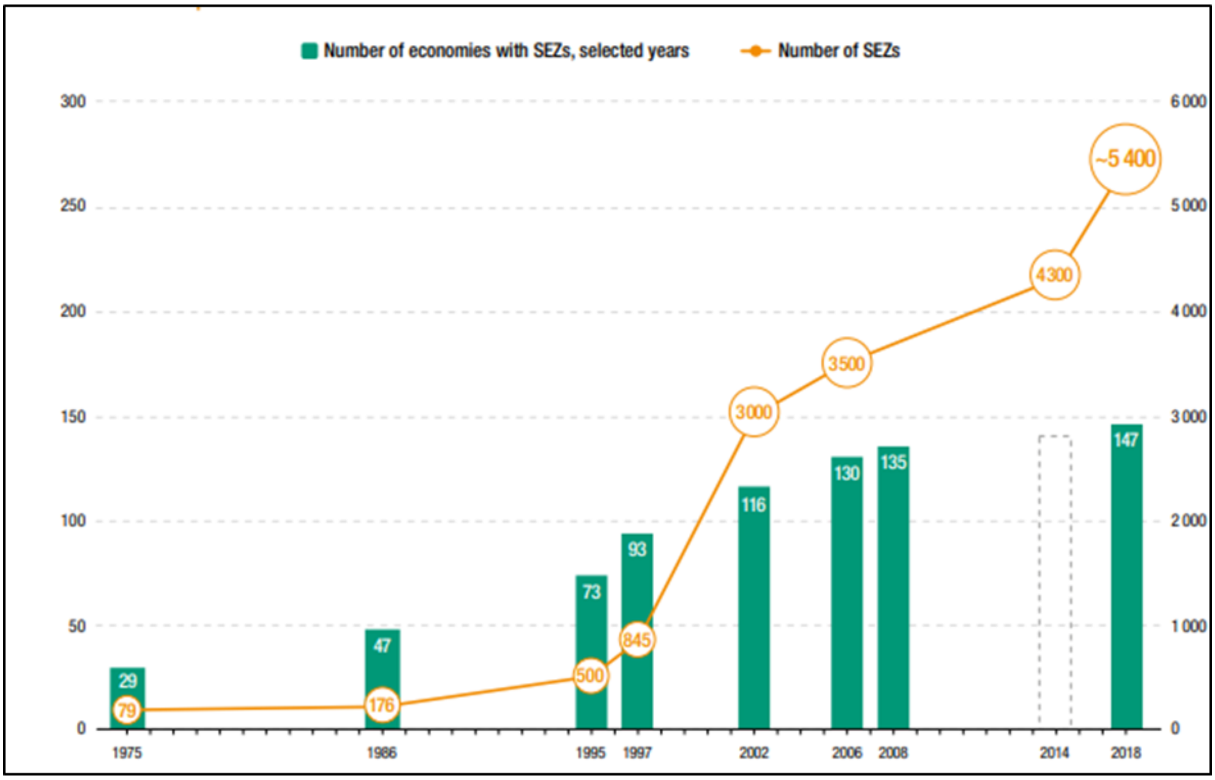

Figure 1: Historical trend in SEZs (UNCTAD, 2019)

According to Page and Tarp (2017), several African countries, including Liberia, Mauritius, and Senegal, launched SEZ programs in the early 1970s. However, most African countries did not operationalize their programs until the 1990s or the 2000s. As of 2014, the majority of countries in Sub Saharan Africa had active SEZ programs, most of these being traditional Export Processing Zones (EPZs) and industrial parks. Except for Mauritius and the partial initial success of Kenya, Madagascar, and Lesotho, most African zones have failed to attract significant investment, promote exports and create sustainable employment (Farole, 2011). Staritz and Morris (2013) noted that even where SEZs have had some initial success, the quality of investment and employment has often been poor, undermining their sustainability. For instance, Madagascar's economic growth declined due to the political turmoil in 2009 leading to loss of tens of thousands of jobs in SEZs and the country's subsequent suspension from the African Growth and Opportunity Act (AGOA).

Despite the advantages and clear success cases in Japan, China, Denmark, and South Korea, traditional SEZs are facing competitiveness. World Investment Forum (2018) has pointed out that, to promote sustainability, SEZs will need to pursue business activities in a more socially and environmentally responsible manner that advances the Sustainable Development Goals (SDGs). These challenges call for a modernization of the traditional SEZs and industrial parks to achieve economic, environmental, and social benefits.

Recent research and discussions indicate that the planning and development of these zones should be enhanced by seeking innovative ways of incorporating the concept of resource-use efficiency, cleaner production, and industrial symbiosis from the onset of the projects (UNEP, 2011; World Bank, 2014). According to Tan & Meyer (2011), SEZs need to be developed in an eco-friendly approach while achieving socio-economic benefits. These approaches emphasize the methods which take the 3R-principle of reduce-reuse-recycle. The report postulated that, by greening these traditional SEZs and industrial parks, it calls for reduction of wastes and emissions in individual plants, through a high level of coordination of their environmental initiatives and by effective treatment of wastes in collective facilities for reuse by other enterprises. This initiative results in the development or transition into Eco-Industrial Parks (EIPs).

The concept of EIPs as discussed in detail by Lowe (1997) and UNIDO (2016a) focused on companies cooperating and with the local community trying to reduce waste and environmental pollution. Further, efficiently share resources and help to achieve sustainable development, to augment economic gains, and improve environmental quality. Utilizing material, water, and energy recycling, different types of plants and enterprises are connected into a symbiotic association in which resources are shared and by-products are interchanged. The waste or by-products of one plant may become raw materials or energy resources for another. Trying to simulate the natural ecological system and establish the circulation mechanism of "producer-consumer-decomposer", the system seeks to obtain closed material circulation, multilevel utilization, and the minimum output of waste. This system of production is referred to as a circular economy model (Zhang et al., 2010).

Industrial symbiosis can be viewed as one of the possible approaches to realizing the circular economy (CE) and achieving green growth. However, the translation of the industrial symbiosis/CE concept into national policies creates opportunities as well as challenges. Eco-Industrial Parks involve inputs from a variety of disciplines and stakeholders representing a wide spectrum of interests. UNIDO, World Bank & GIZ (2017b) indicated that the interrelated topics relevant to the parks (e.g. advancing resource efficiency, industrial synergies, collective park level infrastructure, utility services, effective park management structures); are often unfamiliar to decision-makers in the public sector. Awareness, knowledge and skills on these topics are critical for advancing analysis, reform, and implementation of EIP-related policies at all levels. Governments play a crucial role by creating the appropriate market conditions, policy, and regulatory frameworks, technical guidelines, and by initiating learning and participation processes.

Countries such as Denmark, France, Japan, and the Republic of Korea, among many others, have leveraged key elements of the EIPs concept to promote more inclusive and sustainable action, to improve industrial competitiveness in line with climate change goals (UNIDO, World Bank & GIZ, 2017a). China has a strong top-down approach to industrial symbiosis, accompanied by a clear vision and comprehensive strategies for a circular economy at the national and regional levels (Zhang et al., 2010). Industrial symbiosis exchanges in China have been actively facilitated by municipal and regional actors and networks, in combination with key private companies. However, in other countries, industrial symbiosis initiatives are often characterized by a bottom-up approach, where private companies and business parks are driving development, while industrial symbiosis is largely missing from the national-level policy agenda as seen in Kalundborg EIP in Denmark (Chertow & Ehrenfeld, 2012). In Kenya specifically, there are no local policy instruments that directly support industrial symbiosis or CE and these concepts are not explicitly a part of the development strategies.

The Government of Kenya launched the Kenya Industrial Transformation Programme in July 2015, that provided a framework for the country's industrialization process. A key component of this program is the setting up of industrial zones and parks. Currently, Kenya has gazetted 67 SEZs to spur economic growth by providing incentives and policies to promote and attract investment. Policies governing the SEZs in Kenya are incorporated in the draft SEZ policy and the SEZ Act No. 16 of 2015. The documents highlighted integrated infrastructure facilities, access to business and economic incentives, as well as the removal of trade barriers and impediments. It considers this, as being key benefits accorded through the SEZ regime. The draft Supplemental SEZ Regulations of 2019 provided additional benefits to encourage investors. The major selling point is the tax shields offered within the confines of an SEZ. Licenced SEZ enterprises, developers, and operators benefit from various tax rebates such as exemption from excise duty, customs duty, value added tax and stamp duty. Further incentives include; advantageous corporate income tax rates and preferential withholding tax rates, especially concerning profit repatriation.

The policy framework for green economy in Kenya is documented in the constitution of Kenya Constitution 2010, as well as; Kenya Vision 2030, Green Economy Strategy and Implementation Plan (GESIP) of 2015, National Climate Change Response Strategy (NCCRS) of 2010, National Climate Change Action Plan (NCCAP) of 2013, the draft Environmental Policy of 2013, the draft Kenyan Climate Change Policy of 2014 and the Climate Change Act of 2016. However, the draft SEZ policy, the Supplementary Regulations, and the Act itself does not prioritize the need to develop low carbon, green, and resource-efficient SEZs. These government policy documents do not integrate the desired sustainability elements of industrial ecology and circular economy agenda. Nonetheless, currently, there is a deliberate move seeking to transition from the traditional SEZs and industrial parks to EIPs to attract green foreign direct investments (FDIs) (GIZ, 2015).

Following this, some of the major initiatives include ongoing research funded by Green Climate Fund (GCF) to support Kenya to shift towards a low-carbon and climate-resilient industrial development model and support a paradigm shift away from Kenya's current linear model of industrialization. The project, which runs from October 2018 to September 2024, through UNEP will mobilize investments for the introduction and scale-up of industrial symbiosis and environmentally sound technologies and practices in existing and upcoming Industrial Zones/Parks in Kenya (UNEP, 2017). Another research project funded by DANIDA, the "Green & Circular Innovation for Kenyan Companies, (GeCKO)´´, will be undertaken by research institutions and universities both in Denmark and Kenya between 2018 and 2020, targeting 31 companies within the Ruaraka Business Community in Kenya as a pilot case. The project aims to provide scientific insights and an algorithm for designing and projecting high-circular Eco-Industrial Parks in Kenya (Danida Fellowship Centre, 2019).

Kenya Electricity Generating Company (KenGen) is setting up a Green Energy Park within the Olkaria geothermal resource area. The goal of this is to promote industrial activities through land leasing and sale of low-cost electricity, geothermal brine, steam, geothermal gases and raw water for cheaper manufacturing and production (KenGen, 2016a). The Green Energy Park is to be developed through a partnership with private manufacturing/processing firms. The park development will target to optimize KenGen's business operations, and also support the government of Kenya's industrialization strategy as a pillar for economic growth and social development.

However, the framework and definition of the Green Energy Park are still vague and an attempt to develop structures and set of rules governing the operationalization within the EIP International Framework will be important. Similarly, the current master plans governing the planning, design, construction, and set-up of the park are based on the wasteful linear economic development model of extracting raw materials, converting them into consumable products and discarding the resultant wastes into a landfill or reinjection wells (for waste geothermal fluid).

A much more promising economic development model is one that seeks to promote sustainability by optimizing the use of materials, energy, and wastes in a circular approach. The wastes of one industry, become the raw materials for another industry within the park, hence minimizing waste and enhancing resource-use efficiency.

1.1. Project focus

The basis for the development of Kenya's SEZ regulations was the wasteful linear flow of materials where raw materials are extracted, converted into products, and consumed with the resultant wastes being landfilled (Khisa, 2016; UNEP, 2017). What this means is that the regulations do not treat waste as a valuable resource. The key research would be to consider the possibility of symbiotic relationships between the industries to increase waste-to-value and improve resource efficiency. By considering the industrial symbiosis and circular economy model, the KenGen Green Energy Park is developed as an Eco-Industrial Park that will enable it to foster networks between businesses for knowledge sharing, exchange by-products, and cascade energy and materials. This will seek to gain environmental, social, and economic benefits to various stakeholders within the park. This is possible through supportive policy interventions and stakeholder participation in the development.

A close collaboration between UNIDO, World Bank, and German Development Cooperation (GIZ) enabled the development of the International Framework for EIPs (UNIDO, World Bank & GIZ, 2017a). The standard framework provides a common understanding of EIPs and an approach for defining minimum performance requirements for EIPs. A practitioner´s handbook for EIPs was established. It contains an EIP toolbox to provide a practical set of flexible tools to assist in the development and implementation of EIPs. The toolbox contains the EIP Policy Support Tool, that provides a platform for policy development and implementation process regarding EIPs and the Stan2web software that maps material flow between different manufacturing processes (Cencic & Rechberger, 2008). The standard policy and framework are used as a benchmark to propose a governance structure that can be adopted in developing the KenGen Green Energy Park with a set of rules, code of practice, and performance requirements. The Stan2web software will be used in this study to; simulate a material flow between processes to determine resource efficiency (material and energy) and to identify the possibility of industrial symbiosis in the KenGen Green Energy Park. The key approach is to determine industry requirements in terms of raw materials, waste, energy, water, utility, and infrastructure that can be shared within the Park. This will transform the greenfield park into an Eco-Industrial Park and promote sustainability.

1.2. Research questions

Currently, most industrial parks in Kenya are operated through a linear development model (Khisa 2016; UNEP, 2017). The parks are not designed according to the requirements of cleaner production, the concept of a circular economy, and ecological industry principles. This model of production is wasteful and does not promote sustainable development.

The main research question that the study seeks to answer is;

How can KenGen Green Energy Park (KGEP) embrace a stronger circular economy approach in its development, while at the same time being bound by best practices outlined in the EIP International Framework?

To tackle the key question the following questions must be probed:

1. Which industrial clusters are emerging in the KGEP?
2. What material flow patterns and symbiotic relationships exist in the identified clusters?
3. Are there opportunities for industrial symbiosis within the evolving identified industrial clusters?
4. How can the standard EIP International Framework guide in developing minimum performance requirements for KGEP?
5. Which appropriate management structure can promote the circular economy within the park?

1.3. Research objectives

The main objective is to assess the possibility of strengthening the circular economy in the proposed KenGen Green Energy Park using industrial symbiosis as environmental governance tools. In doing this, the study seeks to transform the wasteful linear model into a greener and sustainable closed-loop supply chain and upgrade it into a more economical, environmental, and socially-acceptable project.

Specific objectives include:

1. To determine the evolution of industrial clusters at the KenGen Green Energy Park;
2. To propose and assess material flow models and symbiotic relationships within the clusters;
3. To identify emerging industrial symbiosis opportunities arising within the clusters;
4. To develop best practices and policy recommendations based on the EIP International Framework;
5. To establish an appropriate management and governance structure that can promote the development of a circular economy model.

1.4. Justification of the study

Special Economic Zones have played an important role in the economic growth of many developing and advanced-developing nations (Kechichian and Jeong, 2016). These zones provide tailored infrastructure and business services, and they have become a successful model for large-scale job creation, transfer of skills and technology, export diversification, and industrial development facilitated by foreign direct investment. In these zones, sustainable business practices are widely ignored or overlooked by most of the enterprises. Due to challenges related to global climate change and a decrease in the stability of resources such as fuels, ecological and social factors are becoming crucial in the industry's plans to remain competitive. Governments and the private sector have become supportive of a more modern and sustainable investment regime for industrial zones. One of the paramount pathways is to change modes of production, consumption, and resource recovery and shift from a linear to circular (reduce-reuse-recycle) technology for efficient management of resources and waste in industrial zones.

The set up of the industrial economy in most countries is dominantly upon a linear model. It is based on the extraction and consumption of raw materials and energy to fulfill the growing customer demand. The linear model has generated important losses and detrimental impacts along with the value and material chain (Belaud et al., 2019). It has caused economic losses, structural waste, supply risks, and degradation of natural ecosystems. The main focus for most businesses and policymakers has been to address the following two simultaneous purposes; how to preserve the positive aspects of a continued development cycle while ensuring resources and environmental protection hence seeking new ways to enhance resource efficiency and to minimize the system risks. These requirements have introduced the transition to the circular economy (CE) model. The circular economy concept is defined as restorative and regenerative by design and aims to keep products, components, and materials at their highest utility and value at all times (Ellen-MacArthur-Foundation, 2015).

To achieve this, the country's SEZs should seek to organize and sequence the industrial production lines in a manner that mimics the circular flow of matter in natural ecosystems so that waste from one production line becomes feedstock for another production line (Aggarwal, 2019). Despite a significant increase in waste materials recovery in Kenya, the end of the life cycle for most of the country's products is unfortunately at the landfill (Khisa, 2016). There is a need for the development of infrastructural mechanisms for diverting waste from the landfill. Kenya is making advances in trying to address the country's ever-increasing waste problem and to address the country´s resource constraints and environmental pressures will accelerate its transformation from a linear extraction-use-throw-away model of economic growth into a closed-loop supply chain. Deliberate construction of green eco-industrial provides an enabling environment for improved resource-use efficiency, enhanced eco-innovation, and a workable industrial symbiosis. A key achievement is to transform wasteful industrial zones into eco-industrial parks and put in place effective waste management regulations that seek to reduce the volume of wastes at source and encourage recovery and recycling of the inevitable wastes. The Kenyan legislation is limited when addressing the need for green growth in industrial zones. It does not incorporate or define Eco-Industrial Parks (EIPs) and the approach of industrial symbiosis has not yet been implemented.

The study introduces EIP as a development approach to achieving green growth at the KenGen Green Energy Park and particularly focuses on the application of circular economy and industrial symbiosis concepts in a resource-scarce environment to rationalize its consumption.

1.5. Thesis outline

This thesis is divided into nine chapters:

Chapter one begins with an introduction section, reviews the background of the study that includes the problem statement, outlines the research focus, and states specific research questions and objectives. The research justification is also discussed.

Chapter two introduces the concept of Eco-Industrial Park and how material flow analysis has become a useful tool in industrial ecology; gives an overview of how regions are transitioning from the traditional Industrial Parks to Eco-Industrial Parks; gives an outline of the emerging EIPs in the world; presents a review of the International Framework for Eco-Industrial Parks. This chapter also gives an overview of the Kenyan Legal and Institutional Framework promoting green growth; the geothermal development in Kenya, an overview of direct use applications, and existing sustainability measures undertaken at the KenGen geothermal area.

Chapter three outlines the methodology, research approaches, and tools used in this study.

Chapter four describes in detail the study area; the current status of KenGen Green Energy Park development; discusses proposed industries co-located within the park; highlights industry requirements in terms of raw materials, energy and water; identifies industries desired products, wastes, and co-products that can be shared within the park; discusses energy available for the industrial park and the possibility of cascading thermal energy through various production processes. The amount of thermal energy from the geothermal fluid is calculated to estimate whether it is sufficient for industrial use.

Chapter five describes circular economy approaches, cluster development, and industrial symbiosis within the park; proposes clusters of companies and generates material flows models for each cluster. It highlights the evolution of industrial symbiosis networks and identifies emerging industrial symbiosis opportunities between companies within the KenGen Green Energy Park.

Chapter six discusses the EIP international framework as a benchmark and standards for developing policies in KGEP and gives policy recommendations by proposing effective EIP-related policies to support the EIP development. It highlights the risks associated with EIP development.

Chapter seven identifies stakeholders and ranks them in terms of influence and interest. It proposes a park management structure based on expanded triple helix collaboration for green growth; identifies the suitable performance monitoring and reporting structure for KenGen Green Energy Park.

Chapter eight gives an overall discussion of the study and evaluates how industrial symbiosis and circular economy are valuable principles in the development of the proposed EIP.

Chapter nine concludes the study and makes further recommendations for the development of the eco-industrial park. The recommendations are the potential avenues for further research on the topic.

2. Literature Review

2.1. Eco-Industrial Park (EIP) concept

As defined by Lowe (1997), an eco-industrial park is a community of manufacturing and service businesses located together on common property. Member businesses seek enhanced environmental, economic, and social performance through collaboration in managing environmental and resource issues. By working together, the community of businesses seeks a collective benefit that is greater than the sum of individual benefits each company would realize by only optimizing its performance.

In a resource-constrained world, eco-industrial parks are increasingly seen as an effective way to limit resource consumption in our economy. This is achieved through industrial symbiosis, which is a means by which companies can gain a competitive advantage through the physical exchange of materials, energy, water, and by-products. Park and Behera (2013) indicated that EIP involves mostly eco-industrial synergies whereby mutualization synergies are related to mass and energy flows, as well as other components, such as infrastructure, equipment, services, employee technical skills, and specific waste collection and treatment. The pooling of these resources leads to reduced economic and environmental costs.

According to GIZ (2015), an eco-design should be embedded at an early stage of an EIP and the SEZ developer needs to consider the following: integration of the park in surrounding infrastructure; efficient land-use planning; planning of park infrastructure; energy supply; water supply, waste disposal techniques; wastewater treatment facilities; and environmental, emergency, and social facilities. This will simplify the SEZs incorporation of EIP concepts and save significant costs to the operator and tenants in the long term.

Tudor et al. (2007) discussed the need for creating an enabling environment for EIP development by establishing an appropriate set of enabling policies for mixed-industry developments by creating relevant fiscal incentives to promote competitiveness between businesses. There is also the need to encourage co-location, through tax breaks to enable waste and emissions to be reused by industries in the same proximity. By encouraging synergies between industries, a great symbiotic network including information and resource sharing can be constructed. Other important factors enhancing development are building awareness on resource efficiency (materials and energy) and the benefits of an efficient waste management system/design as illustrated in Figure 2. Deog-Seong et al. (2005) stated that unlike the conventional industrial parks, EIPs focus on increasing the community's sense of belonging (or cultural identity), primarily because this is one of the most important factors for increasing the commitment of local stakeholders by providing various cultural activities and recreation facilities, which could promote communal activities within the park. A key part of greater multi-stakeholder involvement has to be hinged on increased education and awareness of the concepts and benefits of EIP development.

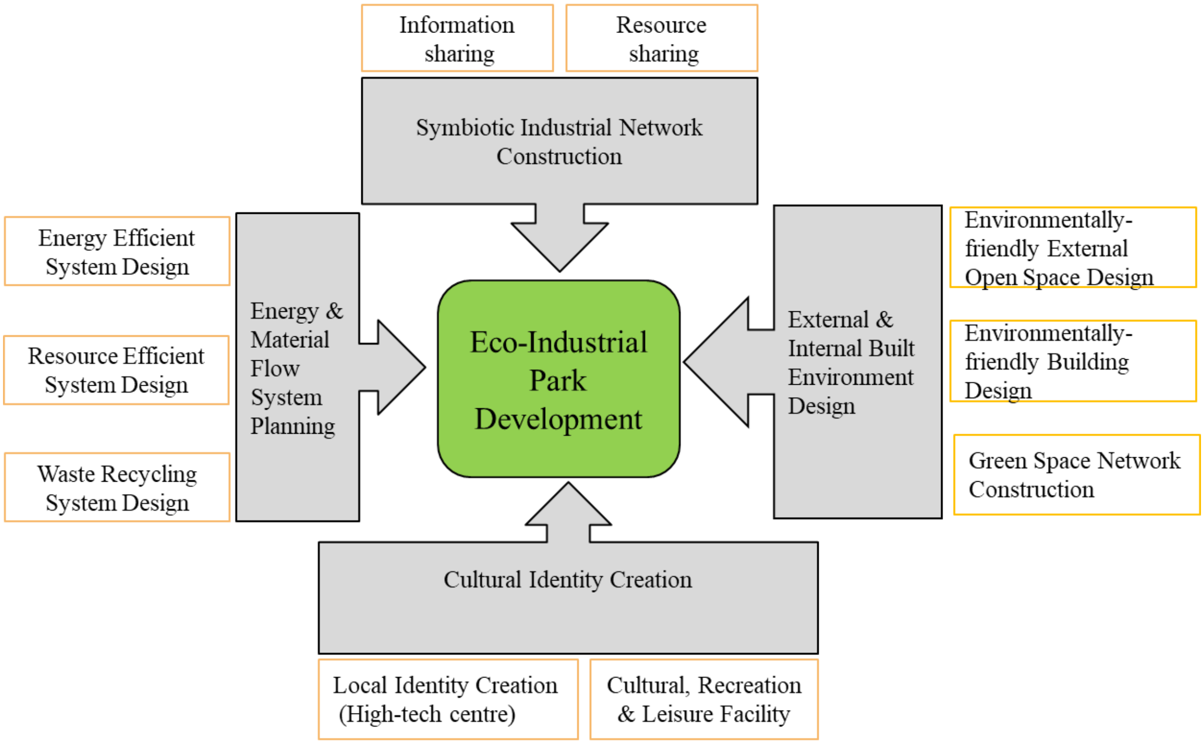

Figure 2: A conceptual model of EIP development (Deog-Seong et al., 2005)

EIPs can serve a significant role in realising economic, environmental and social benefits both to individual businesses well as to a cluster of firms. Tudor et al. (2007) explained that the emphasis for the EIP should mainly be on a systems approach, rather than focusing on specific streams. A sound support system needs to be established to ensure its long-term viability. Five major initiatives are identified by Panyathanakun et al. (2013) as the driving factors for a sustainable EIP as illustrated in Figure 3. These five categories are technical, economic, environmental, societal and organizational.

The technical category aims to achieve the physical infrastructure with a focus on eco-design and eco-centers. This is achieved through proper master planning, zoning, and sound infrastructure development.

The economic category aims at achieving economic benefits for the co-located industries within the park, improving the local economy and the wider community. Developing the market, transportation, and logistics is also the main focus of this category.

The environmental category largely emphasizes on resource use efficiency, pollution control, and occupational safety. This targets the management of wastewater, air pollution, industrial solid waste, energy efficiency, noise pollution, and health and safety. It also highlights the importance of environmental monitoring, mitigation measures, and eco-friendly industrial process.

The societal category encourages the improvement of the quality of life for industrial park workers and the surrounding communities.

The organizational or managerial category aims to establish a collaboration among stakeholders, improving maintenance, efficient the park management system, and effective information and report management. This systematic management process promotes continuous improvement.

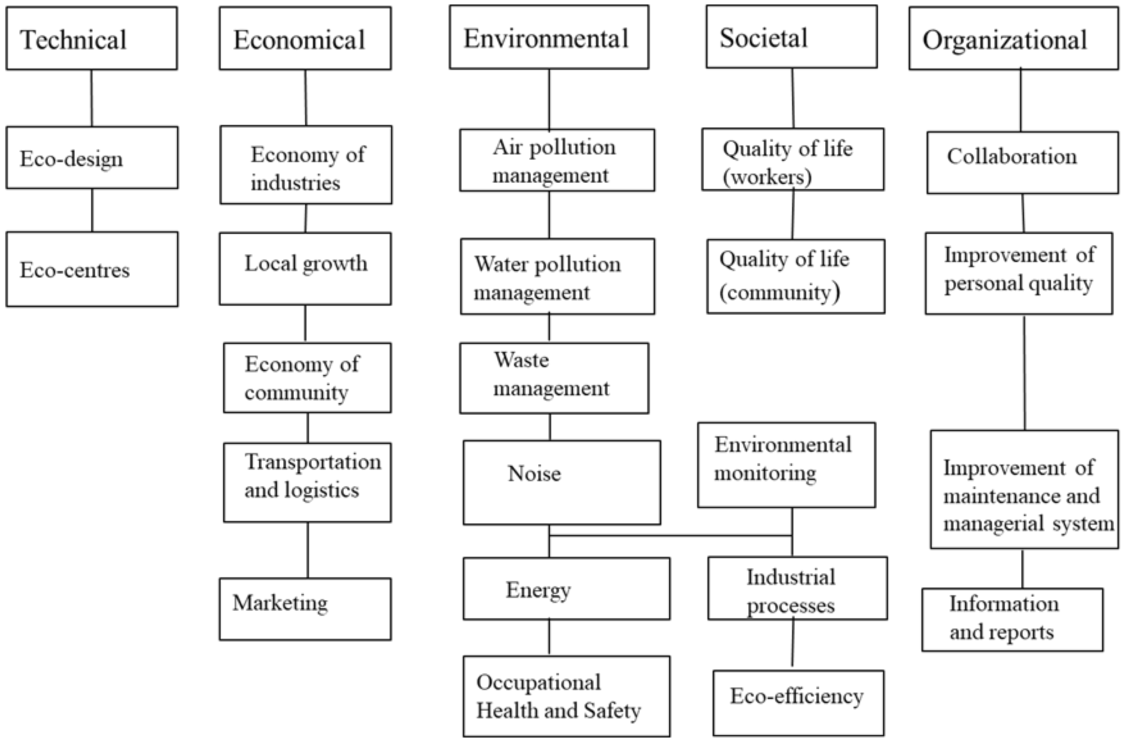

Figure 3: Initiatives to developing an EIP (modified from Panyathanakun et al., 2013)

The initiatives are a crucial component and can be customized by stakeholders in KenGen Green Energy Park. This would be in line with developing a framework for eco-efficiency evaluation, industrial process assessment and monitoring of compliance for continuous improvement.

Industrial activities in an EIP area can produce significant negative environmental externalities, which can come from point sources or dispersed sources. These are mainly in the form of air emissions, water pollution, land contamination, and over-exploitation of resources. Furthermore, industrial parks that are not properly managed can negatively impact the workforce and communities in which they operate. An EIP framework in tandem with national and local legislation allows associated risks to be appropriately managed and sustainable development opportunities to be maximized. This will aid in mitigation and managing of the potentially adverse impacts of industrial parks.

Key drivers for Eco-Industrial Parks include: reducing an industrial park’s environmental footprint; promoting efficiency gains; enabling community cohesion; providing better access to finance and technical support; and enhancing business competitiveness (UNIDO, WB & GIZ, 2017a). Sound International Industrial Best Practice demonstrates a wide range of economic, environmental, and social benefits from EIPs as enlisted in Table 1.

Table 1: Three key drivers and benefits accruing from an EIP (Source: UNIDO, World Bank & GIZ, 2017a)

Economic	**Environmental**	**Social**
•Direct and indirect employment creation; •Skills-upgrading of the labor force; •Linkages between industrial park firms and small and medium-sized enterprises (SMEs) and communities outside the industrial park; •Technology and knowledge transfer through foreign direct investment; •Demonstration effects arising from the application of good international industry practices and regional development approaches; • Minimize operational costs.	•Climate change commitments at the global and national levels; •The presence of relevant policy mechanisms (e.g. taxes and carbon pricing); •Greening the supply chain and alleviating resource constraints; •Better resource management and resource conservation; •Ensuring infrastructure is resilient to higher resource costs and adapts to climate change risks; •Responding to environmental and social concerns from consumers; •Increased demand to improve efficiency and growth.	•Better working and labor conditions; •Creation of local jobs; •Improvement of gender equality; •Better security and crime prevention; •Provision of social infrastructure to workers and community; •Support to local community well-being and community outreach; •Provision of vocational training; •Improved occupational health and safety; •Transition to more sustainable land use.

2.1.1. Circular Economy

This is a system of production that is increasingly been adopted worldwide as a way to overcome the current production and consumption model. The circular economy is intended to increase the efficient use of resources, with special attention to industrial waste. Further, achieving a better balance between the economy, environment, and society by promoting certain adoption production patterns within the economic system. A circular economy feeds back into its development and thus closes the loop (Jørgensen and Pedersen, 2018). It is a regenerative economic model aimed at minimizing waste and reducing resource dependency as shown in Figure 4. This sustainable economic approach, uses a ‘repair, reuse, recycle’ model of production and is more beneficial than the traditional linear ‘take, make, dispose’ model. Cavallo (2018) listed other benefits of a circular economy as; reduction of environmental footprint, increased economic growth, create greater collaboration between companies, improving the products and saving on production costs, enhancing the business competitiveness and creating more jobs.

Khisa (2016) postulated that a circular economy powered by resource-efficient cleaner production (RECP) will improve resource security of the economic zone, reduce associated environmental impacts associated with waste disposal, and offer new opportunities for economic growth and wealth creation. Furthermore, according to Chertow & Ehrenfeld (2012), industrial symbiosis is achieved when there is efficient cooperative management and the exchange of resource flows through clusters of companies.

Wastes that remain are recovered for use as feedstocks by other businesses within the system. This invariably reduces the need for sourcing and transporting additional virgin and otherwise wasted resources. When implemented holistically, industrial symbiosis accelerates the transformation from a linear ´extraction-use-dispose´ model of economic growth into a ´closed-loop´ supply chain, changing how industries and communities relate to each other.

2.1.2. Industrial Symbiosis (IS)

IS is recognized as an approach towards the transition to a circular economy and its use contributes to environmental and economic benefits. It is a collaborative approach concerning the physical exchange of materials, energy, and services among different firms: accordingly, wastes produced by a given firm, are exploited as inputs by other firms (Albino & Fraccascia, 2015). This approach can generate remarkable environmental benefits since it allows the reduction of the number of wastes disposed off, in the landfill, lower amounts of primary inputs, raw materials, and fossil fuels used by industry, and lower amounts of greenhouse gas (GHG) emissions generated.

Mirata (2004) reported that the social benefits of industrial symbiosis are the creation of new firms and new jobs. To foster the adoption of IS, the symbiotic exchanges should make economic logic to the participating firms (Fraccascia et al. 2019). Through industrial symbiosis, firms are interested to achieve competitive advantage coming from lower production costs and revenue increase. Therefore, the first requirement for the establishment of a symbiotic relationship is its economic sustainability for all the firms involved. The need for coordination among firms occurs when the adoption of IS practice determines the existence of interdependencies between firms to manage.

Establishing waste exchanges among firms can be achieved either through a top-down or bottom-up approach (Chertow, 2007). The bottom-up approach occurs as the result of a spontaneous self-organized process undertaken by firms as in the case of Kalundborg EIP in Denmark. Mirata (2004) demonstrated that both these models can be successful where the participating firms are interested to collaborate exchanging wastes with each other because driven by the willingness to obtain economic benefits.

2.1.3. Material Flow Analysis (MFA)

Material flow analysis (MFA) methodology can be utilized in EIP modeling to analyze material flows and to measure the flow of natural resources and materials through various scales of the economy. Geng et al. (2011) indicated that the quantitative method focuses on resource input, resource consumption, integrated resource utilization and reduction of waste generation. The analysis of all the raw materials, energy and water flows used in the system is important. Similarly, the process outputs (products, by-products, emissions, and wastes) should be monitored to identify whether the processes have significant environmental impacts. Also, in situations in which raw material decreases at expenses of energy or water consumption, then effective recycling can be detected. Subsequently, in an EIP, as the use of all resources should be improved, all should be quantified.

Key to this analysis is the recognition of several basic design principles in industrial ecology that suggest the utilization of MFA; controlling pathways for materials use and industrial processes, creating loop-closing industrial practices, dematerializing industrial output, systematizing patterns of energy use and balancing industrial input and output to natural ecosystem capacity (Brunner & Rechberger, 2004). A better understanding of industrial metabolism requires a description of the most relevant material flows through the industrial economy. The results of an MFA reveal the most important processes during the life cycle of the material. Similarly, the analysis detects relevant stocks of the material in the economy and the environment; shows the losses to the environment and the final sinks, and tracks down internal recycling loops. Additionally, MFA can be used to compare options on the process level and at the system level.

Hatefipour (2012) classified different exchanges amongst firms and industries in the form of synergies. The exchanges are categorized between industries and actors as supply, by-products, and utility synergies. Since different exchanges have different geographic proximity, which refers directly to the spatial scale, Chertow (2008) proposed a methodology based on a taxonomy of five different material exchange types, considering both spatial scale and material exchanges amongst firms;

- Type 1: through waste exchanges
- Type 2: within a facility, firm, or organization
- Type 3: among firms co-located in a defined Eco-Industrial Park
- Type 4: among local firms that are not co-located
- Type 5: among firms organized virtually across a broader region

Types 3-5 offer approaches that can readily be identified as industrial symbiosis. However, this study will focus majorly on EIPs, precisely corresponding to Type 3.

2.2. The transition from traditional industrial parks to EIPs

Traditional industrial parks have been recognized as an efficient means of unifying industrial activities with business, infrastructure and service objectives. Most of them are planned and developed to foster economic growth and improving a location’s competitiveness through potential collaborative and efficiency gains. These parks or economic zones also share a common attribute in that they all typically fail to incorporate the environmental and social externalities stemming from their activities (UNIDO et al., 2018). Therefore, in the context of mounting pressure to address climate change and foster international development, it is becoming increasingly clear that industrial parks need to move beyond their traditional resource-intensive business models to integrate environmental and social dimensions to remain a frontrunner in the economic activities in their respective countries. This means that there is a need to use fewer resources per unit of economic output and reduce the environmental impact of any resources that are used, or economic activities that are undertaken (UNEP, 2011).

Figure 4 captures the essence of the two key aspects of decoupling as applied to sustainable development, namely; resource decoupling and impact decoupling. This has been successfully achieved by incorporating industrial symbiosis and having a clear industrial policy that promotes a circular economy and overall sustainability. In turn, it resulted in many industrial parks minimizing environmental impacts and attracting direct and indirect benefits to the industrial sector in general, and resident enterprises in particular. Firms and industrial sectors in EIPs can improve capital efficiency, achieve utility cost savings, sustain business continuity, produce goods that are preferred by global buyers, attract foreign direct investment (FDIs), increase exports and generate additional revenues (UNIDO et al., 2018).

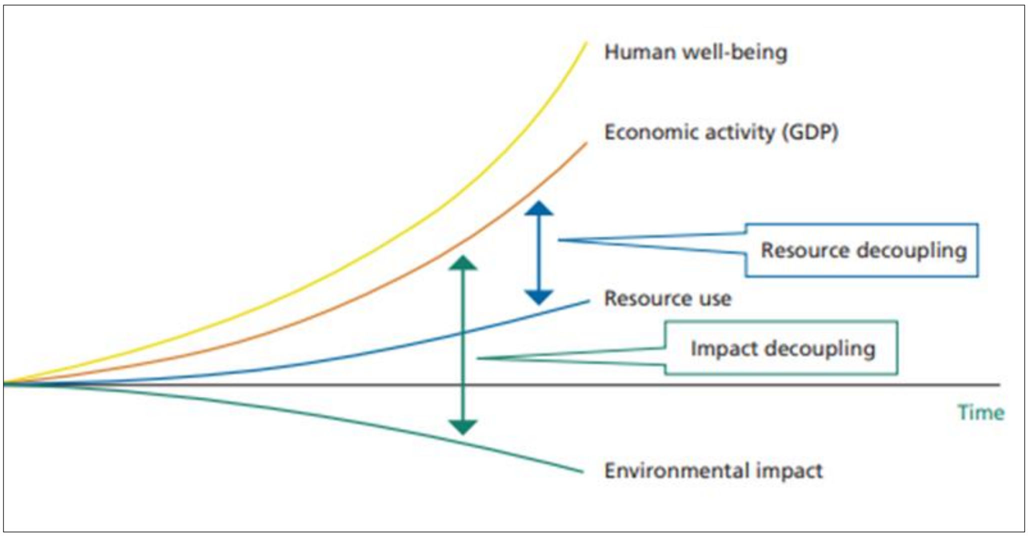

Figure 4: Decoupling natural resource use and environmental impacts from economic growth (UNEP, 2011)

Boix et al. (2015) explained that the optimal design of industrial symbiosis allows for a decrease in environmental impacts and promotes industrial activities by developing synergies between production firms of the EIP. This concept leads to the use of resources as optimally as possible and consequently, the total environmental impact of economic activities aims to stabilize and can decrease as demonstrated in Figure 5.

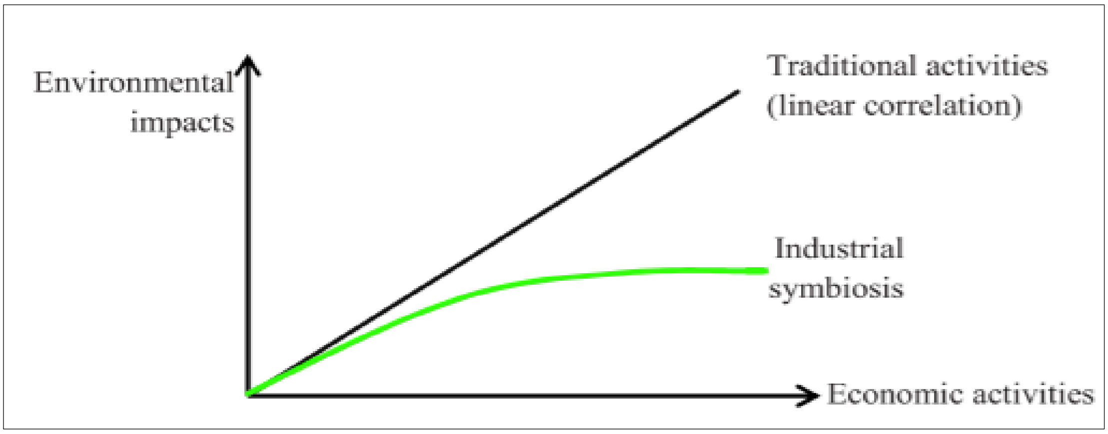

Figure 5: Decoupling environmental impacts from economic activities through industrial symbiosis (Boix et al., 2015)

According to UNIDO (2016a), an industrial zone or park can turn into an eco-industrial park through the combination of the following factors:

- Plant level efficiency: resulting in minimization of waste and emission generation from individual enterprises;
- Collective synergies: resulting in optimized resource exchanges between companies;
- Environmental and utility systems;
- Proper zoning and planning;
- Environmental management of park operations.

The objective of this approach is to upscale and expand resource-efficient and cleaner production activities to move beyond the borders of EIPs and incorporate them into sustainable cities as indicated in Figure 6. In such cities, economic and social symbiosis can be achieved in all aspects of sustainable urban planning. Waste streams can be exchanged on a regional scale, making use of a wider range of infrastructure, logistics and recycling wastes and cascading energy resources.

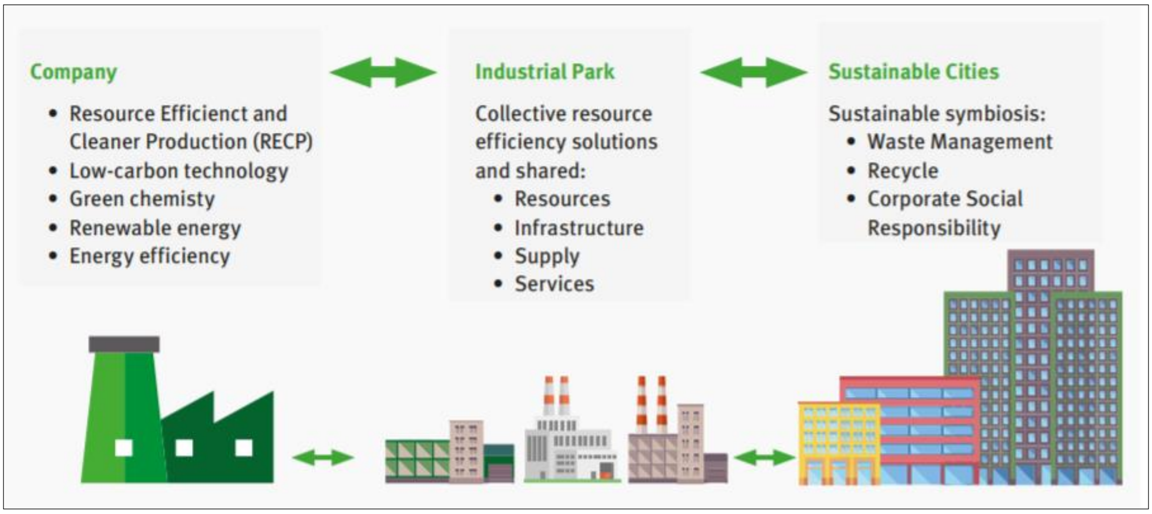

Figure 6: Industrial-urban symbiosis showing networks among enterprises forming sustainable cities (UNIDO, 2016a)

EIB (2015) noted that a transition to a circular economy needs a systemic approach involving various stakeholders that challenge the following:

- Businesses to develop circular business models and enabling technologies;
- policymakers and legislators at all levels of governance to put in place effective regulation and incentives;
- the financial sector to work towards improving the availability of financing and to improve its approach to appraising linear and circular risks;
- increase of public awareness and improving consumer education by public authorities and civil society to contribute.

Making the transition from traditional linear to a circular economy can be challenging, especially for companies whose structures, strategies, operations and supply chains are deeply rooted in the linear approach. Even if the shift often makes economic sense, production processes first need to transform from linear to circular. This may require initial investments, modification of processes, feedstock, equipment and output, training and building capacity, and coordination within the wider value chain. The accelerated efforts to adopt the industrial ecology concept in Kenya are likely to be hindered by these factors especially in the existing Industrial Parks (brownfields). In this context, the upcoming Industrial Parks (greenfields) like the KenGen Green Energy Park should incorporate the circular economy approaches and develop a framework during the planning and design phases of the park development.

2.3. Emerging Eco-Industrial Parks in the world

Eco-Industrial Park can occur through two evolution paths; self-organized and constructed or designed approach (Saikku, 2006). Self-organized eco-industrial parks have evolved spontaneously without any policy management or administrative plans to develop cooperation e.g. Kalundborg Eco-Industrial Park in Denmark. However, governments and the private sector are beginning to recognize the impacts of enhanced resource and energy efficiency on a country's overall industrial competitiveness, including the additional value that EIPs can provide. Many Nations today, have become more conscious of green approaches in combining manufacturing and competitiveness. Some of them include Bangladesh, China, Colombia, Egypt, India, Japan, Morocco, South Korea, Thailand, Turkey, and Vietnam. They are now looking to scale up inclusive and sustainable industrialization by developing a national EIP framework.

Figure 7 shows the global growth in the number of EIPs. In 2000, only 11 EIPs were in non-OECD countries (Kechichian and Jeong, 2016). By 2010, EIPs were a prominent global tool for new industrial zones, while retrofit activities continued in over 40 countries. There are now more than 300 industrial zones in 140 countries.

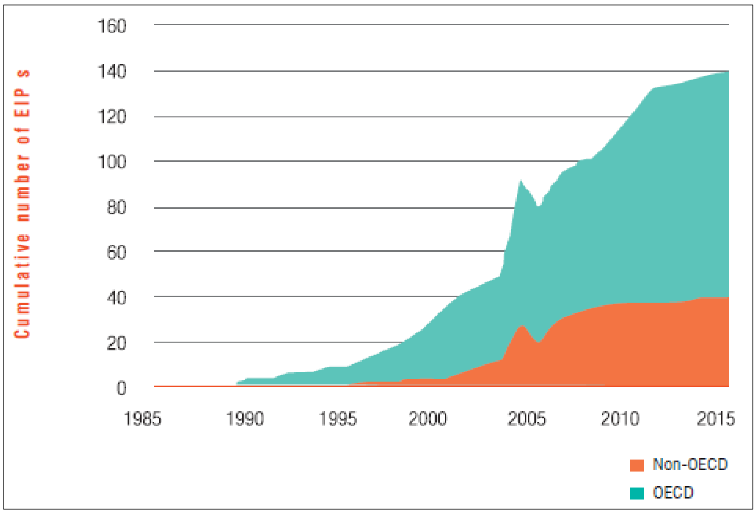

Figure 7: The global growth of EIPs (Kechichian and Jeong, 2016; UNIDO, 2016b)

UNIDO (2016b) stated that EIPs are either operating or planned EIPs of which 77 percent are operational as seen in Figure 8. Most of the operational EIPs are industry-oriented zones. They resulted from retrofitting existing EIPs (59 percent), followed by planned EIP greenfields (34 percent). About 7% are organically or non-planned development of EIPs (Beers et al., 2019).

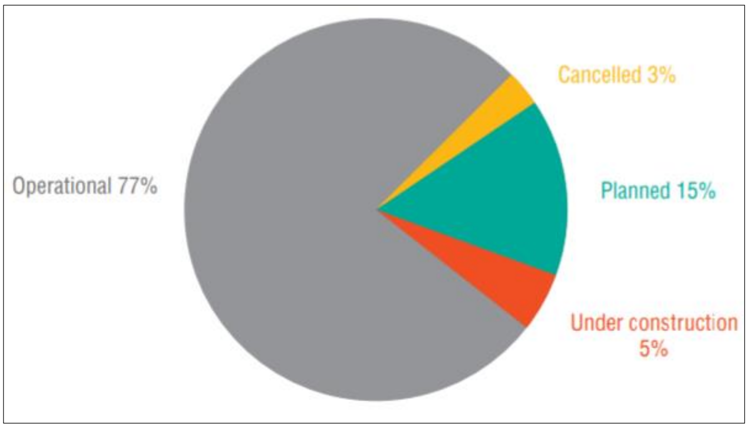

Figure 8: Operating status of existing EIPs in 2016 (UNIDO, 2016b)

2.4. International Framework for Eco-Industrial Parks

The framework provides the basis for defining and setting prerequisites and performance requirements for EIPs. It focuses on four key categories; park management performance, environmental performance, social performance and economic performance (UNIDO, World Bank & GIZ, 2017a). As a baseline, EIPs must comply with all applicable local and national regulations as well as the broader performance requirements set out within this framework. The performance requirements for EIPs are defined so that environmental and social impacts go beyond regulatory requirements as stipulate in Figure 9. The framework provides the basis for defining and setting prerequisites and performance requirements for EIPs based criteria (benchmarks). These criteria are inclusive in scope and are aimed at all types of industrial parks in different contexts (Beers, et al., 2019). The criteria relate to stakeholders in the private and public sectors (e.g., park management, tenant companies, local/regional/national government agencies) wherever these industrial parks are located. While adherence to all of these criteria is recommended, it is understood that some countries may wish to adjust the criteria to their local specificities.

The EIP framework and corresponding performance requirements provide a useful guideline toward the mainstreaming of EIPs. Additionally, it serves as a tool to build capacity and sound institutional frameworks. On an operational level, the EIP framework assists practitioners and park managers in assessing opportunities where further strengthening is required in line with international good practices.

UNIDO, World Bank & GIZ, (2017a) stated that compliance with national and local regulations is an absolute requirement for all industrial parks, regardless of their specific geographic location and characteristics. An EIP, as a collective entity of residing firms, must comply with all applicable national and local laws, regulations, and standards. When applying the international framework to a specific park, stakeholders will be required to check and ensure regulatory compliance, standards, and protocols are observed. Meeting the EIP standard requirements is a primary step in integrating sustainability criteria within industrial parks. Where technically, socially, and economically possible, EIPs must strive to go beyond the expectations set out within the international framework.

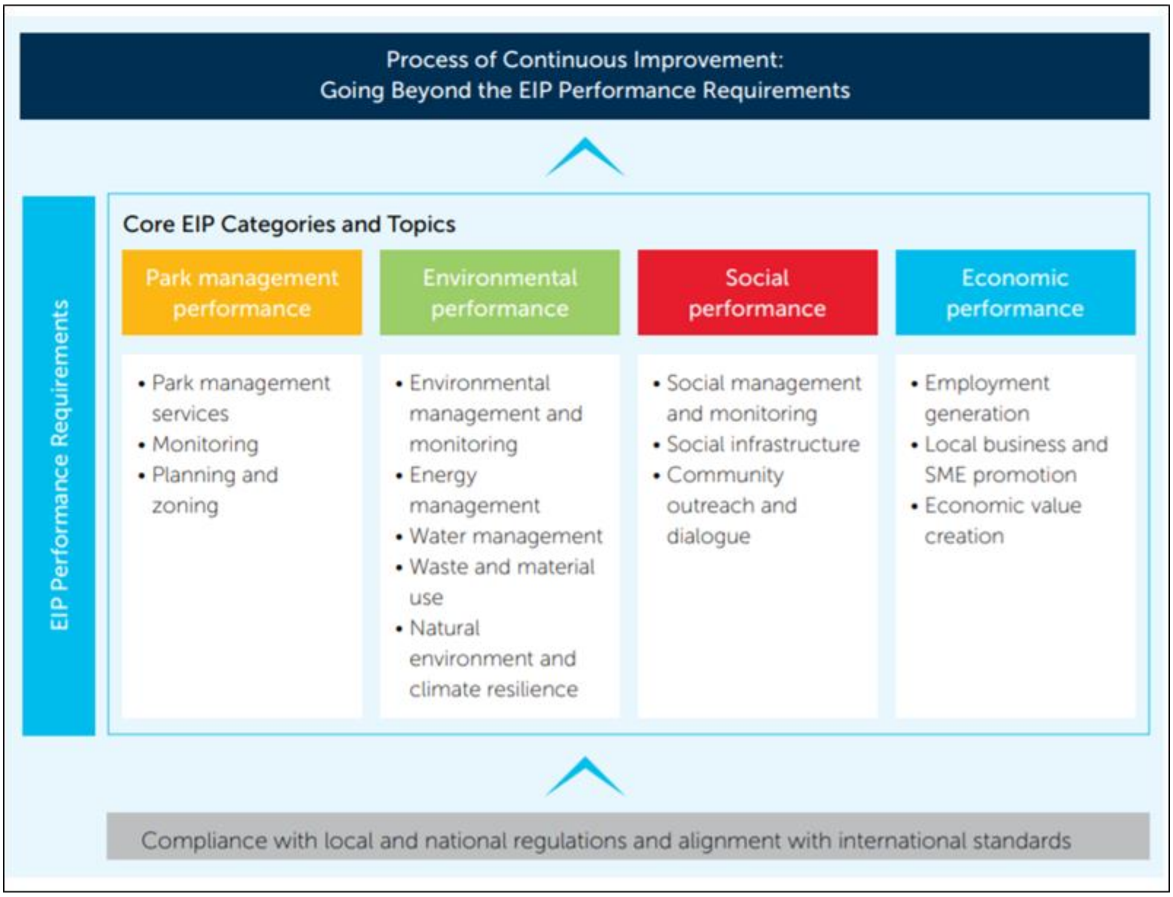

Figure 9: Eco-Industrial Park Framework (UNIDO, World Bank & GIZ, 2017a)

As well as park regulations, the EIP and related businesses are expected to comply with local and national regulations (UNIDO et al., 2019). These include national regulation and local laws of environmental and social aspects as listed in Table 2.

Table 2: Regulatory compliance for all EIPs (modified from UNIDO et al., 2019)

Environmental	Air emissions (SOx, NOx, greenhouse gas and chemical odor)
	Water (water exploitation, watershed management, discharge limits)
	Hazardous waste transportation and disposal (labeling, maximum volume, storage, and recycling)
	Noise limits in activities (ambient darkness and surrounding, measured in dB)
	Protection of natural environments and biodiversity (sensitive marine environments, native forests, flora, and fauna)
	Energy and resource efficiency as well as other regulations related to efficiency (3Rs: reducing waste, reuse, recycling)
	Climate change mitigation and adaptation
Social	Occupational Health and Safety (protective clothing and equipment, safety features of machines)
	Labor laws/regulations (working hours, child labor)
	Human rights and gender laws, discrimination
	Protection of indigenous people (traditional, tribal and other land-connected people)

	Anti-corruption (access to information, accountability, bribery, conflict of interest)
	Violence and crime prevention (cybercrimes, theft, violence against women, children, elderly)
Economic	Reporting of financial performance and disclosure
	Employment creation and local skills development
	Promotion of SMEs and local business development
	Technology transfer and intellectual property protection
	Capacity building and skills development
	Financial, trade and fiscal regulation (tax exemptions and incentives)
Park Management	Land use planning, zoning and permitting
	Emergency awareness and preparedness (risk monitoring and management)

Meeting the performance requirements is an important and meaningful achievement for an industrial park. However, exceeding the performance requirements and instilling a culture of continuous improvement is crucial to achieving a lasting and significant impact on EIPs. The industrial park needs to comply with national and local regulations and exceed minimum requirements to meet the approach set out in UNIDO, World Bank & GIZ, (2017a), for assessing the performance level of parks through a three-tier classification system of bronze, silver, and gold levels as seen in Figure 10. This performance assessment can be applied both to support the planning and development of new Eco-Industrial Parks (greenfield), as well as to the conversion and optimization of existing industrial parks into Eco-Industrial Parks (brownfield).

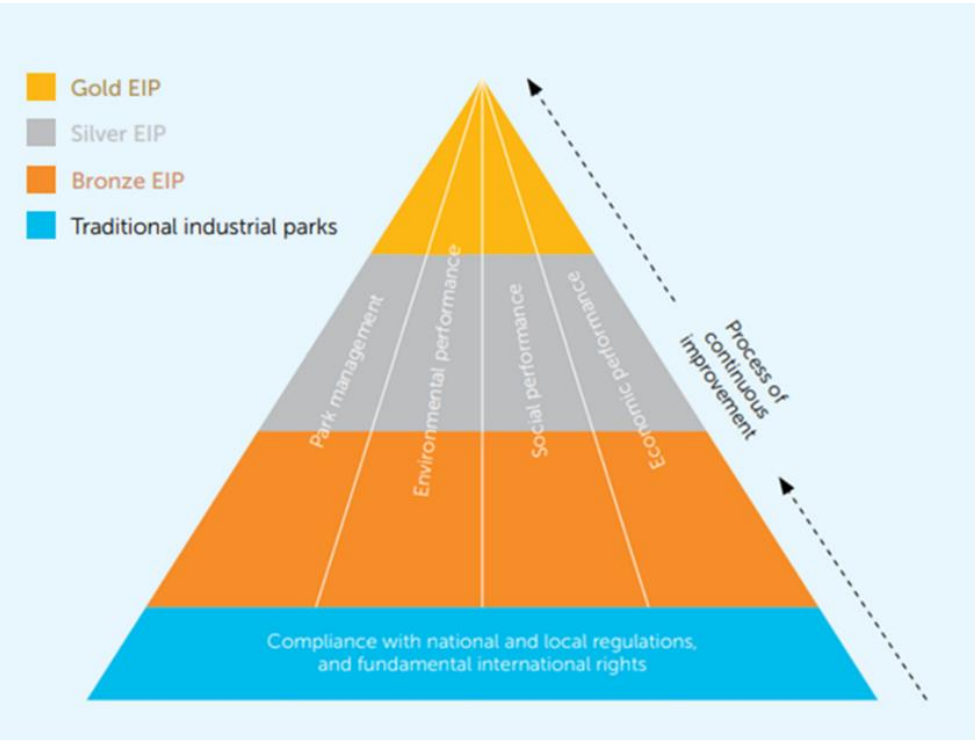

Figure 10: Performance and Continuous Improvement-Based Framework for Assessing EIPS (UNIDO, World Bank & GIZ, 2017a)

2.5. Kenyan Policy Framework

To promote green growth, the Kenyan Government has developed a green economy strategy that will support its development efforts towards addressing key challenges of poverty, unemployment, inequality, environmental degradation, climate change and variability, infrastructural gaps and food security (Government of Kenya, 2014). The policy framework for a green economy in Kenya is spelled out in the following documents.

Kenya Constitution 2010

The Constitution of Kenya (2010) forms the basic framework for the formulation of adaptation and mitigation legislation, policies and strategies by guaranteeing the right to a clean and healthy environment under the Bill of Rights (Government of Kenya, 2013). A clean and healthy environment (Articles 42, 69 and 70) is a fundamental right under the Bill of Rights. This right cannot be fully provided for unless action is taken to address environmental pollution, which can be supported through a low carbon climate-resilient development trajectory (Government of Kenya, 2010).

Kenya Vision 2030

The Kenya Vision 2030 also has environmental goals outlined under the social pillar. According to the pillar, Kenya aims to be a clean, safe and sustainable environment by 2030. The country aims to achieve this goal by for example improving pollution and waste management strategies. By commissioning an environmental impact assessment study for the the project, the proponent has displayed his desire to support the Kenya Vision 2030.

National Policy on Water Resources Management and Development (2006-2008)

While the national Policy on Water Resources Management and Development (1999) enhances the systematic development of water facilities in all sectors for promotion of the country's socio-economic progress, it also recognizes the by-products of this process as wastewater. It, therefore, calls for the development of appropriate sanitation systems to protect people's health and water resources from institution pollution. Industrial development projects, therefore, should be accompanied by corresponding waste management systems to handle the wastewater and other waste emanating therefrom (Government of Kenya, 2006).

Green Economy Strategy and Implementation Plan (GESIP) 2016 – 2030

The strategy and implementation plan focuses on overcoming the main binding social-economic constraints towards the attainment of the Kenya Vision 2030. It targets multiple challenges including the infrastructure gaps, food insecurity, environmental degradation, climate change and variability, poverty, inequality, and employment (GESIP, 2016).

Kenya Industrial Transformation Program 2015

This is a strategic document to guide industrial development in Kenya towards transforming the country into an industrial hub. This would be done by launching sector-specific flagship projects that build on Kenya´s comparative advantages, creating an enabling environment to accelerate industrial development through industrial parks/zones, encouraging small and medium scale enterprises, and creating an industrial development fund (GOK 2018). The strategy acknowledges the creation of the green industry as a priority to drive a low-carbon green economy.

National Climate Change Action Plan 2018 - 2022

Kenya's National Climate Change Action Plan is a five-year plan that helps Kenya adapt to climate change and reduce greenhouse gas emissions. NCCAP 2018-2022 aims to further Kenya's development goals by providing mechanisms and measures to achieve low carbon climate-resilient development in a manner that prioritizes adaptation (Government of Kenya, 2018).

Manufacturing Priority Agenda 2018

Pillar five of the agenda focusses on securing the future of the manufacturing industry by ensuring its operations are environmentally friendly and sustainable and keep pace with the ever-changing technological advances which necessitate continuous skill development of the labor force (KAM, 2018). Organization for Economic Cooperation and Development (OECD, 2011) established that green growth can be seen as a way to pursue economic growth and development while preventing environmental degradation, biodiversity loss, and unsustainable natural resource use. Other actions that have been suggested by the policy include; promotion of self-regulation for manufacturer on environmental issues, applying for the green climate change fund, supporting the finalization and implementation of the National Water Policy; promoting industry symbiosis to encourage green economy and create a new culture of economic growth, and promoting and recognizing the certification mark for responsible care.

SEZ ACT, 2015

The document defines the Kenyan special economic zones and establishes the Authority and regulatory provisions that bind the operations within these zones**.** The Act guides on the issuance of licences and renewal procedures for the park operators. The Act administers the formation of a one-stop-shop at the headquarters of the Authority to facilitate the performance of all functions, powers, and responsibilities assigned to the Authority (Draft SEZ Regulation, 2016).

The SEZ Regulations

Both the SEZ Regulations of 2016 and the draft Supplemental SEZ Regulations of 2019 provide complementary measures regarding administration and issuance of licences, certificates, permits, approvals or authorisations to the park developers and operators. The regulations give guidelines on imposing sanctions and dispute resolutions, labour rules, Interzone goods movement and taxation (tax exemptions and incentives) rules. The regulations do not provide laws for environmental management, however, the Authority may delegate the park management the responsibility for establishing and enforcing rules on the use of hazardous or flammable materials, noise disturbance and disposal of waste.

Climate Change ACT, 2016

The act provides regulations for enhancing response to climate change and calls for the adoption of a green growth development trajectory that is a low carbon, resource-efficient and socially inclusive in terms of the creation of decent green jobs. Incentives are provided by the Act for the promotion of climate change initiatives including reduction of greenhouse emissions and the use of renewable energy. The incentives promote the advancement of the elimination of and mitigation against climate change and its effects.

The legal and institutional frameworks that shall guide the performance monitoring processes for environmental compliance in the proposed green energy park are enlisted in Table 3.

Table 3: Kenya Legislations and Administrative procedures

Aspect	Description	Legal Framework
Air pollution		The Local Government Act, Cap. 265 (Revised 2010) Section 163 (e)
		The Physical Planning Act, Cap. 286 Section 36
		The Penal Code, Cap. 63, Section 192
		The Environmental Management and Co-ordination Act, 1999, Section 71
Noise	Noise pollution	The Environmental Management and Co-ordination Act, 1999, Section 102
		The Penal Code, Cap. 63, Section 193.
	Noise Vibration	The Environmental Management and Co-ordination (Noise and Excessive Vibration Pollution) (Control) Regulations, 2009 Regulation3(1), (2)
Wastes	Solid waste disposal	The Public Health Act, Cap. 242, Section 118 (c)
	Wastewater discharge	The Public Health Act, Cap. 242, Section 118 (d)
	Pollution prevention	The Environmental Management and Co-ordination (Waste Management) Regulations, 2006, Regulation 14
Water	Water pollution	The Penal Code, Cap. 63, Section 191
	Water resource conservation	The Environmental Management and Co-ordination Act, 1999, Section 42
	Protection of water sources	The Environmental Management and Co-ordination (Water Quality) Regulations, 2006, Regulation 6
	Water pollution prohibition	The Environmental Management and Co-ordination (Water Quality) Regulations, 2006, Regulation 24
	Obstruction or pollution of watercourse or water resource.	The Water Act, 2002, Section 94
	Compliance with water quality standards	The Environmental Management and Co-ordination (Water Quality) Regulations, 2006, Regulation 24
	Water pollution prohibition	The Environmental Management and Co-ordination (Water Quality) Regulations, 2006, Regulation 24, Regulation 24
Sustainable resource use		The Constitution of Kenya, 2010, Article 66, 69
Safety	Occupational health and safety	The Occupational Safety and Health Act, No. 15 of 2007, Section 6, 21, 47,55
	Fire safety	The Occupational Safety and Health Act, No. 15 of 2007, Section 79,82

Protected areas, ecosystem conservation		The Wildlife (Conservation and Management) Act, Cap. 376, Section 15
Protected areas		The National Museums and Heritage Act, Cap. 216, Section 34
Energy	Use of geothermal resources	The Energy Act, No. 1 of 2019, Section 81
	Energy efficiency	The Energy Act, No. 1 of 2019, Section 187,188,189

2.6. Overview of Geothermal Development in Kenya

Kenya is naturally endowed with an enormous potential of geothermal energy that is a clean indigenous environmentally benign source of renewable energy used for electric and non-electric uses (Mangi, 2013). Studies have estimated that the geothermal resource potential in Kenya is about 7,000-10,000 MWe across the fourteen (14) prospective resource areas in Kenya (Omenda, 2012; Ogola, 2013). With Olkaria geothermal area currently in an advanced development phase, Kenya is ranked at position eight (8) globally with an installed capacity of about 840 MWe from geothermal generation (ThinkGeoEnergy Research, 2019). Menengai, Eburru, Barrier and Paka-Silali geothermal fields are currently in different stages of development with a plan to deliver a total of 5,000 MWe by 2030. According to worldwide geothermal direct use data (Lund & Boyd, 2015), Kenya has an energy capacity of 22.40 MWt, annual energy use of 50.70 GWh/yr with a capacity factor of 0.26.

Unfortunately, there is limited utilization of the country's geothermal energy potential for direct use applications despite its huge potential. However, the direct utilization of geothermal energy is continuously gaining popularity due to its economic, environmental and energy efficiency benefits. In Kenya, a few direct use applications exist with health spas operating in Olkaria and Bogoria, crop dryers at Eburru, greenhouse heating and carbon dioxide enrichment at Oserian flower farms and water harvesting for domestic purposes both at Eburru and Suswa geothermal areas. A demonstration centre with four direct use projects in Menengai geothermal area was set up in 2015 to test the technical and economic viability of a geothermal energy cascade design. The projects include a milk pasteurizer, a heated greenhouse, heated aquaculture ponds and a laundry unit (Nyambura, 2016).

Geothermal energy in Kenya has primarily been used for electricity generation while the separated brine is normally reinjected back into the ground while still containing huge amounts of thermal energy. Further, no other by-products of geothermal energy such as mineral extracts or gases are extracted for useful purposes. As a result, there is inefficient utilization of the geothermal resource. It is expected that the establishment of a geothermal industrial park will address some of these problems to a large extent. Also, thousands of jobs will be created for the local population and businesses through employment and provision of services to the industries in the park.

The utilization of geothermal energy depends on resource temperature. A high-temperature resource (>150°C) mainly used for electricity generation in condensing power plants. Low to medium temperature geothermal resources (<150°C) are utilized for direct uses or binary power plants (Mburu, 2009). Innovative use of geothermal heat is a cascade utilization for power generation and sequential use of geothermal heat for various direct uses, or by use of thermally activated technologies. The concept of cascading can be an effective method to maximize the use of geothermal resources of low to medium enthalpy as shown in the Lindal diagram in Figure 11. The use of Combined Heat and Power (CHP) technologies make more efficient use of the geothermal resources by cascading the geothermal fluid to successively lower temperature applications, thereby improving the economics of the entire system dramatically (Lund & Chiasson, 2007). The geothermal steam, after being used for power generation, can be used for milk pasteurization, greenhouse heating, aquaculture pond and swimming pool heating before reinjecting it back to the reservoir.

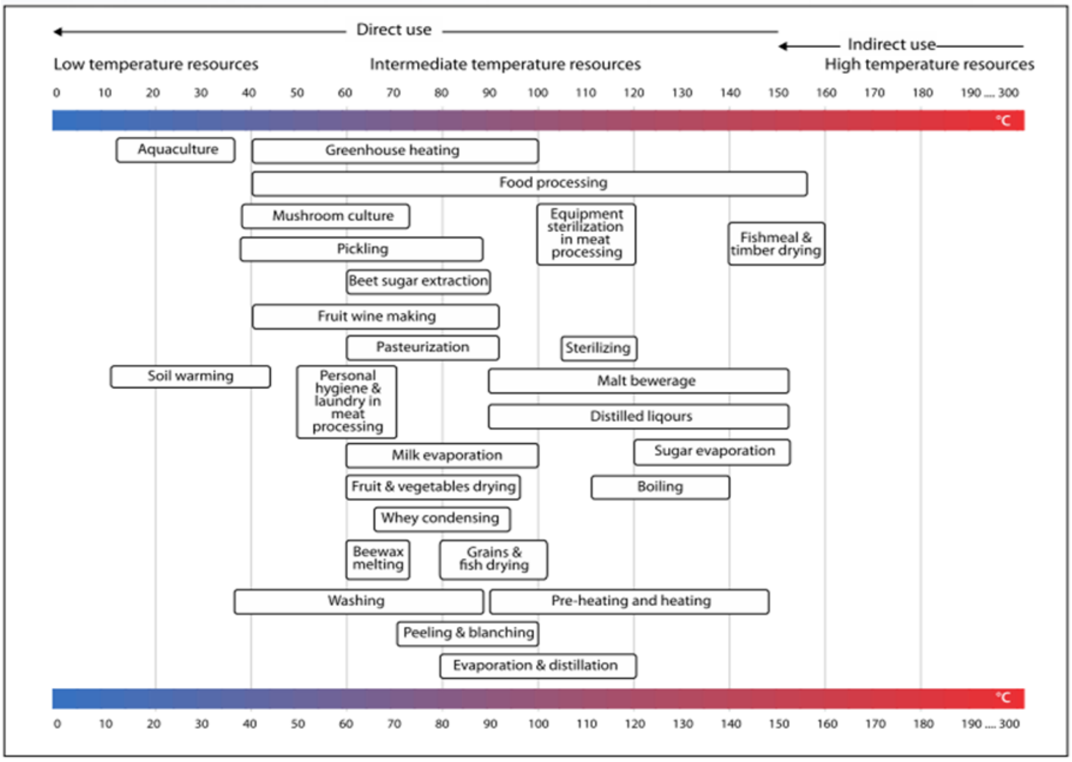

Figure 11: Lindal diagram (Van Nguyen, 2015)

Industrialization in Kenya has faced challenges due to the high cost of energy and its unreliability. Electricity from the grid costs about USD 0.1-0.12/kWh during peak hours (Regulus, 2020). A power outage is a common occurrence in Kenya due to routine rationing and unstable grid which forces most industries to incur an extra cost of installing and running standby diesel generators for several hours every month (VEGA, 2014). Similarly, most industries that require steam for their operations normally use industrial diesel oil or furnace oil to fire boilers. These sources are known for the emission of greenhouse gases. Besides, their prices are usually volatile and in most cases high, which eats into the manufacturers' margins and makes it difficult to predict profits accurately. Geothermal energy, on the other hand, is cheaper, cleaner and more reliable than the other sources of energy currently being used. In addition, the direct use of geothermal energy presents an opportunity to eliminate the use of fossil fuels to generate thermal energy for industries.

In this regard, plans are underway at the Olkaria Geothermal area to set up a green energy park to utilize geothermal resources to tap environmental, economic and social benefits for KenGen and the community. A feasibility study conducted in Olkaria in 2016 identified the available geothermal resources to be utilized in the park. These include cheap electricity generated from the geothermal plants, more than 2,000t/h of brine from several separator stations at 130°C. Further, steam from low to medium enthalpy wells; wells with unique characteristics e.g. cyclic wells, CO_2 or SiO_2 rich wells; and drilled wells that are located far from the existing power plants. According to KenGen (2018), there are more than sixteen geothermal wells that are currently not assigned to any future electricity generation project due to the aforementioned reasons. These wells have been earmarked for connection to the industrial park. The identified industrial and service applications to be developed within the park range from mineral extraction from geothermal brine, textile, steel and glass manufacturers, eco-friendly fertilizer production, milk processing plants and recreation facilities. These industries have different energy needs. It follows then that, a design to promote an exchange of resources among these processes in a cascade approach, will result in better resource utilization and sustainability.

The concept of energy parks within/near the geothermal resource areas is gaining momentum with Sudurnes Resource Park in Iceland as a successful example. The resource park is located next to Svartsengi and Reykjanes geothermal power plants, which are owned and operated by HS Orka hf (Albertsson and Jónsson, 2010). Besides economic considerations, the geothermal resource park is based on the concept of waste reduction due to the sharing of by-products. Albertsson (2013) indicated that the geothermal energy parks are built on the following principles: integrated utilization of the various resources available from geothermal energy; sustainable development resulting in an ecological balance due to minimizing of waste through by-product sharing; economic prosperity due to creation of jobs in various disciplines; and social progress due to development of innovation, new job opportunities, and environmental awareness; a collaboration between different professions and companies resulting in sharing of equipment, machinery, and manpower as well as increased sustainability in the utilization of geothermal resources due to increased efficiency within the resource area.

2.7. KenGen’s sustainability structure (Sustainability Approaches)

KenGen´s corporate governance seeks to mainstream environmental sustainability goals within all its operations of sustainable energy generation and continues to comply with applicable environmental laws and regulations. KenGen recognizes that its operations have impacts on the environmental, social and economic aspects at the national and global levels and hence the need to mainstream environmental sustainability objectives in all its operations and activities.

The Environmental management section of the Environment and Sustainable Development Department ensures KenGen’s operations and activities comply with and exceed the requirements of all applicable environmental laws, regulations, permit and license conditions and other requirements to which the organization subscribes to (KenGen Website, 2020). The company´s sustainability strategies focus on social safeguards, project appraisals & monitoring, climate change services, environment management, and environmental sustainability.

To ensure environmental management and sustainability, the company conducts preliminary Environmental Impact Assessment (EIAs), appraisals and environmental and social monitoring for proposed project sites and also runs other projects like tree nurseries for protection and restoration of ecosystems. Natural Capital Assessment and Accounting (NCAA) is an emerging mechanism for measuring a nation´s natural capital stocks as well as ecosystem services that flow from these stocks into the economy. NCAA can be used as a benchmark by which policy-makers, investors, and civil society evaluate their approaches and determine if they are supporting a sustainable model of development. Also, NCAA can be used as a monitoring tool for bringing together diverse pieces of information about the environment (Reuter et al., 2016). Both EIAs and NCAA are essential assessment tools when developing large projects like an industrial park.

KenGen has developed climate change mitigation projects within the geothermal resource area to provide environmental and social benefits to the communities around the projects. The company has registered two geothermal Clean Development Mechanism (CDM) projects under the United Nations Framework Convention on Climate Change (UNFCCC). The annual estimated Corporate Environmental Responsibility (CER) from KenGen's registered projects are as indicated in Table 4. CDM projects have contributed to benefits for KenGen's stakeholders through Community Benefit Projects funded by part of the revenue from the CDM projects.

Table 4: Clean Development Mechanism Geothermal projects (KenGen Website, 2020)

Project	**MW**	**Estimated tCO_2eq/year**
Olkaria II	35	149,632
Olkaria I	140	635,049
Olkaria IV	140	651,349

Setting up an industrial park within the geothermal resource area will need to be in line with KenGen´s set environmental and social standards to gain acceptance and promote sustainability. The Government in collaboration with relevant stakeholders will set up minimum operational standards dedicated to sustainable environmental conservation and promoting sustainable development in the park. These minimum performance requirements will be in line with national and local regulations as well as guided by the best practices from international institutions. Unregulated industrial activities such as increased levels of pollution in the form of climate-changing emissions and solid wastes within the park will affect KenGen's efforts to provide positive direct and indirect impacts on biodiversity and natural ecosystems in its areas of operation and the surrounding community.

Social safeguards policies often provide a platform for the participation of stakeholders in project design through consultation meetings. They can serve as a mechanism for integrating social concerns into development decision-making and have been an important instrument for building ownership among local populations. According to World Bank (2017), social safeguard policies require an elaboration of adequate responses, which are spelled out in policy documents and implemented as part of the project activities. Policy documents specify the activities, implementation arrangements, institutional responsibilities, and monitoring mechanisms. KenGen has a vibrant Stakeholder Coordination Committee to facilitate stakeholder relations through public outreach to obtain input from those individuals, groups and host communities in all areas of operation.

Large scale projects like park development in Olkaria is expected to generate employment and economic opportunities. According to the feasibility study (KenGen, 2016a), the KenGen Green Energy Park is estimated to provide up to 100,000 skilled and unskilled employment opportunities in the first fifteen years of operation. These include service opportunities like provision of catering and transport services to the various contractors and supply of locally available construction materials. Unless the criteria of hiring temporary employees and awarding contracts for existing economic opportunities are well defined and managed, this can result to dissatisfaction and protests by the local communities and disruption of construction activities as it has been occasionally witnessed at the Olkaria geothermal area.

Social change is inherent to and inevitable with any development. Whilst development aims to bring about positive change, it can lead to conflicts as well. For instance, the diminishing of local culture due to increased industrialization. The indigenous Maasai community that lives near the park has experienced a shift in a culture largely influenced by the mixture of the modern infrastructure and traditional lifestyles during the development of the geothermal projects (Mwangi-Gachau, 2015). This nomadic community which originally shelters in traditional manyattas with polythene roofing has been relocated to modern housing of corrugated iron sheets and is largely engaging in other modern forms of farming. The cultural center built close to the industrial park will be significant for preserving cultural identity and showcasing cultural activities.

3. Research Methodology

3.1. Overall research approach

The study uses the following research approaches:

1. Access to policies: This is a factor directly related to the study of existing policies to identify the country´s plan to achieve green growth and the fiscal incentives and taxes to promote environmental sustainability and socio-economic development.

2. Remedial approach: With this approach, consideration will be given to the application of industrial symbiosis and cleaner production within the proposed EIP to increase overall efficiency and reduce damage to humans and the environment.

3. Methodological approach: The research process focuses on clustering the manufacturing firms in the park for efficient resource recovery and the use of Material Flow Analysis software (Stan2Web) to demonstrate the inflow of raw materials (including energy and water) into the park, resource sharing, wastes recycling and outflow of finished products to the end-user. The international EIP framework is used as a benchmark to set performance requirements as a standard to go beyond national and local regulations.

3.2. Source of Data

Primary data was gathered from KenGen´s unpublished internal reports including geothermal resource data and KenGen Industrial Park feasibility studies (KenGen, 2016a). Other sources include the Green Energy Park Expression-of-Interest (EOI) documents and KenGen´s environmental sustainability information (website and reports).

Secondary data was acquired through desktop study and reviews of various published literature. These include several official Kenyan industrial survey reports, sessional papers, private sector development strategies (PSDSs), Kenya Vision 2030 blueprint, development plans, Acts of Parliament, and environmental audit/ impact assessment reports. During the planning phase of the research, a review of several UNIDO, World Bank and GIZ documents on EIP implementation handbooks and International Framework was done and the background information about EIPs was collected and case examples of Vietnam, China, and South Korea studied to build the basis for comparison.

3.3. Research design

To address the research question, the following steps are undertaken in the study; clustering of the firms in the industrial park, determination of the possibility of synergies between companies by creating a symbiotic network to show material flow between processes and identification of emerging opportunities for industrial symbiosis. Using the standard EIP International Framework, the development of a multi-criteria assessment of policy interventions and recommendations applicable to the energy park is done. A Stakeholder matrix and existing EIP management models are used to develop a stakeholder map which is essential in developing a management and governance structure of the park, hence efficient performance monitoring and reporting. A graphical structure of the research is outlined in Figure 12.

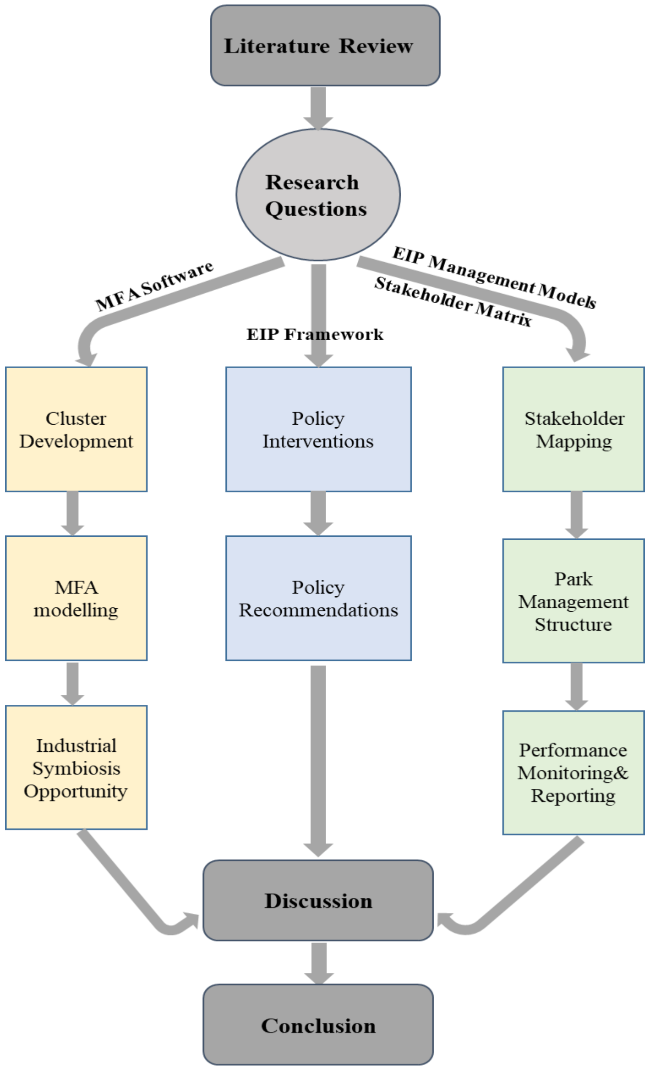

Figure 12: Graphical Overview of the research

3.4. Tools and benchmarks

Indicators for measuring the performance of circular economy initiatives in most industrial parks include material flow analysis (MFA), life cycle analysis (LCA), CO_2 emissions and economic returns (Geng et al., 2013). These performance indicators measure the success factors of the systems.

Life Cycle Analysis (LCA) is a tool used to assess environmental impacts associated with all stages of production of a commercial product from raw material input, product manufacture, output, waste generated, recycling and disposal. The methodology is used in this study to determine potential industry requirements (raw material, water, energy, and wastes generated) from the park. This will build the basis of determining the environmental impacts of the proposed industries. As illustrated in Figure 13, the LCI results from various inventories provide information on the impact of the industrial processes on human health, ecosystem quality, climate change, and natural resources (Chowdhury et al. 2018).

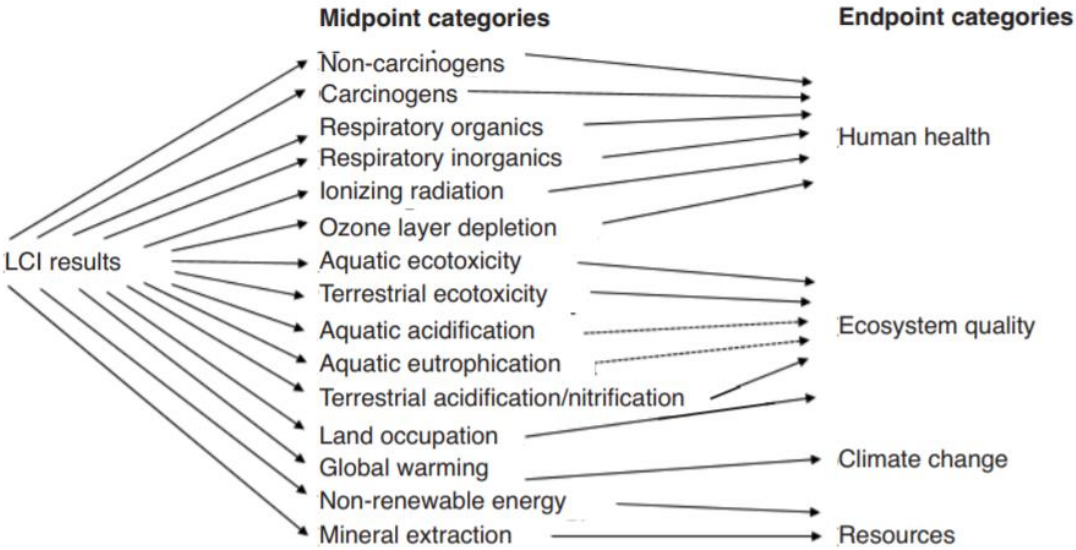

Figure 13: Overall scheme of the IMPACT 2002+ framework, linking LCI results via the midpoint categories to damage categories (Chowdhury et al. 2018)

Industrial clustering involves the classification of industrial firms in the industrial park on a sector-wise basis and based on the highly efficient use of resources and minimization of waste generation. Rather than following a linear material flow of production accompanied by increased resource use, firms should move towards an integrated system, where energy consumption and waste generation is reduced by reusing and recycling materials within the same firm or by other firms in the cluster, in a quasi-closed or, ideally, in a closed-loop system (Anbumozhi et al. 2013). Within the participating clusters, waste and by-product streams in the selected cluster firms were identified and analyzed further for possibilities of linking them with other businesses that benefit from generated by-products and wastes of other firms.

Stan2Web is a Material Flow Analysis (MFA) software outlined by (Cencic & Rechberger, 2008) to aid in the understanding of the material flow in the clusters and enables the classification of by-products and waste streams within and outside the cluster. The software maps the value chain of materials and by-products; groups users of identical resources together; analyze possibilities for raw material cascading and waste/by-product exchange; assess possibilities for physical infrastructure sharings; evaluates the sustainability of waste sources; explores options for on-site waste reuse and recycling, and determines the potential for the creation of a network for raw material; energy and waste exchange provided (UNIDO, World Bank & GIZ, 2017).

EIP Policy Support tool clearly defined by Beers et al. (2019), provides technical support for EIP policy planning and development (Figure 14). Eco-Industrial development toolbox contains a policy tool used to conduct a multi-criteria decision analysis on EIP policy interventions. The tool will be used to review applicable policies relevant to EIP and intends to provide an understanding of potential trade-offs between EIP policy intervention options against various criteria of economic, environmental, and social aspects.

Policy interventions assessed in the study are;

- National Action Plan on EIP
- Foreign Direct Investment
- Renewable energy use in the industrial park
- Incentives and tax exemptions
- Industrial symbiosis and resource efficiency
- Social capital creation.

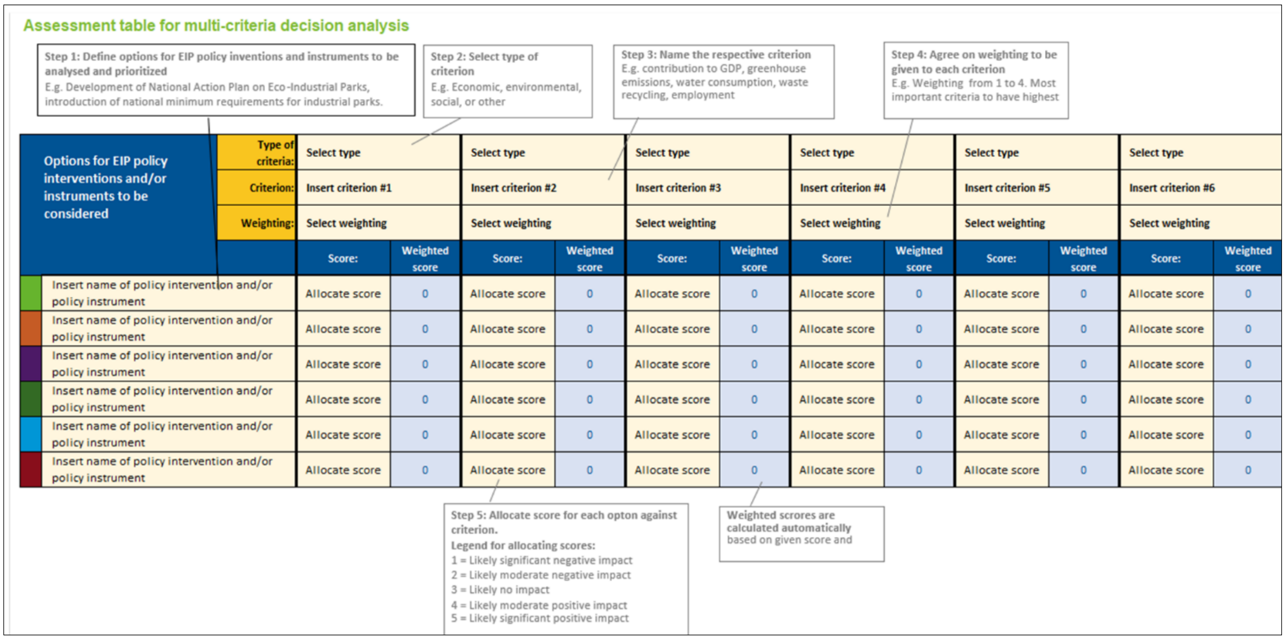

Figure 14: EIP Policy Development Tool (Beers et al., 2019)

4. The KenGen Green Energy Park (KGEP)

KenGen has completed plans to set up an industrial zone within the Olkaria geothermal resource area as illustrated in Figure 15. The feasibility study for energy park development concluded that there is a viable business case for the establishment of the park. The study identified four suitable sites for the first phase of development that can allocate to manufacturers and processing firms. The parcels of land are Sites A, B, C, and D with a total of 309 acres (KenGen, 2016a).

KenGen Green Energy Park is centrally located within the country making it easier to connect and exchange with other parks for mutual benefit. The park is connected both by railway and road to major seaport and airports and supported with the necessary logistical installations, making it ideal for transportation of raw materials and valuable products to various markets. The Standard Gauge Railway from Mombasa to Naivasha is a key installation that connects several existing and proposed industrial parks. It provides a gateway into East Africa, making it a regional economic hub hence reducing time to market for the industrial products.

Other major advantages of its location are, the abundant farm products found within the Suswa-Naivasha regions that include grains, pulses, and other food products, that are affected by post-harvest losses. These food products can be processed and packaged within the park for value addition. There is an abundant supply of hides and skins from the local pastoralist community, which is a major raw material in the leather industry. Again, fish found in abundance from the nearby Lake Naivasha will be a source of raw products for a potential fish processing plant. The industries will benefit from KenGen and the Government through infrastructure development, facilitation and fiscal and operational incentives favorable for the businesses.

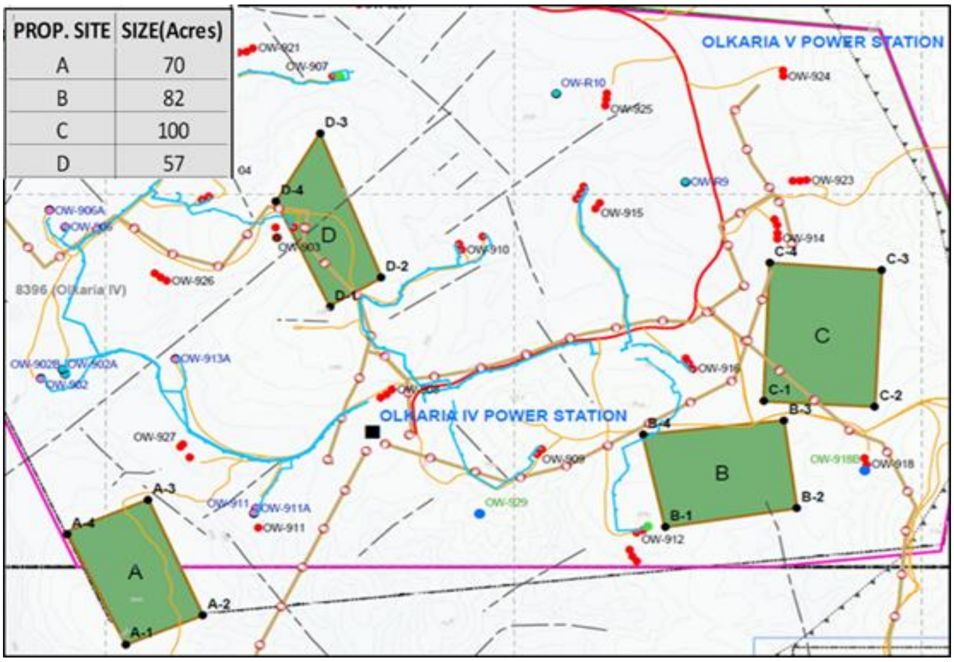

Figure 15: Location of the proposed sites for the KenGen Green Energy Park near Olkaria IV (140 MWe) and Olkaria V (165 MWe) power plants.

Water intake and pumping facilities will be installed nearby Lake Naivasha. As the location of the selected site is higher than the Lake Naivasha, it will be necessary to install a water pumping facility. The water supply source needs to be secured for stably-supply the water in the site.

The primary water supply source shall be Lake Naivasha. However, boreholes have been drilled to supplement the water need (KenGen, 2016b).

4.1. Present Situation

A feasibility study was conducted in 2016 to determine the viability of the park development. The study assessed different business models and confirmed that an industrial park within the Olkaria geothermal area was a viable project. The consultants carried out these tasks; selection of suitable sites; identification of potential demand, analysis and forecasting; design and dimensioning "master planning" within the park; construction cost estimation, financing, and economic feasibility; environmental and social management framework. Phases for the development of the park are indicated in Figure 16;

Currently, the detailed design process is ongoing after the identification of the manufacturing firms and financiers. A 30 km road connecting the Standard Gauge Railway is currently under construction. Other infrastructure developments underway are pipelines and waste & water treatment plants. The next phase of development will be the construction of buildings and structures; operation & maintenance; and monitoring and evaluation.

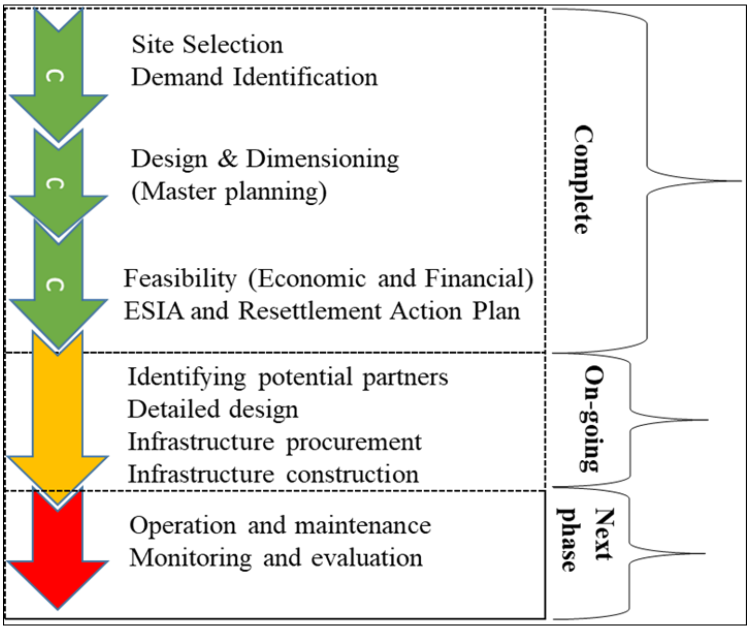

Figure 16: Development Stages for the KenGen Green Energy Park

According to the KenGen procurement document (KGN-BDD-2019), the manufacturers are expected to develop individual infrastructure as follows;

a) Construction of own factory buildings/sheds, sewerage system, and wastewater disposal systems
b) Connection of steam, brine and raw water to sheds from the interface to be agreed with successful firms
c) Civil works for leveling of site and perimeter fence
d) Installation of own water treatment plant
e) Conduct the operation and maintenance of its facilities

KenGen´s effort to attract investors and become highly competitive is largely dependent on the sale of energy directly from the power plants to the industrial park operators. The Energy and

Petroleum Regulatory Authority (EPRA) in February 2020 approved a lower electricity tariff of USD 0.05/kWh, which is about half of the electricity cost from the grid (USD 0.1-0.12/kWh) at peak time (Regulus, 2020). The industrial park investors are offered a lower tariff as a selling point to cushion them from high production costs associated with the cost of energy.

Similarly, the energy park offers an opportunity for a land lease at a nominal rate on a 20-year renewable lease term (KenGen, 2016a). Under the lease, the manufacturing/ processing firms will be supplied with geothermal steam, brine (hot water), and raw water at the rate outlined in Table 5.

Table 5: Rate at which utilities are sold to the industrial park (KenGen, 2016a; Regulus, 2020).

Resource	**Rate (USD)**
Land (ha) (annual rate)	1200
Steam (ton/hr)	4
Brine (ton/hr)	4
Raw water (m^3)	0.5
Electricity (kWh)	0.05

4.2. Sustainability approaches to KGEP

KenGen Green Energy Park has been designed to be an eco-friendly park with adequate green spaces. The master planning and land use plan at the site included identification and calculation of estimated demands of administration, manufacturing, warehousing, commercial, social, parking, recreational parks, access roads, railway connections, water supply, sewage, solid waste and water treatment plant, power supply, steam and brine supply, and telecommunications networks facilities (KenGen, 2016a). The masterplan identified alternatives for land use plan for the park to accommodate all the above functions effectively to minimize conflicts between different uses and to maximize the efficiency of land users (Figure 17).

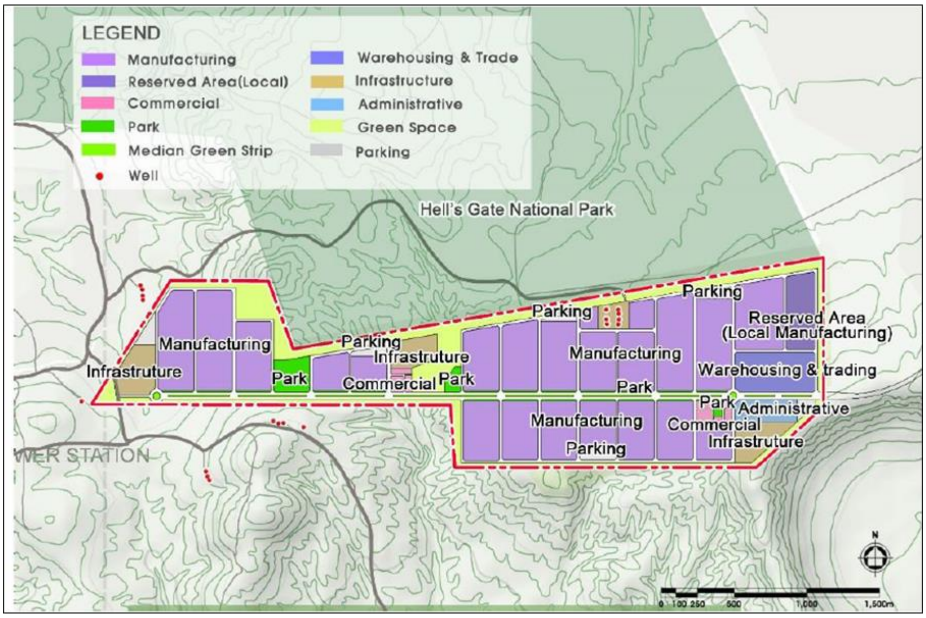

Figure 17: Proposed Land Use Plan in the Industrial Park (KenGen, 2016a)

The land-use plan allows sufficient green spaces to interface with the surrounding natural habitat in the Hell's Gate National Park and also to provide rest areas for the employees. The design of the park includes the utilization of green energy and a robust environmental management plan (EMP). It provides for abundant green space within the park and a water treatment plan. Working with this, the current master plan attempts to provide an approach for sustainable benefits to the surrounding environment, while attaining economic benefits to individual operators, within the park. This will improve the green economy within KenGen Green Energy Park and is poised to perform better than a traditional industrial park.

The study incorporates industrial symbiosis and circular economy to the current design and assesses the potential benefits (Figure 18). It suggests some aiding policies to develop the park into an Eco-Industrial Park that gives a competitive edge within the region.

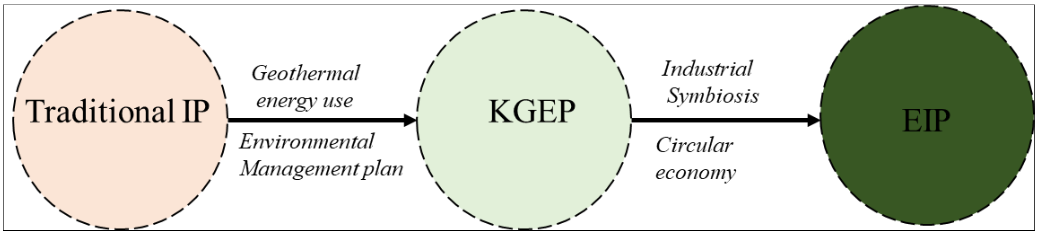

Figure 18: The proposed transition of KGEP to an EIP

4.3. Proposed industries

Manufacturing firms expressed interest to work within the park and after evaluation, the following categories of companies were identified as early locators in the park;

- Textile and apparel industry
- Steel manufacturer
- Glass manufacturer
- Fertilizer manufacturer
- Milk processor/pasteurizer
- Food processing and packaging (Grain dryers)
- Leather industry

The seven (7) processing plants identified were classified into six (6) clusters on a sector-wise basis. The composition of the firms in each of the clusters is expected to change as more companies express interest in setting up their businesses in the park. The identified clusters were steel, glass, garments, organic fertilizer manufacturing, food processing and leather industry as tabulated in Table 6.

Table 6: Recommended Clusters for the new KenGen Green Energy Park

Number	**Cluster**	**Number of firms**	**Production Type**
1	Steel	1	Steel manufacturing
2	Glass	1	Glass manufacturing
3	Fertilizer	1	Eco-fertilizer using organic waste
4	Garment	1	Apparel /textile industry
5	Food industry	2	Milk processing and grain drying
6	Leather	1	Hides and skin processing

4.3.1 Steel Manufacturing

Steel is produced through two alternative routes: the Integrated Cycle, where steel is produced from virgin raw materials, and the electric route, which produces steel by melting scrap in an Electric Arc Furnace (Colla et al., 2017). The processes of production in the steel plant are; the iron ore sinter plant, blast furnace, lime production plant, basic oxygen furnace, continuous casting plant, and hot rolling plant. Burchart-Korol (2013) postulated that the steel industry requires approximately 70 % of all refractory materials. The 30% refractory material remaining after use accounts for around 9 million tons of spent refractories per annum available for recycling or land refilling. Therefore, it should also be the biggest source of recycled materials. The main raw materials, additives and fuel input in steel manufacturing include iron ores, dolomite, limestone, lubricant oil, water, and electricity. The main by-products and wastes include sludge, dust, scale, wastewater, iron scrap, gases, and pig iron.

The steel industry can produce a large number of wastes which can be a major environmental concern to society. Initiatives to minimize the hazards should be prioritized by practicing effective waste minimization, hazardous waste management, recovery of resources, waste recycle and reuse.

Fruehan et al. (2000) reported that raw steel production from iron ore to steel using a basic oxygen furnace will require approximately 6.8MWh per ton of steel produced. This includes the reduction of raw iron ore into pig iron and then conversion of pig iron to steel. Alternatively, by using recycled steel rather than pig iron with an Electric Arc Furnace the energy use is 0.625MWh per ton of steel. This makes steel manufacturing an energy-intensive industry within the park.

Water is used for processes, cooling, descaling, and dust-scrubbing in steel production. However, low water consumption has been recorded. In the Integrated Cycle, 28.6m^3 per ton of steel discharges approximately 25.3m^3 per ton of steel. In an Electric Arc Furnace, water input is 28.1m^3 per ton of steel with an output of 26.5m^3 per ton of steel. Overall, the discharge ranges between 1.6 m^3 to 3.3m^3 per ton of steel, most of the water being lost due to evaporation (Colla et al., 2017). The water can be treated and reused by other production plants within the park.

The steel industry accounts for a high CO_2 emission from direct and indirect carbon flows. As discussed in detail by Zhang et al. (2016), the direct carbon flows are associated with the energy and carbonates used in the steel manufacturing process. Indirect carbon flows come from products and bi-products related to the input-output of the system. Processes using fossil fuels to generate energy are characterized by higher direct CO_2 emissions. However, recent technologies e.g. Coke dry quenching, Combined cycle power plant and CO_2 capture by slag carbonization utilize cleaner technologies and industrial symbiosis have reduced net CO_2 emissions. The authors note that the three cleaner technologies which capitalize on waste heat recovery, account for emission reduction of 256.99kg of CO_2. The residual heat can be cascaded to downstream processes to be utilized by low-energy demanding companies.

A circular economy approach in the steel industry refers to a shift from linear production to a system that enhances reduce, reuse, remanufacture, and recycle. An improvement in energy efficiency is not only a result of advanced equipment use but also optimal operating knowledge and operational control systems (Worldsteel Association, 2020). Other breakthroughs and research on technology advances in the steel industry include; use of hydrogen, biomass, or electrolysis (electricity) instead of carbon as a reducing agent, Carbon Capture and Storage (CCS) and Carbon Capture and Utilisation (CCU).

4.3.2 Glass Manufacturing

The glass industry in Kenya produces glassware that meets domestic needs. However, there is a high cost of production due to high petroleum products and electricity costs, favoring imports from neighboring countries. Common raw materials for glass production are Silica (sand), soda ash, limestone, feldspar, dolomite, and cullet (furnace-ready, recycled glass). These are combined into a specific mixture and heated in a furnace to about 1500-1600°C, based on the desired properties of the product (Schmitz, 2011). The use of cullet is beneficial as it substitutes expensive virgin raw material as well as it is an appropriate measure to save energy.

Glass industries produce a lot of waste ranging from the by-products of the used raw materials to the damaged glass products. Hauwa (2008) indicated that proper utilization of such wastes from glass cullets (containers, flat glass, electronics, and other glass containing products) can minimize the energy requirements and reduce production cost. In Kenya, 45% of wastes are recycled back into production but the remaining are landfilled (Were, 2016).

Producing glass consumes a large amount of energy as high temperatures are needed for melting the raw materials. Due to its high share of energy per tonne of product, the glass industry is usually referred to as an energy-intensive industry (Bergmann et al., 2007). The life cycle analysis for glass production shows a high contribution of CO_2 from the process emissions, raw materials production, raw materials transport, and energy supply. The use of a cleaner source like geothermal energy for glass production accounts for a significant reduction in CO_2 emissions.

4.3.3 Fertilizer production

Organic fertilizers are organic nutrient enhancers of the soil that are more environmentally friendly. These fertilizers include animal manure, compost, blood meal, bone meal, slurry waste, peat, seaweed extracts, sewage, guano waste, and other bio-degradable wastes (Bokhtiar et al., 2005). Sewage sludge from industrial processes can be processed into fertilizer pellets by thickening, dewatering, and fermenting in tanks at 55°C. The water from the sludge treatment can further be treated to make it suitable for use within the park.

4.3.4 Food processing

The two industries clustered in the food processing category are milk processing and crop (grain) drying. These processes have varying energy and water demands and produce different types of wastes.

4.3.5.1 Milk processing
Milk processing by pasteurization is adding value to raw milk through a process of heating milk up and then quickly cooling it down to eliminate certain bacteria. The primary raw material is raw (fresh) milk while the main products marketed are pasteurized skimmed milk (short and long life), cultured milk (yogurt and sour milk), and powder milk.

The main solid waste produced by the dairy industry is the sludge resulting from wastewater purification (Raghunath et al., 2016). There are figures available about the amount of sludge production, e.g. in aerobic systems the sludge production is about 0.5 kg per kg of removed Chemical Oxygen Demand (COD) and in anaerobic systems about 0.1 kg per kg of removed COD. Other waste products in the dairy effluent contain waste heat, dissolved solids, suspended solids, chemical wastes (chlorides, sulphate) oil, and grease.

Wastewater generated in a Dairy facility contains highly putrescible organic constituents. This necessitates prompt and adequate treatment of the wastewater before its disposal to the environment. Almost all the organic constituents of dairy waste are easily biodegradable. Additionally, the cleaning of the plant results in caustic wastewater.

Milk processing has varied energy requirements for different products made. Production of powder milk and cheese requires high temperatures >200 (°C). Besides these dairy products which requires very high temperature, the other products can be readily processed using thermal energy from geothermal brine. Production of powder milk would require the use of geothermal steam as the source of energy (Kiruja, 2017). The thermal energy requirements for producing these products are as shown in Table 7.

Table 7: Thermal energy requirement for milk processing (Kiruja, 2011)

Process	**Energy requirement (kWth/liter)**	**Temperature (°C)**
Low temperature, short term pasteurization	0.56	100
Milk cultures processing	0.35	130
Milk sterilisation (UHT)		
Powder milk, cheese making	0.5	200
Cold storage		100

A high standard of hygiene is required in milk factories and water consumption is therefore high due to cleaning of the plant. Kiruja (2011), postulated that at least 0.6 litres of water are required for every liter of milk processed. The wastewater from milk processors, mostly from cleaning operations, is rich in nutrients. Disposal of this water poses challenges, but it is possible to recycle the nutrients by using the water for irrigation (VEGA, 2013).

4.3.5.2 Crop drying

To prevent post-harvest losses and increase the quality, crops are dried to reduce the moisture content. This is because drying considerably slows down the microbial and chemical reactions that take place after harvesting leading to spoilage. Crop drying using the abundant geothermal heat has been considered as an economical business opportunity in the KenGen Green Energy Park, particularly, cereals produced in plenty in the surrounding farming community.

Industrial drying is achieved using hot air at a temperature of 50-100°C and drying can be done either using batch or continuous dryers. Basak et al. (2014) noted that in batch drying the product is exposed to an elevated temperature for 2-24 hours to achieve the desired moisture content; therefore, the maximum drying temperature should not exceed 75°C, to avoid compromising the quality after drying. However, in continuous drying, the elevated temperature does not have adverse effects on the product because the exposure is for a short period. Energy consumption of about 350 kJ/kg and a temperature of 55-90°C is required to dry cereals to a final moisture content of 13% (Kiruja, 2017).

4.3.5 Leather industry

Leather processing operations involve transforming animal skins and hides into a stable material that can be used in the further manufacture of leather. The main raw material in this industry is the hides and skins. Bondrea & Mocanu (2016) noted that the industry is made up of four main sub-sectors; raw material base (hides and skins), tanneries, footwear, and leather goods manufacturing. The main operations are unhairing, tanning, lubrication, dyeing, and finishing. Only 25% of raw skin is found as a finished product.

In tanneries, high quantities of water and chemicals are required, including sodium sulfite, basic chromium sulfate, ammonium sulfide, ammonium chloride, bactericides, sodium chloride, wetting agents, enzymes (Azom et al., 2012). It has been reported that only 20% of the chemicals used in the tanning process are absorbed by leather - the rest is released as waste. Three categories of waste are emitted within the leather industry: wastewater (liquid), solid wastes (solids), and air emissions (gaseous). The chemical wastes occur either in the solid or wastewater. The waste, if not properly handled, can pose a serious environmental hazard to the surrounding.

Energy requirements in a tannery average about 25 MWh/1,000 m^2 of leather processed with about 50% of the energy consumed by thermal processes. The required thermal energy is used for drying of the processed leather and to heat water to the temperatures needed for chemical processes. Water at a temperature of 35°C – 65°C is required mainly during the tanning process. Also, hot air of up to 80°C is required to dry the treated leather (Cotance and IndustriAll, 2012).

4.3.6 Garment Industry

Raw materials for textile production are either natural fibers (cotton, wool, and silk) or synthetic fibres (polyester and nylon). The textile manufacturing processes in the global textile industry, are producing textile yarn, fiber, fabric, and finished products including apparel (Uddin, 2019). The innovation in textile manufacturing introduced variety in raw materials and manufacturing processes. Therefore, process control to ensure product quality is desired. Monitoring and controlling process parameters may introduce a reduction in waste, costs, and environmental impact.

Uddin (2014) noted that most of the processes performed in textile manufacturing release significant toxic and hazardous waste to water bodies, soil, and air. However, the main concern is the fibre and fabric industry. Particularly when considering fiber and yarn manufacturing, the chemical finishing, pre-treatment processes, dyeing, printing, coating, and drying operations release toxic gases, carcinogenic materials, harmful vapor and lint, and effluent discharge. It follows then that, more stringent environmental regulations, emission, and pollution control, should be enforced to mitigate environmental hazards.

The processes involved in textile manufacture require electrical energy, thermal energy, and freshwater as indicated in Table 8. The chemical processes in textile manufacture are water-intensive. The water to fabric ratio for these processes is 10:1. After the chemical processing, the fabric is dried in tumble driers.

Table 8: Water, energy and chemicals consumption in main processing sections of the textile industry (Uddin, 2019)

Process	**Water consumption (%)**	**Energy consumption (%)**	**Chemicals consumption (%)**
Yarn production	2	8	22
Fabric production	10	8	12
Wet dyeing (dyeing/printing/finishing)	86	79	65
Garment production	2	5	1
Total	100	100	100

The thermal requirements of a textile plant as reported by Kiruja (2017) is summarised in Table 9. The textile processes require water usage at a temperature of 60-100°C. Drying of the fabric in tumble dryers requires hot air at a temperature of 80°C.

Table 9: Thermal energy requirements for textile manufacture processes (Kiruja, 2017)

Process	**Temperature (°C)**
Chemical Processes	60-100
Drying	100

Cotton Incorporated (2009) assessed that GHG emissions were around 1.8 kg CO_2e/kg of fibre produced. In a parallel study performed on Australian cotton, GHG emissions were assessed around 2.5 kg CO_2/kg of fibre produced.

4.4. Energy supply from the Geothermal Field

KenGen provides high quality, cheap, efficient and reliable power supply infrastructure to provide uninterrupted electric energy within the industrial park. The main source of electricity is Olkaria-IV and Olkaria-V Power Plants in the Olkaria geothermal area which are located within the special economic zone, hence reducing the distance that the energy is transported to the industries. The energy-intensive industries will benefit from the cheap power and also thermal energy from brine and low-pressure wells in Olkaria Domes geothermal field. In the field, two-phase geothermal fluid is separated into steam and brine at various separator stations comprising of a series of vertical modular separators designed to separate at 11.8 bar-a pressure (Langat, 2015). The separated steam from all the separator stations is gathered and directed to the power plant for electricity generation.

Wellhead modular generation plants (1-10 MW), are installed units at the wellpad of a geothermal well. The wellhead power plants are designed to best optimize the production characteristics of an individual well or group of wells on a given well pad (Kwambai, 2016). Wellhead generators can be made modular to allow for easy relocation to another well when needed. Waste fluid from various separator stations and power plant condensate is collected and piped for reinjection back into the reservoir through different reinjection wells within the resource area. Thermal energy will be harnessed from brine pipelines for use as energy in the manufacturing zones before reinjecting it back to the geothermal reservoir. Table 10 illustrates the available mass of brine for each proposed site and the reinjection wells available for disposal after thermal energy extraction at the heat exchangers.

Table 10: Mass flow allocated to each proposed industrial site

Proposed Site	Separator station	Reinjection Wells	Brine available (kg/s)
A	SD2 & SD3	OW-911 OW-911A OW-902 OW-913	298.8
B	SP912	OW-912B	30.5
C	SP924 & SP923	OW-928	38.9
D	SD1 & SD4	OW-901 OW-906 OW-906A OW-921B	222.5

Other sources of energy for the green energy park are the wells that are currently unassigned for electricity generation in any power plant at the Olkaria Domes. These earmarked wells can either not sustain self-discharge, have low pressure (below 5 bar-a), or located far from the existing power plants (Table 11). The table shows wells located close to the proposed industrial sites. The low-pressure wells can be utilized using heat pump technology to harness the heat. Modular wellhead generators can efficiently be used to generate electricity from well OW-917A, OW-906, and OW-912E.

Table 11: Wells available for use at the proposed industrial site

Well No.	Status	Total flow (kg/s)	Available for site
OW-926	Can not sustain discharge	-	A
OW-919	< 5 bar a	-	C
OW-908B	< 5 bar a	-	B
OW-922	< 5 bar a	-	B/C
OW-917A	2.7 MWe	10.9	C
OW-906	2.5 MWe	39.5	D
OW-912E	7.0 MWe	30.8	B

The conceptual design for the direct use application will take into account specific characteristics of the geothermal resources such as the chemistry, temperature and mass flow of the geothermal fluid or other local conditions, e.g. the local climate and market targeted for the application, impacting the feasibility of the application (Jóhannesson & Chatenay, 2014).

The brine from separation stations in the Olkaria Domes geothermal field has high concentrations of silica. When the geothermal fluid is cooled down, it becomes supersaturated with silica and consequently poses the risk of scaling. The high concentration in the geothermal fluid limits amount of energy to extract and heat exchangers are, therefore, recommended for heat extraction. A recommended minimum temperature of 130°C of brine will be used in this system to heat fresh water at the heat exchangers. The waste geothermal fluid will be reinjected back to the reservoir after heat extraction, to form a closed-loop system. All the separator stations will be connected to the hot brine reinjection pipeline which will collect the separated brine and transport it for reinjection. The total brine flow in this field is estimated at 185°C, with an average pressure of 11.8 bar-a.

4.5. Thermal Energy

Due to inherent impurities of geothermal fluids and the possibility of corrosion or scaling, proper material and equipment selection is mandatory to enable relatively easy and economical equipment maintenance. The principal reason for having a heat exchanger in geothermal systems is to efficiently extract the heat from the brine. One fluid runs through the tubes while the other fluid flows over the tubes to facilitate heat transfer between the two fluids. In this regard, raw cold water is used to transport the energy for utilisation to the industries. Lund, (2018) noted that there is a temperature differential between the primary and secondary fluids any time the heat exchanger is used. Approach temperatures of less than 6ºC are often uneconomical but depend on heat exchanger type and particular direct use application.

The counter-current flow and high turbulence achieved in plate heat exchangers make them popular in geothermal direct use applications as they provide for efficient thermal exchange in a small volume. Further, they have the advantage when compared to shell-and-tube exchangers, of occupying less space, can easily be expanded when additional load is added, and cost about 40% less (Geo-Heat Centre, 1997).

At the Olkaria Domes geothermal field, brine at 185°C is collected and channeled through the heat exchangers before reinjection. The brine is delivered to the park for direct use utilization at a minimum temperature of 130°C (Figure 19). If it is assumed that there is no heat loss from the heat exchanger to the environment, the amount of energy that can be extracted from the brine is expressed by the following thermodynamic equation;

$$\dot{Q} = \dot{m} * C_p * \Delta T$$

Where:
$\dot{m}$ - Mass flow rate (brine, fresh water) - kg/s;
C_p = Specific heat capacity (brine, fresh water) - J/kg/°K;
ΔT = Temperature difference (brine, fresh water) - °K.

Constant inputs are as follows:

C_p= 4209 J/Kg*K
T_1= 185°C +373°K/°C=558°K
T_2= 130°C +373°K/°C=503°K
ΔT = 55°K

The production of hot water from the brine at the proposed sites A, B, C and D, and from the earmarked wells is determined by the heat transfer from brine to the cold freshwater at the heat exchangers. Applying the thermodynamic equation above, the estimated energy is calculated in Table 12.

Table 12: Estimated thermal energy

Site	Mass flow (kg/s)	Energy (MWt)
A	298.8	69.1
B	30.5	7.0
C	38.9	9.0
D	222.5	51.5
OW-917A	10.9	2.5
OW-906	39.5	9.1
OW-912E	30.8	7.1

KenGen intends to supply the produced hot water to the industrial park for direct utilization. The main responsibility is in improving and maintaining a sustainable production of geothermal brine and fresh cold water distribution. The geothermal fluid from the separator stations and steam from the low-pressure wells runs through the heat exchangers, heating up freshwater producing hot water for use at the park. After the heat extraction at the heat exchangers, the waste brine is reinjected back to the geothermal reservoir. Distribution of the hot water in the park is done in two ways: KenGen sells hot water directly to the customers or through a third party company (private or public) which will supply to individual cluster companies as illustrated in Figure 19.

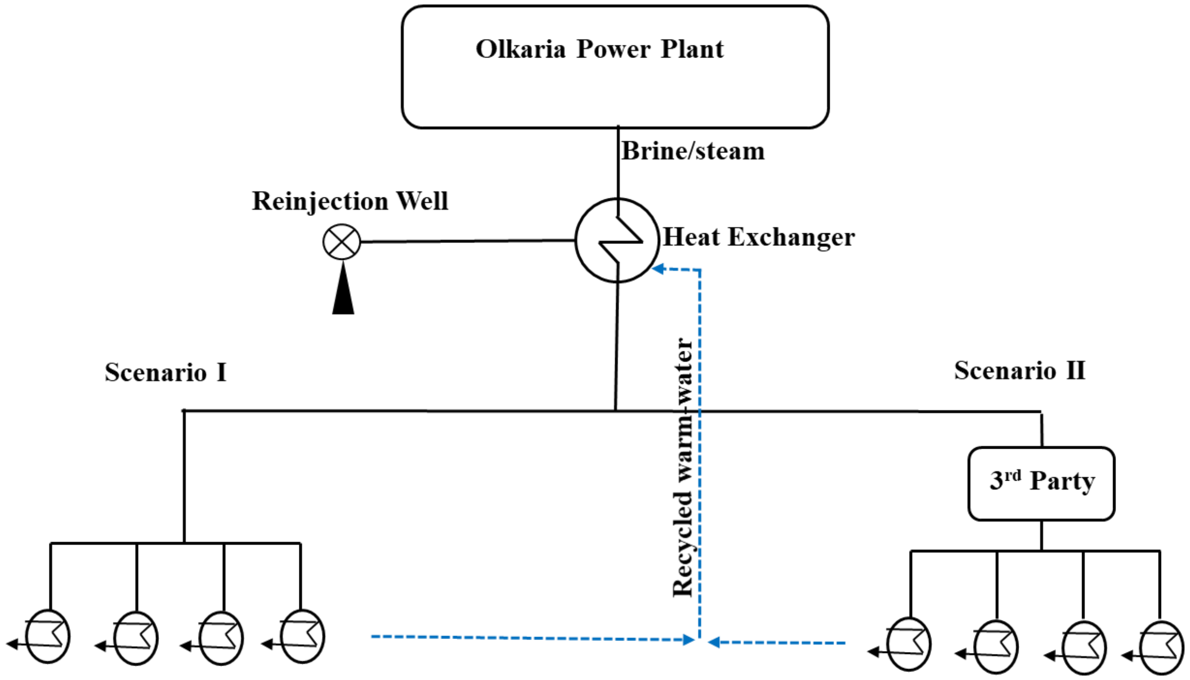

Figure 19: Possible scenarios for the sale and supply of hot water

The distribution of hot water to the proposed sites is discussed using two possible scenarios:

In scenario I, KenGen is the sole producer and distributor of hot water and will collaborate with individual companies during infrastructural development. KenGen´s technical team and park management are responsible for the maintenance of the hot and cold water systems. The main advantage in this scenario is that KenGen gets a higher revenue from its sale of hot water.

In scenario II, where the third-party company buys hot water from KenGen at the heat exchanger and distributes it to end consumers. The third-party company assumed to be a privately-owned company will be responsible for the technical aspects including detailed design of the distribution, development of the infrastructure as well as maintenance. KenGen transfers most risks (economic, environmental, technical, and social) to the private company.

4.6. Cascading Use

All firms require electricity and will acquire it directly from the power plants or the grid. The thermal energy will be tapped from the waste geothermal fluid after electricity generation for downstream processes. Other firms like the steel and glass, produce a high amount of thermal energy as waste which can, therefore, be channeled to other external production lines within the park or utilized within their internal processes. Figure 20 illustrates how the exchange of thermal energy among these processes results in better energy utilization because a single stream of hot water can meet the energy needs of several processes.

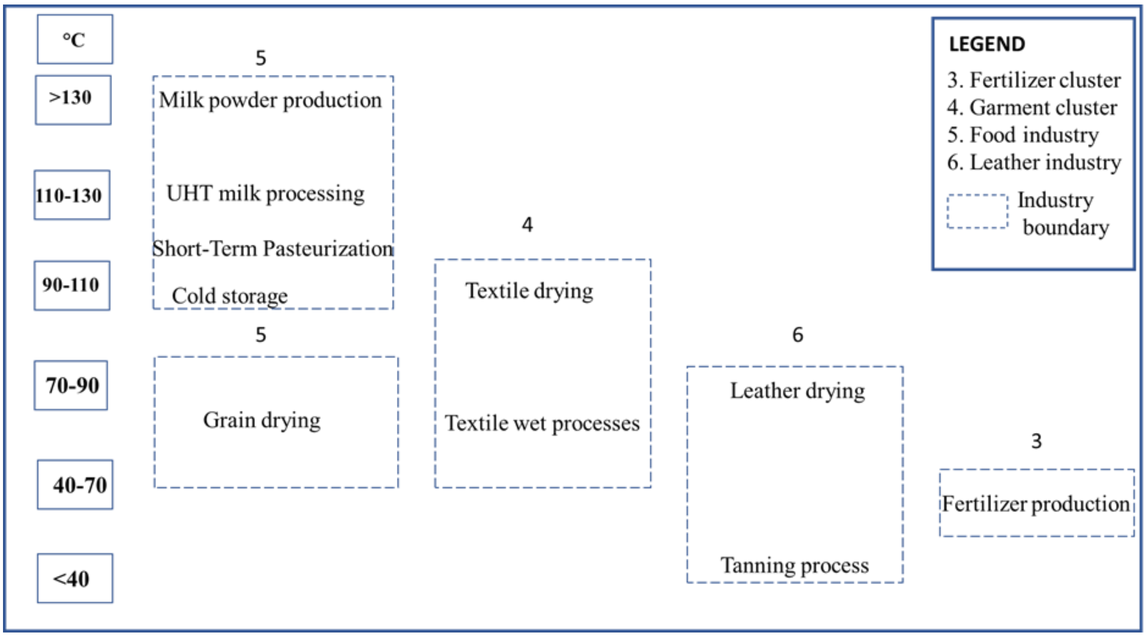

Figure 20: Energy cascade within the KenGen Green Energy Park

The thermal processes in the industries have been categorized into six temperature bands with each band having a temperature range of 20°C. The highest temperature band comprises of processes, which require more than 130°C, while the lowest temperature band processes require less than 40°C. Cold storage, milk powder processing, and deodorizing have the highest temperature requirement, while tanning processes in textile manufacture and fertilizer production, have the lowest temperature requirements. A stream of hot water can be utilized by as many processes as possible of subsequently lower temperature requirements, where each process extracts some energy from the stream. Water below the temperature of 40°C is reinjected back to the Olkaria geothermal reservoir for sustainability forming a closed-loop system of production. As discussed by Gladek (2019), the use of renewable energy in an efficient manner is one of the pillars of a circular economy (CE). The materials required for energy generation and storage technologies are designed for recovery into the system. In CE models, thermal energy is effectively preserved and cascaded when lower amounts of energy are required downstream.

5. Circular Economy and Resource Efficiency

The transition to a circular economy requires significant changes in both the production and consumption of the products. Resource intensive processes require radical innovative approaches and better technology to combine economic with ecological benefits. To quantitatively evaluate circular economy performances of a production chain in an eco-industrial park, an industrial symbiosis system can be constructed.

5.1. Cluster Development

Anbumozhi et al. (2013) stated that eco-industrial clusters are geographic concentrations of interconnected industries in a specialized field. These industries cooperate and coordinate to efficiently share resources and information. This inevitably leads to improved environmental quality, economic gains, and equitable enhancement of human resources for both the business and local community. They emerge as a central concept to furthering innovation and competitiveness, and advancing sustainable development strategies. The fostering of industrial clusters has become a focus of regional development, industrial, and environmental policies.

Geographical proximity is necessary for industrial symbiosis applications as it offers a greater opportunity for co-located firms to develop better synergies. In most cases, co-located firms can build trust and share business information and challenges efficiently. Anbumozhi et al. (2010) observed that, while industrial clusters foster innovation and prioritize economic development and social capital creation, eco-industrial clusters essentially consist of clusters that operate with a higher degree of eco-efficiency, making use of better management practices, technologies, and skills. Economic gains are therefore achieved through the reduction of natural resources and energy costs, waste management costs, and conforming to environmental legislation. The green market potential may also present an opportunity for industrial operators.

Cluster zonation needs to be included in the master planning and detailed design of the park to enable infrastructural layout that facilitates resource sharing. The lead entity (anchor tenant) should be strategically located to allow other companies to be built around it. Similarly, companies should establish mutual trust and be ready to engage in active pooling of sustainability knowledge and know-how. The anchor company should be able to help develop joint internal and external communication networks, that will aid the coordination of zone-wide cluster activities.

The achievement of potential synergies depends on many objective criteria. First, the exchange of some types of flows relies on the distance between factories. For example, the production or sharing of a steam or compressed air, the collective network needs proximity to create technical, economic, and environmental benefits (Taddeo, 2016). Further, as Adoue, (2010), observes, a large distance between companies affects the cost of transport when implementing the synergy. The second selection rule is that common flows must be homogeneous to be exchangeable between companies. Third, the quantity and availability of flows must be uniform, and the synergy has to generate an economical interest in the short and long term for the involved partners.

To cluster the resident firms in the KGEP factors to consider will include the industry requirements (water, steam, and electricity) and the potential environmental pollution that the industries will cause. The key approach is to determine industry characteristics in terms of raw materials, products, co-products, energy, water, waste materials, and CO_2 emissions within the park. A study of documented life cycle analysis (LCA) Gate-to-Gate methodologies provided documented data from different industries worldwide and a range of these values are given in Table 13. This data will be used as a benchmark for this study and the functional unit for energy, water, and CO_2 is given per kg of the finished product. The raw materials, products, co-products, and wastes are not weighted in this study.

As Table 13 indicates, the steel and glass production plants have a higher energy consumption per unit mass of the product (European Commission, 2008; Worldsteel Association, 2020). According to the authors, the steel industry consumes 5.5 kWh/kg of steel produced while the glass industry consumes 2.16 kWh/kg of the glass produced. Grinding of raw materials in the glass production consumes 6.9-7.6 kWh/kg (Schmitz, 2011). However, with the use of recycled materials like steel scrap in the steel plant and cullet in glass manufacturing, the energy consumption significantly lowers to 0.625 kWh/kg and about 0.7 kWh/kg respectively.

Table 13: Anticipated industrial requirements and wastes

Industry	**Raw Materials**	**Electricity (kWh/Kg-product)**	**Steam (kWh/Kg-product**	**Water (Kg/Kg-product)**	**KgCO2/ Kg-product**	**Products**	**Co-products**	**Wastes**	**Reference**
Steel	Iron ore, limestone, dolomite,	4.5-6.8	0.75	1.6-3.3	1.4-1.8	Steel	Slag, tar, ammonium sulphate, coke dust, mill scale, pig iron, scrap	Wastewater, solid wastes, chemicals, emissions (CO2, NO2,SO2), gases	Fruehan et al., 2000; Rackley, 2010; Burchart-Korol, 2013; World Steel Association, 2015; 2018; 2020.
Recycling plant	Pig iron	0.625		0.3	0.3				
Glass	Silica (sand), soda ash, limestone, feldsdpar, dolomite	1.48-2.9 (6.9-7.6)*		1.44	0.57	Glass	Waste glass (cullets)	Wastewater, solid wastes, chemical waste, emissions (CO2, NO2,SO2), dust	Hartley, 2004, Beerkens et al., 2004, European Commission, 2008; Schmitz et al., 2011, GLS-BREF, 2013, Meuleman, 2017.
Recycling plant	Cullet	0.63-0.78			0.19-1.4				
Milk processing	Raw milk, chemicals (NAOH, HNO3)	0.06-0.3	0.22-2.4	1.2-2.8	0.173	Pasteurised milk (short and long life), cultured milk (yoghurt and sour milk) and powder milk.	Buttermilk, whey, ghee, skim milk	Sludge,waste water, suspended solids and gases	Feitz et al., 2007; Ecoinvent centre, 2010; Jungbluth et al., 2016; Keller et al., 2016; Zhao et al., 2017.
Leather processing	Hides and skins, Chemicals	0.07	1.9-2.3	25	2.2	Finished leather products	Hair, fleshings, shavings, trimmings	Waste water, solid wastes, gaseous emissions	Rivela et al., 2004; Cabeza et al., 2011; Buljan, 2012.
Textile processing	Fibers, dye	0.007-3.47	4.2	100-350	1.8-2.5	Yarn and fabric	Fabric off-cuts	Waste water, effluent discharge, toxic emissions, offcuts	Cotton Inc, 2009; Palamutcu, 2010; Kiron, 2014.
Organic Fertilizer	Animal manure, slurry waste, peat, seaweeds, sewage slugde and other bio-degradable wastes	0.05-0.097	0.01		0.2-0.25	Powder, pellets		Methane, Nitrous oxide	Heres et al., 2007; Hao et al., 2004; Fadare et al., 2010; Pergola et al., 2020.
Grain drying	Cereals		0.29			Dry cereals		Waste food products	FAO, 2008; Kinyanjui , 2013.

The steel and glass production processes account for high CO_2 emissions with approximately 1.8 $kgCO_2eq/kg$ of steel produced (Worldsteel Association, 2018) and 0.57 $kgCO_2eq/kg$ of glass produced (Schmitz et al., 2011).

Textile industry shows a range in electric energy consumption depending on the consumption of each processing plant, for instance, yarn spinning, warping and sizing, weaving, wet processing, and clothing manufacturing plants (Palamutcu, 2010). The industry uses high amounts of water ranging from 100 to 350 kg/kg of fabric produced depending on the textile fibers (Kiron, 2014). Leather processing units are less energy-intensive as the steel and glass but use high amounts of water for the tanning process and in turn, discharge an enormous amount of water and pollutants (Dixit et al., 2015). Other chemical and solid wastes include suspended solids, COD, BOD, chlorides, sulphates, and chromium. Most of these are organic and biodegradable but hazardous wastes are still emitted in significant amounts. Textile and leather processing plants are heavily polluting firms emitting CO_2 and other toxic gases into the atmosphere.

The food industry is the least polluting among the firms with the least amount of electricity and water required compared to steel, glass and textile industries. The milk processing plant uses thermal energy ranging between 0.2 to 2.4 kWh/kg depending on the product (Feitz et al., 2007). Producing concentrated milk consumes higher energy than in the production of yogurt, cream, and long life (UHT) milk. A high amount of biodegradable waste is discharged from the milk processing plants (Jungbluth et al., 2016). According to Kinyua (2013), food driers use thermal energy of 0.29 kWh/kg of dried product.

The industries which are to be located within the park have different energy needs. Some processes have high-temperature requirements while others utilize energy at lower temperatures. An attempt is made to access possible scenarios for allocation of the industries on the proposed sites by clustering industries that can benefit from symbiosis as well as the consideration of incorporating new start-up companies, research institutions (R&D) and small-medium scale enterprises (SMEs) to support the local business people.

Table 14: Proposed industrial cluster

Polluting firms	**Cluster**	**Allocated site**
High	Steel, Glass	A
Medium	Textile, Leather	D
Low	-Food processing: milk & grain -Eco-fertilizer production	B/C

To analyze the possibility of a symbiotic relationship and implementation of the circular economy concept in this study, priority is given to a cluster of industries that have high potential to share resources (including raw materials, waste, and by-products). Also, the clustering of companies depends on the utility requirements, level of environmental impacts from emissions and wastes released during production (Table 14). Three suggested clusters in the KenGen Green Energy Park are;

Cluster 1: considers the location of the energy-intensive industries at the edge of the park (Site A) as illustrated by Table 15. The companies are heavy CO_2 emitters and the waste from the steel plant includes steam which can be utilized by other small to medium scale manufacturing firms operating within this zone. Site A is located farther from the power plants and in zones with a high source of freshwater. This is appropriate for the steel plant that requires up to 3.3 kg of water per kg of steel produced.

Cluster 2: proposes an allocation of textile and leather processing industries in site D. The industries in this cluster have a high demand for water, steam and are medium polluters due to high amounts of chemicals in the waste stream. The integration of the small startups and small scale industries within these resident firms are viable as the site has abundant thermal energy. This will be crucial in tapping the waste streams from these companies and utilizing it to create new valuable products and increase revenue streams in the park.

Cluster 3: clusters the food processing firms in sites B & C where the products can be branded eco-friendly since most of the wastes from this food cluster are organic and can be be easily treated and channeled for production of organic fertilizer. Green stickers and eco-labels can be used to brand products as a form of certification of sustainable production. New companies, especially within the food processing industry, will be situated in this site to utilize the abundant thermal energy and explore newer options in a cascade system. Other start-up companies and institutions of research and development in this zone will enable the creation of new ideas and the development of innovative products within the park. The warehouse & trading industry is transportation-dependent and will be located close to the main arterial road and the gate. As highlighted in the feasibility study (KenGen, 2016a), the energy park has a social responsibility for the local communities, and therefore, about 10 hectares are set aside for local industries and SMEs.

5.2. Material Flow Analysis

For resource efficiency and waste monitoring to be effective within the KenGen Green Energy Park, a material flow model should be simulated. This would show the contribution of industrial symbiosis to the circular economy approach. This is mainly to determine the possibility of symbiotic relationships between industries and possible future incorporation of spin-off companies, to utilize the remaining by-products and wastes. Two important factors are to be considered when developing a material flow model; system boundary and the flows.

5.2.1. System analysis

The total industrial area represents 'the system' and comprises of a set of material flows, stocks, and processes within a defined boundary. It coincides with the geographical boundaries of the industrial park. Each cluster represents a subsystem and is defined by the territorial limits of the clustered companies. The flows are characterized by three attributes imports, exports, and outputs as illustrated in Figure 22. Domestic extraction is the resources used extracted inside the system (e.g. recycled wastes and co-products), whereas raw materials and products from other businesses (energy and water), bought or extracted outside the industrial area, are treated as imports. Exports are the products and materials used or sold outside the system boundaries, while emissions to air, wastes, and wastewater are outputs to the environment.

Within the system boundary (Figure 21), the flow model defines the pathways of materials cover from the cradle-to-cradle (closed-loop production) with the co-products recycled into the production process or used by another process as raw material. The results reveal important processes during the life cycle of material, detect relevant stocks of the material in the economy and the environment, show the losses to the environment and the final sinks, and track down internal recycling loops.

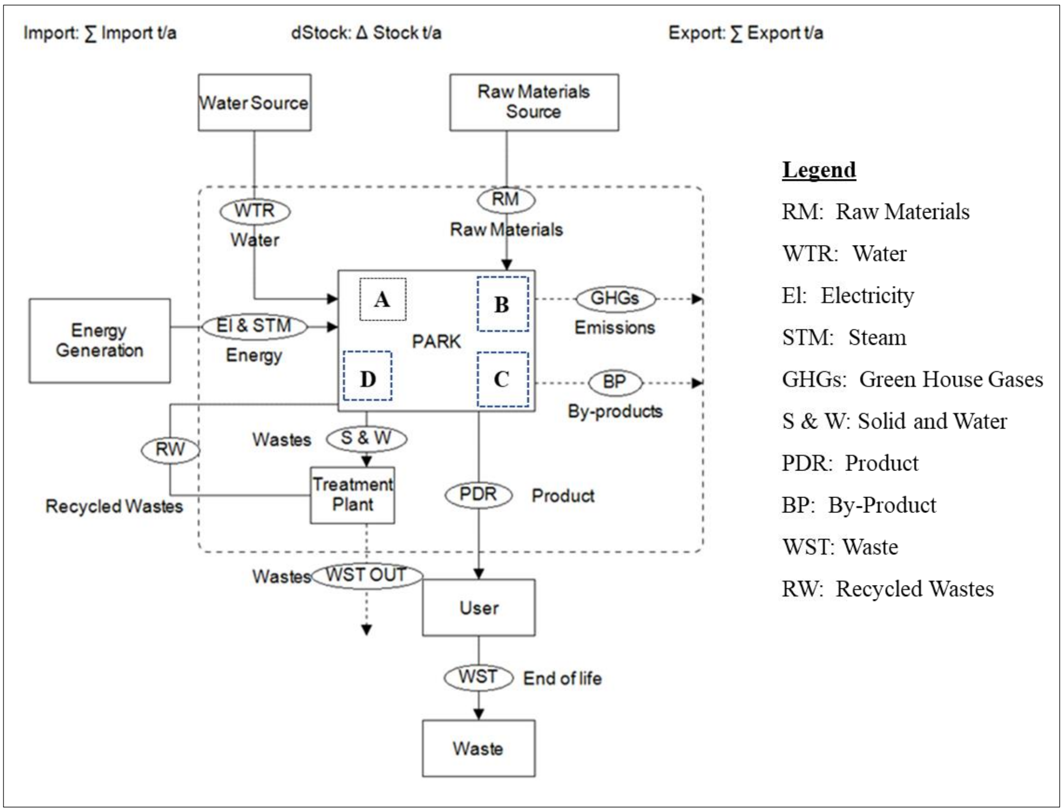

Figure 21. Summary of the overall input and output flows. The dotted line outlines the system boundary for this study.

When constructing a material flow model the following steps were considered; definition of systems boundaries; establishment of a model linking sources, pathways, and sinks for each of the selected wastes and products, and construction of all major flows in the system. This study does not factor in processes and ecological footprint caused by upstream and downstream processes.

Upstream processes include the inflow of raw materials and energy needed for industrial core processes;

- Raw material production
- Farming (in production of milk, textile raw material, grains)
- Transportation of raw materials to the park
- Emissions from energy generation

Downstream processes include transportation from final production to an average distribution platform;

- Transportation of finished product, by-products, wastes
- Usage of the finished product
- Disposal of wastes after use
- Waste treatment outside the park
- Recycling and reuse of wastes

5.2.2. Material flows within the evolving clusters

The Steel-glass cluster comprises of the steel manufacturer and the glass production plants. This cluster is considered an energy-intensive cluster with a considerable amount of CO_2 emission to the atmosphere. Both manufacturing plants required heating to about 1500-1600°C and emits high amounts of waste heat as a by-product. The design should ensure the sharing of resources and infrastructure such as power, water, and steam lines, roads, waste collection system, and water treatment plants. The two companies should have mutual trust and share data about resource utilization and ensure efficient exchanges.

Raw materials from the two companies are transported by rail and road into the park while the products can be transported for export or used for the heavy construction of the energy utilities within the Olkaria geothermal area. The availability of the cheaper product will reduce the overall cost of construction and importantly minimize emissions associated with transportation.

The by-products of the steel processing e.g. pig iron, dust, mill scale, scrap metal and gases (coke gas and BF gas) are recycled into the production cycle. Other co-products like tar can be used in road construction. Ammonium sulphate can be processed and used as fertilizer and the slag can be used as a raw material in glass production. Figure 22, indicates that the glass manufacturing process generates a by-product (cullet) which is recycled back to production to reduce energy and raw material use. Both companies use a high amount of energy and release enough amount of waste heat which can be channeled to other small and medium scale enterprises that utilize thermal energy for their production. A large amount of wastewater is gathered and treated in the shared water treatment plant. The treated water is recycled and reused in the production cycle or reinjected back to the reservoir to recharge the geothermal system.

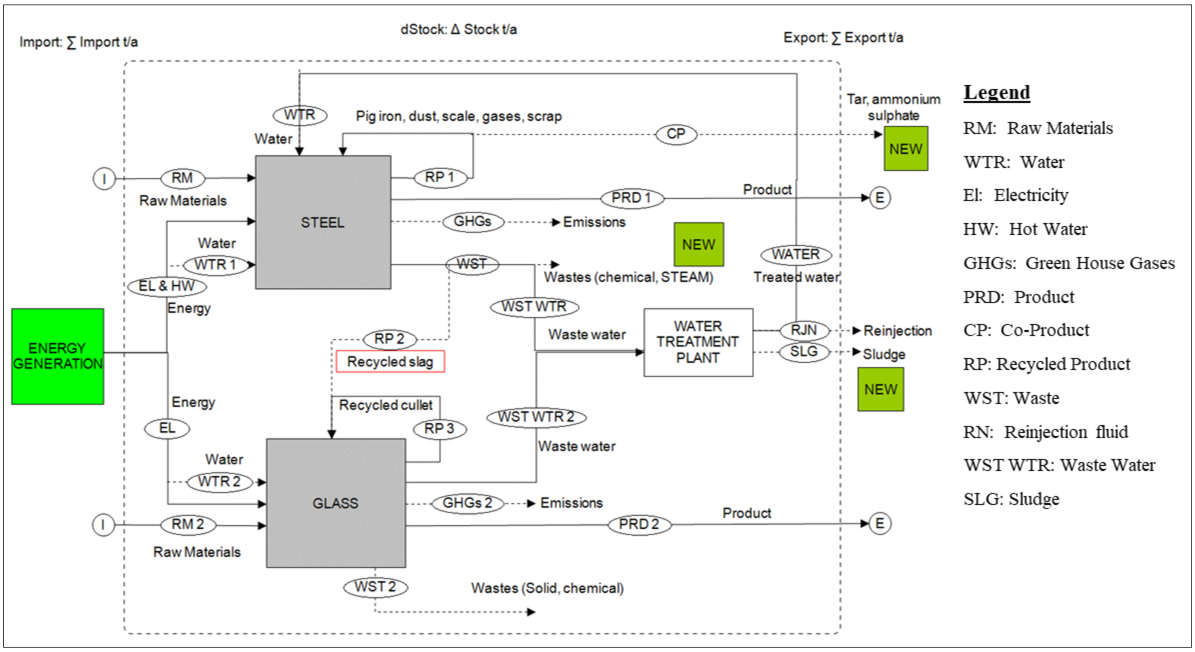

Figure 22: The material flow in the steel-glass cluster.

The sludge from the treatment plant is taken to the organic fertilizer processing units within the park as a raw material while gases can be harnessed and utilized for various uses. The

Carbon Capture technology can be utilized to harness CO_2 from these two large point sources and minimize emissions significantly.

Food-fertilizer cluster comprises of food processing plants (milk pasteurizer and grain driers) and the organic fertilizer manufacturing plant. Key raw materials for this cluster are milk and cereals majorly from the neighboring farming community of the Narok and Nakuru Counties. The desired products from these processes are packaged and transported to the various markets in the country. Energy (electricity and steam) and water are provided by KenGen and a cascade design can be useful as it ensures waste hot fluid from milk processing is run through the grain driers to provide heat for dehydration. Organic fertilizer plant uses low heat and can utilize thermal energy from the warm wastewater from the food driers before disposing into reinjection wells.

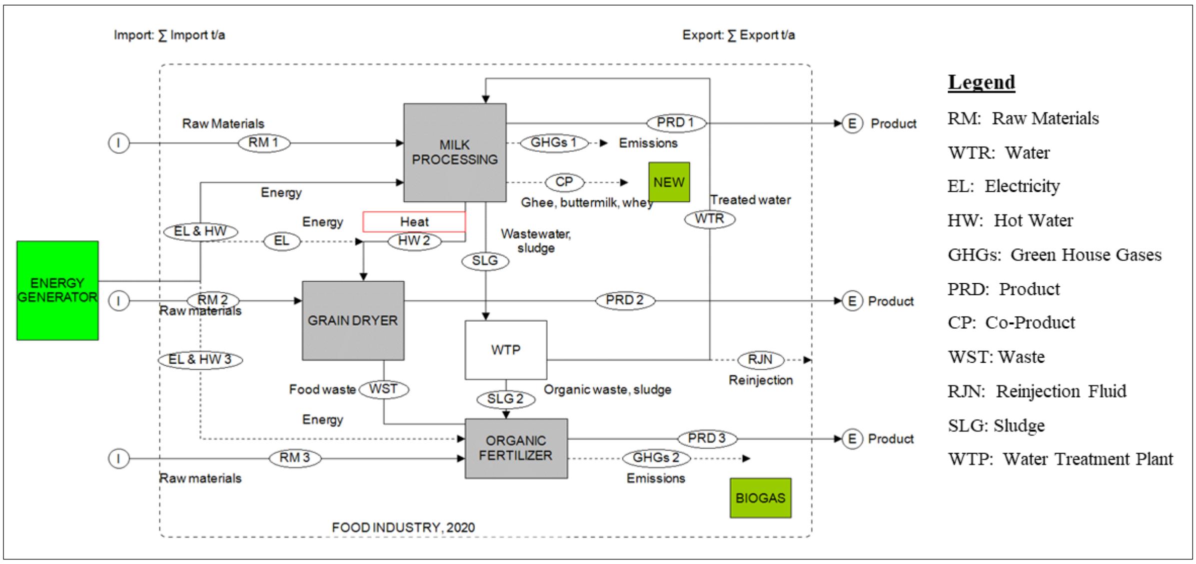

Figure 23: Material flow in the food industry-organic fertilizer cluster.

Some of the marketable by-products of milk processing include buttermilk and whey which can be used to make beverages and sports drinks. Ghee and skim-milk can be valuable raw materials in the production of cheese, sweets, and chocolates. The sludge from the water treatment plant in this zone is treated and used to produce organic fertilizer pellets and powder. Other solid and chemical wastes are treated and transported for use outside the industrial park. Emissions from the production of fertilizer include carbon dioxide and methane which can be sufficiently harnessed for biogas production.

This study proposes sites B and C to be allocated for the food cluster. The available cumulative thermal energy is 16 MWt and wells OW-912E and OW-917A with a capacity of 7.0 MWe and 2.7MWe respectively can be a source of electricity using the mobile wellhead plants technology.

Textile-leather cluster comprises of the garment and leather processing industries. The cluster uses high amounts of chemicals, steam, and water. The two are clustered together to enhance resource efficiency and advanced pollution control measures to curb environmental degradation in this zone.

The raw materials for this zone are transported into the park from several sources including skin and hides from the neighboring cattle farming community. Thermal energy available for site D is 51.5 MWt as provided by the geothermal brine while electricity is harnessed from the grid or possibly from the mobile wellhead plants in the vicinity. Other shared infrastructure includes water lines and water treatment plants which treat an enormous amount of wastewater from these processing plants. A cascade design allows the steam exchange between the high-temperature utilization in the textile plant to the lower temperature leather processing units. Some of the recoverable wastes from this zone include garment off-cuts, chemical, and organic wastes from the textile industry (Figure 24). Others from the leather industry include; hair, fleshings, crust, trimmings, and shavings which are recovered and used as raw materials for organic fertilizer production. The emissions from this cluster are essentially CH_4, NH_3, H_2S, and CO_2 (Nortanicola et al., 2011), which can be harnessed for various uses. Other opportunities for SMEs are available in solid waste management and chromium recovery points. Chrome recovered is used back in the tanning process in the production line. Water recovery and treatment before reuse or reinjection is essential in this zone as it contains a large number of chemicals.

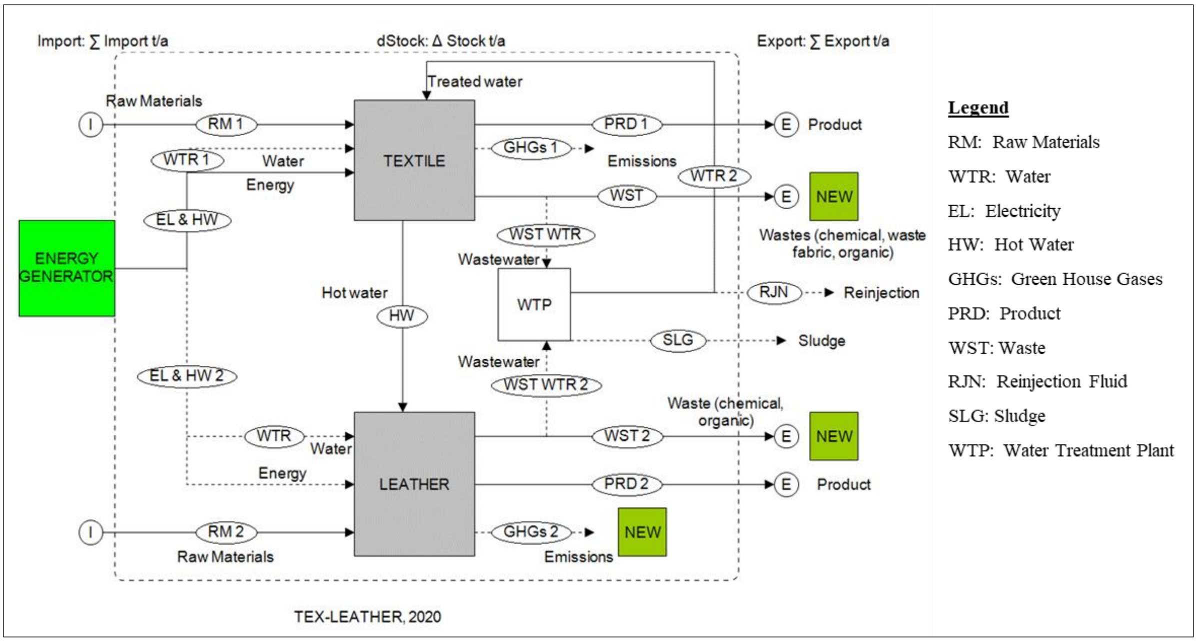

Figure 24: Material flow in the textile-leather cluster.

5.3. Opportunities arising from industrial symbiosis (IS)

KenGen Green Energy Park has a predominance of manufacturing activities with steel, glass, and garment industry as the main tenants. Material flow is a priority in identifying potential synergies. The material flow comprises of the raw materials consumed and the waste/byproducts generated by each company. The cooperation opportunities for environmental management are identified for each of the clustered companies within the park. To increase industrial symbiosis, concerted action must be taken at various levels to encourage companies to develop synergies. Some of the aspects that can contribute to the increase of industrial symbiosis include, but not limited to; changing the legislative framework, making funds available, increased involvement of the county/local governments, the existence of a facilitator or park management, and the use of some industries as anchor tenants.

From the analyzed material flows within the identified industrial clusters, two types of synergies arise; utility/infrastructure sharing and waste/by-product sharing.

a) Utility and infrastructure sharing

The shared use of utility and infrastructure would be mainly water and energy. Identified clusters can be involved in; joint development of security, roads, water treatment plants, water pipelines, electricity, and hot water systems. They can also share maintenance contractors and training facilities. Waste management systems include waste storage, shared transport of wastes, shared waste treatment, and recovery installation.

b) Waste and by-product sharing

This is mainly the recovery and exchange of waste products and by-products that are reused economically or materially by some of the companies. This comprises of; by-products recycle and reuse, wastewater reuse, sludge from wastewater treatment, excess heat/ steam, and gases (CH_4 and CO_2). Others include; symbiotic exchanges of geothermal brine, steam, and geothermal mineral extraction (like silica). These present an opportunity for SMEs to be incorporated within the industrial park and tap resources along the waste streams for use as raw materials in their processes.

Table 15: Marketable waste products based on IS cases

Waste products	**Suitable use and activities**	**References**
Residual sand	Floor and paving	Schwarz and Steininger, 1997
Scrap metal,	Steel foundries	Puente et al., 2015
Waste products from food	Organic fertilizer	
Used oil, slag	Manufacture of cement	Mirata, 2004
Used tyres	Manufacture of carbon fiber, graphite, and coal	Puente et al., 2015
Waste products from textile and sludge from fibers	Manufacture of ceramic materials	Eckelman and Chertow, 2009
Used oils	Recovery and reuse of as oils	Mirata, 2004; Puente et al., 2015
Glass waste	Manufacture of fiberglass	Mirata and Emtairah, 2005
Biological sludge and slag	Manufacture of fertilizer	Puente et al., 2015
Ghee, buttermilk, whey	Manufacture of beverages sports drinks, chocolates, cheese, and sweets.	FAO, 2010
Gases (CO_2 and CH_2)	Biogas production	Atelge et al., 2020
Fabric off-cuts (waste fabric)	Production of bags, sofa sets	Khisa, 2016
Geothermal brine	Mineral extraction; silica, lithium, boron	Lea and O’Sullivan, 2020

6. EIP Framework

The international EIP framework has been developed by UNIDO, the World Bank Group, and GIZ to guide governments, park operators, participating enterprises, and associated stakeholders, who are involved in the development and operation of industrial parks. The developed performance requirements can serve to inform EIP stakeholders about their respective frameworks, auditing procedures, and certification systems where applicable. According to UNIDO, World Bank, and GIZ (2017a), the framework intends to ensure the application of the performance requirements in their respective projects and programs. Further, to encourage partners and stakeholders beyond the boundaries of their projects, to apply these requirements in industrial park planning, development, management, and monitoring. Developing a consolidated EIP assessment framework and performance criteria is important. The criteria can assist stakeholders with the decision making in public and private sectors, assessing performance levels in industrial parks, and decisions on funds allocation. Further, incentivizing industrial areas that meet the criteria, raising awareness, and providing marketing benefits to the high eco-industrial performance of EIPs.

In the process of developing best practices for the KenGen Green Energy Park assessment, criteria for EIP developed by UNIDO, World Bank and GIZ is used as a benchmark. This is to ensure minimum requirements are met and the generation of quick wins to encourage continued support for the policy process. The assessment is conducted for the park´s intended performance. Suggestions are made on specific opportunities that could be undertaken by park management and/or companies to meet the international standard requirements.

6.1. Policy intervention options

To create an understanding of potential proposals for EIP policy interventions, an multi-criteria assessment is undertaken with a focus on the Kenyan Industrial Policy context. EIP policy instruments are valued, weighted, and scored to determine the priority for recommendations. These instruments include a proposed green recruitment policy where all the new tenant companies have to encourage the use of renewable/cleaner energy sources. They should apply for foreign direct investment, consider the industrial symbiosis approach, cleaner production, waste treatment, and recycling. Further, the companies should prepare their eco-designs and construct their buildings using green building standards. The government is encouraged to develop a National Action Plan for EIP to guide all the mentioned policies before the projects start. To promote industrial symbiosis, economic incentives and tax exemptions should be implemented. Implementing tax exemption policies promotes the development of SMEs and local investors as well as the production of the eco-products increasing market competition. Social capital creation is also one of the pillars that transform the SMEs into eco-industrial clusters and promote environmentally friendly development. UNIDO (2016) indicated that the policies related to industrial symbiosis include; e-waste management, energy-saving, emission reduction regulation, green infrastructure development guidelines, cleaner production promotion guidelines, water pollution prevention and control regulation, regulation, and promotion of ISO 14001 certification.

Using the EIP policy tools (Beers et al., 2019), these interventions are analyzed against their economic, environmental, and social impacts. All the criteria are weighted at the highest score of 4 according to their importance in EIP development. The assessed policy interventions are allocated a score of 1 to 5; (1; Significant negative impact, 2; indirect negative impact, 3; no impact, 4; indirect positive impact, 5; significant positive impact). The final scores are a factor of criteria score and the allocated score of the policy instrument.

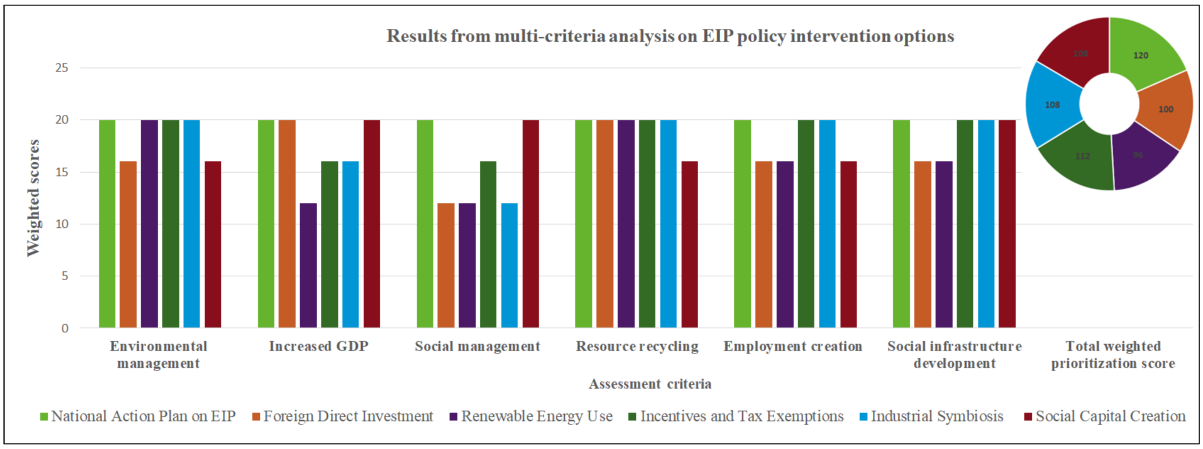

Figure 25: Analysis of applicable EIP policy interventions

National Action Plan on EIP should be formed and implemented together with the existing Kenya Environment Action Plan (2016-2022). The plan will guide the development of the Environmental Action Plans at both the County level and the National level and subsequently help integrate environmental concerns into the development of the EIP. It will provide instrumental inputs to creating a regulatory framework that focuses on EIPs' contribution to environmental management and monitoring, contribution to GDP, improved workers' welfare, energy, water and waste management, direct employment creation, and improved social infrastructure.

Foreign Direct Investment has promoted investment principally in the manufacturing and infrastructure sectors. This has indirectly resulted in increased emissions and industrial pollutants therefore, impacting negatively on the environment. However, the availability of foreign direct investment has a major economic impact contributing to increased GDP, direct employment, improved social infrastructure, and waste recycling and reuse

Renewable energy use in industrial development will shift towards environmental and social sustainability. The geothermal energy use for manufacturing in the KenGen Green Energy Park will produce relatively low greenhouse gases as compared to other forms of energy. As IRENA (2016) discussed, the use of renewable energy results in positive environmental impacts measured as greenhouse gas emissions and materials consumption. A total shift towards renewable energy use indirectly results in economic benefits related to employment creation, expanding infrastructure and overall positive rise in the country's GDP.

Taxes and fiscal incentives are key policy instruments for providing clear and sustained incentives to reduce environmental damage and increase economic and social development. Tax incentives are used to attract investment especially firms that are already highly profitable. However, SMEs can benefit from tax holidays to shield from losses and promote sustainable job creation. Granting tax exemptions and incentives to park operators will have also have an indirect impact on the social wellbeing of workers and the community.

Industrial symbiosis and resource efficiency is a valuable policy instrument that can promote EIP development. No government policy instrument currently focusses on industrial symbiosis and its application towards green growth in SEZs. To promote a circular economy, some interventions that seek to enhance environmental management and monitoring, resource recycling and creation of green jobs need to be incorporated in the development plans. IS will have an indirect positive impact on the country´s GDP and promoting workers´ welfare and local infrastructure.

Social capital contributes to economic growth, productivity, social cohesion, and human well-being. It focuses on relations between stakeholders' willingness to cooperate, trust and realize a common goal. Trust and cooperation are built through intra and inter-firm relationships and networks and institutional strength of clusters. Further, the extent to which this enables, or inhibits the groups of firms, to engage in inclusive collective action, develop supportive localized policy networks and generate collective learning. Social capital contributes indirectly to environmental management and pollution control.

6.2. Policy recommendations

To successfully develop an EIP within the KGEP, there is a need to enhance eco-efficiency and steer the industrial processes towards symbiosis and utility sharing. A framework guiding the development and implementation of EIP needs to be established by the stakeholders. The proposed recommendations made in this study are based on International Best Practices and the EIP Framework (Bellantuono et al., 2017). They are categorized into two dimensions; organizational and sustainability dimensions.

6.2.1. Sustainability dimension

By-product exchange

A successful industrial symbiosis within an industrial site occurs when two or more companies exchange by-products (Park and Behera, 2014). Identifying and quantifying emerging streams of by-products and wastes (wastewater, waste heat, or gases) is an important step to resource sharing. The company producing the by-products can give them, for free or upon payment, to another company that can use them as raw materials or, more generally, as factors of production. The occurrence of by-products exchange opens room for both the economic and environmental benefits to the companies. The proposed EIP should focus on anchoring the park around resource recovery and spin-off companies. Further, there is a need for a cluster of recycling, reuse, remanufacturing and composting firms, to process by-products and supply recycled inputs to manufacturers within the park or externally.

Sustainable use of natural resources

Most of the raw materials used in industrial processes are either non-renewable or slightly renewable resources available in nature in a limited amount. A circular production system encourages reuse, recycle and reduction of waste streams, therefore, reducing virgin resource input. Geothermal steam and brine used in a cascade design allow downstream processes requiring lower temperatures (e.g. food dryers), to use waste steam from other industries operating upstream (e.g. textile manufacturers) with high thermal energy demands. The waste fluid is reinjected back to the geothermal reservoir for sustainable production forming closed-loop system management. EIP designs allow collection and treatment wastewater from individual plants to be reused within the EIP or its surroundings. This is particularly important as water is already a limited resource within the Olkaria geothermal area.

Eco-design
KenGen Green Energy Park is located within a national park hence its design and master plans require a sustainable coexistence with the surrounding habitat. The Park needs to use eco-friendly plant designs, landscaping, choice of materials, infrastructure and building equipment that promote sustainability, it can promote the park´s contribution to global climate change.

Green procurement
The procurement of goods, services, and works should focus on reducing environmental footprint throughout the lifecycle of a process. Green procurement policies should be highlighted within the Public Procurement Act to provide guidelines to suppliers and end-users.

Sustainable transportation management
To provide a sustainable transportation management system within the EIP requires flows of both people and materials to be taken into account, during the design and implementation stages. An example would be building a shared transportation management system that coordinates the disperse transportation demand of the companies. The location of the KenGen park is strategic as it is served by a major Standard Gauge Railway running from the seaport of Mombasa and terminating just 30 km outside the park. Other road networks connect the park to major cities and towns and provide effective linkages to various markets.

Environmental compliance
As documented in Kenya's National Environmental Policy (2013), the companies must comply with laws and regulations on emissions and pollution control, waste management, and other environmental issues. The National Environmental Management Authority (NEMA) in conjunction with Kenya National Cleaner Production Centre, conducts assessments and monitoring to address the industrial pollution challenges concerning the consumption of resources in their processes and promote resource efficiency. The aim is to increase the competitiveness of the industries by promoting waste reduction and resource optimization (water and energy utilization), through the application of cleaner production technologies and techniques.

Social welfare services
The Big Four Agenda established by Kenya's President in 2018, focuses on universal healthcare, manufacturing, affordable housing, and food security, to drive the social pillar of improving the quality of life for all Kenyans. It targets to promote education and training, health, environment, housing and urbanization, children and social development, youth, and sports. The manufacturing companies within the EIP need to offer the workers access to amenities like schools, canteens, recreational facilities, and health services. These should not be restricted to workers of the companies that are located within the EIP but it should include the surrounding community living nearby. Engaging the community surrounding the park enables the developer to gain insight into the views of the citizens as well as imparting knowledge on the social benefits of the project. Initiatives should be taken to strengthen the ties with the local community through seminars, meetings, workshops, and educational programs for schoolchildren or services awareness raising, training of women and young people as well as broader community involvement. Community participation is crucial, especially in building a climate of trust and collaboration.

Training and education
Training of workers within the EIP reduces technical barriers often associated with a lack of information on the changing technologies. Training also exposes workers to, the high

international quality standards, the anticipated improvement of quality of products, health, and safety or environmental protection. The emerging companies within the EIP can jointly manage human resource training on the above sustainability topics. The EIP needs to strengthen linkages to the academia and research and development institutions and other related industries.

6.2.2. Organizational dimension

Development process
Eco-Industrial Parks can either emerge spontaneously or can be intentionally promoted by an initiator. The development can either be designed by adopting a top-down or bottom-up approach (Chertow, 2007). A mixed (mid-point) approach is where the Government is involved with regulations, incentives, and governance while the tenant companies organize themselves to share resources for efficient material flow management within the economic zone. Promoting symbiosis among companies is beneficial for all the parties involved, makes the EIP emerge from the gradual agglomeration of companies mutually linked by symbiotic relationship. This approach is suitable for developing the proposed EIP at the KenGen Green Energy Park.

Anchor tenant
The major manufacturer within the KenGen Green Energy Park can assume the role of an anchor tenant. The company can provide the EIP with a continuous waste stream that can be potentially used by third parties in their manufacturing processes. The Park management needs to identify the park´s anchor tenant to drive the development of networking and linkages with the assistance of the government agencies formulating policies.

Governmental support
The Kenyan Government has established several policies to provide political, coordinative, educational, and infrastructural support to special economic zones. This can be extended to the development of the EIPs. Other supportive initiatives include the provision of suitable infrastructures, rewarding individual actions that generate environmental benefits and several direct or indirect subsidies to the companies that take part in the EIP development.

Heterogeneity
A low level of diversity among firms in an EIP reduces the variety of material exchanges, and the dependency on few material or energy flows may cause instability of the park (Bellantuono et al., 2017). Different industrial sectors enable a wide variety of input and output flows available, for inter-industry exchanges. Also, different sizes of companies including SMEs can facilitate industrial symbiosis opportunities. There is a need to examine all the material flows and establish an input-output relationship between companies. A symbiotic relationship may exist between diverse manufacturers e.g. steel, fertilizer, and glass manufacturing industries.

Cooperation among companies and government
A network of collaboration will enhance and promote the development of an EIP. A successful industrial symbiosis model and efficient operation of an EIP entails, a multi-connected waste recovery system, a robust training program on waste and by-product exchange as well as the related synergy building. Also, there is a need for an infrastructure for waste and by-product recovery and reuse and a system for managing the network and its players. Furthermore, a community liaison and outreach office is essential for managing joint projects with the surrounding community and a vibrant triple helix collaboration for eco-innovation (World

Bank, 2014). The park management can provide a network between several business entities within the park and also outside the boundaries of EIP. A relationship needs to be developed between the park and the suppliers, customers, universities and research centers, government agencies, local government and communities surrounding it. Information sharing between these entities will improve the effective operation of the EIP.

Shared support services
Apart from sharing information, the companies within the park may share a variety of support services e.g. security, transportation, maintenance, training facilities, and waste treatment plants. Management of these common services can save the cost of services in the park.

6.3. Risks associated with EIP development

A serious potential pitfall to initiating cooperation among companies in industrial parks arises when the government plans this cooperation without involving the companies and other stakeholders. With top-down management, there is the risk that there will be no support among the companies for the sustainable development of the eco-industrial park.

The establishment of the essential symbiotic relationships between the companies participating in the project is likely to result in some barriers. The barriers associated with the development of the EIP project is stipulated in Table 18.

Table 16: Key Barriers for EIP and the potential solutions

Risk	**Cause of risk**	**Possible solution**
Technical	-An exchange is technically unfeasible; -Long lead times and disruption in installing innovative technologies; -Lack of standardization	-Companies to conduct a technical feasibility study on their products and wastes; -Provide technological cooperation programs; -Develop technically sound infrastructure and services.
Economic	-An exchange might be economically unsound or economically risky; additional expenses; -Limited financial support for innovation and environmental measure; -Lack of research funding.	-Encourage capital subsidies and financial assistance; -EIPs should engage in dialogue and enterprise to improve awareness of advanced technology solutions.
Informational	-Difficulty in getting businesses to share information	Active participation of companies to the project; -Tenant association as a communication platform; -Cooperation between all stakeholders (triple helix).

Organizational	-The intended exchange might not fit in the current corporate organizational structure; -Lack of company interests; - Park developers´ and authorities´ lack of experience and awareness.	-Encourage a mid-point approach to EIP development; -Develop internal training programs to build capacity and confidence in EIP.
Regulatory/legal	-Unfavorable environmental laws and regulations; -Lack of policies to encourage EIP development and clean technology adoption; -Lack of transparency surrounding EIP regulations.	-Set favourable targets for the development of EIPs; -Develop fiscal incentives that encourage EIPs; -Seek to understand key national and local barriers to the adoption of EIP standards

7. Stakeholder Mapping and Management Structure

A successful and stable eco-industrial park has a functional governance model that is formulated based on stakeholder theory. The theory stipulates the mapping of all relevant stakeholders, to highlight the crucial groups or companies to engage with, and formulate how they can benefit from the project's impact. Different kinds of stakeholders have different views, benefits, and goals in the eco-industrial park. They also provide complementary resources for the EIP such as policy, funding, technology, information, raw materials, or services.

7.1. Stakeholder mapping

As defined by UNIDO et al. (2019), stakeholders represent any organizations or groups that are affected by or can affect industrial parks' efforts to implement EIP initiatives. These stakeholders include members of the local community, government officials, research institutions, or any other individuals, groups, or companies, located inside and outside the industrial park (Figure 26). Stakeholder mapping is essential before and during project implementation. The mapping identifies and classifies them as key, primary and secondary stakeholders, determining their roles, responsibilities, and expectations of the EIP project. It is important to understand these expectations to assess whether a stakeholder's interests and needs are aligned with the project objectives.

KenGen has put in place an efficient sustainable review and engagement mechanism aimed at enhancing its reputation and relationships with all key stakeholders. This mechanism includes the set-up of stakeholder engagement plans for the project. These include developing a stakeholder engagement plan to ensure smooth relations with the local community. KenGen has Community Liaison Officers who assist in stakeholder management and the Stakeholder Coordination Committees have been formed to support the implementation of the Green Energy Park project.

Inappropriate management of stakeholders may lead to poor relations and adversely affect the park operations and attainment of its objectives. Project development leads to potential displacement of the human population and wildlife which can trigger hostility from the local communities and biodiversity pressure groups.

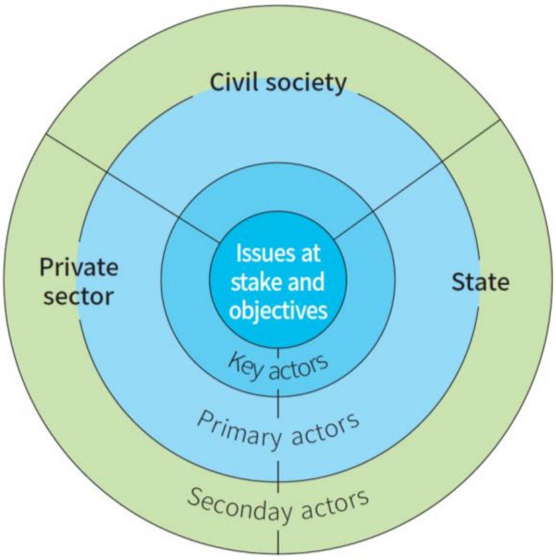

Figure 26: Stakeholder Mapping (UNIDO et al., 2019)

To attain an EIP status, the study has identified some relevant stakeholders and the information generated allows for the synthesis and formulation of a governance structure applicable to the KenGen Green Energy Park. These stakeholders are classified as having a *low, medium,* or *high* interest or influence on the EIP project (Figure 27).

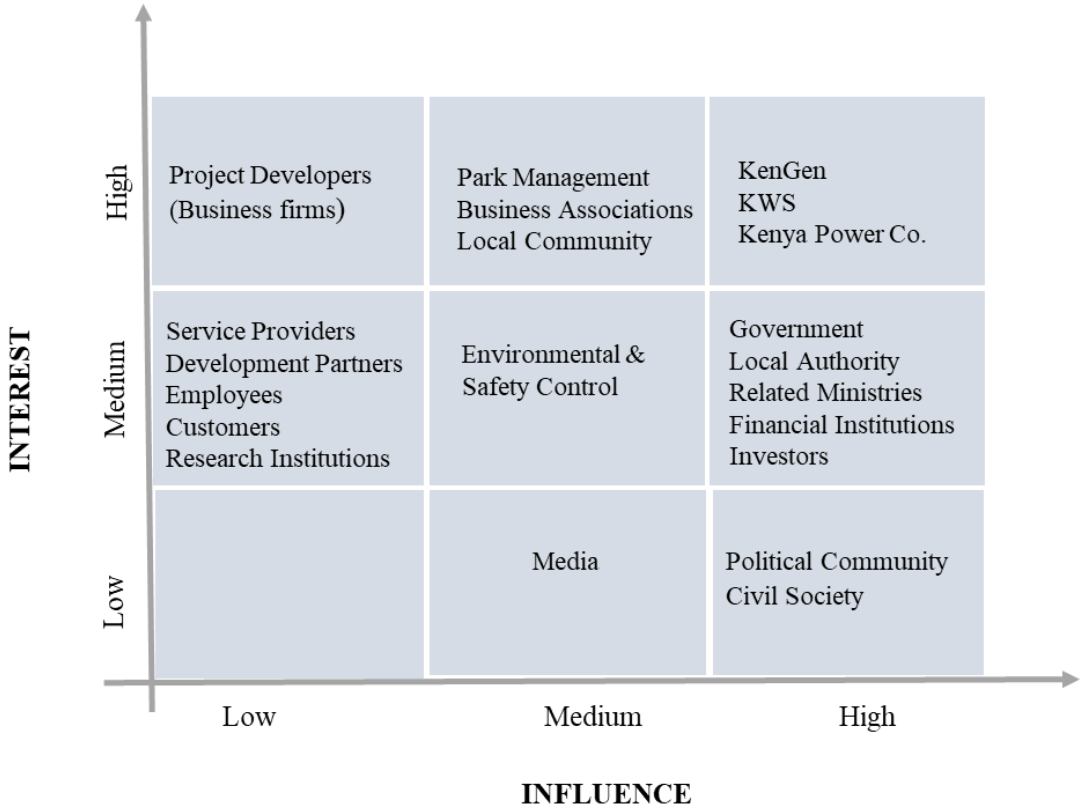

Figure 27: Stakeholder matrix for the proposed EIP

Large industrial complexes that deal with multiple stakeholders, such as government and various agencies, investors and NGOs, will benefit from a single point of contact. Having a governing entity (park management) ensures seamless coordination among multiple parties.

7.2. Park Management Structure

The management structure of the park needs to be assessed based on its ability to network and create synergies for waste and by-product exchange, engage academia in the eco-innovation promotion and general commitment to the ideals of a green economy. The basic requirements should be the willingness of firms to actively cooperate and participate in all the stages of the development.

Little (2014) outlined that a governing entity ensures the formulation of integrated development plans. A large industrial complex needs an entity to plan and execute plans such as land preparation, infrastructure, facilities, utilities, and peripherals. This entity can serve as a developer or master planner in the coordination of these various activities. Other benefits of having a governing entity are to source and manage funds and bring strong marketing capability focusing on promotional strategies to attract investors.

Good governance applied to eco-industrial parks includes consulting a wide range of stakeholders who can participate in the design of the park management structure, as well as in monitoring performance (UNIDO, World Bank & GIZ, 2017b). EIP management models are highly dependent on the nature of the park (e. g. industrial sector, size), its constitutive enterprises, the prevailing political environment (national and local), the level of investment and financial availability and the capacities of the stakeholders in the EIP site location. Three types of models adopted in many industrial parks are discussed in Table 17.

Table 17: Type of management models for EIPs (UNIDO, World Bank & GIZ, 2017b)

Model type	**Description**	**Development Approach**
Associative management model	Tenant association comprising of property owners or leasers in the EIP. When the association is legally formalized, it can act as EIP management.	Bottom-up
Government management model	The government manages the EIP through a dedicated team issued from a designated national, county, or local authority. KenGen as a government entity controls park operations.	Top-down
Public-Private management model	A Park Management body can be formed to represent KenGen, local authorities and the tenant companies who work in partnership to manage the EIP.	Mid-point

Some EIPs have been managed successfully using the *tenant association management model.* This applies when there is a bottom-up process of self-organization of the resident companies with little intervention from the government in terms of physical development, operation or management. In this model, there´s minimal political interference and higher capital independence, as the park relies heavily on debt financing than government funding. The governing entity in this model has a faster response to risk management and mitigation compared to the government management entity.

The government management model is applicable through a dedicated team issued from designated government entities. It is often the case for special economic zones requiring high government investment. These economic zones are formed and governed through a top-down approach and the governing entity can protect the interest of the public as well as align with the country's strategy. The government acts as a facilitator to investors hence has high investor friendliness and financial self-sustainability.

The *private-public mixed model* allows for the formation of a dedicated park management team from both the Government, KenGen, and tenant companies. In this mid-point approach, the Kenyan Government form appropriate policies to enhance successful collaboration and networking between firms. This model uses both the strengths of the tenant association and government management models and hence KenGen Green Energy Park can benefit from inputs of the government entities and the companies.

The draft Supplemental SEZ Regulations of 2019 provided clear stipulations on the governance of the economic zones and the role played by the zone Authority and other relevant government entities. For instance, granting full recognition and enforcing all Authority-issued licenses, permits, certifications, and other relevant approvals through the National Environmental Management Authority (NEMA) and Water Resource Authority (WRA). The draft SEZ Regulation permits the secondment of personnel with appropriate skills and experience from Government entities to the Zone Authority to assist it in performing its functions through a signed MOU.

Supplemental Regulations also has mandated the Zone Authority to sign agreements with the tenants, to avail compliance requirements and procedurally related information and be made publicly available, through the Authority's website portal. However, the regulations are weak on the promotion of environmental stewardship and do not prioritize low-emission, resource use optimization and socially-inclusive and climate-resilient development pathways that promote green growth. In many Kenya economic zones, there is insufficient park management post-construction support, that targets resident industries in their collective efforts of continual improvement (Khisa, 2016).To develop the Authority's capability to advance low-emission, resource use optimization and socially inclusive development pathways, a robust governance structure should be enforced.

Kenya´s draft SEZ regulations and the Supplemental SEZ regulations do not provide a framework for EIP development. The top management in collaboration with these departments, therefore, has the responsibility of championing the low-carbon activities using technologies that encourage resource efficiency, circular economy, cleaner production, and industrial symbiosis. These activities can be supervised directly by the technical team in the environmental compliance and liaison department.

Developing strong partnerships that seek to strengthen the Zone Authority's capacity to drive the green growth agenda, is achieved through the strengthening of the triple helix collaboration between Government/Financial institutions-Research/Academia-Industry collaboration (Albertsson, 2011; Khisa, 2016). The key role of knowledge institutions is to undertake demand-driven research, that will help the economic zone adopt the best practices and innovation of waste and by-product exchange (Figure 28).

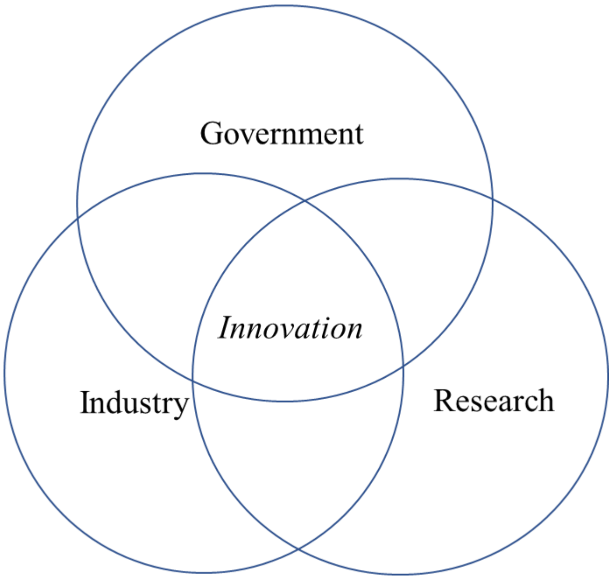

Figure 28: Triple Helix collaboration

The triple helix collaboration will also seek to work with government ministries to encourage policy development from a green growth perspective. Further, to work with the financial institutions to encourage the development of low-interest loans for green growth. This will be achieved through their sustainable financing initiatives and funding SMEs that uptake the wastes and utilize as raw materials in their processes (industrial symbiosis). In a nutshell, this will promote a circular economy model in the park and reduce environmental resource constraints.

The proposed management structure for the KenGen Green Energy Park has two bodies at the top of the governance structure. The park management officials and the Advisory Board. The park management is dedicated team members drawn from KenGen, County, and local authorities; SEZ developers, SEZ operators, SEZ enterprises. The technical team actively maintains infrastructure, constant supply of cold and hot water, assists with environmental and social compliance and coordinates with external authorities. The Advisory Board comprises of selected members from investor groups, local community leaders, representatives from established SEZ resident associations from adjacent communities. Others include; relevant government ministries, KGEP tenant´s association, other industry associations and international organizations/consultants e.g. UNIDO.

Proposed shared departments in the energy park are information technology, marketing, and communication; human resource, training, occupational safety, and health protection. Others include; environmental compliance and liaison; maintenance, transport and logistics, and security & common infrastructure and service providers as illustrated in Figure 29. For a functional circular economy, the park management needs to emphasize three key pillars;

i. Value Network: establishing good communication, provide support to partners, create awareness, develop energy and material efficiency-driven practices, and develop eco-designs for recovery, recycling and reuse;
ii. Customer Value Proposition and Interface: promotion on the park website, sales and advertising of the eco-friendly products, customer involvement in circularity initiatives;
iii. Managerial Commitment: an attitudinal and behavioral commitment of the companies´ management towards adopting circular economy business models.

The park clusters will create symbiotic networks of resources and efficient information flows that can be shared between operators to identify gaps and evolving opportunities. Clusters can be used as a context for learning, promoting the development of cluster skill-centers to stimulate innovation and entrepreneurship. These research and development centers are incubators for innovative solutions and technological advances. The solutions promote the emergence of start-ups working towards green growth and overall environmental, economic and social gain in the park and the entire community.

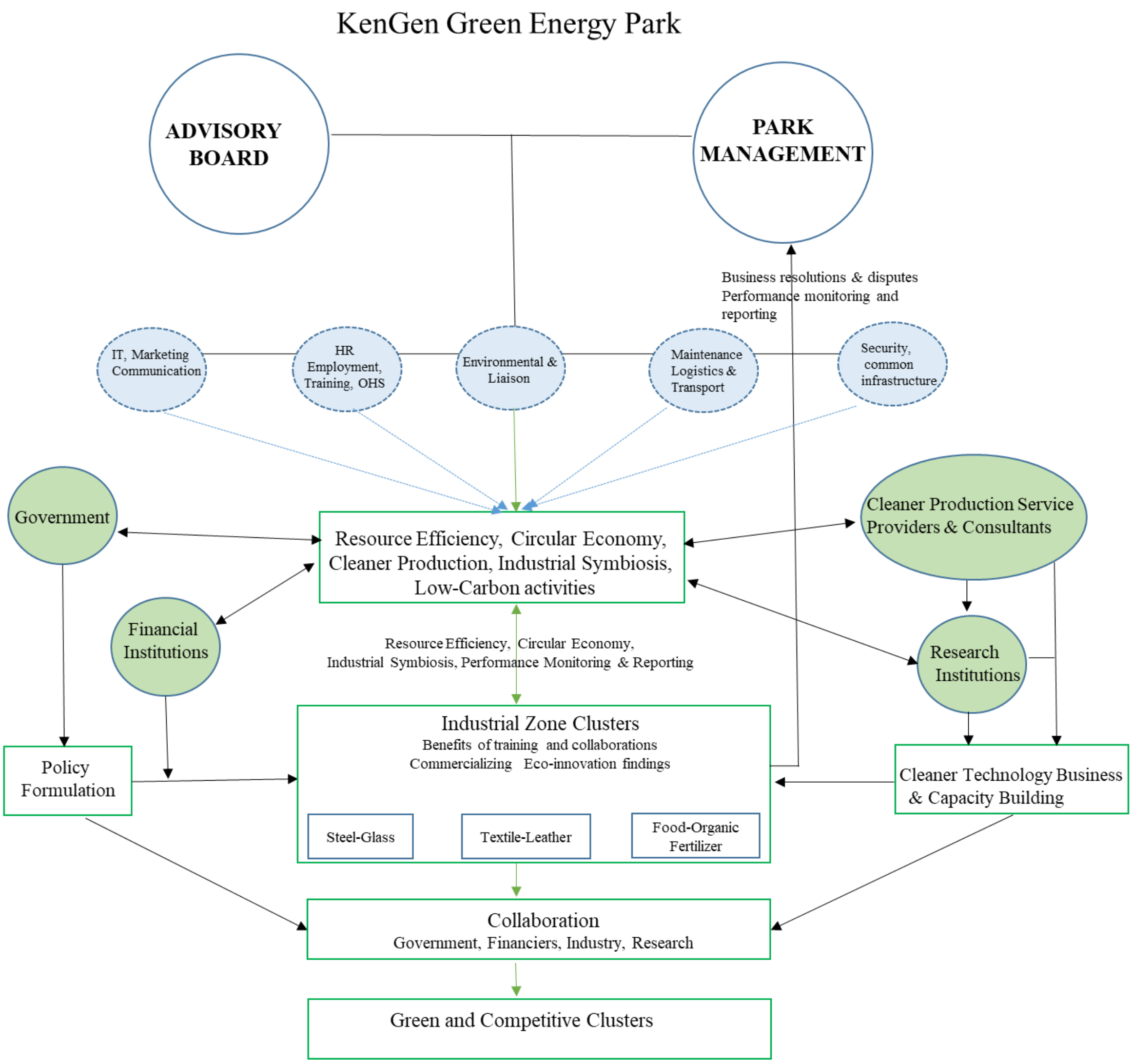

Figure 29: EIP development model under the proposed management structure

7.3. Performance Monitoring and Reporting

Monitoring the park´s performance is important to track progress against the environmental, economic, and social performance targets in an efficient, transparent, and accountable manner. Successful EIP operations include carrying out robust monitoring processes to measure different indicators and improve its performance. Monitoring and efficient reporting are prerequisites for good environmental management and mitigation of potential adverse environmental impacts. Benefits of performance monitoring in an EIP as outline in UNIDO, World Bank & GIZ (2017b) including avoiding and minimizing adverse impact on climate, natural environment, and human health; improving park processes and operations; reducing cost and increasing competitiveness, and helping financial sectors and funding agencies to allocate financial aid to the park.

All the industrial parks and resident firms in Kenya are required by law to comply with all applicable national and county laws, regulations, and standards. This includes, but not limited to, compliance with; national air emission limits, discharge limits, water, and energy resource efficiencies; waste handling, and transportation requirements. Others include; waste disposal and recycling techniques, hazardous waste handling restrictions; noise limits during operations. National employment regulations; emergency preparedness; and occupational health and safety

(OHS) are also included, as highlighted in Table 2. In enforcing these requirements, all relevant stakeholders (Government, KenGen, and park management) will ensure national and local compliance and align with international standards and benchmarks. The most relevant regulatory compliance requirements for industrial parks are; park management, environmental, economic, and social compliance.

The monitoring responsibility lies with the park management team working closely with the government entities, mandated with performance assessment like NEMA and WRA. Changes in the park need to be clearly documented and communicated efficiently to relevant stakeholders inside and outside the park to assist in decision making. Four key implementation steps towards efficient monitoring of the KenGen Green Energy Park are;

i. Defining performance indicators; The firms in the park and the park management team select the highest priority issues to monitor and set performance measures to achieve objectives of the eco-park development, community involvement, and economic achievement. Most of the environmental and social issues are outlined in the Kenyan policy framework and regulations like the Environmental Management and Co-ordination Act, 1999; Water Act, 2002; Energy Act, 2019; Public Health Act; Occupational Safety and Health Act, No. 15 of 2007; Wildlife (Conservation and Management) Act; Employment Act, 2007; Local Government Act; and Ethics and Anti-Corruption Commission Act, 2011.

ii. Establish baseline, benchmarks and performance target levels; Baseline data is collected before park operations to provide a benchmark for measurement and monitoring. Performance target levels are outlined in the national and local laws and these targets should be within the internationally accepted limits. The frequency of monitoring is also established.

iii. Defining the most suitable performance monitoring and management system; Park management decides on the monitoring and evaluation tools applicable to the resident industries and the diverse processes within the park. Sector-specific manuals guide operating procedures and systems relevant to the processes. Methods and procedures for data collection and processing should be clear, simple and replicable.

iv. Performance monitoring, reporting, and continuous improvement; The actual process of data collection, validation, processing, and reporting should be periodically done to feed in the established monitoring and management system. Besides the mandatory environmental and social compliance monitoring, park management should also monitor the impacts of applications of industrial symbiosis and cleaner production technologies. This should be done within the clusters and in the park to assess the effectiveness of the circular economy, and address the gaps to resource efficiency. Proper reporting of these impacts will inform future interventions that promote continuous improvement.

8. Discussion

KenGen Green Energy Park has been identified as one of the revenue streams apart from electricity generation within the Olkaria Geothermal Resource Area. The park will utilize cheap electricity from the geothermal power plants and thermal energy harnessed from separated brine and steam from low pressure / low enthalpy wells within the geothermal field. The study presents two scenarios for thermal energy distribution in the park. In Scenario I, KenGen will develop infrastructure and distribute the hot water to the industrial park. KenGen wholly assumes all the risks and the revenues accruing from the sale of the hot water. Potential risks are technical, economic, environmental, and social. For higher energy efficiency, KenGen should include a cascade use setup in master planning. This will enable infrastructural layout that least results in structural losses of energy in distribution. In Scenario II, KenGen sells hot water at the heat exchanger terminal and the private company distributes it to the park. Costs of installation and piping the hot water are absorbed by the private company. Lower revenue will be realized by KenGen in scenario II compared to the scenario I.

From the application of the Lindal concept, it is evident that it is possible to enhance the feasibility of geothermal projects with cascading and combined uses. The possible utilization depends on the resource temperatures, available flow rate, the chemistry of the geothermal fluid, and the type of application. Use the geothermal brine first for industrial utilization and thereafter for food drying and recreational purposes will continue being a recent research focus in Olkaria (cascade uses). Plans for Combined Heat and Power – CHP production will be viable as Olkaria is surrounded by many hotels and facilities that are interested in hot water for their daily domestic use.

The first co-located firms have been identified and initial phases of infrastructure development have begun. The firms are manufacturers of steel, glass, organic fertilizer, textile, leather, and food processing industries. These companies have been clustered depending on utility requirements, anticipated pollution intensity, and potential symbiotic relationships for easy resource exchanges. Steel-glass cluster is energy-intensive and accounts for high CO_2 emissions associated with coke gas production and the melting of raw materials in both the steel and glass manufacturing plants. Textile-leather cluster has a potential of releasing high amount of chemical waste in wastewater and solid wastes. The food and organic fertilizer are clustered in two proposed sites close to the power plants. These production plants account for lower CO_2 emission and eco-friendly products from these sites can be certified and labeled to attract a higher value. The Eco-labels presents a mark of approval for environmentally benign products and services and act as market instruments to access the regional and international markets at premium prices.

By incorporating industrial symbiosis technology in Green Energy Park, linkages between companies will be realized. Two major exchanges are envisaged; utility and infrastructure, and resources (wastes and by-products). Clear cooperation between the tenant companies will encourage symbiotic relationships and also promote the emergence of other SMEs and start-up companies that will benefit from opportunities arising from industrial symbiosis.

As discussed in chapter 5.2.2, opportunities arising from resource efficiency include the manufacture of beverages sports drinks, chocolates, cheese, and sweets from dairy by-products. Fabric waste can be used to produce bags, furniture covers, diapers, and wipes among others. Food wastes and all biodegradable wastes are raw materials for organic fertilizer production (Figure 30). The farms around Lake Naivasha provide part of the raw (food) materials to be processed e.g. grains, vegetables, and fish from the lake. Other projects that are currently being evaluated for viability are mineral extraction from geothermal brine. Silica and Lithium mining is one of the projects driving the circular economy in the green energy park. Also, the collection of gases for methane production and CO_2 for use in beverage production is under evaluation. Carbon Capture and Storage or Utilization is an innovative technology that will be used to harness up to 90% of the CO_2 and promote a carbon-negative environment both in electricity generation and the industrial processes at the park.

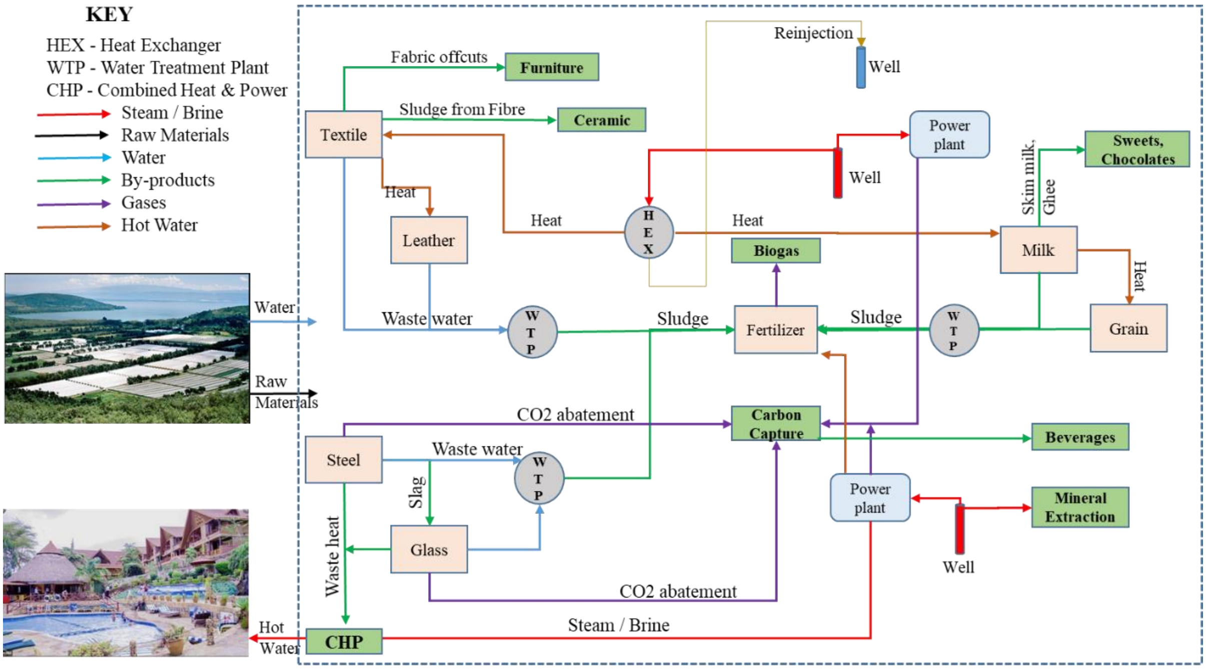

Figure 30: Industrial Symbiosis opportunities for KGEP

The park is set to be a hub for regional economic development that will create an enabling environment for accelerating industrial development, spark innovation, and create more jobs. Networking may provide companies with a competitive advantage mainly by giving access to critical resources and by allowing for cost-saving measures and inter-organizational learning. Collaboration and partnerships between businesses, local government, and community will improve infrastructure networks, sharing resources, information, and security services. Other social wins in the area focus on job creation and improving working conditions. Attention is paid to generally improving the livelihoods of the community while gaining economic and environmental sustainability. Triple helix collaboration as discussed in chapter 7.2 is beneficial where research institutions, Government, and industry operators partner to foster research and innovation for continuous improvement.

Kenyan Government supports the development of a clean and healthy environment in special economic zones through established policies in the Kenyan Constitution, the Kenyan Vision 2030, Green Economy Strategy and Implementation Plan (GESIP) of 2016-2020, and the Climate Change Action plan (2018-2022). However, more policy interventions that promote EIP development need to be incorporated in the countries legal documents by developing the National Action Plan on EIP to the existing Kenya Environment Action Plan (2016-2022) to strengthen the industrial policies set within the SEZ Act, SEZ regulations and the Kenya Industrial Transformation Program of 2015. These interventions include the provision of taxes and fiscal incentives for renewable energy use in industrial parks; tax holidays for SMEs and start-up companies to shield from potential risks; promote industrial symbiosis and resource efficiency in the regulations and encourage a shift towards circular economy within industrial zones. Social capital creation is significant to develop good cooperation between stakeholders and mutual trust conducive to EIP development. Creating Shared Value (CSV) within the park will be enhanced by the trust for the creation of mutual benefit.

A private-public management model is suitable for governance in the KenGen Green Energy Park. The government, financial institutions, cleaner production service providers, consultants, and research institutions in partnership with the park management should collaborate through policy and infrastructure development, funding, or capacity building. Figure 29 illustrates the cooperation of these institutions towards resource efficiency, cleaner production, industrial symbiosis, and other low-carbon activities within the park to transform the KGEP into an Eco-Industrial Park with greener and competitive clusters producing high-value products. Benefits of training, collaboration, eco-innovation, and social welfares are monitored within the clusters and reported to the park management for continuous improvement. In addition, environmental and quality management should be periodically monitored to guide in proper decision making towards sustainable development.

9. Conclusion

The results of the study show that KenGen Green Energy Park (KGEP) can utilize the industrial symbiosis and circular economy approaches to bring numerous gains including environmental, economic, and social benefits. All conclusions drawn from this research are as follows;

1. The environmental benefits of EIP development are as a result of the potential reduction in wastes, emissions, primary inputs, and energy. The economic convenience comes from the savings due to reduced costs for both wastes disposal and primary inputs purchase. Furthermore, the social benefits focus on the creation of new firms and jobs from the emerging spin-off companies and SMEs, that benefit from wastes and co-products of the major manufacturing companies. KenGen Green Energy Park needs to encourage start-ups and research companies to scale up the research and innovation and create a platform for new ideas.
2. There are three emerging industrial clusters within the KenGen Green Energy Park. Factors that informed the grouping of the industries in this study include the energy and water requirements; and the amount of waste and emissions they potentially produce.
3. Material Flow Analysis helps to map the inflow of resources, products, by-products, and wastes generated. When a strong infrastructure for waste recovery and recycling is provided, the wastes and by-product exchange will lead to the creation of more green jobs, lowering GHG emissions, and costs of production.
4. The main source of thermal energy is the brine from separator stations and earmarked geothermal wells. The estimated thermal energy is between 2.5 MWt and 69.1 MWt depending on the energy source. The preferred scenario for hot water distribution is Scenario II, in which KenGen sells hot water to the private entity that distributes to the end-user. This scenario is beneficial as it transfers risks (financial and technical) to the 3rd party. However, KenGen is responsible for the maintenance of the brine pipeline and the heat exchanger.
5. The national and local laws provide clear guidance on the development and operation of the KenGen Green Energy Park. Additionally, the standard International EIP Framework provides minimum performance requirements for industrial parks to transform and operate as eco-industrial parks, that will achieve sustainability and benefit from competitiveness within the region.
6. Stakeholder Coordination Committees and the Community Liason teams are tasked to develop stakeholder engagement plans for the project. These teams map and manage stakeholders´ needs to avoid disruptions that may lead to poor relations and adversely affect the park operations and attainment of its objectives.
7. Training and awareness on low carbon activities and the benefits of transitioning to a circular economy should encourage stakeholders and policymakers to incorporate a legal framework that will guide resource efficiency, industrial symbiosis, and cleaner production.
8. Park Management that is keen on promoting green growth agenda is essential for the EIP initiatives in KGEP. The team in collaboration with the government can develop a code of conduct and a firm governance model to champion the industrial symbiosis, resource efficiency, and circular economy and target to surpass the minimum requirements of the EIP Framework. International institutions like UNEP, UNIDO, World Bank, and GIZ should participate in capacity building and facilitate funding to develop EIP. A triple helix collaborative framework between universities, industries, and the Government should create an innovative ecosystem powered by Research,

Development, and Demonstration (RD&D) to foster innovative ideas as pathways to EIP development.

9. Lower energy tariffs are beneficial to KenGen as it makes the industrial park more competitive. However, other marketing strategies should be put in place to improve the image of the park and brand it as an innovative center. A strong MoU with an international institution e.g. UNEP can facilitate funding and training. Also, benchmarking activities for best practices in leading EIPs such as Kalundborg EIP in Denmark and Surdunes Resource Park in Iceland are essential.

9.1. Recommendations and Future Work

1. Material Flow Analysis can be used during the park operation to quantify flows of resources and wastes and effectively optimize the system. There are numerous mathematical models for design optimization of operating EIPs to maximize the total quantity of exchange flows, total economic benefits of the park, quantify environmental pollution, and waste treatment cost. These models can be applied during the operation of KGEP to optimize the system.
2. Review of clusters and synergies as new companies and opportunities are emerging. New exchanges should be anticipated and a continuous review is essential. A detailed assessment of the energy allocation to different clusters is also crucial and should be included in the detailed masterplan.
3. Natural Capital Assessment and Accounting (NCAA) mechanisms measure and value natural resource assets in both monetary and non-monetary terms. It is recommended that NCAA be included in all sectors of the economy and at all levels of public and private decision-making. During the development of the KGEP, the County-level NCAA can improve land-use planning by incorporating participatory decision-making, community empowerment, and shared values. Such a planning framework and environmental impact assessments should document natural capital assets and the ecosystem services they provide.

References

Adoue, C., 2010: *Implementing industrial ecology*. Methodological tools and reflections for constructing sustainable development. *CRC Press*, Boca Raton, 168 pp.

Aggarwal, A., 2019: *SEZs and economic transformation*. Towards a developmental approach; Transnational Corporations, Volume 26, Number 2, 27-47.

Albertsson, A., 2013: *Iceland geothermal cluster*. Geo-Direct study visit. HS Orka, Reykjavik, 41 pp.

Albertsson, A. and Jónsson, J., 2010: *The Svartsengi Resource Park*. Proceedings, World Geothermal Congress 2010, Bali, Indonesia, 2 pp.

Albertsson, A., 2011: *Sudurnes Resource Park*. GeKon, Reykjavík, Iceland, 34 pp.

Albino, V. & Fraccascia, L., 2015: *The Industrial Symbiosis approach*. Classification of business models. Procedia Environmental Science, Engineering, and Management. 2. 217-223.

Anbumozhi, V.; Gunjima, T.; Prem Ananth, A.; Visvanathan, C., 2010: *An assessment of inter-firm networks in a wood biomass industrial cluster*. Lessons for integrated policymaking. Clean Technol. Environ. Policy, 12, 365–372.

Anbumozhi, V., Thangavelu, S.M., & Visnathan, C., 2013: *Eco-Industrial Clusters*: A Prototype Training Manual: Asian Development Bank Institute, Japan

Atelge, M.R., Atabani, A.E., Banu, J.R., Krisa, D., Kaya, M., Eskicioglu, C., Kumar, G., Lee, C., Yildiz, Y.Ş., Unalan, S., Mohanasundaram, R. & Duman F., 2020: *A critical review of pretreatment technologies to enhance anaerobic digestion and energy recovery.* Fuel, 270, 117-494.

Azom, M R., Mahmud, K., Yahya, S.M., Sontu A. & Himon. S.B., 2012: *Environmental Impact Assessment of Tanneries*: A case Study of Hazaribag in Bangladesh. International Journal of Environmental Science and Development, Vol.3, No.2, 151-156.

Basak, H., Madakbas, S. Y. & Gurdal, G., 2014: Feasibility of Vegetable Drying Technic by Geothermal Heating at City of Kirsehir.*TURKISH Journal for Agricultural and Natural Sciences*, Kirsehir, Turkey, 6 pp.

Beers, V.D., & Flammini, A., Meylan, F., & Stucki, J. 2019: *Lessons Learned from the Application of the UNIDO Eco-Industrial Park Toolbox in Viet Nam and Other Countries*. Sustainability. In press, (17).

Beerkens, R.G.C., Van Limpt, H.A.C. & Jacobs, G., 2004: *Energy efficiency benchmarking in glass furnaces.* Glass Sci. Technol. 77(2), 47–57.

Belaud, J., Adoue, C., Vialle, C., Chorro, A., & Sablayrolles, C., 2019: *A circular economy and industrial ecology toolbox for developing an eco-industrial park.* Perspectives from French policy. Clean Techn Environ Policy, 21, 967–985.

Bellantuono, N., & Carbonara, N., & Pontrandolfo, P., 2017: *The organization of eco-industrial parks and their sustainable practices*. Journal of Cleaner Production,161, 362-375.

Bergmann, M., Schmitz, A., Hayden, M., Kosonen, K., 2007: *Imposing a unilateral carbon constraint on energy-intensive industries and its impact on international competitiveness*. Data & Analysis. Economic Papers, 298.

Bondrea, D. & Mocanu, R. 2016: *The impact of the leather industry left on the environment*. Proceedings: 5th International Conference on Thermal Equipment, Renewable Energy and Rural Development, Golden Sands, Bulgaria, Vol 1. 472-476.

Boix, M., Montastruc, L., Azzaro-Pantel, C., & Domenech, S., 2015: *Optimization methods applied to the design of eco-industrial parks.* A literature review. Journal of Cleaner Production, Vol 87, 303-317.

Bokhtiar, S. & Sakurai, Katsutoshi., 2005: *Integrated Use of Organic Manure and Chemical Fertilizer on Growth, Yield, and Quality of Sugarcane in High Ganges River Floodplain Soils of Bangladesh*. Communications in Soil Science and Plant Analysis- 36. 1823-1837.

Boyenge, J., 2007*: ILO database on export processing zones (Revised)*. ILO Working Papers, International Labour Organization.

Brown, C., King, S., Ling, M., Bowles-Newark, N., Ingwall-King, L., Wilson, L., Pietilä, K., Regan, E., & Vause, J., 2016: *Natural Capital Assessments at the National and Sub-national Level*. UNEP-WCMC, Cambridge, UK.

Brunner, P.H. & Rechberger, H. 2004: *Practical handbook of material flow analysis*. *The International Journal of Life Cycle Assessment, Volume 9, Issue 5, 337–338*

Buljan, J., & Kral, I., 2012: *Benchmarking in the Tanning Industry*. Vienna: United Nations Industrial Development Organization (UNIDO).

Burchart-Korol, D., 2013: *Life cycle assessment of steel production in Poland*: A case study, Journal of Cleaner Production, Volume 54, 2013, 235-243.

Cabeza, L. F., Solé, C., Ghosh, H., Ahasanuzzaman, A., Rahman, M.A. & Kral, I., 2011: *Energy savings in Bangladeshi tanneries through solar energy use and electrical performance improvement*. 31st IULTCS Congress.

Cavallo, M., 2018: *Circular Economy: Benefits and good practices*. Edizioni Ambiente, pp 77.

Cencic, O. & Rechberger, H., 2008: *Material flow analysis with software STAN*. J. Environ. Eng. Manag., 18, 3.

Chertow, M.R., 2007: *Uncovering industrial symbiosis.* J. Ind. Ecol., 11 (1), pp. 11-30.

Chertow, M.R., Ashton, W.S., & Espinosa, J.C., 2008: *Industrial Symbiosis in Puerto Rico*: Environmentally Related Agglomeration Economies. Regional Studies; 42 (10), 1299 – 1312.

Chertow, M., & Ehrenfeld, J., 2012: *Organizing Self-Organizing Systems*: Toward a Theory of Industrial Symbiosis. Journal of Industrial Ecology, 16(1), 13-27.

Chowdhury, Z & Ahmed, T & Antunes, P & Paul, H. 2018: *Environmental Life Cycle Assessment of Leather Processing Industry*. A Case Study of Bangladesh. Society of Leather Technologists and Chemists. 102. 18-26.

Colla, V., Matino, I., Branca, T.A., Fornai, B., Romaniello, L., & Rosito, F., 2017: *Efficient use of water resources in the steel industry*. Water, 9 (11). p. 874.

Cotance and IndustriAll, 2012: *Social and environmental report: European Leather Industry*. IndustriAll, Brussels, 48 pp.

Cote, R.P., & Cohen-Rosenthal, E., 1998: *Designing Eco-Industrial Parks*. A Synthesis of some Experiences. Journal of Cleaner Production, 6, 181 – 188.

Cotton Incorporated, 2009: *Summary of Life Cycle Inventory Data for Cotton (Field to Bale*. version 1.1 – 2 July 2009). Cotton Incorporated, United States of America, 31 pp.

Danida Fellowship Centre, 2019: *Green and Circular Innovation for Kenyan Companies GECKO***.** https://www.geckoproject.dk/about.

Deog-Seong, O.; Kyung-Bae, K.; Sook-Young, J., 2005: *Eco-Industrial Park Design*. A Daedeok Technovalley case study. *Habitat Int*., 29, 269–284.

Dixit, S., Yadav, A., Dwivedi, P.D. & Das, M., 2015: *Toxic hazards of the leather industry and technologies to combat the threat.* A review. J. Clean. Produc. 87: 39-49.

Eckelman, M.J. & Chertow, M.C., 2009: *Quantifying life cycle environmental benefits from the reuse of industrial materials in Pennsylvania*. Environ. Sci. Technol. 43, 2550-2556.

Ecoinvent Centre, 2010: *Ecoinvent data v2.2.* Ecoinvent reports No. 1–25. Swiss Centre for Life Cycle Inventories, Duebendorf, Switzerland.

Ellen Macarthur Foundation, 2015: *Towards a Circular Economy*. The business rationale for an accelerated transition, 20 pp.

EIB, 2015: *Access-to-finance conditions for Projects supporting Circular Economy*. DG Research and Innovation, European Commission, 82 pp.

European Commission, 2008: *Integrated Pollution Prevention and Control (IPPC).* European Commission, Feb 2008.

Fadare, D., Bamiro, O. & Oni, A., 2010: *Energy and cost analysis of organic fertilizer production in Nigeria*. Energy. 35. 332-340.

Farole, T., 2011: *Special Economic Zones in Africa: Comparing Performance and Learning from Global Experiences*. Washington, DC: World Bank.

FAO, 2008: *Basic principles of grain drying. Food and Agriculture Organisation*, website: www.fao.org/home/en/

FAO, 2010: *Greenhouse Gas Emissions from the Dairy Sector*. A Life Cycle Assessment, 98 pp.

Feitz, A.J., Lundie, S., Dennien, G., Morain, M. & Jones, M., 2007: *Generation of an industry-specific Physico-chemical allocation matrix*. Application in the dairy industry and implications for system analysis. Int. J. LCA, 12, 109–117.

Fraccascia, L., Giannoccaro, I. & Albino, V., 2019: *Business models for industrial symbiosis*: A taxonomy focused on the form of governance. Resources Conservation and Recycling. 146. 114-126.

Fruehan R. J., Fortini. O., Paxton. H.W. & Brindle. R., 2000: *Theoretical Minimum Energies to Produce Steel for Selected Conditions*. *Energetics*, Inc, U.S.A, 43 pp.

Geng, Y., Fu, J., Sarkis, J., & Xue, B., 2011: *Towards a national circular economy indicator system in China*: An evaluation and critical analysis. Journal of Cleaner Production. 23: 216–224.

Geng, Y., Sarkis, J., Ulgiati, S., and Zhang, P., 2013: *Measuring China's circular economy*. Science, 339 (6127), 1526-1527.

Geo-Heat Center., 1997: *Geothermal Direct-Use Equipment*. Quarterly Bulletin, 19(1), Klamath Falls, OR, 38 pp.

GIZ, 2015: *Planning of New Industrial Parks and Investment Zones*. Indo-Germany Partnership on Sustainable Industrial Development.

Gladek, E., 2019: *The Seven Pillars of the Circular Economy*. Metabolic, News, and Insights.

Government of Kenya, 2010. *The New Constitution of Kenya*. Printed by the Government Printers on 27th August 2010; Nairobi, Kenya.

Government of Kenya, 2006: *The National Water Resources Management Strategy (2006-2008)*. Ministry of Water and Irrigation, Nairobi, Kenya.

Government of Kenya, 2013: *National Climate Change Action Plan (NCCAP) 2013 – 2017*. Ministry of Environment, Water and Natural Resources, Nairobi, Kenya.

Government of Kenya, 2014: *Draft National Climate Change Framework Policy, Ministry of Environment, Water and Natural Resources*. Nairobi, Kenya.

Government of Kenya, 2015: *Draft Special Economic Zone (SEZ) Policy*, Ministry of Trade.

Government of Kenya, 2015: *Kenya Green Economy Strategy and Implementation Plan (GESIP) for 2016 – 2030*. A low carbon, resource-efficient, equitable and inclusive socio-economic transformation, Ministry of Environment, Water and Natural Resources, Nairobi, Kenya.

Government of Kenya, 2018: *National Climate Change Action Plan (Kenya) 2018-2022*. Ministry of Environment and Forestry, Nairobi, Kenya.

Government of Kenya, 2019: *Draft Supplemental Special Economic Zones Regulations*. Nairobi, Kenya.

Graedel, T., Allenby, B., Telephone, A., & Company, T. 1995: *Industrial Ecology*, Prentice-Hall, Upper Saddle River, NJ, USA, 29-49.

Hartley, C.A., 2004: *A study of the balance between furnace operating parameters and recycled glass in glass melting furnaces*. Glass Technology Services Ltd, Chapeltown.

Hatefipour, S. 2012: *Facilitation of industrial symbiosis development in a Swedish region*. Licentiate thesis, Linköping University, Linköping, Sweden, 56 pp.

Heeres, R.R., Vermeulen, W.J.V. & Walle, F.B., 2004: *Eco-industrial park initiatives in the USA and the Netherlands: First lessons*. *J. Clean. Prod.* 12, 985–995.

IRENA, 2016: *Roadmap for a Renewable Energy Future, 2016 Edition*. International Renewable Energy Agency (IRENA), Abu Dhabi, www.irena.org/remap.

Jóhannesson, T., & Chatenay, C., 2014: *Direct Use of Geothermal Resources*. In the Utilization of Low- and Medium-Enthalpy Geothermal Resources and Financial Aspects of Utilization. Santa Tecla, El Salvador: UNU-GTP.

Jørgensen S., Pedersen L.J.T., 2018: *The Circular Rather than the Linear Economy*. In: Restart Sustainable Business Model Innovation. Palgrave Studies in Sustainable Business, In Association with Future Earth. *Palgrave Macmillan*, Cham, 264 pp.

Jungbluth, N., Keller, R., Doublet, G., König, A. & Eggenberger, S., 2016: *Report on life cycle assessment, economic assessment, potential employment effects, and exergy-based analysis*. part I—LCA vol Deliverable 7.3. SUSMILK: Re-design of the dairy industry for sustainable milk processing, 147 pp.

KAM, 2018: *Manufacturing Priority Agenda*: Sparking Kenya's industrial transformation for job creation, 64 pp.

Kechichian, E. & Jeong., M.H., 2016: *Mainstreaming Eco-Industrial Parks*. Conclusions from the Eco-Industrial Park 2015 Event in Seoul. Washington, D.C., World Bank.

Keller, R., Jungbluth, N. & Eggenberger, S., 2016: *Milk processing – life cycle assessment of a detailed dairy model and recommendations for the allocation to single products*. ESU Services, Zurich.

KenGen, 2016a: *Feasibility Study of KenGen Industrial Park in Naivasha*. Final Report, KenGen Internal Report, 346 pp.

KenGen, 2016b: *Hydrogeological and Geophysical Investigations in Olkaria Domes Area and Around Well Pad OW-922 for the Proposed Industrial Park Project*. KenGen Internal Report, 52 pp.

KenGen, 2018: *Geothermal Development Prioritization Task Force Report*- Report No. 4, KenGen Internal Report, 26 pp.

KenGen, 2020: KenGen Website: *https://www.kengen.co.ke/index.php/business/business-sustainability/enviromental-sustainability.html*

Kiron, D., 2014: *Water Consumption in Textile Processing Industry*. Water Management Review. 55. 29-33.

Khisa, K. 2016: *Development of an industrial ecology model for the Athi River Special Economic Zone*: Policy implications for green growth in Kenya; Ph.D. Dissertation, University of Nairobi, Kenya, 192 pp.

Kinyanjui, S., 2013: *Direct use of geothermal energy in Menengai, Kenya*: Proposed geothermal spa and crop drying. Report 9 in Geothermal training in Iceland 2011. UNU-GTP Iceland, 109-142.

Kiruja, J., 2011: *Use of geothermal energy in dairy processing*. Report 16 in Geothermal training in Iceland 2011. UNU-GTP, Iceland, 303-326.

Kiruja, J., 2017: *The viability of supplying an industrial park with thermal energy from the Menengai Geothermal Field, Kenya*. M.Sc. Dissertation, Reykjavik University, Reykjavik, Iceland, 55 pp.

Kwambai, C.B., 2016: *High-Temperature Geothermal Power Plants and overview of Wellhead generators*. SDG Short Course I on Exploration for Geothermal Resources, organized by UNU-GTP, GDC, and KenGen, at Lake Bogoria and Lake Naivasha, Kenya, 9 pp.

Langat, R.K., 2015: *Topping unit at Olkaria IV Geothermal Power Plant, Naivasha, Kenya.* Number 18 in Geothermal training in Iceland 2015. UNU-GTP Iceland, 357-392.

Lea J. & O'Sullivan M., 2020: *Silica and Other Minerals Extraction from Geothermal Brine in New Zealand*. Proceedings World Geothermal Congress, Reykjavik, Iceland

Lowe, E.A. 1997: *Creating by-product resource exchanges: strategies for eco-industrial parks*. Journal of Cleaner Production. 5 (1-2): 57-65.

Lund, J., & Chiasson, A., 2007: *Examples of combined heat and power plants using geothermal energy*. Proceedings, European Geothermal Congress, Unterhaching, Germany.

Lund, J. W., & Boyd, T. L., 2015: *Direct Utilization of Geothermal Energy-Worldwide Review*. Proceedings, World Geothermal Congress 2015, Melbourne, Australia, International Geothermal Association, 31 pp.

Lund, J.W., 2018: *Direct Heat Utilization of Geothermal Resources Worldwide*. In Power Stations Using Locally Available Energy Sources; Bd., 9; Bronicki, L.Y., Ed.; Springer: New York, NY, USA, 297–325.

Mangi, P., 2012: *Geothermal resource optimization: A case of the geothermal health spa and demonstration center at the Olkaria geothermal project*. Short Course VII on Exploration for Geothermal Resources, organized by UNU-GTP, GDC, and KenGen, at Lake Bogoria and Lake Naivasha, Kenya, 10 pp.

Mangi, P., 2013: *Direct utilization in Kenya: A case of a geothermal spa and demonstration centre at Olkaria*. Short Course VIII on Exploration for Geothermal Resources, organized by UNU-GTP, GDC, and KenGen, at Lake Bogoria and Lake Naivasha, Kenya, 14 pp.

Mangi, P.M., 2014: *Geothermal direct use application: A case of geothermal spa and demonstration centre at Olkaria geothermal project, Kenya*, Short Course IX on Exploration for Geothermal Resources organized by UNU-GTP, GDC, and KenGen, at Lake Bogoria and Lake Naivasha, Kenya, 12 pp.

Meuleman R., 2017: *The efficient future for the glass industry is "all-electric*. Proceedings 14th International Seminar on Furnace Design Vsetin, Czech Republic.

Mirata, M. 2004: *Experiences from early stages of a national industrial symbiosis program in the UK: determinants and coordination challenges*. Journal of Cleaner Production, 12 (810), pp. 967 – 983.

Mirata, M., & Emtairah, T., 2005: *Industrial symbiosis network and the contribution to environmental innovation*. The case of the Landskrona industrial symbiosis programme. J. Clean. Prod. 13, 993-1002.

Nyambura, E., 2016: *Direct use of geothermal energy: Menengai direct use pilot projects in Kenya.* Proceedings, 6th African Rift Geothermal Conference, 6 pp.

Notarnicola, B., 2011: *Life cycle assessment in the agri-food sector*. Int. J. LCA, 16 (2), 102-105.

OECD, 2011: *Towards green growth*. A summary for policymakers, pp 28

Omenda, P., 2012: Geothermal Development in Kenya: A Country Update, *Proceedings*, 4th African Rift Geothermal Conference, 5 pp.

Omenda, P., and Simiyu, S., 2015: *Country Update Report for Kenya 2010-2014.* Proceedings, World Geothermal Congress 2015, Melbourne, Australia, International Geothermal Association, 11 pp.

Ogola, P.F. A., 2013: *The power to change: Creating lifeline and mitigation adaptation opportunities through geothermal energy utilization*. Ph.D. Dissertation, University of Iceland, Reykjavik, Iceland, 249 pp.

Page, J., and F. Tarp., 2017: *The Practice of Industrial Policy: Government-Business Coordination in Africa and East Asia*. Oxford: Oxford University Press.

Palamutcu, S., 2010: *Electric energy consumption in the cotton textile processing stages*. Energy, 35(7), 2945–2952.

Park, H. S., & Behera, S. K. 2014: *Methodological aspects of applying eco-efficiency indicators to industrial symbiosis networks*. Journal of Cleaner Production, 64, 478-485.

Panyathanakun, V., Tantayanon, S., Tingsabhat, C., & Charmondusit, K. 2013: *Development of eco-industrial estates in Thailand*. Initiatives in the northern region community-based eco-industrial estate. Journal of Cleaner Production. 51. 71–79.

Pergola, M., Persiani, A., Pastore, V., Palese, A., D'adamo, C., Falco, E. & Celano G., 2020: *Sustainability Assessment of the Green Compost Production Chain from Agricultural Waste*. A Case Study in Southern Italy. Agronomy. 10 pp.

Puente, M.C.R., Arozamena, E.R. & Evans, S. 2015: *Industrial symbiosis opportunities for small and medium-sized enterprises*. Preliminary study in the Besaya Region (Cantabria, Northern Spain). J. Clean. Prod. 87, 357–374.

Rackley, S. A., 2010: *Overview of Carbon Capture and Storage*. Carbon Capture and Storage Science Direct, 19-28.

Raghunath, B., Punnagaiarasi, A., Rajarajan G., Irshad A., Elango, A. & Mahesh, G., 2016: *Impact of Dairy Effluent on Environment*. A Review-3, 22 pp

Regulus, 2020: Regulus. Website: stima.regulusweb.com/.

Reuter, K.E., Juhn, D., Portela, R. & Venter, J., 2016: *Natural Capital Accounting across the Gaborone Declaration for Sustainability in Africa*. A Desktop Scoping. Report Prepared for the Gaborone Declaration for Sustainability in Africa: Gaborone, Botswana. Pp. 188

Rivela, M.T., Moreira, C., Bornhardt, R. & Meandez, G., 2004: *Life Cycle Assessment as a Tool for the Environmental Improvement of the Tannery Industry in Developing Countrie*s. Environ. Sci. Technol. 38. 1901-1909.

Saikku, L., 2006: *Eco-industrial parks*: A background report for the eco-industrial park project at Rantasalmi. Publications of Regional Council of Etelä-Savo, 71.

Schmitz, A., Kamiński, J., Scalet, B. & Soria, A., 2011: *Energy consumption and* CO_2 *emissions of the European glass industry*. Energy Policy. 39. 142–155.

Schwarz, E.J. & Steininger, K.W., 1997: *Implementing nature's lesson*: The industrial recycling network enhancing regional development. J. Clean. Prod. 5, 47-56.

Staritz, C., and Morris, M., 2013: *Local Embeddedness and Economic and Social Upgrading in Madagascar's Export Apparel Industry*. Working Paper, Austrian Foundation for Development Research (ÖFSE). Vienna: ÖFSE.

Taddeo, R., 2016: *Local industrial systems towards the eco-industrial parks*. The model of the ecologically equipped industrial areas. J Clean Prod. 131:189–197.

Tan, D., & Meyer, K.E., 2011: *Country-of-origin and industry FDI agglomeration of foreign investors in an emerging economy*. Journal of International Business Studies 42(4), 504–520.

ThinkGeoEnergy Research, 2019: *Global geothermal capacity reaches 14,900 MW*. New Top 10 ranking of geothermal countries.

Tudor, T., Adam, E. & Bates, M., 2007*: Drivers and limitations for the successful development and functioning of EIPs (eco-industrial parks)*. A literature review. Ecological Economics. 61. 199-207.

Uddin F., 2014: *Environmental concerns in antimicrobial finishing of textiles*. International Journal of Textile Science. 3(1A). 15-20.

Uddin, F., 2019: *Introductory Chapter: Textile Manufacturing Processes*. Reviewed: June 11th, 2019 Published: August 28th, 2019.

UNEP, 2011:*Towards a Green Economy: Pathways to Sustainable Development and Poverty Eradication*. A Synthesis for Policy Makers. www.unep.org/greeneconomy

UNEP, 2017: *Greening Kenya Industrial Zones*. Stimulating competitiveness and investments in the face of resource scarcity and climate change; Concept Note, Global Climate Fund Documentation, pp 44

UNIDO, 2016a: *Global Assessment of Eco-Industrial Parks in Developing and Emerging Countries*. Achievements, Good Practices and Lessons Learned from Thirty-Three Industrial Parks in Twelve Selected Emerging and Developing Countries; United Nations Industrial Development Organization: Vienna, Austria.

UNIDO, 2016b: *Eco-Industrial Park Initiative for Sustainable Industrial Zones in Viet Nam*. Project Brochure; UNIDO: Vienna, Austria.

UNIDO, 2017a: *Implementation Handbook for Eco-Industrial Park*s. United Nations Industrial Development Organization: Vienna, Austria.

UNIDO., World Bank Group. & GIZ., 2017b: *An International Framework for Eco-Industrial Parks*. World Bank, Washington, DC, USA.

UNIDO., World Bank Group., GIZ, & Ministry of Trade, Industry and Energy of the Republic of Korea., 2018*: A Practitioner's Handbook for Eco-Industrial Parks*. Implementing the International EIP Framework. World Bank, Washington, DC. USA

UNIDO, 2019: *Eco-Industrial parks: Achievements and Key Insights from the Global RECP Programme 2012–2018*. United Nations Industrial Development Organization: Vienna, Austria.

UNIDO., World Bank Group., GIZ., & Ministry of Trade, Industry and Energy of the Republic of Korea., 2019: *A Practitioner's Handbook for Eco-Industrial Parks*. Toolbox. World Bank, Washington, DC. USA

United Nations Conference on Trade and Development, 2018: *Promoting investment in Sustainable Development Goals*. Investment Advisory Series, Series A, Number 8. World Investment Report. 75pp.

United Nations Conference on Trade and Development, 2019: *Special Economic Zones*. Key messages and overview. World Investment Report. 49pp

Usbeck, C,V., Pflieger, J. & Sun, T., 2011: *Life Cycle Assessment of Float Glass-Summary Report.* Glass for Europe, 31 pp.

Van Nguyen, M., Arason, S., Gissurarson M. & Pálsson, P.G., 2015: *Uses of geothermal energy in food and agriculture*. Opportunities for developing countries. Rome, FAO.

VEGA, 2014: *The geothermal direct use guidebook*. USAID-Kenya, Nairobi, 94 pp.

Were, A., 2016: *Manufacturing in Kenya*: *Features, Challenges, and Opportunities*. A scoping exercise. Supporting Economic Transformation, UKaid, 45 pp.

World Bank, 2017: *Environmental and Social Framework*. The World Bank, Washington, DC, USA, 121 pp.

World Bank, 2014: *Low-Carbon Zones*: *A Practitioner's Handbook*. Investment Climate Department: Washington, DC, USA.

World Steel Association, 2015: *Water Management in the Steel Industry*. Worldsteel Position Paper, 7 pp.

Worldsteel steel association, 2018: *Steel industry Co-products*. Worldsteel Position Paper, 10 pp

Worldsteel Association 2020: *Steel´s contribution to low carbon future and climate-resilient societies*. Worldsteel position paper, 6 pp.

Zhao, R., Xu, Y., Wen, X., Zhang, N. & Cai, J., 2017: *Carbon footprint assessment for a local branded pure milk product*. Food Sci. Technol. Vol.38, No.1.

Zhang, L., Yuan, Z., Bi, J., Zhang, B., Liu, B.. 2010: *Eco-industrial parks: National pilot practices in China*. Journal of Cleaner Production. 18. 504-509.

Appendix: EIP Policy Interventions

Options for EIP policy interventions and/or instruments to be considered	Type of criteria:	Environmental		Economic		Social		Environmental		Economic		Social		Total weighted prioritization score	References and remarks
	Criterion:	Environmental management & monitoring		Increased GDP		Social management and monitoring		Energy, water and waste management/recycling		Employment creation (Local business & SMEs promotion)		Social infrastructure/ community dialogue			
	Weighting:	4		4		4		4		4		4			
		Score:	Weighted score	Score:	Weighted score	Score:	Weighted score	Score:	Weighted score	Score:	Weighted score	Score:	Weighted score		
National Action Plan on EIP		5	20	5	20	5	20	5	20	5	20	5	20	**120**	UNIDO, 2016a
Foreign Direct Investment		4	16	5	20	3	12	5	20	4	16	4	16	**100**	UNIDO, 2016a; Government of Kenya, 2018
Renewable Energy Use		5	20	3	12	3	12	5	20	4	16	4	16	**96**	UNIDO, 2016a; Government of Kenya, 2019
Incentives and Tax Exemptions		5	20	4	16	4	16	5	20	5	20	5	20	**112**	UNIDO, 2016a; Government of Kenya, 2015
Industrial Symbiosis & Resource Efficiency		5	20	4	16	3	12	5	20	5	20	5	20	**108**	UNIDO, 2016a; KAM, 2018
Social Capital Creation		4	16	5	20	5	20	4	16	4	16	5	20	**108**	UNIDO, 2016a; Government of Kenya, 2018

School of Science and Engineering
Reykjavík University
Menntavegur 1
101 Reykjavík, Iceland
Tel. +354 599 6200
Fax +354 599 6201
www.ru.is